John M. Cioffi

Ask Me Again in Ten Years!

"What? Provide leadership reflections?" was my culpable response when old friend and VP of Publications Prof. Arye Nehorai first asked me to write this short note. "I'm too young for that," I shuddered, "ask me again in ten years." The thought of reflecting on my career sounded too much like an epitaph for me to consider. That's for the old geezers (I won't name names, but not me yet). Too much fun remains, I thought to myself. Furthermore, I'm not finished with what I really want to do to be able to reflect. Nonetheless, the grim reaper gave me another year, and then Arye patiently asked again. It dawned on me that whatever my age and health, I'll probably never be quite ready to reflect and therein is my thesis—*Ask me again in ten years.*

The first time I heard that sentence used in this context was by Prof. Mac E. Van Valkenburg, who was in his 60s when an unsuspecting reporter unsuccessfully tried to trip him into a vain moment. The reporter asked Mac, then dean of engineering at Illinois, "Well, Mac, what was the biggest achievement of your career?" I could envision the impish fun-loving grin on his face that I grew to know and love so well as a student in his classes. He told the reporter to ask him again in ten years. His point of course was he was not done yet, nor should he be. Neither are we. Of all the great engineers, billionaires, and visionaries I've come to know in my career, I thank God that I met Mac first. He had quite a positive influence on all, and that one piece of wisdom as a reflection can guide many careers, young and old—keep up that positive attitude, look ahead to the future enthusiastically. For that is what he really meant with his rhetorical response.

If anyone asked me when I was a student whether I would be a professor, I would have responded "no way." Life certainly has its surprises. We often reevaluate what we do, and inevitably things improve in technology. The ten-year cycle can manifest itself in many forms: jobs, lives, and families. I'll keep this article to technology but will digress to mention that I often threaten to install a psychiatrist's couch in my Stanford office and charge $300/hour for personal advice. (Most asked question: "Should I get married?" to which I always respond "Do you love her/him?") For you, the engineers who love mathematics and technology, reflect only to guide the enthusiastic march into technological progress. Forget the torpedoes and full speed ahead!

At the earliest stages of my career, signal processing was declared dead, especially for anyone who wanted to use signal processing to improve data-transmission performance. Wow, bummer, I thought—this signal processing is good stuff, even if then only appealing to us "techies" or, worse yet, "propeller heads" as the real business guys like to call us. ("Propeller head" is a reference to the beanie copter hats of the cartoon "Beanie and Cecil" that we immature childish engineers are envisioned to be sporting when dreaming of technology that could be. I want Cecil to come and thrash the MBA who uses that term when I hear it. "Help, Cecil, Help!") It was the beginning of a lean decade for engineers like me. It was coming from every direction, "young man, don't waste your career," we just don't need this signal processing stuff. But, oh, what a difference ten years made.

For this issue's leadership reflections, I invited John Cioffi of Stanford to provide us with some insight of his distinguished career. His initial response was "I'm too young for that, ask me again in ten years!" Thankfully, he reconsidered and provided us with this excellent article containing the insight to how he has gotten where he is. His main advice is that if you believe in a certain area of technology, stick with it, despite what some people may say. This advice has driven John's career and has provided him with the great success he has had. As he says, "Forget the torpedoes and full speed ahead!" Enjoy John's column and look forward to ten years from now when we will again ask him to provide us with more leadership reflections!

—Arye Nehorai
"Leadership Reflections" Editor

1053-5888/04/$20.00©2004IEEE

The Wireless Depression

As a Bell Labs employee in the early 1980s, I vividly recall being told that "wireless is dead; we already engineered the microwave links to within .25 dB and very few people use or need a car phone." Be mature you signal processing guys, you have to understand that this mathematical science you love is a bygone artifact of a transitional epoch where bandwidth was limited. Having just completed a 1984 Ph.D. in the area, this was a tough pill to swallow. My proposal to Bell Labs that I work on adaptive antenna arrays for wireless was heresy; "but, but, the spatial bandwidth we could get is incredible," I said. Sorry, "who needs it" was the response, and let us tell you a little secret we're about to expose on those who work in this area. "We now have infinite bandwidth, think lightwave networking or you're doomed." Bell Labs wireless gurus were cajoled into fiber research (or out of the company). It was easy to join the pessimists if one wanted an accolade of any sort. Some accepted the portended inevitability, some did not. In fact, one wireless research head (who was supportive of my proposal and was to be my boss), adamantly resisting the pressure, took European leave (a nice way of saying "he quit"). He proceeded to ignite the GSM wireless effort in Britain and then Europe. That success inspired interest in cell phones and prompted formerly military-funded spread-spectrum enthusiasts to offer their version of wireless, and within a decade, the gurus (some of whom secretly kept their interests alive) were being encouraged to leap back into the wireless areas. Wow, what a difference a decade makes. And now, yet another decade further, the area is unconscious with opportunity. I wonder what it will see ten years from now? *Ask me again then.*

The Recording Channel

Being of very modest means upon finishing school, I needed to find somewhere I could work in the area I liked but still pay the bills. I heard disk drives were like communications channels, so I joined IBM's research laboratory where signal processing at least was hot for potential increase in the storage density of a disk (hurray, a com channel in disguise!). The storage channel was great, and my suggestion that one use an "adaptive equalizer" there (the channel changes as a function of radius on the disk) was met with some guarded enthusiasm. I persuaded another of the less-needed signal processing specialists from my old group to join me at IBM. He developed the world's first adaptively equalized storage detectors and, ten years later, they were being mass produced. Signal processing remains a significant driver of higher and higher densities in recording of all types today. The adaptive part was key. Thank goodness someone needed us. One of my former Ph.D. students now heads the read-controller area at the world's largest supplier of read-channel detectors. I wish I could say publicly what is planned for that area.—*Ask me again in ten years.*

Despite the storage area being a temporary savior for my misdirected career in signal processing, the yearn to stretch a communications link to its limits just would not take leave of my psyche. The allure of this signal processing for data transmission was addictive. But where? A friend was leaving his academic position at a major eastern U.S. university to start a small company. He was trying to find a replacement for himself and suggested I visit and interview. As most students do to me today (oh, if I could get $300/hr for this stuff) and I also did then to my old advisor, I asked what he thought of my joining this eastern university. "What?" he said—"You told me you'd never teach in a university!" Yes, yes, I know, and sorry, but I have these ideas I'd like to try. A week later, one of his colleagues called and said they would have an opening at Stanford, a bastion of signal processing types who had not yet got the word that we were all doomed. I thought they'd seen and heard more than enough from me earlier as a student, but they pardoned my youthful indiscretions and offered me a job. So, hoping for band-limited data transmission resurrection, I figured at least give this area another six to ten years (six was the tenure cycle) and took the job.

Copper Telephone Lines

At this time in the late 1980s, integrated services digital network (ISDN) was starting to heat up, and the data rates of ISDN were only a tiny fraction of what was possible on the copper. I wrote a proposal to the old NSF Presidential Young Investigator (PYI) program on this subject—somehow, somewhere, someone pulled a string, and I became a PYI. But when they announced it publicly and in the newspapers (which was customary for all the PYIs at the time), they cited "John M. Cioffi—area of expertise 'fiber'." Nowhere was fiber listed in my proposal, but I was glad to get the money and proceed—no complaints that NSF fiber funds were misdirected to this copper heresy. These particular awards had a significant industrial matching component, so a PYI had to find sponsor money to get NSF's money, one-for-one matching, essentially $100K/year (a lot at the time). Well, here it came again "John, you are wasting your career in this signal processing transmission stuff—it has no future." Come on, broaden your horizon, "you need to think big, think infinite bandwidth and networks." A retired Pacific Bell executive joined Stanford to head a

telecom center and told me and anyone who would listen that "Pacific Bell" will have fiber to everyone's home by 1994—it's in the ILEC five-year plan and will happen—"copper transmission research is a waste of money." Ouch, and I was coming up for tenure in a few years.

IBM had a wonderful and insightful policy of helping people who leave and go to universities. They gave me money to work at Stanford with the IBM group doing the adaptive equalizer for recording. I took that IBM money to NSF and said "Hey, look here it is, match it." Not fiber, but ok, recording sounds good. Thing was, I used the matching money for the copper telephone-line project. (NSF today lists that as one of their successes in procuring their annual federal allocation.) Almost by chance, I met a man who'd change the course of my life, Dr. Joe Lechleider of Bellcore, who happened to be speaking at a Globecom conference in Tokyo in 1987, just before me. He was Mr. ISDN and near retirement. We talked for about five hours straight, going to dinner afterward. He believed in the high data rates on copper and ran a small group at Bellcore (he managed to convince the fiber researchers to fund this effort as higher speeds would promote a greater need for fiber) on what he called asymmetric digital subscriber (ADSL) lines. He provided a tiny amount of matching funding as best he could that was more spiritual in support than substantive and called about two years later to somewhat despondently tell me he had retired, but not to give up. (The same retired Pac Bell executive then told me that he had heard it on high authority within the ILECS that there would never, ever, ever be a single line of ADSL deployed in the United States.) We stayed with it, Joe, and thanks for the encouragement! This was technology heaven; the ADSL channel needed to operate near the fundamental theoretical limit of capacity. We had to throw everything we learned (and more) at it to get to any reasonable data rate. In 2004, ten years after the Bell System's projected five-year-plan death of copper, there are 100 million lines of ADSL in operation around the world. ADSL will service a billion customers someday. DSL transceivers today are easily the most sophisticated signal processing designs ever mass produced. And, the speeds march upward (we keep finding ways to recompute a higher fundamental capacity), and there remains fantastic continuing opportunities in copper. Not a single fiber line, other than experiments, has been deployed all the way to anyone's residence anywhere; however, fiber is now being deployed to intermediate points in the copper network because of ADSL's success. Higher speeds on copper did eventually make the business case for fiber to shorten the phone lines (but not eliminate them—Joe, you were right).

A,B,G, and EPONs speeds will all have to be revisited because the attached DSL drops will overwhelm the original PON speeds envisioned. The sky is the limit in this area: *Ask me again, please, in ten years about this area!*

Two former Ph.D. students founded and run a company that produces chips that allow 10 Gb/s on 100 meters of Ethernet category 5e (and 6 and 7) cable—10,000 times the original 1 Mb/s Ethernet speeds. The signal processing in these tiny transceivers break sophistication records. *Ask me again in ten years about 10GBaseT.*

Two other former students founded and run a company to use signal processing to transmit 10 Gb/s and higher speeds over multimode fiber. The reason: the copper is getting so fast at the ends of the network that the inner-network fiber can no longer handle the speed and needs a boost. Signal processing for multilevel transmission in fiber is in its infancy in this area. I'll probably be working on much higher speeds that press fiber limits some day. *Ask me again in ten years about 10GBaseLRM (and 100GBaseLRM)!*

Mac's vision is rock solid. Whether it is signal processing or some other area of technology that the engineer loves. Stay with it if you believe in it, the best is yet to come. You'll see—*just remember to ask yourself again in ten years.*

John M. Cioffi received his B.S. degree from Illinois in 1978 and his Ph.D. from Stanford in 1984, both in electrical engineering. He is an electrical engineering professor at Stanford University and is on the advisory boards of Portview Ventures and Wavion. He founded Amati Communiations Corp. in 1991. He is on the board of directors of Marvell, Teknovus, ASSIA (chair), Teranetics, and ClariPhy. His interests are in the area of high-performance digital transmission. He holds the Hitachi America Professorship in Electrical Engineering at Stanford and is a member of the National Academy of Engineering. He received the *IEEE Communications Magazine* best paper award in 1991, the ANSI T1 Outstanding Achievement Award in 1995, the IEEE Fellow in 1996, the University of Illinois Outstanding Alumnus award in 1999, the IEEE Millennium Medal and the IEE JJ Tomson Medal in 2000, the IEEE Kobayashi Medal in 2001, and the ISSLS 2004 Outstanding Paper award. He was an NSF Presidential Investigator from 1987 to 1992. He has published over 250 papers and holds over 40 patents.