

Remembering David Mills (1938–2024)

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DAVID L. MILLS, Professor Emeritus of Electrical and Computer Engineering and of Computer and Information Sciences at the University of Delaware and the Internet's "Father Time," passed away on January 17, 2024, at the age of 85. Mills was an Internet pioneer who built the first version of the National Science Foundation's Network (NSFNET) and also solved a crucial challenge to synchronize networked devices via his Network Time Protocol (NTP).

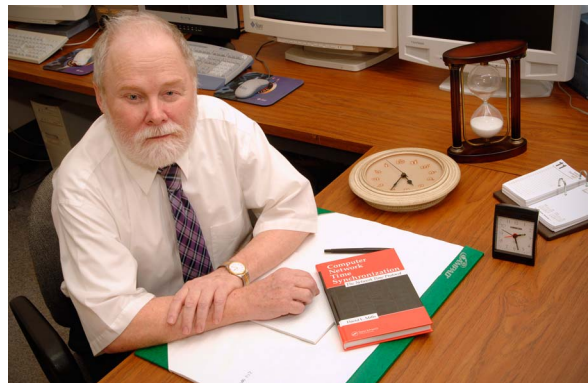
Mills was born in Oakland, California, on 3 June 1938. He was born with glaucoma, but a surgeon saved some of the vision in his left eye when he was a child, and he attended a school in San Mateo, California, for the visually impaired. A teacher's comment that because of his disability he would never go to college further inspired the headstrong young David to do just the opposite. It was "like waving a flag in front of a bull," he later told a journalist.

After graduating from high school, Mills went on to complete his undergraduate and graduate studies at the University of Michigan, earning bachelor's degrees in engineering science and mathematics, master's degrees in electrical engineering and communication sciences, and completing his Ph.D. in computer and communications science in 1971.

During his graduate studies, Mills performed early research into distributed computing and worked on the Advanced Research Projects Agency (ARPA)-sponsored Conversational Use of Computers (CONCOMP) project, which developed hardware and software for a Digital Equipment Corporation (DEC) PDP-8 minicomputer that allowed terminals such as Teletypes to connect over phone lines to an IBM 360/67 mainframe.

Mike Alexander, a member of the research staff of the University of Michigan Computing Center and Information Technology Division Research Systems from 1965 to 1996, worked with Mills from 1965 until 1971 and remembers both his curiosity and his sense of humor.

"In 1966, I was laying the foundation for what would become the Michigan Terminal System, and Dave



David L. Mills. Photo courtesy of University of Delaware.

was designing and building the data concentrator to connect the outside world to it," recalls Alexander. "The data concentrator was almost certainly the first non-IBM device to be connected to an IBM channel, and we spent many hours together debugging the interface. Dave was very low vision even then. It's amazing he did as much as he did without today's modern low-vision aids. We used to joke that he would wire his nose into the back panel of the concentrator since he got so close to see the pins."

After completing his Ph.D. study at Michigan, Mills worked at the University of Edinburgh (1971–1972), the University of Maryland (1972–1977), COMSAT Corporation (1977–1982), and Linkabit Corporation (1982–1986) before joining the faculty of the University of Delaware in 1986. He became an emeritus faculty at Delaware in 2008.

While at Maryland, Mills invented "The Fuzzball," the first modern router and application server; it was used for network prototyping. Fuzzballs were DEC PDP-11 computers loaded with Mill's software. Six fuzzball routers were later used in 1986 to build the first 56-kb/s backbone of NSFNET, which evolved into the modern Internet, and this deployment allowed for the further development and testing of the TCP/IP protocols. Calling these devices "fuzzballs" is classic "MillsSpeak"—he loved colorful neologisms and was the source of many over his career.

Hans-Werner Braun, chief engineer of the NSFNET backbone in the 1980s, said, "Dave taught me how the



Photo taken by David Mills of a Fuzzball router located under the desk in his den in Maryland, about 1986. Photo courtesy of Eileen Schnitzler.



Undated photo of David Mills while a student at the University of Michigan. Photo courtesy of Eileen Schnitzler.

Internet works. Eric Aupperle once, in perhaps 1984 or 1985 at the University of Michigan, gave me a couple of 8" floppy disks and asked whether I would be interested in checking them out. They were from Dave Mills with this RT-11-like Fuzzball code... I got hooked quickly on the Fuzzball software and decided that this Internet concept was certainly much more enticing than working on code for Merit's non-IP packet switches."

Ole Jacobsen, author/editor of *Connexions* and the *Internet Protocol Journal*, remembers Mills' creative use of naming and language. He said, "My memories of Dave go back to my days when I was working at the Norwegian Telecommunications Administration Research Establishment (NTARE) with Paal Spilling. Dave had a Fuzzball router at NTARE and would occasionally send us instructions and pointers to patches he had made while we were all asleep. His use of language always amused me: 'I left on your Fuzzball a flock of files ...'."

After departing Maryland, Mills worked for the COMSAT Corporation, where his work brought him into close contact with researchers working on the ARPANET, a precursor to the Internet. He began his work on what would become his most notable contribution: NTP, which provides for clock synchronization between computer systems over packet-switched, variable-latency data networks. This work addressed the many challenges related to maintaining time in the face of devices and network branches operating with differing speeds and latencies.

NTP was first implemented in 1985 and tested on the Fuzzball-driven NSFNET. By 1988, Mills had refined

NTP to the point where it could synchronize the clocks of connected computers that had been telling significantly differing times to within tens of milliseconds, and later to within a few microseconds.

"Dave had a love, perhaps even an obsession, with timekeeping," said Charles Boncelet, Professor of Electrical and Computer Engineering and Computer and Information Sciences at the University of Delaware and a collaborator with Mills. "He was a fan of unusual clocks and calendars, such as the Mayan calendar. His laboratory had an atomic clock. He also had various radio clocks. He took a problem that few realized was a problem, synchronizing networked clocks, and made it his life's work."



Fuzzball disks sent from David Mills to his collaborators at the University of Michigan Computing Center in the 1980s. Photo courtesy of the University of Michigan.

Famous for NTP, Mills' contributions were prolific and took many forms. Jack Haverty, an early Internet implementer and pioneer, recalls how Mills was able to point the way for others by exposing errors and failure points. "Few people probably realize one of Dave's crucial contributions to Internet technology—the concept of "autonomous systems," which survives today, 40 years later," he said. "Dave didn't invent it, but he caused it. The antics of his Fuzzies forced Eric Rosen and me to create autonomous systems and the Exterior Gateway Protocol as a firewall mechanism to keep the [BBN-run] Internet core safe from the marauding Fuzzies and their occasional collateral damage."

Himself a tinkerer, Mills had a vision for the Internet and served as the first chair of the Internet Engineering Task Force, a standards organization for establishing internet standards, and actively participated in the evolution of IP, TCP, TELNET, FTP, SMTP, and related protocols which are now widely used in the Internet. He was also an active participant in the open source community.

He took a strong, and some would say absolute, say in the evolution of NTP, maintaining control of it and building on it as the needs of the Internet grew. The current version, version 4, was released in 2010 and continues to keep time for all types of internet-connected devices, ensuring that all manner of computers and other Internet-connected devices worldwide, from mobile phones to air traffic control centers,

run "on time" and ensure that our interconnected world runs smoothly.

Mills was elected to the U.S. National Academy of Engineering in 2008. He was also a member of the Internet Society, the American Association for the Advancement of Science, and he was a Fellow of both the Association for Computing Machinery and the Institute of Electrical and Electronic Engineers (IEEE). He was recognized in 2013 with the IEEE Internet Award "for significant leadership and sustained contributions in the research, development, standardization, and deployment of quality time synchronization capabilities for the Internet."

Outside of his career's many achievements, Mills' hobbies included running an amateur radio station (W3HCF) out of his home in Newark. He was also a member of the American Radio Relay League, the Radio Society of Great Britain, and the Amateur Satellite Organization.

Mills is survived by his wife Beverly Mills, his daughter Eileen Schnitzler, his son Keith Mills, and his brother Gregory Mills.

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