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Nervous System: The Computer That Taught HAL to Sing

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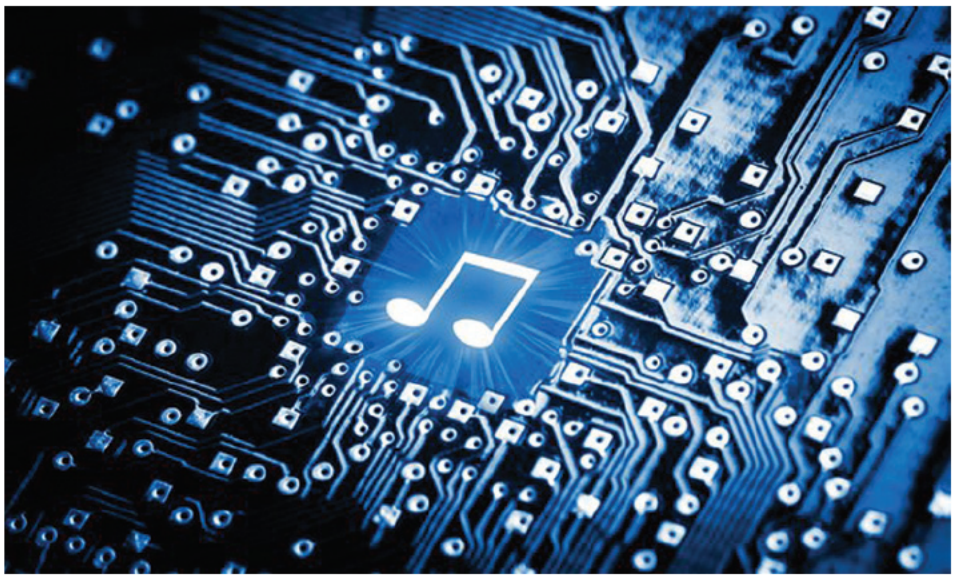
With the aggressive pace of technological change and the onslaught of news regarding data breaches, cyber-attacks, and technological threats to privacy and security, it is easy to assume these are fundamentally new threats. The pace of technological change is slower than it feels, and many seemingly new categories of threats have actually been with us longer than we remember. ***Nervous System*** *is a monthly blog that approaches issues of data privacy and cybersecurity from the context of history—to look to the past for clues about how to interpret the present and prepare for the future.*



As a society, we have been continuously moving the goalposts of what constitutes machine intelligence. Over time, people have staked out positions that "no computer can think unless it [fill in the blank]." As computers have met and crossed those thresholds—playing chess, painting art, carrying on conversations, winning on *Jeopardy!*—we stake out new thresholds.

One such threshold was crossed very early—it was in 1961 that a computer first *sang*. The song was "Daisy Bell," and one of the people in the audience to hear that electronically recreated tune was the author Arthur C. Clarke. A few years later, in his landmark novel *2001: A Space Odyssey*, Clarke created a fictional thinking machine named HAL-9000, whose mental breakdown was punctuated by that familiar song.

Clarke's encounter with the singing computer came about as a fluke. In 1962, as he was working on *2001*, Clarke visited his friend John Pierce. Pierce was in a unique position to offer thoughts on Clarke's epic story of extraterrestrial life and intelligent machines. Pierce was an acerbic wit and a brilliant electrical engineer, and he was also a science fiction writer. Known for such cracks as "Funding artificial intelligence is real stupidity," and "After growing wildly for years, the field of computing appears to be reaching its infancy," Pierce was conducting research at the Bell Labs facility in Murray Hill, New Jersey.

That lab was home to arguably the most advanced computer of its day, the IBM 704 Scientific Computer. One thing

that set the 704 apart from its peers was an esoteric feature called "floating point" calculations. To understand the significance of "floating points," it helps to think about how writers like Clarke juxtaposed small, intimate human details with events on a cosmic scale. That kind of juxtaposition is easy for poets and novelists, but it is wrenchingly difficult for computers. For example, ask a computer to perform calculations on a miniature scale for engineering microelectronics *and also* calculate the distance in light years of a star, and the machine's processors face a seemingly impossible contradiction. Any trade-off in precision at one end of the scale can cause catastrophic rounding errors on the other. The solution is the "floating-point"—the ability to set a relative level of precision and then expand or contract the decimal point's position as needed.

The 704 was also the first computer that could create music. This was thanks to a program written by Max Mathews, called, bluntly enough, "MUSIC." This software enabled the machine to generate audio waveforms digitally. Mathews used it to compose a pioneering work of synthetic music, a 17-second-long work played without traditional instruments.

The computer's ability to digitally synthesize sound has other applications. For centuries, researchers and inventors had worked on efforts to synthesize speech. Wolfgang von Kempelen invented a crude "Acoustic-Mechanical Speech Machine" in 1791, and Charles Wheatstone created a more functional artificial speech generator in the mid-1800s. These contraptions used air bellows and other physical mechanisms to mimic a human voice box, but in 1962 physicist John Kelly Jr. and Louis Gerstman found a way to use the 704 to electronically synthesize spoken words. They taught the machine to talk.

Like the fortuitous discovery that two great things go great together ("you got your peanut butter in my chocolate!"), Kelly's team and Mathews collaborated to teach the machine to *sing*.

This was what Clarke witnessed—the bizarre spectacle of a massive metal box of wires and tubes singing a childish ditty in a robotic, singsong voice. Kelly and his colleague Carol Lockbaum programmed the 704 with the lyrics to Harry Dacre's 1892 song "Daisy Bell" (also known as "Bicycle Built for Two"), and Mathews programmed the musical accompaniment. The simple, lilting melody, combined with the space-age technology involved and the machine's robotic inflection, created a memorable but disorienting experience. (You can experience it yourself. **Click here** to listen to the IBM 704 sing "Daisy Bell," along with some non-musical speech experiments—"Daisy Bell" starts at around 0:50.)

Clarke was inspired by the performance. He recognized the dissonance of the advanced technology involved in creating something that seemed primitive—a theme that ran throughout *2001*. Clarke added a scene in which the advanced computer HAL's artificial intelligence deteriorates and regresses to its earliest experiences, back to singing "Daisy Bell." When Stanley Kubrick directed the film adaptation, he employed Shakespearean actor Douglas Rain to provide HAL's voice.

Rain passed away in November 2018 at the age of 90. Despite the ubiquity of talky computers today and an audience accustomed to hearing Siri and Alexa chatter, Rain's rendition of HAL's voice is embedded in the public imagination as the way a thinking machine would speak—or sing.

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