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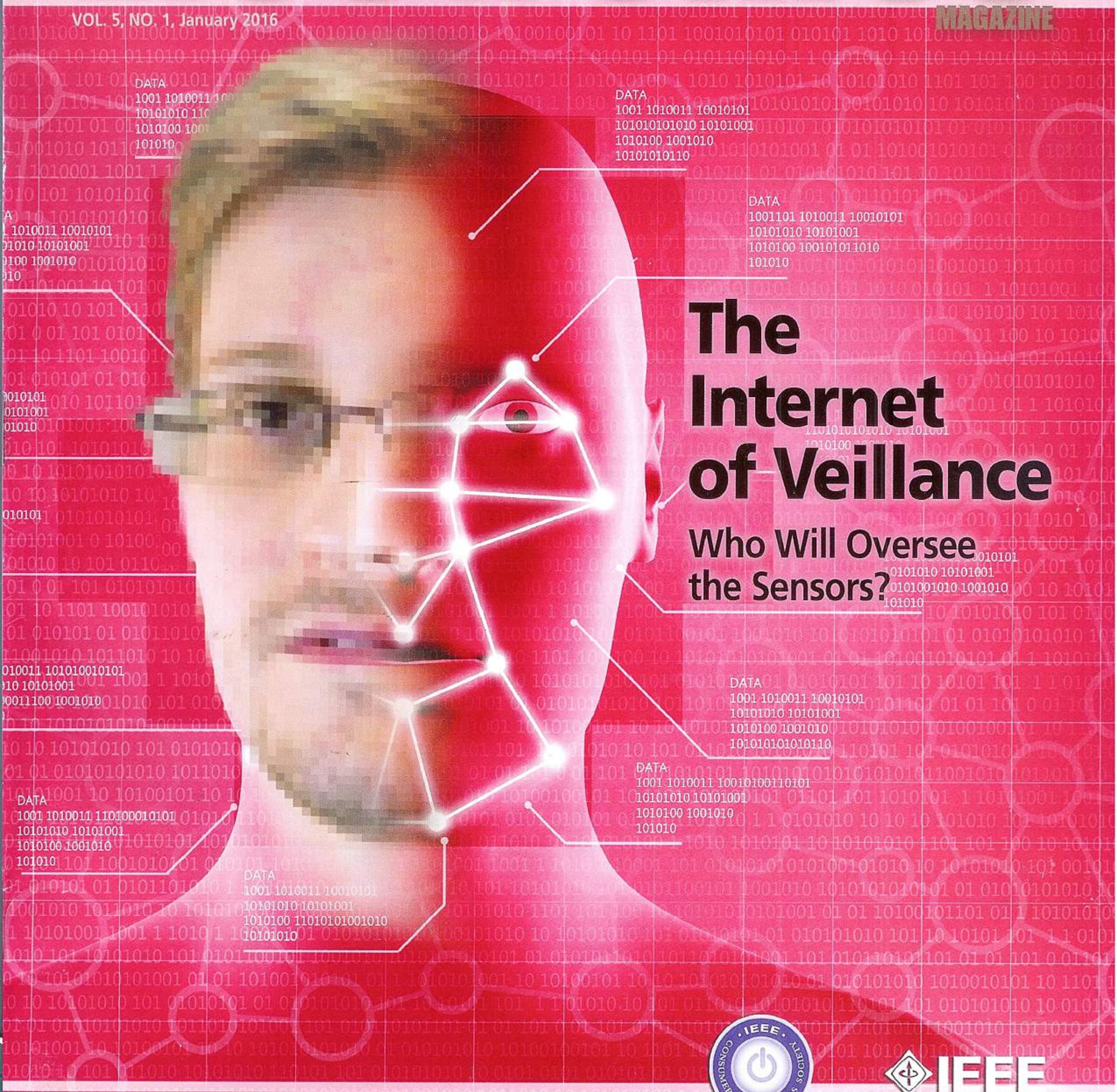

The Internet of Veillance

Who Will Oversee the Sensors?

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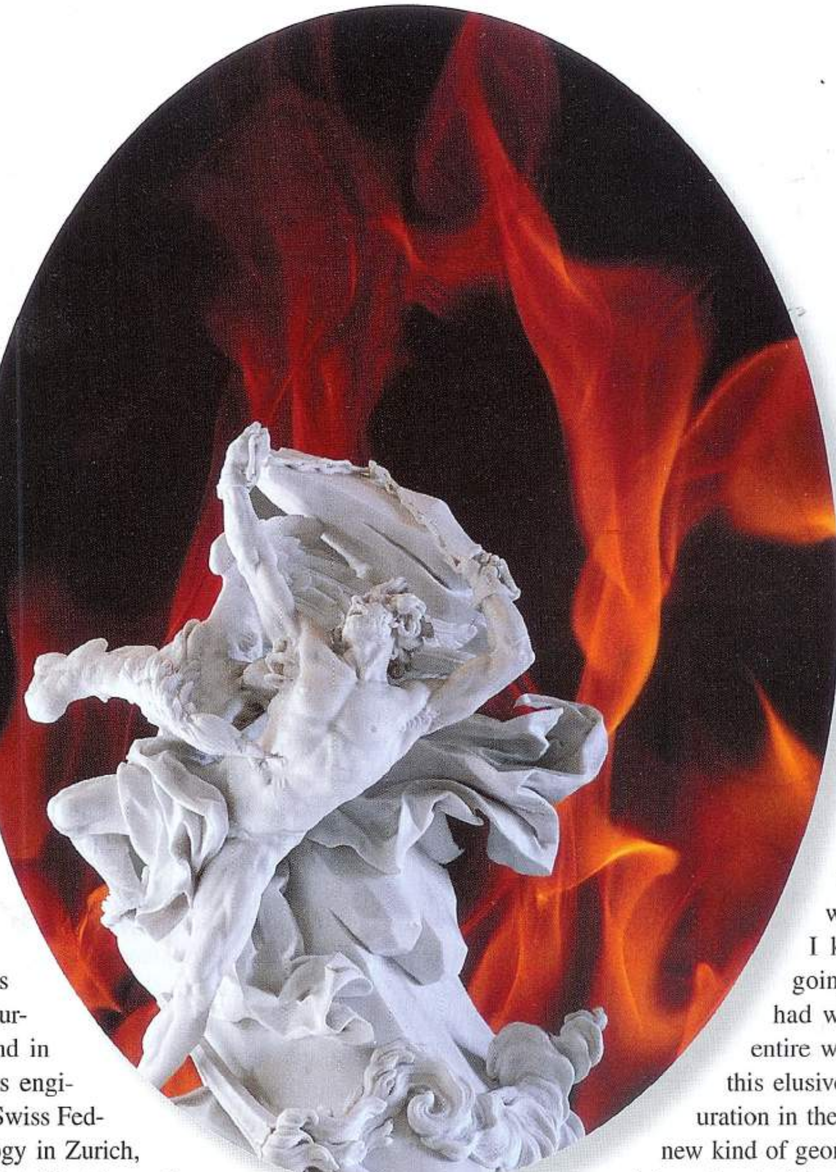
Self Absorption

Where will technology lead us?

By Joe Carvalko



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LOOKING BACK on my early experiences as a young engineer, I am reminded how little my colleagues and I appreciated that what we did would change the world, for better and for worse. I am also reminded how Marcel Golay, one of my early mentors, understood the duality of technology and how it plays a large part in its application for the right purpose. Born in Switzerland in 1902, Golay received his engineering degree from the Swiss Federal Institute of Technology in Zurich, the same college from which Einstein graduated. He is best known for the invention of the Golay cell used in gas chromatography and optical spectroscopy, the development of the Savitzky–Golay smoothing filter, the discovery of Golay codes, the generalization of the perfect binary Hamming codes to nonbinary codes, and his work on the complementary sequence autocorrelation functions used in Wi-Fi and 3G standards and on the Golay hexagonal nearest-neighbor logic used in pattern recognition schemes, of which I had the good fortune to be a part.

During the development of the pattern recognition schemes, Golay commandeered the blackboard, lighting up an expanse of slate, furiously scribbling in a language that only the scientists across from him and he understood. Everyone tried to anticipate what he was about to chart, but I knew where he was going; after all, he and I had worked in the lab the entire weekend trying to find this elusive "cancerous" configuration in the pixels that mapped a new kind of geometry. My mind drifted in and out of the conversation that followed as I thought about the moment—a space of physical things: air, bodies, tables and chairs, and then beyond into the space of the symbols that only a few in the world understood. Here, we could do anything we put our minds to: square the circle, craft Plato's ideal triangle, overcome the impossible by chalking constructs of the real world and immersing ourselves in Golay's abstruse theory. I wondered how I got there and where would it all lead.

In 1967, I went to work for PerkinElmer's Optical Signal Processing (OSP) Group as a research associate for a Harvard-graduate physicist, who widely published his papers in holography, optical computers, lensless microscopes, and a type of

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artificial intelligence that dealt with pattern recognition. My background in signal processing and optical systems was a good fit. The research department, which included the OSP Group, was home to individuals who had distinguished themselves in lasers, holography, and even cosmology. Charles Towne, a Nobel laureate and one of the inventors of the laser, was a frequent visitor, and Fritz Zernicke, whose father won a Nobel Prize for physics, was our lab neighbor. Golay, however, was dean among the researchers. In 1961, he received the Fisher Award in Analytical Chemistry (one of chemistry's highest accolades). He told his audience that he was not a chemist but a communications engineer. He asked that they remember that "... many ... advances in science are due to the cross-fertilization of, at first view, separate distinct fields." As I got older, I came to understand that this is as much the miracle of the modern world as it is its menace.

The OSP Group used Golay logic for optical pattern recognition (GLOPR), a parallel computer built before microprocessors were invented, to automate microscopy routines performed by pathologists and lab techs throughout the world. The idea involved imaging cells using a scanning microscope, feeding the image into a computer, and using Golay's new geometry (hexagonal parallel pattern transformations) to make topological measurements on cell shape, size, texture, curves, ridges, and craters. The final step was fitting the data to a statistical model that would come to represent a cell's morphological classification.

For nearly five years, I worked in this introverted "cerebellum" of a laboratory, where, on any given day, our sanctuary, dimly lit by blue gaseous pin-like lamps, fluttered the passing effects of the thousands of binary bits flowing through the silicon vortex of our parallel processor. Our subjects were well lit by the yellow sodium lamp marking the center of our cytological universe, the place where we burned images of leukocytes from one or more uranium mine workers or leukemia victims, the day's cell, through a pin hole onto the conductive cathode of a photomultiplier that moved kernels of cytoplasmic data, photon by photon, to waiting digital microelectronic circuits. From there, electronics digested a mix of digital numerology and alchemy, collecting metadata as input to pattern recognition algorithms, breathing life into a machine capable of doing what men and women spent a century trying to perfect. As we succeeded in scanning blood cells, we tried doing other things: finding malaria, looking for signs of syphilis, analyzing cancerous papanicolaou smears, and automatic karyotyping of chromosomes.

I have lived through many challenging and heart-pumping events, but in terms of adrenaline flow, few have compared to those first moments watching GLOPR miraculously report the names of each blood cell it found: basophile, monocyte, lymphocyte, neutrophil, and eosinophil. With the advent of the new computer, we were able to penetrate the unfelt world, to explain disease through light carrying evidence, to reconcile differences in the nature of biological specimens, and to unlock the unobservable through geometry. But, outside my inner sanctum, the civil rights movement and the Vietnam War pounded and twisted the country. U.S. cities were set afire, stores looted, homes vandalized, and churches fire bombed. Civil rights activists and antiwar revolutionaries were being beaten or worse—killed—some by lone madmen and others by men in the service of a band of thugs or police and national guardsmen following orders. The Weather Underground and Symbionese Liberation Army, both in opposition to the war, were self-styled and well-organized revolutionary groups. All those who participated in violence would be deemed, by today's standards, domestic terrorists. Yet I refused to divert my attention to what was happening outside. I locked myself, not in a room with spatial dimension, but into the nervous system of computers, the hypergeometric space of numbers, multivariate statistics, mottled and sparkling lasers beaming off specimens, the inner space of life itself, where I peered into the deadly corners of cellular mystery. What could be more mesmerizing (or escapist)?

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But regardless of what was happening in the world or whether I was mesmerized in my own world, progress relentlessly moved down unexpected paths, some light and others dark. On the lighter side, I had coauthored and published an article in 1969 that included pictures I had taken of red and white blood cells under different colored light in transmission ranging from pure blue to dark green to vibrant red. Each cell, depending on the color, resembled a Martian surface. Some were filled with deep valleys and others with craggy mountains. I learned later that Craig Kaufman, a California artist, reproduced the pictures into large lithographic prints and displayed them in an abstract expressionism exhibit titled "California Prints." The Museum of Modern Art, New York, eventually acquired the collection. I saw something in one medium and Kaufman saw it in another. Although I did not see it then, I now see how something done can serve as the basis for something else largely unrelated and yet cross-connected in some surprising way.

On the darker side, as the Vietnam War labored on, the OSP Group was drawn into changing direction, moving from the high purpose of medical science to war. Since our processes could recognize biological specimens, it could, in theory, be used to recognize military targets—more to the point, photographic images taken over southeast Asia. It was easy to turn a machine made for a humanitarian purpose into a machine made for war. In short order, we trained our creation to tell a river from a riverbank, a boat from a river, and a sampan from a patrol boat. Unfortunately, it could not distinguish a good guy, military or civilian, from a bad guy. In December 1971, I presented "The Evaluation of Golay Transforms as Applied to Aerial Photo Interpretation" to the Symposium on Automatic Photo Interpretation and Recognition in Washington, D.C.

How ironic that technology, so beneficial, or at least neutral, more times than not degenerates into a weapon of war. And, for me, it was not the first time. I was privileged to assist Emil Bolsey (also an alumnus of the Swiss Federal Institute of Technology in Zurich), who invented an electronic tracking system that, when mounted on a spacecraft and pointed at a planet, could figure the attitude of the craft (its pitch, yaw, and roll) and how fast the ground was passing by. One application was to move a camera lens to determine the pan rate to compensate for the movement between a moving craft and an object being photographed, thus reducing blur. Between 1966 and 1967, five lunar orbiters circled the moon, with onboard Bolsey scanners helping to relay high-resolution photographs to NASA so it could choose the Apollo moon-landing site. I last saw Bolsey in the mid-1980s when we met to discuss his suspicion that the government was infringing on the tracking system that we had so assiduously developed nearly 20 years before. I later learned that the system guided cruise missiles in Iraq in 1991, then Kosovo, and Iraq, again.

We know that what makes us individual is that each of us travels in diverse emotional and intellectual orbits. We may spin in and out of creative control, hardly ever contacting other inspired souls who may be circling close or we may crisscross as we move into other spaces—like Kaufmann and I. Isabel Myers in *Gifts Differing* said, "We often see different perspectives because each of us looks at the territory from different orientations." Golay spoke to cross-fertilization, but he left unsaid that it can have both good and bad consequences, for in science, discoveries can move into opposite poles.

We must be vigilant to spot those instances where scientific progress serves peace and reconciliation on the one hand and war on the other, or how technology fortifies effectiveness in a national vital endeavor but weakens our cherished values. By the 1960s, we had known for some time about the atom's potential to supply a near perpetual source of energy and also knew of its power to annihilate. In the first instance, the United States conservatively allowed the construction of nuclear power plants and in the second instance barred its use as a nuclear weapon. In the 1960s, we did not know if a computer-on-a-chip, still in its infancy, or the artificial intelligence we were creating freed us to soar to new heights or tether us to a world where government would hear and see all. With the events of 11 September 2001 and the ensuing march toward the detection of terrorism, a picture has emerged, one characterized by revelations that the U.S. National Security Agency has cornered the market on private information, euphemistically referred to as "metadata."

Yet we can look to a brighter side, one I could never have imagined in the 1960s when the chromosomes we karyotyped would be uncoiled to lay bare the genome as an instrument for critical medical diagnoses, to set free those erroneously convicted of crime, or enlighten us about Mitochondrial Eve, our common mother. I could not have pictured the long journey that began 200,000 ago—the journey that brought me into the world of physical things, air, table and chairs, and beyond, into the space of the geometries and cohorts, like Golay and Bolsey, who helped me better understand my universe, the one either too small or too far to see, unless aided by the eyes of science and technology. I once wondered how I got here, and now I think I know, but I am afraid my second query, "where will it lead?," will remain an open question.

One cannot predict with any precision where technology will lead us, although it has the indisputable potential to reduce suffering, extend life, and increase living standards. And, in the hands of the powerful, we witness its misuse altering natural patterns: ecosystems, the sustainability of organisms, to kill with greater efficiency. If we were separated from modern inventions, we would remain alive not more than a few days, weeks for survivalists. Invention does not only express our ingenuity, it expresses a societal conscience commensurate with the kind of world we collectively choose to live in. But ingenuity itself has little control over where it leads, and I have long wondered whether one might, in the words of Hamlet, "rather bear those ills we have, than fly to others that we know not of."

My granddaughter left for college this fall, deciding to study science, but I know she will inevitably become steeped in new technology. To what end will her pursuits be applied toward the good as she takes her place in her chosen profession? What should I tell her? I say pursue science and technology because, like Prometheus, the fires of invention burn bright, and although we may not always know where it leads us, a world darkened by the fear of treading upon the unknown is unimaginable.

AUTHOR'S NOTE

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