1. Introduction

Many thanks . . . It’s wonderful to be here today . . . to learn about your exciting work in system architecture . . . and to have this opportunity to ponder with you . . . what the future might bring . . .

And while doing so . . . to sense the strength of our engineering culture . . . as it empowers our collective imaginations for exploring that greatest frontier . . . the frontier of what it’s “possible to do.”

It’s also exciting to meet and share war-stories with friends and colleagues. Even more than the tracks we’ve left behind, it’s the memories of teams we joined and adventures we shared together . . . that count.

When I joined [Xerox PARC](http://en.wikipedia.org/wiki/PARC_%28company%29) in 1973 . . . I had no idea what a wild ride was ahead . . . as the research staff began surfing waves of innovation that launched the interactive [personal computing](http://www.amazon.com/Dealers-Lightning-Xerox-PARC-Computer/dp/0887308910/) and VLSI revolutions.

I learned some cool things from that experience: how to catch glimpses of such incoming waves . . . looming just beyond the time-horizon . . . and clues to how to swim out there and [catch them](http://blackdreamer.com/surfing-wallpaper-1920x1080-3-free.html) . . .

I sense we’re entering another such disruptive time right now . . . as innovators, engineers, designers and users all around the world begin interconnecting and embedding smart microsystems into . . . thus functionally enhancing . . . almost everything . . .

But before visualizing the adventures ahead . . . the **adventures** **you’re** going to go on . . . let’s reflect on some earlier techno-social revolutions. As Winston [Churchill](http://en.wikipedia.org/wiki/Winston_Churchill) said:

“[The farther backward you can look, the farther forward you can see.](http://blog.primalpastures.com/wellness/staying-healthy-road-challenges-answers/)”

2. Back to the Future: Visualizing past waves of disruptive innovation

In the Age of Discovery, a mix of technologies commingled and reinforced each other . . . in shipbuilding, navigation, timekeeping and map-making . . . and the onset of communication by printing triggered an exponentiation of excitement, exploration and expansion ‘beyond the horizon’.

The Industrial Age was similarly empowered by the commingling of innovations in coal and iron mining, steam-power and railroading . . . then suddenly exponentiated by telegraphy . . .

The mines and railroads, empowered by coal and steam, yielded more coal and iron for building more steam-powered trains and their railways . . . Like an invasive species spreading all across the earth, it provided infrastructure people could use to go on adventures, to go exploring, to find things and to send back news of what they’d found . . .

During the VLSI revolution . . . as fabrication technology rode “Moore’s Law” scaling . . . and by building on advances in interactive personal computing and networking . . . a set of innovations in design methods, courses, design tools, rapid-prototyping and e-commerce infrastructure . . . bootstrapped and launched an exponentiating techno-social ecosystem of “fabless design” and “silicon foundries.”

What caused the “gain in that system”? . . . Well, computers printed in microelectronics were exploited to design more functionally powerful computers and print them in microelectronics . . . and the evolving internet communication and e-commerce infrastructure enabled positive feedback . . . leading to ever-more rapid prototyping, evolution and commercialization of results.

By ‘Going Meta’, we can visualize such unfolding dramas not as making things and spreading them across seas and landscapes . . . but as coalescings of innovative-ideas . . . and launchings of those ideas into dynamic motion in the minds of expanding groups of interconnected people . . . ideas about how to make and use things to explore terra-incognita, and to send-back news of what’s out there . . .

When we notice positive feedback and sense the onset of system gain . . . we can anticipate disruptive exponentiation in such exploration-ecosystems. 3. What do you see ahead, Obstacles or Opportunities?

Disruptive breakouts often occur during periods of technology maturation . . . as earlier paradigms reach their limits . . . as appears to be happening now . . . For example, we hear lots of dire talk about things like The End of Moore’s Law and Dark Silicon and The Innovation Valley of Death

However, you folks here at UCLA are seeing some openings, in Accelerator Rich Architectures . . . in innovatively-exploiting FPGA’s . . . and in innovation-transition methods .

As we’ll see . . . folks scattered all across this new techno-social space . . . are also seeing openings . . . and as all these viewpoints hbridize, it’s just a matter of time before it hits critical mass.

4: Visualizing the Incoming Wave of Innovation

The rising visibility and understanding of microsystems is about to trigger a huge tsunami of wonder, imagination, engineering-exploration & entrepreneurism . . . and this is the “BIG ONE” . . . embedding modular microsystems into almost everything . . .

But to catch glimpses of the incoming wave . . . out there, just over the social horizon . . . we must grasp the social physics and timing of its underlying technology-generating ecosystem.

Folks in microsystems have seen bits and pieces of this coming in an ever-widening array of innovations in [microelectronics](https://www.google.com/search?q=microelectronics&tbm=isch&tbo=u&source=univ&sa=X&ei=r1_lUp6kNsqFyQGdzYAI&sqi=2&ved=0CEkQsAQ&biw=1214&bih=553), [MEMS](https://www.memsnet.org/about/what-is.html), [micromachining](https://www.google.com/search?q=micromachining&tbm=isch&tbo=u&source=univ&sa=X&ei=G8_jUreCM6jXyAGgv4GgCw&sqi=2&ved=0CFMQsAQ&biw=1021&bih=553), microassembly and [nanotechnology](http://science.howstuffworks.com/nanotechnology.htm). However, those pieces have been deeply embedded in macroworld things such as smartphones, wearables, autos and drones.

So far, that explosion of micro-innovations has remained out-of-sight, underappreciated and underexploited by most users and system-integrators . . . even as they witness their transformative functionalities . . . such as the out-of-body-experiences enabled by flying Parrot Bebops using Oculus Rifts . . .

When we look back on what’s about to happen, one conceptual milestone will stand out: Motorola's "[Project Ara](http://www.engadget.com/2013/10/29/motorola-project-ara-modular-smartphone/)" to create modular smartphones . . . as reconfigurable [LEGO-like](http://en.wikipedia.org/wiki/Lego) microhardware assemblages of visible microworld subsystems . . . signaling that hardware apps will join [software apps](https://play.google.com/store/apps) in the public imagination.

Suddenly, innovators will exploiting [MEMS](http://www.i-micronews.com/mems/) IMUs, [sensors](http://blog.gsmarena.com/samsung-describes-what-each-of-the-nine-sensors-on-the-galaxy-s4-does/), micro[cams](https://www.google.com/search?q=microcameras&tbm=isch&tbo=u&source=univ&sa=X&ei=QZHmUtP8HaWOyAGW6IHYCw&sqi=2&ved=0CGQQsAQ&biw=1223&bih=553), transducers and their MCUs . . to craft micro-HW Apps that [plug-n-play](http://www.techterms.com/definition/plugandplay) via novel woven, printed and wireless interconnections within [macroscale](http://techcrunch.com/2013/01/06/lego-mindstorms-ev3-the-better-faster-stronger-generation-of-robotic-programming/) products.

Such innovations will also be fed-back into micro-manufacturing and micro-embedding systems, such as 3D printing and additive manufacturing . . . closing the cybernetic loop . . . and providing "gain" in the microworld exploration ecosystem.

4b. But where will all the innovators come from?

Will 20th century engineering education, mostly focused on narrow analysis and [stove-piped](http://searchsoa.techtarget.com/definition/stove-piped-development) optimizations of existing systems, provide the answer? I don't think so.

[A wave of change is sweeping our universities](https://www.youtube.com/watch?v=U6FvJ6jMGHU), as MOOCs, [flipped courses](https://www.youtube.com/watch?v=tkd-srAj0E8), experiential and [blended learning](http://video.mit.edu/watch/blossoms-using-geometry-to-design-simple-machines-with-professor-daniel-frey-3626/) foster [multidisciplinary](https://www.youtube.com/watch?v=293KKDBHGc0), user-centered problem-solving in [exploratory team-project environments](https://www.youtube.com/watch?v=YqF_mfbF6Kk) . . . and as innovations are increasingly shared via [open-access journals](https://www.youtube.com/watch?v=L5rVH1KGBCY), e-newsletters, [wiki's](http://www.semiwiki.com/) and [webinars](http://spectrum.ieee.org/webinars).

Many incoming students today have been to [LEGO Camps](https://www.youtube.com/watch?v=gZUhsWeP2Mk), are in the [Maker movement](http://makezine.com/) . . . used [Raspberry Pi's](https://www.youtube.com/watch?v=P5KEiuTT_E8) and [Arduino](http://www.arduino.cc/), worked in [FAB LABS](http://www.nytimes.com/video/science/100000002402479/whats-a-fab-lab.html), and been in [robot competitions](https://www.youtube.com/watch?v=MnDgAk3tXUg). . . motivating them towards real-world, user-engaged, team-problem-solving to meet [human needs](http://www.bloomberg.com/news/2014-01-17/google-unveils-smart-contact-lens-project-to-monitor-glucose.html).

But what tools will we use to explore the future microworld? EDA tools augmented by multi-physics modeling and [rapid prototyping](https://www.google.com/search?q=rapid+prototyping&tbm=isch&tbo=u&source=univ&sa=X&ei=P63mUq2eD8K2yAHNs4HICw&sqi=2&ved=0CGQQsAQ&biw=1223&bih=553) are enabling rapid innovation of digitally-makeable microsystems . . . as in the current rush to exploit 3D [chip-stacking](http://www.xilinx.com/products/silicon-devices/3dic/index.htm) using TSVs and interposers . . . kicking the door open to ever-tinier, increasingly-powerful, microhardware apps.

At the same time, a revolution is underway in EDA tools for user-engaged 3-D [visualization, modeling, simulation and prototyping](https://www.youtube.com/watch?v=vSqYx2OuxYo) . . . as in [Dassault Systems](http://www.3ds.com/) "[3D Experience Platform](http://www.3ds.com/about-3ds/3dexperience-platform/)" . . . supporting participatory user/designer/fabricator explorations to [embed microsystem functionality](http://rogers.matse.illinois.edu/) in macroscale products.

4c. As an example, let's visualize what's ahead for the auto industry:

The need to embed rapidly-evolving information, communication, entertainment devices . . . along with increasing numbers of sensors and actuators to meet operational and safety requirement . . . is now straining existing models of in-vehicle connectivity and parts-replacement.

There’s already seeing a move away from [wiring harnesses](https://www.google.com/search?q=wire+harness&tbm=isch&tbo=u&source=univ&sa=X&ei=jNvjUrDND-6uyAGqp4Eo&sqi=2&ved=0CEUQsAQ&biw=1020&bih=553) towards [modular "KSK" Customer-Specific Harnesses](http://www.mentor.com/products/electrical-design-software/multimedia/modular-ksk-harness-design-webinar) that support subsets of user options. But even KSK methods are being strained as designers struggle to interface in-vehicle systems with [driver wearable](http://www.wearable-technologies.com/)s and [intelligent vehicle/roadway systems](https://www.google.com/search?q=intelligent+vehicle+system&tbm=isch&tbo=u&source=univ&sa=X&ei=Et7jUqXFIumisQSN14GgBA&ved=0CEMQsAQ&biw=1036&bih=553).

The auto industry will thus stimulate and be affected by many innovations in signal & power interconnection among modular microsystems distributed within partially-customizable, upgradable products of all kinds.

We also glimpse an incoming shift in auto architecture to low-drag "[Very Light Cars](http://www.autoweek.com/article/20130419/carnews/130419847)" (VLCs) such as the Edison2. Exploiting high-tech, parameterized, lightweight [Drive-train](https://www.google.com/search?q=hybrid+vehicle+drivetrain&tbm=isch&tbo=u&source=univ&sa=X&ei=WpPmUu_tGMK82wXEuYHgDQ&ved=0CEMQsAQ&biw=1223&bih=553) Axle-assemblies containing electric motors, regenerative brakes and wheel sets -- VLCs can be powered by battery modules and/or internal-combustion-engine/generator modules, depending on regional driving conditions, energy markets and [roadway infrastructure](https://www.google.com/search?q=roadway+infrastructure&source=lnms&tbm=isch&sa=X&ei=D2XqUsuJLuGsyAGwqIAQ&ved=0CAcQ_AUoAQ&biw=1280&bih=595#q=intelligent+highways&tbm=isch).

Microsystem-enhanced VLC outer shells and compartments could be modularly fabricated by [OEM's](http://smallbusiness.chron.com/difference-between-tier-1-tier-2-companies-25430.html), by regional and local manufacturers, or by collaborative combinations of the above - enabling the targeting of widely varying international submarkets based upon local user needs and driving conditions . . . and local labor, material and energy costs.

The regionally diverse microsystem-enhancement of such auto-products will then further cross-trigger the embedding of modular-interconnected microsystems into clothing, mobility technology, homes, buildings and cities . . .i.e., almost everything.

4d. The Breakout

As this wave of innovation spreads, microsystem manufacturers won't be limited to selling into narrow-industry, [tiered supply chains](http://smallbusiness.chron.com/difference-between-tier-1-tier-2-companies-25430.html) . . . they’ll instead connect with diverse innovative makers, multiproduct supply-chains and emerging markets . . . as the supply-chains for the electronics, clothing, automotive, medical, home-appliance and building industries will begin to cross-couple and commingle.

We'll thus see a rapid expansion beyond production of commodity-microparts aimed at mass-markets, into production of a vast range of higher value-added, higher-margin, specialty-market componentry.

We'll also see [reshoring](http://www.reshorenow.org/), dispersal and market-democratization of many areas of manufacturing, including the rise of many specialized component-integration/subassembly shops, with user-engagement, creative partial-customization, order-to-delivery time and logistics being key market-success factors.

Ah, but what about the complexity of the interactive-connections among multi-industry markets, investors, innovators, designers, entrepreneurs, intellectual property (IP) brokers, tool builders, fabricators, supply chains, system integrators, logistics systems, e-commerce infrastructure and engaged users?

How on earth will companies connect and thrive within such a massive, rapidly-evolving, collaborative-competitive industrial-ecosystem?

The enabler: The commingling and hybridization of design and simulation tools, digital manufacturing and [social-media](https://www.google.com/search?q=social-media&source=lnms&tbm=isch&sa=X&ei=iXWPU8XoGtekyATxy4DADQ&ved=0CAYQ_AUoAQ&biw=1257&bih=602) will provide multi-technology "[exploration infrastructure](http://www.nytimes.com/video/science/100000002402479/whats-a-fab-lab.html)" for widespread user-engaged market development and rapid [open-source](https://www.youtube.com/watch?v=C8Wv3LCJcUE) technology evolution.

By exploiting [collaborative learning](http://www.scoop.it/t/leadership-trust-and-e-learning), [crowdsourcing](http://en.wikipedia.org/wiki/Crowdsourcing), [crowdfunding](https://www.kickstarter.com/hello), [IP brokering](http://www.semiwiki.com/forum/content/section/1642-ipnest.html), [agile methods](https://www.youtube.com/watch?v=sy0-VhKAr7s), [rapid-digital-prototyping](https://www.google.com/search?q=rapid+prototyping&tbm=isch&tbo=u&source=univ&sa=X&ei=P63mUq2eD8K2yAHNs4HICw&sqi=2&ved=0CGQQsAQ&biw=1223&bih=553), e-commerce and more, everyone . . . from users to [makers](https://www.google.com/search?q=play&source=lnms&tbm=isch&sa=X&ei=vX2QU9CXDciZyAS4n4KwBg&ved=0CAYQ_AUoAQ&biw=1258&bih=602#q=maker+faire&tbm=isch) . . . will be able to dramatically scale up their connectivity, participation and impact.

As this incoming wave crests, it will trigger disruptive change. “Microworld embeddings and interconnections” will suddenly become widely visible, innovatively explored and intensely exploited.

5: Reflections on what’s ahead

Connecting the dots . . . it’s becoming clear that this is the “Big One” . . . a microworld-exploitation ‘Gold-Rush’ has begun . . . and is exponentiating due to gain in exploration-ecosystems in emerging ‘Silicon Valleys’ and ‘Maker Valleys’ all around the world. . . . . . Earth.

Furthermore, this revolution in human enterprise is technologically, economically, politically and socially inevitable, because the long term success of humanity depends upon sustainably providing ever-more infrastructural functionality and life empowerment per person, while consuming ever-less energy and material resources per person . . . Sunrise

It can also move societies towards more diverse, inclusive and thriving futures, as ever more people migrate from being isolated consumers of mass-produced goods and entertainment towards being innovative participatory team-customizers of their habitats and life experiences . . . It’s going to be quite an adventure!

Readings and Q/A . . .

“If you want to change the future, start living as if you’re already there.”

“Embrace and enjoy the escalating rate of techno-social change”

“You’re going to live farther into the future than you’ve ever imagined!”