The Disappeared: Beyond Winning and Losing

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When "others" such as women and people of color make innovative contributions in STEM, they often "disappear" from later history and their contributions ascribed to people who are remembered. Sometimes the contributions are lost altogether, or never come to fruition due to discouragement. This is seldom deliberately caused; it is the accumulation of advantage by those expected to innovate. "Others" are not expected to innovate and lose advantage, reinforcing expectations. In this paper we chronicle an example disappearance and introduce the "Conway Effect," an extension of sociologist Robert Merton's Matthew Effect and historian Margaret Rossiter's Matilda Effect, to elucidate the disappearance process.

This special issue of *IEEE Computer* points at struggles of women and under-represented minorities in the computing-related fields. It has much company. People throughout STEM have been debating this issue for decades.

As a transgender person who transitioned from male to female fifty years ago, I have learned much about our society's treatment of 'others'. These experiences provide interesting perspectives on the issue at hand.

This report is my own personal account. It might be dismissed by some as more axe-grinding by someone with an axe to grind. But that is not its intent. It is motivated by the idea that important hidden causes of the struggles of 'others' in STEM can be uncovered. In this case, we investigate why even those 'others' who make major contributions 'disappear' from later history.

Disappearances

The arc of this story is not difficult to understand. Millions have seen director Theodore Melfi's 2016 film based on Margot Lee Shetterly's book *Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race*. It tells a true story that had disappeared about the critical role played by women in the 1960s space race between the United States and the Soviet Union.

Megan Smith, former U. S. Chief Technology Officer, discussed in an interview in 2015 how women who played key roles in the U.S. computing industry had disappeared.[1] As a classic example, she described how the women involved in developing Apple's McIntosh computer disappeared from historical accounts.

The phenomenon is neither new nor limited to the space program or computing: as historian Margaret Rossiter notes in her three volume *Women Scientists in America*, women have been disappearing from the history of science for a long, long time.[2] Rossiter called this the "Matilda Effect", namely the systemic repression of contributions of women scientists and the attribution of women's contributions to male colleagues.[3]

That such disappearances happen is beyond dispute. Of course, some women are remembered. Marie Curie is recognized as an important female scientist. After much rehabilitation, Ada Lovelace was recognized as the first female – and perhaps the first, period – computer programmer. Grace Hopper is revered in the computing world. But compared to the legion of men remembered for their contributions, the ranks of women seem small indeed.

What Causes such Disappearances?

Having visualized that such disappearances often happen, the big question is *why they happen*. It would be convenient to focus on stories that revolve around bad vs good, with bad people "disappearing" the stories of good people. Such accounts make for popular storytelling, perhaps with bad men disappearing good women. However, that is far too narrow a view of the phenomenon.

Sociologist Robert K. Merton had an interesting idea that influenced Rossiter. He coined the term "Matthew Effect" to describe how eminent scientists get more credit than lesser-known scientists, even if the work of the eminent scientist is similar to that of the lesser-known one.[4] For example, prizes are often awarded to the most senior researcher in a project, even if a graduate student or post-doc did the primary work.

This is an example of "accumulated advantage" in which advantages flow to the prominent, not the less prominent. In societies where men are more prominent than women, it is the "natural order of things" and accepted that advantages flow to men. Over time, the less prominent might become discouraged and stop striving, thereby unwittingly reinforcing the perceived natural order and the cycle continues. Many good people are prominent. They are not deliberately being bad. They do not even notice what is going on.

The foregoing suggests that the issue is *culture* rather than explicit policies. It is doubtful any major organization – such as a university or tech company – would tolerate an explicit policy to reward prominent men over less prominent women. Yet the problem remains, in large part because it is deeply buried within our culture, and culture can be difficult to change.

To illustrate these effects, I discuss my personal experiences in the Very Large Scale Integration (VLSI) revolution in silicon microchip design and manufacturing. It is a story of engagement and disappearance.

The VLSI Revolution

I was involved in the "VLSI Revolution" that spawned the "microchips" that triggered the expansion and impact of California's Silicon Valley. It built upon the 1960s "integrated circuits" of transistors and wiring "printed" onto chips of silicon. As advances in lithography enabled smaller features to be printed, the number of transistors printable on chips increased. In 1971 the Intel 4004, the first "microprocessor," a complete computer on a chip, was created with 2300 "field-effect" transistors (FETs). Each FET was analogous to an almost perfect little "toggle-switch".

Gordon Moore of Intel observed the number of transistors on commercial chips doubled about every two years. Prof. Carver Mead of Caltech dubbed this insight "Moore's Law." At Caltech, Bruce Hoeneisen and Mead determined no physical limits to printing a million submicron FETs per chip. Dennard et al at IBM Research determined that as FETs were scaled down their power density remained constant, as both voltage and current scaled down with length.[5]

"Dennard scaling" made conceivable "supercomputers" on single chips by 1990, without excessive heat generation. However, there were no means to design such complex chips. It was as if the printing press had been invented, but no written language existed in which to write printable stories.

In 1976, Bert Sutherland, Manager of System Sciences at Xerox Palo Alto Research Center (PARC) and Ivan Sutherland, Chair of Computer Science at Caltech, launched an effort to attack

this problem. A collaborative project began, led by me at PARC using my expertise in computer architecture and by Carver Mead at Caltech using his expertise in semiconductor device physics.

It was the perfect place and the perfect time, given PARC's recent innovations in personal computing and networking, including interactive-display mouse-controlled "Alto" personal computers, "Ethernet" local-area networks, and the xerographic "laser printer." PARC was also connected to the ARPANET, precursor to the internet. Few outside advanced computer research circles knew that such technologies existed. We entered a vast new frontier for exploration, armed with these 'secret weapons'.

Our collaboration in '76 and '77 yielded results. We created new methods for designing digital systems in silicon – methods that could be quickly learned by digital system designers having limited backgrounds in semiconductor circuit design and device physics – enabling wider explorations of architectural potentials of silicon technology.

The methods enabled designers to visualize and craft digital systems using graphical design software tools running on Altos. A key was a novel set of scalable VLSI layout design rules expressed as dimensionless geometric inequality equations. These enabled chip layout patterns to be numerically encoded, scaled, and reused as Moore's law advanced. The rescalable rules also enabled sharing of chip subsystem modules in what we now call "open-source."

Our explorations intertwined technological and social innovation (i.e., they were techno-social). For example, one could envision a "scripted iterative process" coalescing into a social ritual as Moore's law progressed. Design tools running on current computers would be used to design chip-sets for more powerful future computers, and these chip-sets then printed using the next-denser fabrication process. Some of the more powerful chip-sets would be used to enhance the computer-design computers and chip design tools. The whole process repeated, iteration after iteration – with iteration timed by Moore's law. As more engineers and design-tool builders engaged the process, working on more powerful computers, the process could generate ever more powerful and innovative digital systems.

However, even a powerful "canned script" cannot take off through unfocused, scattered actions. The engineers and programmers needed could not be recruited and trained at scale through existing methods. A solution was to create a rapidly evolving textbook that *looked like one published ten years after the VLSI revolution had already happened*. The book would show working design examples applying the new VLSI methods, and have all the basic concepts of digital design, computer architecture, electronic design automation and chip fabrication. It would consistently express materials *using and only using* the new streamlined VLSI design methods. The methods would be presented as *already proven and "sound*." I suggested this, and Mead agreed. The result was an evolving, computer-based book, quickly printed on PARC's laser printers, and circulated. This became the seminal 1980 textbook *Introduction to VLSI Systems*, which has been called "the book that changed everything".[6]

Charles Steinmetz in 1912 used his seminal text to propagate his revolutionary AC electricity methods at Union College.[7] A sabbatical from PARC in the fall of 1978 enabled me to use the Steinmetz story as a script while developing a VLSI design course at MIT using the draft book. Students learned the streamlined methods of chip design and then did design projects. Their chip designs were fabricated at Pat Castro's Integrated Circuit Processing Lab (ICPL) at HP Research and packaged chips returned to them shortly after the course. One student (Guy Steele) designed a complete LISP microprocessor.

The MIT course stunned top people in Silicon Valley.[8] Then mysterious, large scale chip design was the province of a few engineers working for chip manufacturers with access to

semiconductor "printing plants." Now, apparently anyone could do it, and many major research universities wanted to offer such courses. It held the promise of "freedom of the silicon press"!

We faced the challenge of how to quickly fabricate project chips for many courses. This led to the visualization of an embryonic "e-commerce" system: Students remotely submitted digital design files via the ARPANET to a "server" at PARC. The server's software then packed the designs into files for multi-project chips (MPCs) and multi-project wafers (MPWs). These were then fabricated as one small lot among many boatloads of mass-production chips.

This method promised widely-shared, economical-access by many individual chip designers to expensive chip manufacturing facilities. Users could electronically transmit design specs to a remote "silicon foundry" (as they later became called), where their designs would be "manufactured to spec" and shipped back to them. Key in this was Pat Castro. She and HP Labs were willing to participate again. Also critical was PARC's readiness to participate.

With all the pieces in place, an announcement was made on the ARPANET to EECS departments at major research universities about what became known as "MPC79". On the surface appearing to be official and institutionally based, it was done in the spirit of a classic "MIT hack".[9] Namely, a visible technical stunt covertly pulled off that stuns the public who can't figure out how it was done or who did it. (I'd been an undergrad at MIT in the 1950s.)

The *bait* was the promise of chip fabrication for all student projects. Faculty members at 12 research universities signed on to offer Mead-Conway VLSI design courses. This was bootleg, unofficial, and off the books, living the principle that "it's easier to beg forgiveness than to get permission."

MPC79 escalated into a huge ARPANET "happening". Faculty and 129 participating students and researchers acted together, creating scores of innovative designs.[10] The resulting chips were returned from Pat Castro's "foundry" one month after the design cutoff, an astonishingly short turnaround time. One prototype design, the "Geometry Engine" by Stanford's Jim Clark at, led to Silicon Graphics, Inc (SGI).

A huge success by any measure, MPC79 provided a demonstration and validation of the VLSI design methods, the book, the design courses, the design tools, and the e-commerce chip-prototyping infrastructure. MPC79 also bootstrapped a budding VLSI techno-social ecosystem for design into existence. By 1983, Mead-Conway VLSI design courses were being offered at 113 universities around the world. Moore's Law held for decades. Modern chips contain complex systems composed of billions of transistors.

Early Notice, Then Disappearance

By the early 1980s it was clear that "VLSI" was important. The prominent industry trade magazine *Electronics* honored both Mead and me with its Annual Achievement Award for our "effort to create a common design culture for the very large-scale integrated era." Our pictures were on the cover and a story about us was included.[11] We both received the Pender Award from the Moore School of the University of Pennsylvania in 1984. We both received the Wetherill Medal from the Franklin institute in 1985. Mead was elected to the National Academy of Engineering (NAE) in 1984, and I was elected in 1989.

My disappearance began in the late 1980s. George Gilder, an influential speechwriter for Ronald Reagan and author of the anti-feminist *Sexual Suicide* (1973) and *Men and Marriage* (1986), published in 1989 *Microcosm: The Quantum Revolution in Economics and Technology*.[12] He described Carver Mead as behind the rise of Silicon Valley and an exemplar of elite-science-based capitalism. High-tech business and conservative political organizations

liked the book, and it became a national best-seller. Gilder later became a founding fellow of the Discovery Institute and promoted 'intelligent design'. His book mentioned my activities, but I was portrayed as Mead's assistant.

Mead received increasing attention. He was elected to the National Academy of Sciences and the American Academy of Arts and Sciences, received the EDAC Phil Kaufman Award, the IEEE John von Neumann Award, the ACM Allen Newell Award, the $500,000 Lemelson-MIT Prize, the Computer History Museum Fellow Award, the National Academy of Engineering Founders Award, induction into the Inventors Hall of Fame, and the highest award of all – the National Medal of Technology.

Whether Mead deserved these awards is not the point. The point is that I no longer received any such awards. Some of Mead's awards cited innovations that were solely mine. MPC79 wasn't even noticed, despite its role in innovating, prototyping, and demonstrating at large scale an internet-based, evolving "techno-social dynamical system" that was foundational and paradigm-shifting. As a woman, I disappeared from history and so did my innovations!

In 2009 the disappearance was completed with the Computer History Museum's gala celebration of the 50th anniversary of the integrated circuit. Sixteen men were described by the media as "the valley's founding fathers." They were inducted into the National Inventors Hall of Fame for their contributions to microelectronics. Top billing went to Gordon Moore and Carver Mead.[13] I not invited to the event. I didn't even know it was happening! Pat Castro was not mentioned, either. Thus, as with the McIntosh story, key women (Conway and Castro) disappeared along with their contributions. Again, no one set out to do this. It just happened.

Investigation, Reappearance and Reflection

My reaction to this disappearance was one of accumulating shock, stress, and even despair. Then, one day while reflecting on Rossiter's work, I had an epiphany of the opportunity to do interesting research on why and how I had disappeared. It seemed that when weirdness breaks out, it is best to not get upset. Much better to go-meta and do science on it!

I began by telling the story as I remembered it, compiling an online "VLSI Archive" with help from veterans of the VLSI revolution.[14] By 2010 the archive contained scans of many original documents, technical reports, course notes, design reports and chip photos. A treasure trove of artifacts, it provided a foundation for my research. I built a timeline, sorting out flows of events.

As my research progressed, previously foggy events became clear. I began writing. For the first time in decades, I began sharing my perspectives. I wrote reminiscences of the IBM-ACS project,[15] of the MIT '78 VLSI design course,[16] and of the overall VLSI revolution in a special issue of the IEEE *Solid State Circuits Magazine*.[17] I clawed my way to reappearance.

I also came to see how my transgender journey impacted my role in the VLSI revolution.[18] I was fired from my research position at IBM while transitioning in 1968 and had to start my career again in a covert identity. I rose from contract programmer to computer architect at Memorex and was then hired by Xerox PARC in 1973 – all the while living like a foreign spy in my own country. I was always looking over my shoulder, terrified that I'd be outed and lose my career again. Never wanting to call attention to myself, I used the practical "tradecraft" learned during my transition to take covert actions to make interesting things happen. In some ways I disappeared myself.

My reminiscences are having the effect of reappearing me.[19] I became a member of the Hall of Fellows of the Computer History Museum in 2014, and the same year received an honorary doctorate at the Illinois Institute of Technology. I received the prestigious James Clerk Maxwell Medal from IEEE and the Royal Society of Edinburgh in 2015. In 2016 I was named a Fellow of the AAAS and received an honorary doctorate from the University of Victoria.

The Conway Effect

However, perhaps the greatest payoff of my recent research has been the coalescing of what I call the "Conway Effect".[20] It borrows from Merton's Matthew Effect, and from Rossiter's Matilda Effect. It then adds a new element: *People tend to be blind to innovations made by 'others' whom they do not expect to make innovations.* People usually do not notice when something that has never been done before is being done right in front of their eyes. Even if people sensed it was an innovation, they'd think a 'known innovator' responsible, not a person in front of them who is not expected to make innovations.

Examples of Blindness to Innovations

Consider that most students in the MIT'78 course thought they were learning "how chips were designed in Silicon Valley," the known institutional innovator. Following what they perceived as the true innovator, most didn't realize they were learning radical new methods not used in the Valley. Silicon Valley's cognoscenti were in turn astonished at "what MIT did", but, then again, MIT was a known innovator. Many universities rushed to follow the leader and offer "MIT VLSI design courses".

The participants in MPC79 took for granted the innovative infrastructure they were using, not realizing it was a deliberately and covertly generated, paradigm-shifting hackathon that would launch "fabless design," "silicon foundries," and "internet-based e-commerce." Flying under the radar and exploiting the ARPANET and PARC's computing power, we had deployed a radical new techno-social functionality that appeared to users as already-existing institutional infrastructure.

MPC79's success validated the Mead-Conway VLSI design methods. DARPA began a major VLSI program in 1981. It funded Mead-Conway style research explorations in VLSI system architecture and electronic design automation (EDA). It also funded the technology-transfer of the MPC79 system to the USC Information Science Institute (ISI) to provide ongoing chip prototyping to the emerging DARPA funded VLSI research community. ISI's "MOSIS" service, which became a national research infrastructure for advanced chip prototyping, is historically 'known' as a development of established innovator DARPA.

In tradecraft terminology, by covertly sailing under the "false flags" of MIT and DARPA, we spurred and spread the VLSI revolution. DARPA's mystique as an innovator was so great that government-sponsored MOSIS-like services sprung up in other countries. MIT's mystique triggered the rush to offer VLSI design courses at other research universities. The VLSI revolution appeared to proceed from known innovative institutions. Few knew that it had been covertly orchestrated via an escalating series of techno-social "happenings", all sailing under false flags of elite institutions.

The Social Process of Credit Assignment

Social awareness of important innovations spurs the process of credit assignment. Credit for innovation is subliminally assigned, gained, granted, bartered, seized, etc., as modulated by visibility, status, prestige, class, power, location, credentials, prejudice, popularity, influence, wealth, and accident. Wide public visibility via awards, medals, high-honors, media coverage, biographies, etc. often masks the story of how innovations are made and sustains the social crediting rituals – rituals that then reinforce beliefs about how and by whom innovations are made.

One might argue that Gilder's storytelling projected Mead as a vital force behind the rise of Silicon Valley, and the story spread in the consciousness of high-tech industry leaders and national political leaders. Mead never explained in detail how the VLSI revolution had unfolded. He didn't have to. Gilder had framed the story.

For decades I remained hidden and silent, but in 2012 emerged to explain my view of how the VLSI Revolution had been orchestrated. By then gender stigmatization had diminished somewhat, and I hoped my account would rise above the noise. Portions of the story are now understood, at least by some.

A Corollary

It is possible to trigger a large paradigm-shift in the open, so long as people have no clue what you're doing and thus don't question and/or resist you. Expertise creates silos. Most people are not programmed to "notice" that a profound change is underway, much less visualize the degree to which they are recruits in bootstrapping and exponentiating that change. They just go along with the flow. MPC79 was subsequently (sometimes subliminally) reverse-engineered. It was mimicked and evolved into a diverse techno-social e-commerce infrastructure. Four decades later the public has enough experience using this 'futuristic infrastructure' to evolve shared concepts and language to talk about, and possibly follow, the story behind the innovation.

Time and Change

Discussions of "broadening participation" – the preferred phrase of some organizations for issues like "diversity" and "underrepresentation" – usually close with a lament of the shortfalls and insist on vigorous redress. Yet the problem persists. Change, even though seeming in the right direction, takes a long time. Perhaps Theodore Parker was speaking about this when he said of slavery in 1853, "*The arc of the moral universe is long, but it bends toward justice.*" Those who suffer injustice find cold comfort in the "long" part, but some (even some before they pass) may eventually become recognized as having been on the winning side.

Change can accelerate as it bends toward justice, but this requires addressing root causes. One root cause is expectations. If computing innovations are not expected from women, the stories of women's innovations, even major ones, disappear. This has a manifold effect on innovation by women. Credit for the innovations goes to men associated with the innovations who do not have to aggrandize credit. Credit goes to men as they are remembered and as women disappear. This discourages women who do or would innovate, and adds to the perception that women do not innovate. Women can be discouraged from acquiring the necessary skills to be innovators. If women are not prepared the "pipeline" is blamed, and the problem is perpetuated.

Winning and Losing

Who wins and who loses? Obviously, women who make innovations only to disappear afterwards lose. The larger society suffers loss of knowledge about how the innovations were

made – sometimes even loss of knowledge about what the innovations were. Women are discouraged from coming into or staying with computing, seeing the game rigged against them.

Further loss is seen in society's failure to obtain contributions that might have been made but were not, because the contributors did not do the work or quit before it was finished. This is worse than loss incurred when the contribution is made but improperly attributed. There are no means to account for contributions that never occur.

Perhaps the biggest loss is to the social order that suffers when behaviors are both unjust and inefficient, as this story of disappearance reveals. To be able to 'win at innovation', women must be *expected* to be able to win. This expectation must be in the women themselves. To be there, it must first be in the society. The culture must change.

Signals of Progress

Despite setbacks, some progress is being made. The *#MeToo* movement is calling attention to long-buried (therefore long-accepted), deeply harmful behaviors. Efforts to bring more 'others' into computing might be sustained, despite the difficulties.

On the gender front, constructive anxiety about gender roles and expectations is painful but helpful. It enables what sociologist Susan Leigh Star noted when previously marginalized people are brought in and expected to contribute.[21]

As one of the previously marginalized, my struggle was difficult at times – especially during the decades of my disappearance. Fortunately, that struggle yielded insights into how people can be wronged even when no one is deliberately doing wrong. Such insights can empower the marginalized and trigger positive social change.

Keywords

Moore's Law, microelectronics, silicon chips, Mead and Conway, VLSI revolution, Silicon Valley, computing, e-commerce, techno-social systems, history, women in STEM, disappearance, the Conway Effect.

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