Artificial Intelligence and the Future of Cognitive Enhancement

Trent McConaghy, PhD
Founder & CTO @ Solido

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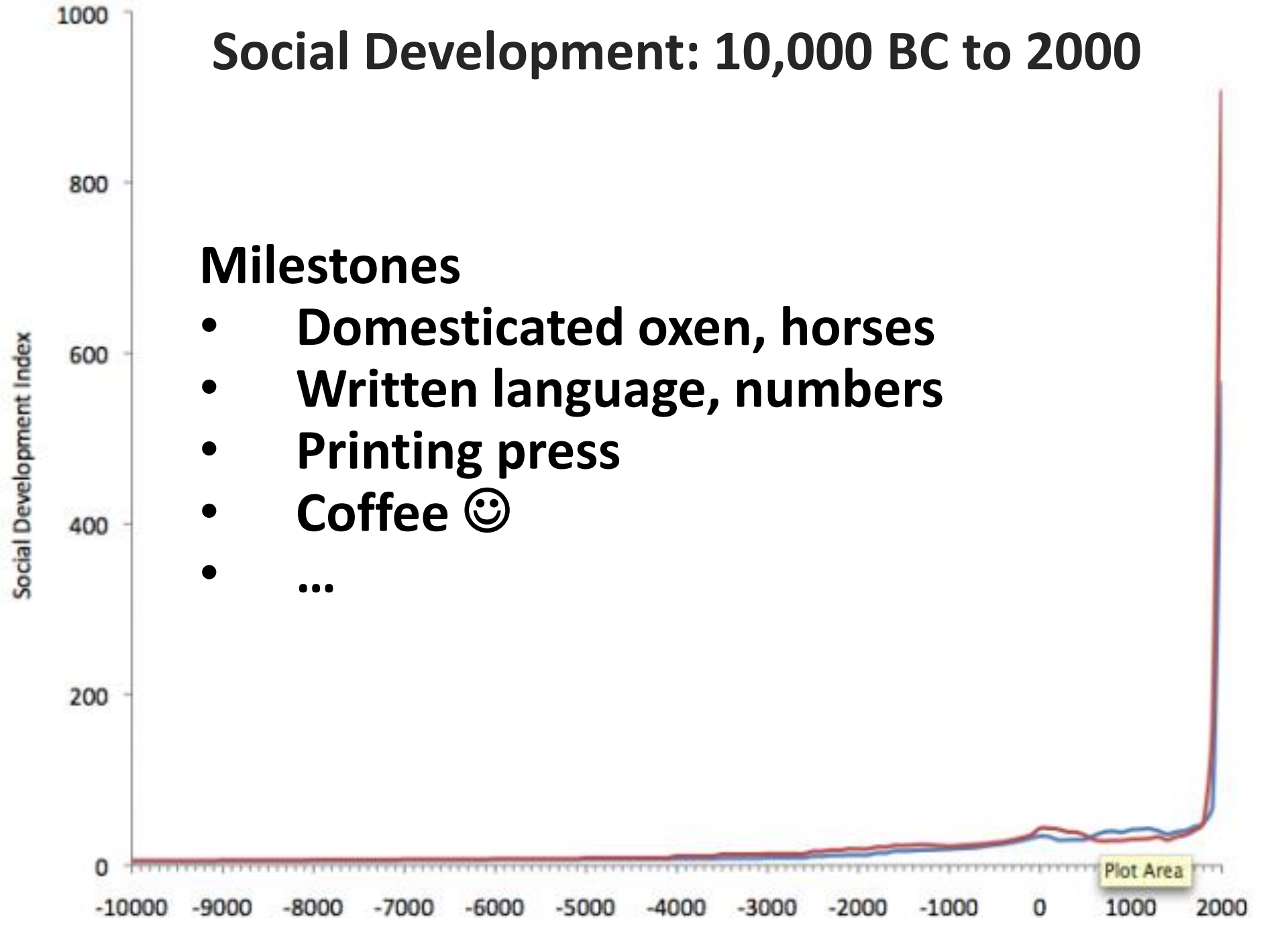
DESIGN AUTOMATION

Social Development: 10,000 BC to 2000



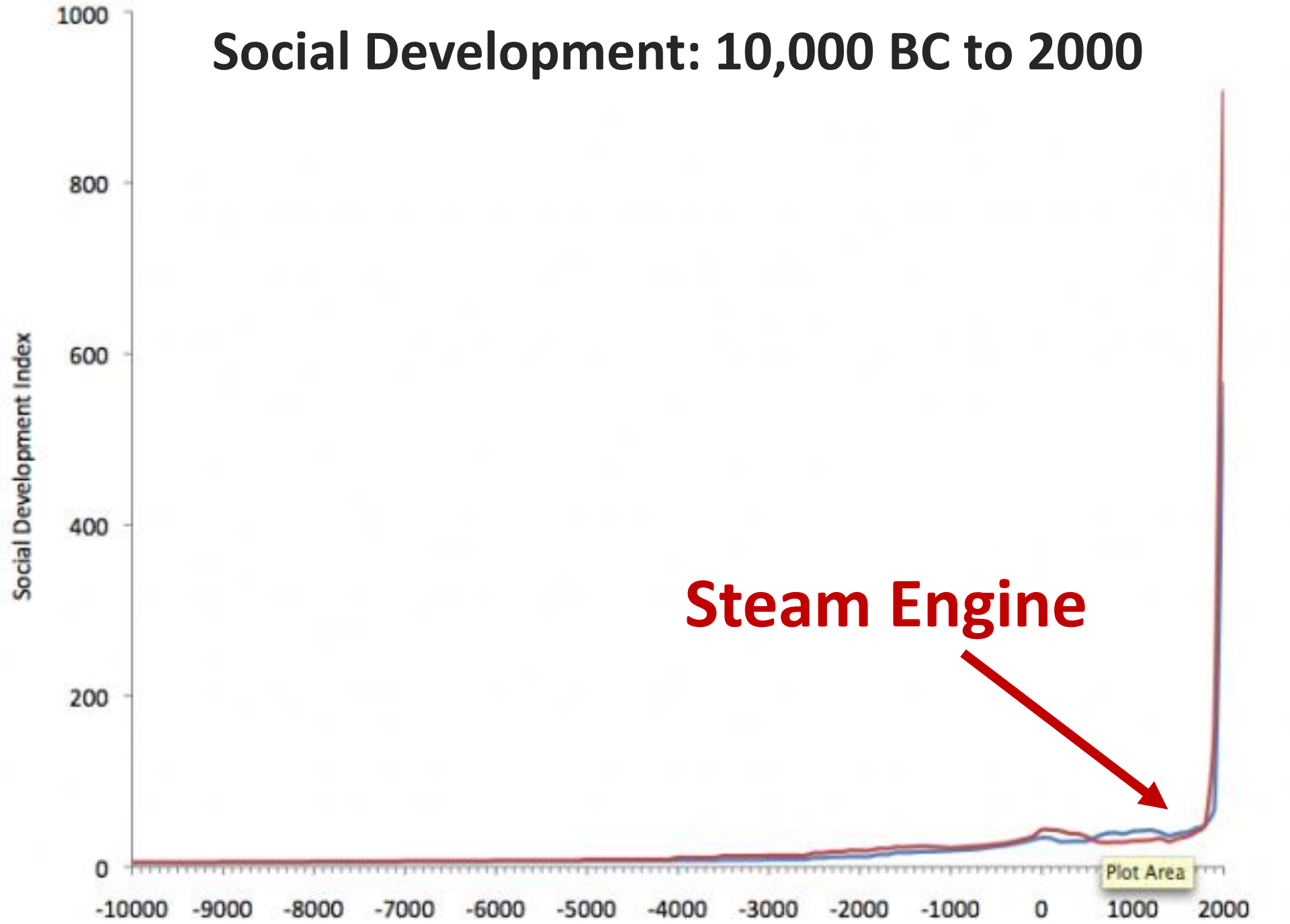
Milestones

- Domesticated oxen, horses
- Written language, numbers
- Printing press
- Coffee ☺
- …

I. Morris, Why The West Rules, 2010

http://andrewmcafee.org/2011/06/mcafee-industrial-revolution-computerization-human-development/

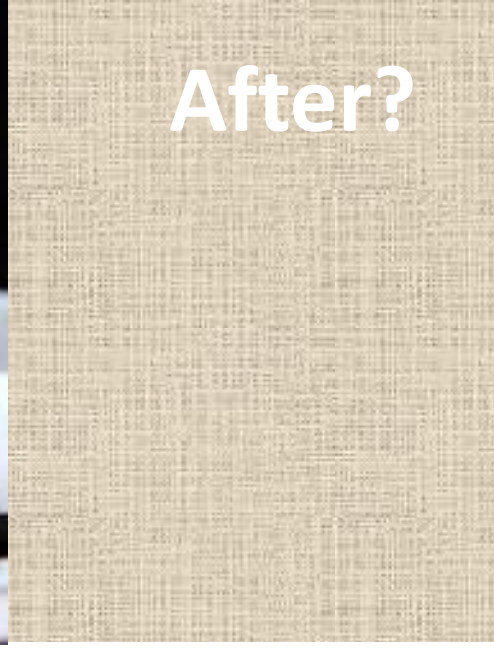
Social Development: 10,000 BC to 2000



I. Morris, Why The West Rules, 2010

Machines augmenting muscles
= Industrial Revolution
= First Machine Age

Everything changed.



Machines augmenting brains

= Second Machine Age

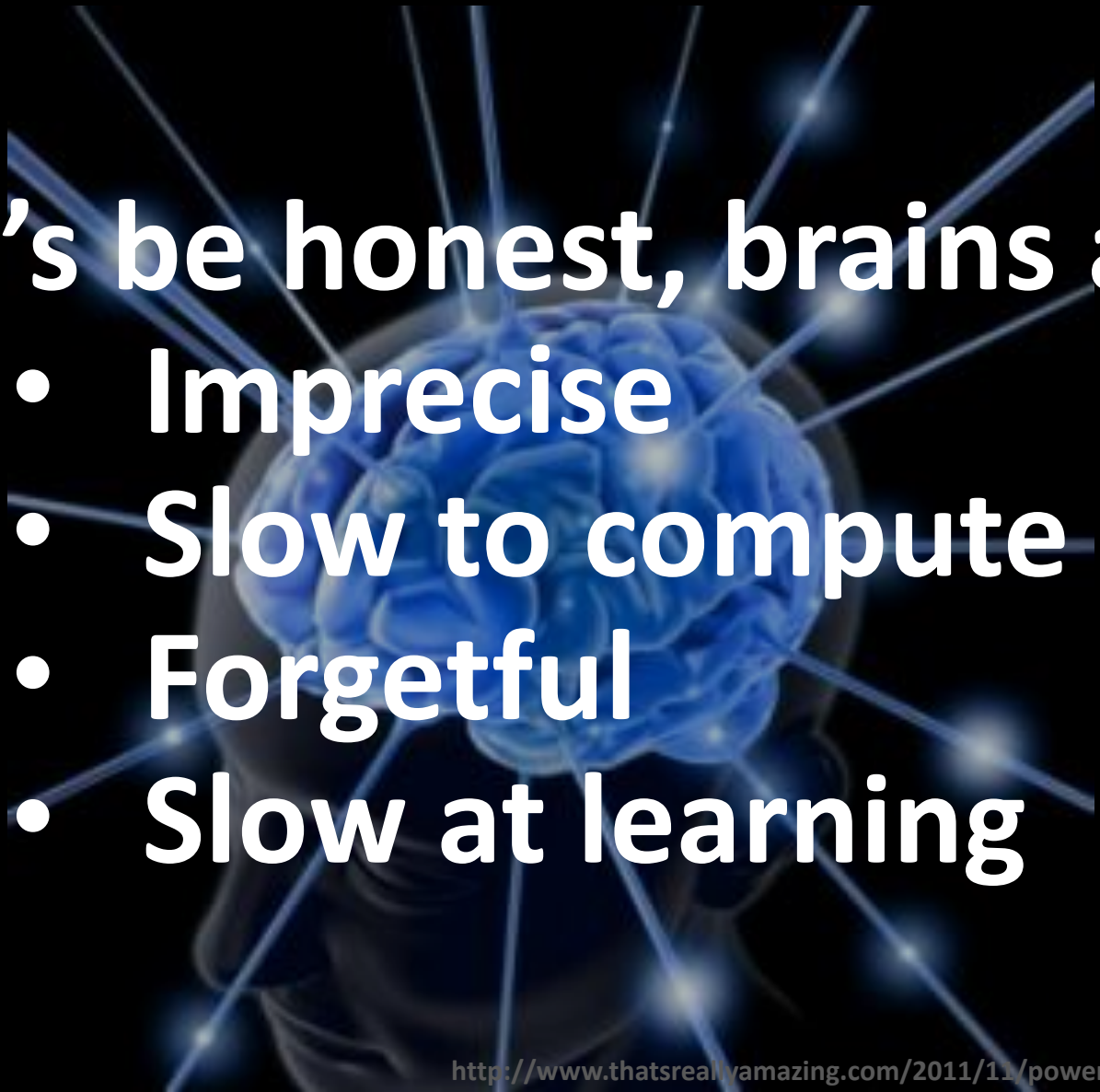
=*Cognitive Enhancement*

Intro to Cognitive Enhancement (CogE)

Sometimes, our brains fail us.

Sometimes, our brains fail us.

~~OMG, brains are AMAZING!~~

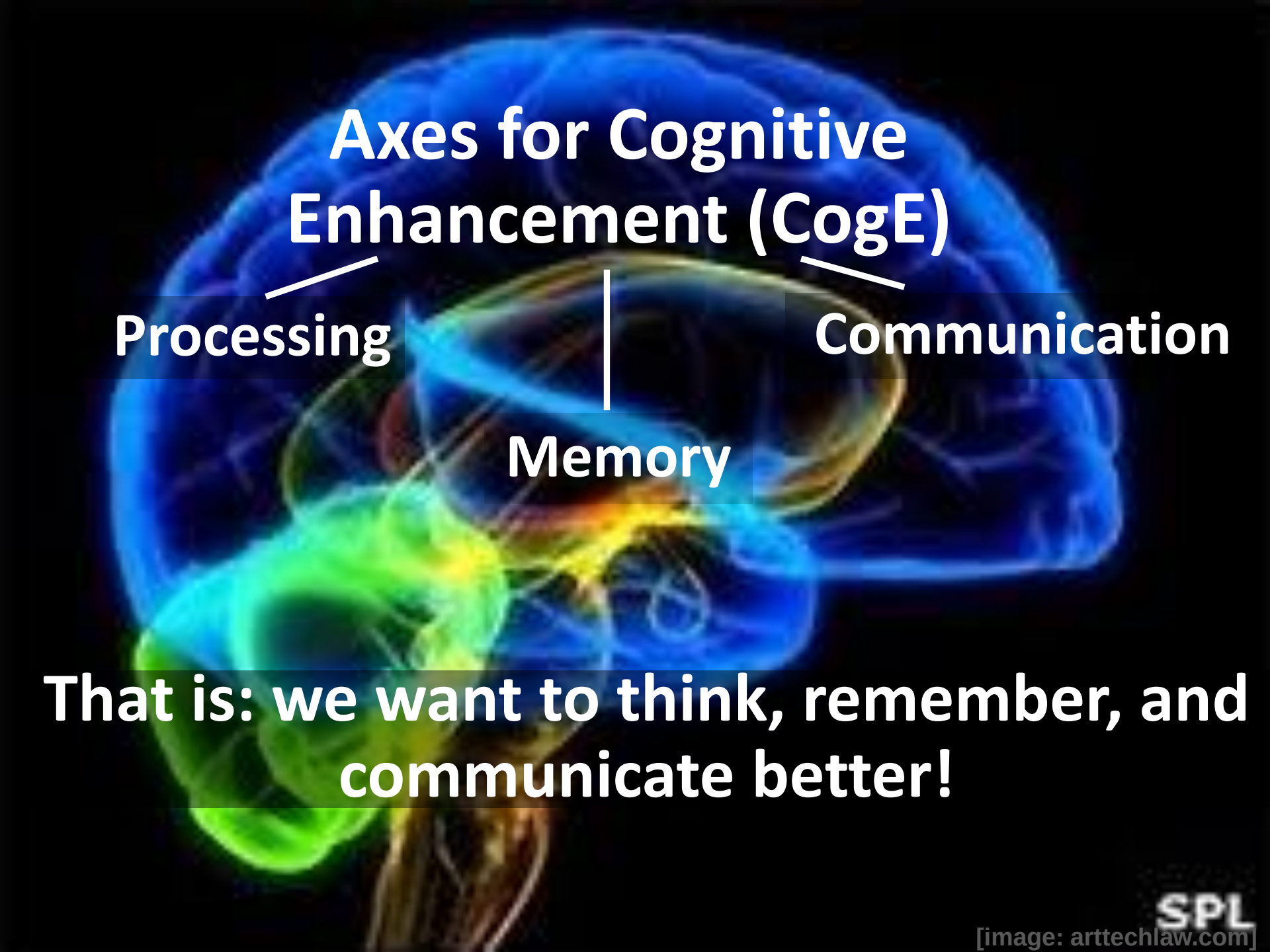


Let's be honest, brains are:

- Imprecise
- Slow to compute
- Forgetful
- Slow at learning

http://www.thatsreallyamazing.com/2011/11/power-of-human-mind-amazing/

Simple Cognitive Enhancement

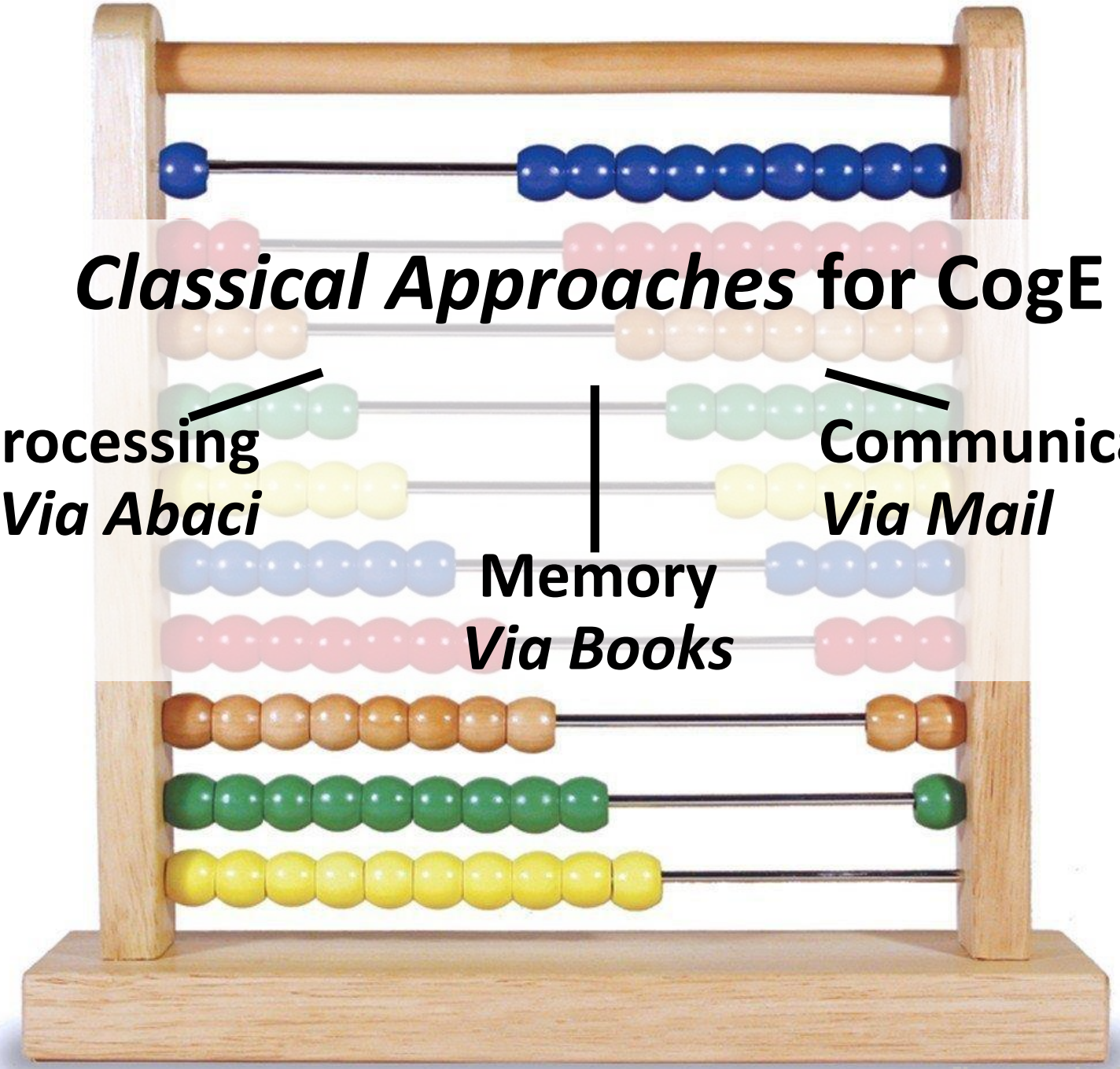

Axes for Cognitive Enhancement (CogE)
Processing
Communication
Memory
That is: we want to think, remember, and communicate better!
SPL
[image: arttechlaw.com]

Classical Approaches for CogE

Processing
Via Abaci

Memory
Via Books

Communication
Via Mail



[image: dealbreaker.com]

Computing for CogE

Processing Via Calculators

Memory Via Online Calendars

Communication Via Texting

State-of-the-Art: *Computing + AI* for CogE:

Processing
Via Computer-Aided Design (CAD)

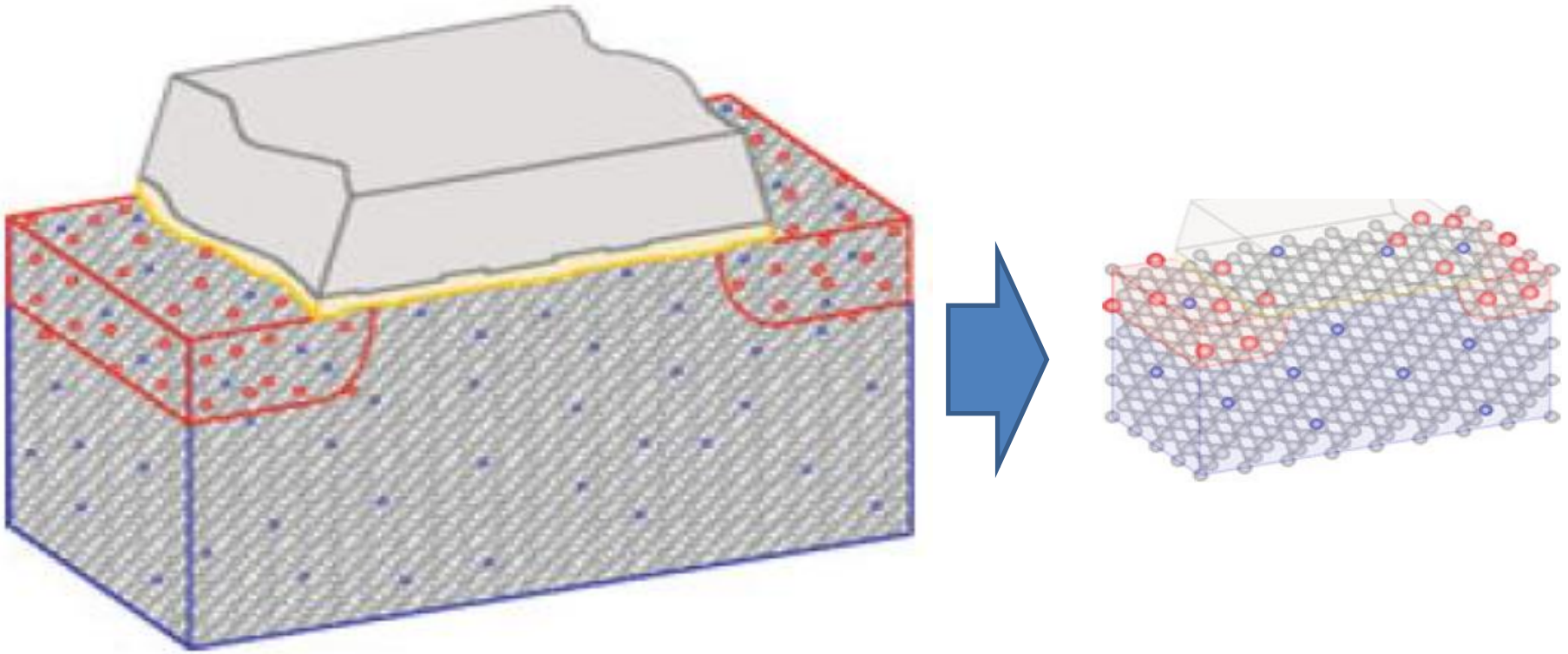
Memory
Via Google
Eg "What's the capital of China?"

Communication
Via Facebook

Deep-Dive CogE Example:

Industrial Circuit Design

Transistors are shrinking …but atoms aren't.



At <22 nm (now), *even one atom out of place* is trouble…

A. Asenov, Extreme Statistics in Nanoscale Memory Design, Springer, 2010

Circuit Design Challenge

- Each part has a tolerance of +/- 25%
- Your circuit has *a billion* parts
- By the way:
  - It has to be twice as fast as before
  - With half the size
  - And the same power
- If the chip fails, it will lose our company $50M+ in manufacturing and $100M+ in sales
- You have 3 months, go!

Circuit Design Challenge

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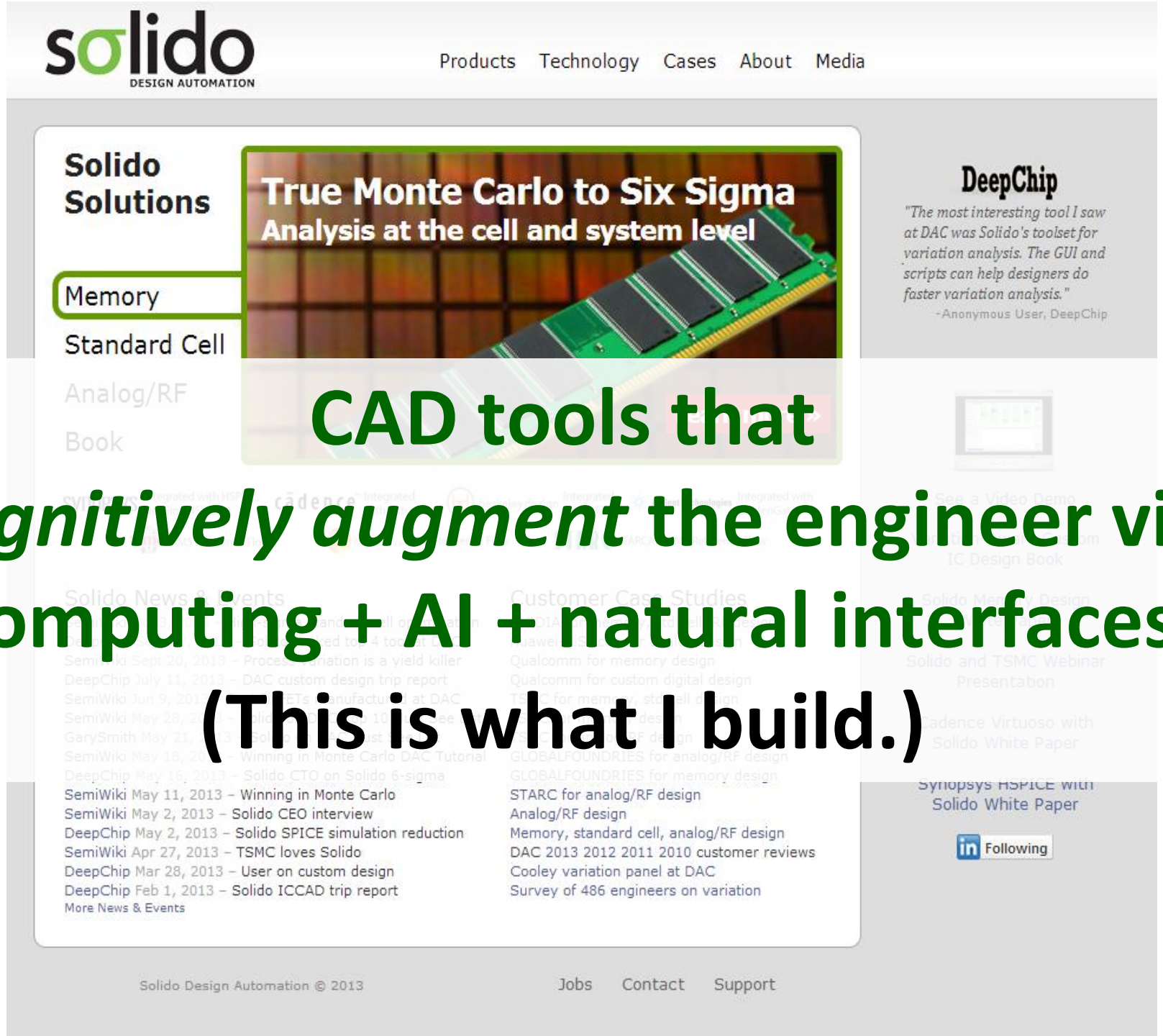
Key Solution: CAD tools that *cognitively augment* the engineer via computing + AI + natural interfaces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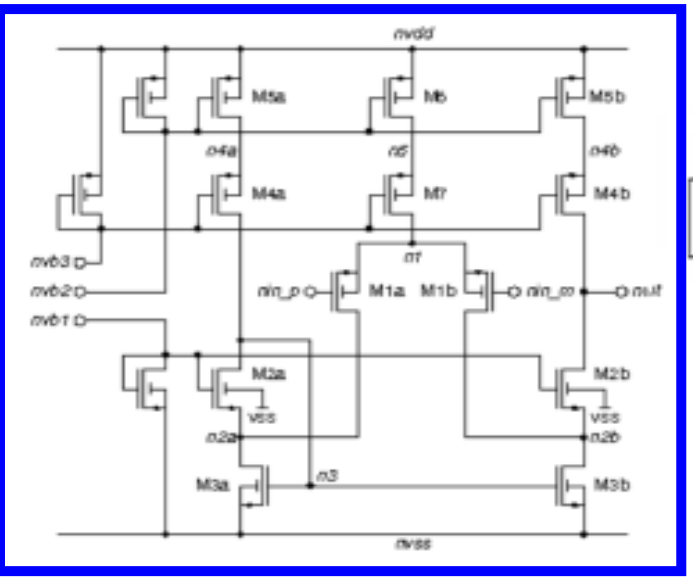
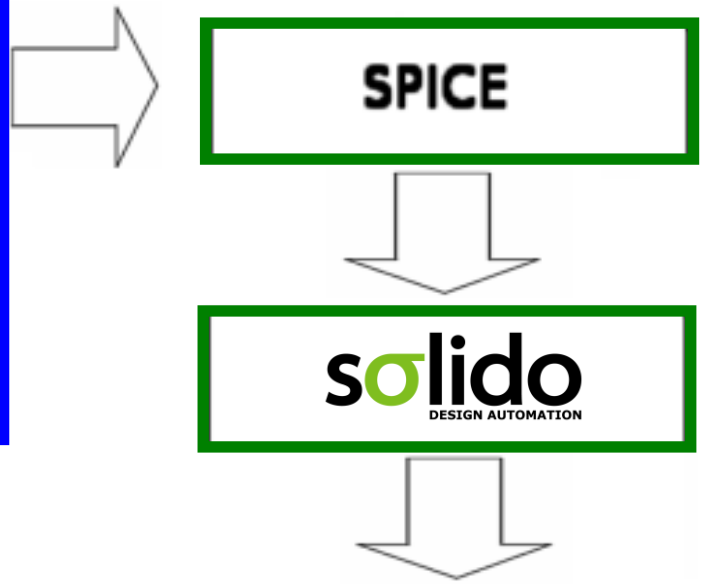
DESIGN AUTOMATION
Products Technology Cases About Media
Solido Solutions
Memory
Standard Cell
Analog/RF
Book
True Monte Carlo to Six Sigma
Analysis at the cell and system level
DeepChip
"The most interesting tool I saw at DAC was Solido's toolset for variation analysis. The GUI and scripts can help designers do faster variation analysis."
-Anonymous User, DeepChip
CAD tools that
cognitively augment the engineer via computing + AI + natural interfaces
(This is what I build.)
SemiWiki May 11, 2013 – Winning in Monte Carlo
SemiWiki May 2, 2013 – Solido CEO interview
DeepChip May 2, 2013 – Solido SPICE simulation reduction
SemiWiki Apr 27, 2013 – TSMC loves Solido
DeepChip Mar 28, 2013 – User on custom design
DeepChip Feb 1, 2013 – Solido ICCAD trip report
More News & Events
STARC for analog/RF design
Analog/RF design
Memory, standard cell, analog/RF design
DAC 2013 2012 2011 2010 customer reviews
Cooley variation panel at DAC
Survey of 486 engineers on variation
Synopsys HSPICE with Solido White Paper
Following
Solido Design Automation © 2013
Jobs Contact Support

CogE of an Engineer's *Circuit Analysis* Capability

What: High-dim Whitebox Regression (an original aim of ML)

How: Pathwise Regularized Learning + Aggressive Filtering



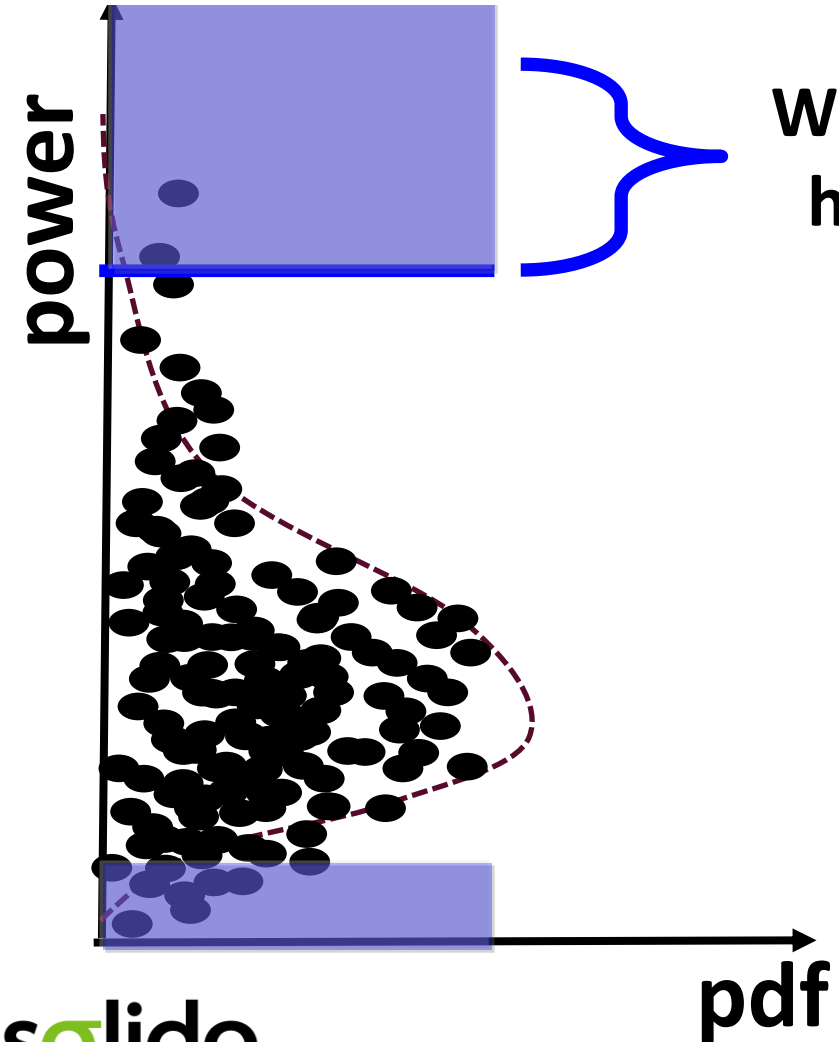


Perf.	Expression
A_{LF}	-10.3 + 7.08e-5 / id1 + 1.87 * ln(-1.95e+9 + 1.00e+10 / (vsg1*vsg3)+ 1.42e+9 *(vds2*vsd5) / (vsg1*vgs2*vsg5*id2))
f_u	10^(5.68 - 0.03 * vsg1 / vds2 - 55.43 * id1+ 5.63e-6 / id1)
PM	90.5 + 190.6 * id1 / vsg1 + 22.2 * id2 / vds2
V_{offset}	- 2.00e-3
SR_p	2.36e+7 + 1.95e+4 * id2 / id1 - 104.69 / id2 + 2.15e+9 * id2 + 4.63e+8 * id1
SR_n	- 5.72e+7 - 2.50e+11 * (id1*id2) / vgs2 + 5.53e+6 * vds2 / vgs2 + 109.72 / id1

[McConaghy 2005, 2012]

CogE of an Engineer's *Yield Analysis* Capability

What: High-dim rare event estimation + natural interface ("Black Swan Simulation")



What is probability of this rare, high-impact event happening?

How: Active learning on 10K+ dimensions; rank 10G-10T pts

(That is, sorting 10TB-10 PB.)

(5G pts ≈scale of Google search)

Brute force: 2 mos. on 100 cores

With AI: 20 min. on 10 cores

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[McConaghy et al, 2012]

CogE of an Engineer's *Circuit Design* Capability

How: GPMs / high-dim Bayesian opt. + natural interface

Benefit: Speed of opt. with control & insight of manual

Impacts On Margin

Impact	Variables	Initial	Current	Best	Exp ID=3
54.73%	sc22_MP1__l	-2.500	-3.800	-3.100	-2.300
30.94%	sc22_MP1__l, sc22_MP1__w	-2.500, 12.50	-3.800, 11.50	-3.100, 12.20	-2.300, 11.50
14.33%	sc22_MP1__w	12.50	11.50	12.20	11.50

Candidates Table

	Initial	Current	Best	Exp ID=3
Simulated	False	N/A	N/A	False
Margin	-52.13m	-83.04m	-4.044m	-49.17m
END1	5.244	8.354	406.8m	4.947
END2	-738.3m	-861.0m	-812.8m	-638.3m
IVDD	-2.500	-3.800	-3.100	-2.300

Sweeps on Netlist (Bufref_tran.sp)

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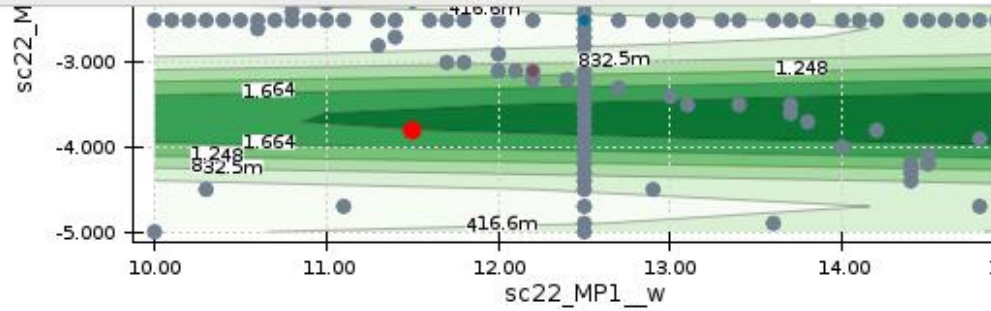
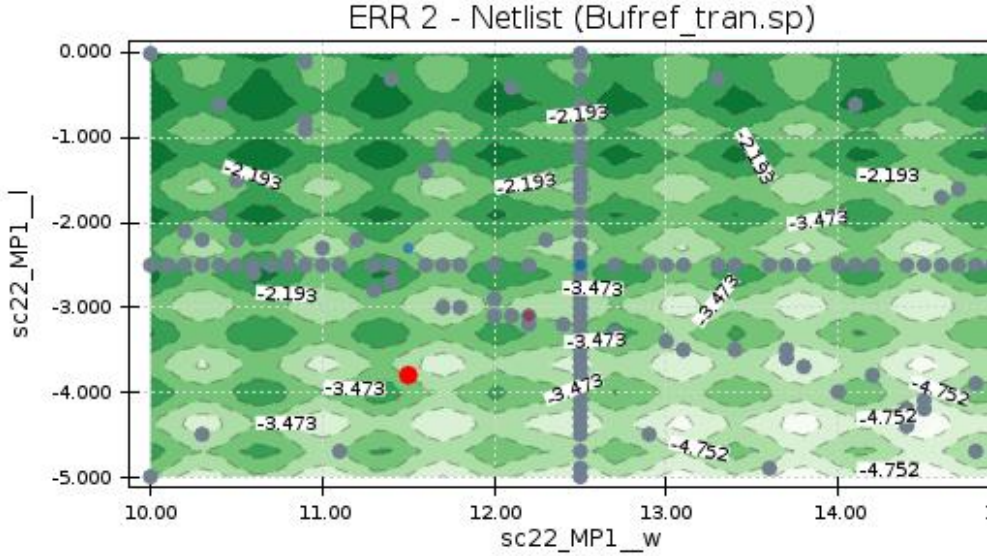
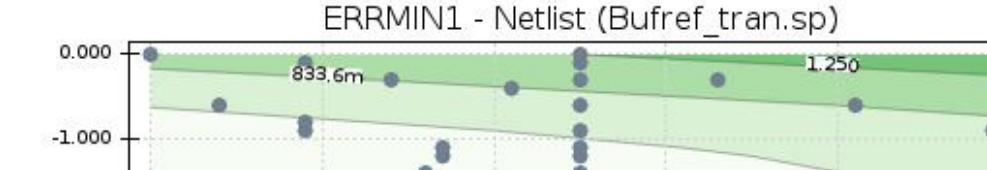
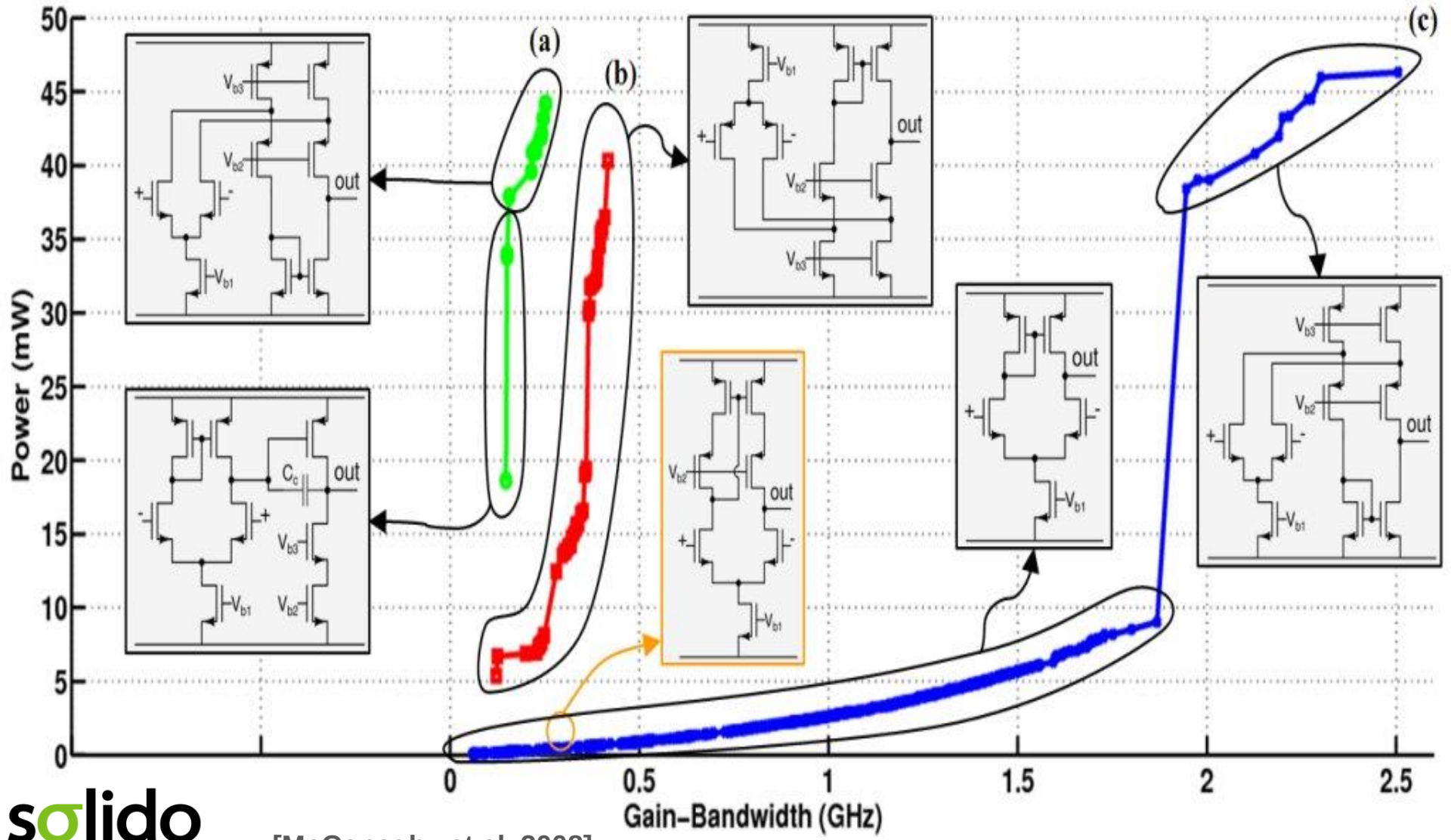






CogE of an Engineer's *Structural Design* Capability

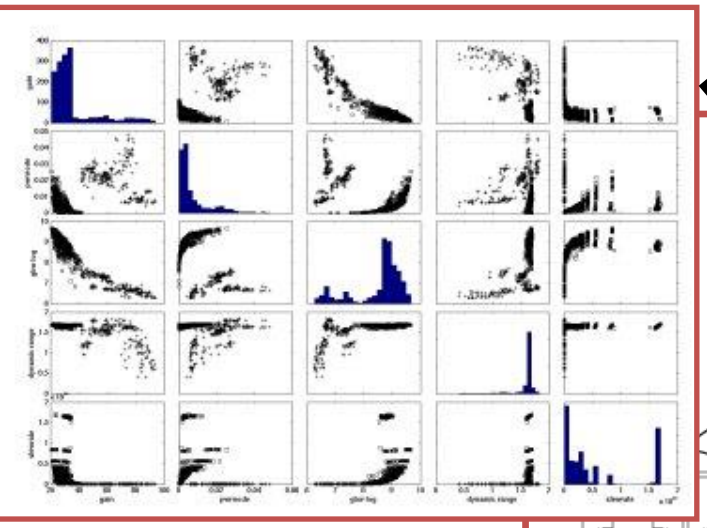
How: Design a language for circuit topologies; populate it; then do grammar-constrained multi-obj. tree search

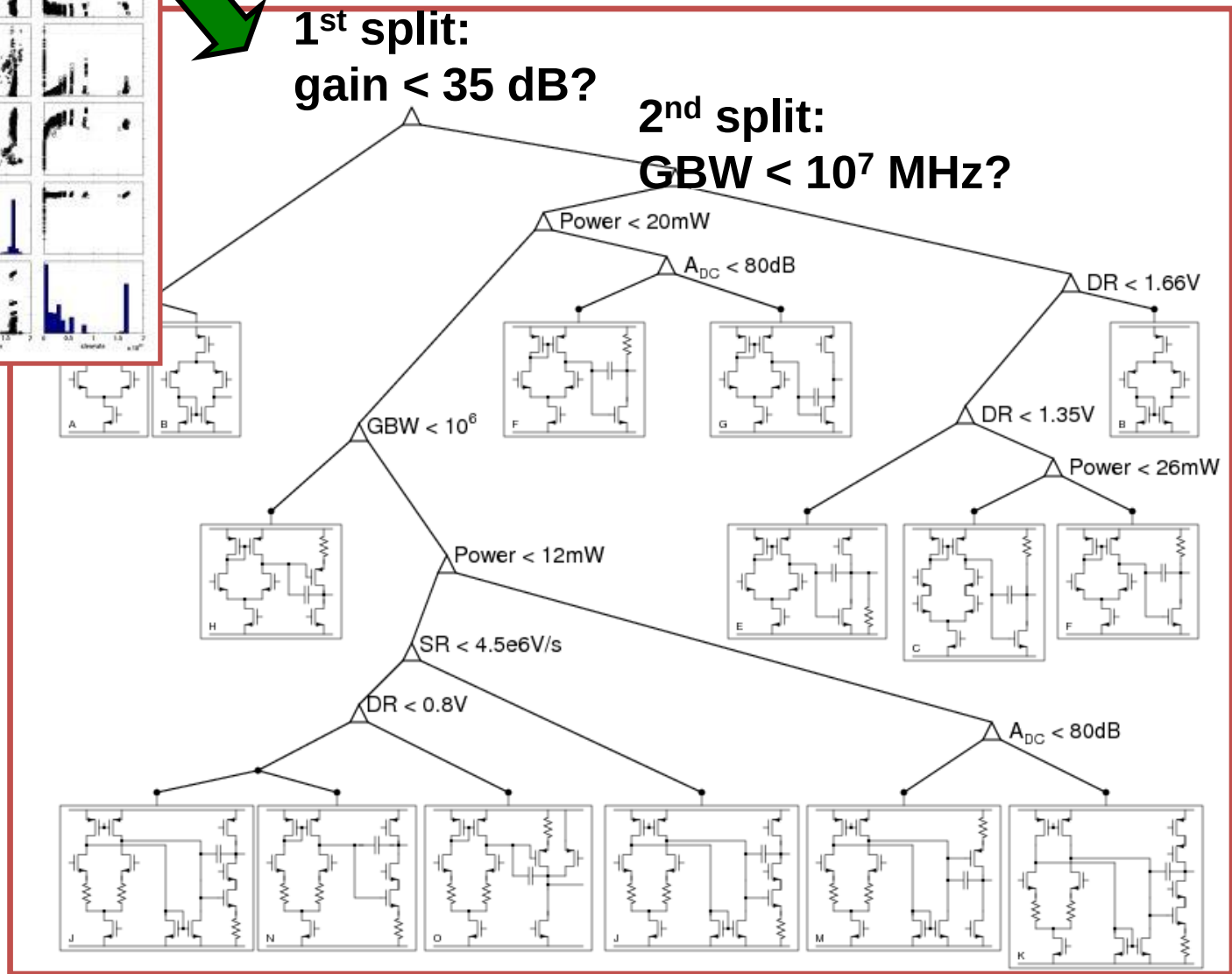


[McConaghy et al, 2008]

CogE of an Engineer's *Structural Design* Capability

Cont'd: Decision tree induction for natural interface





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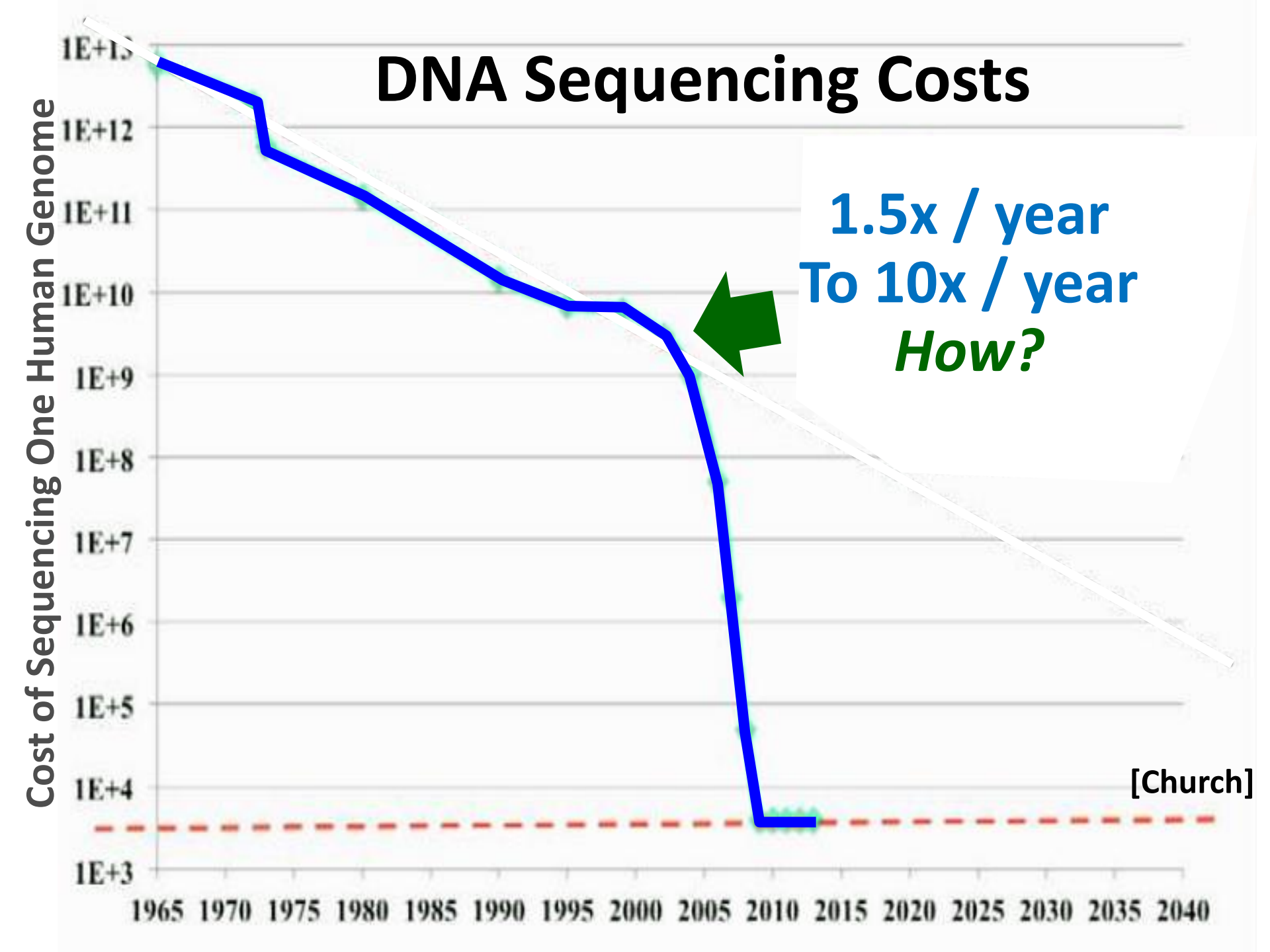
Future of CogE?

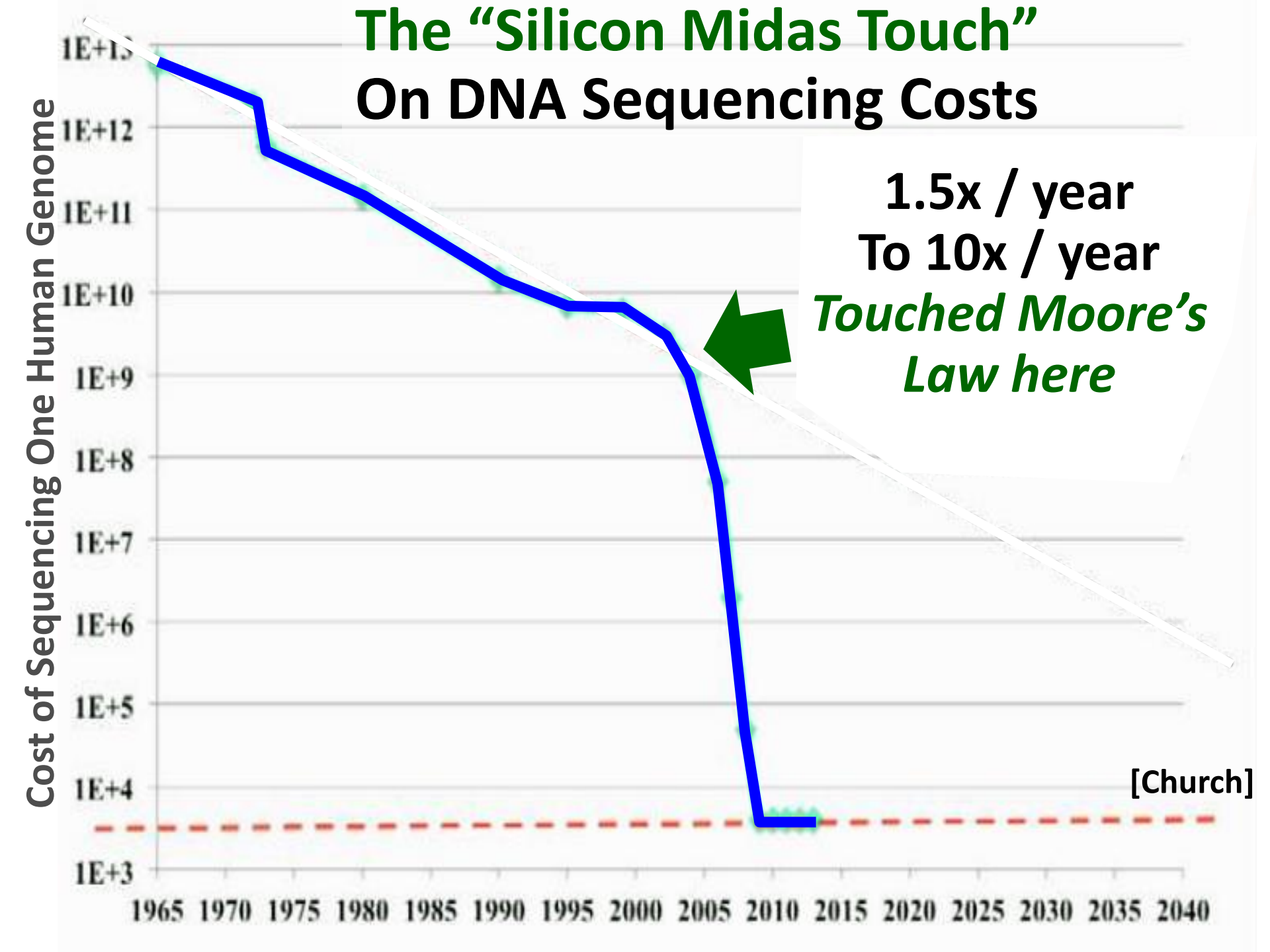
Prediction frameworks:

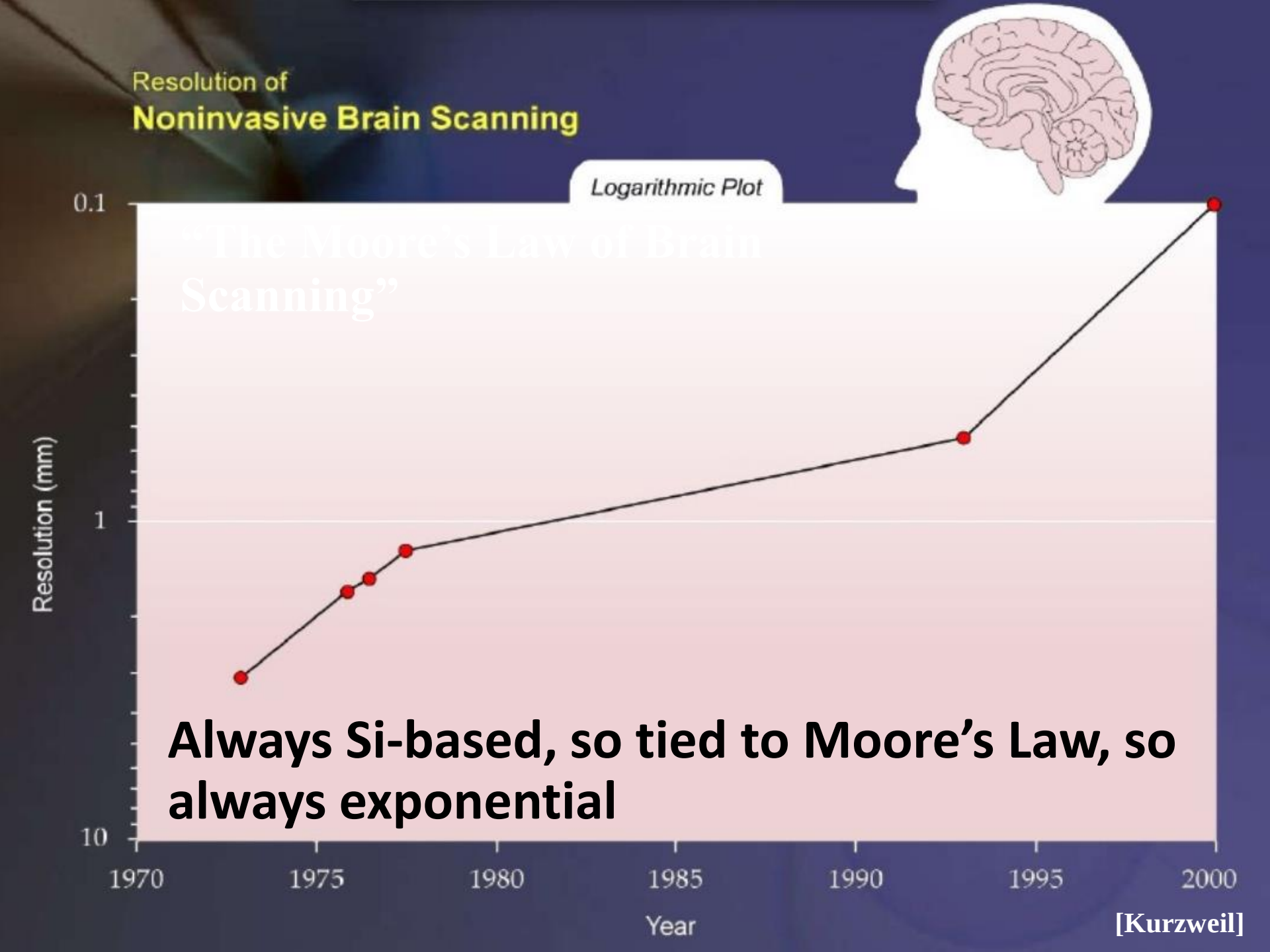
1. **Extrapolate, with Si**
2. **Identify future CogE artifacts**

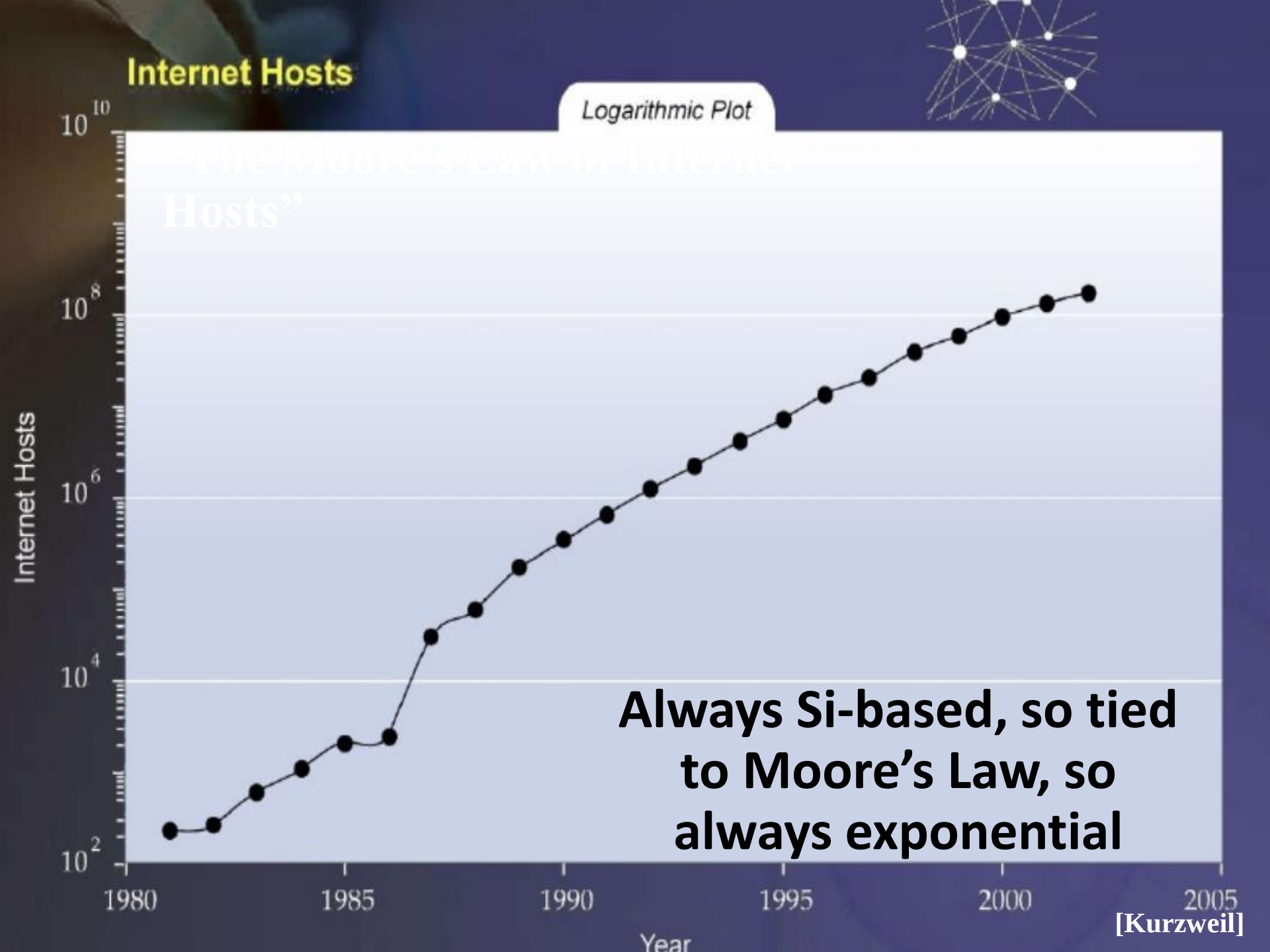
Future of CogE?

Prediction framework #1: Extrapolate, with Si


DNA Sequencing Costs
Cost of Sequencing One Human Genome
1E+12
1E+11
1E+10
1E+9
1E+8
1E+7
1E+6
1E+5
1E+4
1E+3
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040
1.5x / year
To 10x / year
How?
[Church]

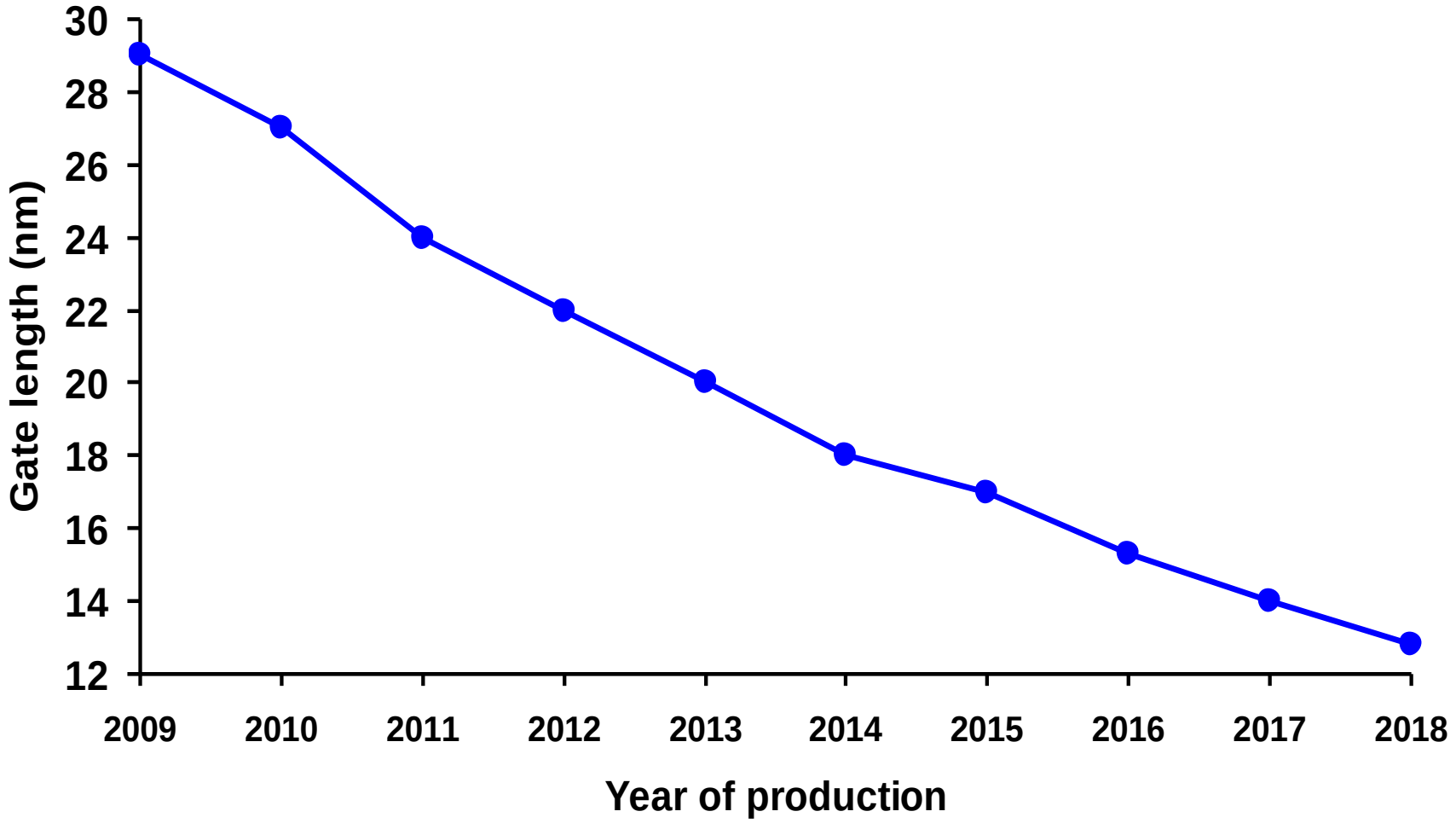

The "Silicon Midas Touch"
On DNA Sequencing Costs
1.5x / year
To 10x / year
Touched Moore's Law here
[Church]
Cost of Sequencing One Human Genome
1E+12
1E+11
1E+10
1E+9
1E+8
1E+7
1E+6
1E+5
1E+4
1E+3
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040


Resolution of
Noninvasive Brain Scanning
Logarithmic Plot
"The Moore's Law of Brain Scanning"
0.1
1
10
Resolution (mm)
1970
1975
1980
1985
1990
1995
2000
Year
Always Si-based, so tied to Moore's Law, so always exponential
[Kurzweil]


Internet Hosts
Logarithmic Plot
"The Moore's Law of Internet Hosts"
Internet Hosts
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
1980
1985
1990
1995
2000
2005
Year
Always Si-based, so tied to Moore's Law, so always exponential
[Kurzweil]

Moore's Law : Definition

Silicon transistor size 2x smaller every 18 months. *An exponential over time.*

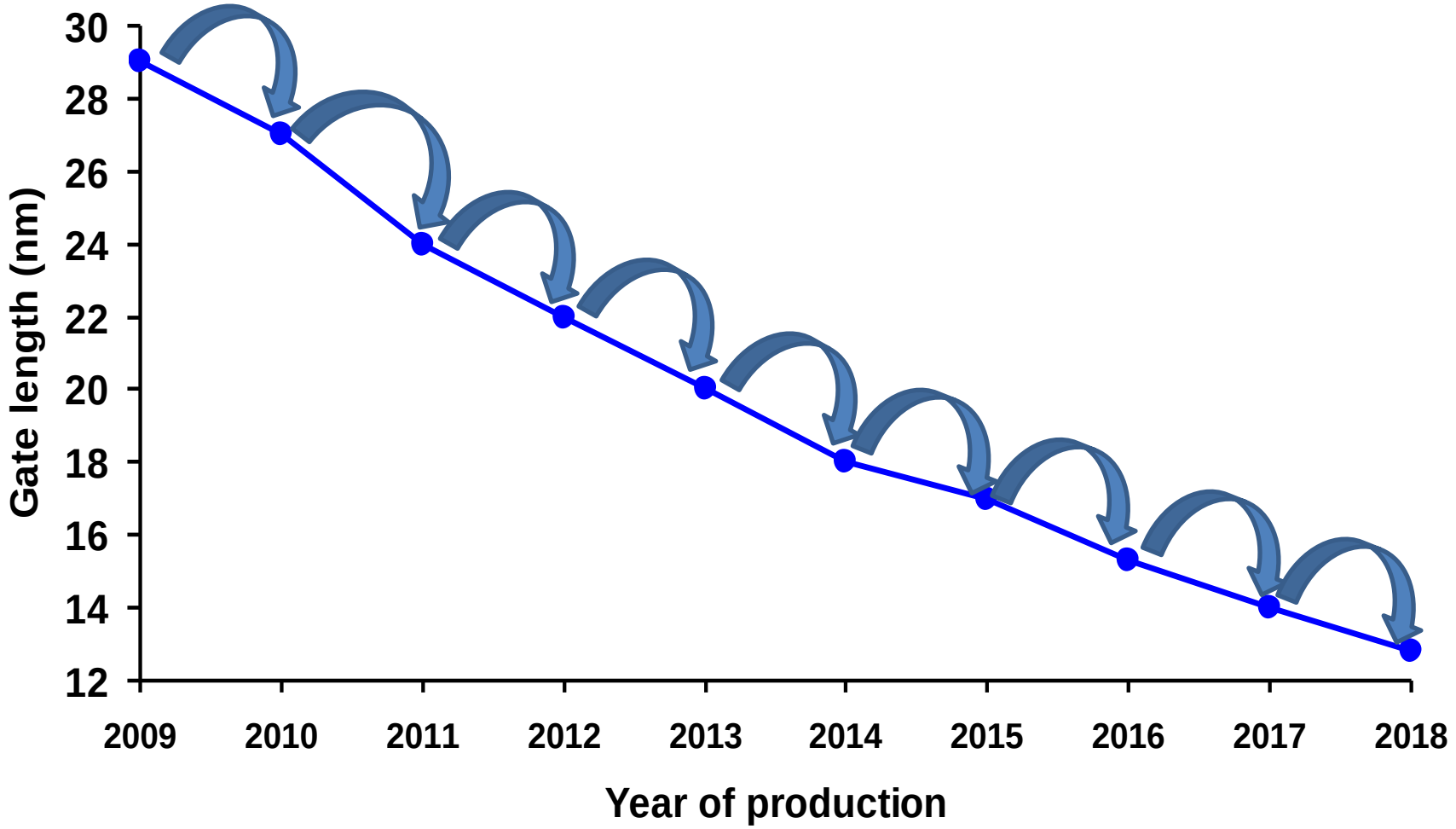


[International Technology Roadmap for Semiconductors, 2011]

Moore's Law: *How?*

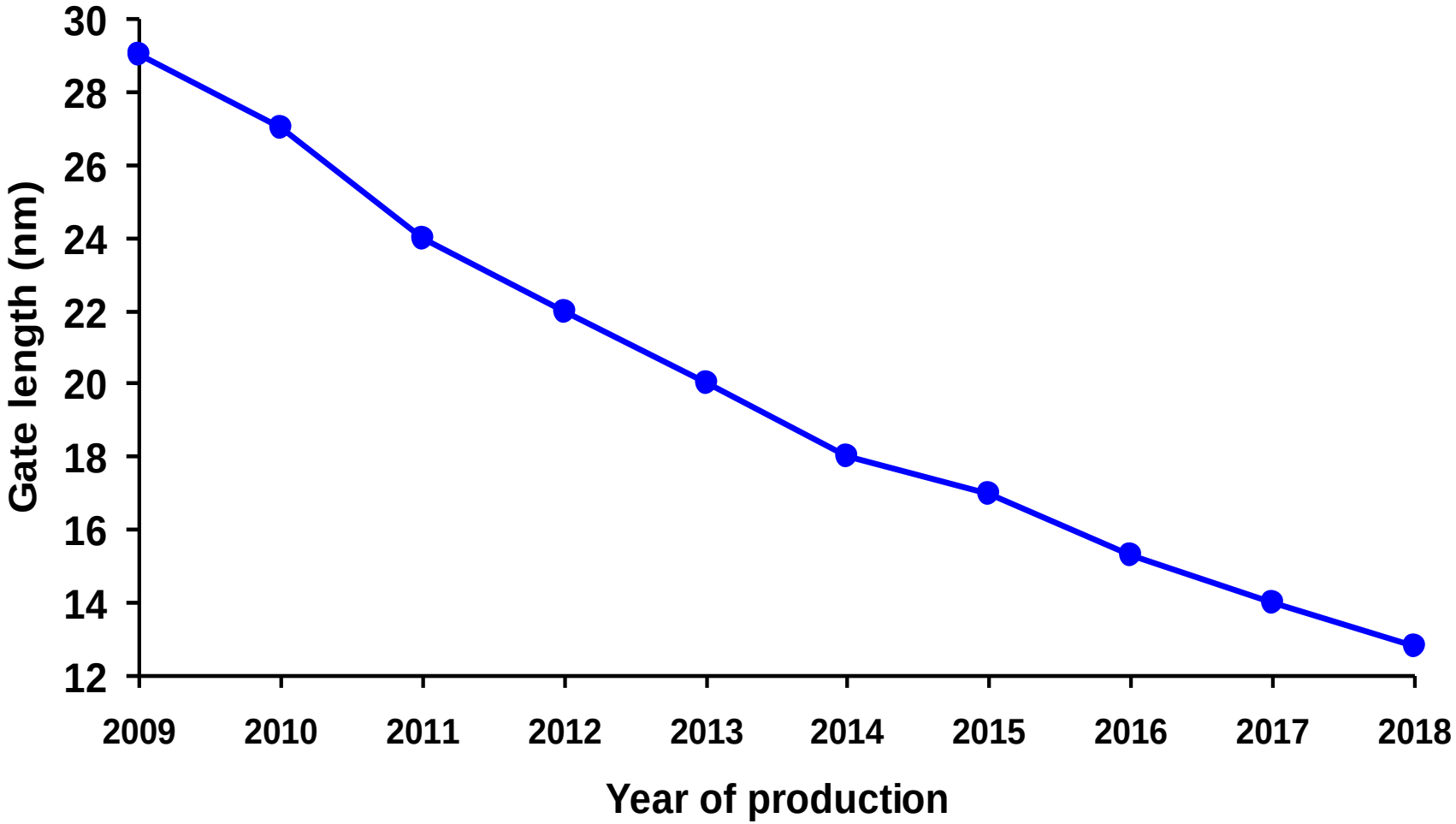
A: Silicon Midas touch *applied to itself*

AI-powered CogE (*CAD*). One generation of machines to design the next generation. The ultimate bootstrap!



In Predicting the Future of CogE:
Simply, use Moore's ~~Law~~ Schedule

Improving chips for communication, processing, memory



[International Technology Roadmap for Semiconductors, 2011]

Future of CogE
Prediction framework #1: Extrapolate, with Si

Takeaways:

- **“Si Midas Touch” causes exponentials**
- **Most notably, on Si itself**
  - **=Moore’s Law**
  - **AI-powered CogE (CAD) closes the bootstrap loop**

Future of CogE
Prediction framework #1: Extrapolate, with Si

Takeaways:

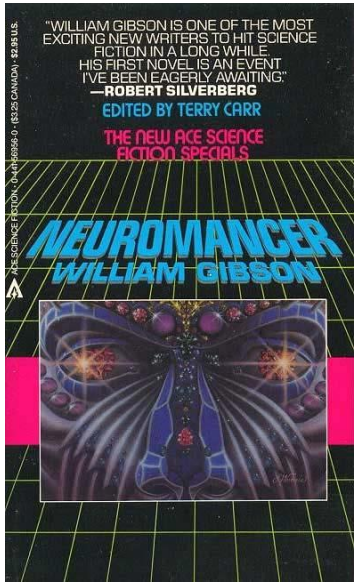
- **"Si Midas Touch" causes exponentials**
- **Most notably, on Si itself**
  - **=Moore's Law**
  - **AI-powered CogE (CAD) closes the bootstrap loop**

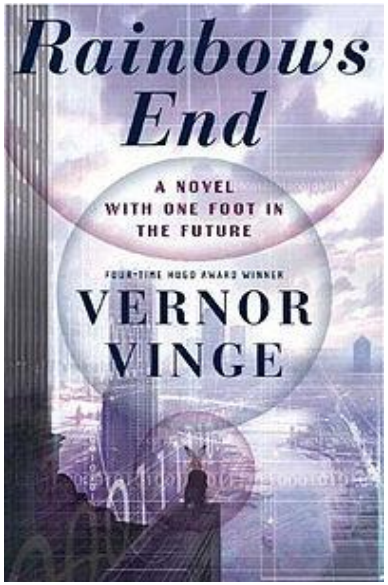
- **But extrapolation doesn't paint a picture of the future..**

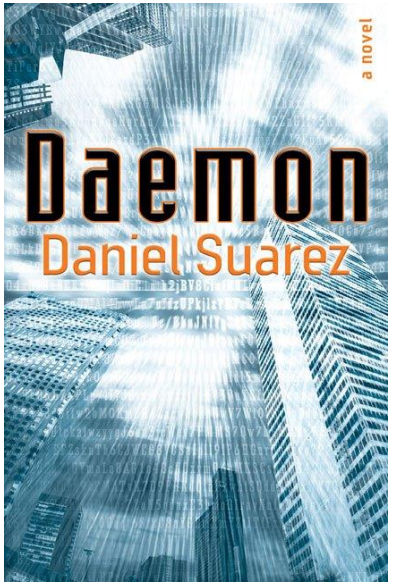
Future of CogE

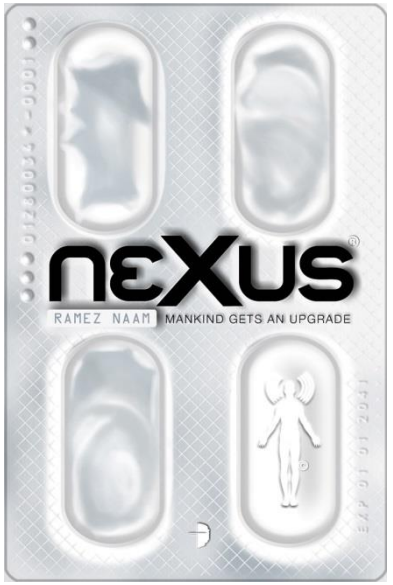
Prediction Framework #2: *Future Artifacts*

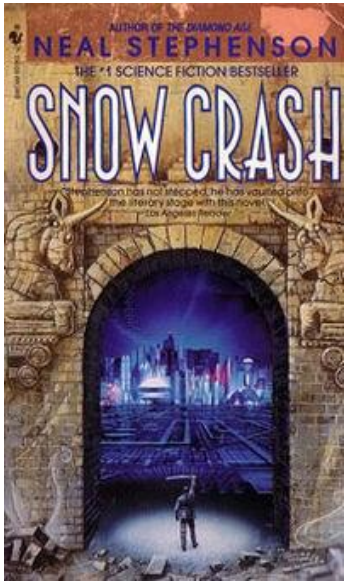
A Source for Artifacts:
Sci-fi: Choose Your Own ~~Adventure~~ Future

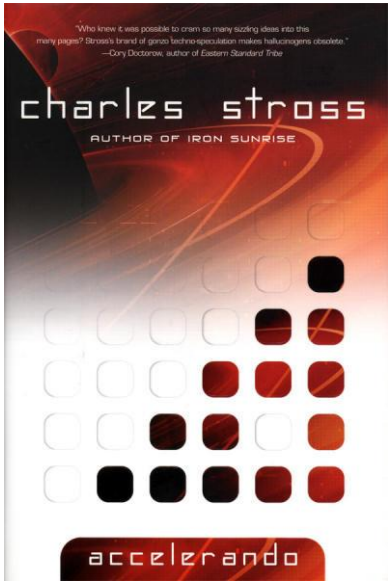


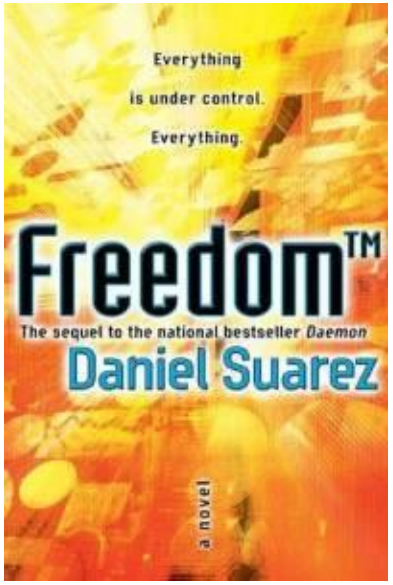


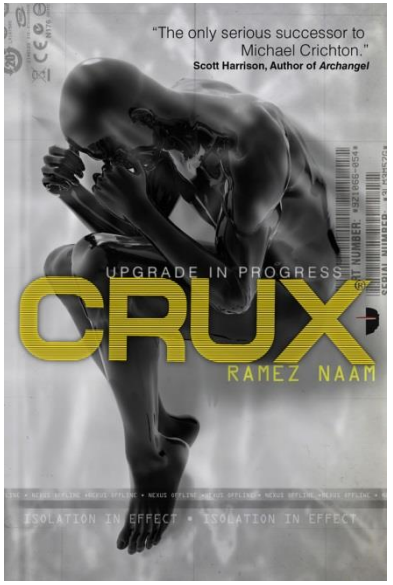












A Future Artifact from “Accelerando”

“… [His] glasses zoom in …”

“He pipes the image stream up to … his websites in real time.”

…he pulls [his glasses] on and is besieged by an urgent flurry of ideas demanding attention.

…[He] plunges into one of those unavoidable fits of deep interaction, fingers twitching on invisible keypads and eyeballs jiggling as his glasses funnel deep media straight into his skull through the highest bandwidth channel currently available.

[Photo: Shutterstock]

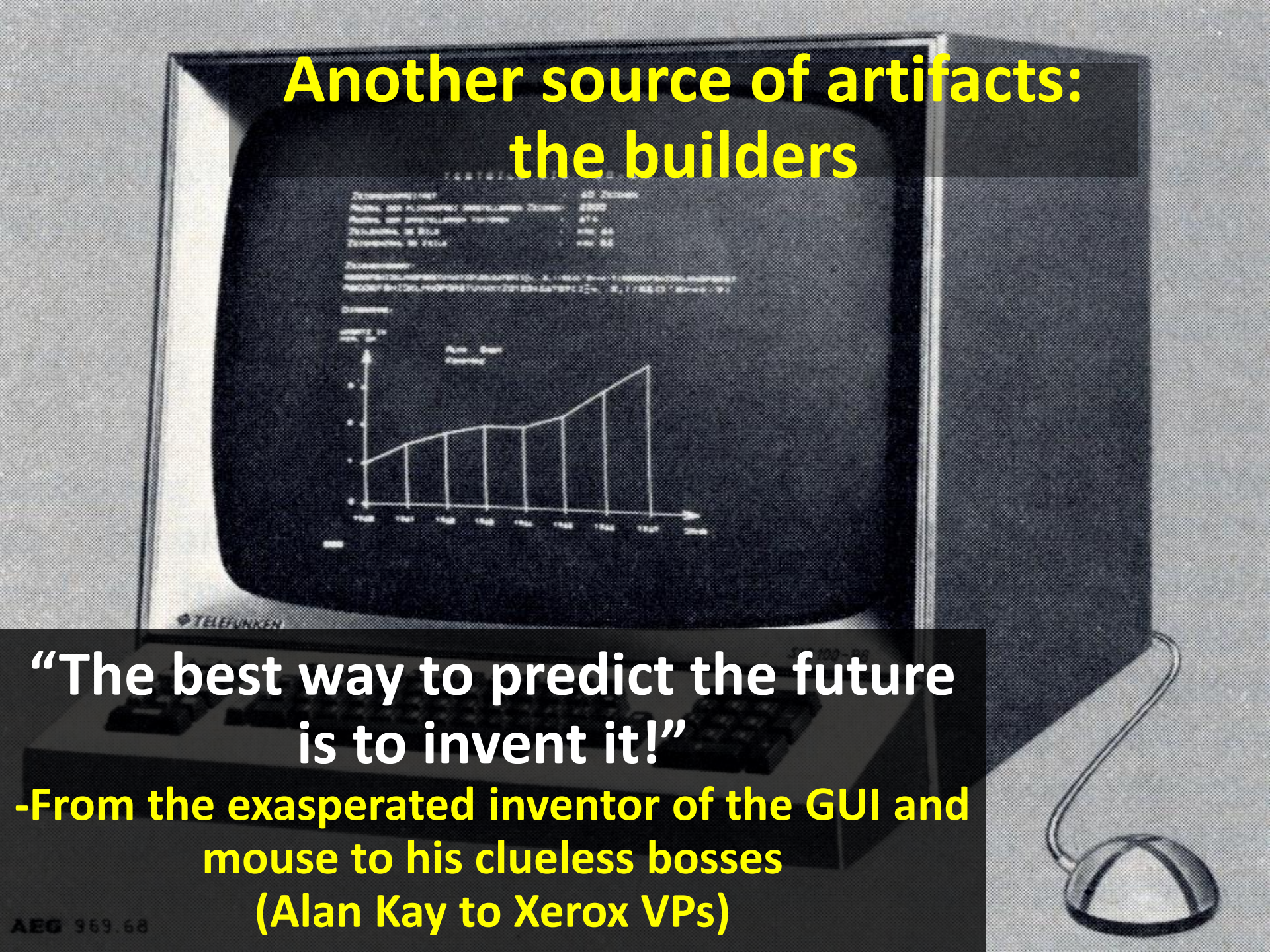
A Future Artifact From “Rainbows End”

sming
= silent messaging
= sending text or voice
by *thinking* about it

“…there was a glimmer of connectivity, enough for *sming*:
Miri --> Miri Gang: <sm>I think we're getting close.</sm>
Lena --> Miri Gang: <sm>…Get out of there.</sm>

…He *sminged* back, voice format: “…”

Another source of artifacts: the builders



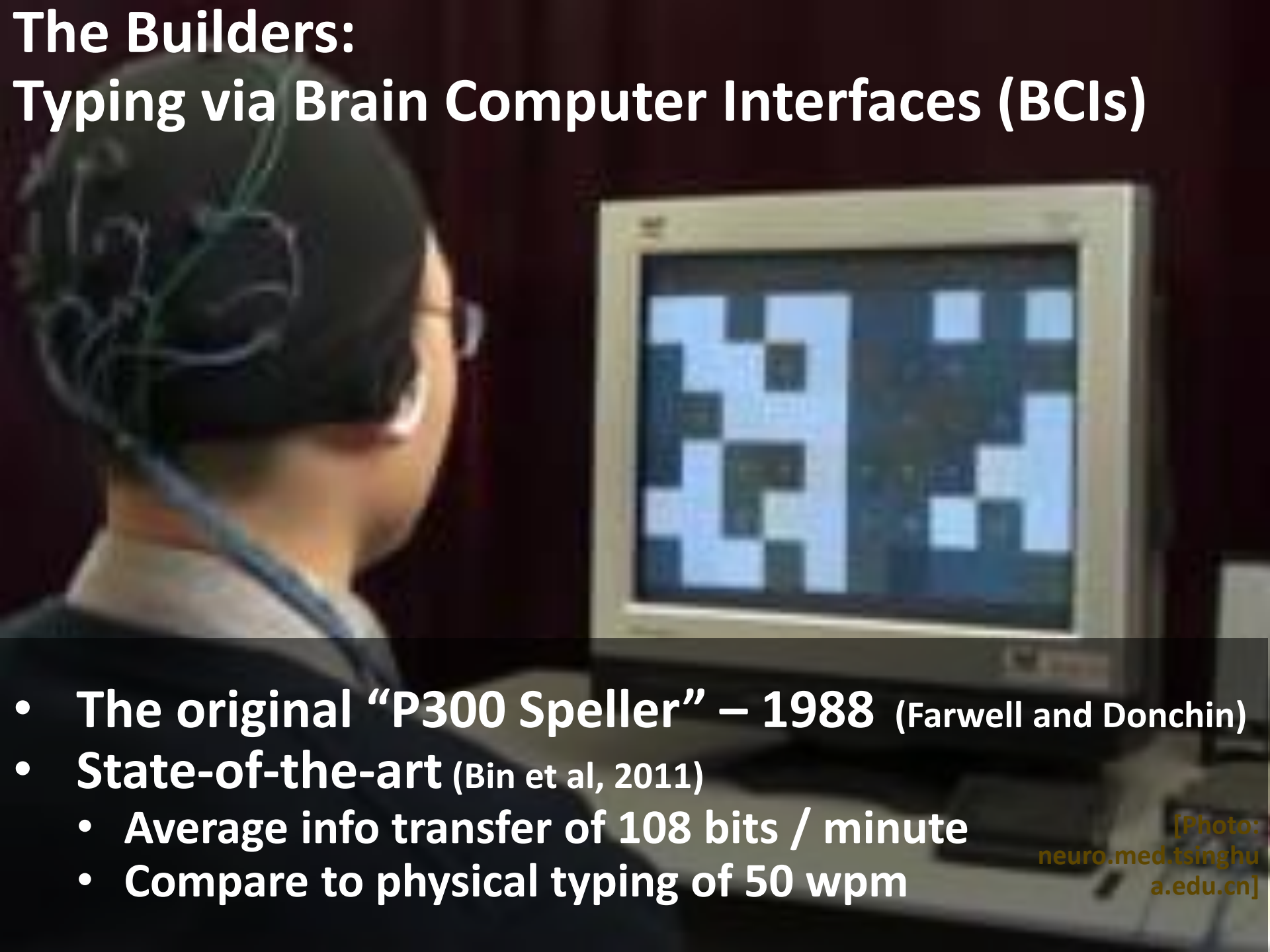
“The best way to predict the future is to invent it!”

-From the exasperated inventor of the GUI and mouse to his clueless bosses (Alan Kay to Xerox VPs)

The builders:
Virtual Reality-based CogE

The Builders:
Augmented Reality-based CogE

The Builders:
Typing via Brain Computer Interfaces (BCIs)



- The original "P300 Speller" – 1988 (Farwell and Donchin)
- State-of-the-art (Bin et al, 2011)
  - Average info transfer of 108 bits / minute
  - Compare to physical typing of 50 wpm

[Photo: neuro.med.tsinghua.edu.cn]

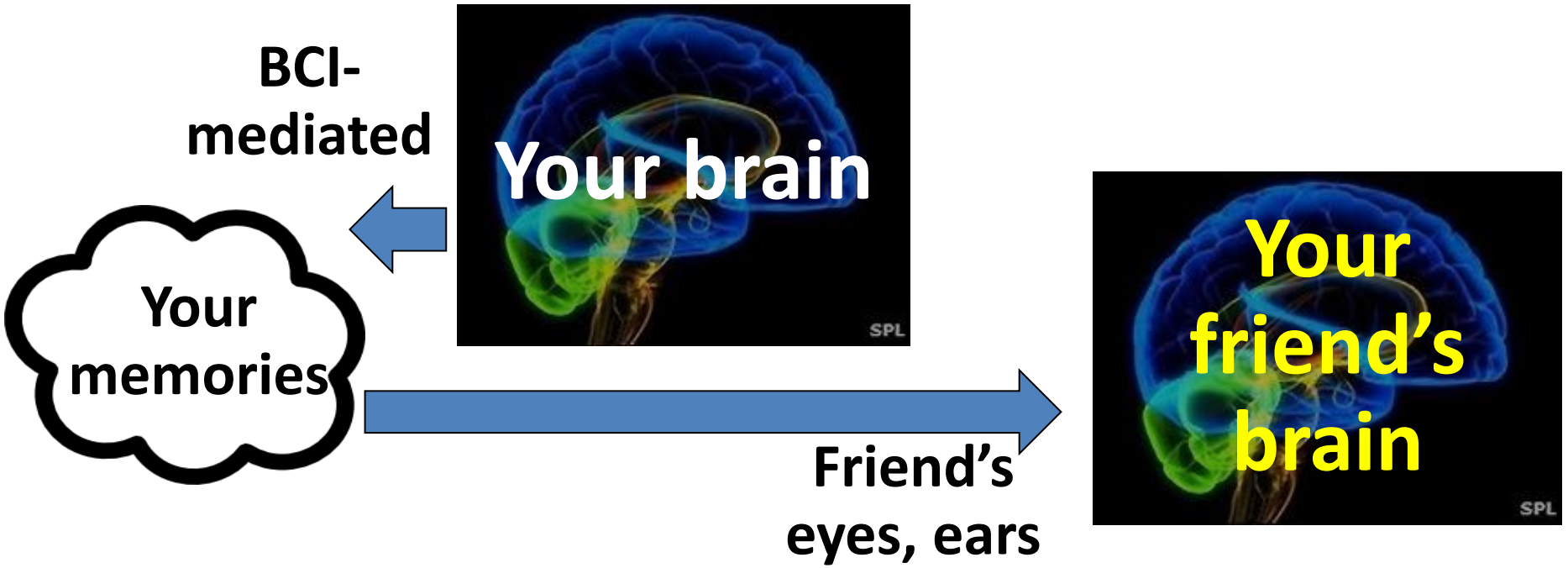
Dropbox Your Brain:
AR / BCI Goggles For CogE of Memory

- Everything you see and hear goes to the cloud
- Use EEG interface to browse past memories
- Re-view past sights & sounds into goggles

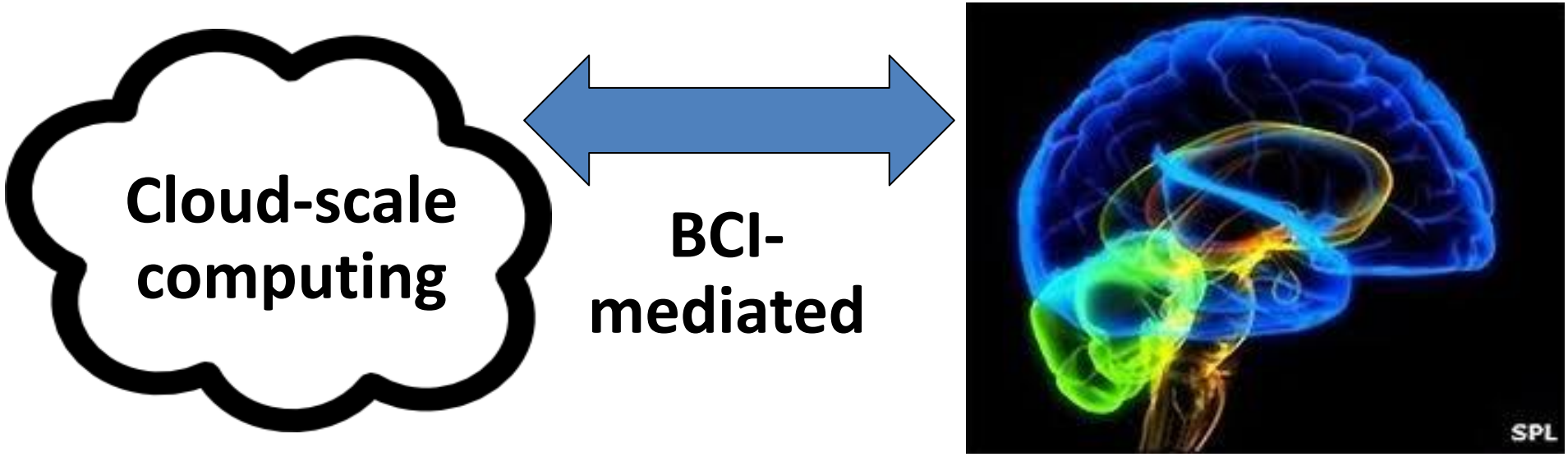
Perfect memory in the cloud (or locally)

BCI-mediated

YouTube Your Brain:
AR / BCI Goggles to Stream Memories



Supercompute Your Brain:
AR / BCI Goggles for CogE of Processing



CogE – Artifact Predictions

Now:

- Prototype Low-Latency VR (Oculus)
- Prototype AR (Google Glass, annotated reality)

1-2 Years:

- Production Ultra-Low Latency VR (Oculus / FB)
- Prototype next-gen virtual worlds (FB?)

5-12 Years:

- "Real" AR (repainted reality)
- Production SR sming
- DropBox your brain (perfect memory)
- YouTube your brain (talk in pictures)
- BW+, +, +, …
- Then, where does "self" end? And other Q's…

CogE - Opportunities

- **Anything that increases communication, BW, or memory between brain and computer.**
- **Anything that drives Moore's Law**

- VR, AR, AR/BCI apps. AI-powered
- 10x+ ML algorithms, eg 1000x past Fast Dropout
- ML co-processors
  - DeepPUs (deep NN processing units)
  - RFPUs (random forests)
  - LCPUs (linear classifiers + ML reductions)
- Mobile-worthy brain-scanning tech.
  - Fast, low power, high-res, non-invasive please
  - To study planets, you need a telescope!
- Brain OS a la "Crux"

Conclusion

- 1st machine age: augmenting muscles
- 2nd machine age: augmenting brains
  - = Cognitive Enhancement (CogE)
- Today's CogE
  - Search, friend recommend, ..
  - CAD has extreme CogE, simply to ship chips
- Future CogE
  - Catalyzed by AI & "Silicon Midas Touch"
  - VR → AR → AR/BCI → BW++++
  - Profound change!