50 Years of Engineering Changes

by Wilson Greatbatch, *New York Nu '50,* P.E.

FIFTY YEARS AGO I joined the student branch of the Institute of Radio Engineers (now the IEEE) on the Cornell campus. If my memory serves me right, I think I organized the chapter. Thus, I became an engineer, or so my classmates were labeled by the rest of the student body. Immediately I was immersed in a continuing philosophical change which is still going on 50 years later.

Nearly all in our class were older men in their twenties; nearly all were G.I.s who had been radar or radio technicians in the services. My only honor upon graduation was that I had more kids than anyone in the class! We thought *engineering* was either motors and generators, or transmitters and antennas. We had no other options. But Cornell was building the predecessor of the Arecibo Radio Telescope and needed the soldering expertise of us ex-G.I.s to build the receivers. So we found out that *engineering* was radio astronomy and Boltzman's Constant, and that space had noise. I have always thought that it was wonderful that Cornell made it possible for undergraduate engineers to participate in this cutting edge new science. (Shades of Vladimir Karapetov.)

But change didn't stop there. Across the hall in Franklin Annex was a grad student measuring the blood pressure in rats by measuring the change in the diameter (electrical impedance) of the tail as a pulse of blood came down the artery. When the grad student got his master's degree, he left for NIH, and I got his job. So I found out that *engineering* was electronic plethysmography and Pavlovian psychology. (Very useful when, 10 years later, I got the opportunity to build the amplifiers that went on SAM, the first monkey to fly in the U. S. space program.)

Then a couple of brain surgeons from Boston came to Cornell on sabbatical doing research on some of our animals. They carried their lunches in brown paper bags, as I did, and we often sat out in the Ithaca sun, talking shop. They taught me about complete heart block, a condition in which a nerve in the heart stops functioning, resulting in a slow heart beat. I knew I could fix it, but not with the vacuum tubes and storage batteries we had at the time.

From Cornell came another change, to Cornell Aeronautical Laboratory in Buffalo, where I found that *engineering* was true airspeed, relative air density, and ram pressure. Then a big change — as we put our first transistors into a helicopter low-airspeed indicator. We cut its weight from 50 pounds down to five pounds and doubled its sensitivity. We drastically reduced slip-ring noise by putting a transistor amplifier out at the end of the helicopter blade, spinning around at 300 G's. Unheard of with vacuum tubes, but a cinch with transistors. A good deal, even with the silicon transistors at $90 each!

If transistors can do that, what about complete heart block? Now *engineering* became heart-tissue impedance, battery chemistry, and something we named electrochemical polarization of physiological electrodes. This says that electricity flows through metals by electron flow, but through fluids and tissue by ion flow. To get an ion from an electrode you need a chemical reaction. That reaction takes place within a micron of the surface of the metal. It is a different reaction at the anode than at the cathode, and the reaction itself is a function of the electrode metal you use. Thus, the same pacemaker driving the same heart, using four different electrode metals, may go through four different books of electrochemistry. The principal reaction on platinum is the modulation of an adsorbed layer of monotomic oxygen, which makes the interface look like a capacitor. On a stainless steel anode, it can be a corrosion reaction; not very desirable in a heart electrode! In 1983 I wrote a book on 25 years of pacemaking and found that *engineering* is technical writing and itself involves change, from a pencil to a word processor, but I guess the world is leaving me behind, because I still form my first drafts in pencil.

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So what are the changes in store for *engineering* as the next millennium approaches? Conceptually, I see all the sciences coalescing into one. Strangely enough, I see that one as molecular biology. We engineers feel happy about Ohm's Law, always the same, today, tomorrow, and through the next millennium. But we forget that this consistency is because we are averaging out billions of chaotic electrons; their motion is random, but the average is always the same. As we get into the macro sciences, like chemistry and physics, things aren't always the same anymore. And in biology and medicine, things are never the same, and sometimes medicine becomes as much an art as a science.

But when we get into molecular biology, we are dealing with a human genome of a twisted ladder four-billion rungs long. Each rung has two nucleotides. There are only four you can use A, C, G, and T (or sometimes its RNA counterpart U). Three rungs code for (describe) an amino acid, and an assembly of amino acids make up proteins, which along with some other chemicals, make up us. So everything we are is bound up in the sequence of these tiny nucleotides. They are so small that you cannot see them in a microscope, not even in an electron microscope. You can only tell what they are by what they do. But when you put them together they pretty much go together the same way every time, sort of like Ohm's Law. So my life science friends tell me they are working in molecular biology, but I tell them they are working in genetic engineering, and that is *my* field. I have a plaque on my wall that says I am a New York State licensed professional engineer. Reaching? A little maybe. But biology is working its way into engineering: the NAE made bioengineering the theme of its 1977 fall meeting, and MIT is including biology in its freshman engineering curriculum.

I see more big changes in the coming millennium. By 2050 AD many engineers think we will run out of economically recoverable fossil fuels. We will have run out of places to put the residues from our nuclear fission reactors. All the sources of alternative energy, solar, tidal, geothermal, wind, and hydro, will not supply 25% of our needs. We will have no place to go but nuclear fusion.

But nuclear fusion seems an elusive goal. We seem to have given up on magnetic confinement and are shutting down the TOKAMAK. Inertial confinement, with a multiplicity of concentrically aimed laser beams, has not worked to-date, and cold fusion is out. But up at the Fusion Technology Institute in Madison WI, Gerald Kulcinski (an NAE member) has demonstrated a helium-deuterium reaction utilizing electrostatic confinement of helium-3. (Remember picking up paper scraps with a charged comb?)

Instead of a 150 ton supercooled electromagnet, he uses a 1,000 lb. spherical wire cage (in a vacuum enclosure). The ultimate goal is a helium-helium reaction in which two He-3 ions are combined into one He-4, which is the innocuous gas we put in kids' balloons. The fuel is nonradioactive, the process is nonradioactive, and the residue is nonradioactive. It is a perfect fuel. Of course, the reaction takes place at a temperature much hotter than the surface of the sun. And there is practically no He-3 on Earth, but I tell my engineering students that these are just minor engineering challenges!

He-3 comes to us from the sun on the solar wind. But the Earth's magnetic field diverts it away, and it eventually lands on the moon. We just have to go there and get it, which we will do! A shuttle load (25 tons) would run the whole U.S.A. power establishment for a year, at an amortized cost (including the manned moon station and the halfway space station stop) of about $12 per barrel of equivalent oil. We now pay about $30. The project is not only technically feasible, but economically feasible. But if we want to get there by 2050 AD, we had better start now!

So 50 years of engineering has involved many changes. The enjoyable part has not been just rolling with the changes, but keeping up with them. We haven't made a lot of money, but we sure have had fun. And we're not through yet. After all, I won't be 81 until September!

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The author with pacemaker patient in Victoria Children's Hospital, Melbourne, Australia, 1998.

Most noted for his invention of the implantable cardiac pacemaker, Prof. Greatbatch was named to the National Inventors Hall of Fame in 1986 and received the National Medal of Technology in 1990. After service in the U.S. Navy during 1939-45, he received his B.E.E. at Cornell in 1950 and his M.S.E.E. at the University of Buffalo in 1957 and has been awarded several honorary doctorates. He is a fellow of the AAAS, ASME, IEEE, American College of Cardiology, American Institute of Medical and Biomedical Engineering, and several other societies. A member of Tau Beta Pi, Eta Kappa Nu, and Sigma Xi, he holds more than 150 patents and has contributed more than 100 articles to scientific journals.