"Surfing the waves of techno-social evolution"

by Lynn Conway

[Reminiscence evolved from a talk at IEEE-SOCC 2022]

Titanic Belfast's Main Hall

Opening:

Dear Readers, I'm thrilled to join all of you.

Seems that, at age 84, I may be the oldest one here. Which is great! Because I get to play "a voice from the past" who shares and reflects on "old war stories".

We'll first be using our imaginations to "Surf the Waves of Techno-Social Evolution" in earlier periods of rapid, entangled, technological and social acceleration.

We'll then reflect on my VLSI adventures back in the 1970s and 80s, and how they were framed by lessons-learned from such earlier stories. The take-away: "When staging the future, mine the past".

Finally, we'll ponder "What's ahead?" and "How can we better prepare for turbulent incoming times?"

But First a Warning When Entering Stormy Seas:

We'll begin by imagining we're in the Main Hall of Titanic Belfast in Northern Ireland, where I gave the first version of this talk. If you roam that structure's online images, you'll be in awe of its stunning architecture and interior. Many of you have also experienced the emotional impact of the movie *Titanic*.

Such complex techno-social artifacts raise intriguing questions: Why do we so emotively commemorate great infrastructure tragedies? To preserve lessons learned? And if so, what lessons?

The Titanic sailed at a peak time in the industrial revolution. It was a time of exuberance and hubris, a time of dramatic new powers over the forces of nature. But gaps in metallurgical knowledge had yet to be filled, thus she sank unexpectedly quickly. At an AI-panel at South-by-Southwest-2018 I noted:

"In early bridge engineering, the public knew who built them. There was transparency and a clear culprit if things went wrong. There is no transparency the way that AI is now managed. We're going to have an AI Titanic … things are bound to go wrong … it's how we learn. BUT gads, we sure do need to be careful.

The overall theme at IEEE-SOCC 2022 was "the impact of "AI & machine learning" on system-on-chip and semiconductor technologies – a theme aimed at motivating the determined amongst attendees to move out and seize the moment. But notice the recursive dependencies: As their enhanced AI/ML chips surge into the world's techno-social ecosystems, they also become further embedded in the next-generation tools used to create more such chips. My advice was to "expect the unexpected," and move out swiftly when it starts!

1. Envisioning Adventurous Engineering in the Past:

Humans are natural born explorers. We team up and imagine doing wild and crazy things. We go off on adventures, come back and tell stories. Stories about how we geared up, where we went, what we did, and what we found. And sometimes stories of what went wrong, where not to go, and what NOT to do.

When imagining adventurous engineering out into new territory, it's fun to learn of the journeys of earlier explorers. And not just of what they did, but HOW they did it. Sometimes you can tune-into their methods and channel those earlier adventurers, because "While History Doesn't Repeat Itself, It Often Rhymes".

For example, imagine the rapid diffusion of moveable-type printing in the mid-1400s, and how that accelerated the Renaissance. Try to envision the sweeping grandeur of it all, including its panarchic dynamic symmetry across multiple scales.

Now think how courageous mariners in the 1500s triggered the age of 'open-ocean' exploration – by making skilled, trusting use of gimbal-compasses, astrolabes, printed charts and seaworthy Portuguese Carracks.

Then think of the rapid entangled co-evolution of railroading and telegraphy in the mid 1800's, and how it accelerated the industrial revolution by scaling-down communication and transportation turnaround times.

Using your imaginations, envision the inner mental labyrinths of human experiences during such bursts of "techno-social evolution". Imagine the wild adventures of the original surfers of those waves.

Doing so helps us step outside our local silos and comfort zones, and envision our own entangled roles in waves of change. It can also provide clues on how to make the moves on weird incoming waves.

Visualizing how Steinmetz accelerated the "AC Revolution" in the early 1900s:

In the mid-1890s Charles Proteus Steinmetz became famous in elite science and engineering circles for research papers that greatly simplified the analysis of alternating electric current phenomena.

By framing fixed-frequency sinusoidal alternating electrical current (AC) as a steady-state phenomenon, he showed how it could be analyzed algebraically and trigonometrically using imaginary numbers – rather than requiring usage of differential equations. Using his methods, electrical engineers could now almost "do AC in their heads", and certainly do it while using Steinmetz's design rule charts and a good slide rule.

However, by the early 1900s Steinmetz became impatient at the slow diffusion of his methods into mainstream power engineering circles. In response, he wrote books on the gist of the methods and launched them in courses at Union College in Schenectady, NY. Instead of students as spectators "learning of knowledge" that "only experts really understood", they learned newer, simpler methods for actually doing AC power engineering themselves – thus participatorially accelerating the AC revolution.

2. Jumping Forward into the VLSI Adventures of the 1970s-80s:

I joined Xerox Palo Alto Research Center in 1973. But because of my past, I was virtually unknown outside. Although working at the highest level in computer architecture at IBM Research in the 60s, I'd lost those connections when IBM fired me for gender-transitioning in '68.

Living in "stealth mode", I covertly rebuilt my career using my wits rather than relying on credentials and connections. Fortunately it was easy to "cover my past" and remain invisible in tech, because post-transition "I didn't look like an engineer." I'd then landed in a wild techno-culture that Doug Engelbart had launched.

Because of my external invisibility, the foundational nature of my work at PARC wasn't grasped in high-tech circles until many decades later – beginning in 2012 when I published "Reminiscences of the VLSI Revolution" in *IEEE Solid-State Circuits Magazine*. You'll find details there; we'll exploit highlights here.

How Lessons from History Framed the VLSI Revolution:

In 1976, I was tapped by my PARC lab manager Bert Sutherland to be principle investigator of a research collaboration between Xerox PARC and Caltech into how to cope with the looming unmanageable complexity of silicon chip design as the number of transistors per chip exponentiated under Moore's Law.

At the time, microprocessor chip layouts containing thousands of transistors were free-form hand-carved into huge sheets of Rubylith using 40 pages of geometric design rules, and then photo-reduced to make masks. It was like "Blockprinting" before the invention of "Moveable Type".

Those were also the counter-culture days of "Power to the People". One response by PARC's brilliant young researchers was the Alto personal computer. And dreams of architecting "Systems on Silicon" set me seeking "Freedom of Access to the Silicon Press" for system architects working outside fab companies. Back then, it was as if a "writer" could only publish a "novel" if they worked for a "printing plant"!

Collaborating with Carver Mead and his Caltech students, we began by compressing chip design knowledge into ever-simpler "structured methods" – minimalist methods that could be applied using PARC's Altos.

In early spring 1977, I invented a minimal set of scalable, rectilinear, dimensionless design rules enabling rapid design, sharing and reuse of future layouts as Moore's Law unfolded towards millions of transistors. The key was recognizing and exploiting the statistically linearized semi-log nature of socially-synchronized techno-social exponentiation. The resulting rules were only two pages long.

Suddenly we had it all! Using the new methods, even novice digital system designers could do their thing in silicon when using personal computers – analogously reminiscent of Steinmetz's methods and slide rules.

But, what could we do with such knowledge? Write research papers? Design chips? From Steinmetz's story and the Impressionists' saga, I'd learned it was pointless to attempt to bootstrap a new system of knowledge into widespread participatory existence by just publishing bits and pieces amongst traditional work.

Out of the blue the Steinmetz saga "told me what to do," jolting our PARC research-explorations into a wildly adventurous Bootleg Project outside PARC. Emotionally, it felt as if we were on a daring, stealthy military-mission, yet one soundly-guided by Sun Tzu, von Clausewitz, Thomas Kuhn, and Harold Garfinkel's ethnomethodology. Amazingly, PARC senior management gave us 'air cover' for the duration.

The Avante-Garde Launchings of The Book, MIT78 and MPC79:

My opening move was to suggest to the team that "We Write a Book". A book that would "look like" it'd been written after our methods had been "proven sound." Given PARC's powerful new "secret weapons", we could evolve it using our Alto's, share digital drafts via PARC's new ethernet plus the U. S. Defense Advanced Research Projects Agency's new Arpanet, and print drafts on PARC's new laser-printers.

In a dramatic convergence of innovations, tests and trials amongst an expanding underground of newly-networked volunteer collaborators, the book's draft was completed by July 1, 1978 – just in time for an experimental VLSI course I was planning for the fall of '78 when on sabbatical from PARC at MIT.

Knowing they'd be using "PARC methods" to design their own silicon chips and get them fabbed at HP the MIT students went wild, creating many cool design projects. One was a complete LISP microprocessor by Guy Steele. The world didn't realize it, but MIT'78 had launched the VLSI methods "FIRST FLIGHT"!

Imagine the reaction of the cognoscente in Silicon Valley. Top academics wondered "HOW THE HELL DID MIT DO THAT?" We've gotta do it too, or we'll be left in the dust!

Sensing an opening for "expanding the movement", I wondered how we could enable multiple universities to run "MIT-courses" in parallel next fall? Then came The A-HA! What if we built software enabling all student projects to logistically-synchronize via the Arpanet with PARC's "silicon-foundry interface"?

On a design cutoff date, all design files could be sent to that "server", mapped onto a set of what today we call multi project wafers, 'printed' at HP, packaged and returned to the designers. Today we would call it an e-commerce system, as when sending-in artwork-files and getting custom T-shirts printed and returned.

With considerable moxie, in early-summer 1979 we announced to Arpanet-connected research universities that PARC would provide free quick-turn-fabrication for student projects from MIT-like courses that ran according to our guidelines. With research team members Dick Lyon, Alan Bell and Martin Newell, we seized the moment and "charged up that hill". Summer intern Rob Hon captured the crackling atmosphere one evening when saying, "If they only knew who was doing this"!

We also provided my MIT course lecture-notes in a "Guidebook for the Instructor of VLSI System Design", plus a new "Guide to VLSI Implementation" to convey logistical details. A five-chapter preprint of the new textbook was also provided to the students by Addison-Wesley (the full book was published in 12/79).

The MIT course mystique jolted 12 universities into jumping on MPC79. In a huge internet "happening", 82 project files from 124 designers were submitted to PARC on Dec. 4, 1979. Packaged chips were shipped back on Jan. 2, 1980, and among the many groundbreaking projects was Jim Clark's prototype for Silicon Graphics "Geometry Engine". We had successfully bootstrapped and launched a large techno-social dynamical system. Thus began the rapid, entangled techno-social coevolution of 'Systems-on-Chips' + 'Arpanet-Internet' that's continued ever since, analogous to the coevolution of railroading and telegraphy.

DARPA's reaction was dramatic! Our VLSI methods had found a huge patron! In 1980, DARPA began major funding of Mead-Conway VLSI computer architecture and design tool research. DARPA also funded the tech-transfer of the MPC79 system to their software contractor USC-ISI. Starting up in 1981, ISI's "MOSIS Service" has since provided "silicon foundry" access to large numbers of VLSI research teams.

By 1982-83, M-C VLSI courses were running at 112 universities. Just imagine the reactions of technology policy-planners abroad. DARPA's mystique jolted many nations into deploying MOSIS-like services too!

Our VLSI methods had sallied forth in a ship crewed by hardy explorers under a sequence of "false flags". It first sailed as "PARC", then as "MIT", then as "12 Research Universities" and then as "DARPA" – without outsiders knowing who was aboard or what they were doing, much less who'd seized the compass, astrolabe, charts and helm. A vast knowledge-flow avulsion was thus blitzscaled via a classic "MIT Hack"!

Observation: You can accomplish almost anything, if the "larger system doesn't know" what you're doing. The "VLSI gang" spread thru research universities everywhere, marking its exotic presence via totemic artifacts (chip layout artwork on corridor walls). I wonder, could this have happened any other way?

For Another Perspective, Imagine Looking Back on "What We're All Doing Now":

Imagine a distant future after a long dark-age, as novice archeologists unearth artifacts from a deep layer all around the world. Artifacts from an era when earlier humans printed complex electronic machinery onto tiny chips of Silicon – and used them to animate vast ecosystems of innovative techno-social materiality.

As they ponder what we've all left behind, it'll be a huge challenge for them to figure out "What we did" much less "How we did it." Our efforts to decode Sumerian clay tablets will pale by comparison. How could they ever grasp the gist of, and then explain to their young ones, "how we tricked rocks to think"!

Meanwhile, we get to live the grand adventure of "surfing big ones" and leaving tracks along the way!

3. Envisioning the Seas Ahead:

We're sailing at a time when accelerating techno-social evolution is connecting and empowering us in previously-unimaginable ways. At the same time, humanity faces looming limits and boundary conditions that will dramatically constrain lives and threaten political economies. So, what can we do?

By cooperatively generating and sharing ideas for doing "*ever-more with ever-less*," the incoming waves of techno-social innovations have the stunning potential of sustainably providing "*ever-increasing infrastructural functionality and life experiential-amplification per person*", while "*consuming ever-decreasing energy and material resources per person*" – thus helping to "*firmly reign-in our unsustainable over-use of planet earth*" while simultaneously widening the exploration of the greatest frontier of all – the frontier of "*what it is possible to do*." We're all in this together and must do this.

Prepare to Launch:

In the times ahead, waves of shared team-consciousnesses will rapidly arise, evolve and interact. While contributing within (and across mosaics of) such-teams, you'll increasingly encounter diverse, sometimes conflicting ways of being – giving ever deeper meaning to the old maxim "consistency is for small minds".

By building your social-capital as rapid-learners, contributors, innovators, leaders and explorers, rather than merely seeking money, fame, awards, formal positions and the trappings of power – you'll expand your social agility and open-up life-long opportunities to team-up with cool people, 'go-meta', go exploring, have exciting participatory adventures and leave tracks behind.

You'll also benefit from new tools for modeling, mapping, and visualizing where your teams are and where they're headed in the evolutionary flows. Tools well beyond today's data analytics and Gartner Hype-Cycle Charts. Tools based on synchrony in the geometry of biological time, on modeling memetic diffusion through permeable barriers, on category theory and non-linear dynamical systems, on an entangled coevolution with synthetic biology, and on tracking/modeling cognitive evolution via material engagement.

Among other things, be sure to mentor and learn from those who come after you. Because your fates are all bound-up together in the same ships atop a vast ocean. And by embracing rather than fearing techno-social acceleration, you'll experience a wondrous relativistic effect: "*You'll live far-further into the rapidly unfolding future than you ever dared dream!"*

4. Preparing to Cope with Accelerating Change:

How can you vigorously train-up and build the nerve to jump onto the fronts of new waves – out where the action is? Especially while watching others "crash and burn"?

From the perspective of 84 years, I realize my "guides" have been "words left behind" by earlier pathfinders whose life-stories have deeply moved me. Words I turn to when beginning, learning, training, healing wounds, building resilience – and then catching the next looming wave. Words as in this Quoem:

Winston Churchill gives us a compass for our life-journeys when he says,
"The farther backward you can look, the farther forward you can see."

Remember too, as Steve Jobs says,
"Your time is limited, so don't waste it living someone else's life."

Grace Hopper reminds us that,
"A ship in port is safe, but that's not what ships are built for."

And as 'The Great One' Wayne Gretzky says,
"You miss 100 percent of the shots you don't take!"

As social philosopher Eric Hoffer reflects,
"In a world of change, the learners shall inherit the earth, while the learned shall find themselves perfectly suited for a world that no longer exists!"

So don't build 'expertise' and sit on it. Remember B. B. King's cool saying,
"The beautiful thing about learning is nobody can take it away from you!"

As anthropologist Margaret Mead observes,
"Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it's the only thing that ever has."

So, as Bob Noyce says,
"Don't be encumbered by history, just Go off and do something wonderful."

During dangerous passages along the way, be realistic, yet passionately persistent.
As historian and activist Bertha Calloway reminds us,
"We cannot direct the wind, but we can adjust the sails.

In extrema, as gonzo journalist Hunter S. Thompson coolly observes,
"When the going gets weird, the weird turn pro!"

That can be wild but you can get to love it. As Kurt Vonnegut says,
"I want to stay as close to the edge as I can without going over.
Out on the edge you see all kinds of things you can't see from the center."

Sometimes, you can even step across the edge, my own perspective being,
"If you want to change the future, start living as if you're already there!"

Poet Mary Oliver then poses the ultimate question for us all:
"Tell me, what else should I have done? Doesn't everything die at last, and too soon?
Tell me, what is it you plan to do with your one wild and precious life?"

5. Thinking way ahead to when YOU are 84:

What words will YOU leave to guide the young, their children and children's children? To help them boldly adventure-surf ever more wondrous waves of human exploration, innovation and shared-experiences? What words? Then I remember words of legendary French aviator and novelist, Antoine de Saint-Exupéry:

"If you want to build a ship, don't drum up people to collect wood, and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea."

NASA: Earth as seen from its Moon

The chance to share these words with you today means the world to me.
And I wish you all good fortune in the adventures ahead!

Coda:

"History is encoded in tangles that are fun to unravel.
Stories are told in codes that are fun to crack.
The future is encoded in models that are fun to evolve.
Sentience is experienced in lives that are fun to live!" – LC

"Surfing the Waves of Techno-Social Evolution" (StWoTSE) **Background Links**:

Link to key visuals (in progress)
Link to references and readings (in progress)
1981 "The MPC Adventures", Xerox PARC
2012 "Reminiscences of the VLSI Revolution," *IEEE SSCM*
2015 Steinmetz Lecture, Union College
2016 McGill Lecture, Columbia University
2018 "The Disappeared: Beyond Winning & Losing", *IEEE Computer*
2019 "An Invisible Woman", UC Davis *NSF Advance* Seminar: