ENERNET

Internet Lessons for Solving Energy

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Stanford University Computer Systems Colloquium

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You are invited to join a history project called Enernet. Let's mine the rich vein of analogies between information and energy, between the Internet and the Enernet.

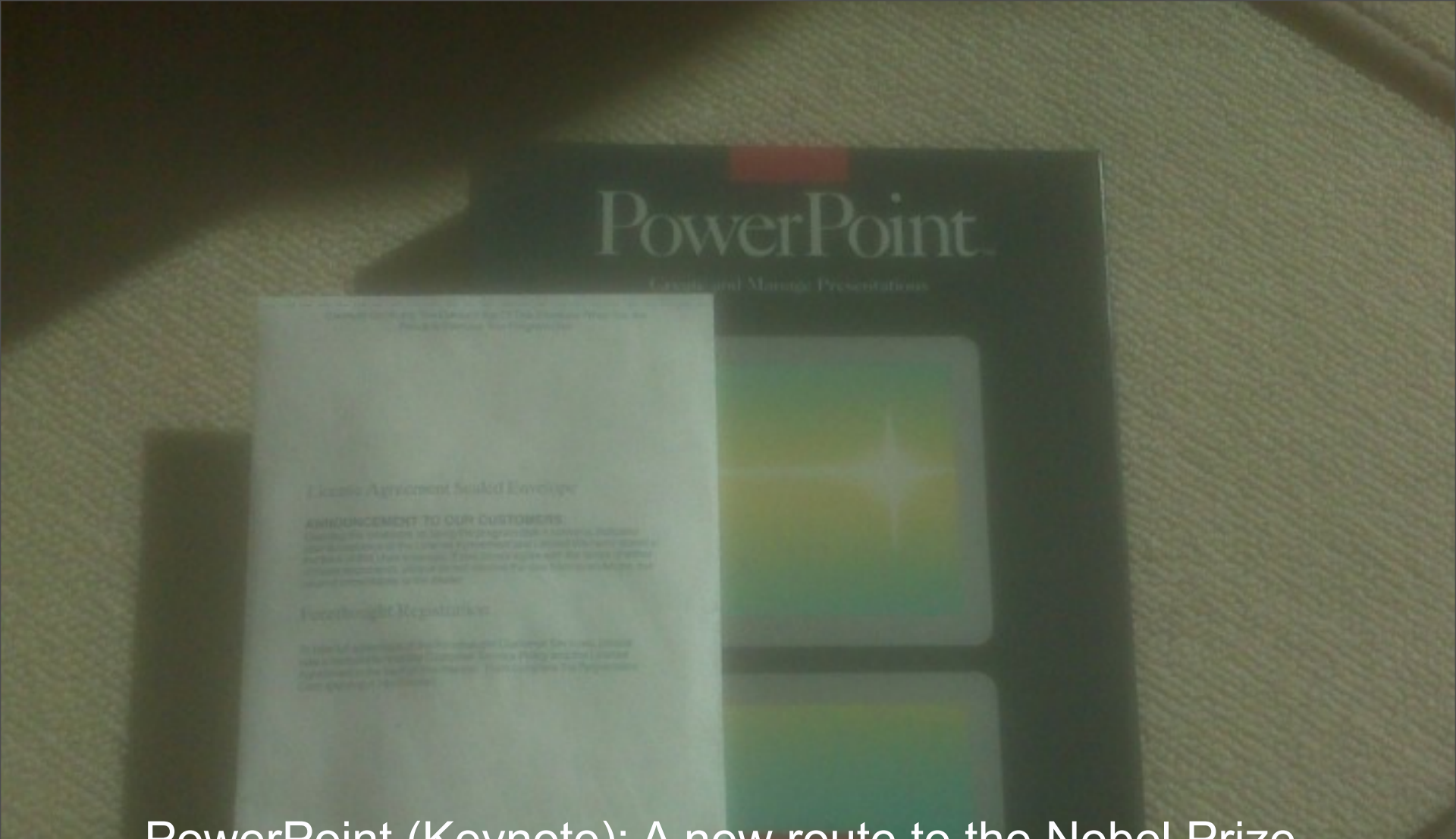
Over the past 63 years, we met world needs for cheap and clean INFORMATION by building the INTERNET. Over the next 63 years, we will meet world needs for cheap and clean ENERGY by building the ENERNET.

Don't confuse Enernet with enertech -- energy technology, like infotech, biotech, mediatech, nanotech ... As a VC, I am growing my enertech portfolio. Enernet is also not to be confused with other net words: Arpanet, Ethernet, Internet…

Enernet is my 2008-2009 book tour, only I don't have a book, just these powerpoints (keynotes, actually). Stops along my Enernet tour include Ember (South Boston, twice), MIT (twice), Internet Cowboys unConference (Jackson Hole), Metro Ethernet Forum (Boston), Big Boys Camp (Green's Island, Maine), American Spectator Magazine (NYC), Telecosm (Lake George), AlwaysOn Venture Summit (Boston), Olin College, Lux Research (Cambridge), Virginia Tech, NSF-ERC (Bethesda), Microsoft Research (Mountain View, CA), Cisco (at the Computer History Museum), Computer History Museum (Mountain View), GigaOm's Green:Net (San Francisco), Boston College (April 3), Cornell (April 7, my birthday), University of Maine (Orono, April 10), Intel Research at UC Berkeley (May 17), Stanford (May 20), Connectivity Week (Santa Clara, June 10), Science Foo Camp (Googleplex, July), Singularity University (NASA Ames, July13)...

Have just started an Enernet blog at enernet.wordpress.com -- go see.

Thanks for your interest (if any). Feel free to pass along this PDF of my keynotes with these speaking notes.



PowerPoint (Keynote): A new route to the Nobel Prize.

These Enernet powerpoints, now in Keynote on my Mac, are my first-ever PowerPoint presentation, which is ironic since I was on the board of the start-up that developed PowerPoint and sold it to Microsoft in 1987 for $14M.

The start-up was Forethought, in Mountain View, CA. Shown are Forethought's 1987 PowerPoint box and yes, unopened Macintosh diskette. I've sent these to the Computer History Museum, which also happens to be in Mountain View, CA.

Why has it taken me 20+ years to use PowerPoint? I have been successfully using handwritten 3x5 cards for my talks -- 5x7 for major speeches -- and never found time to learn PowerPoint. Recently, I got to thinking that my avoidance of PowerPoint, though much admired, was generational, and I'll have none of that. My mid-life crisis is still ahead of me. 60 is the new 30.

I think of PowerPoint as one of the major breakthroughs coming out of Internet development. It is an aid to collaborative intelligence, which we can now apply to building the Enernet.

And if Al Gore can win the Nobel Prize with PowerPoint, so can I, so can you.

Blue is the new green.

Summary: Let's mine Internet history, say since invention of the transistor ~1946. Internet lessons for solving energy.

Beware hardening of the categories, for example: voice, video, and data then vs. feed, food, and fuel now. Long term, technology ceilings matter more than floors -- there is time for science. We used the Internet to build the Internet, so let's use the Internet to solve energy. History teaches that conservation is not what Enernet will be about. Like information and bandwidth, we need energy and power in squanderable abundance, to spread freedom and prosperity.

The color green has baggage, a poor choice for Enernet, which has become an Internet-like movement. We need Enernet laws -- like Grosch's, Moore's, Grove's, Metcalfe's -- to set Enernet's agenda. Expect surprises, like PCs and mobility. Expect silver bullets, like TCP/IP, Ethernet, WWW, and DWDM.

Expect bubbles. We are now in the Global Warming Bubble®, which will burst soon. But bubbles are good -- accelerators of technological innovation, tools against the vicious status quo. Solving energy (blue) is not the same as solving environment (green). Forms of nuclear energy, including forms of solar, look promising for the high-ceiling future, but expect surprises. We need energy science, best from research universities.

Internet history shows the best innovation vehicles are competing teams of research professors, graduating students, scaling entrepreneurs, and venture capitalists. The Internet-based Enernet will be intelligent, layered, distributed, standardized, networked, asynchronous, symmetrical, and it will have storage.

All that is what I mean by, "Blue is the new green."

MIT Energy Initiative launched by President Susan Hockfield.

Sitting in MIT's Kresge Auditorium on May 3, 2006, I heard our then new President Susan Hockfield launch what has become the MIT Energy Initiative (MITEI).

President Hockfield says, "Jump!" and I ask, "How high?" on the way up.

I decided right then to join up, whatever that meant. It turns out to mean that I am growing an enertech portfolio as a venture capitalist at Polaris Venture Partners and that I am active on MITEI's External Advisory Board. Disclosure: I am Class of 1968 and a Life Trustee of MIT.

President Hockfield is shown here at the first MIT vehicle design summit. This human-powered hybrid car is also solar powered. Reportedly, pedaling, you would get 600 miles per gallon, so to speak. Using solar, you could go 50 miles at 50 mph, or so the designers claimed.

Polaris Enertech Portfolio

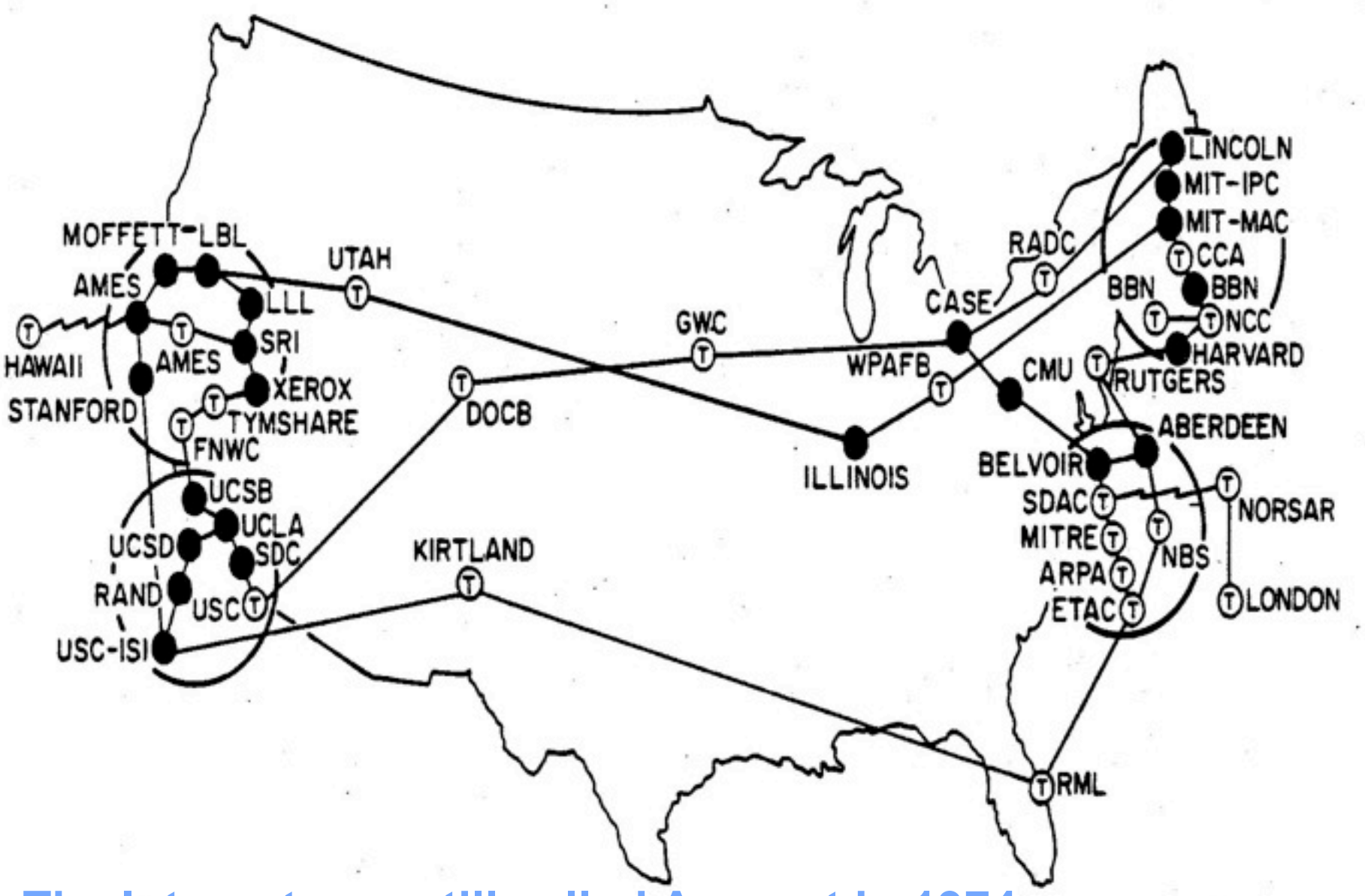
1366	Manufacturing of efficient multicrystalline Si solar cells.
Athenix	Agricultural biotechnology for ... biomass conversion.
Ember	ZigBee wireless networking for energy management.
GreenFuel	Algae-solar CO_2 recycling for feed, food, fuel, chemicals...
Infinite Power	Flexible solid-state Li-ion rechargeable micro-batteries.
Mintera	40-Gbps fiber-optic systems for carrying bits, not atoms.
Nanosys	Nanotechnology for ... fuel cells and solar cells.
Paratek	Tunable ceramics for ... energy efficiency in cellphones.
SiCortex	Open clusters for energy-efficient green supercomputing.
SiOnyx	Black Silicon for photodetectors, cameras, photovoltaics.
Sun Catalytix	Catalysts for converting sun and water into fuels.
SustainX	Distributed energy storage using compressed air.
Wakonda	High-volume thin-film solar cells on flexible substrates.

Polaris Venture Partners in Waltham, MA and Seattle, WA is a diversified venture capital firm.

This list of some of our 100+ portfolio companies is a judgement call by me.

Some of these are pure enertech companies. Others have a variety of applications including enertech. OK, SiCortex is a supercomputer company, but it's a GREEN supercomputing company -- very low electricity consumption. And OK, Mintera is a telecommunications company, but it's on the list mainly so I can have ALL of my current portfolio companies on this list, and it gets here by offering the next generation of Internet core data transmission at 40 Gbps per lambda, which allows even more substitution of Internet communication for energy-consuming transportation -- sending bits instead of atoms.

VCs often tout their portfolios, but I will not today, unless you force me to.



The Internet was still called Arpanet in 1974.

What is my standing in energy? I have lived through the building of the Internet.

By 1974, 35 years ago, I had worked on what would later be called the Internet, from MIT (1822, NCP, Telnet), Hawaii (Alohanet), Harvard (PhD, 1973), Xerox Parc (Ethernet, Pup), and Stanford (TCP/IP).

There were 1 to 4 mainframes and/or minicomputers (and ~0 personal computers) at each of those Arpanet sites, interconnected remotely through packet-switching IMPs using, yes, 50 Kbps AT&T circuits.

To be clear, most “computers” in 1974 were still batch-processing mainframes, inputting boxes of key-punched cards and producing, overnight, green and white striped print-outs. Ask me what a core dump was. The “movement” then was to interactive time-sharing minicomputers. PCs had not been invented. AT&T and IBM ruled their worlds, telephones and computers, respectively.

ENERNET

Lessons from
~63 years of Internet history
about meeting world needs
for
cheap and clean energy.

After 38 years as an Internet innovator, 10 years as a pundit, and with my wife Robyn a PhD student in history, I decided to look back into Internet history for lessons on how to solve energy.

I decided to try to be helpful by going on this informal ENERNET speaking tour during 2008-2009. At each stop on the tour, I invite listeners to join me in mining Internet history for guidance on how to approach energy. You are so invited.

I am proud of my enemies -- what losers they are. Upon reading about this Enernet tour, some cruelly mocked me, saying that to somebody with a hammer, everything looks like a nail. And they say I am a one-trick pony, which I like to point out, defensively, is a lot better than being a zero-trick pony. I have been a has-been several times now and know how to handle it. Has-been beats never-was.

Also, to be even more annoying, and to be clear up front, even before starting this history project, I knew that it would be easier to teach energy to entrepreneurs than it is to teach entrepreneurship to the energy industry.

OK, maybe the analogy between information and energy is not perfect.

Let’s see what Internet lessons we might use to help world economies get a squanderable abundance of cheap and clean energy with which to grow more free and prosperous.

Enernet	Internet
Energy, Power	Information, Bandwidth
Carnot Thermodynamics	Shannon Information Theory
1824 -> Entropy	1948 -- Entropy!
Ergs and Joules	Bits and Bytes
Electrical	Electronic
Power = Joules per second	Bandwidth = Bits per second
Watt (W) = Newton-Meter/Second	Metcalfe (Me) = Bit-Meter/Second (1976)

Enernet is an analogy between information and energy, between the Internet and the Enernet.

The analogy between information and energy has been tried before. In developing his information theory, Claude Shannon saw this analogy and reused the word entropy from Carnot's thermodynamics.

(Excuse my again (since 1976) putting in a bid to have a unit named after me, like what happened to Watt and Hertz. The unit I'm after is the bit-meter per second, to be called the Metcalfe and appropriately abbreviated Me (like the cycle per second, abbreviated Hz after Hertz). Dave Boggs and I used the gigabit meter per second (Gbmps) in our 1976 Ethernet paper, which if I get my way, will in the future be written GMe (;->).)

Those who don't study history are doomed to repeat it?

George Santayana
(1863-1952)

History is a pack of lies about events that never happened told by people who weren't there.

Certainly you have heard this said, mostly by history professors: those who do not study history are doomed to repeat it.

But wait, didn't building the Internet go very well? I think so. So, should we NOT study Internet history and be blissfully doomed to repeat it?

I grabbed Google and went hunting to unravel this tangled conclusion, which can't be right. Who first said this?

According to what I found on the Internet using Google -- try it -- philosopher George Santayana said that those who do not learn from the PAST are doomed to repeat it. What he said about history is less flattering to historians.

In the case of my studying Internet history, at least ... I WAS THERE.

Santayana had many other brilliant insights. Quickly searching for them I inadvertently found:

Google Serendipity:

Carlos Santana (1947-)

You've got to change your evil ways, baby.

Some sloppy typing into Google found me not George Santayana, but Carlos Santana. Serendipity.

Mr. Santana, who is about as old as the Internet and is still with us, also has brilliant insights, like this one for energy:

Internet Era?

1998 Founding of Google
1991 Gore Bill (by George Bush)
1989 World Wide Web by Tim Berners-Lee
1984 Arpanet NCP to Internet TCP/IP
1973 Cellphone, TCP/IP, Ethernet
1969 Arpanet by BBN
1960 Packet Switching by Baran & Davies
1957 Sputnik by CCCP
1946 Transistor, Mobile, Internet, and Me

If we historians are to study the “Internet Era,” when did it start?

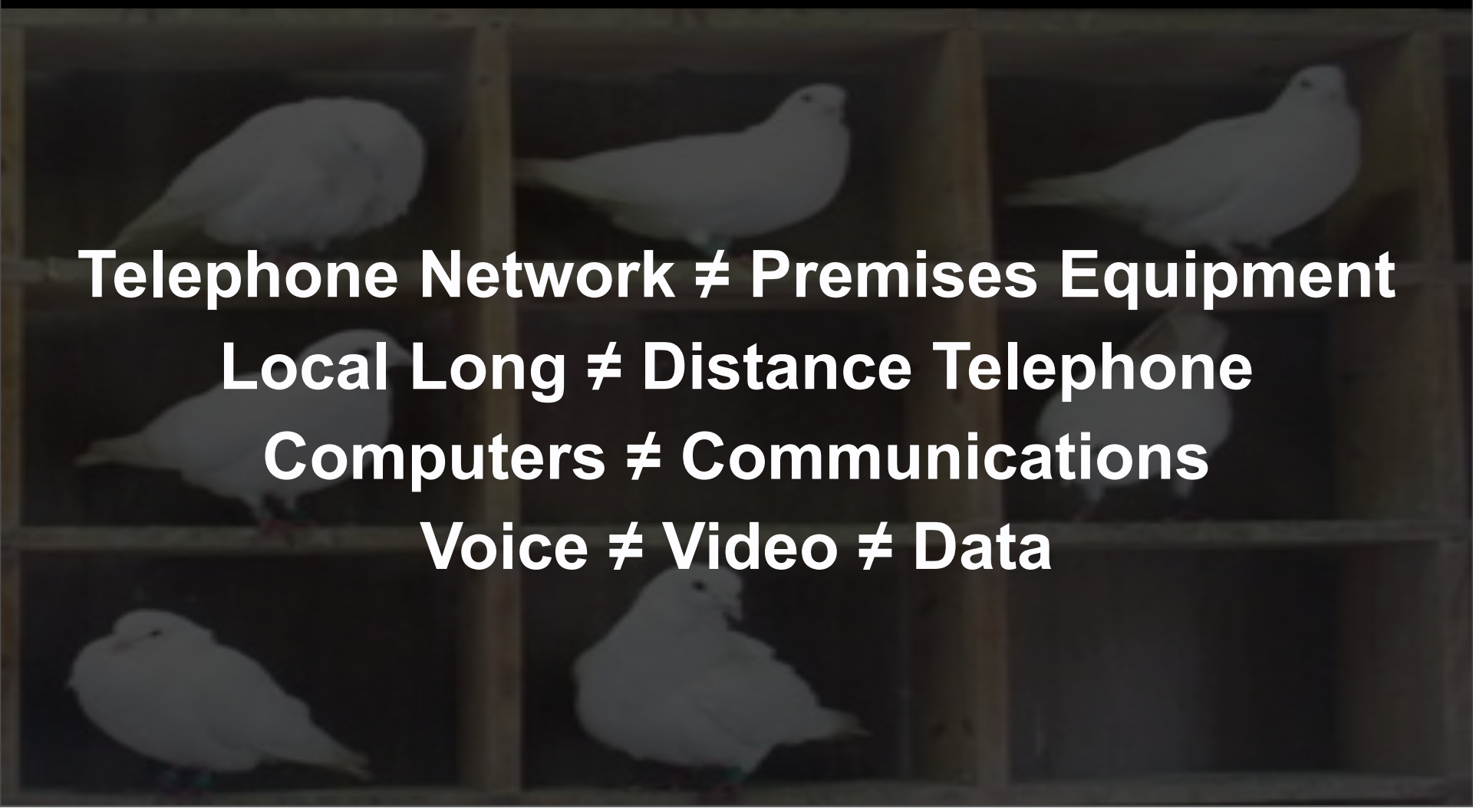
The transistor has obviously been key to the growth of the “Internet,” which I take to mean today’s computers and communications network. The transistor was invented in 1925, 1926, 1933, 1946, 1947, 1948, or some other year, depending on what you mean by the words “transistor” and “invented,” and on whom you believe. It does not matter much, so I choose 1946, the year Bell Labs formed its Nobel-Prize-winning team to invent the transistor, which they showed working in 1947 and announced in 1948.

Who invented Internet “packet switching” is also controversial. IEEE recognizes Baran, Davies, Kleinrock, and Roberts. There is plenty of credit to go around.

People born in 1946: Cher, Bill Clinton, Dolly Parton, George Bush, Linda Ronstadt, and me. Also in 1946, AT&T demonstrated the first mobile phone, a car phone. And the bikini was invented.

Choosing 1946, we have 62 years of history to mine, which is probably plenty. There is the historical complication that the Internet Era is certainly not over.

Hardening of the Categories



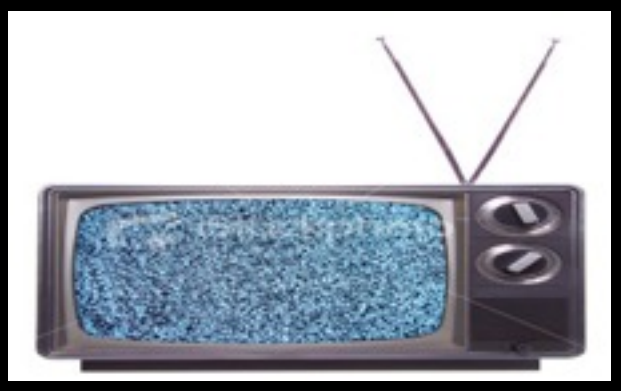
Especially when thinking about 62 years of future, beware “hardening of the categories.” Premature and/or wrong categories send us in the wrong direction and/or slow us down.

The Internet’s early slow-moving telecommunications monopoly AT&T had us all thinking that its telephone transmission and switching network included customer terminals -- old rotary and new (1963) Touch-Tone (DTMF) telephones. It wasn’t until the Carterfone decision by the FCC in 1968 that foreign equipment, not made by AT&T’s Western Electric, could be attached to AT&T’s telephone network. Then came competitive innovations including mobile phones, cordless phones, answering machines, modems, and oh, no thanks to AT&T, the Internet.

Local and long distance telephone service were too slowly distinguished and demonopolized.

The FCC, regulating communications (AT&T), and Justice, regulating computers (IBM), held years of hearings about what exactly were communications vs. computers, so they could harden their categories. The Internet showed communications and computers to be inextricable.

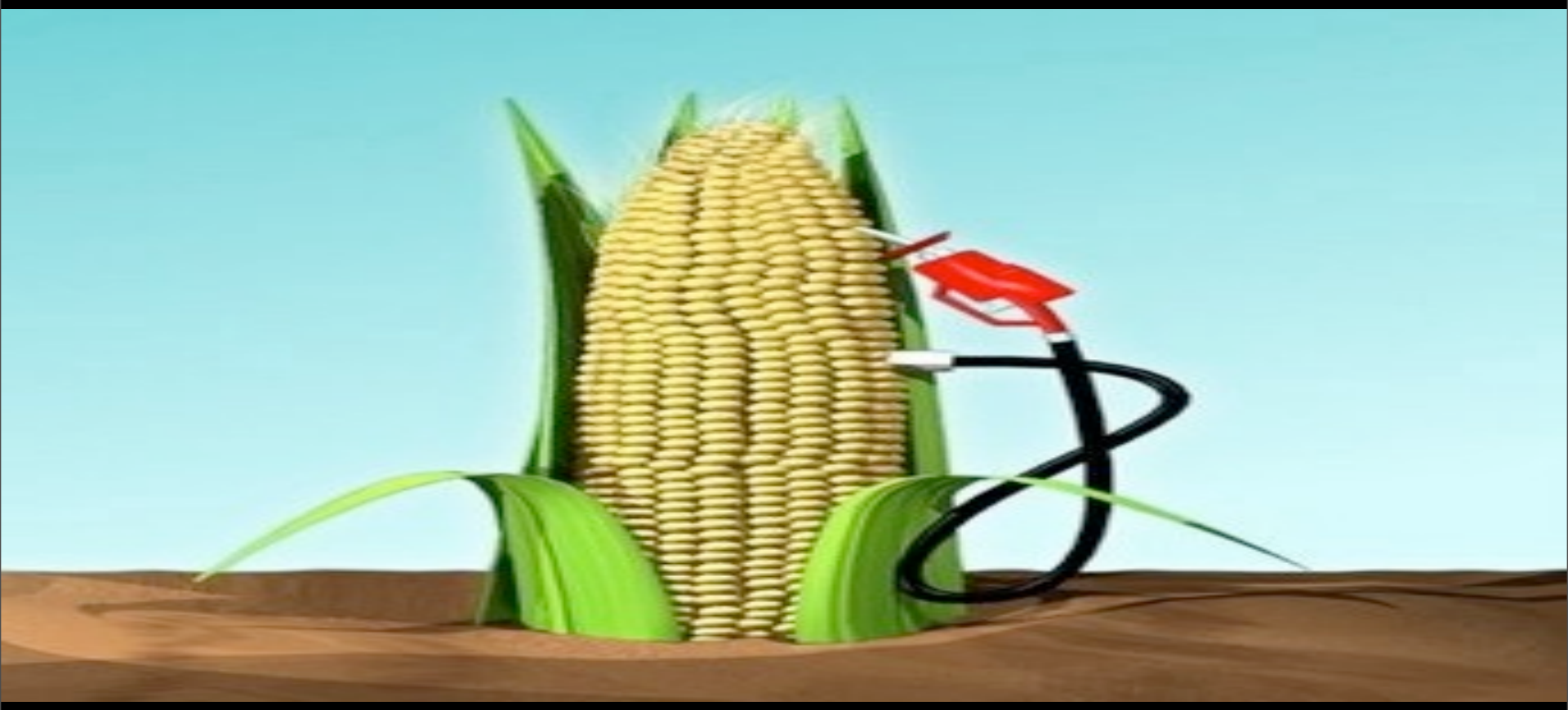
Voice ≠ Video ≠ Data



The voice, video, and data monopolies were surprised when
voice became more than telephone, surprising AT&T and their FCC,
video became more than television, surprising the TV networks and their FCC,
and both became data on the Internet, surprising IBM and their Justice Department.

Left: Early voice recognition dialing system.
Top center: Early “HD snow” on an analog TV (doctored photo).
Right: Model 33 Teletype upon which the Internet’s first messages where typed.
Bottom center: Desktop conferencing today combines voice, video, and data.

(I am on the board of Avistar (NASDAQ=AVSR), a desktop video conferencing company.)



Feed ≠ Food ≠ Fuel

It's hard to list everything wrong with government subsidies for corn ethanol. First on my list would be the very idea of government subsidies. But then…

DC chose to subsidize the wrong feedstock (corn) and the wrong fuel (ethanol). Cellulosic whatever is next. Thanks to hardening of the categories, DC thought they could manipulate fuel markets without disrupting feed and food markets. Not.

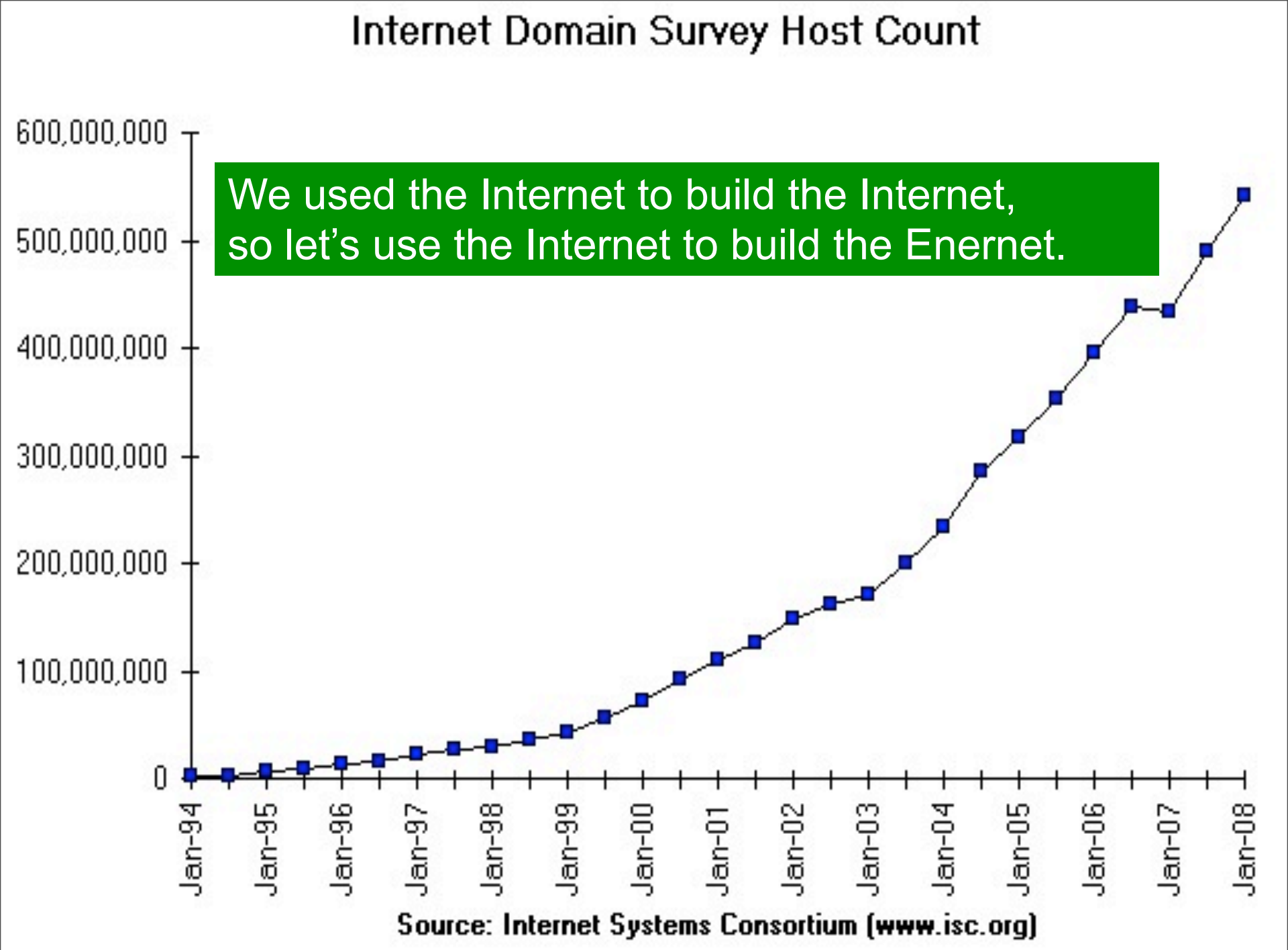
One GOOD thing about corn ethanol subsidies is that they misspend taxpayer monies less in the Middle East and more in the Middle West.

At GreenFuel (of which I am chairman), corn ethanol pales against algae biodiesel.

Algae are many more times productive than agricultural crops, harvested every day, not just once a year. So, for example, algae produce oil 400 times faster than corn, ~48,000 liters per hectare per year.

And algae don't take agricultural land (think desert) or drinking water (think ocean or sewage).

And algae, like corn, is an energy crop that can be used in feed for animals, food for people, and/or fuel for our machines.



The Internet did NOT go away when The Internet Bubble famously burst on March 10, 2000.

We can use the Internet for COLLECTIVE INTELLIGENCE, better to solve energy. For example, we now have competing "new media" -- more choice and better information than was available on the pre-Internet, nearly monopolistic, often nepotistic, and disgustingly propagandistic old media, like my former home town paper, the not fair and balanced, NYT (~ Democratic Party Pravda). Let's use Google News, blogs, Facebook… as cheap and clean tools for Enernet collaboration.

Let's use the Internet for ENERGY MANAGEMENT: HVAC, lighting, demand response, smart grid. More later.

To conserve energy, we can massively SUBSTITUTE Internet communication for transportation. With the emerging Video Internet, we can increasingly transport our bits instead of our atoms.

BTW, when we send our atoms, digress to Internet-enabled mobility on demand and robotransport:

Digressing, here are two Internet-enabled transportation energy conservation ideas: mobility on demand and robotransport.

Mobility On Demand is the term at MIT Media Lab Smart Cities for folding electric automobiles rented around cities like airport luggage carts (pictured lower left).

Robotransport is a term for vehicles that drive themselves, say even on today's existing roads (pictured upper right).

In the US, ~40,000 people die each year in automobile accidents -- a million people worldwide, plus many more injured.

And road transport consumes a lot of fossil fuels. But mass transport is not turning out any better, when you factor in occupancies.

In my lifetime, which I am admittedly expecting to be a long time -- 60 is the new 30 -- I see mobility on demand sooner and robocars later. Imagine no more DMVs. Imagine using the Internet to schedule exactly the car you need (often not an SUV) from a nearby charging station and then having it safely drop you off, potentially automatically carpooling if you and some friends are up for that. Or sending a car to pick up the kids, or some groceries.

You've probably seen this Earth at night picture(s) before. The speaker probably tried to make you feel bad because certain places (like the USA) are so lit up.

Ask: Do we want to turn the world's lights off or on? The USA does not waste energy because we are rich; no, we are free and rich because we have plentiful energy. China, India, and the rest of the developing word want to be free and rich. We should welcome that. Technologies providing cheap and clean energy in squanderable abundance -- at last "too cheap to meter" -- are half the battle.

On the early Internet, to CONSERVE information transmission bandwidth, we stuck too long with punched cards. To be more bandwidth EFFICIENT, we buffered intelligent terminals, compressed files, and used multiplexing, including statistical and then packet switching.

So, today, do we use LESS bandwidth than we did 62 years ago? Do we get along with LESS information? No, we squander computing and communication -- 99.999% is ready but not used. Your PC and LAN are sitting there awaiting your return, and between keystrokes, waiting for your finger to land. Most computing and communication, when used, is squandered on what we call UI.

Let's light up the world with squanderably abundant, cheap and clean energy.

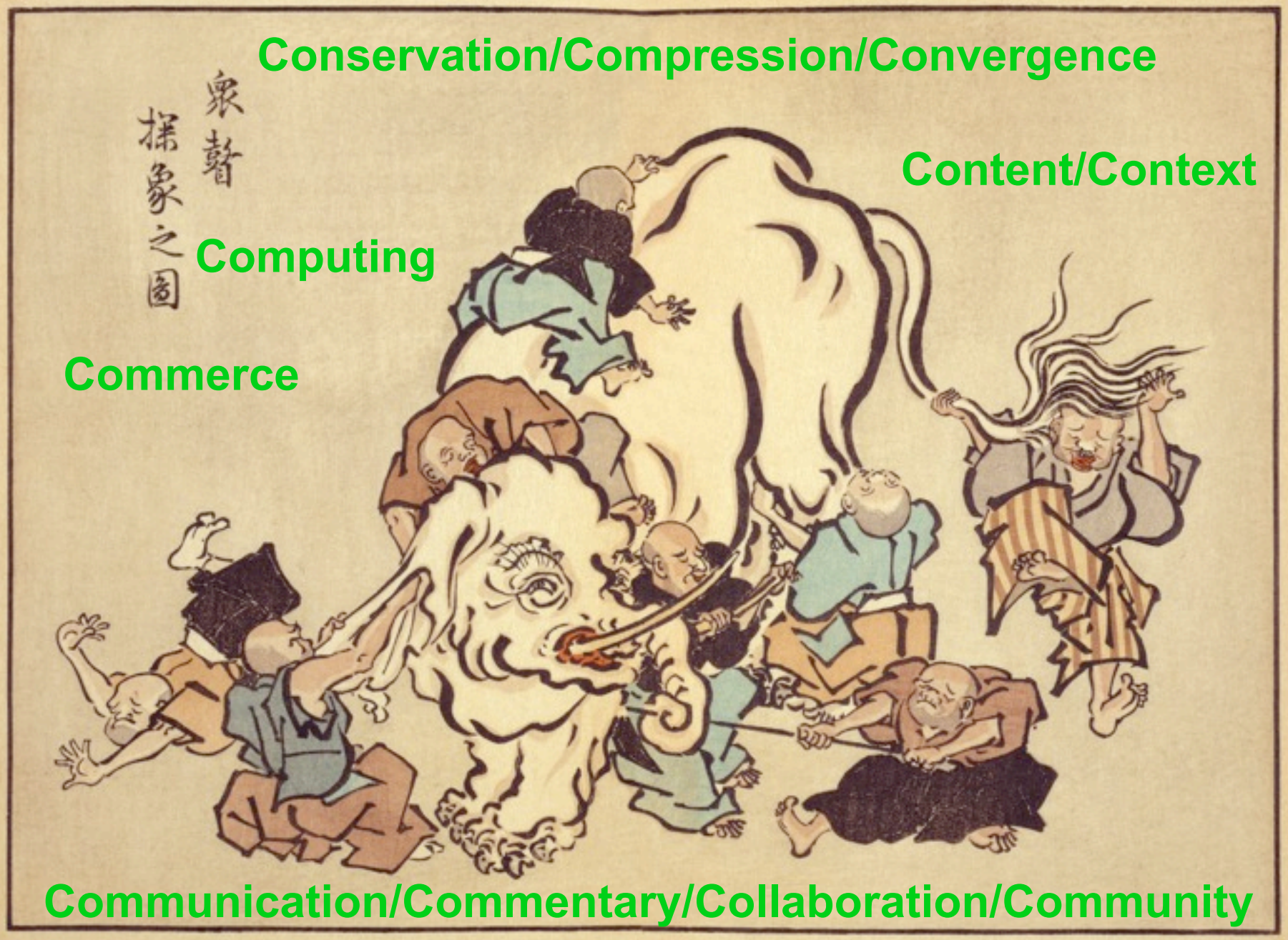
Enernet is not mostly about conservation, but it's not an either-or situation either, and so, I've just moved down from a 12-cylinder S600 Mercedes averaging ~20 mpg to a 3-cylinder Smart Car Mercedes averaging ~35 mpg.

My Massachusetts plate is SMATKA. Toward some future midlife crisis, it's a red convertible. That is not my wife in this photo. My wife Robyn is better looking and certainly more fit than this gorgeous blonde.

My BIG car is a Mini Cooper S, which I now park nose to nose with SMATKA in one parking space.

Just sold my huge gorgeous 9-seat Land Rover up in Maine, DEFENDER, which used about twice a year, to put our small fleet of boats in and out. I'll miss her, DEFENDER, I mean.

The Mini will go next. Then, I'll sell SMATKA for a diesel. Then I'll go hybrid or maybe directly to all-electric. Then I'll take my cars on demand. Then I will leave the driving to robots. Onward!



Recall the Indian parable of the elephant and the six blind men, shown here in Chinese with eight.

An early conception of the Internet (Arpanet) was “resource sharing” (conservation) and “packet switching” (efficiency). We developed Telnet for dumb terminal sessions across the Internet. Then we noticed we needed data with our shared computers, so we did FTP and RJE (content). Then suddenly we found ourselves using FTP to carry email (communication). Next, about 20 years later, the Internet became the World Wide Web to link our content, Google to search it, and now social networks.

Video, mobile, and embedded are happening now. We never imagined WHAT we would use all this bandwidth for. The Arpanet had 50 Kbps long-haul links; today we are moving to 40 Gbps DWDM -- ~1,000,000X.

Energy will likely go through a similar surprising evolution of conceptions. The low hanging fruit is conservation, and right after that efficiency. But what next? New sources of energy, cheap and clean, will open up new uses and new conceptions of energy. What conception of energy might use 1,000,000X more? How much energy for every wall a display and ~100 cameras per room?

What will be energy's YouTubes?

While building Internet 1.0, the Arpanet, envisioned in 1970 by Roberts and Wessler in their "Computer network development to achieve resource sharing," and I remember this clearly, we did not say that our goal was YouTube.

Back in 1970, we were not building the Internet to carry video, and certainly not YouTube. But today, with the Internet providing million of times more cheap and clean bandwidth than we had in the 1970s, surprise, video is most of what the Internet now carries. And today's video is not yesterday's TV. Here comes mobile video and HDTV.

The terminal on my desk at Xerox Parc in 1972 ran at 300 baud. The first, 1973 Ethernet ran to my desk at 2.94 Mbps (~6 Mbaud?) -- ~10,000 times faster. Today, the fastest Ethernets run at 10 Gbps -- ~ 30+ million times faster than 1972.

On my Enernet speaking tour -- Internet Lessons for Solving Energy -- I argue by analogy that in the coming decades of solving energy we will end up supplying mankind not less energy, but more, much more, cheap and clean, in squanderable abundance. Energy conservation and efficiency are energy's low-hanging fruit, and they are just fine, but we humans are not in the end going to put up with using less energy that we use today.

So, looking into energy's remote future, when we have cheap and clean energy in squanderable abundance, what might it be used for? What will be energy's YouTubes?

Am up to four possibilities for enery's YouTubes: (1) generalized prosperity as a function of energy's price elasticity, (2) space travel, (3) clean water, and (4) thanks to Keith Hansen, CO2 sequestration and more direct forms of climate control.

Energy, like information, is a factor of production, which in abundance will bring ever more economic output, freedom<>prosperity, no?

Energy's YouTubes? How about general freedom<>prosperity? Energy is a factor of production.

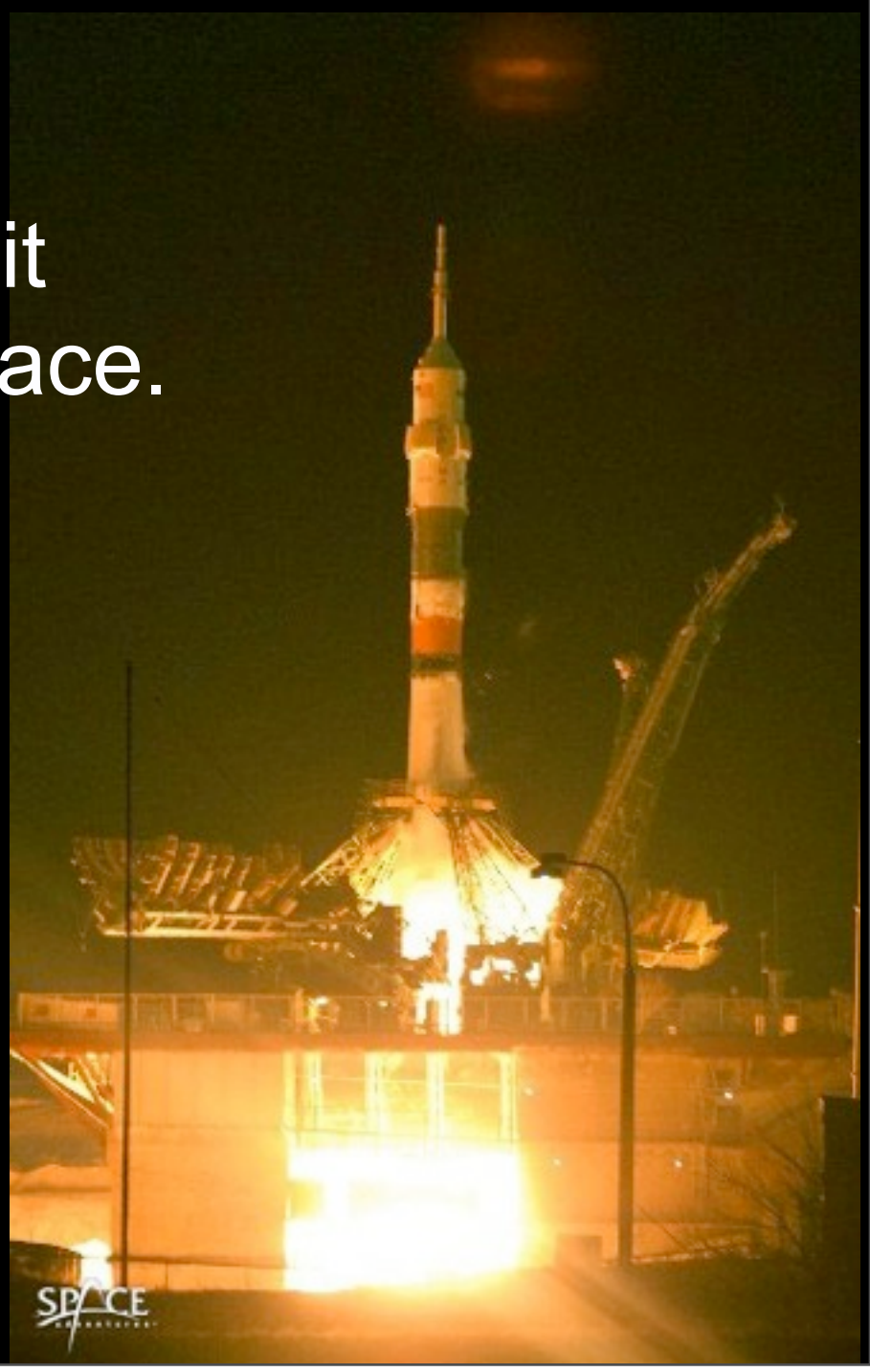
Information is a factor of production; the Internet boosted productivity and therefore economic growth, and freedom<>prosperity.

The Jevons Paradox (The Rebound Effect) is that greater energy efficiency, while in the short-run producing energy savings, in the long-run results in higher energy use. By British economist W. Stanley Jevons, The Coal Question, 1865.

What exactly would happen to world economies over the next 63 years if nothing else changes except (clean) energy costs go down a factor of 10?

By Jevons Paradox, cheap and clean energy use will go UP, but by how much, a factor of 1.1, 2, 10, 100, 1,000, 1,000,000?

Charles Simonyi
rockets into Earth orbit
on his first trip into space.



My friend from Xerox Parc, Charles Simonyi, developer of Microsoft Word, is preparing for his second trip into space, again into Earth orbit, with Space Adventures. His trip to the International Space Station and back will cost him about $30,000,000, so we can't say space travel is cheap, yet.

But, how much cheap and clean energy might therefore affordable space travel consume in 2070? I visited Space Adventures in Vienna, VA to ask this question of CEO Eric Anderson.

On the back of an envelope, Eric estimated that in 2070 there will be 10 billion of us, and, if humanity has become a truly space-faring species, 5% ought to be able to travel in space each year. If each space-faring person, including all of their luggage and life support systems, has a mass of 1,000 kg, and has a 15 km/s velocity "budget" per trip (enabling them to go to the Moon and back, or just one way to Mars), and the rocket they launched on had a 10% mass efficiency, then the energy required per person-trip would be about 1 TJ (terajoule) of kinetic energy, so that the total energy requirement for space travel in all of 2070 might be 500 EJ (exajoules), or about all of the energy that humanity will consume in 2009 for all purposes, before much space travel.

Of course maybe we'll have a carbon nantotube space ladders by then, I was reminded by Amory Lovins.

What other unanticipated (except by us here) major new uses of energy might emerge when it becomes squanderably cheap and clean? What will be energy's YouTubes? How about water.

How much energy could we use for potable water?

How about potable water? There is plenty of water on Earth, but most of it seems not to be fresh, or clean, or nearby. What if in 2070 there were no potable water left and we had to recover it all from ocean or dirty water. We would have to filter, treat, boil, and/or or electrolyze all our water. How much energy would that take?

Let's assume by 2070 that all 10 billion humans are each using (like today's Americans) ~400 liters of fresh water per day in our households, not counting the considerably more water needed for the agriculture to feed us. And let's assume boiling water is all we have to do to make it potable, not counting water transportation, because the boiling will be distributed.

For each liter (=kg) of water, it takes about 4 KJ to raise the temperature a degree Celsius, or going from 20 to 100 degrees C, about 320 KJ/liter. And then the water has to be boiled to kill the germs or leave any salts behind. The energy needed to vaporize water at 100 C is about 2.3 MJ/liter. It will therefore take about 2.6MJ/liter of boiling to make water potable.

So, 10 billion people, times 400 liters per day, times 365 days, times 2.6MJ/liter gives ~3,800 EJ (exajoules), or ~7.6 times more energy than humanity will consume in 2009 for all purposes, before much boiling of water. That will take a squanderable abundance of cheap and clean energy, and distributed too, if we not going to count the costs of transporting water. Amory Lovins notes that we won't actually be boiling water in 2070, so that would bring our swag down how many orders of magnitude?

Energy's YouTubes?

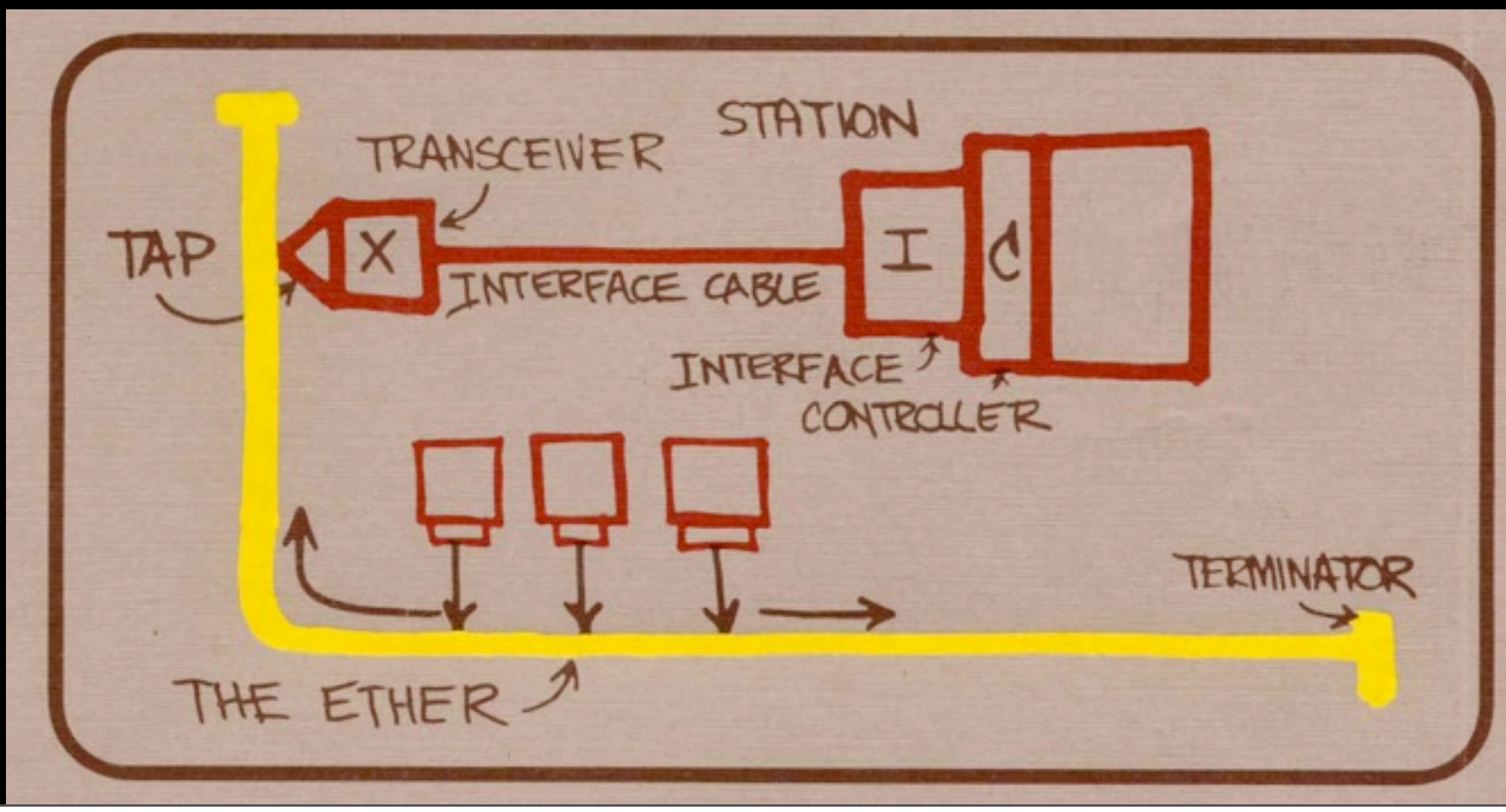
If Global Warming worries you,
let's use squanderably abundant
cheap and clean energy
to scrub 385-ppm atmospheric CO_2.

David Keith, University of Calgary.

Somebody check my math:
Annual worldwide CO2 emissions are ~30 billion tonnes, ~30Gt/y.
Current Calgary estimate of energy to scrub atmospheric CO2 (385 ppm) is 100 kWh/t or 360 MJ/t.
If true, this is impressive. Burning coal produces about 1kg CO2 per kWh, or 1 tonne per MWh, or 10 times the power to clean it anywhere.
Energy to scrub worldwide CO2 emissions would be 100 kWh/t X 30 Gt/y = 3,000 GkWh/y = 3PWh/y = 3x3,600PJ/y = 10.8 EJ/y
Total annual energy consumption today is 500EJ/y.

Not all that much energy, but genetically-engineered trees might be better.

“IP on everything” -- Internet slogan, but what was our movement’s **color**?



Getting to cheap and clean energy has become a MOVEMENT, just like the Internet was. Recall the seven most feared words near the peak of the Internet Bubble? You just don’t get it, do you.

Movements often have dogma, true believers, deniers, slogans, and sometimes colors. Communism in its many failed forms is famously red. Islam is green. USA is red, white, and blue. Feminism is purple.

The Internet Movement’s color seems to have been TRANSPARENT, but the Ethernet and Linux sub-movements, for example, had yellow as their color (and Linux has a Penguin). Movements often have colors, and the energy movement seems to have chosen a color … GREEN.

NYT’s Tom Friedman at Pop!Tech last year questioned whether green was a good choice, with all its baggage. Tom has since chosen to stick with green, but I recommend his new book anyway: HOT, FLAT, AND CROWDED.

Green?

Environmentalism OK

Anti-trade ?

Anti-capitalism ?

Anti-American ?

Anti-technology ?

Anti-nuke ?

Anti-hydro ?

Anti-tidal ?

Anti-wind ?

Anti-solar ?

…

The trouble with GREEN as a movement color is all the baggage it carries.

Safe to say, green is the new red.

And now green is taken up worldwide with cloying regularity.

Even rapacious corporations are into “greenwashing.”

Heck, I’m helping market a “green supercomputer.”

GreenTech investing is all the rage among us venture capitalists.

Please.

In breaking from the past to finally solve energy, I say we’d better change colors.

Green can be traced back to the “Green Revolution” in the 1960s, which celebrated dramatic increases in agricultural productivity thanks to technology.

Black?

Oil
Coal
Silicon
Carbon

Would BLACK be a good color for the energy movement?

Oil is black. Coal is black. Silicon is black. Carbon is black.

Wait a minute, silicon (not its IC packaging) is actually metallic gray, and when polished, a mirror.

Global Warming is Earth being too black, low albedo, reflecting too little sunlight back into space.

Black is depressing. And black isn’t even a color. Forget black.

White?

Too much of a good thing.

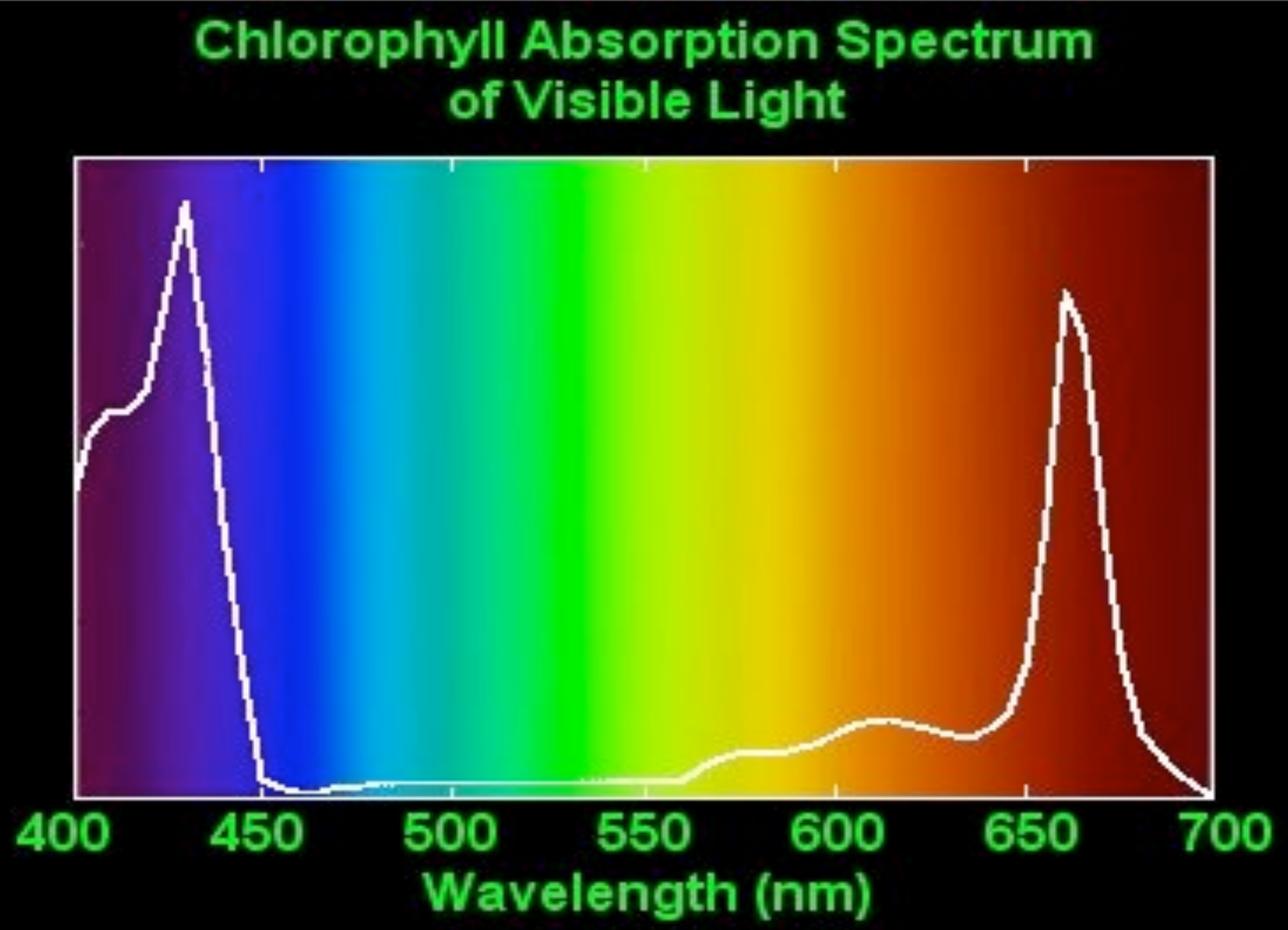
White is all colors, and may be too much of a good thing.

Snowball Earth -- glacial ice from pole to pole, mean temperature -50°C (-74°F). Several times in last couple of billion years. White. Too white. Because most sunlight reflected back into space by white ice. Fortunately, volcanoes put CO2 into the atmosphere, and by the resulting misnamed “greenhouse effect,” eventually melted Snowball Earth, several times, and maybe again.

The fraction of sunshine reflected by Earth is its albedo, from the Latin for white.

~0.1 for liquid water, ~0.3 bare land, ~0.45-0.65 ice, ~0.9 for snow.

NASA: When Earth is covered in ice, its albedo is 0.84, meaning it reflects most sunlight. When Earth is covered by dark green forest canopy, its albedo is 0.14 -- most sunlight is absorbed and Earth is far warmer today. Satellite measurements since 1970s estimate Earth’s current albedo at 0.30 and in decline. We need more science about climate, and then geo-engineering for CONTROLLING climate. White is too much of a good thing -- forget white.



Even plants don’t like green, leaving red and blue.

Let’s look at what green plants prefer. The reason plants are green is that they REJECT green light, reflecting it back at you.

Photosynthesis gets most of its energy from red and blue light. So, shall our energy movement choose red or blue?

When Tim Russert (RIP) decided to standardize the colors for states supporting Democrats and Republicans, he dodged the obvious choice: red for left-leaning Democrats and blue for right-leaning Republicans. Instead he stuck Republicans with the losing color, red. Based on the poor historical performance of various red movements -- the various murderous branches of Marxism -- Democrats were only too happy to get blue.

Even plants don’t like green, and the Democrats stuck Republicans with red, so let’s choose blue.

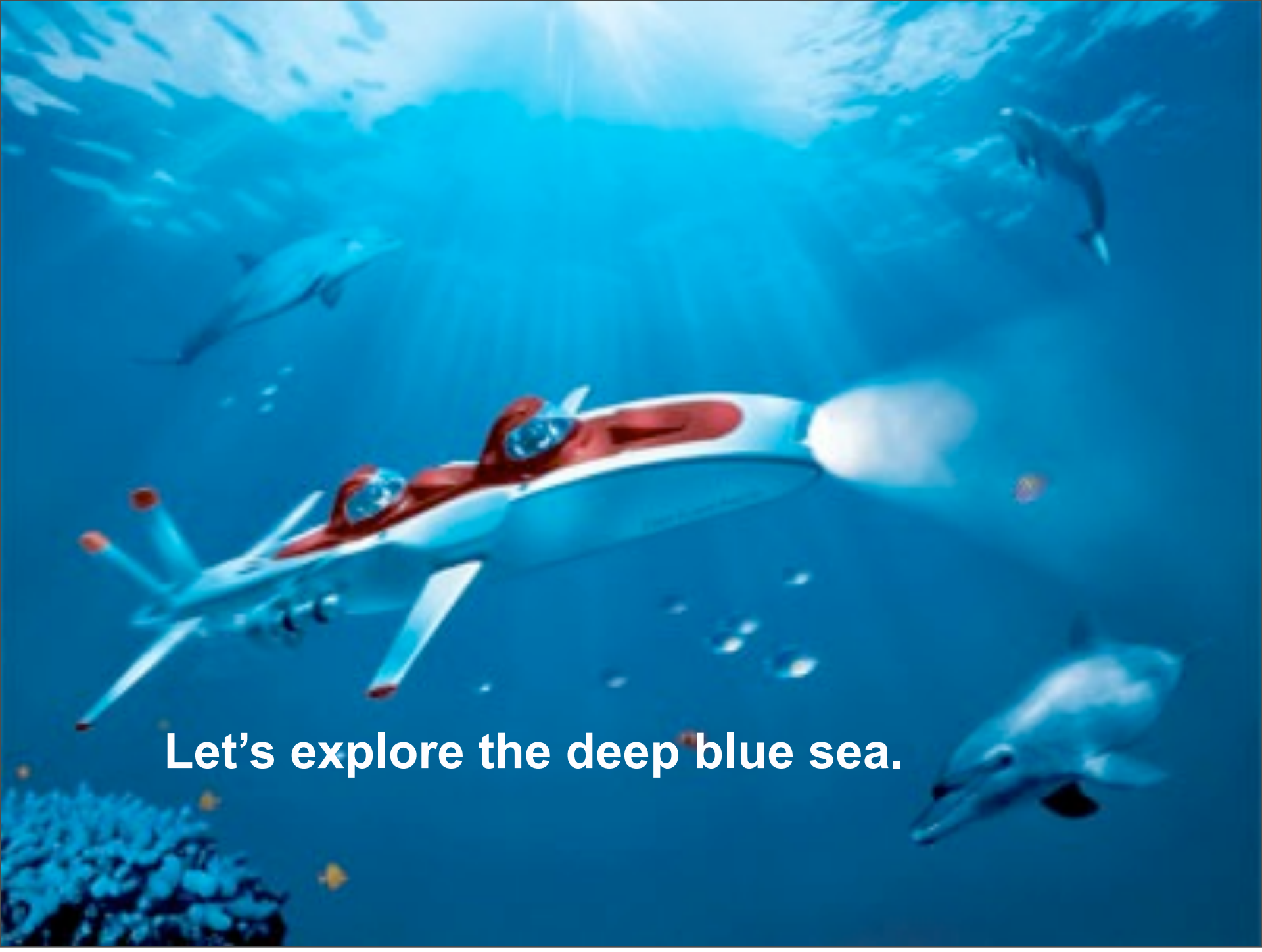
Blue is the new green. I hereby move that Enernet adopt blue.

NASA “True-Color” The Blue Marble

Why blue?
The “true-color” of Earth, according to NASA cameras, is blue, THE BLUE MARBLE.

Of course, looking back up, the sky is blue.
The vast majority of Earth’s energy (including fossil fuels) comes from the sky.
10,000 times the power we use comes from the sky.
Enough in an hour to serve us humankind for a year.

Earth is blue because it is mostly oceans…



Graham Hawkes is the consummate submarine engineer, at www.deepflight.com.

Graham certified me to pilot his two-seater flying subs, then qualified to a depth of 1,500 feet. We aimed to observe aggressive 7’ Humboldt squid in the Sea of Cortez at 700’, but an algae bloom at 100’ thwarted our adventure. Algae everywhere.

Graham’s subs are not underwater elevators like most deep water subs. His literally FLY, which accounts for their looking like jet fighters. Graham has a full ocean depth (~37,000’) submarine near completion, and is launching Ocean Galactic to offer submarine tourism, as pictured.

Graham says Earth is misnamed. Ninety-nine percent (99%) of the living space on Earth is in the oceans, which cover 71% of Earth’s surface, averaging ~12,000’ deep, and are largely unexplored.

Earth’s oceans are likely to be abundant sources of tidal (gravitational), wave, thermal, wind, solar, geothermal, … and/or mineral energy. And they have a lot to do with climate. Let’s explore the deep BLUE sea.

Each hour, more sunlight arrives at Earth than Mankind uses in a year.

And 99% of Earth's living space is in the oceans.

Energy solutions will likely emerge from the sky and oceans.

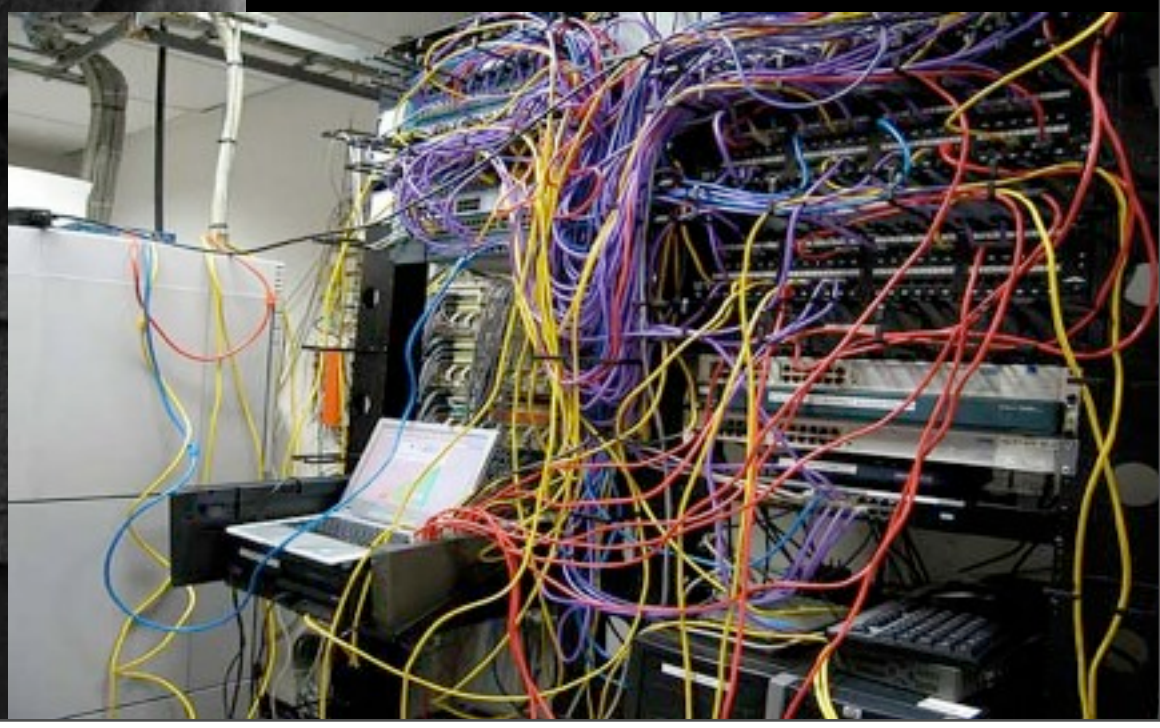
So, again, I move we adopt BLUE as the color of the energy movement.

Internet Surprise

“Incestuous Traffic”

becomes

Ethernet LANs



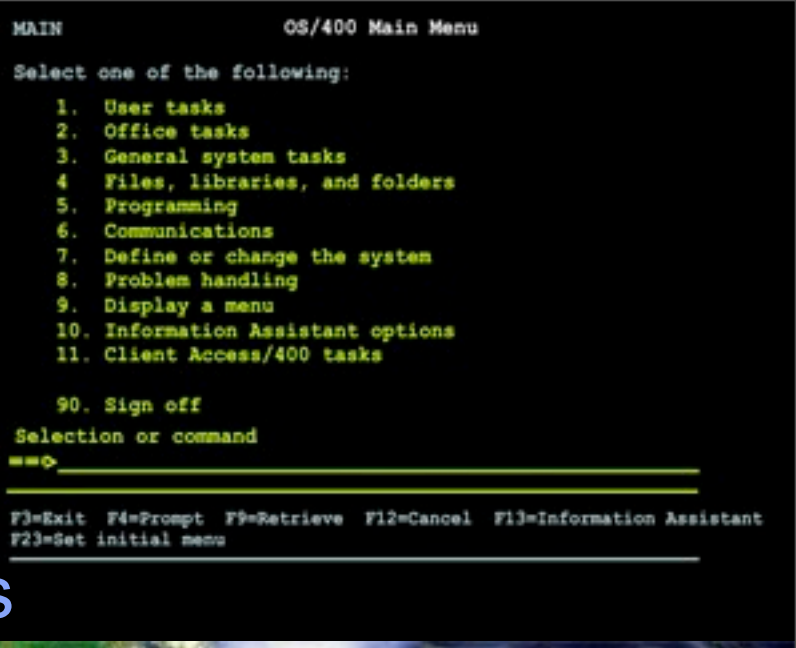
Each Arpanet Imp packet switch (pictured in 1969 with developer Frank Heart of BBN) was delivered with four (4) ports, since universities, unlike everybody else, might have that many mainframes and minicomputers on campus, for administration, teaching, and research.

In 1969, get this, there were NO personal computers.

So when each Arpanet site reported destination counts of our growing Arpanet packet traffic, as counted by Imps, we left off the largest numbers, namely traffic that never left the building, which we dismissed as “incestuous traffic.”

Four years later, in 1973, Ethernet was invented to locally network the first Alto PCs at Xerox Parc. In 1976, the first Ethernet paper was published. In 1977, the Apple II was introduced. In 1981, the IBM PC was introduced. In 1984, 3Com went public selling Ethernet cards to connect PCs in LANs. Surprise: Ethernet LAN traffic is today dominant. This year 350 million new Ethernet switch ports will be shipped, and that’s not counting WiFi.

There will be Enernet surprises too. I wonder how much energy will be generated and consumed all within the same house, in a sort of energy LAN?



Internet Surprise
Timeshared Computer Utilities
Not

Internet Surprises, who would have thought?

Punched Card Batch Processing Mainframes from IBM monopoly, peaked with IBM 360 in 1964.

Interactive Minicomputers, computer utility crusade through 1960s. Grosch's Law.

Standalone PCs: Apple, then Intel, Microsoft, and IBM in 1970s and 1980s. Moore's Law.

Internet PCs and Servers in the 1990s. Metcalfe's Law. Computing and communication CONVERGED. What analogous CONVERGENCE might we look for in energy?

Mobile Handhelds, 4 billion subscribers already this year. Invading the Internet and getting video.

We started Internet development under the AT&T copper monopoly and with broadcast TV. For a while we thought microwave towers and then satellites would take over the long haul.

But then SURPRISE! came the Negroponte Reversal. TV started leaving broadcast wireless for copper cables. And telephones started leaving copper cables for cellular wireless. And telephones started leaving satellites for optical fibers, because of satellite speed-of-light delays.

But then really came fiber-optics, mid-1990s dense wave-division multiplexing = DWDM.

Then came wireless Ethernet, later called WiFi.

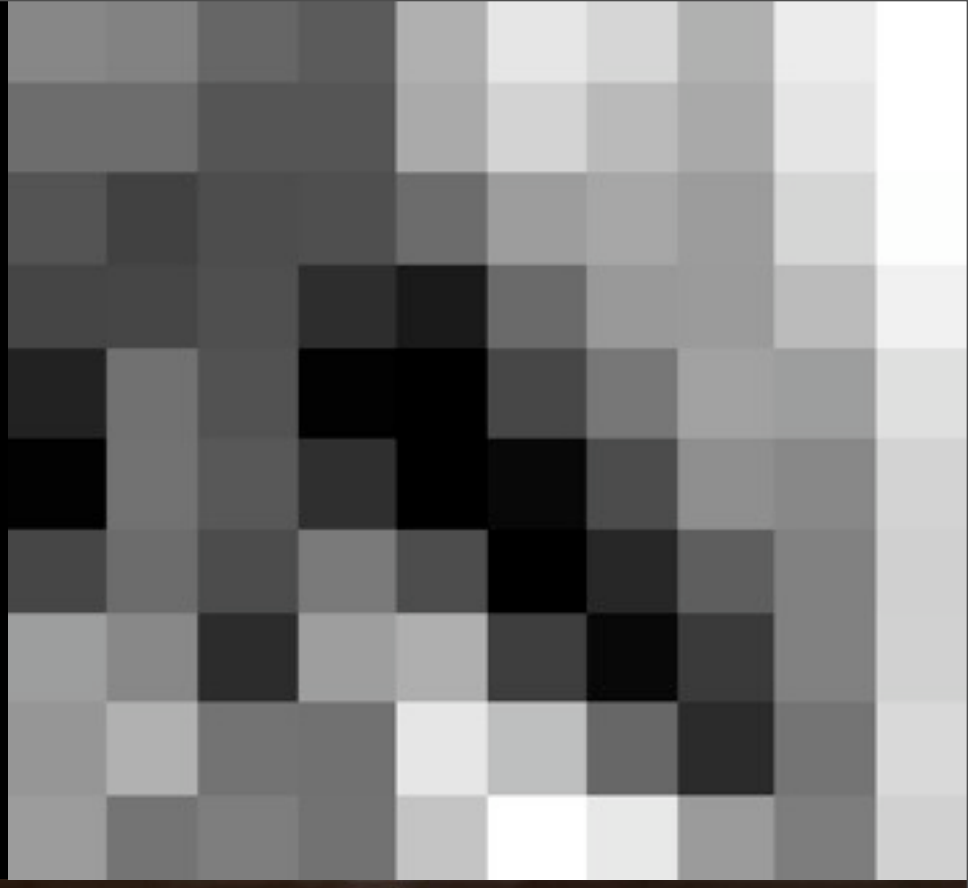
Now we use DWDM fibers long haul (10 Gbps->40 Gbps/lambda) and WiFi for the last 100 meters. Now cellular telephony is getting ever more cellular, with DWDM long haul.

Lesson: Expect surprises.

Internet Surprises (Bugs)

Quality of Service

Security



Economics

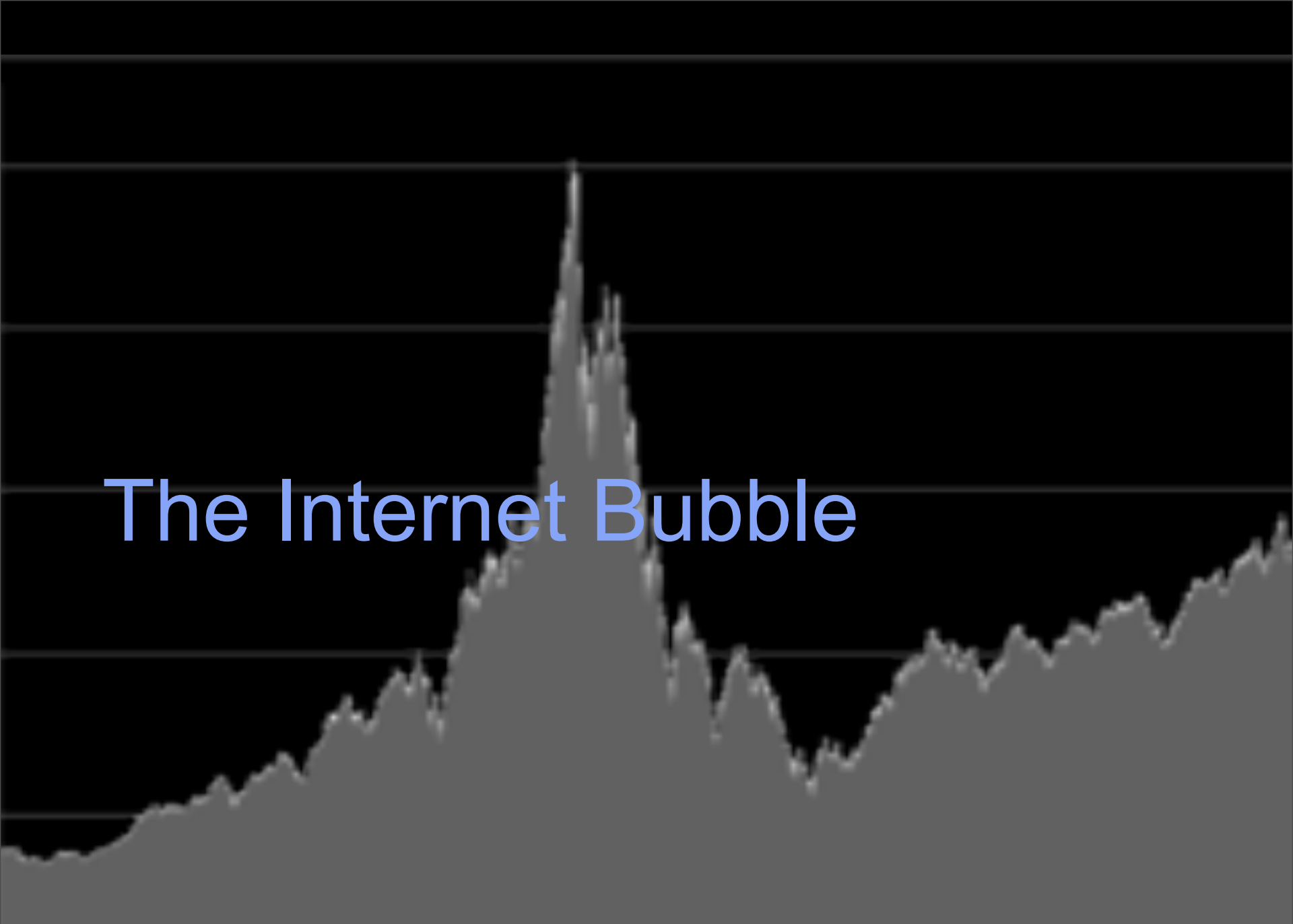
Enernet builders beware. Learn from the Internet. Because the Internet was designed by graduate students starting in the 1970s, it has three major flaws, even today.

Security. Graduate students live protected lives, so they did not build security in. In fact, they made anonymity the default. Today we have spam, viruses, denial of service, and identity theft.

Economics. Graduate students are not paid much, but after that, they get everything for free. So, economics had to be added later. From free (first from the government and later from venture capitalists), to subscription, to advertising, to pay per view. What we need is micropayments infrastructure, but of course this requires security. See above.

Quality of service. Graduate students had Model 33 teletypes in the beginning, and the goal was to get typed characters across the USA in under half a second. Then came upper and lower case. Fonts. Bit maps. Pictures. Sounds. Audios. Movies. Throwing cheap and clean bandwidth at the problem has worked for a long time, but now we are adding quality of service for interactive video.

Let’s make new mistakes with the Enernet, not these.



Expect surprises?
A big event in Internet history was The Internet Bubble.
The Internet Bubble AKA The Dotcom Bubble burst on March 10, 2000.
I predicted it in my InfoWorld columns as collected in INTERNET COLLAPSES.
This was an easy prediction to make -- was off by only four months.
There were MANY Internet bubbles before the BIG one in 2000, and there will be many more.
Recent Internet bubbles include the Social Networking Bubble.
There were over the years PC, memory, storage, spreadsheet, wireless, VOIP… bubbles.
Thank heavens for the Mortgage Bubble; the Internet Bubble doesn't feel so bad now.
Energy?
Energy currently has it's Global Warming Bubble.

How do I know Global Warming is a bubble? Click: Al Gore -- he's back!.
He and I inflated the Internet Bubble together. He doing it again.

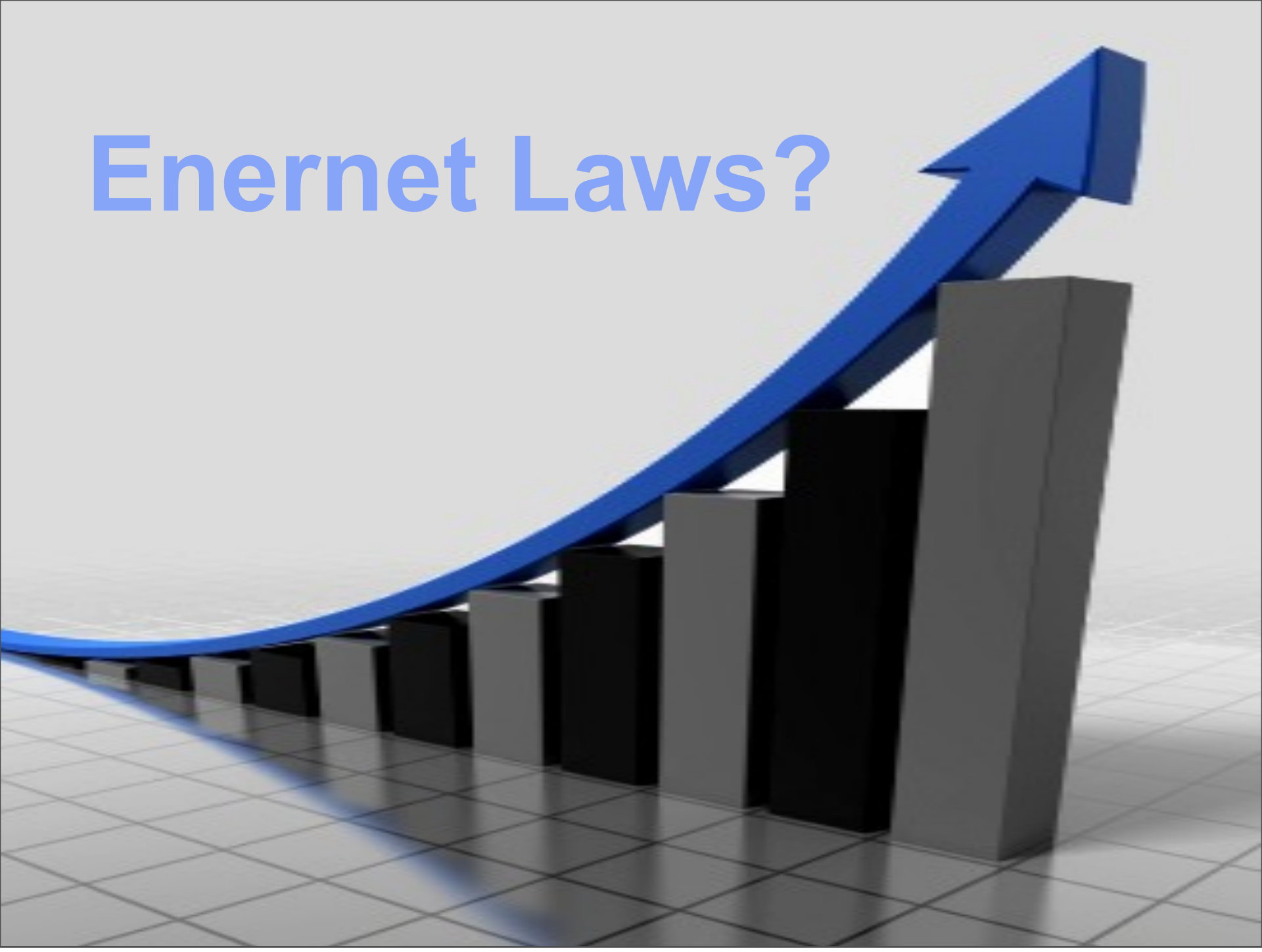
The Global Warming® Bubble

There is clearly a Global Warming bubble.
One sure sign is the phenomenon of corporate “greenwashing.”
The seven most feared words on the Internet: You just don’t get it do you.
On Global Warming we hear: The debate is over.
Those who question Al Gore are called “deniers.” Ugly.

To paraphrase Samuel Johson on April 7, 1775: Science is the last refuge of soundrels.

The big problem is that this bubble entangles two separate issues: energy and environment.
If we could control climate, we would still have an energy problem, and vice versa.

BTW, I recently climbed Mt. Kilimanjaro, reaching the summit at 19,341 feet above sea level after seven days.
We slept that night in the volcanic crator at 18,800 feet.
It was COLD, especially when Sol went down, especially with 40% of sea level O2.
But the glaciers are melting.
Of course, this being equatorial Africa, the glaciers apparantly melt after every ice age.
The mountain is about 100,000 years old; the oldest ice here (at my feet) is 11,000 years old.
In the photos, see our orange tents in the crator next to the glacier remnants.
See me by the glacier, with melt at my feet.
But, I digress.



Internet history is replete with “laws,” the most important being Moore’s Law. But we started slowly with Grosch’s Law, which proves you have to choose your laws carefully.

Grosch’s Law -- build centralized mainframes, cost goes up as square root of computing power

Moore’s Law -- integrated circuits double in density (computing power) every 18-24 months.

Grove’s Law -- telecom monopolies double available bandwidth every … 100 years (ha!).

Cooper’s Law -- cellular vs. Marconi -- wireless conversation per area double every 30 months.

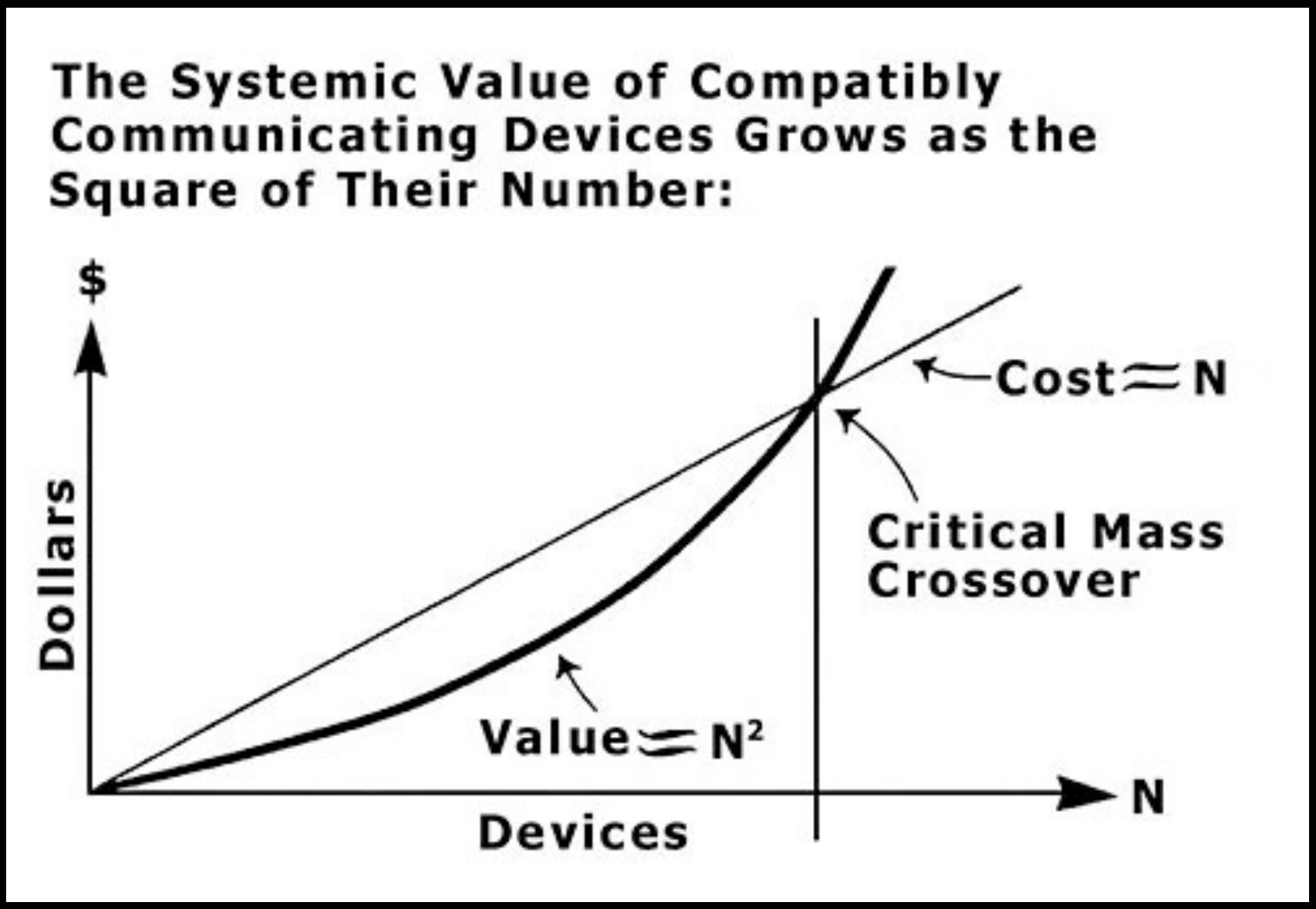
Amdahl’s Law -- Mips ⇔ Mbps

Metcalfe’s Law -- network effect (V~N^2) -- value of a network grows as square of number of users.

(even if I do say so myself)

Let’s collect Enernet Laws… Let’s ask Ray Kurzweil for enertech laws -- The Singularity is Near?

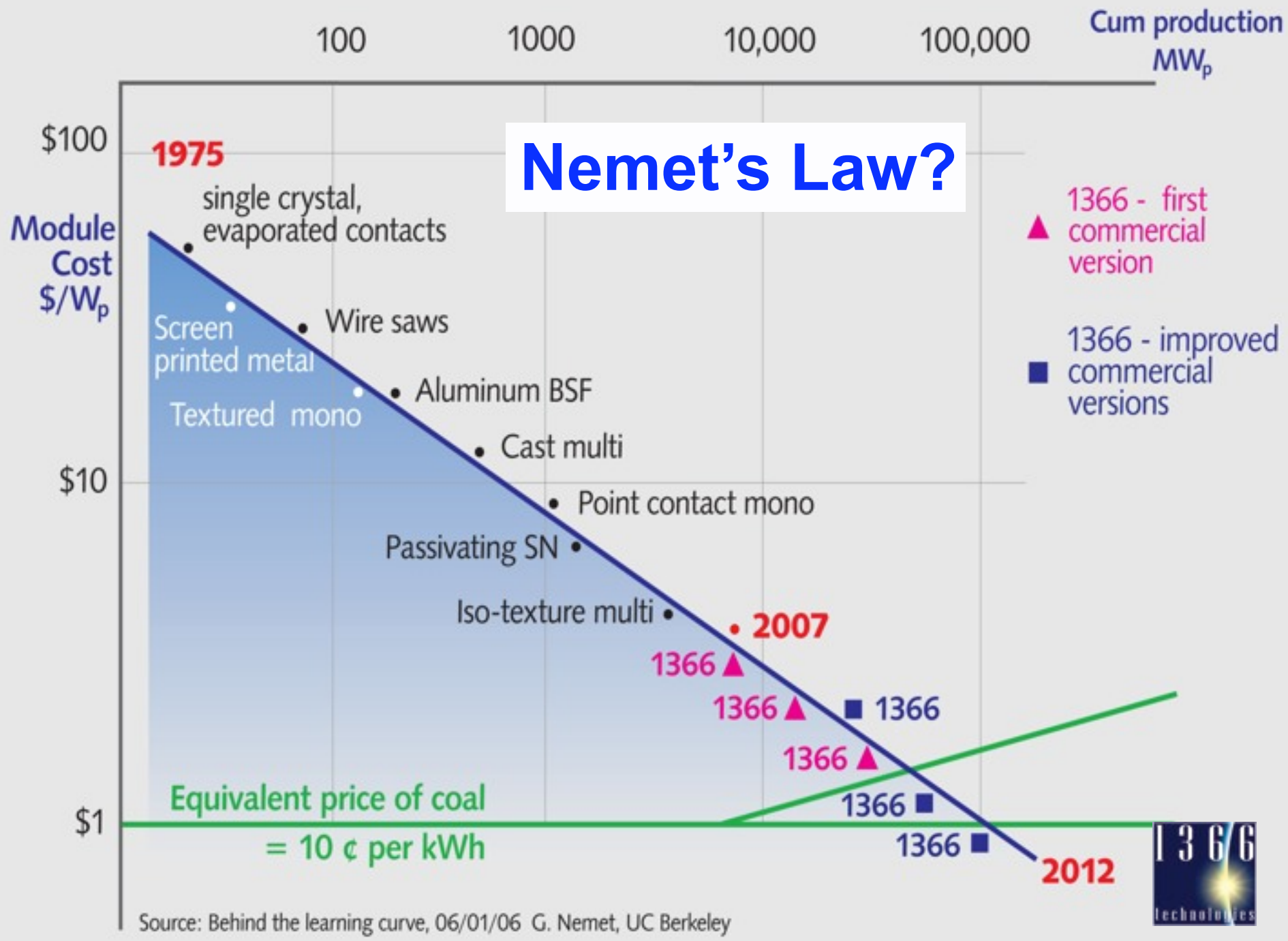
Metcalfe's Law



Circa 1980, I came up with this 35 mm slide to encourage my 3Com customers to buy bigger Ethernet networks, to enjoy network effects by growing their networks past what I called critical mass. In 1993, George Gilder, writing in FORBES, called this slide "Metcalfe's Law." I have been defending it ever since.

What if Enernet is really mostly a networking problem, a problem whose solutions will best be found by looking for them through a networking lens? And if so, might Metcalfe's Law apply to building the Enernet. Well, the so-called "power grid" is certainly a network.

What Metcalfe's Law has in common with Moore's Law is that both begin with M.



There might be a “law” about the cost of solar power ($ per peak Watt) versus cumulative production (millions of peak Watts), a “learning curve” for solar cell manufacturing costs.

This slide is from a presentation by Frank van Mierlo, CEO, and MIT Professor Ely Sachs, CTO, of 1366 Technologies, a Polaris-backed start-up in Lexington, MA. The source of the data is Greg Nemet at UC Berkeley, so maybe we should call this Nemet’s Law.

The goal of 1366 is, by 2012, to drive multicrystalline Silicon solar cells to “grid parity,” beating coal. Not oil, coal.

There may be comparable cost decline laws for wind, geothermal, fission, fusion … let’s find them.

I am sorry, but energy and the environment are NOT the same thing.

Let's be careful with our categories.

How might we be surprised and solve Global Warming tomorrow?
Who is doing research on climate control? More!
Nanotechnical Parasol Effect
and/or
Photovoltaic Parasol at L1
Like fusion, not venture backable, yet.

When we can control global temperature, let's ask the United Nations,
"What temperature would you like Earth to be, exactly?"

But we would still need cheap and clean energy.
Let environmentalists keep green. We Enernauts should move away, to BLUE.

Bubbles Are Good

Speculative bubbles accelerate technological innovation.

Try not to outlaw bubbles; just be sure to have a chair when the music stops.

We saw from the many Internet Era bubbles that investment, speculation, inflation, competition, and collapse are tools of innovators against the status quo. Bubbles accelerate technological innovation. DC's reflex (the reflex of the status quo) with each bursting of a bubble is to outlaw bubbles. This is counterproductive.

In the Internet Era, we had many bubbles, including generations of bubbles in memory, storage, LANs, wireless, PCs, spreadsheets, Internet browsers, databases, operating systems, VOIP, telecom equipment, optical technologies, programming languages, e-commerce, …

They all kept the Internet coming, against the vicious rearguard resistance of the status quo.

They go hand in hand with Christensen Disruption. The status quo declares innovations insufficient, non-standard, unsafe, and just plain HYPE!

Washington DC is a Pro-Am, and we are the Ams.

We hear that energy must develop public awareness, political will, and go to Washington for some sort of Manhattan Project, or perhaps even an Apollo Program.

Trouble is, energy is much bigger and will take much longer than that. More like a Marshall Plan for rebuilding Europe.

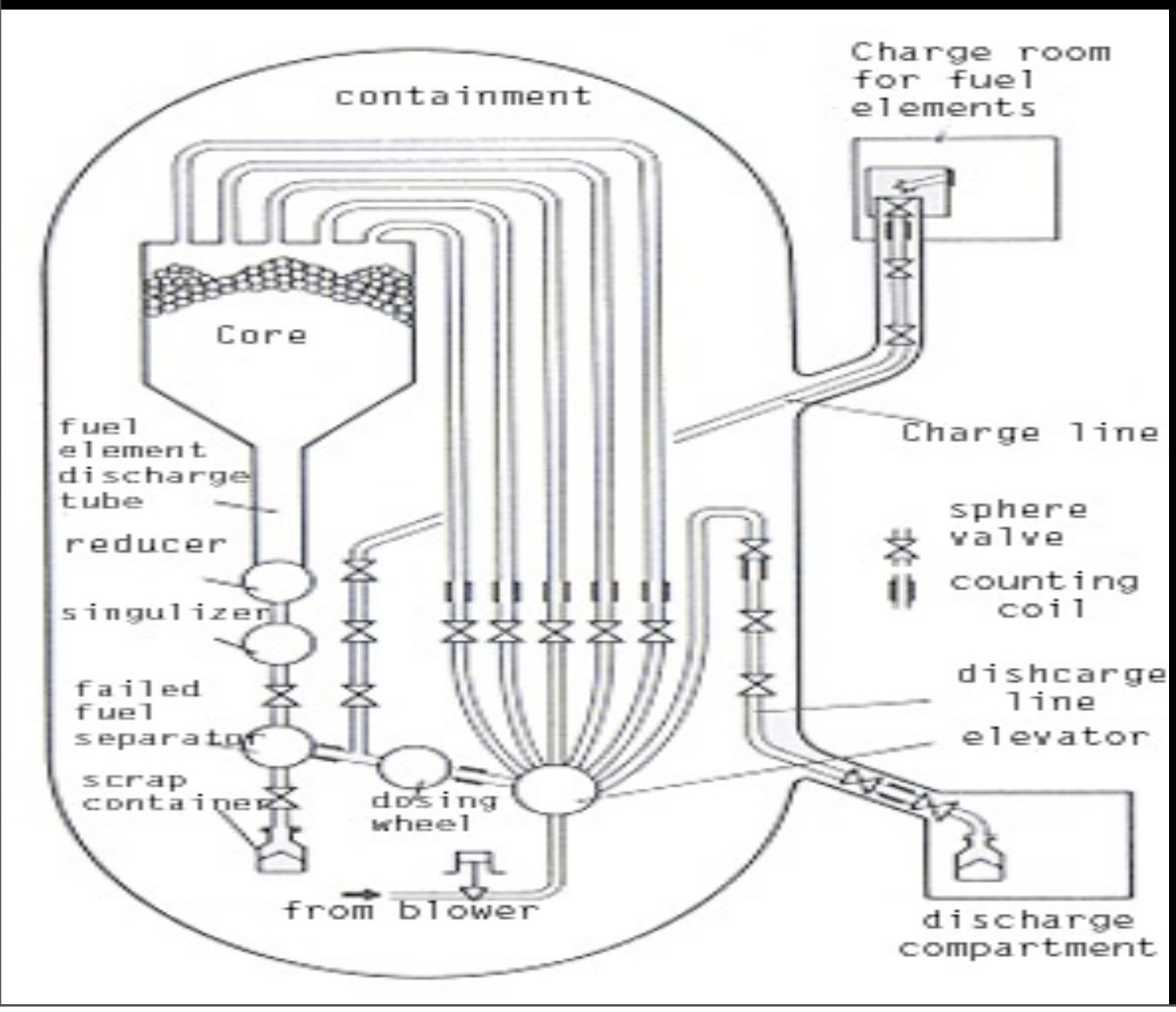
Plus, the status quo runs Washington, through lobbying and litigation, so often, when you go there to get stuff, you get the wrong stuff, for example corn ethanol. Other examples would include prohibition of oil exploration, refineries, and nuclear, for the last 30 years, and dropping fundamental research projects (solar, algae, …) when the price of oil went down again.

The last time we went to Washington for energy, we got DOE, a huge series of earmarks and government jobs programs that leave too little oxygen for energy innovation.

DOE created by Jimmy Carter some 30 years ago to reduce our dependence on foreign oil. DOE employs 10s of thousands with a budget heading past $20B/year. Are we using less foreign oil?

This March On Washington impluse is overpowering right now, with all the change, hope, and shovel-ready stimulation going on in DC today. Leave me out of it.

Nuclear is coming back.



And then there are the opposite of bubbles. Anti-nuclear is such an opposite, thanks to Greens. The US has 104 large fission reactors providing 20% of our electricity. France has about the same number providing about 80% of their electricity -- the lowest carbon footprint in Europe. And yet, our NRC has not approved a new reactor in 30 years.

Robyn and I decided to watch the anti-nuke movie that seems to have shut down nuclear in the US. Confused, we first watched Chinatown, but that was about water. Then we watched The China Syndrome, in which nuclear scientist Jack Lemmon is killed not by a meltdown, not by any kind of radiation poisoning, but by policemen with guns. With Jack Lemmon were Jane Fonda, Michael Douglas, and Wilford Brimley.

Physicists are taunted by the fusion reactor that flies daily across the sky; maybe it's best we keep it 93 million miles away and beam in the small amounts of energy we need.

Earth is itself a huge fission reactor; maybe it's best we energize geothermally.

Pebble bed reactor shown. Several distributed nuclear start-ups are making the rounds, both fission and fusion. If only there weren't all this regulatory risk due to greenish intervenors and the undue processes of law.

Economics – manufactured

Safety – no meltdowns, self regulating

Proliferation – nothing weapons grade, <20%

Waste -- recycled

Scale -- distributed, right-sized

Are fission and fusion blue too?

BTW, here is a photo of the inside of a nuclear reactor.

Notice that the color is BLUE.

This due to “photonic boom” as radiated particles exceed the speed of light in the water.

Washington did actually help the Internet.

Washington isn't all bad. Washington did help the Internet.

Tax Reductions: capital gains taxes were cut in the early 1980s, giving rise to venture capital for many of the companies that built the Internet, including my own, 3Com.

Demonopolization: Carterfone in 1968, AT&T breakup in 1984. Continuing anti-trust oversight of IBM, which signed a consent decree and was restrained from previous anti-competitive activity.

Lead customer: DCA MILNET… Ethernet became a FIPS standard.

DOD/ARPA standard TCP/IP/Ethernet vs. Commerce standard ISO/ISDN?

But most importantly: Federally Funded Research: ARPA, NSF, DOE…

Where is research best done?

Not by corporations, because only monopolies can afford research:

- Bell Labs thanks to AT&T's telephone monopoly
- Watson Labs thanks to IBM's computer monopoly
- Parc thanks to Xerox's copier monopoly
- Microsoft Labs thanks to the PC software monopoly

Monopolies overcharge their customers, but worse, are not motivated to market innovations.

Government labs? Geographical earmarks and government jobs programs. E.g., DOE.

Where?

From Internet history I learned that the best place to put our research dollars is at competing research universities vying for government grants.

Because they graduate students.

There are about 10 such research universities around Boston alone, including my favorite, MIT.

Please stop saying that there are no silver bullets.
Put that energy into discovering and inventing them, please.

IBM punched cards (cellulosic computing)
Transistor and Integrated Circuit
Interactive time-sharing minicomputers
Bit-Mapped Display, Mouse, WYSIWYG
TCP/IP and Ethernet
World Wide Web and Mosaic
Lasers, Optical fibers, DWDM
Google
Cellular
…

After packet switching itself, thanks to Paul Baran and Donald Davies circa 1960, there's DWDM. Prior to DWDM my mother would say "call when you get back to Boston, but hang up after three rings so we don't have to pay for the long distance call." Now we call almost anywhere all the time, and get the Video Internet to boot. Worldwide. As many rings as we want.

CISCO SYSTEMS

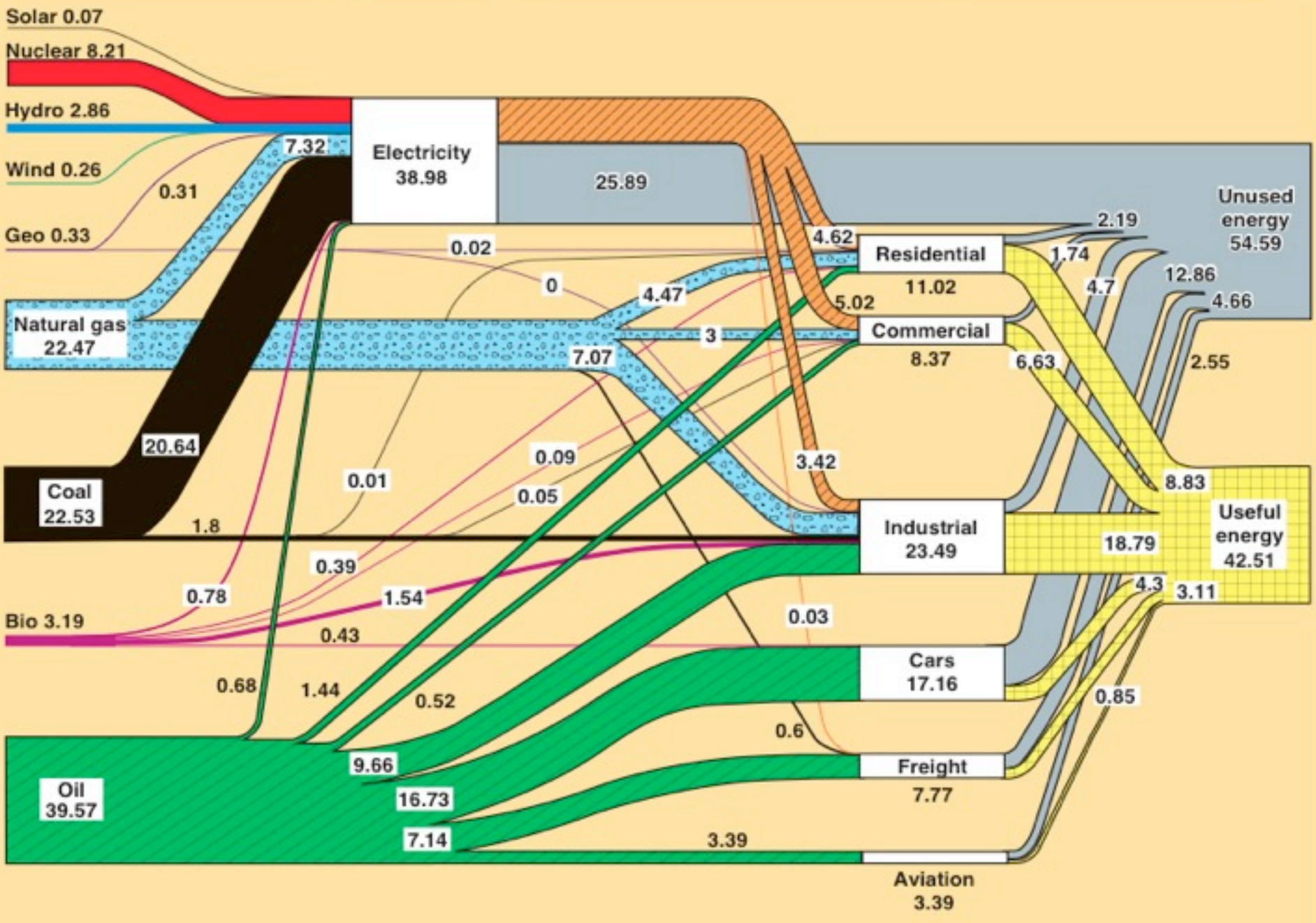
Perhaps THE Internet company, Cisco Systems was founded in 1984 by Sandy Lerner and Len Bosack, out of the Computer Science Department at Stanford University. John Morgridge, after a career at Honeywell Information Systems, Stratus Computer, and Grid Systems, became Cisco employee 34, taking the company as CEO from $5M to $1B. Venture Capitalist Don Valentine of Sequoia backed Cisco and later famously fired Lerner, after which Bosack quit.

Innovation Vehicles

Competing teams:
research professors
graduating students
scaling entrepreneurs (product engineers, manufacturing, SALES, marketing, finance, administration...)
and, yes, venture capitalists.

My favorite among many examples: (sorry these all look like white men)
Akamai, a Polaris-backed start-up out of MIT.
MIT Professor Tom Leighton
Students Danny Lewin (RIP since 9/11) and Jonathan Seelig
CEO George Conrades, former president of IBM USA, Polaris partner

Estimated Energy Usage in 2006 ~97.1 Quads



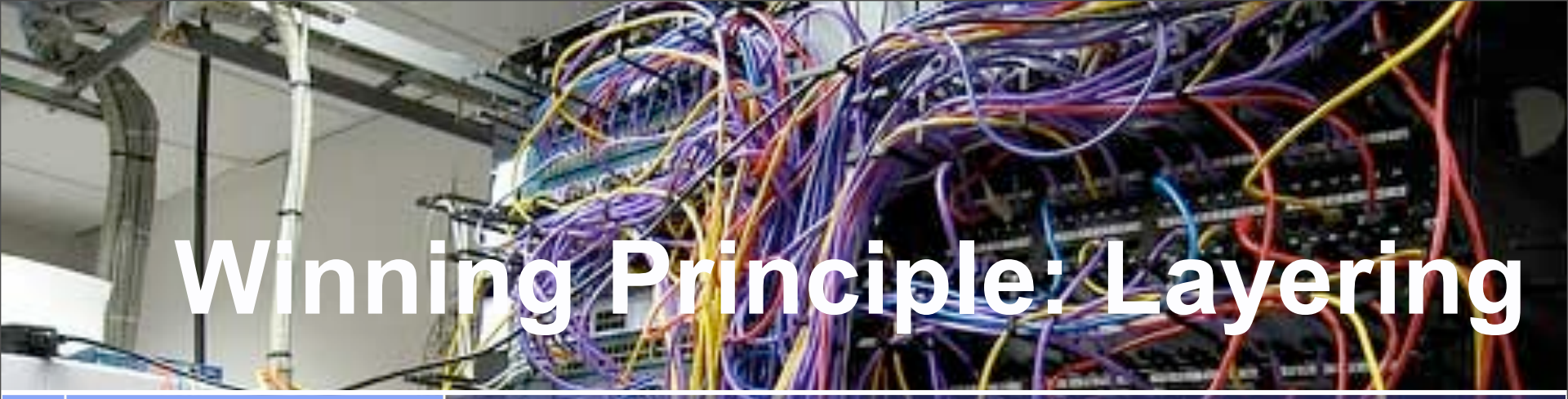
Focusing on the USA, here are 2006 energy source and usage estimates from the excellent National Academies report, “What You need To Know About Energy.”

Go see http://sites.nationalacademies.org/energy.

There is some danger of hardening of the categories here… where are the algae?

According to DOE, more solar energy falls each day on the USA than we use in a year. Incident solar energy is 37 * 10^{16} kWh/year or 46,700 Quads/year, which is, get this ~500 times (=496.28) more than the 97.1 Quads above for 2006. Over the whole Earth, the multiple is ~10,000. Solar has a low floor (.07 shown), but a high ceiling (10,000x).

Look at this huge, old, and very slowly evolving system, with many pieces, levels, connections, interfaces, standards… We Enernet innovators could easily be overwhelmed, not just by the down and dirty status quo, but by the complexity of it all. What to do? How to manage all this complexity while evolving it? What worked for the Internet?

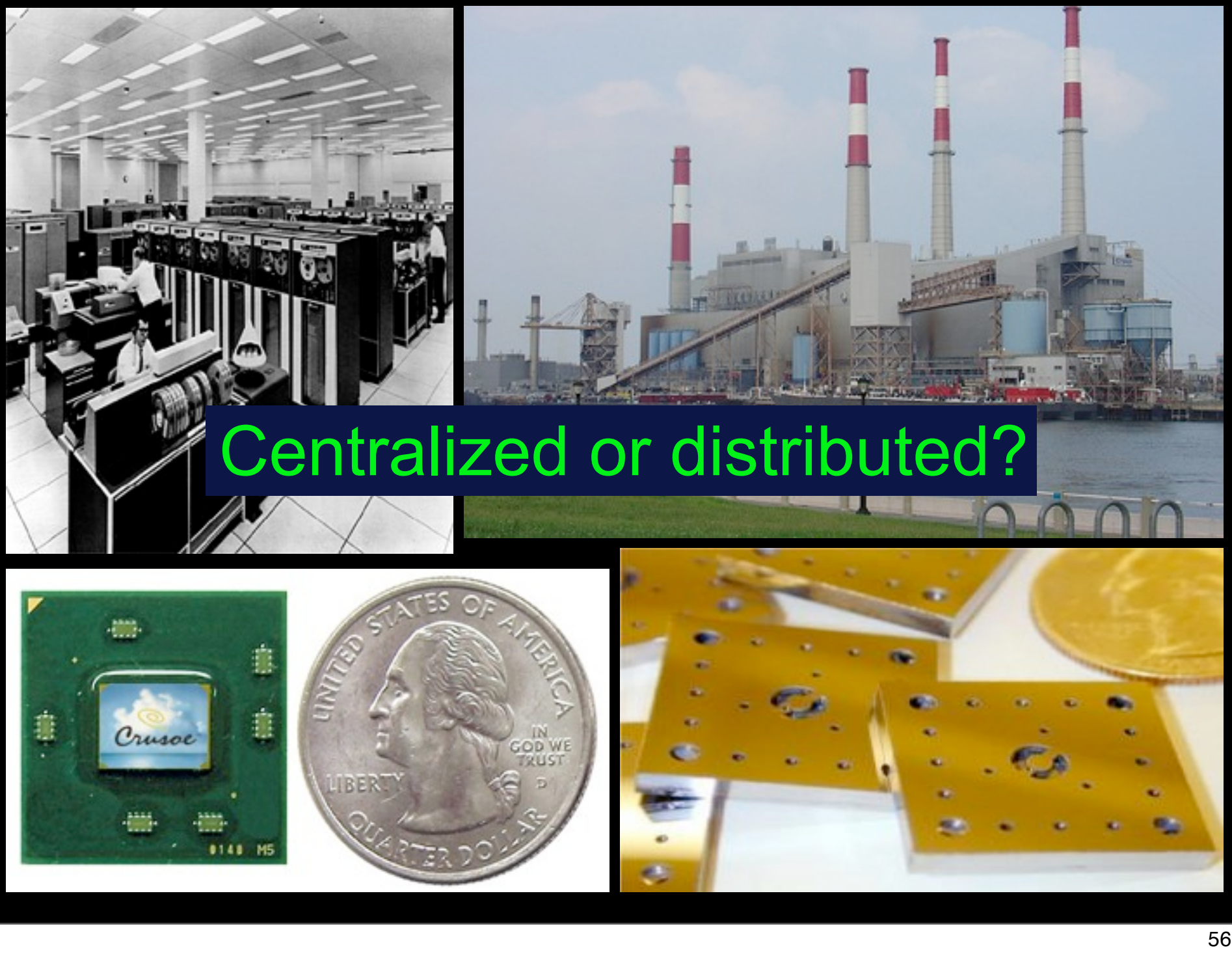


Winning Principle: Layering

7	Application	Telnet, FTP, Email, Usenet, Netscape, Yahoo, Amazon, eBay, Google, Avistar, YouTube, Skype, WordPress, MySpace, Facebook, Warcraft, Quake, Second Life, Ember, EnerNOC, …
6	Presentation	HTML, MPEG
5	Session	DNS, URL
4	Transport	TCP, UDP, HTTP
3	Network	IP
2	Link	Ethernet
1	Physical	Coax, copper, fiber, wireless…

Internet history demonstrates the enormous power of of LAYERING. The Enernet should have layered ARCHITECTURE.

Layering, a winning principle of Internet development: 7 layers of the ISO reference model.
How many layers? An art of system architecture. More or four: Google, Web, Internet, Ethernet.
Technologies develop independently at their own speed.
Specialization: One can live a rich full life at one layer, as I pretty much did with Ethernet.
Generality: each layer is an occasion for interface design, inviting generality.
Standard interfaces and technologies can be developed and interchanged.
Standards (also an art) focus investment to lower costs, to increase value through connectivity.
Serendipity is encouraged, innovation accelerated.
The energy system is much more complicated.
Careful systems design and standardization (but not too much) can help a a lot.



Will we progress to having fewer-larger-centralized or more-smaller-distributed power plants?

If the Internet is any guide, in the future we'll have more smaller DISTRIBUTED power pants.

Upper left is an IBM 7094 mainframe, like the 36-bit IBM I programmed at MIT in 1964.

Lower left is a modern microprocessor, 1000++ times smaller and more powerful.

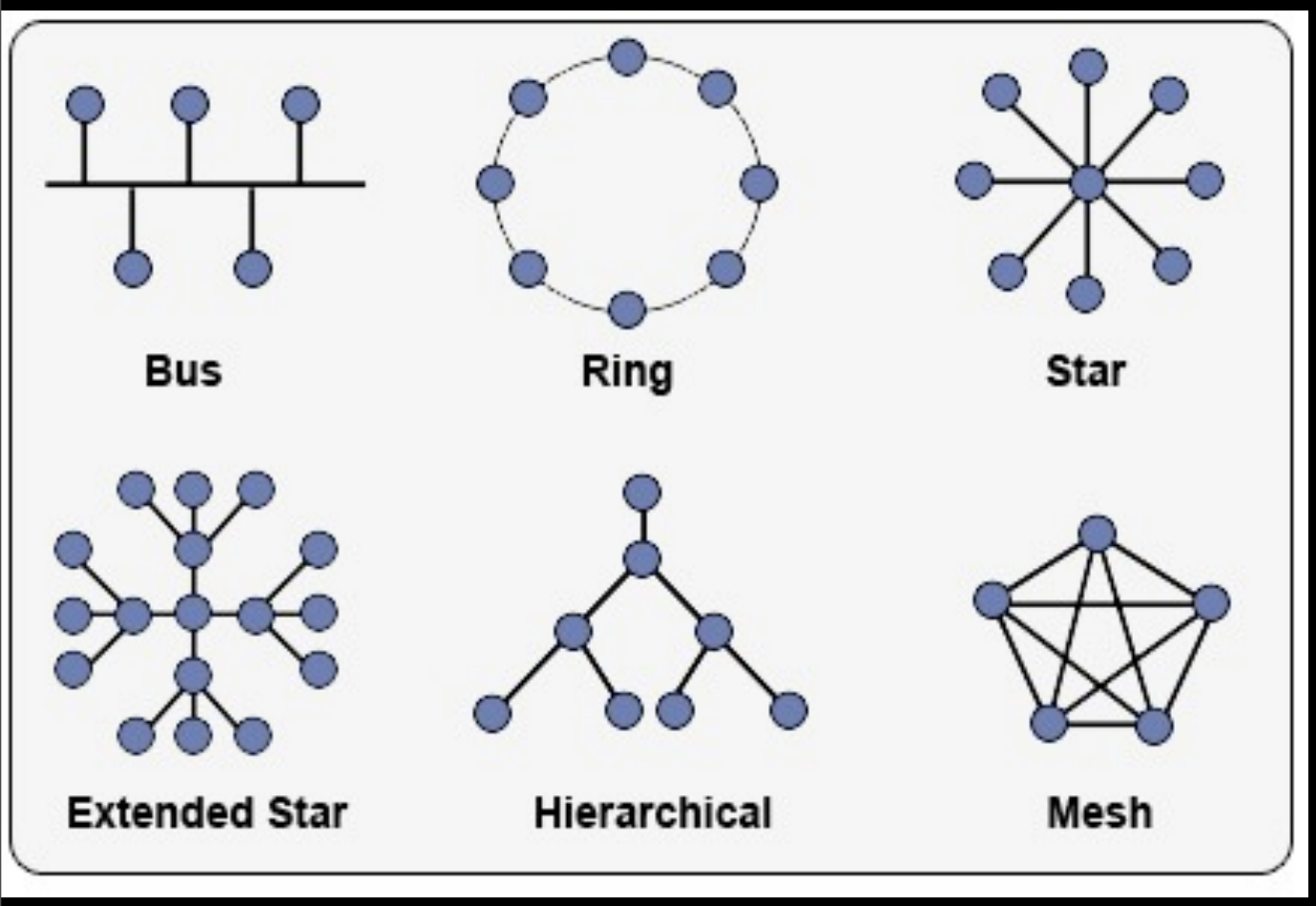
Upper right is a modern centralized power plant that distributes electricity through the grid.

Lower right is an MIT micro gas turbine that might generate electricity for use right there, off grid, and/or from time to time contribute power to the grid.

This may be Internet history's killer lesson for energy: Go distributed!

Not centrally generate power and then distribute it, but generate power in a distributed system.

Network Topology?



Not just distribution -- networked, symmetrical.

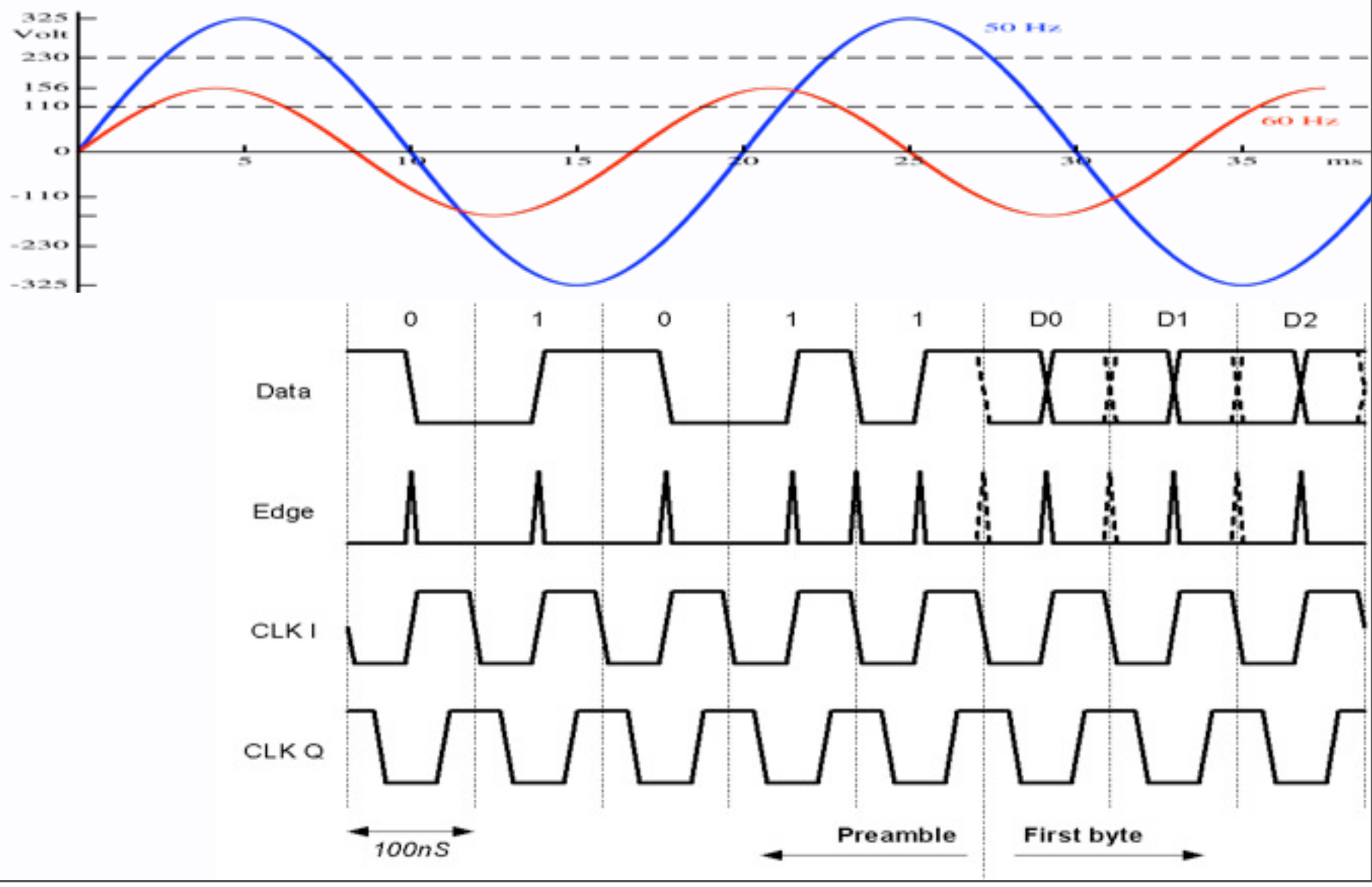
Our energy systems already have grid topology through which energy is distributed. How we further develop energy grids can be informed by Internet history. Layering, for example.

Today we talk about energy “distribution,” from central power plants down to light bulbs, which is slightly different from having distributed energy, much of which is not on the grid, like standalone PCs used to be. Enernet energy is more likely to be EXCHANGED than distributed.

Distributed energy (in the Internet sense) means the grid become more peer-to-peer, more multi-vendor, with more standards, more competition (FOCACA). The transmission of energy then become more networked, and more symmetrical, more among than between. I want my home and car energy systems to be able to buy energy from power grids, but also to sell. Radios and TVs are being replaced by PCs, which upload, not just download. Ditto nodes in energy grids.

Build it, and they will come; don’t, and they won’t.

Asynchronously switched DC grid?



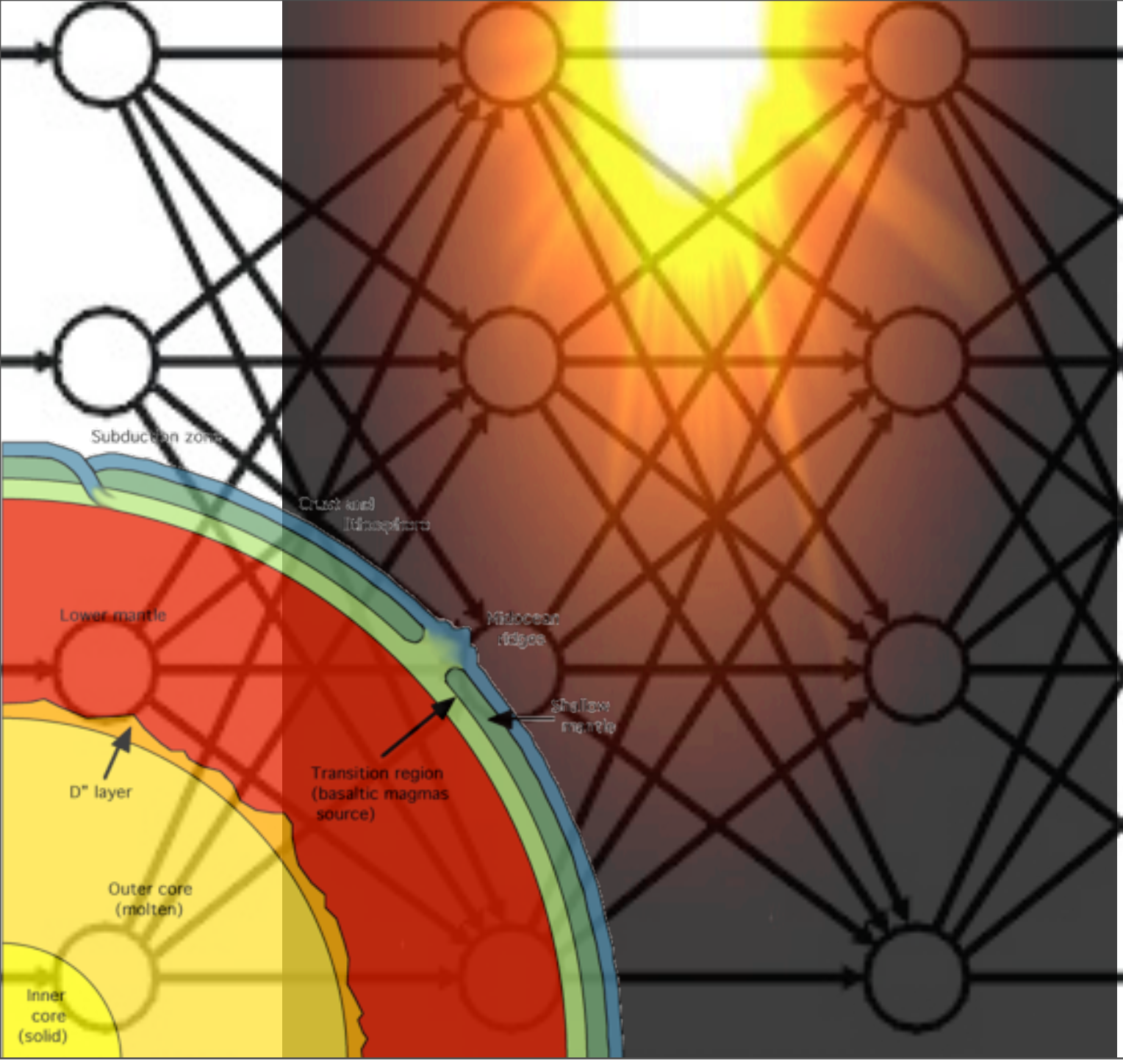
The Internet has for decades been slowly replacing old telephone infrastructure, today based on SONET -- a “synchronous optical network” hierarchy optimized for switching 64 Kbps digital telephone conversation circuits. The Internet’s Ethernet plumbing is optimized for carrying digital data packets ASYNCHRONOUSLY. Ethernet packets carry their own clocks, so that the whole worldwide Internet does NOT have too be synchronized. Ethernet is replacing SONET.

Today’s electricity grid is synchronous, 60Hz-110V AC in the US, because of lighting, motors, and transformers in the days of Edison and Westinghouse. But AC makes the grid fragile and inefficient. By analogy, for a new Enernet, maybe we should consider standardizing an asynchronously switched grid, say switching packets of DC power.

Internet switching deals well with high peak-to-average ratios -- getting efficiency by asynchronous statistical multiplexing. But with varying supply and demand, the Enernet is getting high peak-to-average ratios too. Enernet packet switching.

Surprise: Since electricity goes almost everywhere, in the early days of Ethernet we tried (and generally failed after repeated attempts) to carry Ethernet over “powerline carrier” -- using installed 60Hz electricity wires also to carry digital data packets. A surprising recent development is an emerging standard called Power Over Ethernet -- 48V-15W DC over Ethernet copper cable pairs along with data packets. Are we seeing early signs of CONVERGENCE between information and energy, between bandwidth and power?

The pre-Internet telecommunications grid was synchronous and storageless.
The Internet is asynchronous and has all kinds of storage. Ethernet has its clock in each packet. Imps had core.
The Dumb Grid is, yes, synchronous anbd storageless.
If the Internet is our guide: Desynchronize and storify the Smart Grid.



Overplaying Internet lessons so far, I see an Enernet in 63 years
that is mostly a distributed, layered, symmetric, asynchronous, switched DC power grid,
with networked intelligence extending to trillions of leaves of the smart grid,
with energy harvested and stored, off, on, and in the grid,
from Sun's fusion reactor, using distributed solar harvesters,
from Earth's fission reactor, using distributed geothermal harvesters,
from man-made distributed and perhaps mobile fission and fusion reactors,
networked with electricity and information, including robotransport on demand,
with squanderable abundant, cheap and clean energy providing
clean water, space travel, ..., freedom, and prosperity for all.
God Bless America.

Questions? Comments? Corrections? Ideas?

Bob Metcalfe

Dr. Robert M. Metcalfe is a venture capitalist, with Polaris Venture Partners in Waltham, MA since 2001. Bob is a director of Polaris-backed technology start-ups including 1366, Ember (chairman and past CEO), GreenFuel (chairman and past CEO), Infinite Power Solutions, Mintera, SiCortex (past chairman), SiOnyx, and Sun Catalytix.

Bob is also advisor/director/trustee to Avistar (NASDAQ: AVSR), National Academy of Engineering (Audit Committee), St. Mark's School, Singularity University, USC Stevens Institute for Innovation, Massachusetts Institute of Technology (MIT '68, Life Trustee), and MIT's Technology Review Magazine, McGovern Institute for Brain Research, Energy Initiative, Electrical Engineering and Computer Science Department, Dean of Engineering, and Dean of Science.

Metcalfe's career is technological innovation, where he is best known for inventing Ethernet (1973), founding 3Com (1979), and writing eight years of Internet columns in InfoWorld, collected in his book, INTERNET COLLAPSES (2000), still available down the long tail at Amazon.com. In a culmination of the American Dream, President George W. Bush invited Bob to the White House in 2005 with his parents, Ruth C. and Robert I. Metcalfe, to receive the National Medal of Technology, for "leadership in the invention, standardization, and commercialization of Ethernet." Bob shares four expired patents on Ethernet, of which, according to IDC, 350 million new switch ports were shipped in 2008, and that's not counting WiFi.

Bob was born in Brooklyn in 1946, and after 22 years in Silicon Valley, now lives with his family in Boston and Maine. Actually, the kids are off to university, but we keep their rooms for them.

Questions, corrections, and comments are welcome, and might even get answered by email at Metcalfe@PolarisVentures.com. Twitter BobMetcalfe.

Polaris Enertech Portfolio

1366	Manufacturing of efficient mutlicrystaline Si solar cells.
Athenix	Agricultural biotechnology for ... biomass conversion.
Ember	ZigBee wireless networking for energy management.
GreenFuel	Algae-solar CO_2 recycling for feed, food, fuel, chemicals...
Infinite Power	Flexible solid-state Li-ion rechargeable micro-batteries.
Mintera	40-Gbps fiber-optic systems for carrying bits, not atoms.
Nanosys	Nanotechnology for ... fuel cells and solar cells.
Paratek	Tunable ceramics for ... energy efficiency in cellphones.
SiCortex	Open clusters for energy-efficient green supercomputing.
SiOnyx	Black Silicon for photodetectors, cameras, photovoltaics.
Sun Catalytix	Catalysts for converting sun and water into fuels.
SustainX	Distributed energy storage using compressed air.
Wakonda	High-volume thin-film solar cells on flexible substrates.

Polaris Venture Partners in Waltham, MA and Seattle, WA is a diversified venture capital firm. This list of some of our 100+ portfolio companies is a judgement call by me. Some of these are pure enertech companies. Others have a variety of applications including enertech. OK, SiCortex is a supercomputer company, but it's a GREEN supercomputing company -- very low electricity consumption. And OK, Mintera is a telecommunications company, but it's on the list mainly so I can have ALL of my current portfolio companies on this list, and it gets here by offering the next generation of Internet core data transmission at 40 Gbps per lambda, which allows even more substitution of Internet communication for energy-consuming transportation -- sending bits instead of atoms. VCs often tout their portfolios, but I will not today, unless you force me to.