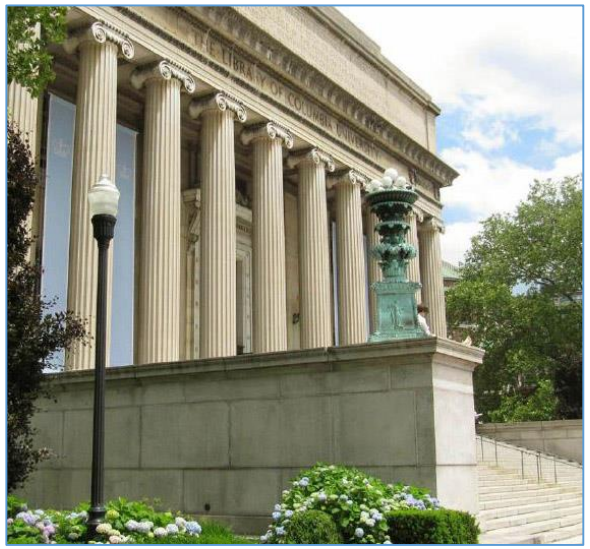
Our Travels Through Techno-Social Space-Time: Envisioning Incoming Waves of Technological Innovation



Lynn Conway
Professor of EECS, Emerita
University of Michigan, Ann Arbor

2016 Magill Lecture
Fu Foundation School of Engineering and Applied Science, Columbia University
March 23, 2016

Note: This slideshow is posted online for later reference:
http://ai.eecs.umich.edu/people/conway/Memoirs/Talks/Columbia/2016_Magill_Lecture.pptx
[V 3-21-2016]

Notes re my student and early career years, 1955-68:

Studied Physics at MIT . . . EE, CS, Anthropology here at Columbia . . . did CS, EE at IBM Research.

My thought-influencers and heroes back then:

Galileo, Kepler, Newton, Maxwell, Einstein, Heaviside (math, electrical engineering), Steinmetz (AC revolution), Armstrong (radio revolution), Turing (math, computer science), Von Neuman (math, computer science), Weiner (cybernetics), Wilkes (computer science), Shannon (logic, Information theory), Van Quine (logic, quantitative philosophy), Hoffer (social philosophy), Malinowski (anthropology), Benedict (anthropology), Mead (anthropology), Merton (sociology), Rogers (diffusion of innovations), McCluhan (media theory), Kuhn (structure of scientific revolutions), Garfinkel (ethnomethodology).

My intellectual-passion during the 5^{+} decades since then (re-encoded into current-day phrasing):

"Meta-ethnomethodology": Noticing, observing, decoding, abstracting, restructuring, re-encoding and exploratorily-diffusing "techno-social memetic-scripts", partly out of curiosity and partly to better navigate my own journeys (forwards, sideways and backwards) through techno-social space-time (i.e., avant-garde artistry in generating "techno-social paradigm-shifts").

By exploiting insights gained along the way and by playfully using our imaginations,

Let's now do some visualizing about where we've been, where we are, and where we're headed!

We'll begin by visualizing some past waves of techno-social change . . .

Dropping-back-in just before them, then coming forward through time . . .

But as we travel through space-time . . . be sure to keep these words in mind:

Link

“The farther backward you can look, the farther forward you can see.”

— Winston Churchill

We begin in the 1400s, during the Renaissance, a time of transformational cultural advances . . .

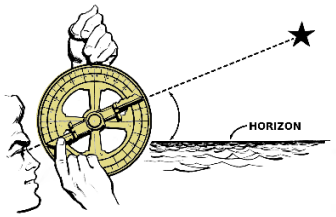
When looking at the mechanization of astronomical calculations by the Prague Astronomical Clock, c. 1410:

We see a stunning confluence of the highly advanced Mathematics, Science, Engineering Architecture and Art at that time . . .

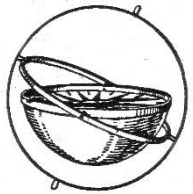
Photo by Hector Zenil (www.hectorzenil.net)

By the late 1400's advances in shipbuilding, navigation & mapping reached a 'tipping point' . . .

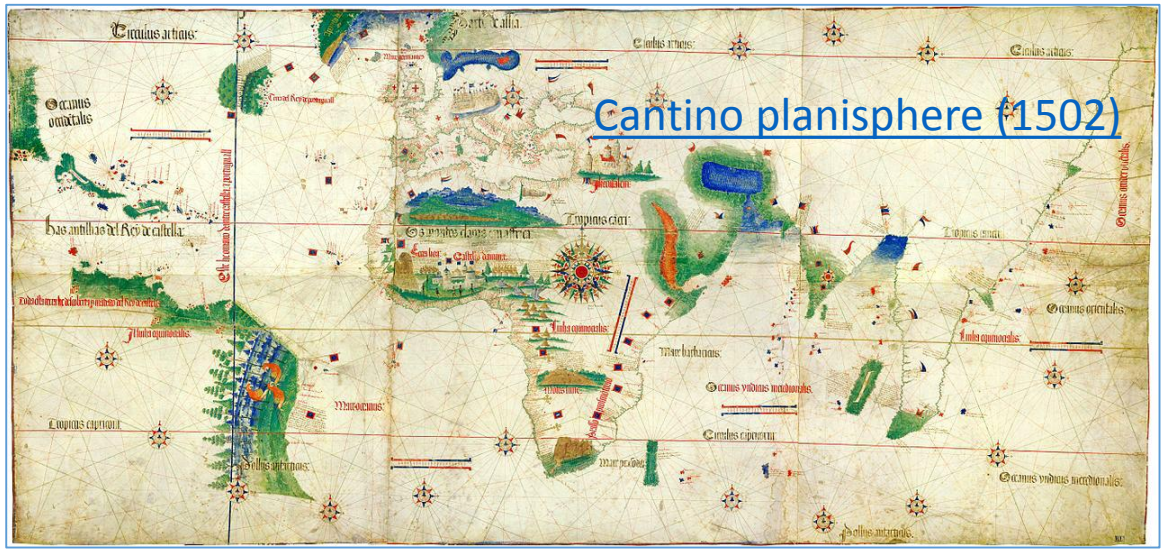
Triggering the **Age of Discovery** by enabling explorations across the open seas . . .



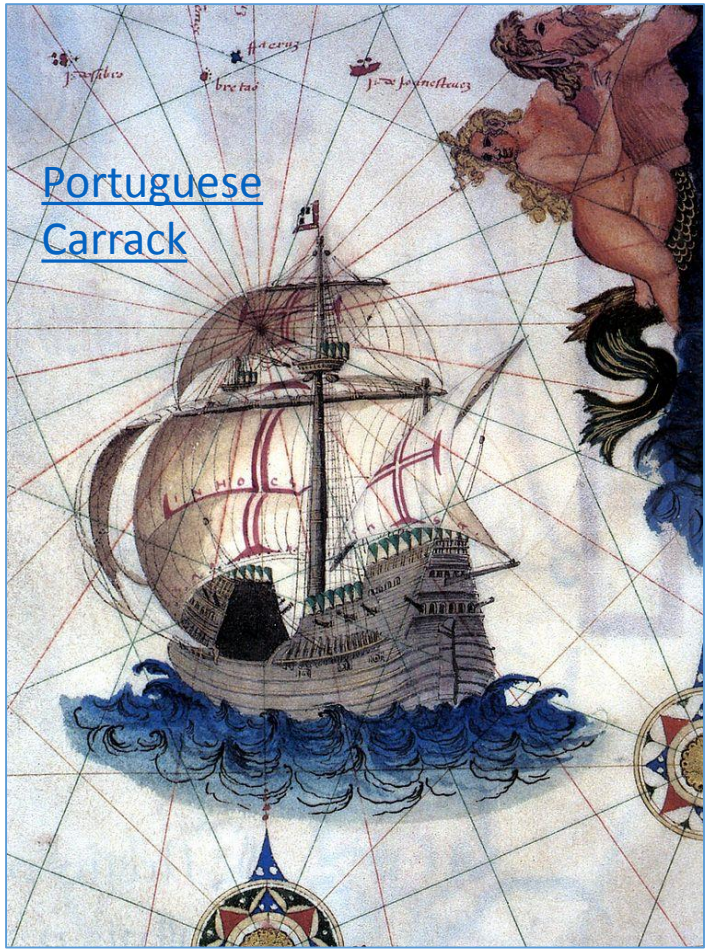
Mariner's Astrolabe



Gimbal Compass

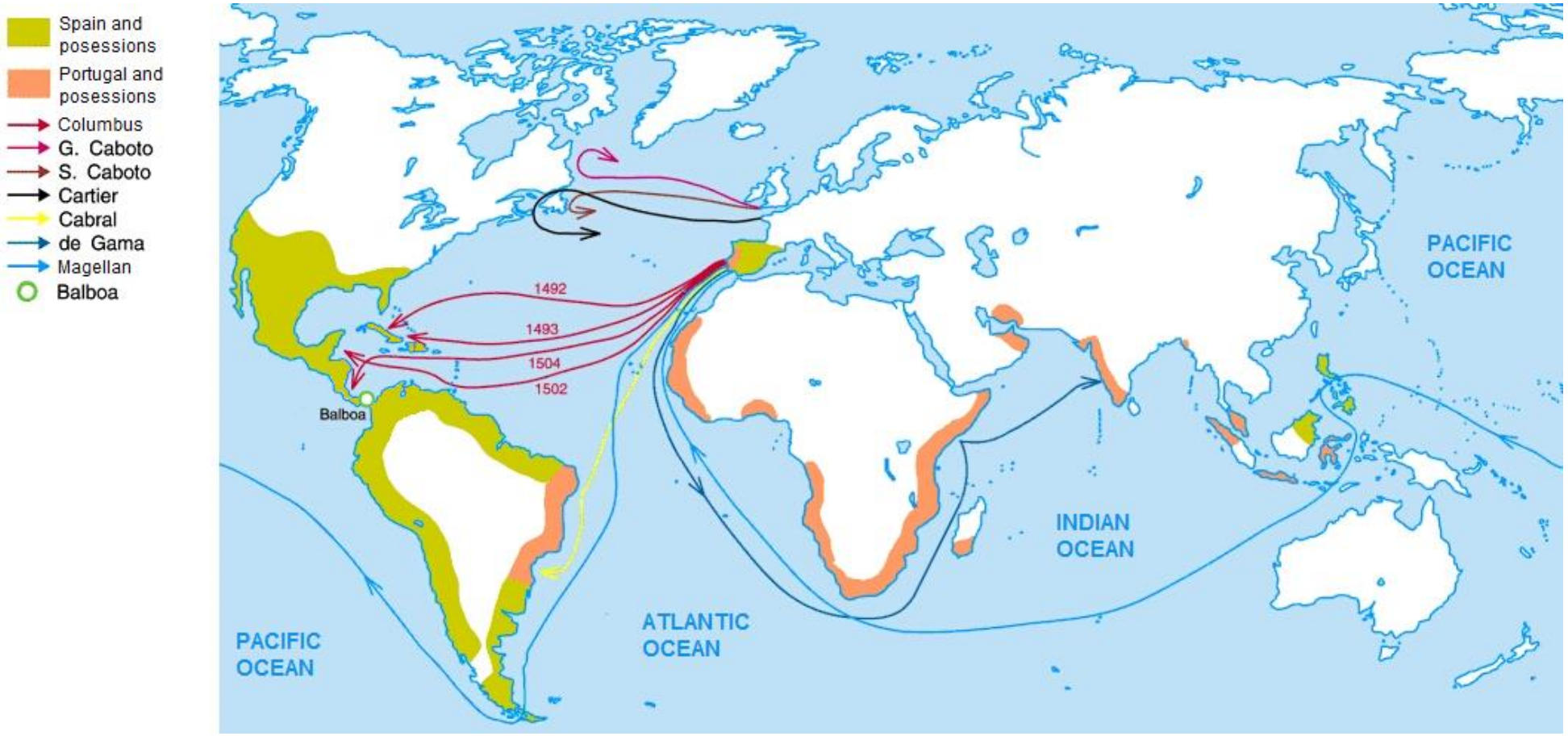


Cantino planisphere (1502)



Portuguese Carrack

Thus it begins: Charting the Early Voyages during the Age of Discovery, c.1492-1522 . . .



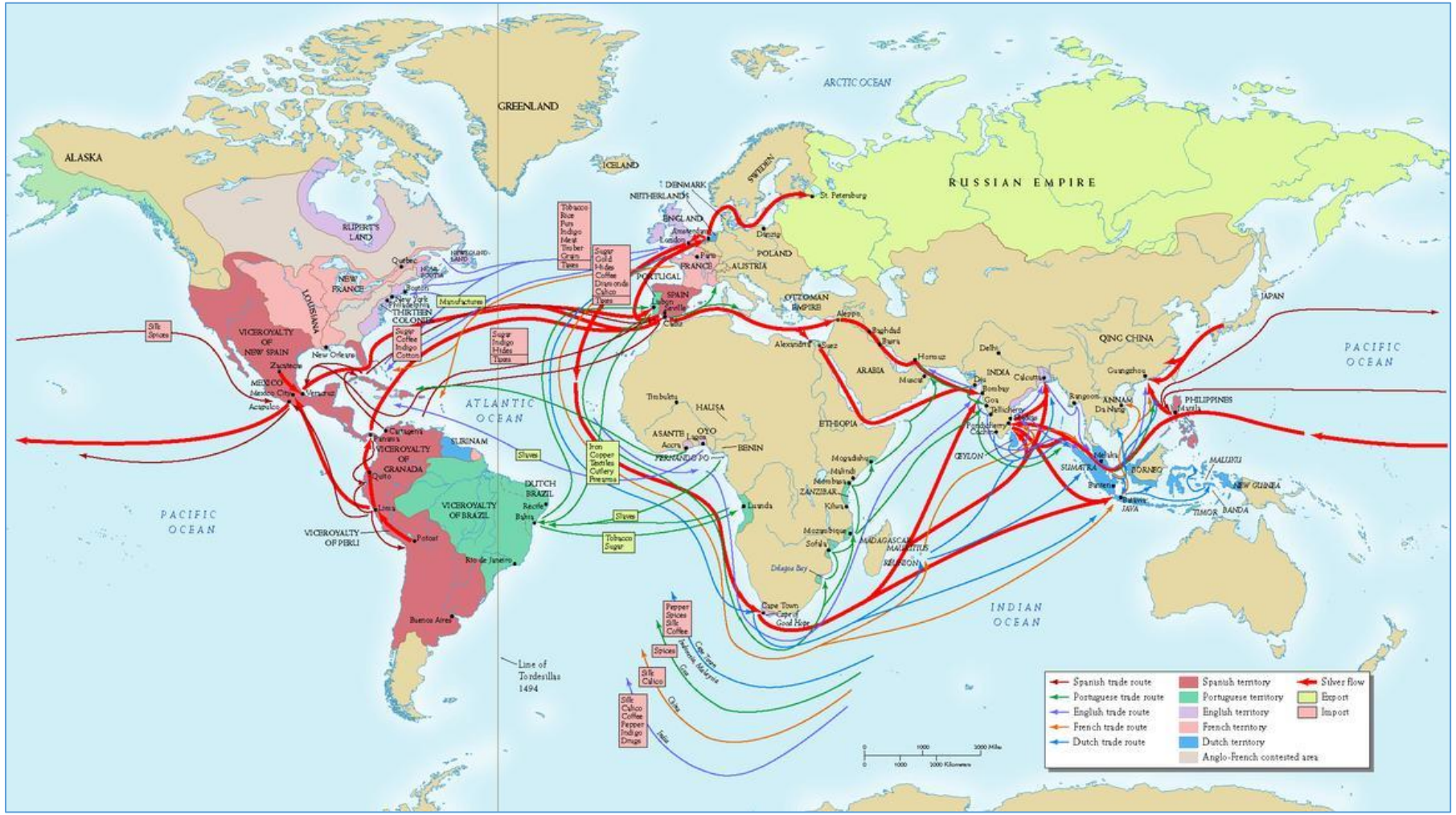
Wiki Commons

As mass-communication by printing spread in the late 1400s, it enabled adventurers to ever-more quickly propagate news of what they'd found and where they'd found it . . . dramatically escalating the exploration rate . . .

Replica Gutenberg Press at the Featherbed Alley Printshop Museum:

Link; Attribution: Aodhdubh at English Wikipedia

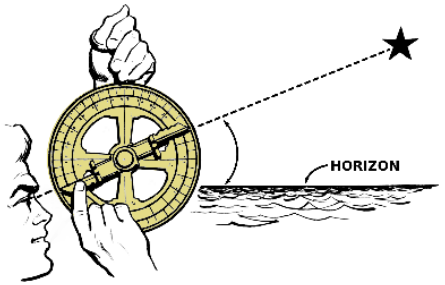
By the early 1700's, exponentiation had generated a massive global trading system . . .

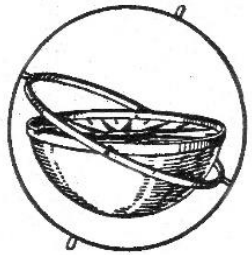


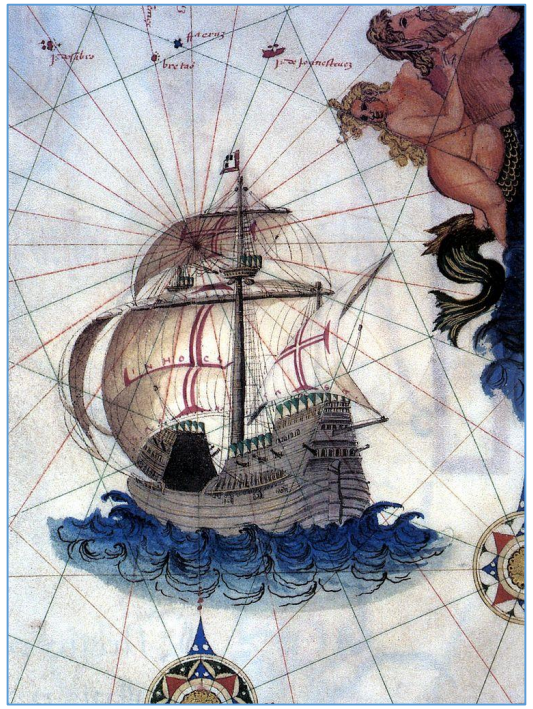
Source

Now, what' happening here?
Just exponentiation of THINGS?
Is that all this is?

Or also exponentiation and diffusion of key clusters of innovative IDEAS thru the minds of ever more people?
IDEAS on how to MAKE and USE things . . .





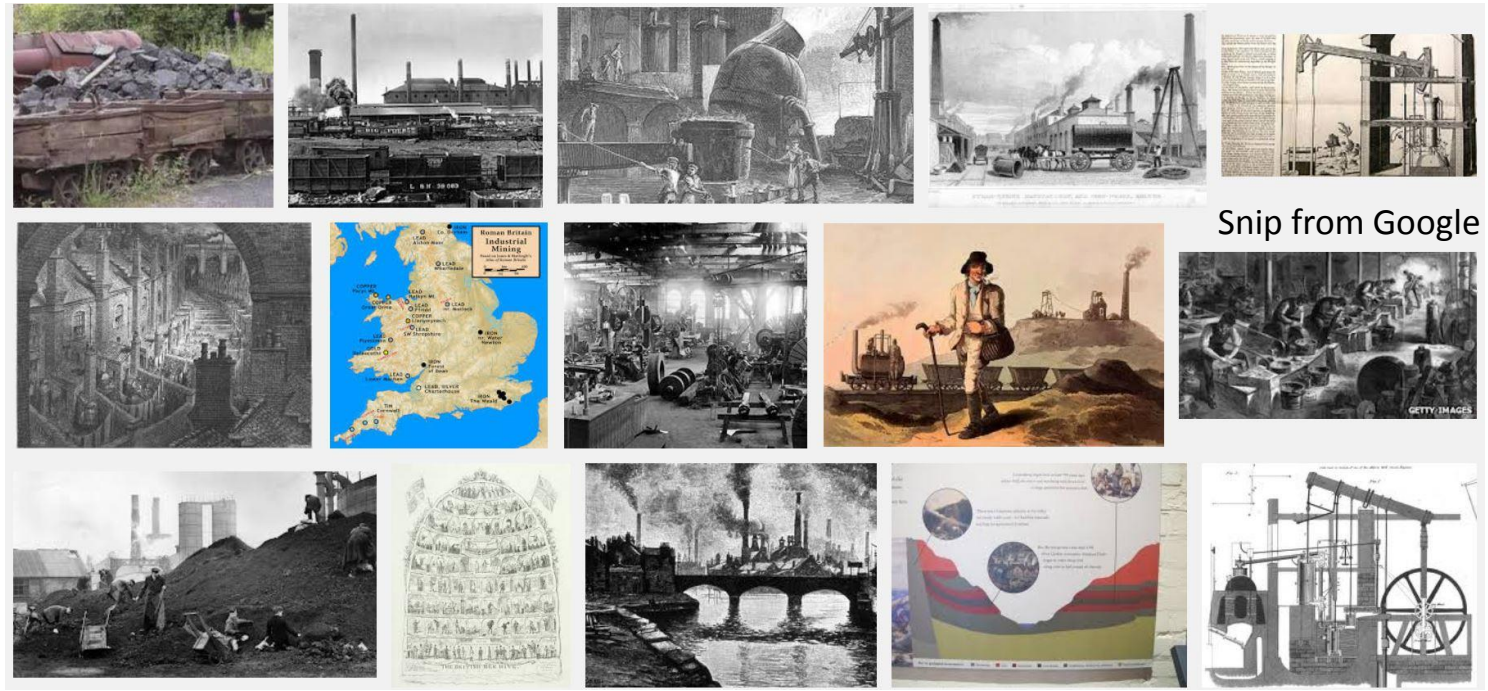


By the mid-1700's, the stage was set for yet another tremendous disruptive wave of innovation . . .

and so began the industrial revolution (~1760) . . .

Link

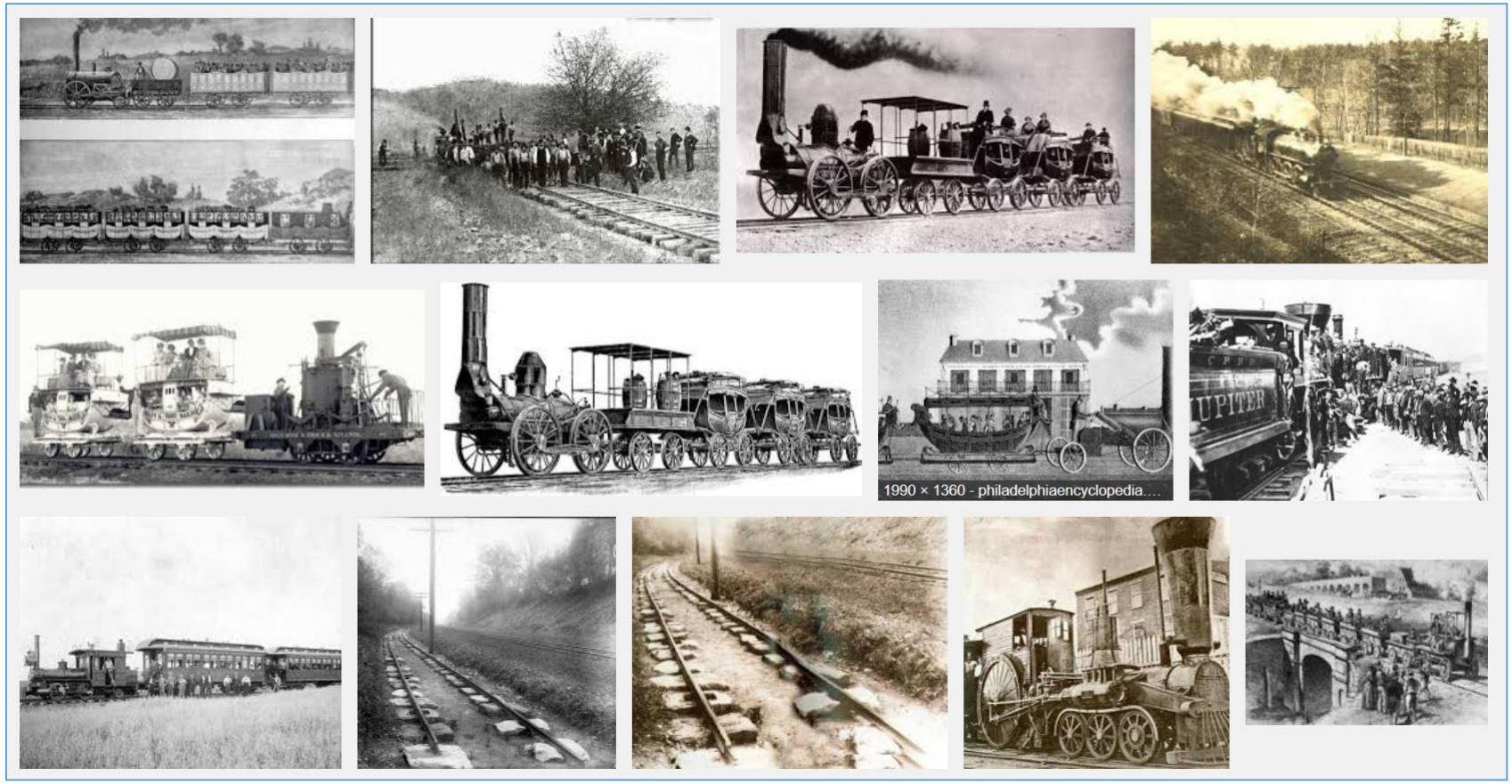
During the Industrial Revolution the mining/processing of coal and iron-ore was greatly amplified by steam-power . . .



Snip from Google Images

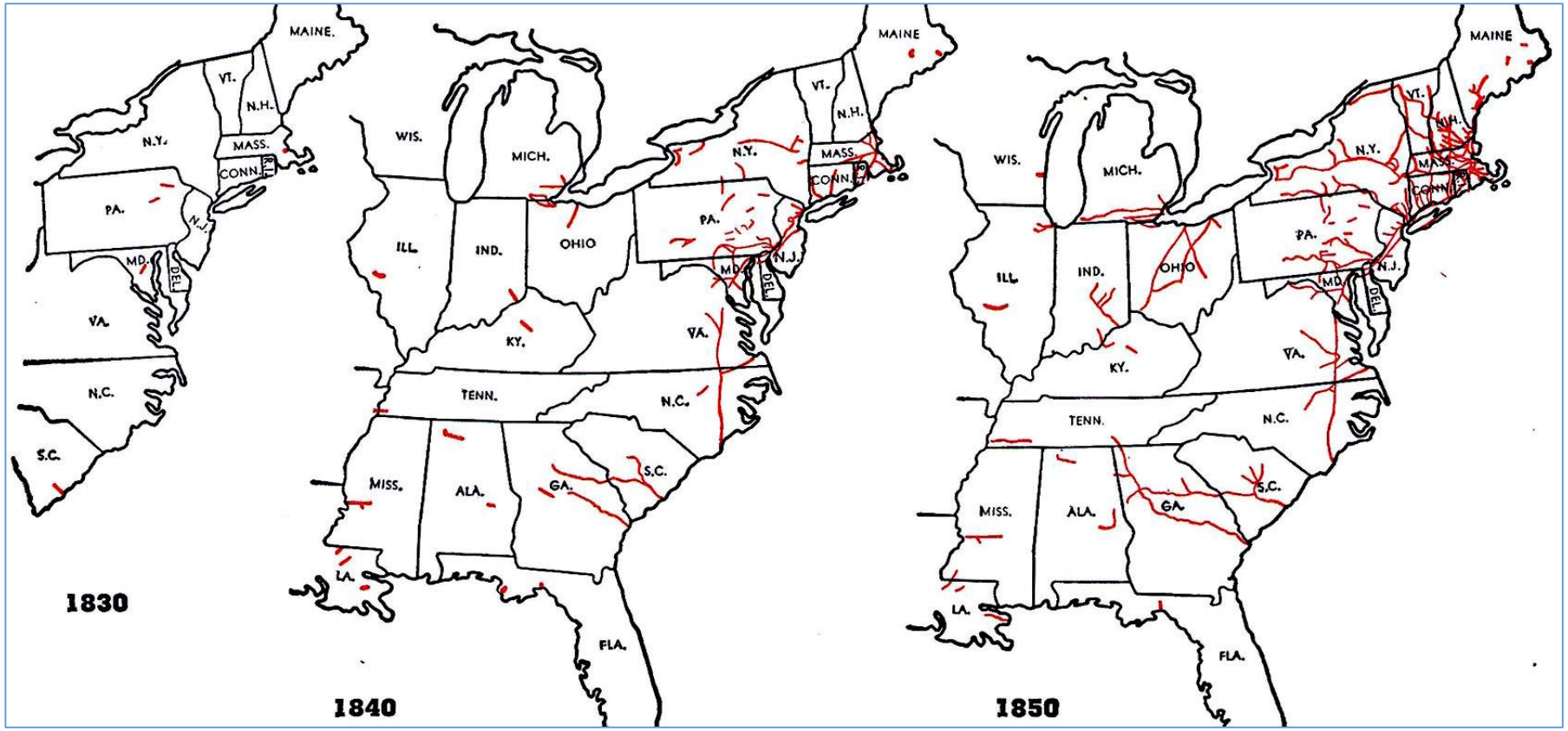
Some of the resulting iron was used to make more steam engines, and this positive feedback fueled an iterative expansion-process . . .

By the 1830's, steam-powered railroads began interconnecting mines to iron-works and rail-makers, enabling ever more rapid expansion of the railroads . . .



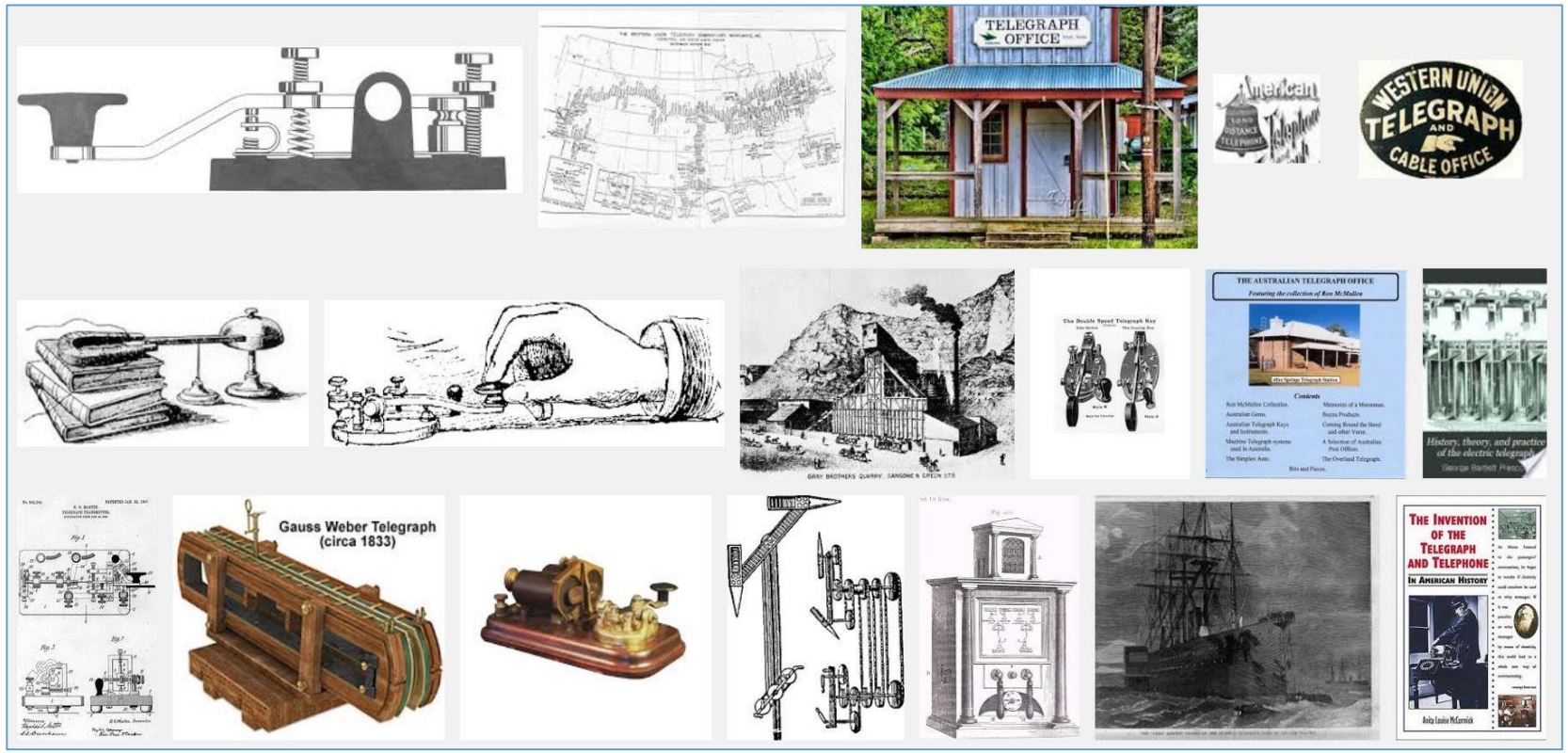
Snip from Google Images

These maps show the rapid early-spread of railroading in the United States. . .



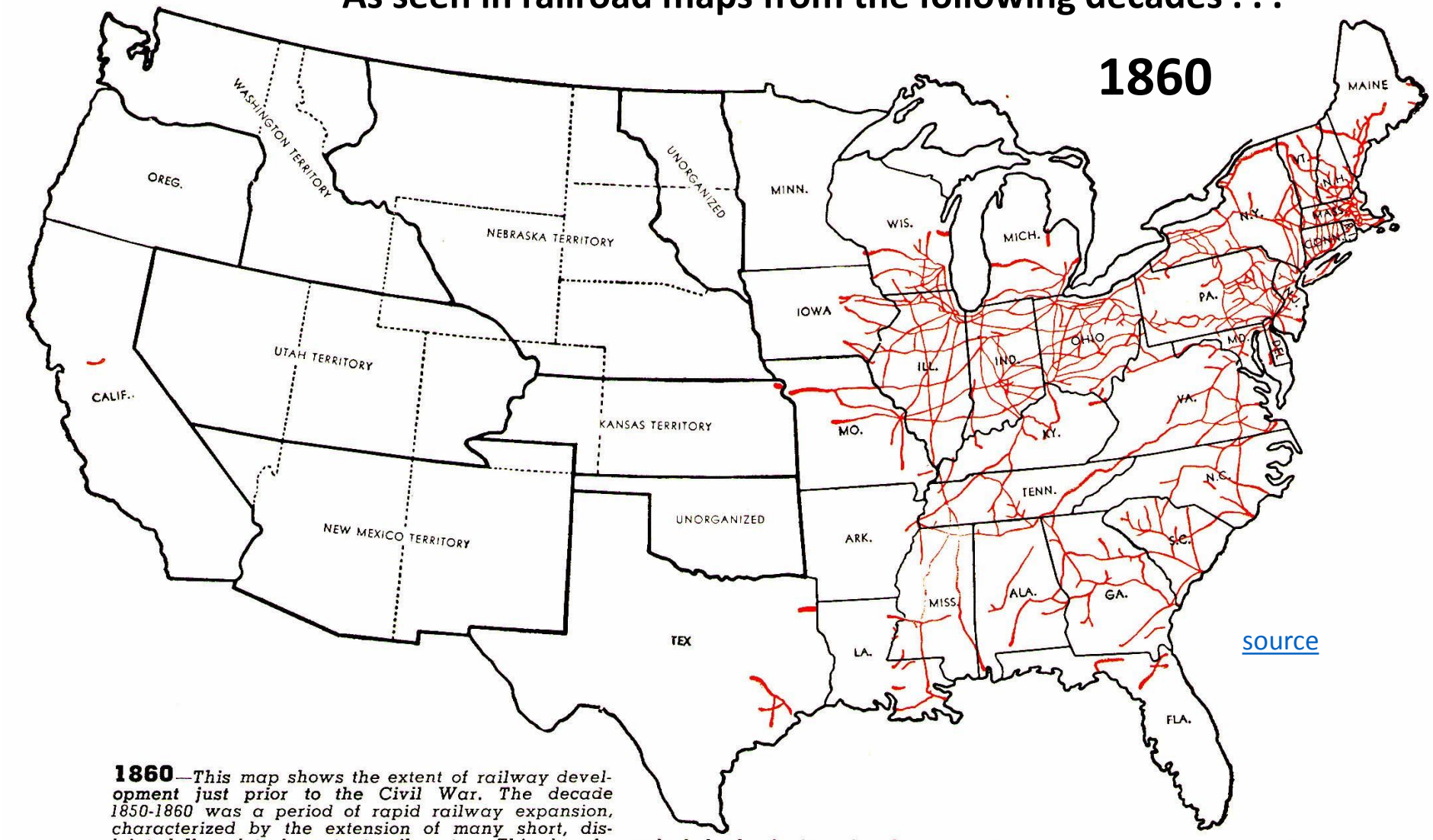
http://www.cprr.org/Museum/RR_Development.html#2

The expansion was accelerated by the rapid-spread of *telegraphy* in the 1850s, an effect analogous to that of *printing* during the age of discovery . . .



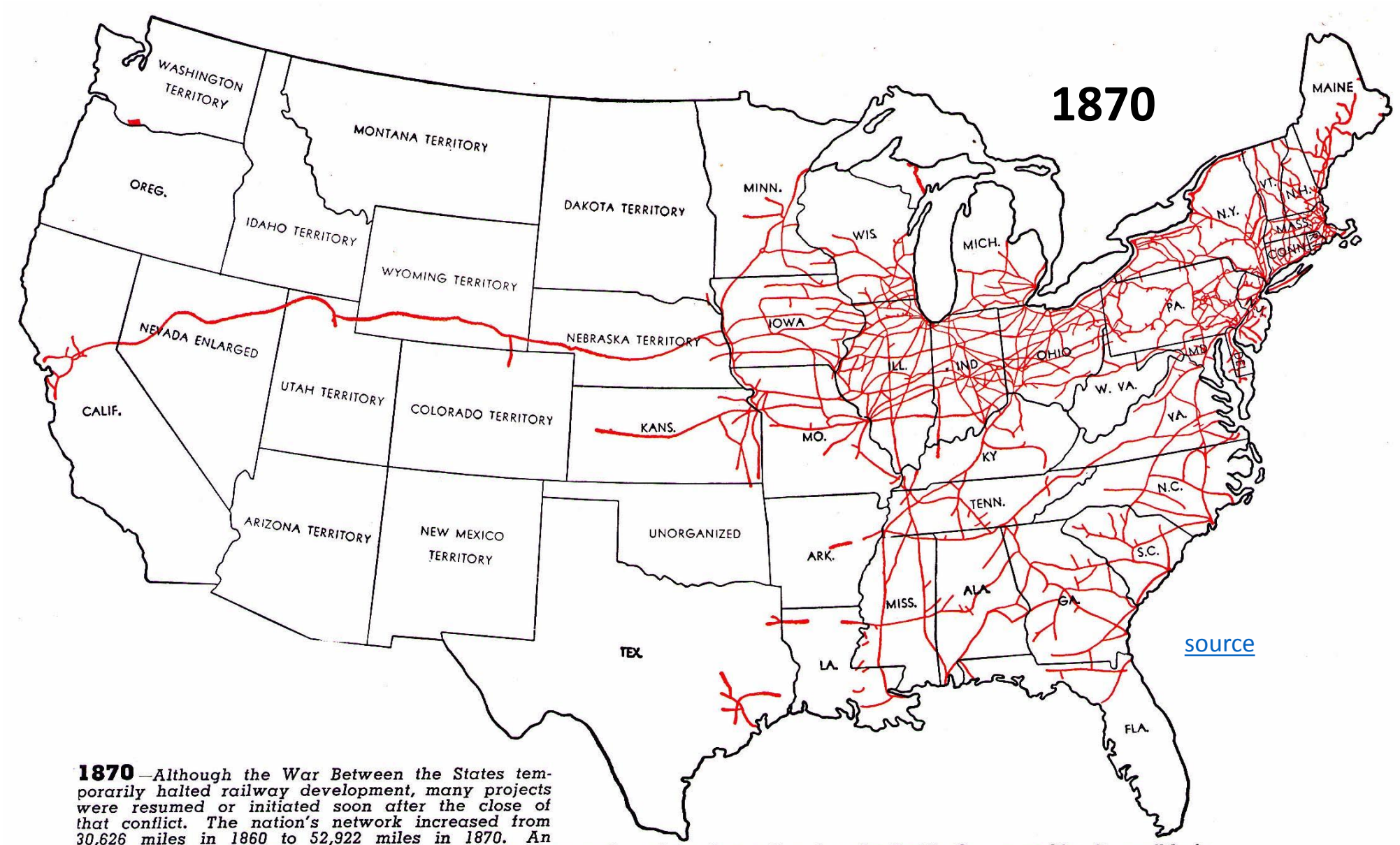
(Snip from Google Images)

As seen in railroad maps from the following decades . . .



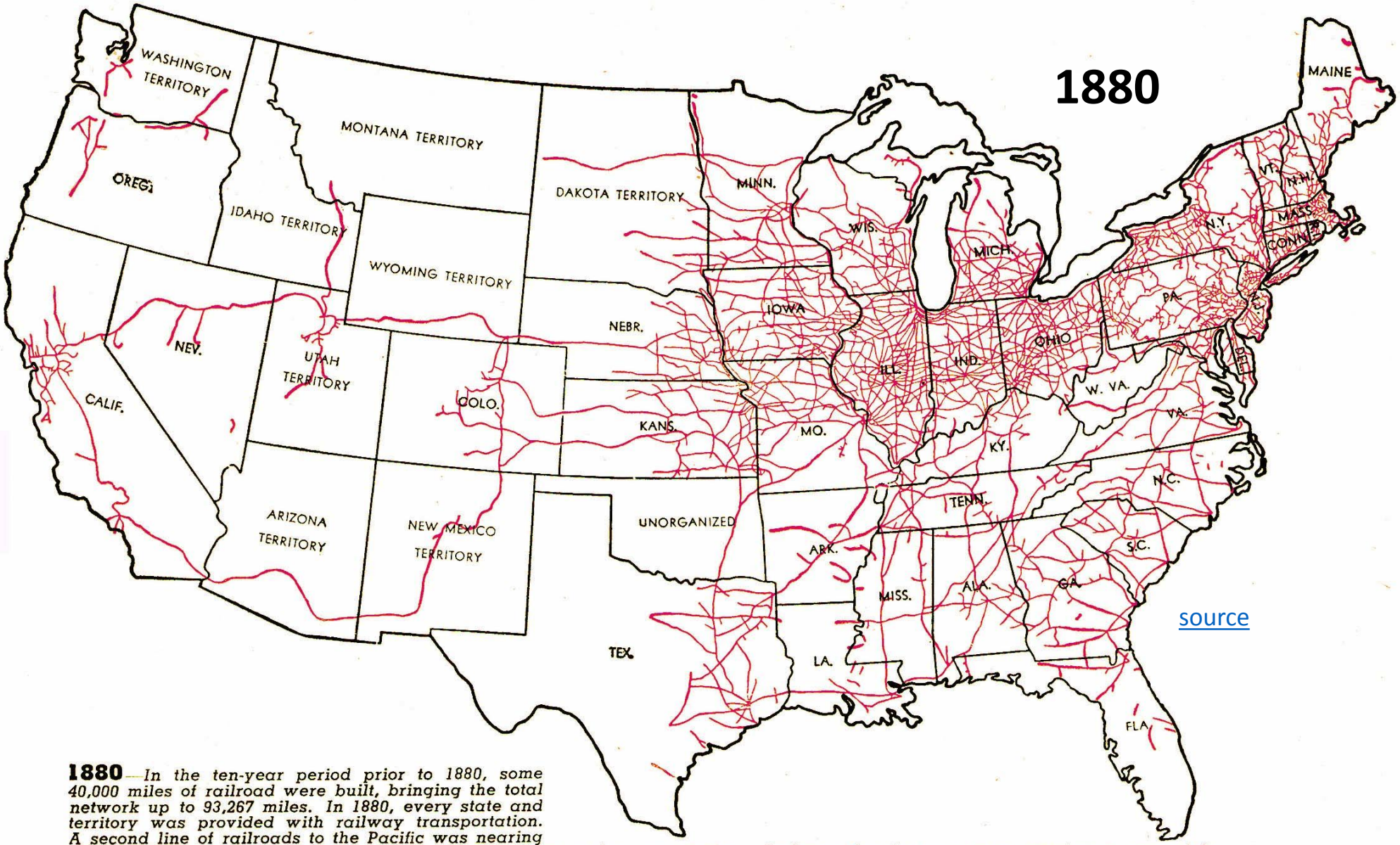
source

1860—*This map shows the extent of railway development just prior to the Civil War. The decade 1850-1860 was a period of rapid railway expansion, characterized by the extension of many short, disjointed lines into important rail routes. This decade marked the beginning of railway development in the region west of the Mississippi River. By 1860, the "Iron Horse" had penetrated westward to the Missouri River and was beginning to make itself felt in Iowa, Arkansas, Texas, and California.*



source

1870—*Although the War Between the States temporarily halted railway development, many projects were resumed or initiated soon after the close of that conflict. The nation's network increased from 30,626 miles in 1860 to 52,922 miles in 1870. An outstanding development of the decade was the construction of the first railroad to the Pacific Ocean, making it possible for the first time to travel all the way across the country by rail. Railway development in the Mississippi and Missouri valleys was especially notable during this period.*



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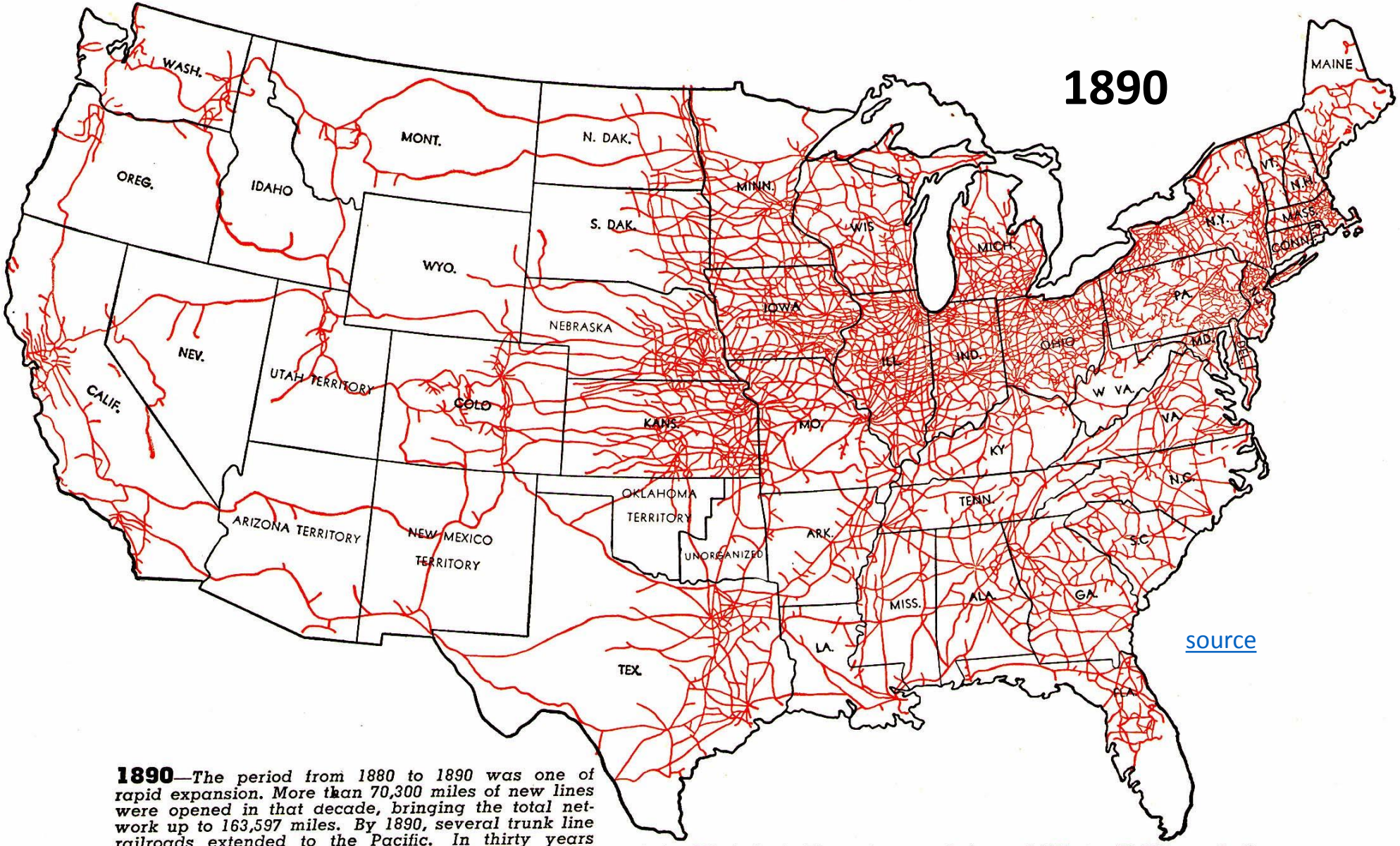
1880—*In the ten-year period prior to 1880, some 40,000 miles of railroad were built, bringing the total network up to 93,267 miles. In 1880, every state and territory was provided with railway transportation. A second line of railroads to the Pacific was nearing completion, and other transcontinental railroads were under construction. Railway development was exerting a powerful influence upon immigration and agricultural and industrial growth throughout the country.*



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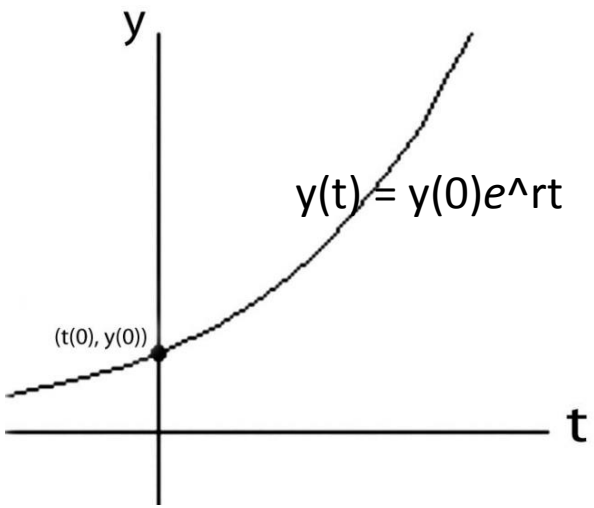
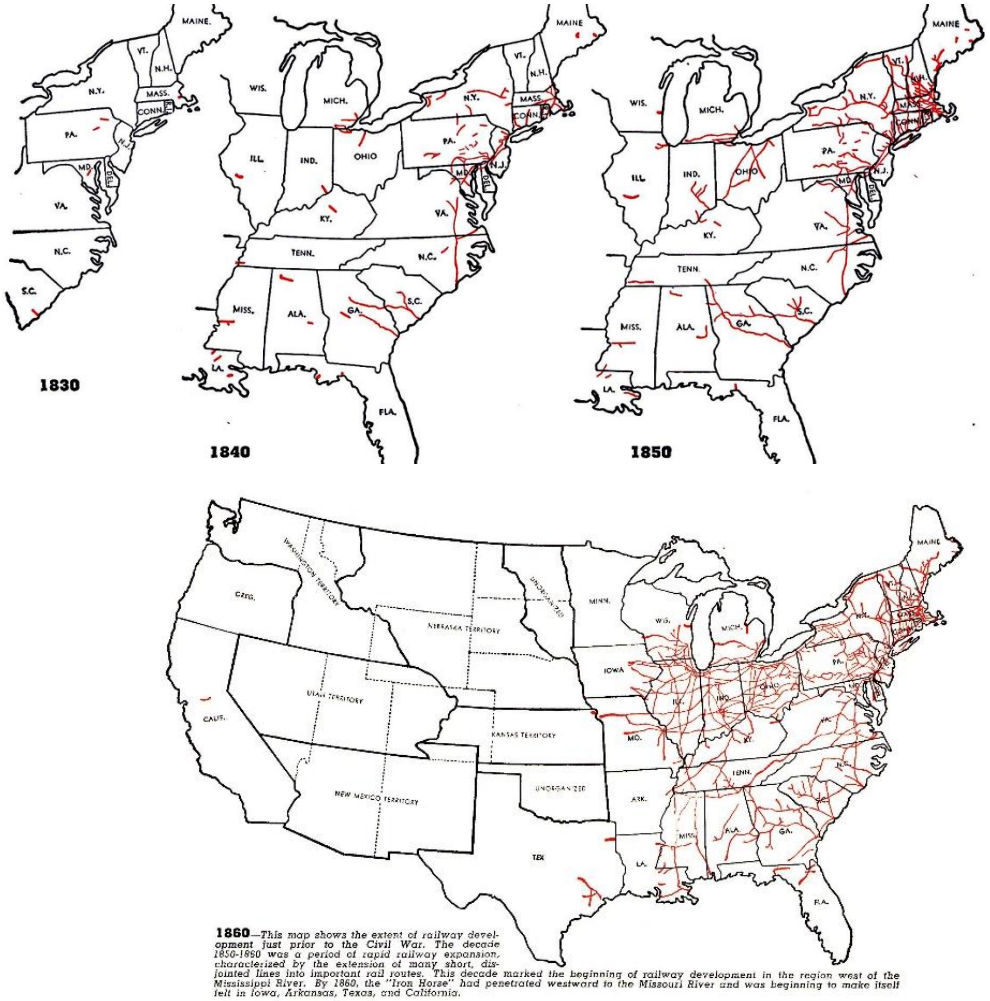
1890—*The period from 1880 to 1890 was one of rapid expansion. More than 70,300 miles of new lines were opened in that decade, bringing the total network up to 163,597 miles. By 1890, several trunk line railroads extended to the Pacific. In thirty years from 1860 to 1890, the total mileage of the region west of the Mississippi River increased from 2,175 to 72,389, and the population of that area increased fourfold.*

Like compound interest, the early social-diffusion rate of such clusters of technological ideas is proportional to what has materially accumulated at any given point in time . . .

(I.e., it's an exponential function):

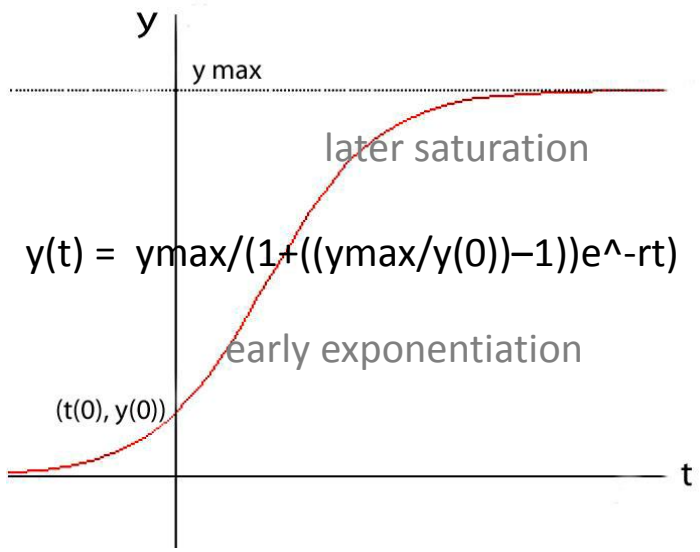


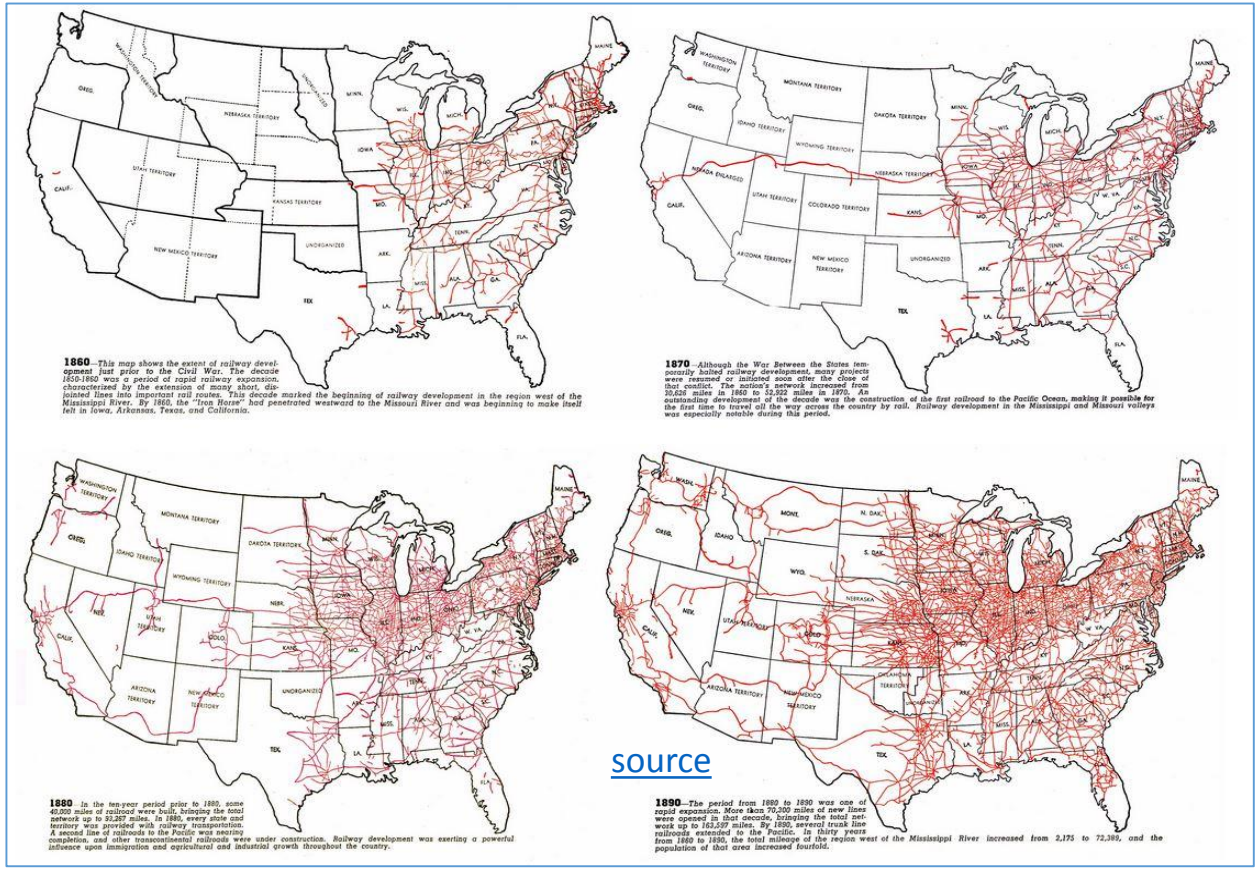


source

But as the opportunity-space fills, diffusion of those technological ideas slows as that cluster nears its materially-expressed expansion limits . . .

(I.e., it becomes a logistic function):





source

As a result of a widespread harnessing of electricity in the 1890's, innovative technology clusters lurched out into wild dimensions . . . as electric generators and motors were embedded into new industrial and transportation systems:

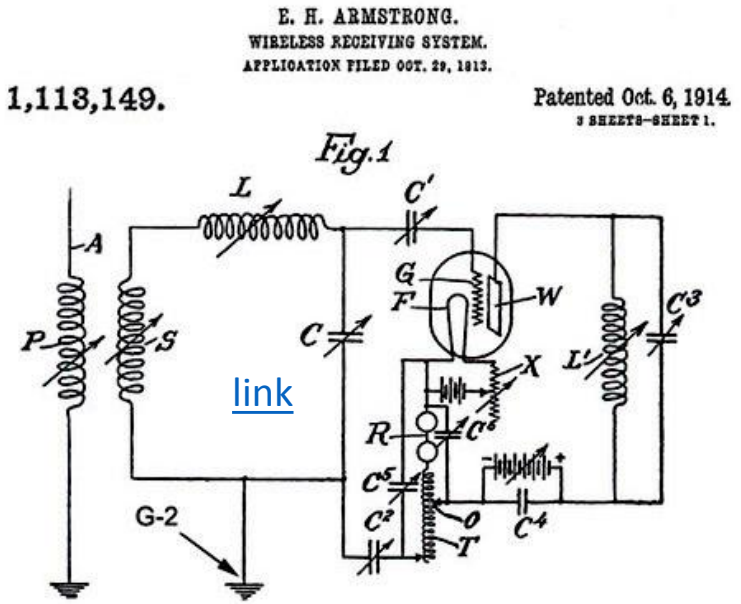
Electrical Generators

Electrical Motors

Interurban rail

Subways [Planning the IRT, 1891]

The rapidly diffusing electrification then co-evolved with rapidly-diffusing electric rail, subway, telephone and lighting systems, and with the new ‘wireless’ radio communication systems . . .

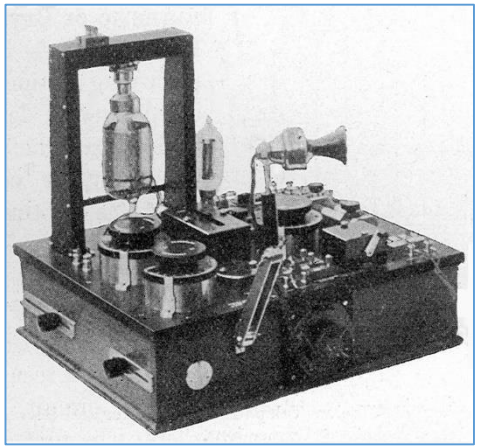

E. H. ARMSTRONG.
WIRELESS RECEIVING SYSTEM.
APPLICATION FILED OCT. 29, 1913.

1,113,149. Patented Oct. 6, 1914.
3 SHEETS—SHEET 1.

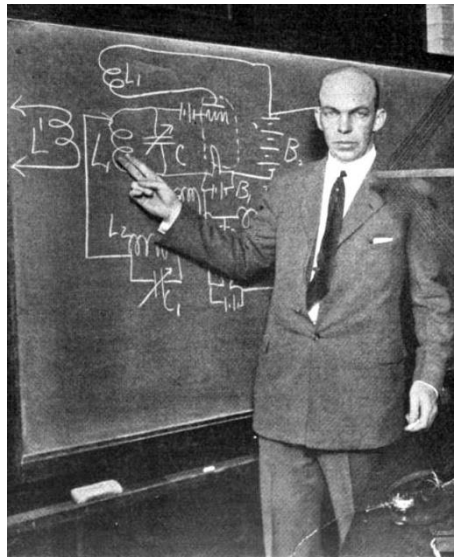
Fig. 1

link

WWI military radio receiver

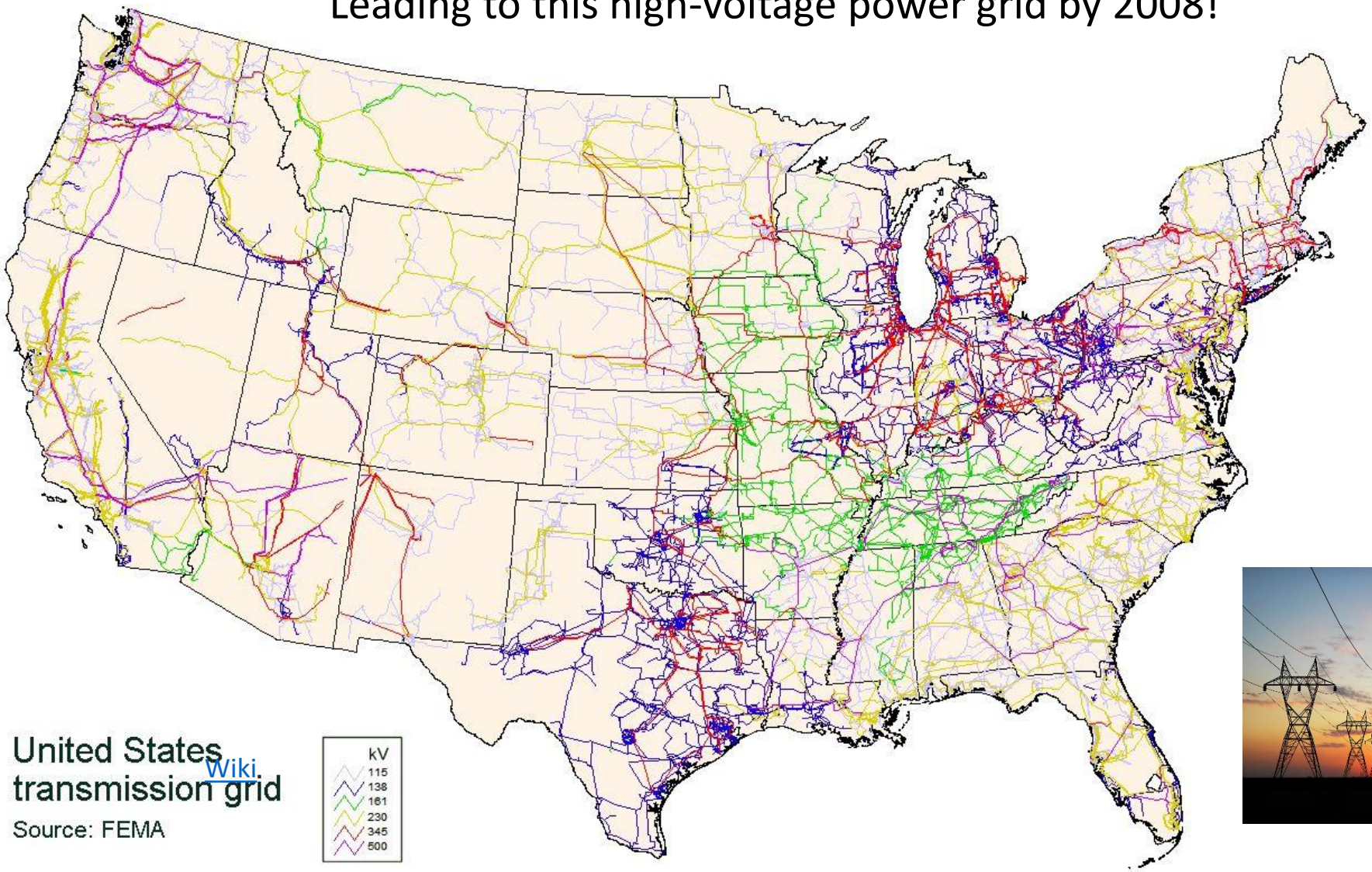


Armstrong at Columbia 1922



Back then, Edison, Westinghouse, Tesla, Steinmetz, Bell, Marconi and Armstrong became household names for their seminal ideas behind these wild technologies.

Leading to this high-voltage power grid by 2008!



United States transmission grid

Source: FEMA

Wiki

The dramatic results of the exponentiation of electrification are easily seen from space today . . .

NASA

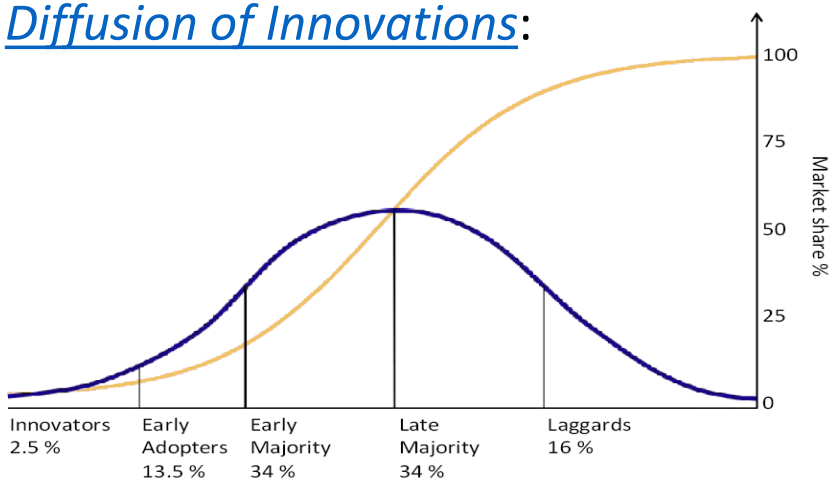
Think how many minds by now the foundational ideas of Faraday, Maxwell, Hertz, Steinmetz, Marconi, Armstrong, etc., have cycled through to make this happen!

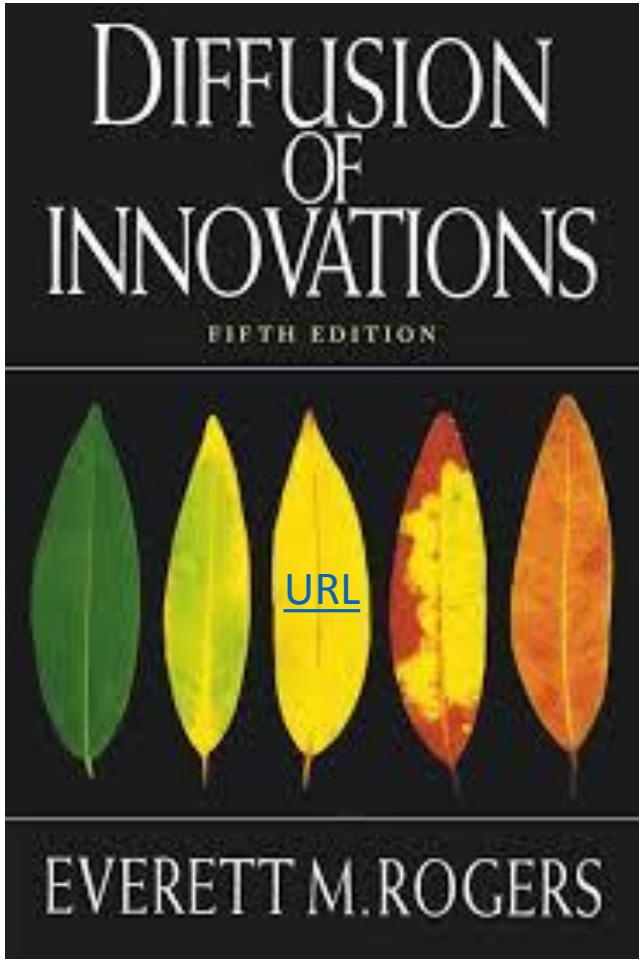
Let’s now look at a wave of innovation that I surfed back in the 1970’s:

The revolution in VLSI (Very Large Scale Integrated) microchip design . . .

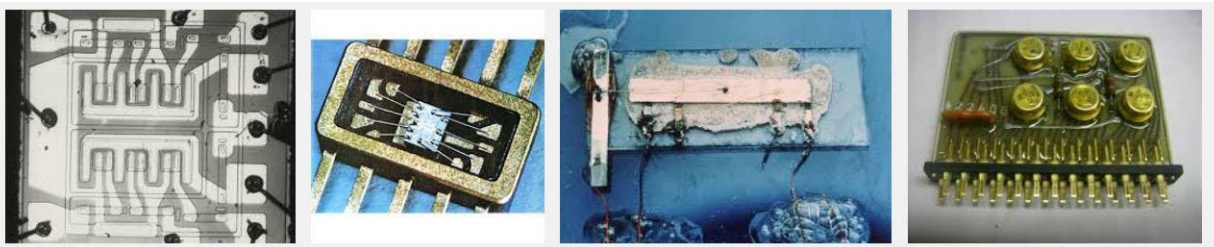
While doing so, let's more-consciously note how "the flow of ideas" expands . . . as a function of the increasing connectivity and bandwidth . . . and the decreasing time-delays, in techno-social communication . . .

While also thinking along lines explored by Everett Rogers in his seminal 1962 text *Diffusion of Innovations*:



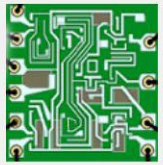


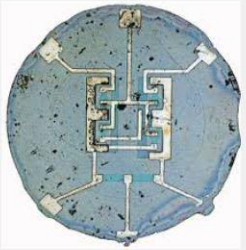
The stage was set by innovations in integrated circuitry in the 1960's, enabling transistors and wiring to be lithographically 'printed' onto chips of silicon . . .

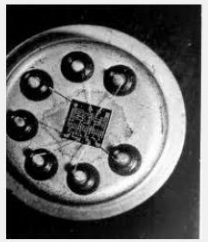


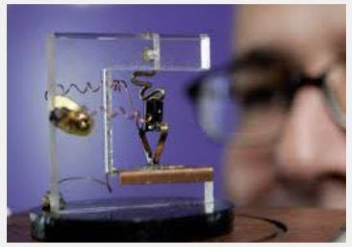
Snip from Goggle images

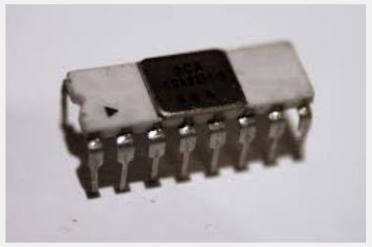
Some early integrated circuits:

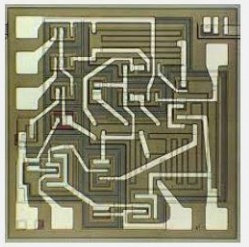










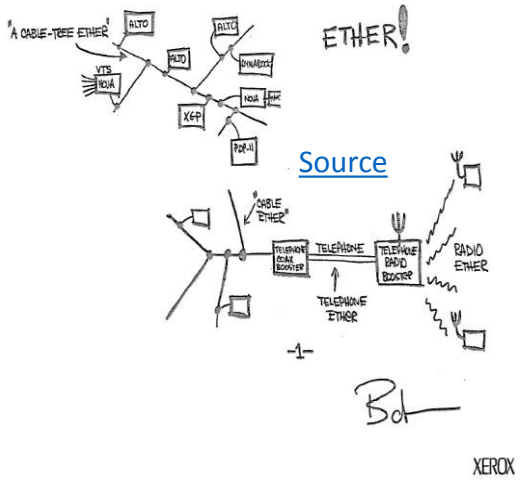


It was further set by innovations in computing at Xerox PARC in the early 70's, including the "Alto personal computer", the "Ethernet" and the "laser printer". . . and by the rapid evolution of the "Arpanet" (the early internet) at DARPA . . .

Xerox Alto, 1973

Wiki commons

Metcalfe's original Ethernet sketch, 1973



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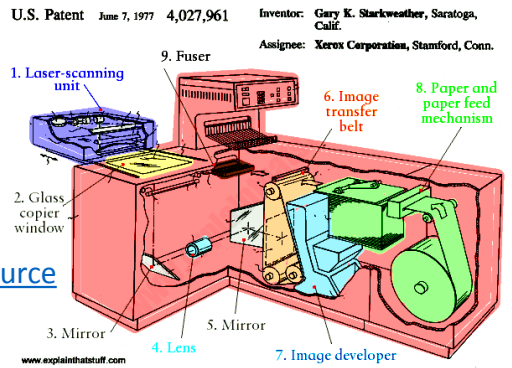
Laser printer, 1971



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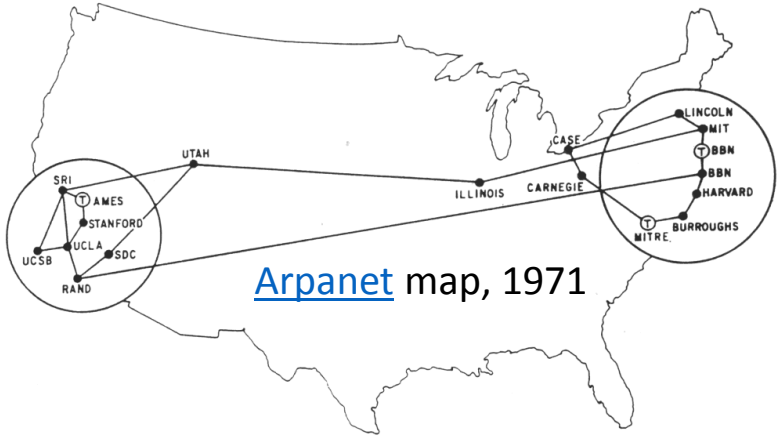
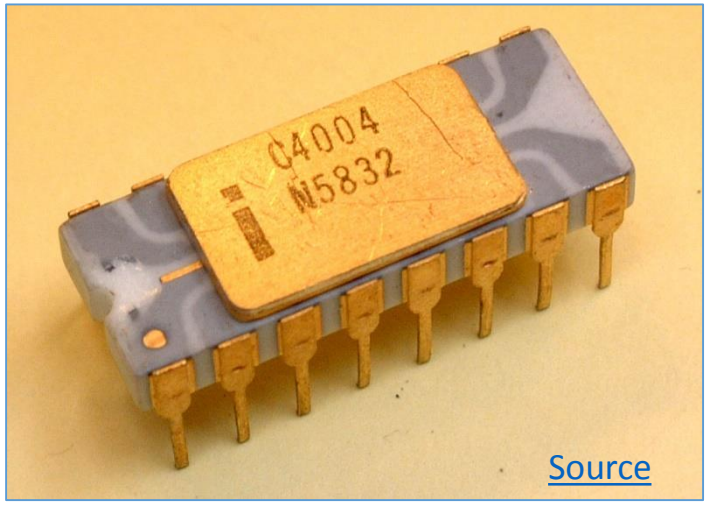


Arpanet map, 1971

Advancing lithography enabled the ‘printing’ of ever-increasing numbers of transistors on single chips.

A watershed was crossed in 1971 with the introduction of Intel’s 4004, the first single-chip “microprocessor”

It contained 2300 transistors . . .



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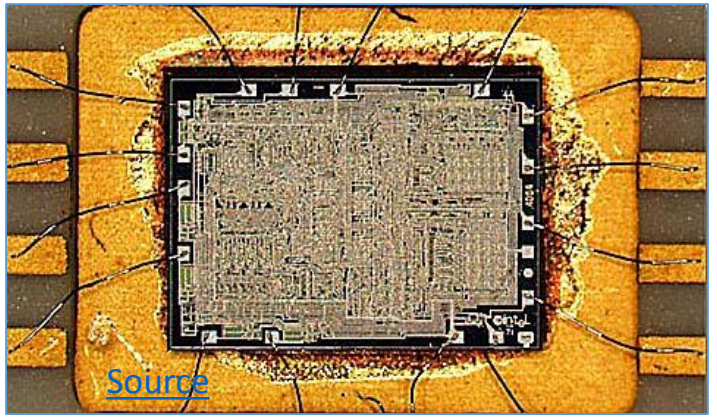
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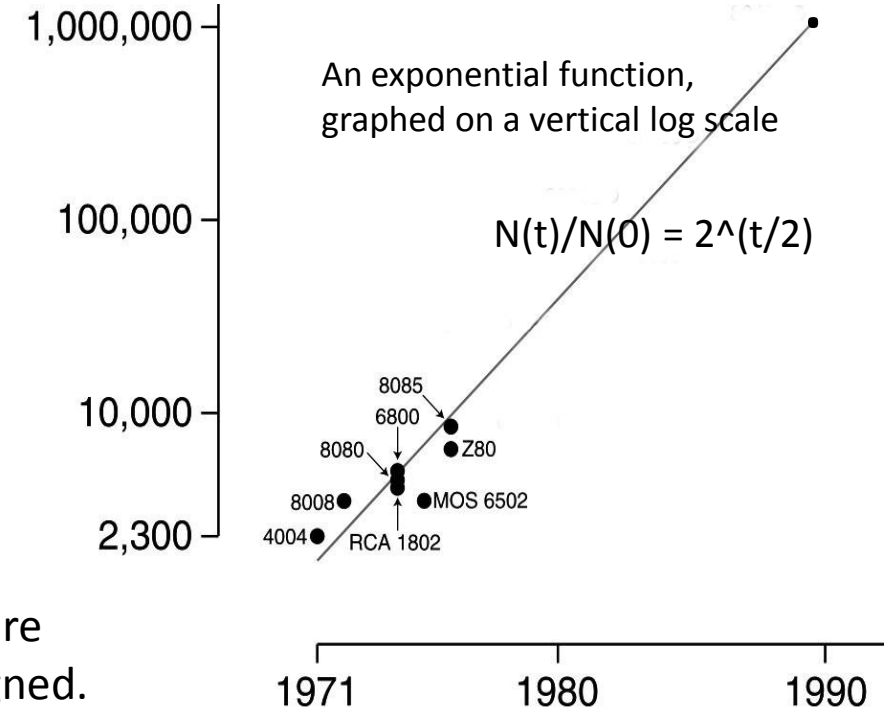
Gordon Moore at Intel noted that the number of transistors reliably printable on a chip was approximately doubling every two years . . .

Caltech's Carver Mead named this "Moore's Law" and his grad student Bruce Hoeneisen proved there were no physical limits to increasing the number up to at least 1 million transistors.

It appeared possible, even likely, that by ~1990 an entire "supercomputer" could be printed on a single chip . . .

In 1976 this set-off a huge push by collaborating research teams at Xerox PARC and Caltech to figure out how to enable such complex chips to be designed.

Moore's Law (as of 1976)



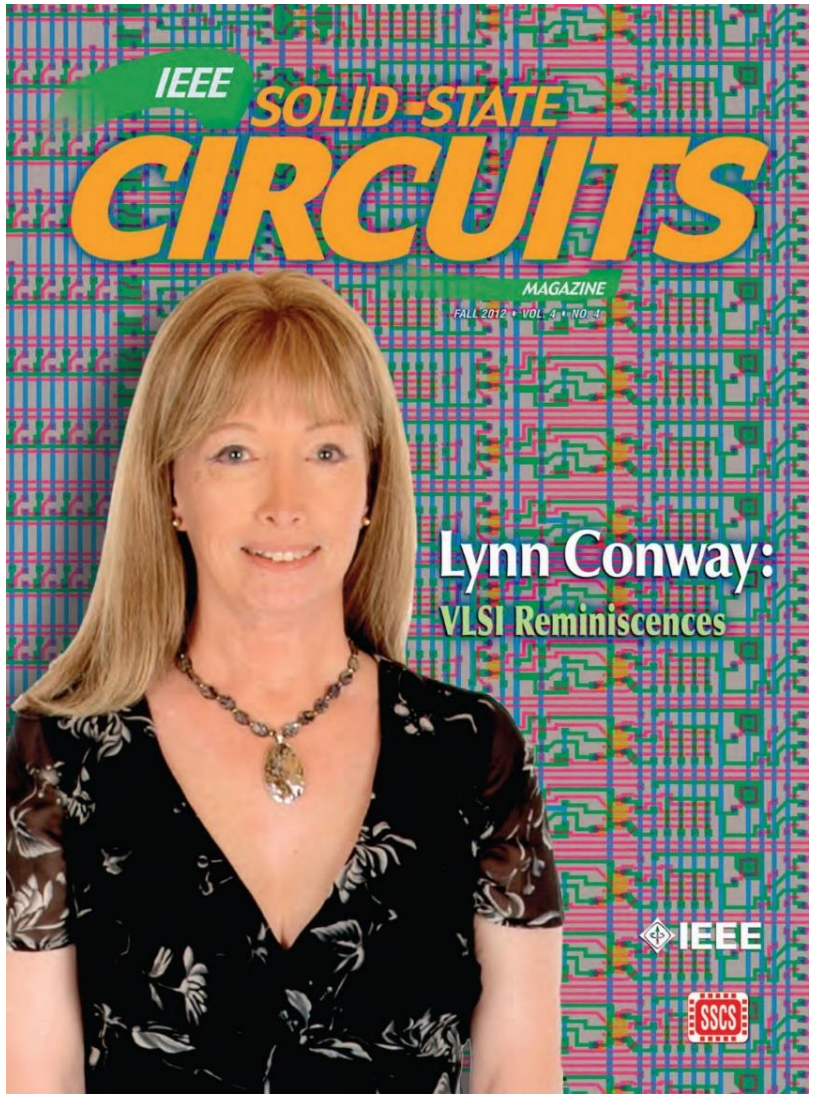
The story of what happened over the next four years is quite a saga . . .

You'll find insights into that saga in my "Reminiscences of the VLSI Revolution" in Fall 2012 IEEE *Solid State Circuits Magazine*

That was the very first time I'd stepped forward to tell the story . . .

Till then, since I didn't look like an engineer, Silicon Valley had no clue what I'd done back during the 1970's! (and still doesn't!)

For now we'll just hit some highlights . . .



The breakout was triggered by a cluster of abstract innovations at Xerox PARC and Caltech . . .

Included were a set of digital scalable VLSI chip-layout design rules, framed as dimensionless inequality equations (Conway, PARC).

These enabled abstract chip designs to easily be digitally created, shrunk down and reused as Moore's law rapidly advanced . . .

They also enabled accruing digital designs to be widely open-source-shared . . .

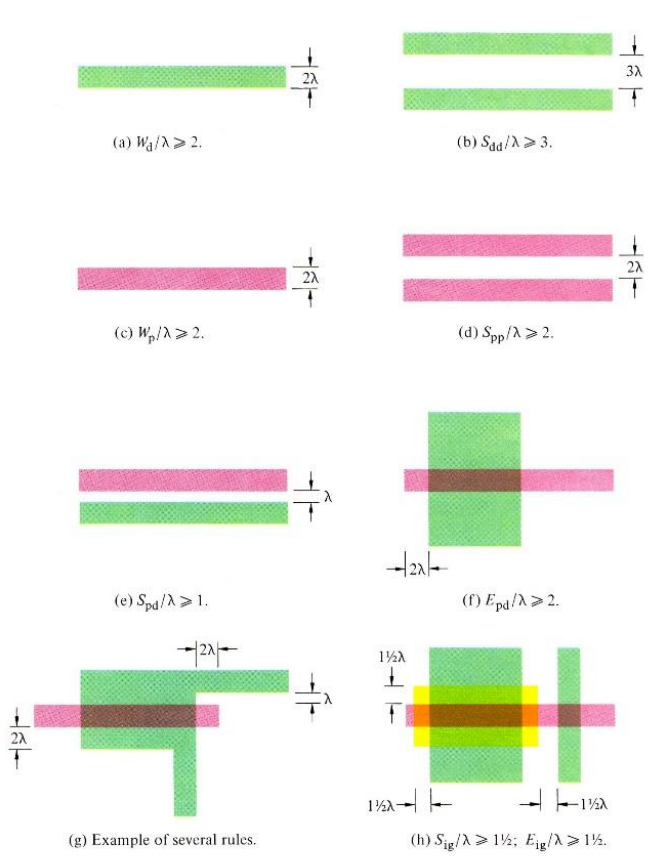


PLATE 2 *n*MOS design rules

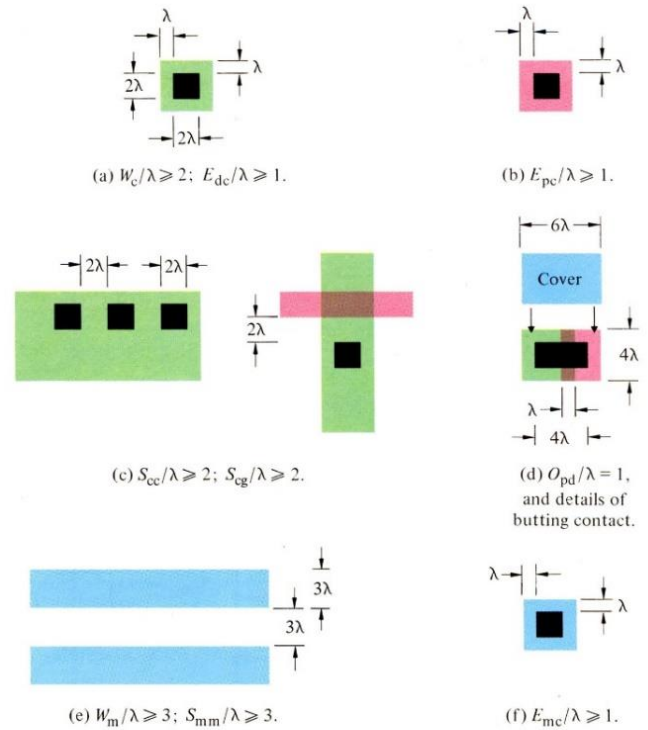


PLATE 3 *n*MOS design rules (continued)

Link

The driving meta-architectural idea:

Given: As chip lithography scales-down according to Moore's Law, ever-more ever-faster transistors can be printed on individual chips as time passes.

STEP (i): Use a computer to design the chip-set for a more powerful computer . . . then "print" that chip-set using the next-denser fabrication process.

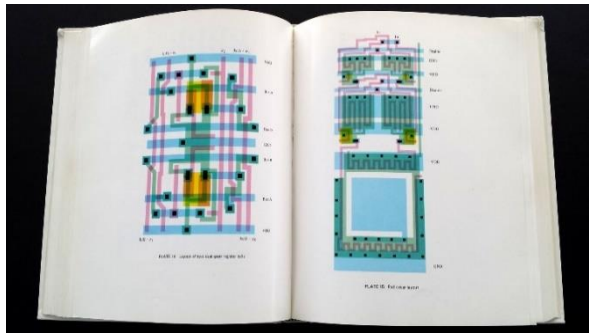
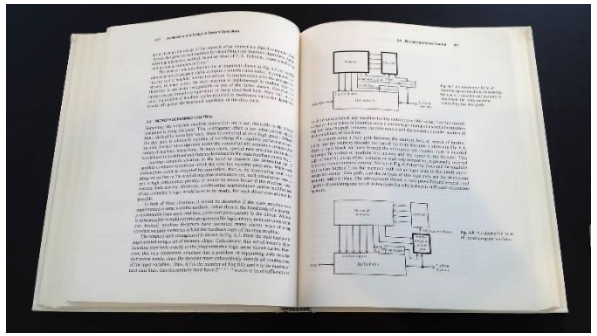
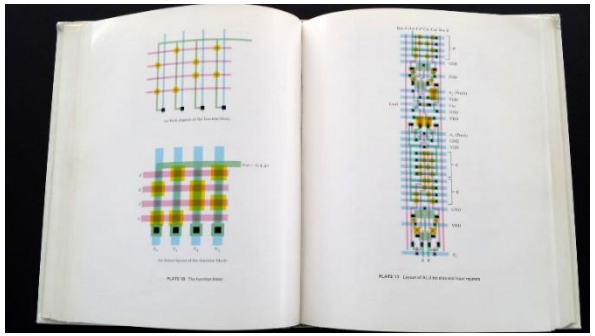
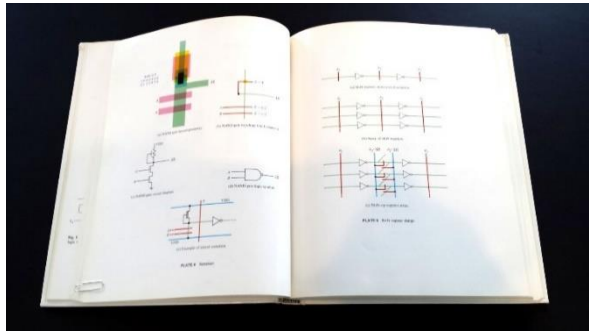
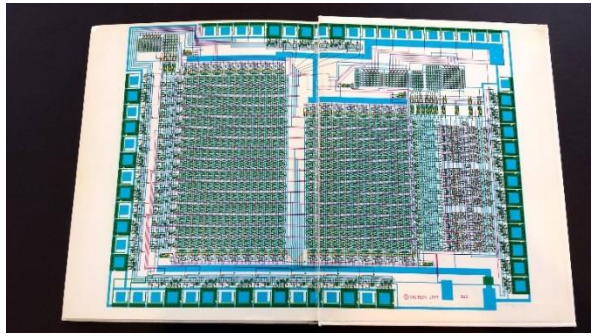
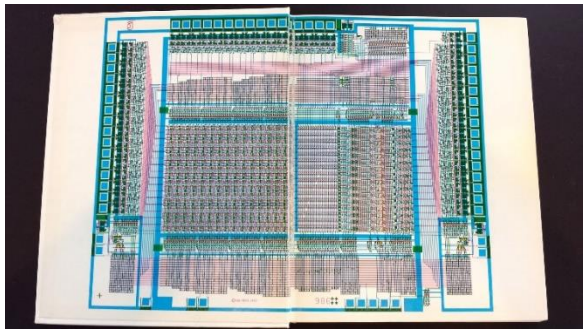
STEP (i+1): Use that more powerful chip-set to update your "computer-design computer" and its design tools, then repeat step (i).

If ever-more engineers and design-tool builders began doing this (on an expanding number of increasingly powerful computers), the iterative techno-social expansion-process could explosively generate ever-more, ever-more-powerful, digital systems . . .

I.e., that techno-social process could **Exponentiate!**

But there's a big problem: Where will all these engineers/programmers come from, and how will they learn to do all this?

To cope with this, I began documenting the new system of simplified, restructured chip design methods in an evolving computer-edited book . . .

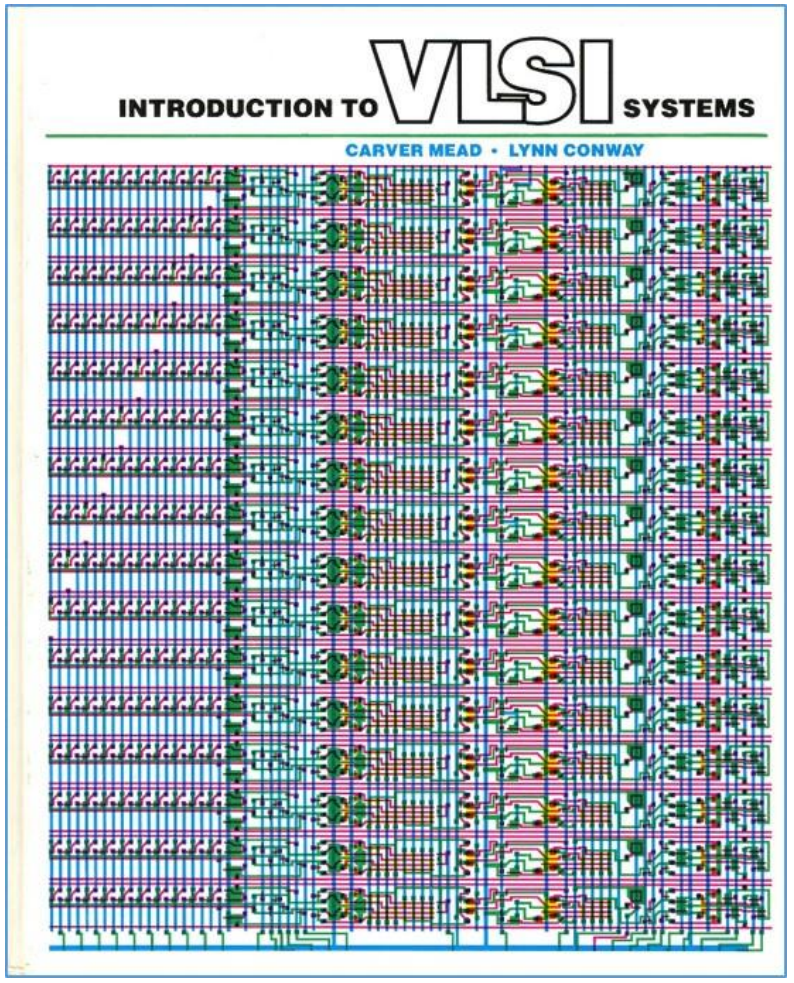







Link

Thus using Alto computers not only to mechanize the generation of chip-designs, but also to mechanize the evolution of the design-knowledge-book itself . . .

That computer-edited, rapidly evolving book, printed using the laser printers at PARC, became the draft of the later-iconic textbook . . .

Introduction to VLSI Systems
by Mead and Conway,
published in 1980 . . .



Then, following the techno-social-script used by Charles Steinmetz to propagate his revolutionary AC electrification methods at Union College in 1910+, I introduced the new design methods in a special VLSI design course at MIT in 1978.

THE M.I.T. 1978
VLSI SYSTEM DESIGN COURSE

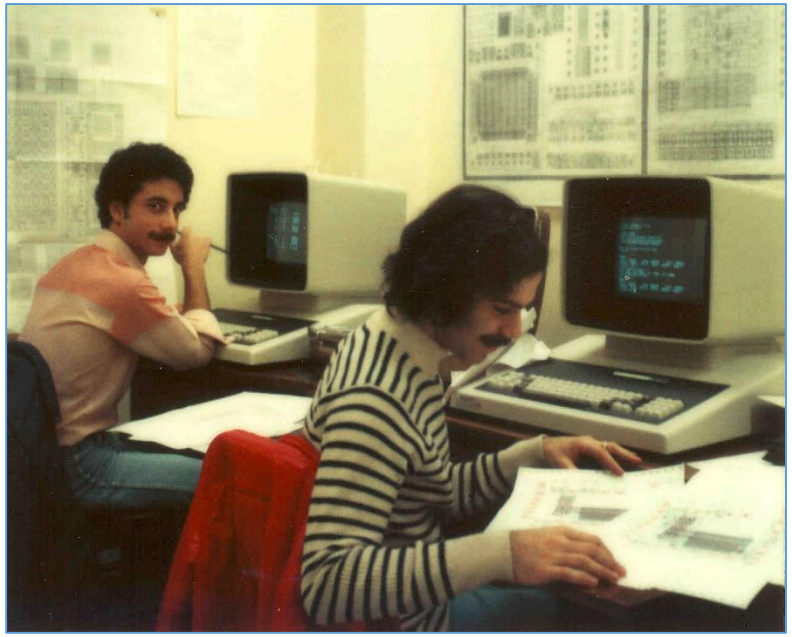
Link
Link
Link

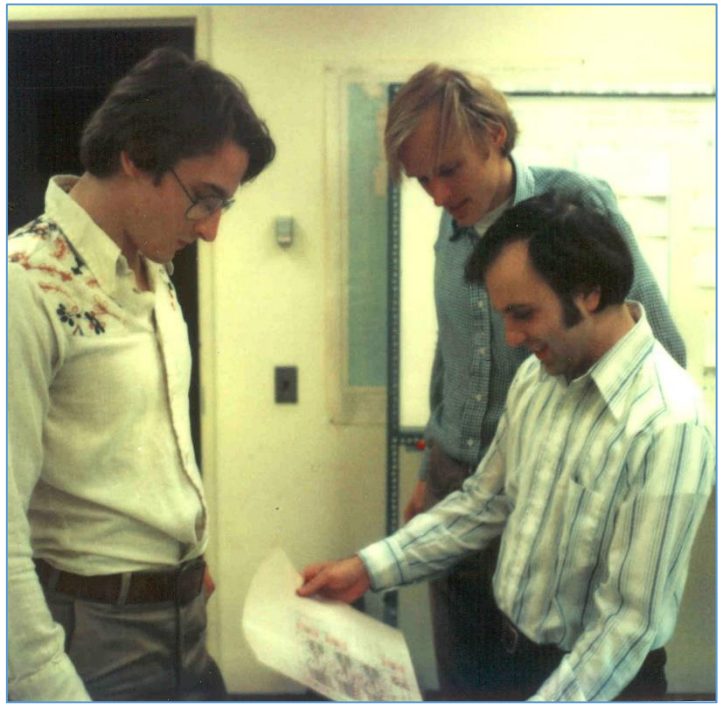
by Lynn Conway

[Update: 11-14-07]

This course was an important milestone in the development, demonstration and evaluation of the Mead-Conway structured VLSI design methods. Lynn Conway conceptualized and planned the course during the late spring and summer of '78, and taught the course while serving as Visiting Associate Professor of EECS at MIT in the fall of '78 and early '79.

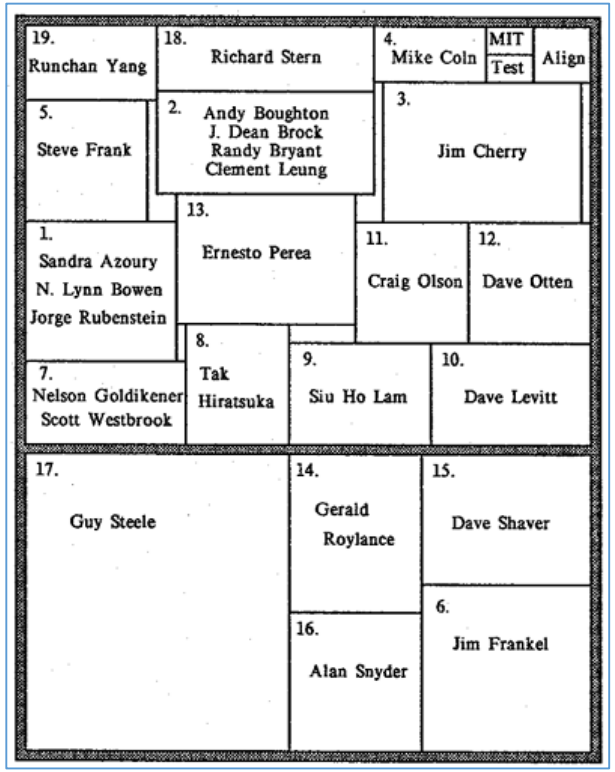
Students learned the design methods in the 1st half-course & designed project-chips in the 2nd half, which were then "printed" at my colleague Patricia Castro's laboratory at HP . . .

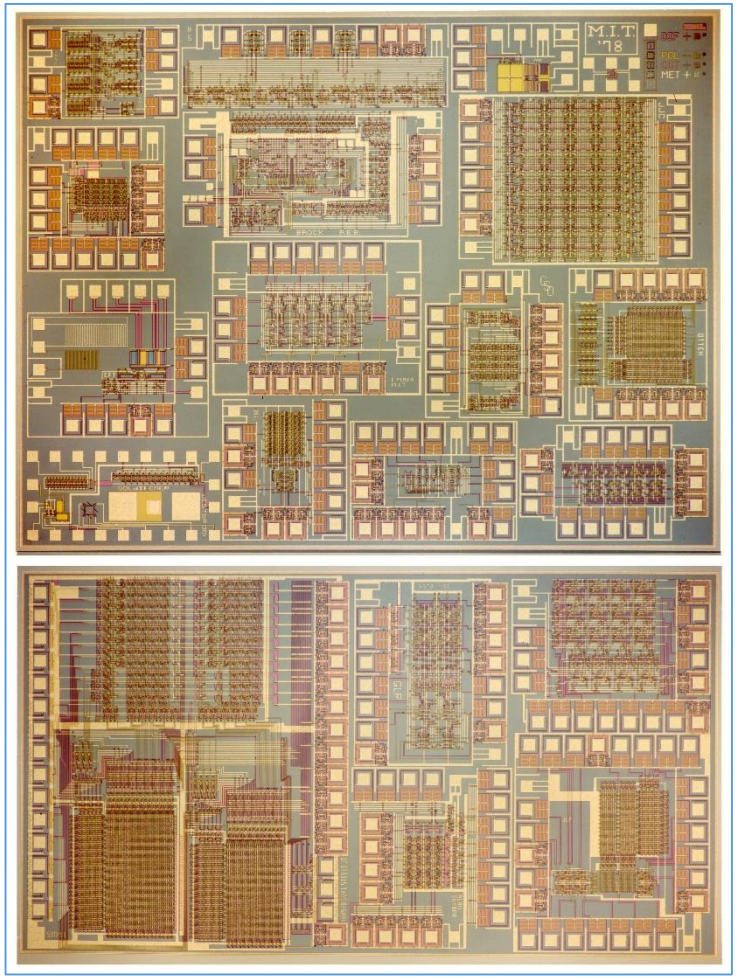




The many amazing results included a complete Lisp microprocessor chip by MIT grad student Guy Steele . . .

[Map and photomicrograph]
of the 19 student projects on
the MIT'78 'MultiProject' Chip





For more about the [MIT'78 course], see [Lynn's "MIT Reminiscences"]

The MIT'78 course stunned various top folks across Silicon Valley . . .
Chip design till then had been a mystery, only grasped by a few computer engineers working for chip manufacturers . . who thus had access to the "printing plants" . . .

Many other top research universities wanted to offer an "MIT-like" course. But how?

After intensive pondering, I grasped the answer: Rerun the MIT'78 course at a dozen research universities . . . using my MIT lecture notes to keep everything in sync.

But how to "print" all the student project chips?

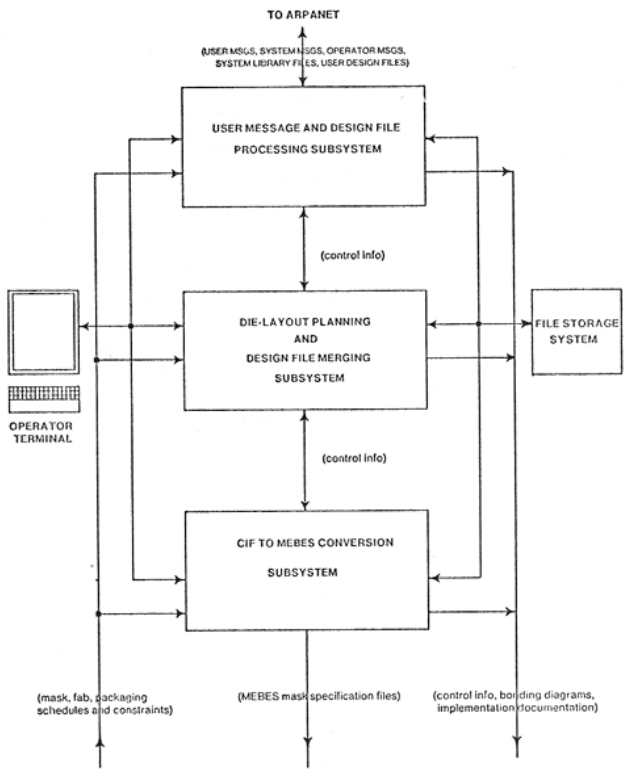
I suddenly envisioned the conception of an "E-commerce" system, enabling student design files to be remotely submitted over the Arpanet to a "server" at PARC . . .

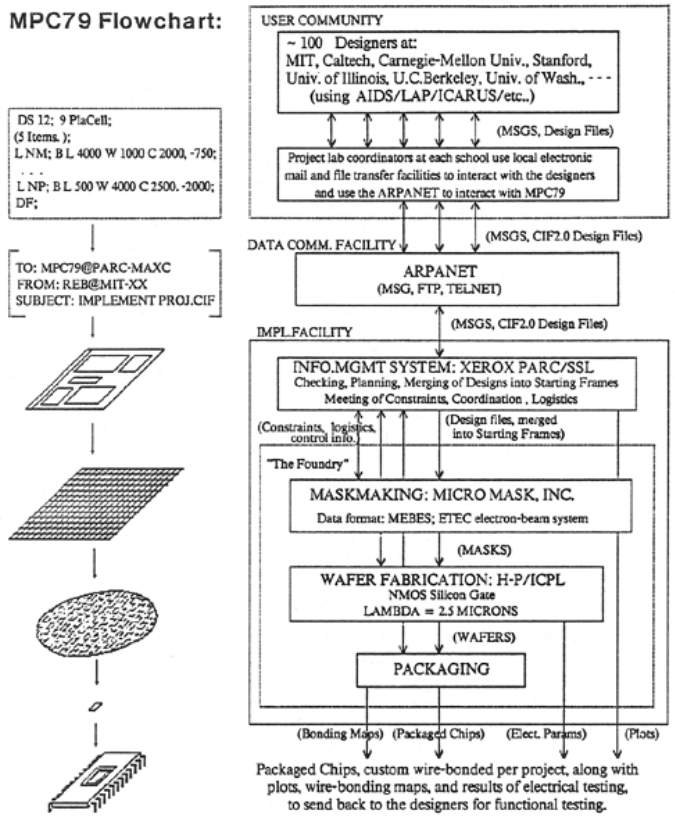
It would run software to pack designs into multi-project chips (like composing the print-files for a magazine, using remotely-submitted articles) . . .

We'd then "print" the MPC's again at HP (where Pat Castro had prototyped the first "silicon foundry"), and quickly return the chips to students.

From PARC, I announced*, and then orchestrated, a huge “internet-happening” (MPC79) in the fall of ‘79 . . . recruiting 129 budding student designers to take new Mead-Conway VLSI courses at 12 research universities . . .

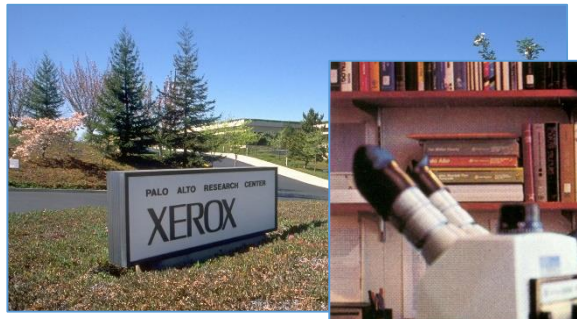
MPC79 Arpanet E-commerce system:



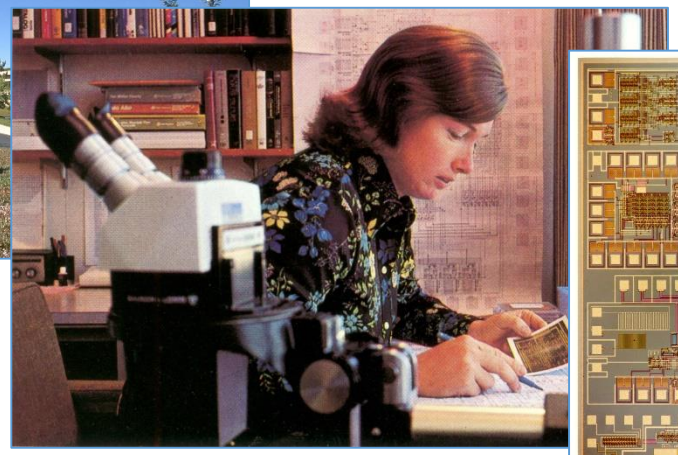


*On my own initiative, without explaining to anyone what I was actually attempting . . .

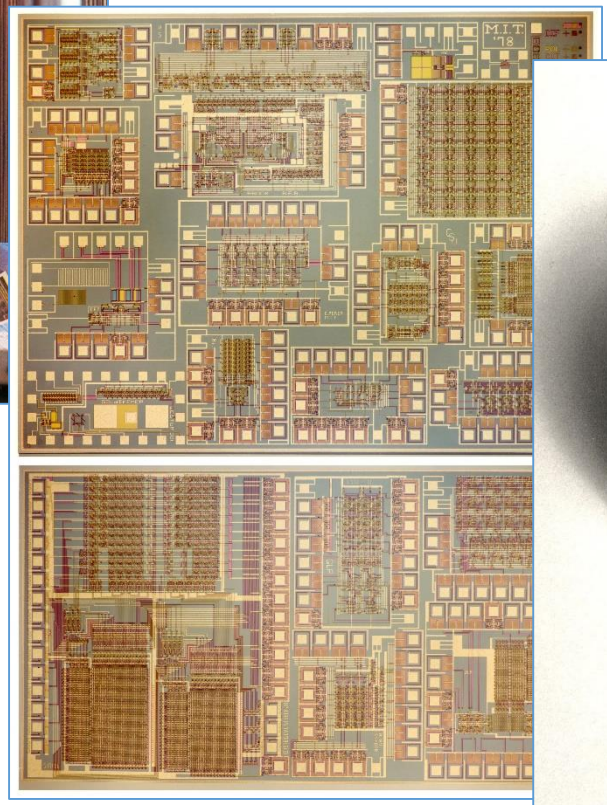
1976



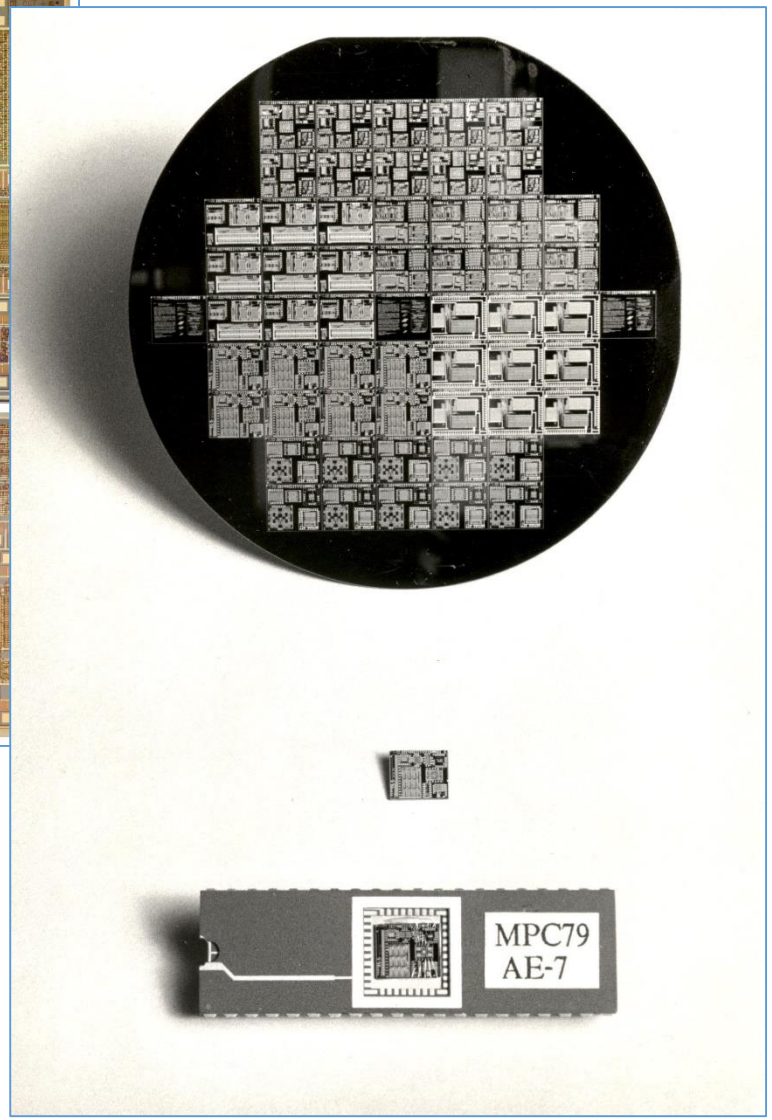
1977



1978



1979



Envisioning the exponentiating wave of VLSI innovation . . .

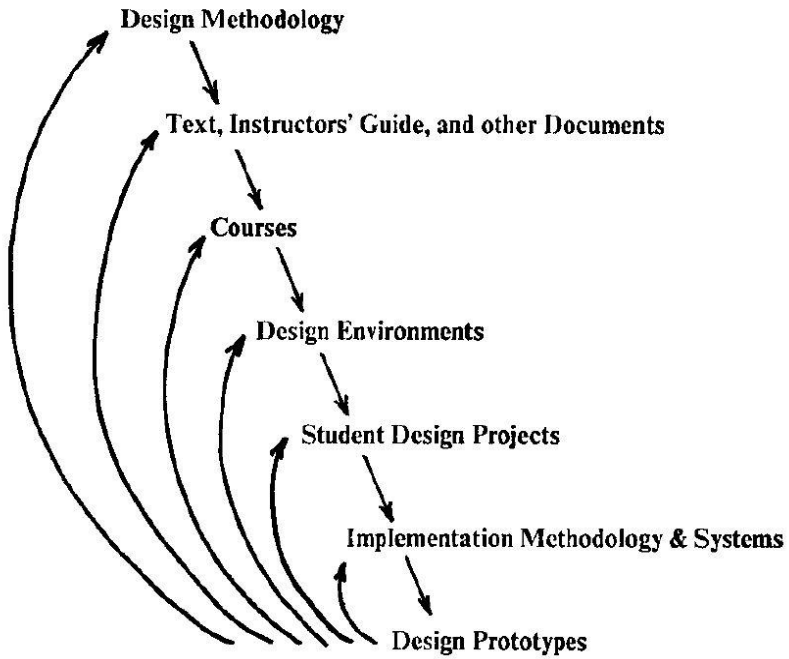
’76: How to cope with VLSI complexity?

’77: Inventing scalable VLSI design rules.

’78: Launching the VLSI methods at MIT!

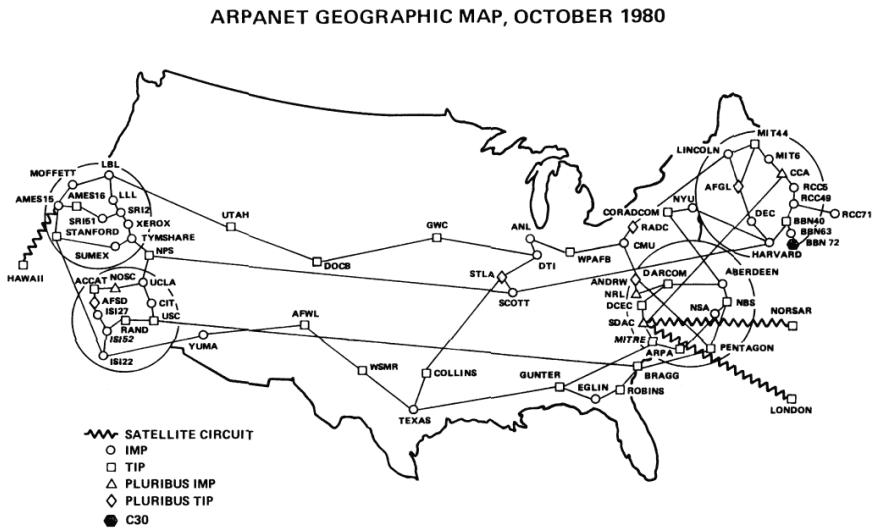
’79: Launching the VLSI courses via MPC79!!

Visualizing how techno-social system dynamics triggered exponentiation in the evolution and diffusion of the new VLSI design ideas . . . in the emerging ARPAnet computer research community:



From The MPC Adventures (p. 16)

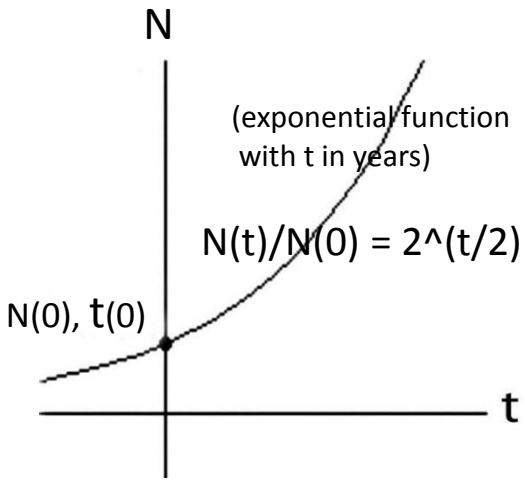
Figure 8. The Joint Evolution of the Multi-Level Cluster of Systems



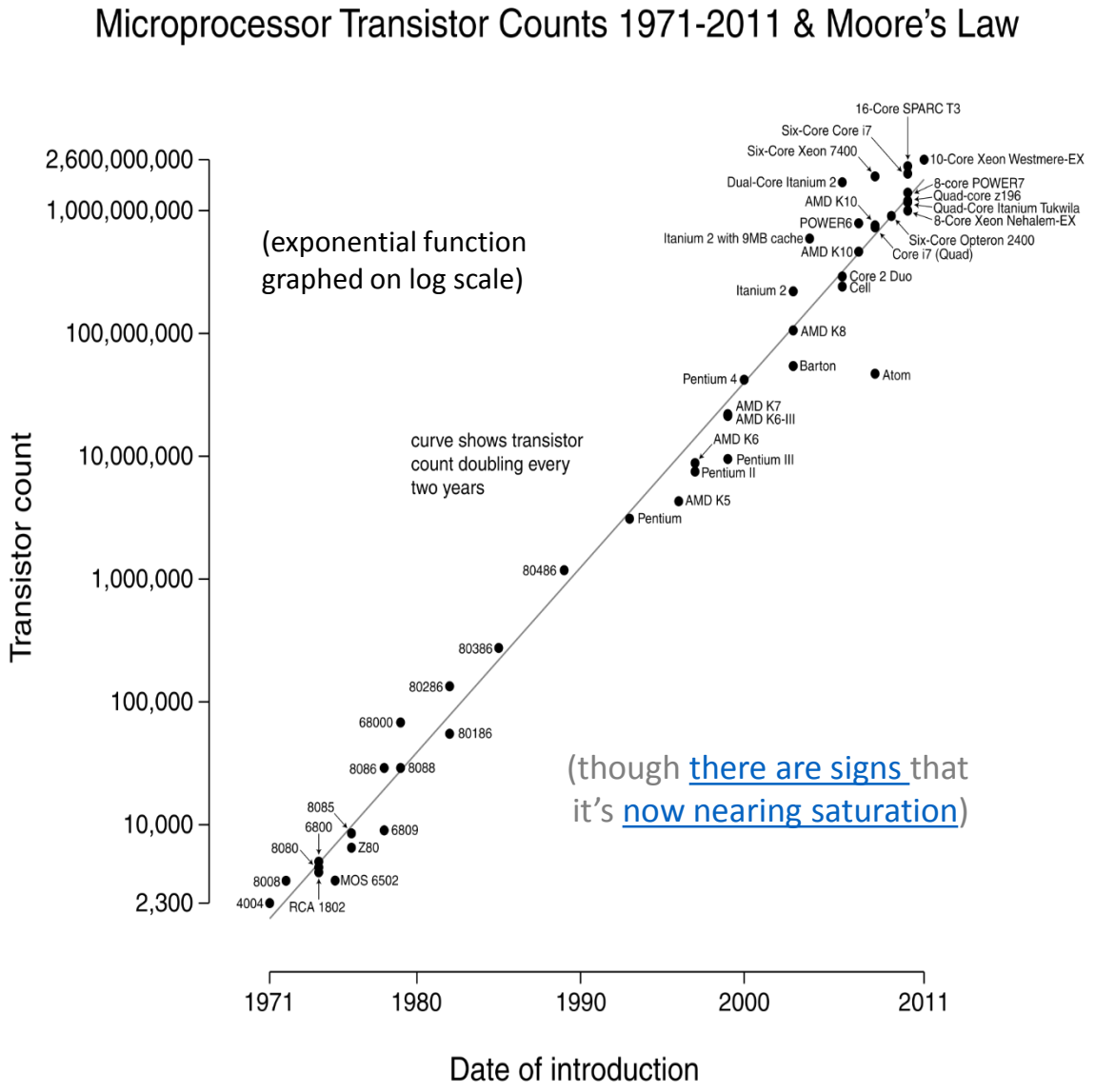
By 82/83, Mead-Conway VLSI courses were being offered at 113 universities around the world . . .

Thereby bootstrapping the modern "fabless-design" + "silicon-foundry" paradigm of chip-making . . . and establishing the "Freedom of the Silicon Press"!

And over the past 40+ years Moore's Law has stayed on-track all the way . . . as a "techno-social synchronization function"



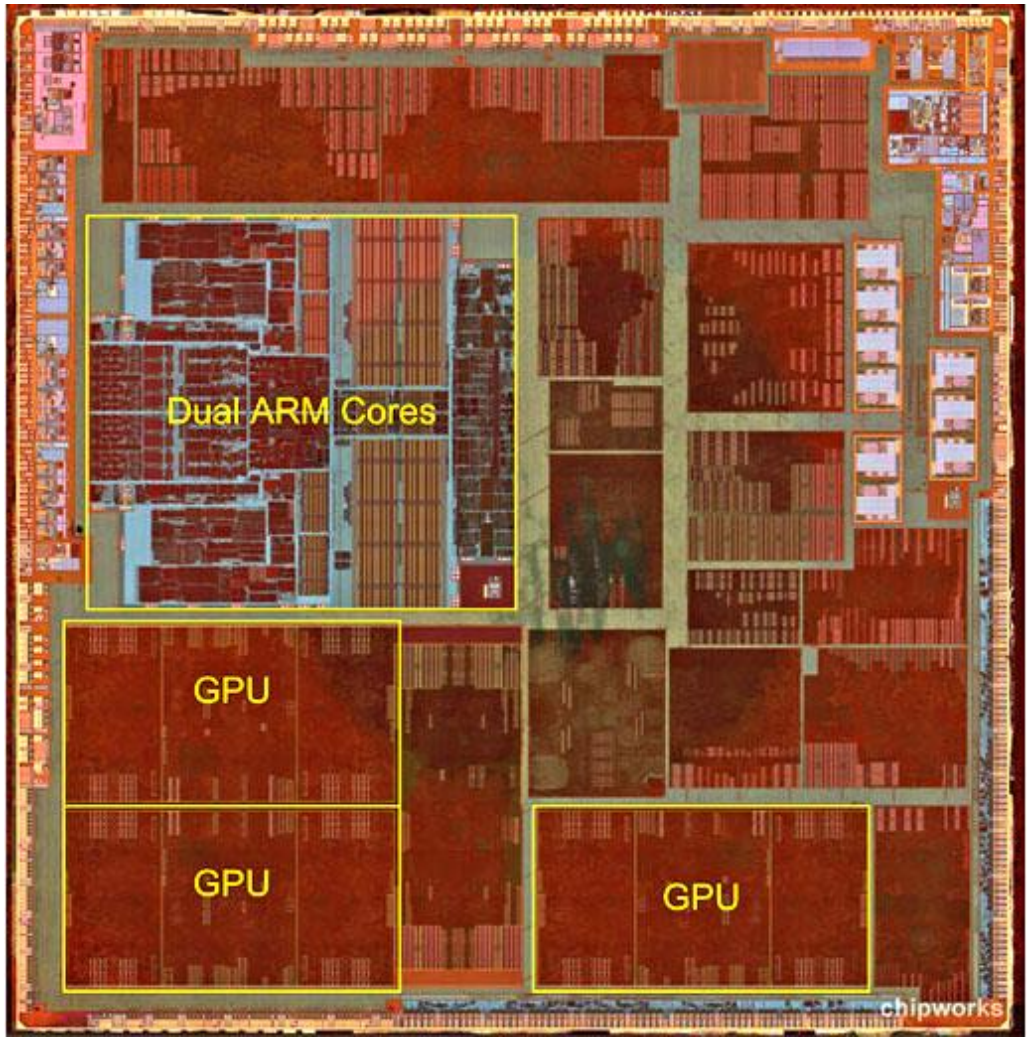
Starting with several thousand in 1971, the number of transistors on single chips had passed several billion by 2011!



For example, this [iPhone 5 ‘A6’ chip] contains several billion transistors!

<----------->

Source



Source

Such chips are now used by engineers/programmers/makers to mechanize mathematical-logic and thus functionally empower . . . all sorts of things they're embedded inside of . . .

Smartphones

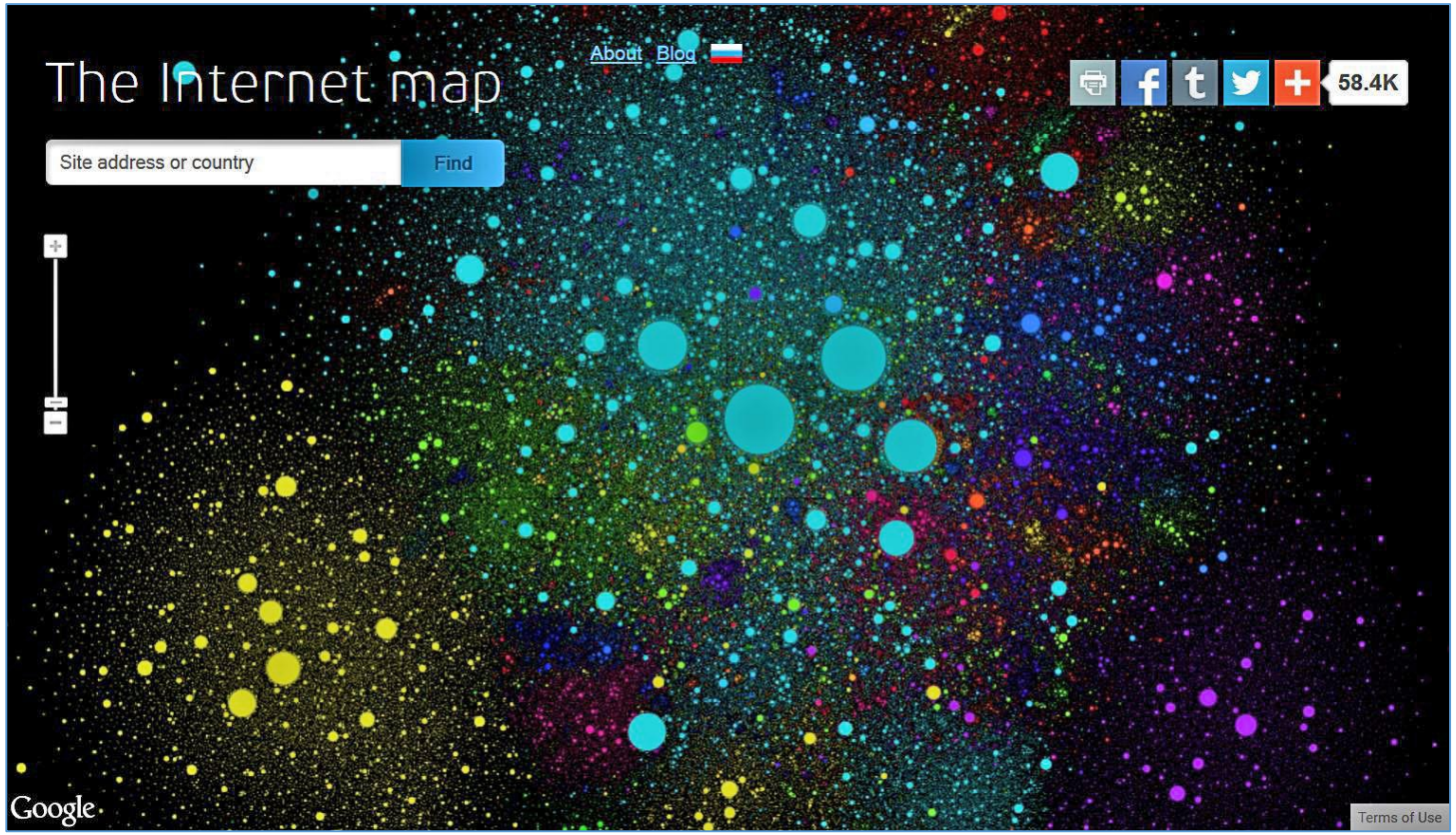
Wearables

Autos

Drones

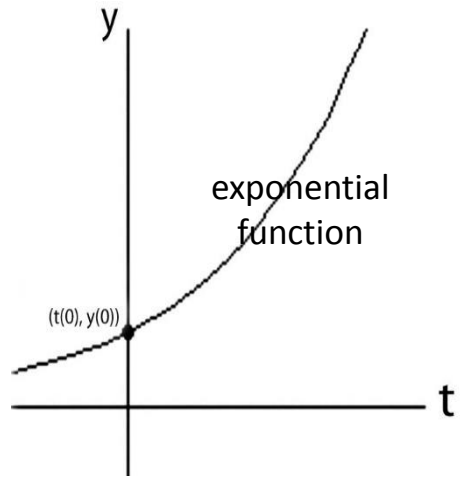
Snips from Google Images

Including the chips that empower the vast internet infrastructure,
which also continues to expand exponentially . . .



Link

Interactive Zoom-in
Internet Map, 2015

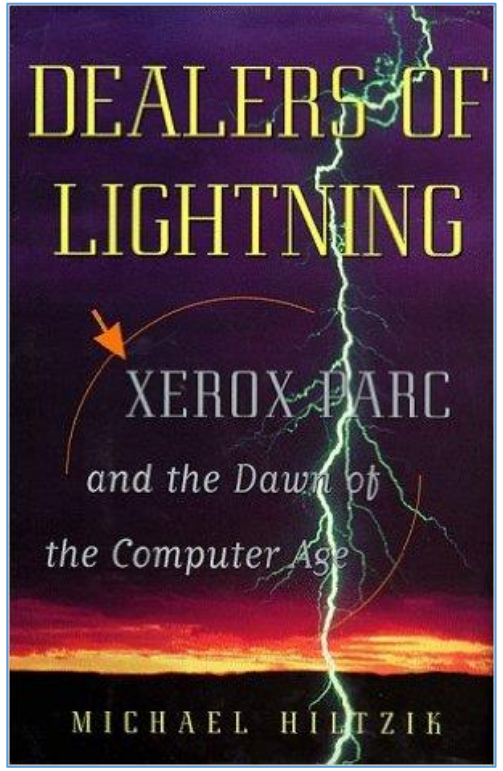


And with the internet connecting ever-more people and chip-empowered things, just imagine what's going on out there now . . . all around the world!

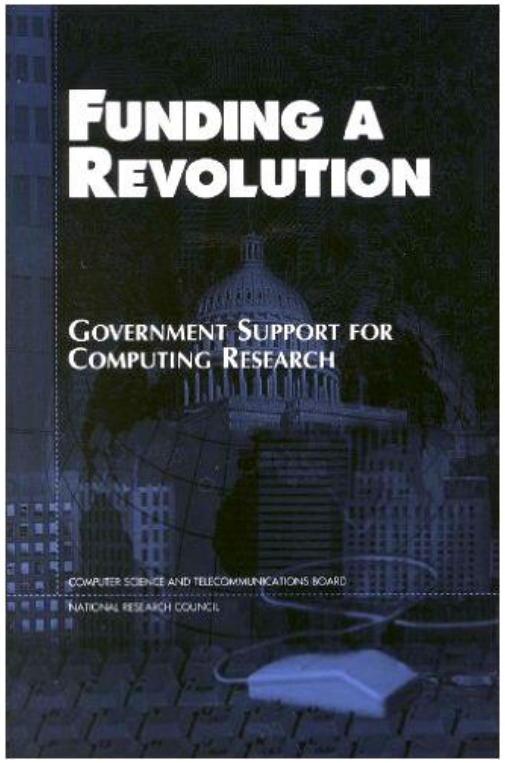
NASA: Earth from space at night

Setting the stage for what's coming next . . . !

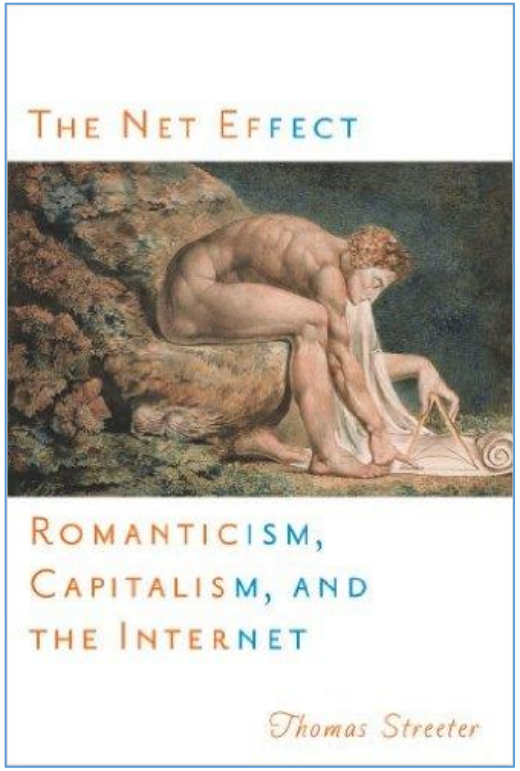
For more about PARC and the amazing things done there, see Michael Hiltzik's *Dealers of Lightning*:



For insights into the role of gov't in VLSI's emergence, see this book from the NRC:



For a wider sociological perspective on the internet's emergence, see Thomas Streeter's *The Net Effect*



"What's past is prologue" – William Shakespeare

It’s now time to look forward, into the future . . . !

As we turn 180^{o} and look ahead . . . we can glimpse another huge incoming wave of innovation . . . It’s out there now, just beyond the social-time-horizon . . .

One thing for sure: This is the “Big One”! . . .

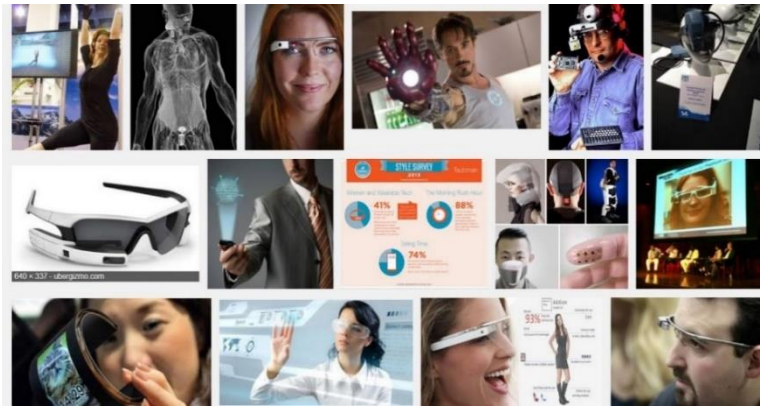
URL

But why is it starting now?

Until now microsystems have been deeply embedded,
out-of-sight and out-of-mind inside “things” like . . .

Smartphones

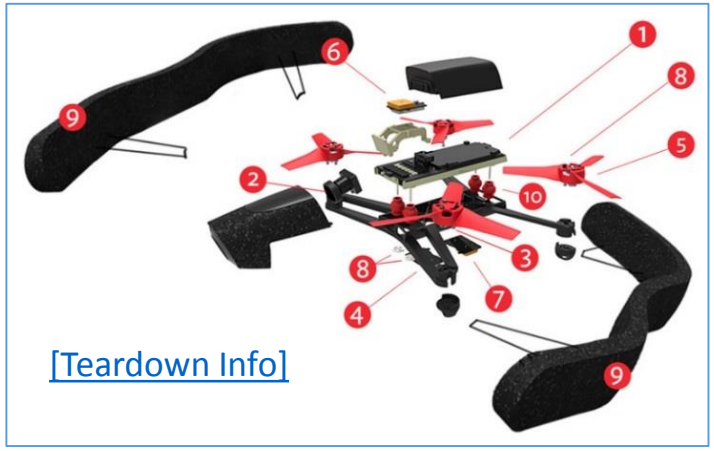
Wearables



Autos

Drones

Thus few folks can visualize the “ideas in motion” behind effects like the astonishing ‘out-of-body’ experiences while flying a Parrot Bebop using an Oculus Rift . . .



[Teardown Info]

www.youtube.com/watch?v=6ZdSMAG90Rs

www.youtube.com/watch?v=Io6V0NR7DN0

But that's all about to change, as things like modular smartphones and modular wearables begin to popularize micro 'Hardware Apps' . . .

Namely, tiny modular micro-hardware versions of up-till-now 'big things" like cameras, GPS units and inertial measurement systems.

The many microsystems in smartphones and wearables will suddenly become socially-visible . . .

Especially the tiny micro-mechanisms (MEMS chips) designed on computers and "printed" in "foundries". . .

To sense where this is headed, check out the ONAGOfly smart nano drone: a soon to be available $300 “micro-animated system” . . .

Indiegogo www.onagofly.com

Extremely tiny, it includes an HD videocam, IMU, GPS, MCU, IR obstacle avoidance, auto following, livestreaming and more…

It’s evolvable functionality has so many dimensions, it’s hard to say where the “system” begins and where it ends . . . as seen in this VIDEO!

These aren’t frivolous play-things . . . they instead illuminate a vast frontier for human empowerment and amplification . . .

Consider a patient confined to a hospital:
She can now explore the world beyond her window, using her smartphone to control her drone and see what’s out there . . .

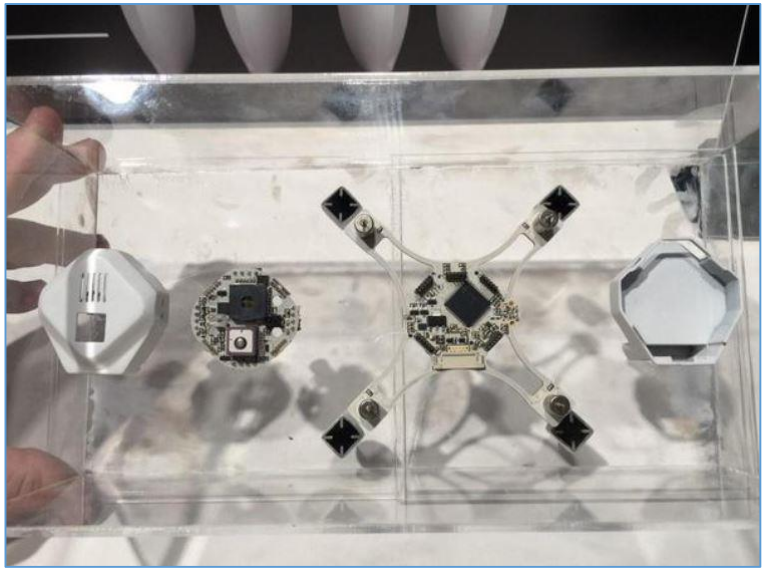
Now imagine joining a group “drone-tour” of some remote exotic place, right from your own individual homes . . .

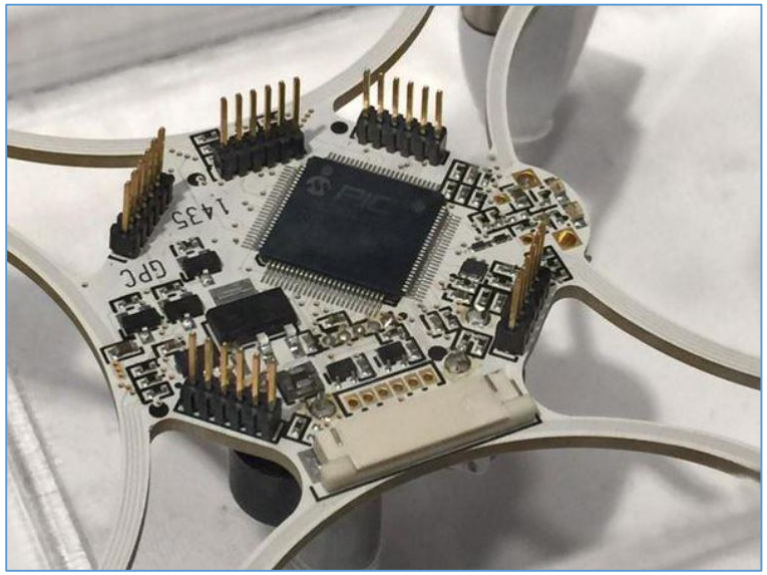
With each your drones remotely “carrying your eyes”, in the form of fisheye lens microcams (as in the Parrot Bebop) . . .

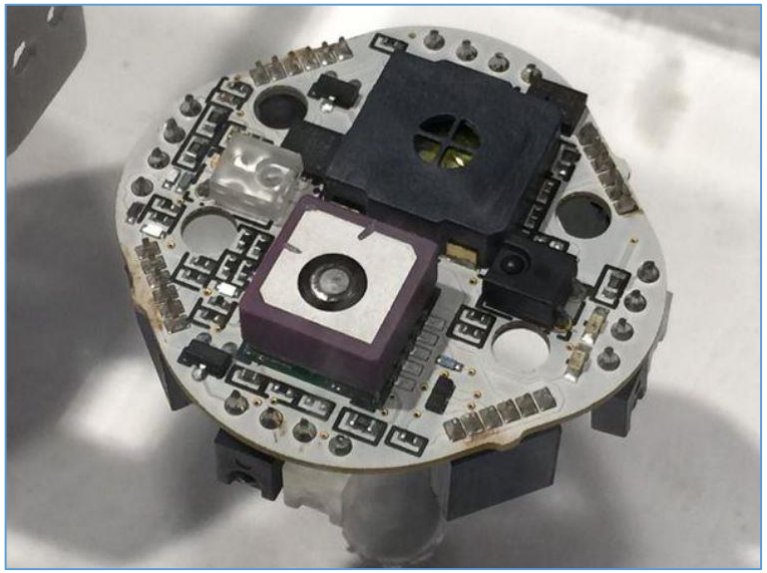
Which you look through using your Oculus Rift over the internet!

Then too, imagine the impact on tomorrow's children when they start taking apart old nanodrones!

Imagine the wild things **they** might figure out how to do in time!

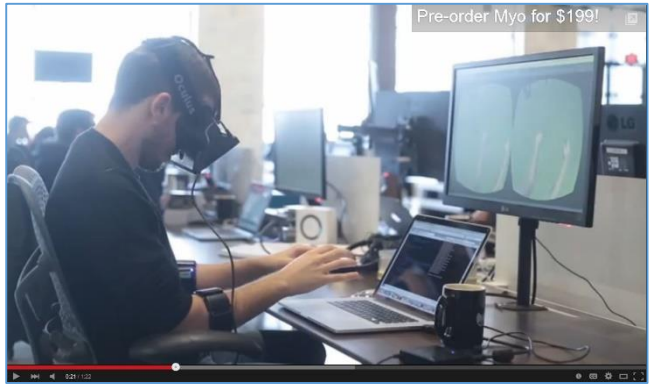






URL

Some further “ideas-in-things” in the coming wave of innovation are hinted-at by the Myo gesture control armbands from the mechatronics engineers at Thalmic Labs:



VIDEO VIDEO VIDEO VIDEO!

So, what's happening here?

Instead of printing a billion transistors onto single "large" smartphone chips.

We could also millions of transistors onto thousands of tiny but powerful chips. [And you can do a LOT with a million transistors!]

Thus we could embed lots of tiny micro-control-processors . . . and MEMS micro-mechanisms . . . into almost everything.

Putting them where they measure and process local physical-data such as position, acceleration, temperature, pressure, etc.

Enabling embedded-clusters of tiny-chips to animate and interactively-control lots of macro-things . . . In robots, drones, mobility and health systems.

The embedded-microsystems revolution is getting up a big head of steam in emerging techno-social innovation centers all around the world …

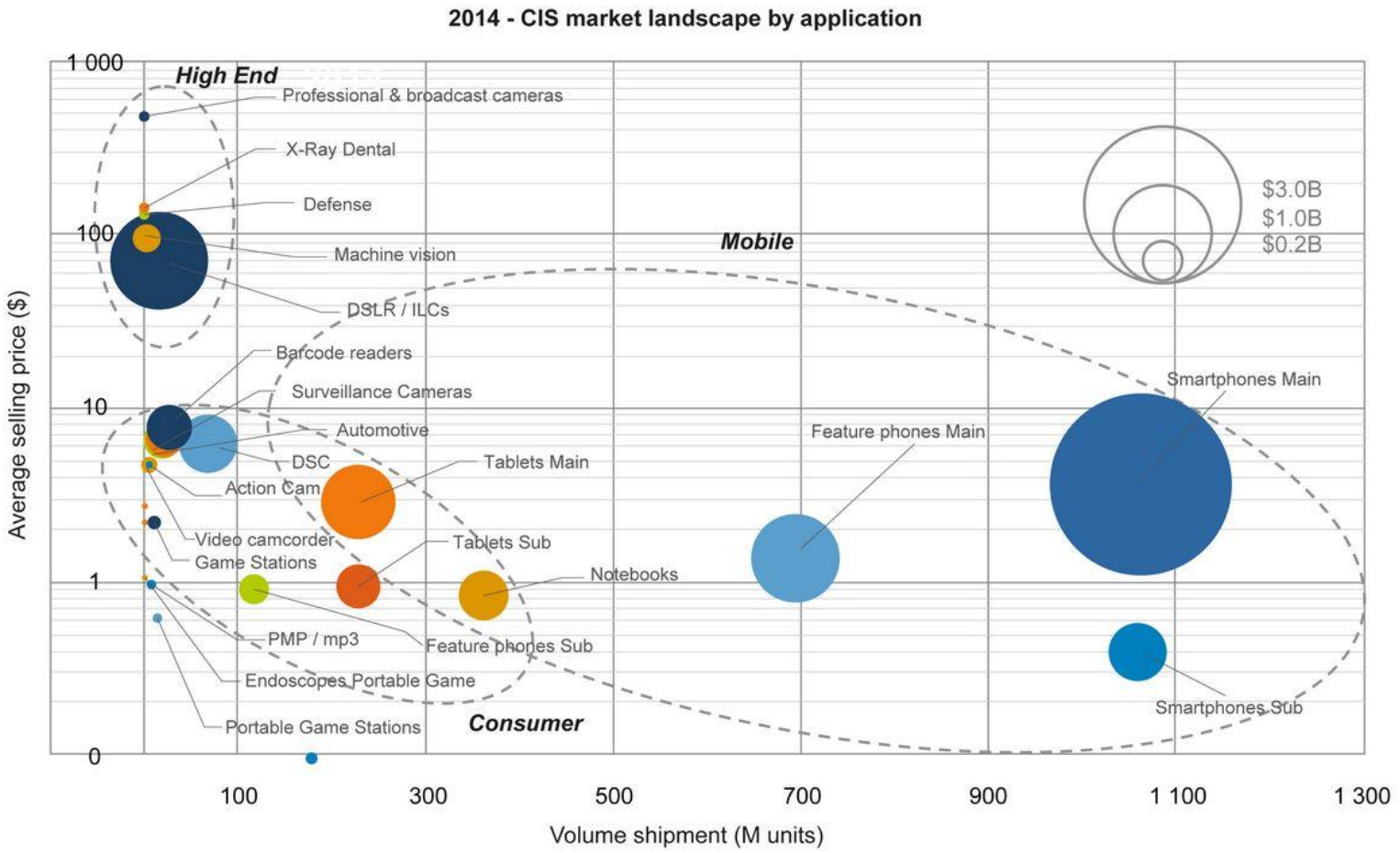



But how on earth can we visualize and follow what’s going on?

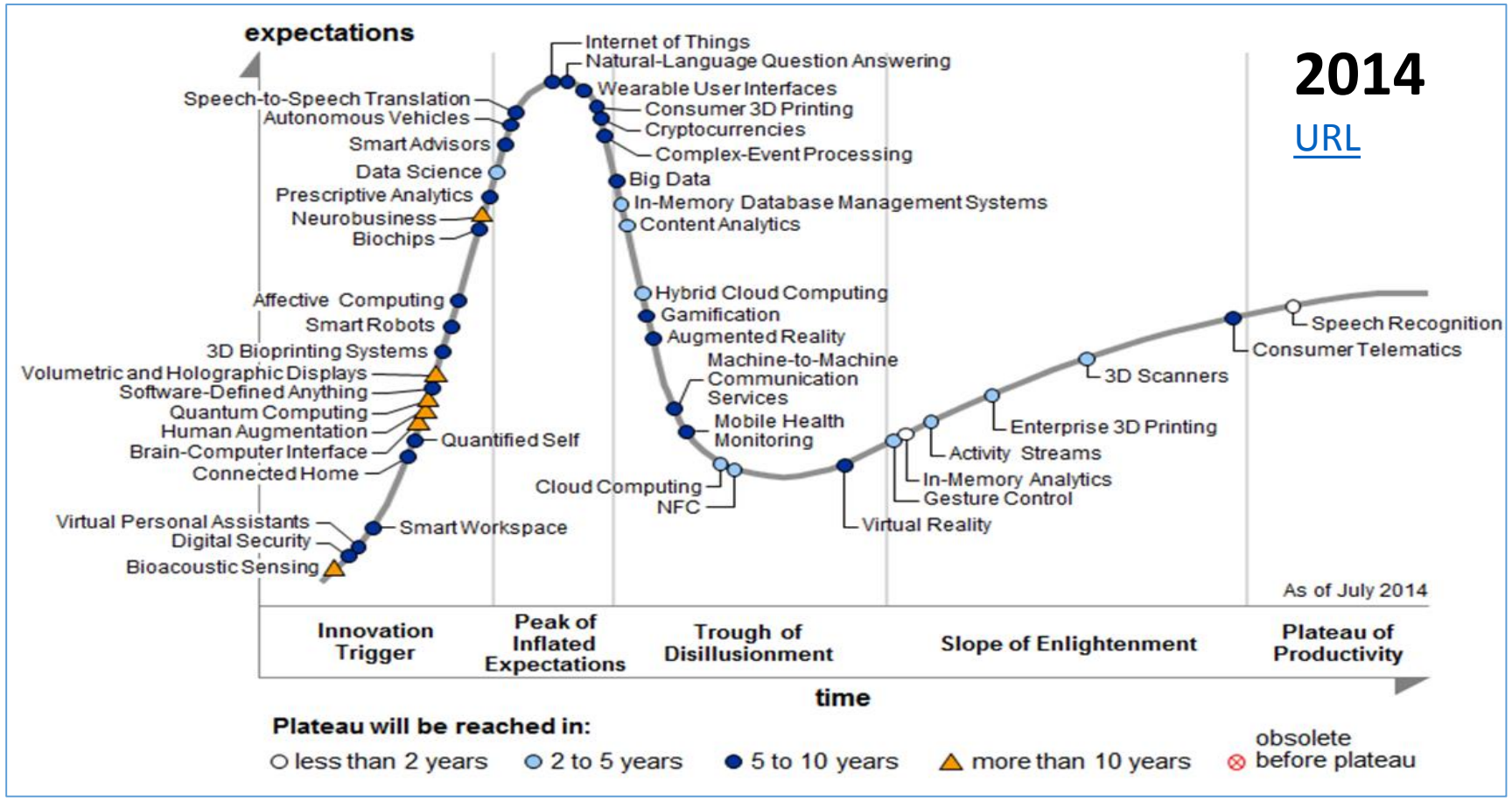
We can zoom-in on evolving fine-details in specific micro-technology areas by using tech-mappings like this for [microcamera image sensors](#) . . .

2014 CMOS image sensor market landscape

(Source: Status of the CMOS Image Sensor Industry report, Yole Développement, January 2015) Source

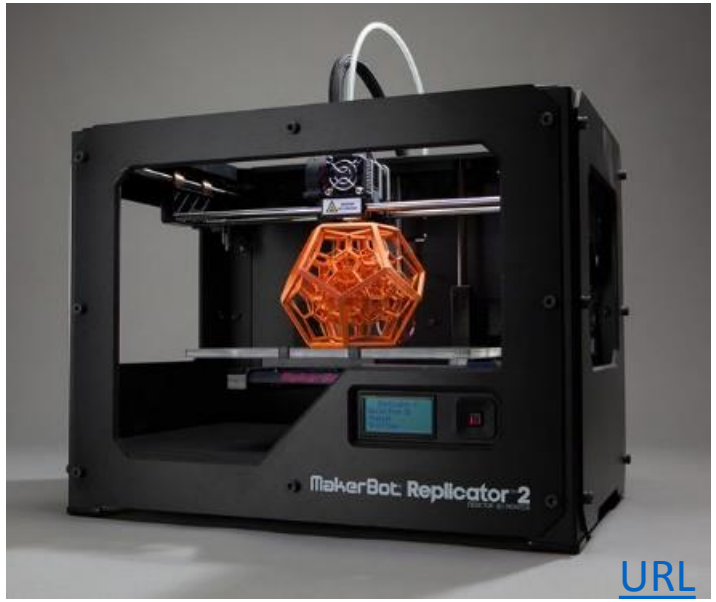


For the bigger picture we can zoom-out and follow paths of emerging application-clusters along Gartner “Hype Cycle” infographs that frame the overall technology-wave . . .



Thereby gaining the venture capital community’s perspective on it all . . .

Look at just one **cluster** on that incoming wave: "consumer 3D Printing". . . Enabling all kinds of "things" to be rapidly "printed" from digital design specifications created on personal computers . . .



URL

URL

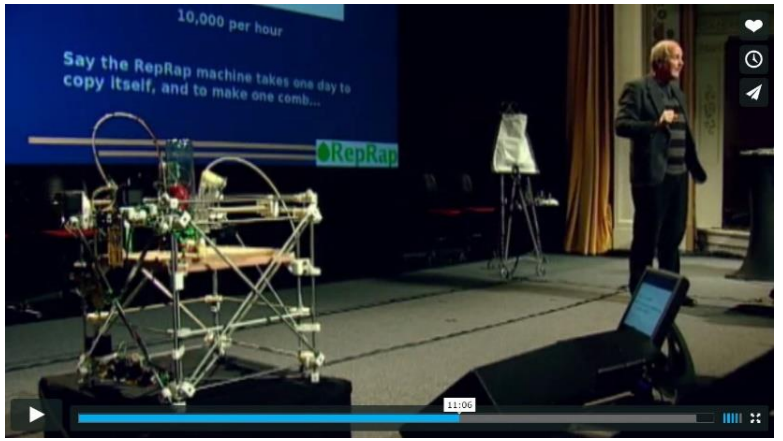
3D printed prosthetic <---------- hand

Once perfected, such digital design files can be shared electronically with and/or marketed to users of 3D printers anywhere . . .

Even better, think about making 3D printers that print 3D printers!

That's Adrian Bowyer's vision for the global RepRap Project:

For more about RepRap
and the philosophy behind it,
watch this remarkable video:
"A machine that builds itself?"

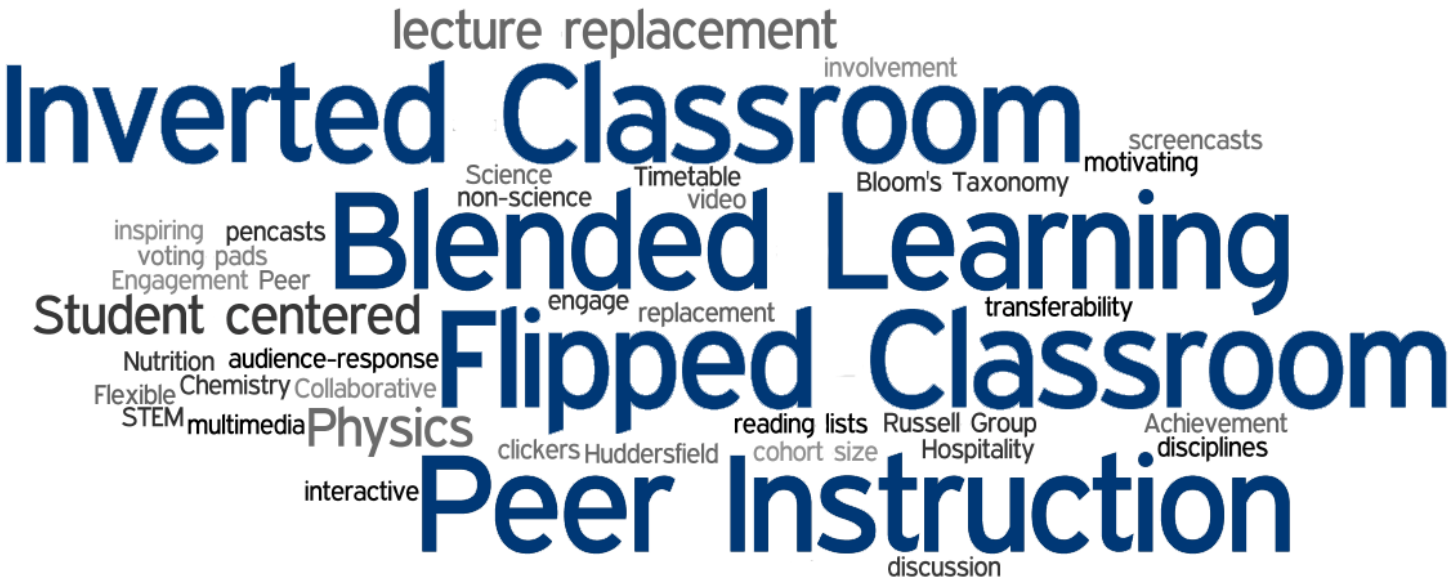


Just as some iron was fed-back to make more steam engines to help make more iron to further empower the industrial revolution . . .

Providing such systemic positive feedback can provide large "gain" in the emergent 3D-printing technology-generation ecosystem.

But where will all the young innovators come from?
And how can they learn to surf on this vast incoming wave?

Fortunately, a wave of change is also sweeping through STEM education, just in time!



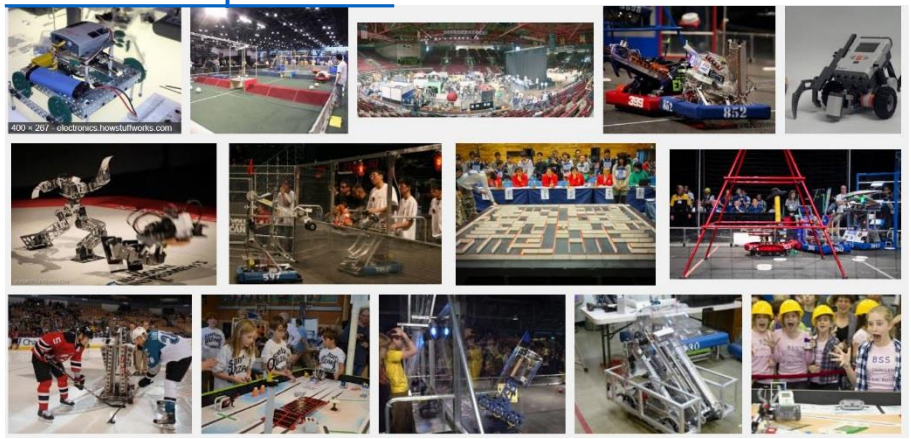
Many incoming students also have gained hands-on team-experiences at . . .

LEGO Camps

Maker Faires

FAB Labs

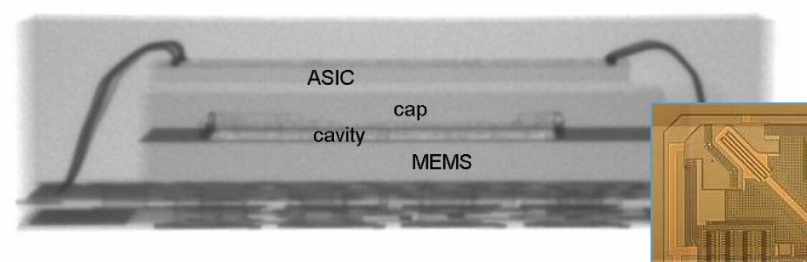
Robot Competitions



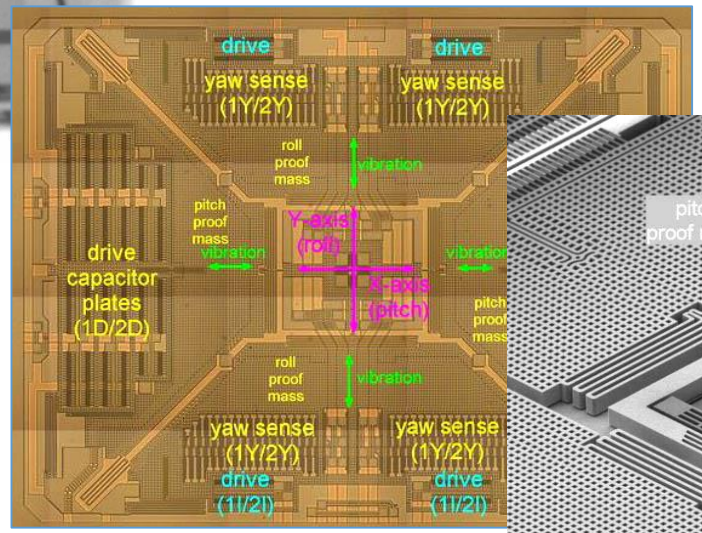
They'll also gain emerging knowledge, just-in-time as needed, using rapidly evolving internet-based learning-resources . . .

Image source

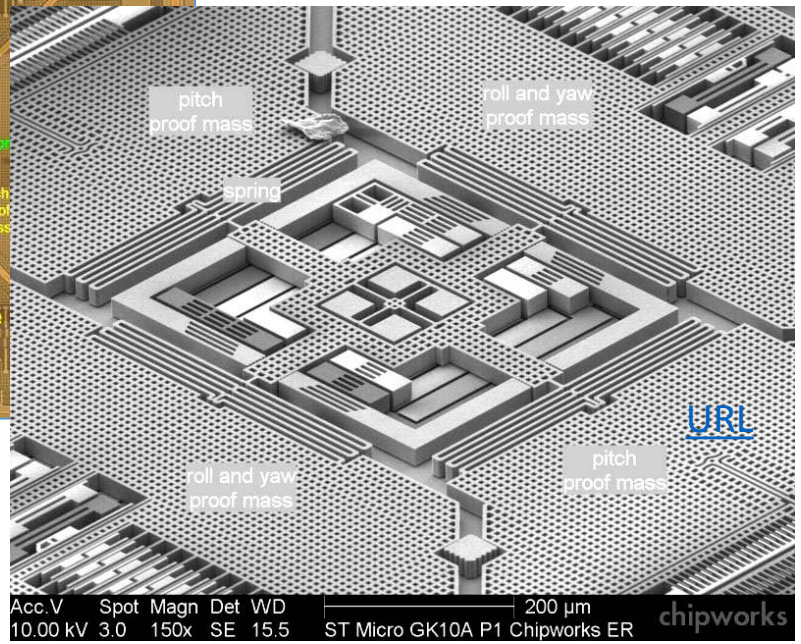
Some engineers will exploit new **“multi-physics” design tools** and **electronic design automation (EDA)** to innovate new micro-systems:



Gyro Chip



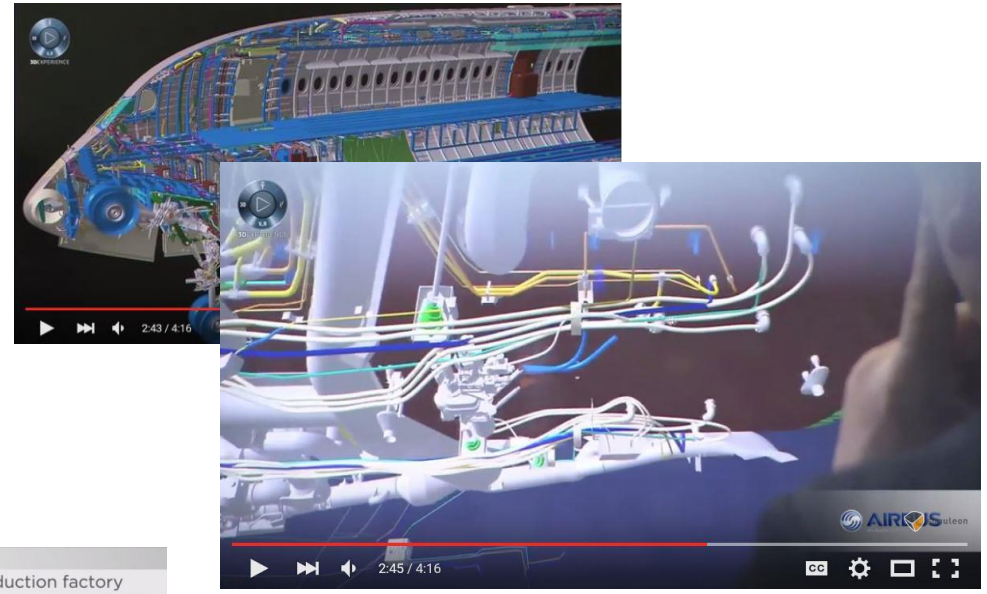
Close-up of the MEMS Gyro chip tuning-forks



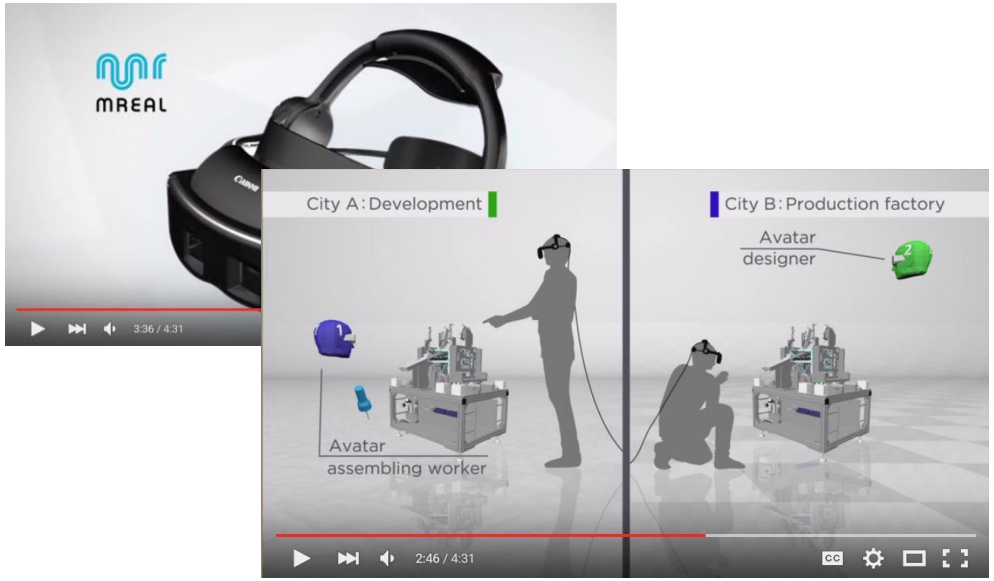
Example:
A MEMS 3-axis gyroscope for motion-sensing in an iPhone 4

Combined with a micro electronic compass and a micro 3-axis accelerometer, this provides full 9-degree-of-freedom motion sensing.

While mechatronics designers will use team-based augmented reality systems, such as Dassault's [3D Experience Platform] and Canon's [MREAL System] . . .



https://www.youtube.com/watch?v=hJ6vMfzMz5k

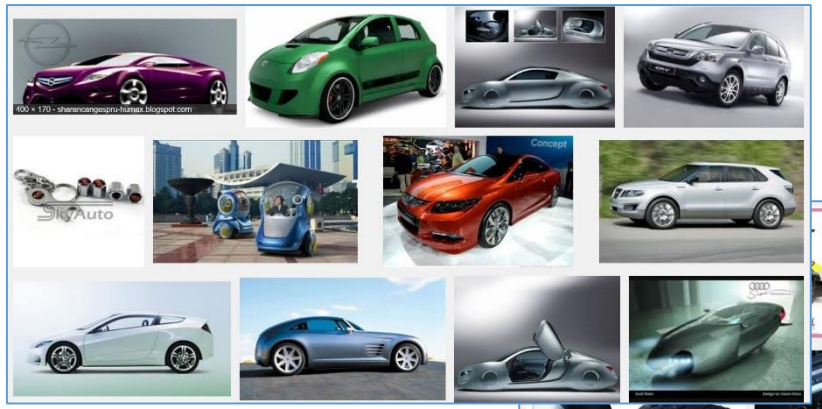


https://www.youtube.com/watch?v=Ymsea8aEImE

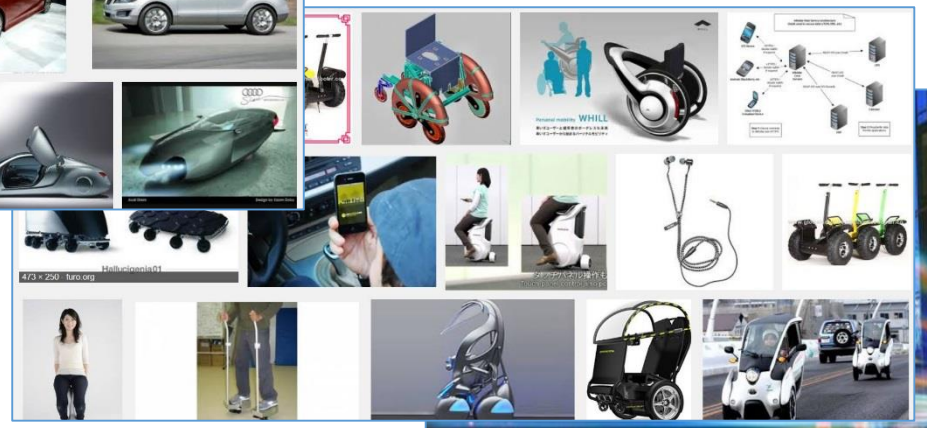
To imaginatively embed smart modular micro-hardware into, and thus animate, a new wave of human-scale systems . . .

World-wide, automotive technology will be a huge driver of rapid embeddings of micro-hardware Apps into human-scale systems:

Starting in cars, then in Self-Driving cars



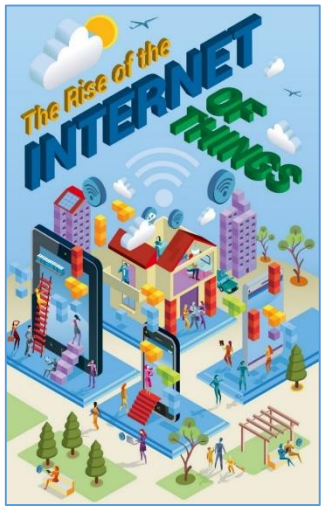
On into Mobility Technology



On into Smart_Travelways

The innovative embedding of ever-tiner micro-hardware apps will quickly spread . . .

And begin enhancing the functionality of just about everything:



http://blogs.jabil.com/2014/08/13/internet-of-things-infographic/

But how will we cope with the ‘complexity’ of the emerging techno-social ecosystem?

From: The Age of Opportunity: Harnessing Complexity To Solve Big World Problems
by Frank Spencer, kedgefutures.com

We'll exploit rapidly-evolving new techno-social-coordination methods, such as collaborative learning, crowdsourcing, crowdfunding, IP brokering, agile design rapid-digital-prototyping and more . . .

Enabling everyone from engaged-users to innovators to makers to scale up their levels of participation and impact.

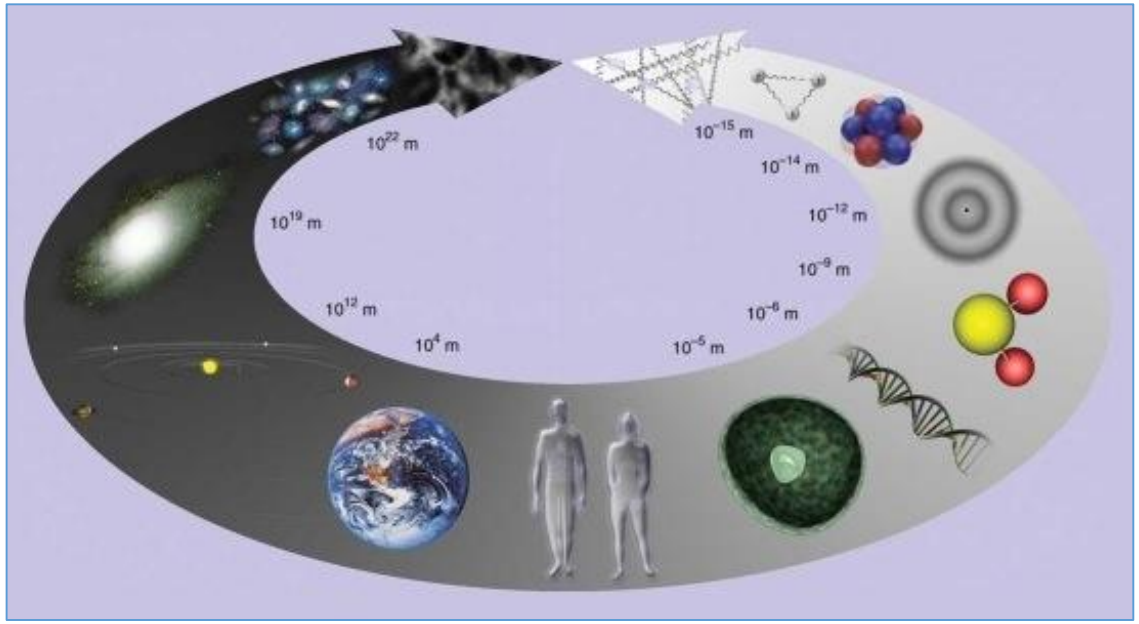
Link

Only now, instead of just exploring how to make ever-bigger things that go ever-further, ever-faster . . . such as erecting skyscrapers that poke into the clouds, and shooting ever bigger stuff out into “outer space”. . .

NASA

We'll increasingly invert our spherical-perspective by 180^{o} and peer down into the "inner spaces" of the micro/bio/nano/pico worlds . . .

Randy Scott Slavin

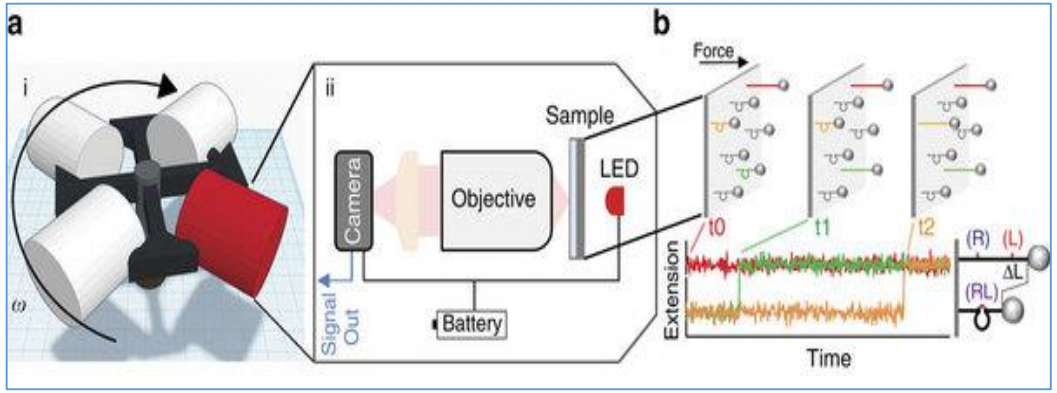


nupex.eu

As we explore how to make, share and exploit vast-exponentiations of ever-tinier, ever-more humanly-empowering "micro/bio/nano things" . . .

For example, as researchers zoom ever-further into the micro-biological, molecular and atomic levels . . .

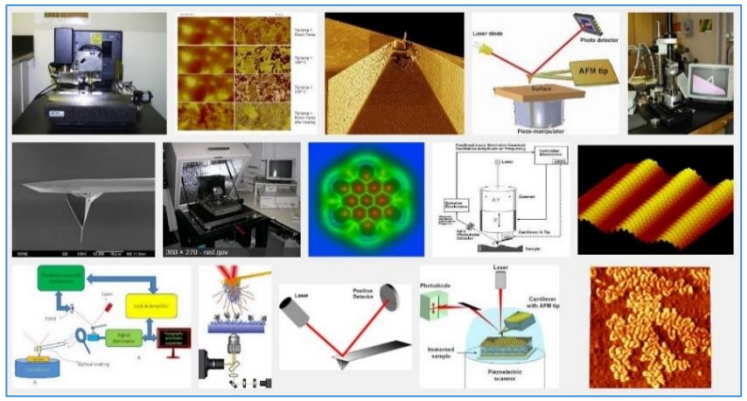
Multiplexed Centrifuge Force Microscopy (CFM)



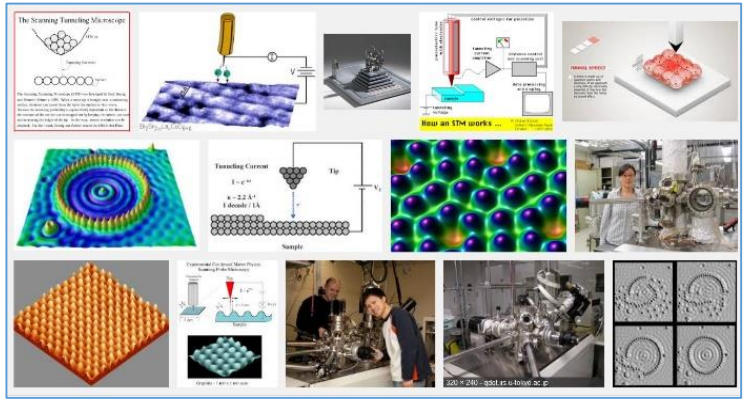
Democratizing high-throughput single molecular-pairs' force analyses using integrated DNA nanoswitches multiplexed into miniature benchtop CFMs. Just announced on 3/17/16 by Harvard Wyss Institute.

Their findings will help other adventurers better gear-up for explorations in places & frontier-fields such as . . .

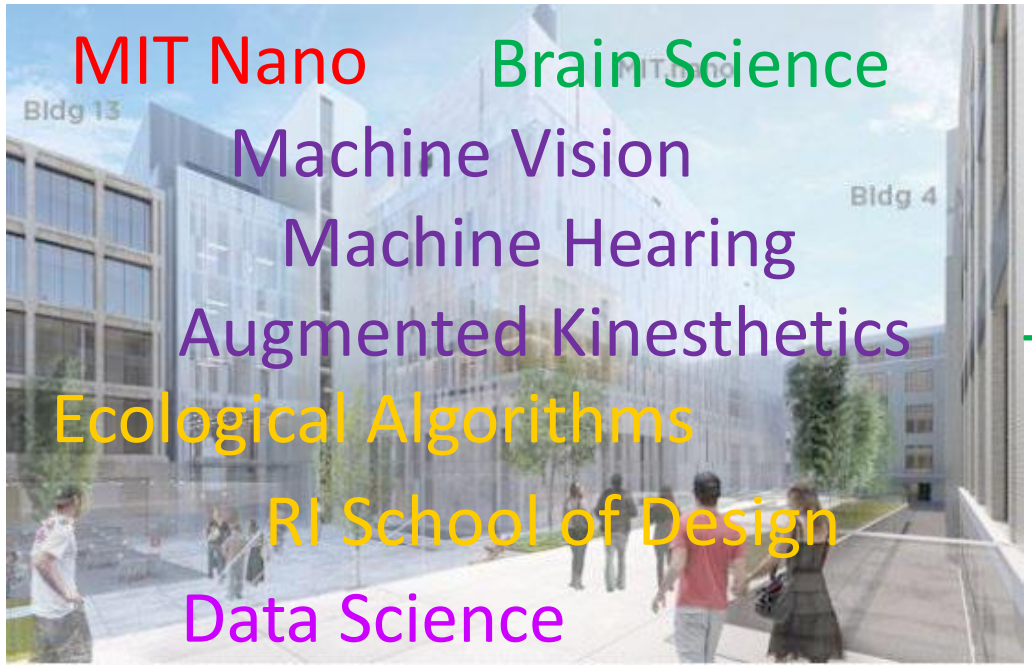
Scanning Tunneling Microscopy (STM)



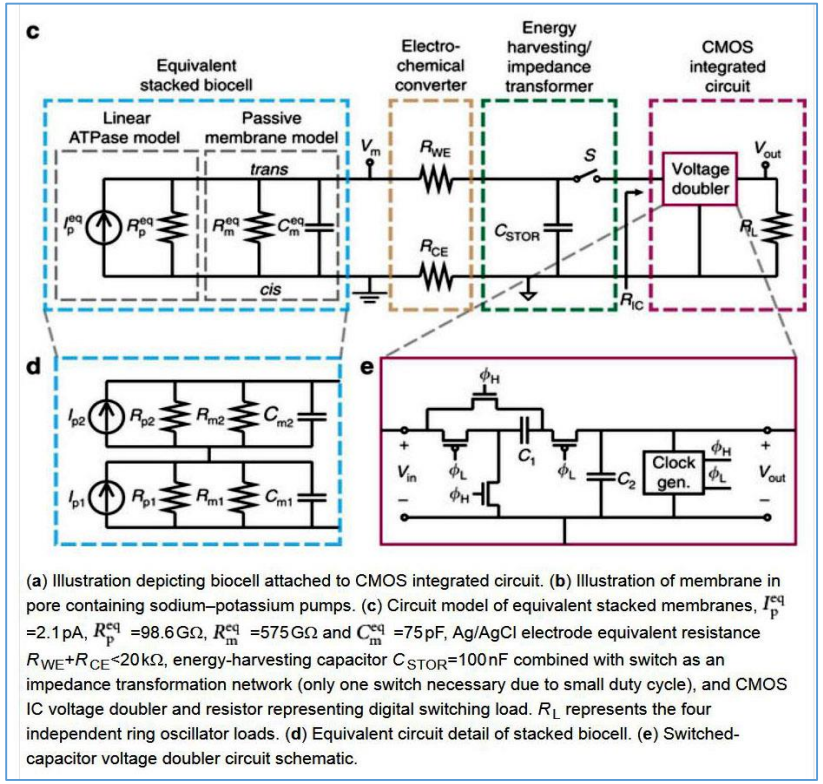
Atomic Force Microscopy (AFM)



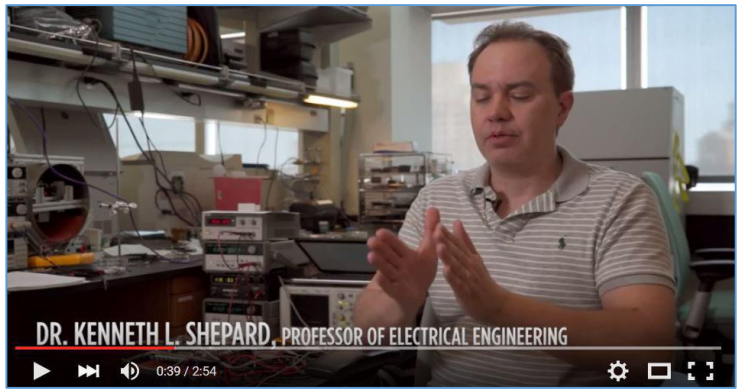
Multi-physics EDA
Augmented Reality
Teleautonomous Systems
Photonics
Wyss Institute
Bio-Electronics
Exploratory robotics
Hyperscaling
Model-Based Design
Biologically Inspired Engineering
Draper Lab
MIT Nano
Brain Science
Nano Technology
Multiengineering
Machine Vision
Social Physics
DARPA Microsystems
Machine Hearing
Research Universities
Meta^2Mathematics
Augmented Kinesthetics
Techno-Social Dynamics
Google ATAP
Ecological Algorithms
Synthetic Biology
Meta Architecture
RI School of Design
UPS
Social Machines
Microsoft Research
Data Science
Genetic Algorithms
Metamaterials
Self Assembling Systems
Biosocial Learning
Facebook
Techno-Social Exploration-Infrastructure
Amazon
AI & Machine Learning
STEM + ARTS = STEAM

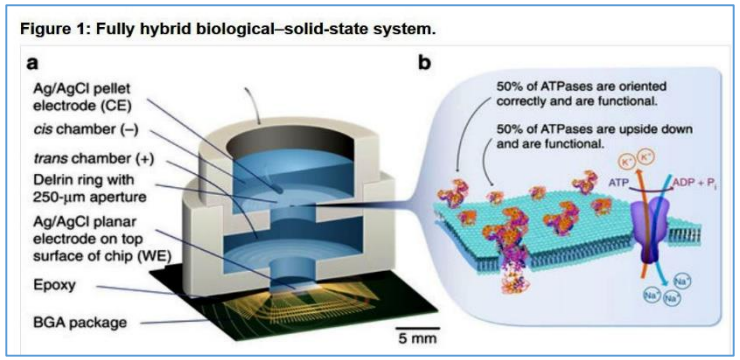


Study, for example, the [first fully-hybrid biological-solid-state system](#) just created in [Ken Shepard](#)'s [Bioelectronics Systems Lab](#) here at Columbia's SEAS ([video](#)):



(**a**) Illustration depicting biocell attached to CMOS integrated circuit. (**b**) Illustration of membrane in pore containing sodium–potassium pumps. (**c**) Circuit model of equivalent stacked membranes, I_p^{eq} =2.1 pA, R_p^{eq} =98.6 GΩ, R_m^{eq} =575 GΩ and C_m^{eq} =75 pF, Ag/AgCl electrode equivalent resistance $R_{WE}+R_{CE}$<20 kΩ, energy-harvesting capacitor C_{STOR}=100 nF combined with switch as an impedance transformation network (only one switch necessary due to small duty cycle), and CMOS IC voltage doubler and resistor representing digital switching load. R_L represents the four independent ring oscillator loads. (**d**) Equivalent circuit detail of stacked biocell. (**e**) Switched-capacitor voltage doubler circuit schematic.

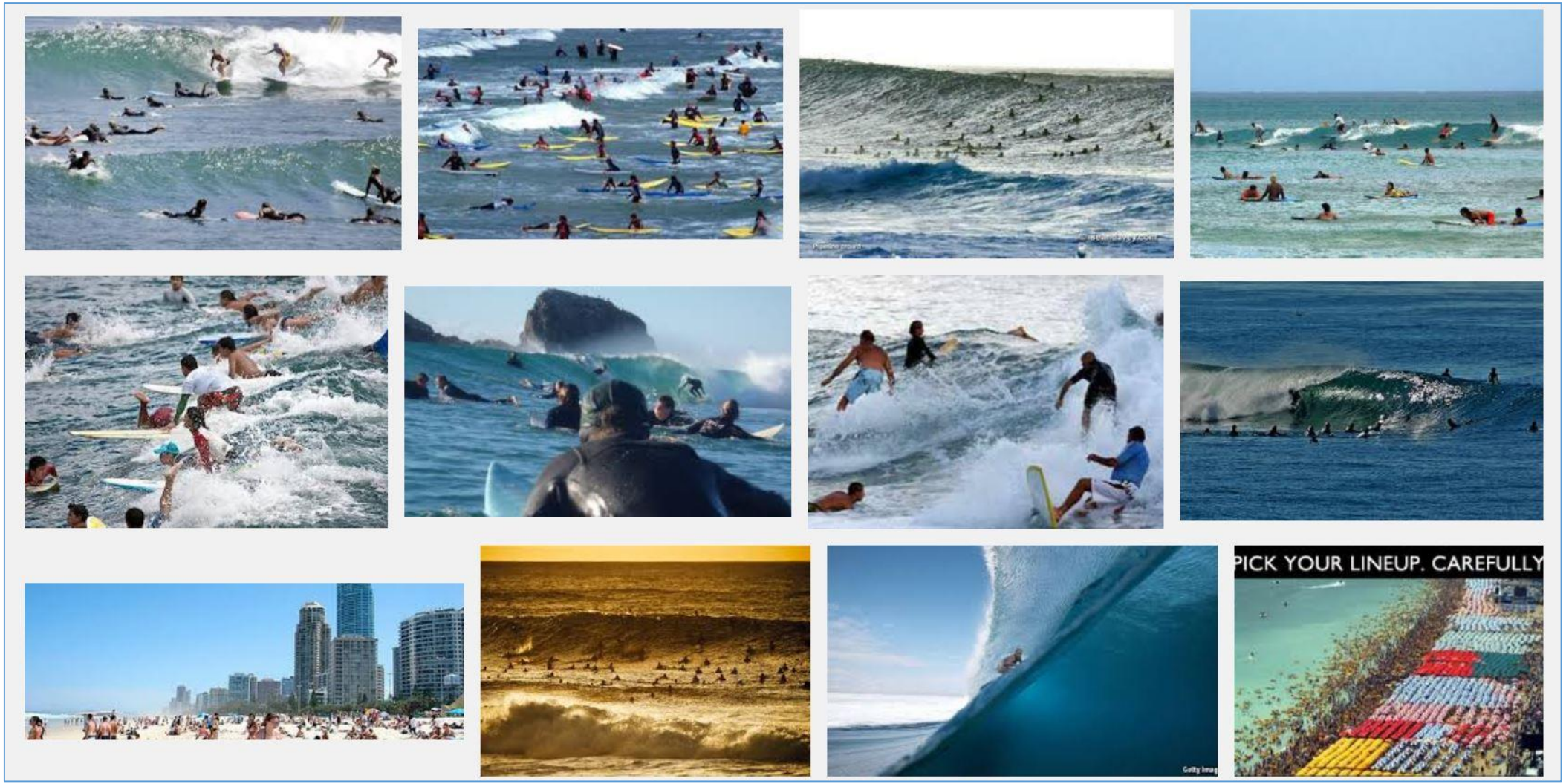




By powering [CMOS](#) microcircuitry using [ATP](#) in an in-vitro electrogenic ion pump, this work opens a path to powering tiny nano-chips embedded inside living cells!

Thus it begins, as such knowledge rapidly spreads, all around the world . . .

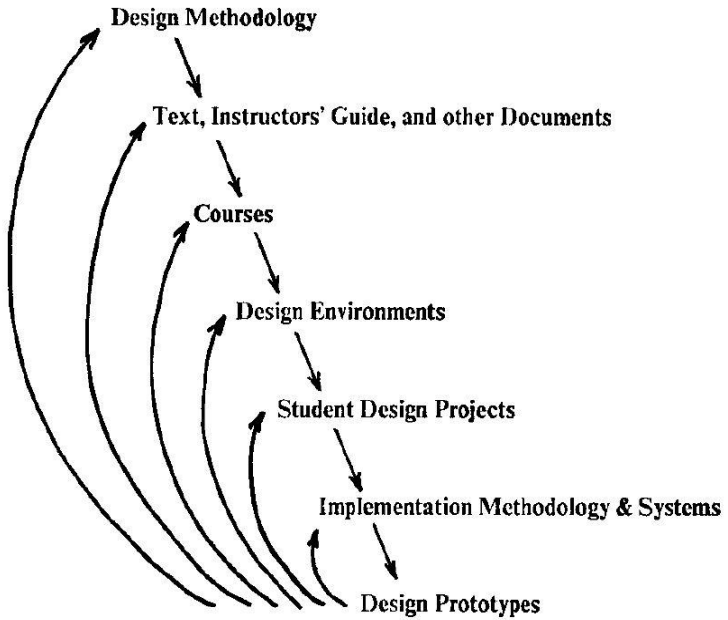
Before long, adventurers <u>everywhere</u> will be “surfing” <u>somewhere</u> on these waves . . .!



But how on earth will humanity ever grasp and knowingly guide
what's happening in such massive techno-social waves?

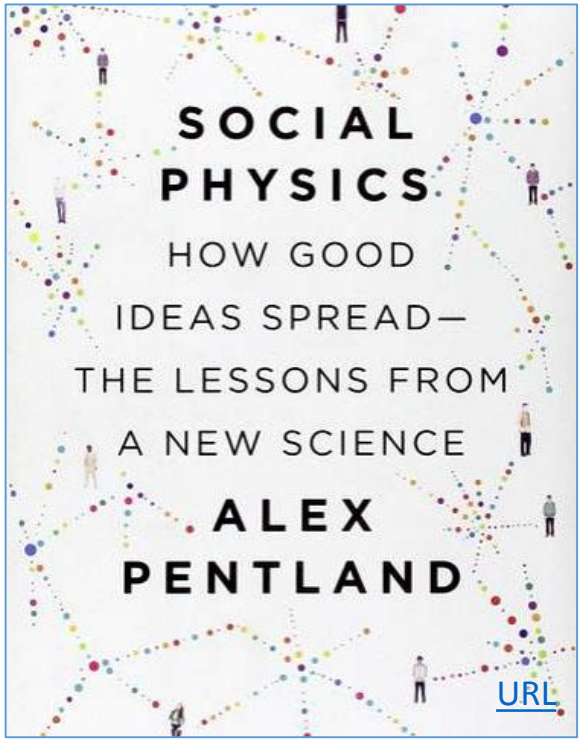
We'll evolve techno-social methods that help us meaningfully
reflect-back-on and knowingly peer-ahead-into such evolving labyrinths,
methods and projections akin to today's weather models . . .

Ex: To envision the masses of ideas now cycling in techno-social motion, recall how we diagrammed the nested-social-evolutionary-processes of the VLSI revolution.
Only now, vastly more such processes are running in parallel and cross-fertilizing.
And a new science is beginning to explore and map-out what's happening . . .



The MPC Adventures (p. 16) Xerox PARC 1981.

Figure 8. The Joint Evolution of the Multi-Level Cluster of Systems



URL

Epidemic Processes are already providing mathematical frameworks for partly-modeling techno-social dynamical-systems:

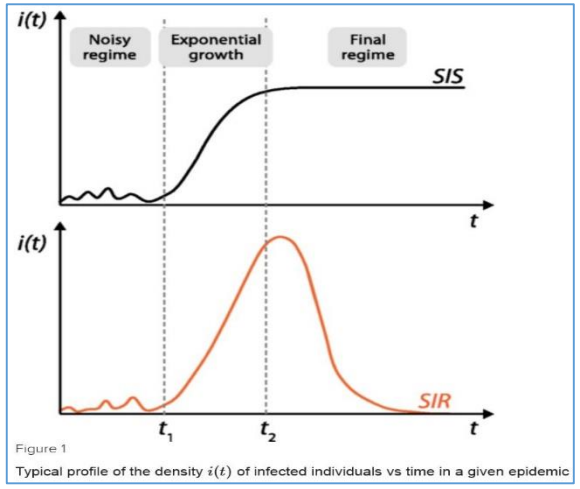


Figure 1
Typical profile of the density $i(t)$ of infected individuals vs time in a given epidemic

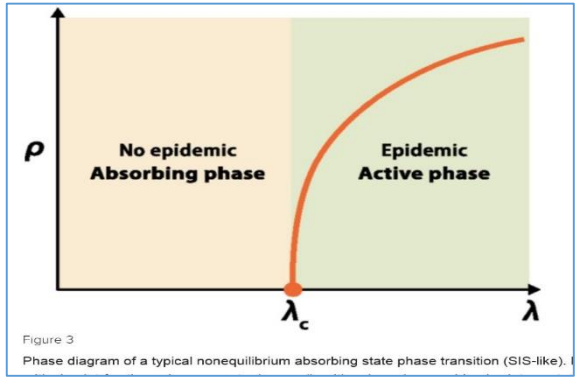


Figure 3
Phase diagram of a typical nonequilibrium absorbing state phase transition (SIS-like).

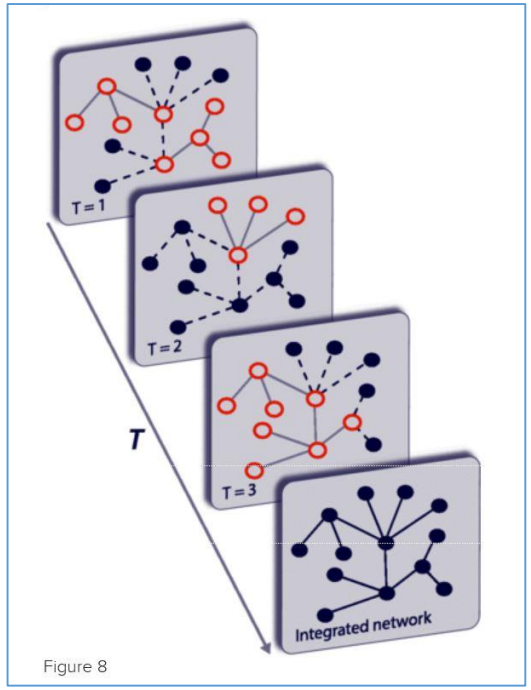
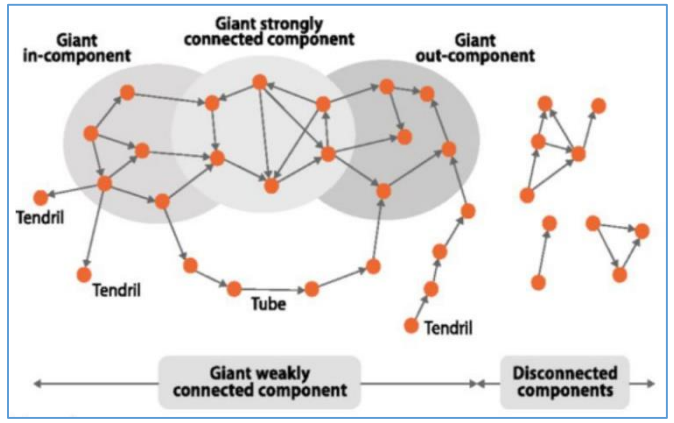
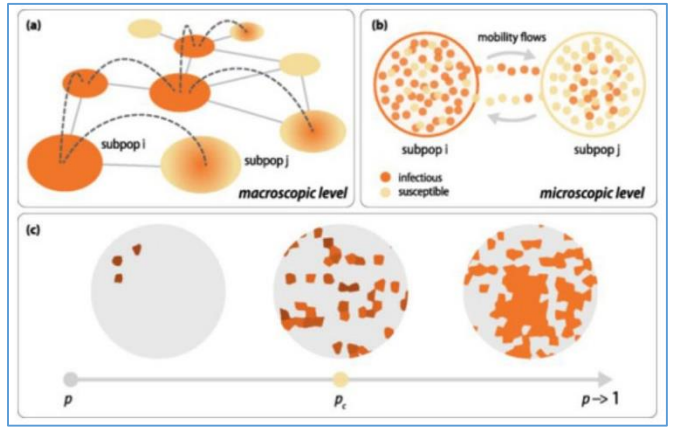


Figure 8

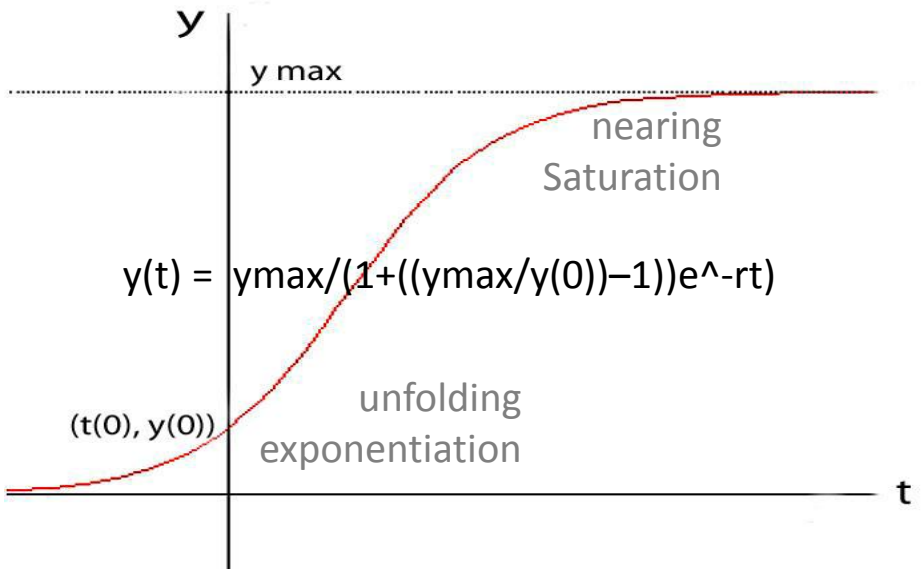




From: "Epidemic processes in complex networks" by Pastor-Satorras, et al, *Rev. Mod. Phys.* 87, 925 – 8/31/15

See also recent work in CNNs, LVars, etc.

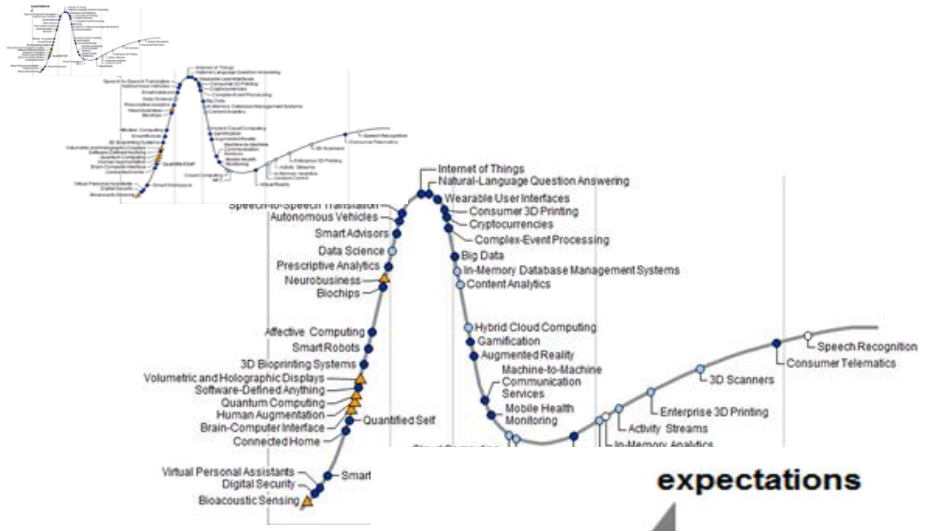
Now note that the big incoming wave is way more than a few nested logistic ‘epidemic’ processes where each looks something like this:



And even in this simple case, each 2D slice hides tons of what “composes the wave”*

*For more insight into this all this, see Van Quine’s discussion of “the river” in *From A Logical Point of View, Ch.IV.*

Let’s re-slice and zoom into our incoming wave in $4D^{+}$ to gain a better perspective



Meta-ethnomethodology:

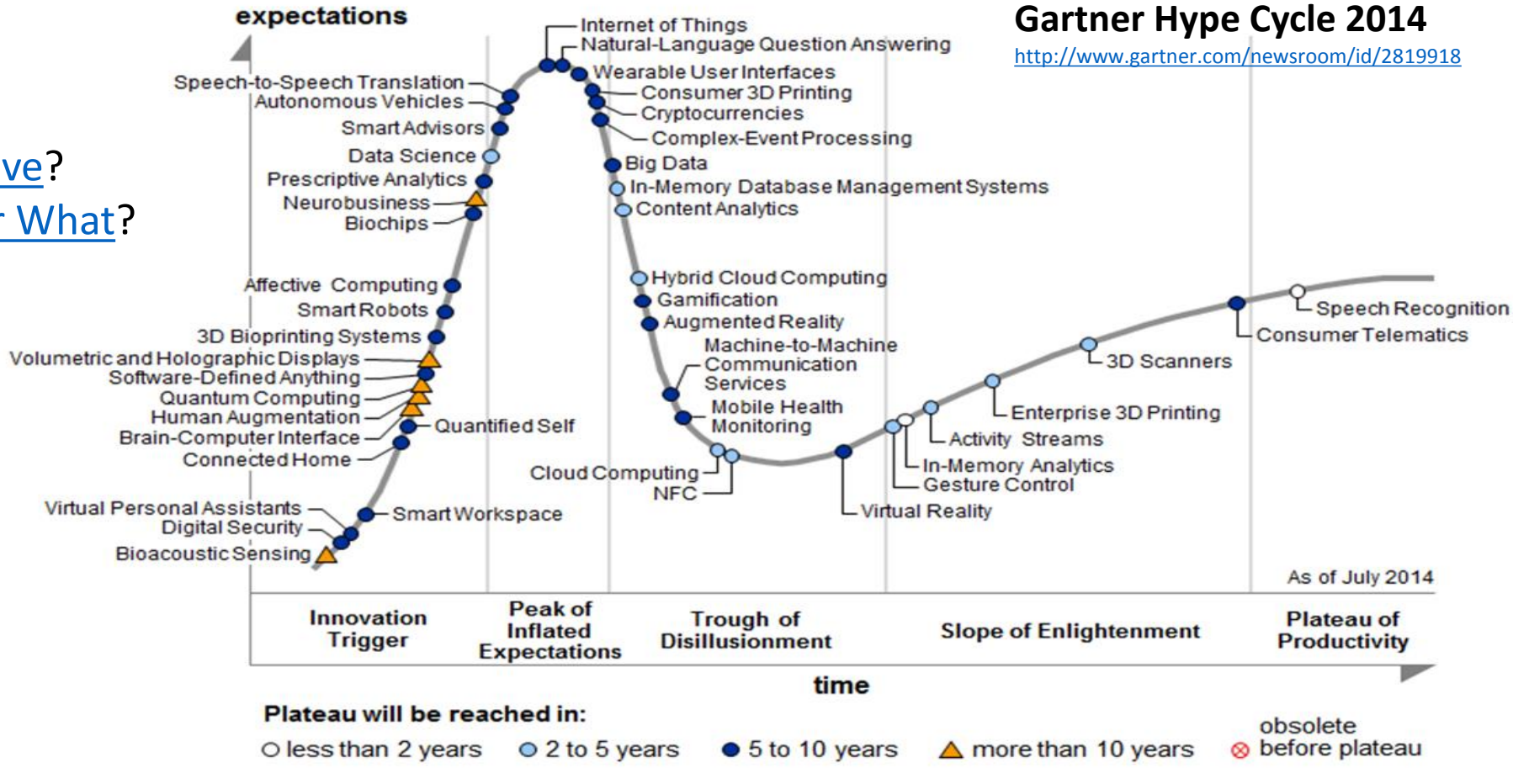
Envisioning the incoming wave of innovation as a time-series of "GHC profiles"(i.e., $2D^+$ slices thru the $3D^+$ wave at increments in time) . . .

Is this a Traveling Wave?
A Standing Wave? Or What?

This stunning video* hints at ways to think about what it all means . . .

*"Water," by Morgan Maasen
http://vimeo.com/90429499

Gartner Hype Cycle 2014
http://www.gartner.com/newsroom/id/2819918



Zooming-in, these processes seem remarkably similar to the workings of the alchemists, i.e., the labyrinths of techno-social processes that evolved and eventually "self-abstracted" into the sciences of chemistry and materials.

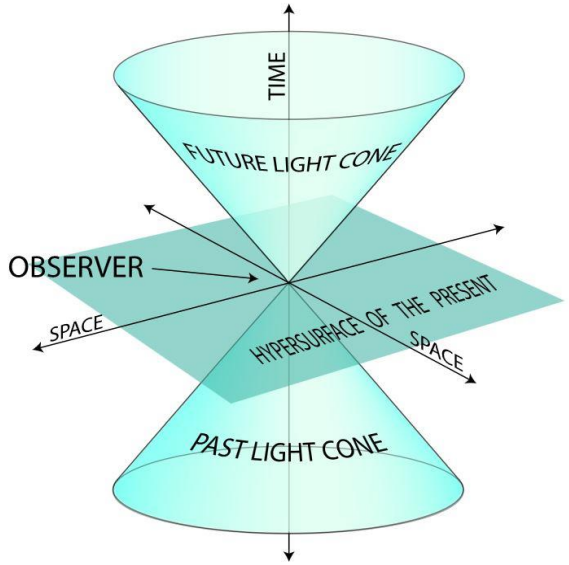
Especially see work at Columbia and Princeton on reenacting the unfolding of medieval European alchemy, in a deep form of hands-on, techno-social reverse-engineering of what happened back then:

The Making and Knowing Project
by Pamela Smith, Columbia (video).

Decoding Alchemy freshman seminar
by Jennifer Rampling, Princeton.

See also Scientiae and the Society for the History of Alchemy and Chemistry (SHAC)

Zooming out, such processes can be visualized as actions partially-bounded within regions of enhanced Minkowski-like $4D^{+}$ techno-social space-time diagrams:

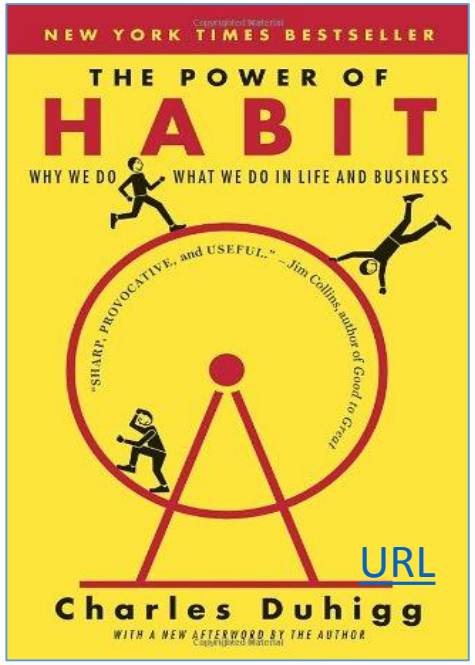


To practice visualizing 4D space-time see Online Resources on 4D like Curved Spaces and 4D Draw

As bandwidths, connectivity & latencies improve, escalating rates of techno-social change will challenge existing cultural patterns, because of the massive accumulation of social habits:

What's the new game?
Who gets to play?
What rules do we play by?
Where can we turn for guidance?

Especially, how do we drop old habits?



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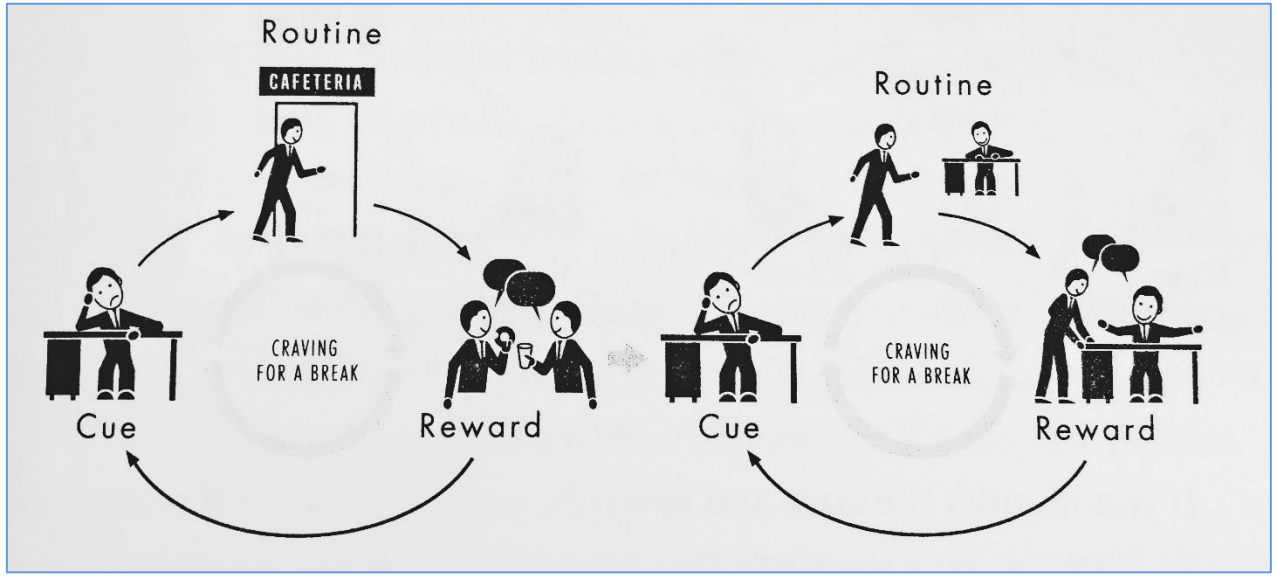


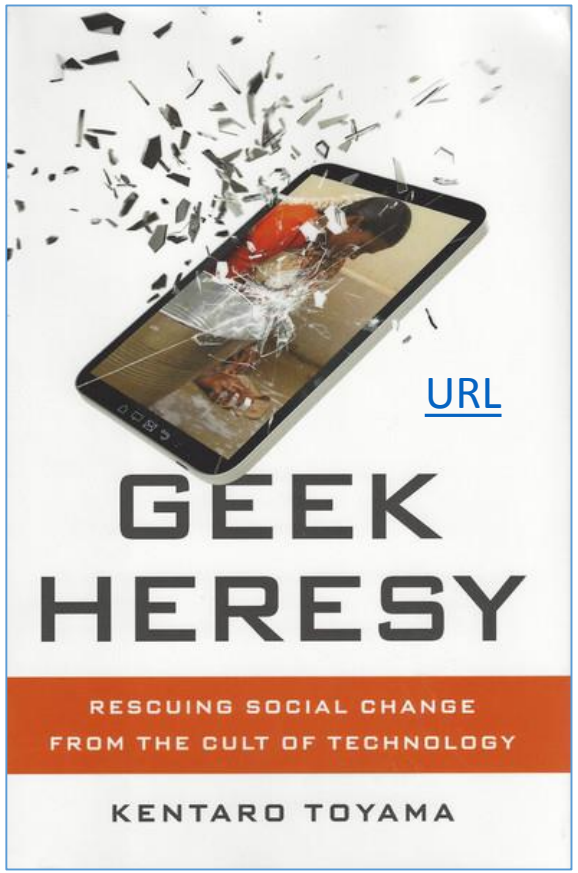
Then too, “How can we ever adjust and keep up?”
Hasn’t the train already left the station for many folks?

Words to ponder:

"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" – Eric Hoffer

Meantime, something awesome has begun:

“As the rate of techno-social change increases, we’ll all live far further into the unfolding techno-social future than we ever dared dream“ – Lynn Conway

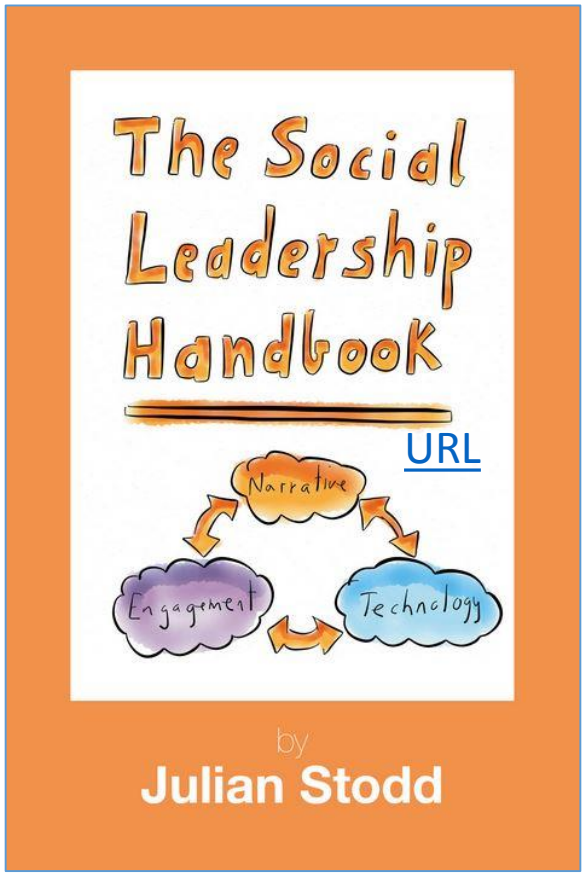


Kentaro Toyama, 2015

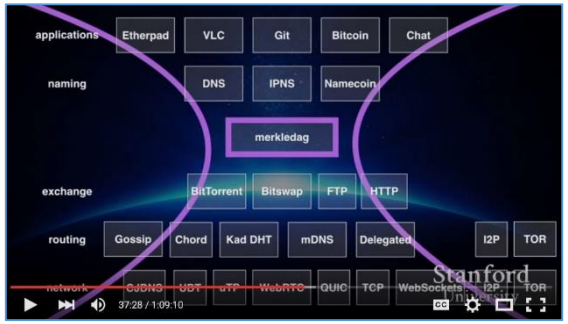
And, a word of caution!
Do avoid becoming distracted by all the rapidly-emerging "things."

As Kentaro Toyama says in *Geek Heresy*, "technology alone won't change the world". . . We must instead rescue "Social Change from the Cult of Technology"!

One key will be the evolution of empowering "social-teaming" and "social leadership" for the incoming "Social Age", as discussed by Julian Stodd . . .



Julian Stodd, 2014



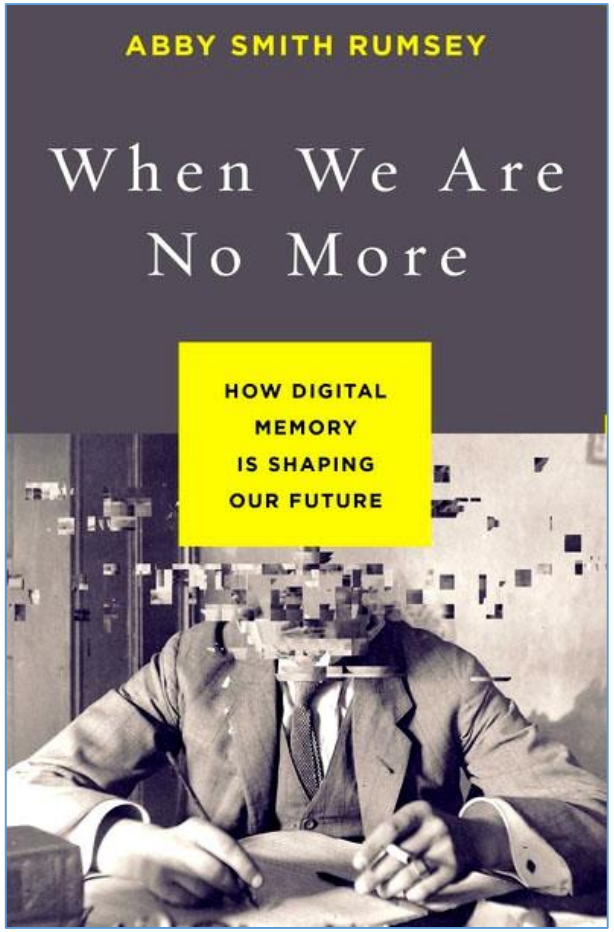
Juan Benet, 2015

There are also extremely deep concerns about Data and Memory, as in Juan Benet's discussion of IPFS and the Permanent Web as a means to ensure the Web's survival.

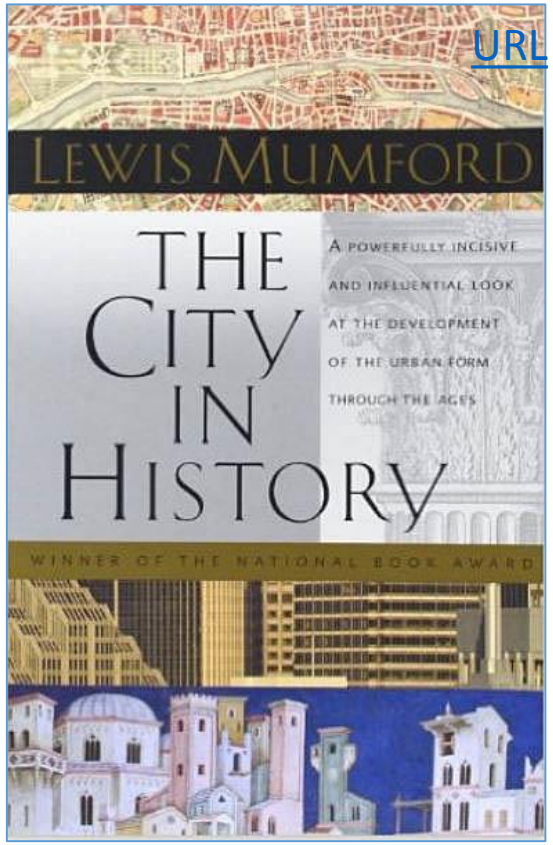
But then see "DNA Data Storage Safe for Centuries", NYT 12-3-15

And then explore historian Abby Rumsey's breathtaking new book:

"A call to consciousness, When We Are No More explains why data storage is not memory; why forgetting is the first step towards remembering; and above all, why memory is about the future, not the past. "



Abby Smith Rumsey, 2016



URL

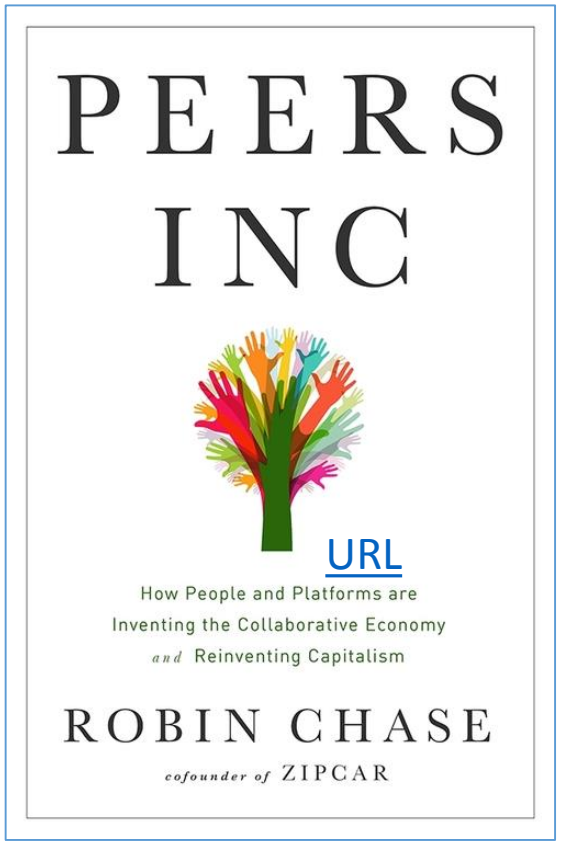
Lewis Mumford, 1961

Again, this isn't about things.

It's about the escalating rate of generation + diffusion of ever-better ideas on how to make and use things!

This is triggering huge re-alignments in political economy, including the role of *The City in History*.

And to the emergence of the new "cooperative capitalism", as discussed by Robin Chase of ZipCar fame in *Peers Inc*



URL

Robin Chase, 2015

In Conclusion, a Conjecture about possible futures:

By cooperatively generating and sharing ideas for doing **ever-more** with **ever-less**, the incoming wave of techno-social innovation has the stunning potential of:

(1) Sustainably providing **ever-increasing** infrastructural functionality and life experiential-amplification per person,

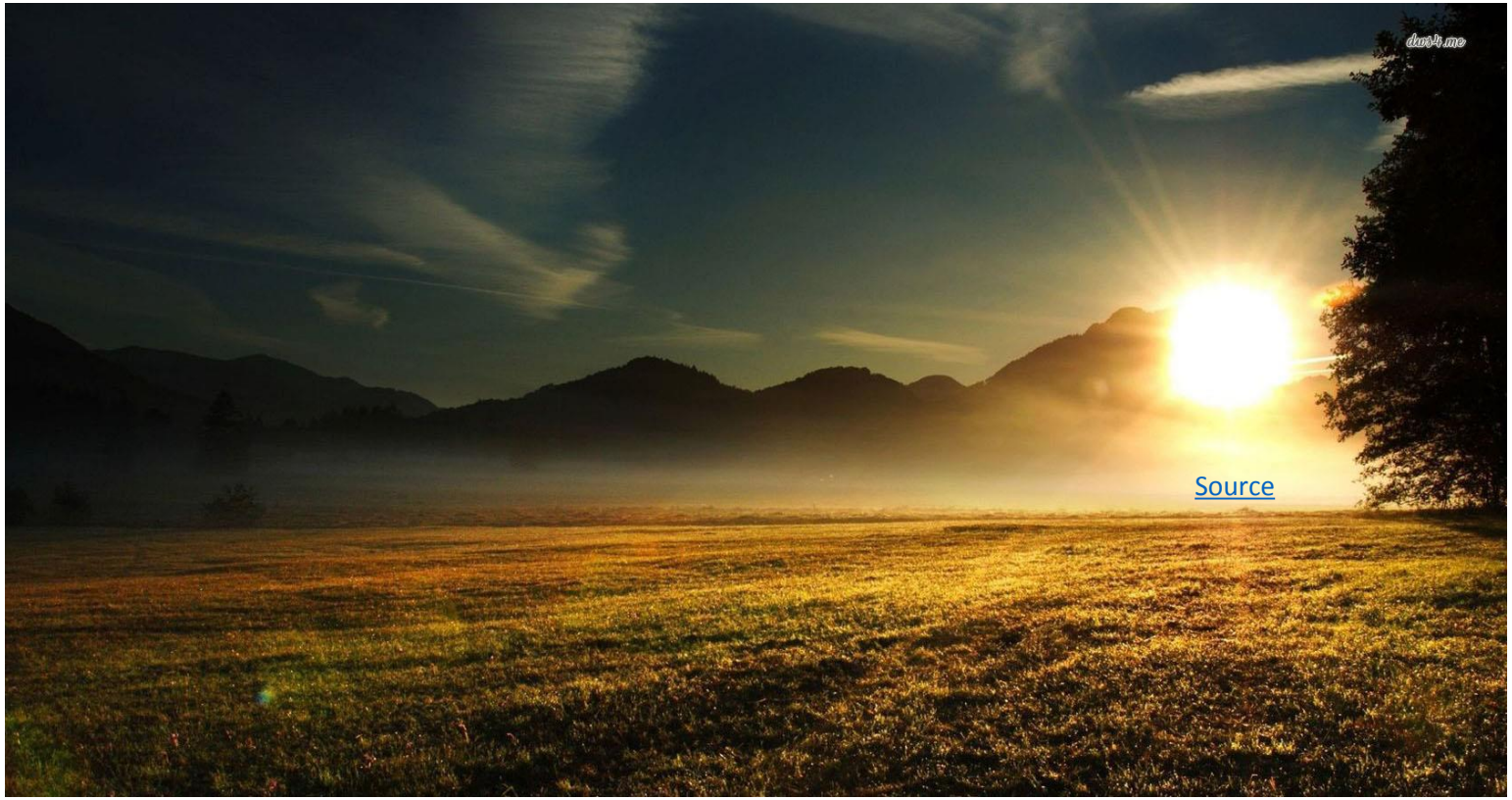
(2) While consuming **ever-decreasing** energy and material resources per person

(3) Thus beginning the **reigning-in** of our unsustainable over-use of planet earth

(4) While simultaneously **opening-up** unprecedented explorations of the greatest frontier . . . the frontier of **what it's possible to do**!

Thus we Begin another Renaissance, as we Enter the Techno-Social Age.

Finally, a personal perspective on “Our Travels Through Time”. . .



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

– Lynn Conway

END

Links to Powerpoint Slides, Notes & References

http://ai.eecs.umich.edu/people/conway/Memoirs/Talks/Columbia/2016_Magill_Lecture.pptx
http://ai.eecs.umich.edu/people/conway/Memoirs/Talks/Columbia/2016_Magill_Lecture_SlidesNotesRefs.html