“It’s not a human move …”

We just experienced another milestone in machine intelligence:

Alpha Go of Deep Mind (Google) winning Go against Lee Sedol, one of the world’s top go players.

March 11, 2016

http://www.wired.com/2016/03/sadness-beauty-watching-googles-ai-play-go/?mbid=social_fb
Recent concerns about the “machines” taking over

“Those disposed to dismiss an 'AI takeover' as science fiction may think again after reading this original and well-argued book.”
– Martin Rees, Past President, Royal Society

“Worth reading Superintelligence by Bostrom. We need to be super careful with AI. Potentially more dangerous than nukes.”
– Elon Musk

“If our own extinction is a likely, or even possible, outcome of our technological development, shouldn’t we proceed with great caution?”
– Bill Joy

“Success in creating AI would be the biggest event in human history. Unfortunately, it might also be the last, unless we learn how to avoid the risks.”
– Steven Hawking

Slide adapted from Larry Smarr, UCSD

Supercomputing Frontiers 2016, Singapore | March 15 – 18, 2016
And what about supercomputers?

- At any given time one of the most powerful computers to solve scientific and engineering problems
- Supercomputers and HPC are largely absent from the public discussion about progress in AI
Exascale initiatives are advancing the computational power of supercomputers

- NSCI (National Strategic Computing Initiative) announced by President Obama in June 2015
- Exascale Computing Project ECP started by DOE in the US
- Similar initiatives in Europe, Japan, and China
1. Current Trends in Supercomputing
   (The Path to Exascale)

2. Computing and the Brain
   (Hype and reality)

3. What Computers Still Can’t Do
   (and what I think the real dangers are)
The TOP500 Project
(by Meuer, Strohmaier, Dongarra, Simon)

Listing of the 500 most powerful computers in the world
Yardstick: Rmax of Linpack

• Solve Ax=b, dense problem, matrix is random
• Dominated by dense matrix-matrix multiply

Updated twice a year:
• ISC’xy in June in Germany
• SCxy in November in the U.S.

All information available from the TOP500 web site at: www.top500.org
## 41st List: The TOP10

<table>
<thead>
<tr>
<th>#</th>
<th>Site</th>
<th>Manufacturer</th>
<th>Computer</th>
<th>Country</th>
<th>Cores</th>
<th>Rmax [Pflops]</th>
<th>Power [MW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>National University of Defense Technology</td>
<td>NUDT</td>
<td><strong>Tianhe-2</strong>&lt;br&gt;NUDT TH-IVB-FEP, Xeon 12C 2.2GHz, IntelXeon Phi</td>
<td>China</td>
<td>3,120,000</td>
<td>33.9</td>
<td>17.8</td>
</tr>
<tr>
<td>2</td>
<td>Oak Ridge National Laboratory</td>
<td>Cray</td>
<td><strong>Titan</strong>&lt;br&gt;Cray XK7, Opteron 16C 2.2GHz, Gemini, NVIDIA K20x</td>
<td>USA</td>
<td>560,640</td>
<td>17.6</td>
<td>8.21</td>
</tr>
<tr>
<td>3</td>
<td>Lawrence Livermore National Laboratory</td>
<td>IBM</td>
<td><strong>Sequoia</strong>&lt;br&gt;BlueGene/Q, Power BQC 16C 1.6GHz, Custom</td>
<td>USA</td>
<td>1,572,864</td>
<td>17.2</td>
<td>7.89</td>
</tr>
<tr>
<td>4</td>
<td>RIKEN Advanced Institute for Computational Science</td>
<td>Fujitsu</td>
<td><strong>K Computer</strong>&lt;br&gt;SPARC64 VIIIfx 2.0GHz, Tofu Interconnect</td>
<td>Japan</td>
<td>795,024</td>
<td>10.5</td>
<td>12.7</td>
</tr>
<tr>
<td>5</td>
<td>Argonne National Laboratory</td>
<td>IBM</td>
<td><strong>Mira</strong>&lt;br&gt;BlueGene/Q, Power BQC 16C 1.6GHz, Custom</td>
<td>USA</td>
<td>786,432</td>
<td>8.59</td>
<td>3.95</td>
</tr>
<tr>
<td>6</td>
<td>Los Alamos NL / Sandia NL</td>
<td>Cray</td>
<td><strong>Trinity</strong>&lt;br&gt;Cray XC40, Xeon E5 16C 2.3GHz, Aries</td>
<td>USA</td>
<td>301,0564</td>
<td>8.10</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Swiss National Supercomputing Centre (CSCS)</td>
<td>Cray</td>
<td><strong>Piz Daint</strong>&lt;br&gt;Cray XC30, Xeon E5 8C 2.6GHz, Aries, NVIDIA K20x</td>
<td>Switzerland</td>
<td>115,984</td>
<td>6.27</td>
<td>2.33</td>
</tr>
<tr>
<td>8</td>
<td>HLRS – Stuttgart</td>
<td>Cray</td>
<td><strong>Hazel Hen</strong>&lt;br&gt;Cray XC40, Xeon E5 12C 2.5GHz, Aries</td>
<td>Germany</td>
<td>185,088</td>
<td>5.64</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>King Abdullah University of Science and Technology</td>
<td>Cray</td>
<td><strong>Shaheen II</strong>&lt;br&gt;Cray XC40, Xeon E5 16C 2.3GHz, Aries</td>
<td>Saudi Arabia</td>
<td>196,608</td>
<td>5.54</td>
<td>2.83</td>
</tr>
<tr>
<td>10</td>
<td>Texas Advanced Computing Center/UT</td>
<td>Dell</td>
<td><strong>Stampede</strong>&lt;br&gt;PowerEdge C8220, Xeon E5 8C 2.7GHz, Intel Xeon Phi</td>
<td>USA</td>
<td>462,462</td>
<td>5.17</td>
<td>4.51</td>
</tr>
</tbody>
</table>
Tianhe-2 (TH-2) at NUDT, China – #1 on the TOP500 list

Summary of the Tianhe-2 (TH-2) Milkyway 2

Model: TH-IVB-FEP

- Nodes: 16,000
- Processor: Intel Xeon IvyBridge E5-2692
- Speed: 2.200 GHz
- Sockets per Node: 2
- Cores per Socket: 12
- Coprocessors: Intel Xeon Phi 31S1P
- Coprocessors per Node: 3
- Cores per Coprocessor: 57
- Operating System: Kylin Linux
- Primary Interconnect: Proprietary high-speed interconnecting network (TH Express-2)
- Peak Power (MW): 17.8
- Size of Power Measurements (Cores): 3,120,000
- Memory per Node (GB): 64

Summary of all components

- CPU Cores: 384,000
- Accelerators/CP: 48,000
- Accelerator/CP Cores: 1,024,000 GB

Summary of the Tianhe-2 (TH-2) or Milkyway-2

<table>
<thead>
<tr>
<th>Items</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processors</td>
<td>32,000 Intel Xeon CPU’s + 48,000 Xeon Phi’s (+4096 FT-1500 CPU’s frontend)</td>
</tr>
<tr>
<td></td>
<td>Peak Performance 54.9 PFlop/s</td>
</tr>
<tr>
<td></td>
<td>(just Intel parts)</td>
</tr>
<tr>
<td>Interconnect</td>
<td>Proprietary high-speed interconnection network, TH Express-2</td>
</tr>
<tr>
<td>Memory</td>
<td>1 PB</td>
</tr>
<tr>
<td>Storage</td>
<td>Global Shared parallel storage system, 12.4 PB</td>
</tr>
<tr>
<td>Cabinets</td>
<td>125 + 13 + 24 = 162</td>
</tr>
<tr>
<td>Power</td>
<td>17.8 MW</td>
</tr>
<tr>
<td>Cooling</td>
<td>Closed air cooling system</td>
</tr>
</tbody>
</table>
Two Supercomputers in Berkeley
1. Current Trends in Supercomputing
   (The Path to Exascale)

2. Computing and the Brain
   (Hype and reality)

3. What Computers Still Can’t Do
   (and what I think the real dangers are)
The Exponential Growth of Computing

Adapted from Kurzweil, *The Age of Spiritual Machines*
The Exponential Growth of Computing

Adapted from Kurzweil, *The Age of Spiritual Machines.*
Growth of Computing Power & “Mental Power”

Arguments against this simplistic view

– Naïve extrapolation of current performance trends
  - transition to Post Moore’s Law computing not clear
  - HPC systems are focused on excelling in scientific computing
– Scaling of AI and machine learning to millions of cores
  - most powerful computers today are not being used for cognitive tasks
– Successes of machine learning are accomplished through progress in algorithms
History Lesson: 1987

“Legendary” CM-2 by Thinking Machines

Architecture evolved into CM-5 (1992) built as MPP for scientific applications

Early history of AI applications on parallel platforms has been lost
History Lesson: 1997

- IBM Deep Blue beats Gary Kasparov (May 1997)
- One of the biggest success stories of machine intelligence,
- However, the chess computer “Deep Blue”, did not teach us anything about how a chess grandmaster thinks
- No further analysis or further developments
- 19 years later the story repeats itself with Go
History Lesson: 2011

- IBM Watson beats two best human players
- Still only a narrowly defined game, but Watson demonstrates significant progress in language processing
- Uses supercomputer architecture
- IBM is developing commercial applications based on Watson
- No impact on HPC
Today’s Supercomputers and the Brain

<table>
<thead>
<tr>
<th>Transistors</th>
<th>Memory</th>
<th>Clock (GHz)</th>
<th>Power (W)</th>
<th>Weight (kg)</th>
<th>Size ($\ell$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$9 \times 10^{12}$</td>
<td>$2 \times 10^{15}$</td>
<td>2</td>
<td>$1.2 \times 10^6$</td>
<td>18,800</td>
<td>36,000</td>
</tr>
<tr>
<td>$9 \times 10^{10}$</td>
<td>$1 \times 10^{15}$</td>
<td>$10^{-9} - 10^{-5}$</td>
<td>20</td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>

Neurons | Syn. Conn.

Slide from Peter Denes
Latest simulations in 2012 achieve unprecedented scale of $65 \times 10^9$ neurons and $16 \times 10^{12}$ synapses.
Ananathanarayanan et al., “The Cat is out of the Bag: Cortical Simulations with $10^9$ Neurons and $10^{15}$ Synapses”, Proceedings of SC09.
Recent Evidence for Petabyte Size Memory

- 26 sizes of synapses corresponds to about 4.7 bits per synapse and thus about 4 – 5 Petabytes

from http://www.salk.edu/news-release/memory-capacity-of-brain-is-10-times-more-than-previously-thought/
Compute Power of the Human Brain

• Estimate of compute power for the human brain is about 1-10 Exaflops and 4-5 Petabytes

• Three different paths lead to about the same estimate

• A digital computer with this performance might be available in about 2024 with a power consumption of at best 20–30 MW (goal of the Exascale project)

• The human brain takes 20 W

• A digital exaflops computer using CMOS technology will still be a factor of a million away from brain power
Dimensions of Intelligence

1. Verbal-Linguistic
   - ability to think in words and to use language to express and appreciate complex concepts

2. Logical-Mathematical
   - makes it possible to calculate, quantify, consider propositions and hypotheses, and carry out complex mathematical operations

3. Pattern Recognition
   - capacity to recognize and think about common pattern in our four-dimensional environment

4. Bodily-Kinesthetic
   - ability to manipulate objects and fine-tune physical skills

5. Musical
   - sensitivity to pitch, melody, rhythm, and tone

6. Interpersonal
   - capacity to understand and interact effectively with others

Current State of Supercomputers


Logical-Mathematical

Human Capability

Pattern Recognition

Bodily-Kinesthetic

Musical

Interpersonal

Verbal-Linguistic

Logical-Mathematical

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A Comment about the Turing Test

– Test only one dimension – verbal linguistic

– Need additional tests that explore other dimensions of human intelligence
– My favorite is the “Ikea test” for pattern recognition and 3d spatial thinking: have a robot build furniture from the schematic drawing

Source: TOP500 November 2015.
Historical Perspective, or “Why We Are Here Today ….”

- 60 years of large scale computational physics applications driving computer development
- Remarkable longevity
- Architecture matched to application: Von Neumann architecture and focus on floating point performance

John von Neumann and Robert Oppenheimer, Princeton, IAS, 1952
From the Bomb to the Cloud in Sixty Years

- Von Neumann architecture is ideally suited for large-scale, floating point intense, 2D or 3D grid-based, computational physics applications
- Today we are using the same basic architecture for social networking, Web searches, music, photography, etc.
From A. Merolla et al., Science, Aug. 8, 2014
From A. Merolla et al., Science, Aug. 8, 2014
Recent Neuromorphic Projects

Five complementary approaches to Neuromorphic Computing (massively parallel, asynchronous communication, configurable):

- Commodity microprocessors (SpiNNaker, HBP)
- Custom fully digital (IBM Almaden)
- Custom mixed-signal (BrainScaleS, HBP)
- Custom subthreshold analog cells (Stanford, ETHZ)
- Custom hybrid (Qualcomm)

after K. Meier, Nov. 2014
IBM SyNAPSE Project (D. Modha)

- 5.4 B transistor chip TrueNorth, 4096 neurosynaptic cores, 1 M spiking neurons, 256 M configurable synapses
- 63 mW power per chip, significantly less energy per event (176,000) when compared to a simulator
- Scalability to large system
- Corelet programming model
Challenges of **brain simulation**: link structure to function across scales

Disparate spatiotemporal scales
- nanometers to meters
- picoseconds to years

Diverse data types
- genomics to (functional/structural) connectomics
- electrical, optical and other measurements
- behavior, sensory stimuli, perturbations

Complex analysis issues
- fusion of multi-modal data
- inference robust to noise
- provide insight into computations
- statistical prediction of future events
- extraction of important features

Lack of data and models

Human Brain Project, 2012
### Computation
- Machine Learning (K. Bouchard)
- Data model (BRAINformat) (O. Ruebel)
- Graph Analytics (A. Buluc)
- Real-Time Processing & Vis (D. Donofrio & G. Weber)
- Neural Networks (K. Bouchard)
- Neuron Reconstruction at NERSC (Prabhat)
- fMRI analysis (D. Ushizima)
- Neuromorphic Computing (2 LDRDs, FY’ 16)

### Technology
- High-density electrophysiology (P. Denes)
- Up-Converting Nanoparticles (B. Cohen)
- Opto-acoustic waveguides (P. Schuck)
- Chemical Sensors (C. Chang)

### Experimentation
- Neurodegeneration (C. McMurray)
- Neurological Aging (W. Jagust)
- Sensorimotor circuits (K. Bouchard)
- Neurocognitive Resilience (A. Wyrobek)
- Toxicant impact on host and microbiome (S. Celniker, A. Snijders, J-H Mao)
- Molecular Basis of Epilepsy (B. Brown)

### Facilities
- NERSC
- Molecular Foundry
- ALS
- ESnet
- Allen Institute
- IBM
- Cal-BRAIN
- NIH

### Tri-Institutional Partnership
- UCSF
- Berkeley Lab
- Lawrence Berkeley National Laboratory
Electrical Sensors and Optical Emitters for BRAIN

Ultra high-density electrophysiology

Go from $10^2 \rightarrow 10^5$ electrodes

Data volume
- Today: at limit of “workstation”
- ↑ 3-4 orders of magnitude

Nanocrystalline “light-bulbs”

See deeper into brains

Up Converting NanoParticles

Use blue emission for optogenetic stimulation

Typical Tm/Yb UCNP spectrum

Through 500 μm of mouse brain

Use red emission for optical recording
Advanced Computing for BRAIN at LBL

Common cycle in DOE computing

CRCNS portal and repository for community access to data is hosted at NERSC

Deep neural networks for decoding brain activity
Sparse neural activity for human speech production
HDF5 format and data model for HPC
Proponents of the rapid development of superintelligence use straightforward extrapolation of current computer performance. This ignores the end of Moore’s Law, and the multidimensional nature of human intelligence.

Simulating the human cortex in real time will require a system with 10 Exaflops, 5 Petabytes, and 20 MW.

With the human brain taking only 20 W, current technology is at least a factor of a billion away from human brain performance.

We must investigate new architectures if we want to close this gap.

We must advance various “brain initiatives” to get the necessary data.
1. Current Trends in Supercomputing
   (The Path to Exascale)
2. Computing and the Brain
   (Hype and reality)
3. What Computers Still Can’t Do
   (and what I think the real dangers are)
About 1967

What I learned:
- computers are just machines, wires, batteries, and light bulbs.
- They cannot have a mental state or experience.

Many years later I realized that this position is equivalent to that I don’t believe in strong AI.

Kosmos LOGIKUS “Spielcomputer”

My first computer:
- 10 electric lamps
- 10 switches
- Programming by wiring

http://www.logikus.info/

What I learned:
- computers are just machines, wires, batteries, and light bulbs.
- They cannot have a mental state or experience.
- Many years later I realized that this position is equivalent to that I don’t believe in strong AI.
A typical supercomputer simulation

CAM5 hi-resolution simulations (0.25°, prescribed aerosols)

Michael Wehner, Prabhat, Chris Algieri, Fuyu Li, Bill Collins
Lawrence Berkeley National Laboratory

Kevin Reed, University of Michigan

Andrew Gettelman, Julio Bacmeister, Richard Neale
National Center for Atmospheric Research

June 1, 2011
Strong and Weak AI

Strong AI: A physical symbol system can have a mind and mental states.

Does my play computer get upset when I win?
Does the Edison computer at NERSC know what a hurricane IS?

HDS: This is an interesting philosophical question, but we can leave it aside for this discussion.

Weak AI: A physical symbol system can act intelligently.

Is it possible to develop a computer system that performs indistinguishable from a human?

HDS: Yes, in principle, but it will be very, very hard.
Some challenges ahead for modeling the brain

• Unsuitability of current architectures
  - HPC systems are focused on excelling in computing; only one of the six (or eight) dimensions of human intelligence

• Fundamental lack of mathematical models for cognitive processes
  - That’s why we are not using the most powerful computers today for cognitive tasks

• Lack of data, standards. That’s what the BRAIN initiative in the US should address

• We should be able to model the brain as a complex physical system, but we have barely started
What we should be really concerned about: (1) large scale complex systems controlled by algorithms

Example:

High Frequency Trading (HFT) is now accounting for over 60% of the volume in US equity markets.

The interaction of multiple algorithms create a complex system that we don’t understand any longer, yet our prosperity depends on it.

Dow Jones Index on the day of the FLASH crash

See also Center for Innovative Financial Technologies (CIFT) at LBNL: http://crd.lbl.gov/departments/data-science-and-technology/sdm/current-projects/cift
What we should be really concerned about: (2) confluence of pattern recognition machines + image analysis + big data + behavioral prediction

- Deployment of neuromorphic processors that excel at pattern recognition inexpensively in large scale (IoT)
- Collection of huge amounts of data and image in the cloud
- Capability of real time streaming data analysis
- Behavioral prediction

For friends of SF (Philip K. Dick): I am more concerned about “Minority Report Future” than a “Blade Runner Future”
Towards the pattern recognition machine
Summary – Key Messages

• Supercomputing is an active and thriving field with worldwide impact. Exascale systems will be available within a decade.

• Current HPC technology is about a factor of $10^9$ away from the real time performance of the human brain ($10^6$ in power, $10^3$ in computation, <10 in memory).

• Both technology and architectural innovation are needed to close the gap.

• Given what we know today, an artificial, sentient, superintelligence is unlikely (strong AI).

• Given what we know today, a realistic, highly accurate simulation of brain functions will require major advances in systems, algorithms, and mathematical modeling, in parallel with progress in neuroscience (weak AI).

• The real danger is turning over decisions to systems that we don’t understand and control.
Thank You for Contributions

Erich Strohmaier (LBNL)
Jack Dongarra (UTK)
John Shalf (LBNL)
Peter Denes (LBNL)

Michael Wehner and team (LBNL)
Dharmendra Modha and team (IBM)
Karlheinz Meier (Univ. Heidelberg)
and Wikipedia
Replacement Rate

![Graph showing the replacement rate from 1993 to 2015. The peak is around 2007 with a value of 250, followed by a decline to 129 in 2015.]
DOE / ASCR ➔ BRAIN Initiative?

Neuroscience is a vast field
- BRAIN Initiative is a small part
- Driven by measurement, technology and computing

DOE National Labs would bring
- Team science + interdisciplinary integration
- Systems engineering
- Facilities and problems of scale

ASCR would bring

Data Management

Analysis Methods

Theory and Models

HPC Facilities

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Computing for BRAIN is synergistic with ASCR strategic directions

Computing requirements for BRAIN are well aligned with DoE/ASCR data strategy. Investment in applied mathematics and computer science will be synergistic.

Data Management
Devise standardizations and models for curation, provenance-tracking, and fusion of multi-modal brain data.

Analysis Methods
Develop modality agnostic data analytics methods and visualizations to reveal structure of brain data.

Theory and Models
Construct rigorous mathematical theories and simulations to bridge multiple spatio-temporal scales.

HPC Facilities
Provide community access to centralized data repositories and high-performance computing facilities.
ASCR can uniquely contribute to BRAIN

ASCR can play a unique role in BRAIN computing through advances in applied mathematics and computer science together with HPC facilities.

**Function**  
dynamic data

**Theory & Models**  
abstractions

**Structure**  
static data

Generation and analysis of raw data

Linking structure to function is a ‘grand challenge’ in general biology and materials.
Integration and Synthesis are Crucial

Persistent, open (Web-based) access to multi-modal data to allow the neuroscience community to perform exploratory analysis for data driven discovery (Data Superfacility).

Function
dynamic data

Theory & Models
abstractions

Structure
static data

Derived products
Integration & Synthesis
#3. The brain in action: Produce a dynamic picture of the functioning brain by developing and applying improved methods for large-scale monitoring of neural activity.

#5. Identifying fundamental principles: Produce conceptual foundations for understanding the biological basis of mental processes through development of new theoretical and data analysis tools.

#2. Maps at multiple scales: Generate circuit diagrams that vary in resolution from synapses to the whole brain.

**Function**
- dynamic data

**Theory & Models**
- abstractions

**Structure**
- static data

**Derived products**

**Integration & Synthesis**
Technology to the rescue

Transistor density (mm²)

10⁷

10⁶

10⁵

10⁴

10³

10²

10¹

AMD

IBM

Intel

Motorola

All manufacturers

Year

1965

1970

1975

1980

1985

1990

1995

2000

2005

2010

2015

Minimum feature size (nm)

10⁷

10⁶

10⁵

10⁴

10³

10²

10¹

Neuron

Dendrites

Axon

Electrical Impulses

Neurotransmitter Molecules

Synapse

1 µm

Nanotechnology

Microtechnology

Supercomputing Frontiers 2016, Singapore | March 15 – 18, 2016
Tri-Institutional Partnership - a model

Clinical
Neuroscience
Technology

National Lab
Facilities
Capabilities

Universities
Neuroscience
Clinical data

To unite the research strengths of Berkeley Lab, UC Berkeley and UC San Francisco, the three institutions decided to form the Tri-Institutional Partnership as a means to promote collaborative research. The partnership’s first venture will seed collaborative research projects in neurotechnology. The prize was announced earlier this year with the announcement of a peer-reviewed competition, inviting the participating institutions to catalyze bold, potentially transformative research in neurotechnology at scale.

On March 19, representatives from all three partners convened at Berkeley Lab for “Proposer’s Day,” to learn more about the seed program, the opportunities provided by President Obama’s BRAIN Initiative, and especially to share their research ideas and forge new collaborations.

“Bringing people together across disciplines is difficult, and across institutions even more so,” said Graham Fleming, Vice Chancellor for Research at Berkeley. “But the impressive level of excitement and enthusiasm from all three institutions and the energy in the room demonstrates the level of excitement they share in addressing the neurotechnology challenges posed in the BRAIN Initiative.”

“This is a wonderful opportunity to see such a tremendous turnout for our first Proposer’s Day. Our scientists were joined by 23 scientists from UC SF and 28 from UC Berkeley,” said Brooke Mayer, Program Manager at Lawrence Berkeley National Laboratory. “This demonstrates to me that the Bay Area scientific community is ready for the tri-institutional partnership in order to address new and interdisciplinary scientific challenges.”

Scientists participating in the program will be calibrated on technical excellence, innovation, and the substantive involvement of the collaborative partners across multiple disciplines. To ensure impact, each project must have a clear path from concept to the development of a competitive proposal for outside funding.

Go here to learn more about the Tri-Institutional Partnership and the BRAIN R&D seed-funding project to support innovative neurotechnology.
Technology Trends: Microprocessor Capability

2X transistors/chip every 1.5 years – called “Moore’s Law”

Microprocessors have become smaller, denser, and more powerful

Gordon Moore (co-founder of Intel) predicted in 1965 that the transistor density of semiconductor chips would double roughly every 18 months
Sustained Growth of Technology Allowed Us to Ignore Architecture

- Two technology transitions since 1940s
- Moore’s Law stated for integrated circuits only
- Kurzweil et al. claim accelerated exponential growth across technologies
Motivation for the Title of My Talk

“The computer model turns out not to be helpful in explaining what people actually do when they think and perceive.”

*Hubert Dreyfus, pg.189*

Example: one of the biggest success stories of machine intelligence, the chess computer “Deep Blue”, did not teach us anything about how a chess grandmaster thinks
Why This Is Important

- This could be the beginning of the development of a “right-brain” architecture for computers
- The future is a fast pattern recognition machine. It is not relevant if the chips are actually resembling the brain
- Energy efficiency has been demonstrated with conventional 26nm process
- Small systems could be made available easily to wide developer community (think NVIDIA and CUDA, or Raspberry Pi for pattern recognition)
- Potential widespread use in mobile
- Scale up and integrated into HPC.