"Implications of Brain-Inspired Computing on Next-Gen Cyberinfrastructure Planning"

Invited Talk
ON*VECTOR
Calit2's Qualcomm Institute
University of California, San Diego
February 25, 2015

Dr. Larry Smarr
Director, California Institute for Telecommunications and Information Technology
Harry E. Gruber Professor,
Dept. of Computer Science and Engineering
Jacobs School of Engineering, UCSD

This Time Will Be Different…

I Have Participated in the Last Billion-Fold Increase in Supercomputer Speed:

- **MegaFLOPS**
  - –1965 CERN CDC 6600
- **GigaFLOPS**
  - –1985 NCAR Cray-2
- **TeraFLOPS**
  - –1996 Sandia Intel's ASCI Red
- **PetaFLOPS**
  - –2008 LANL IBM Roadrunner

FLOP = Floating Point Operations Per Second

- **Next Transition is the ExaFLOP 2018-2024**
  - **The Speed Will Approach or Exceed That of the Human Brain**

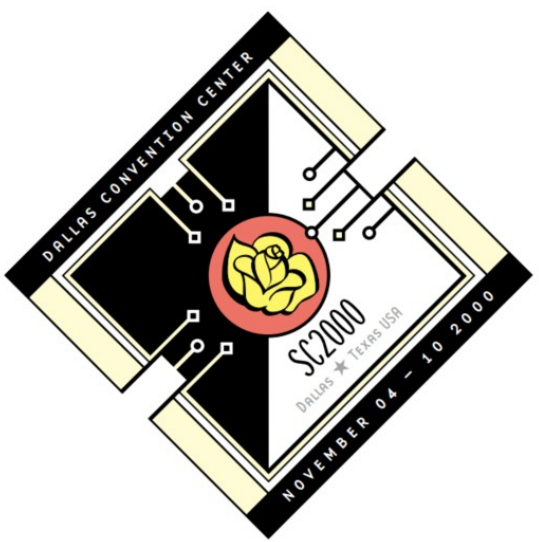
The Fastest Supercomputer Today - Only 20x More to the ExaFLOP

NEWS

China surpassing U.S. with 54.9 petaflop supercomputer

Computerworld | Jun 3, 2013

The Tianhe-2 Has 3.1 Million Intel Cores



MEGACOMPUTERS
Moderator: Larry Smarr
Panelists: Andrew Chien, *Entropia*
Ian Foster, *Argonne National Laboratory*
Thomas Sterling, *JPL*

Predicted in 2000

Dedicated Exascale Supercomputers Will be Needed for Single Instruments Within a Decade

IBM to build exascale supercomputer for the world's largest, million-antennae telescope

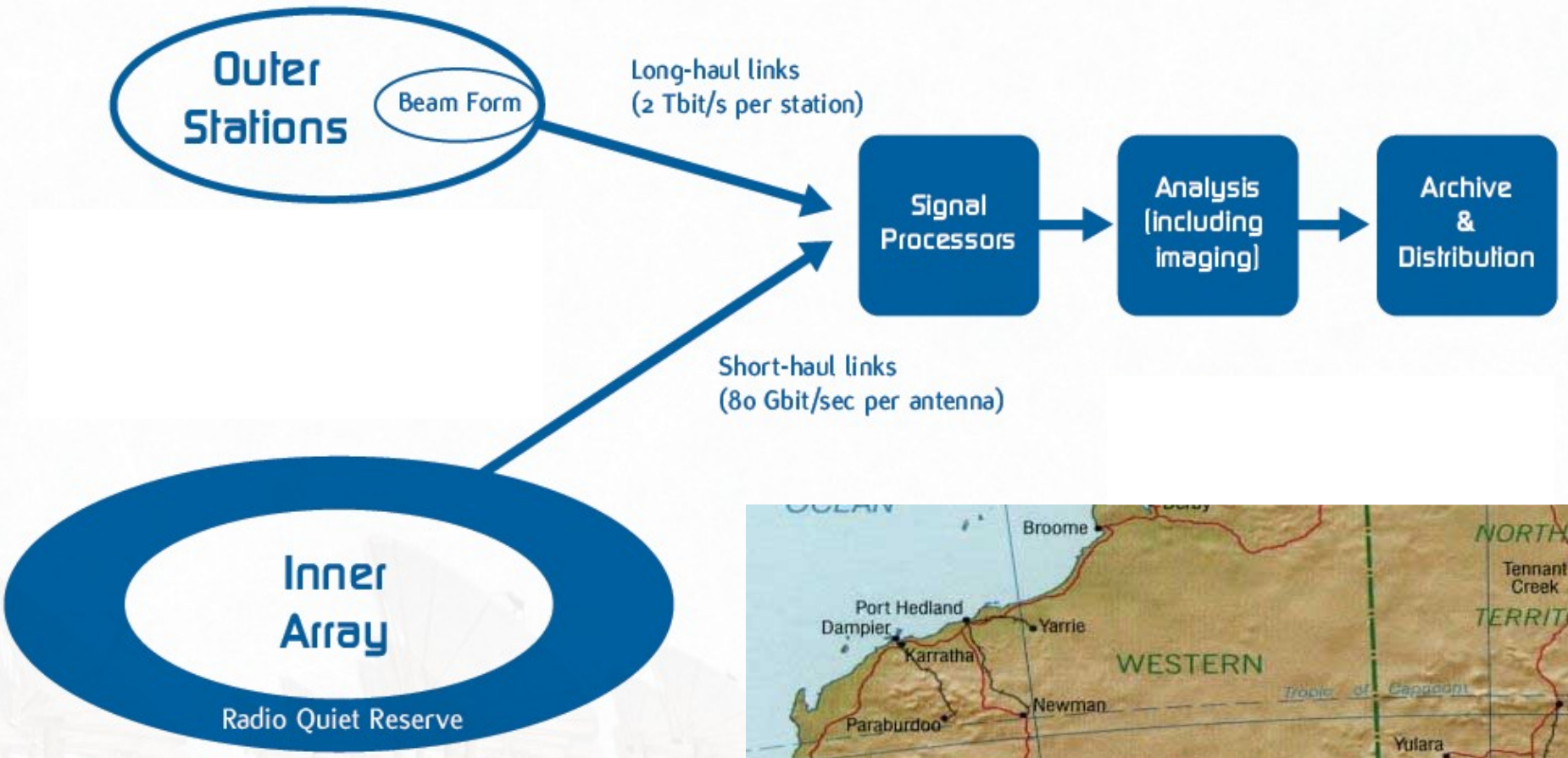
By Sebastian Anthony on April 2, 2012 at 11:48 am | 8 Comments



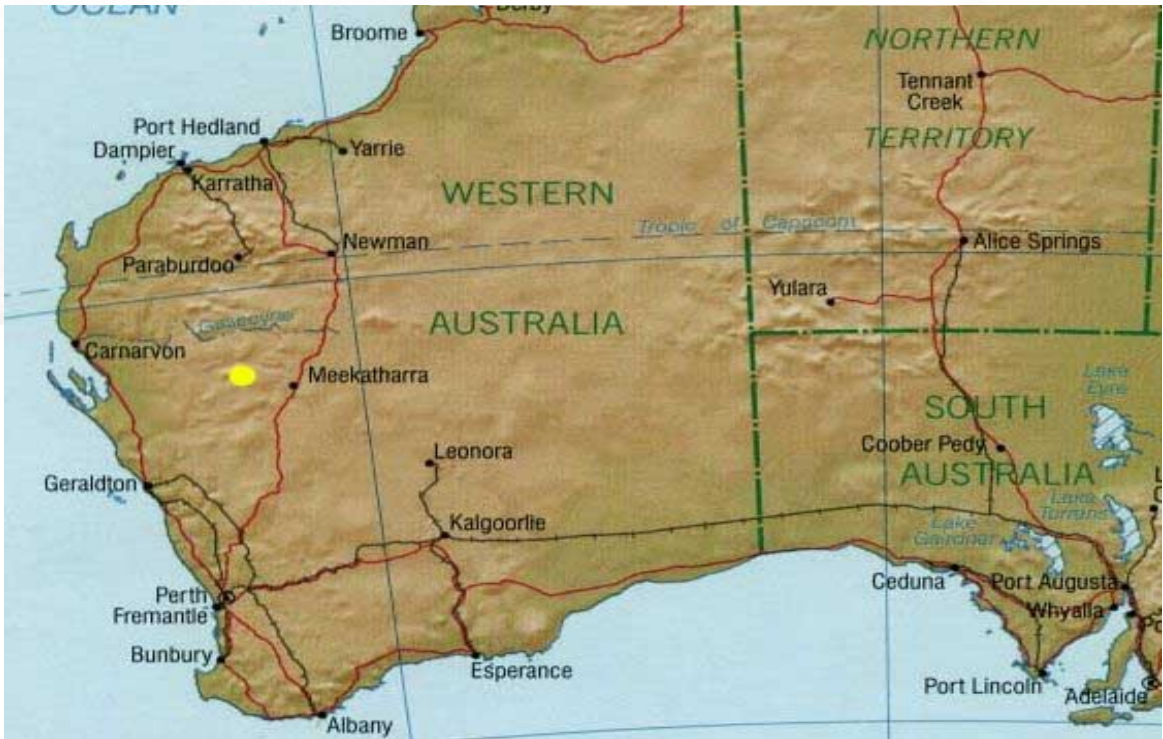
IBM has until 2024 to develop a computer that can process a few exabytes of data per day.

Cisco Predicts daily global IP traffic will surpass 3 exabytes threshold in 2016.

Next Great Planetary Instrument: The Square Kilometer Array Requires Terabit/s Networks



Transfers Of 1 TByte Images World-wide Will Be Needed Every Minute!



The Future of Supercomputing

"High Performance Computing Will Evolve Towards a Hybrid Model, Integrating Emerging Non-von Neumann Architectures, with Huge Potential in Pattern Recognition, Streaming Data Analysis, and Unpredictable New Applications."



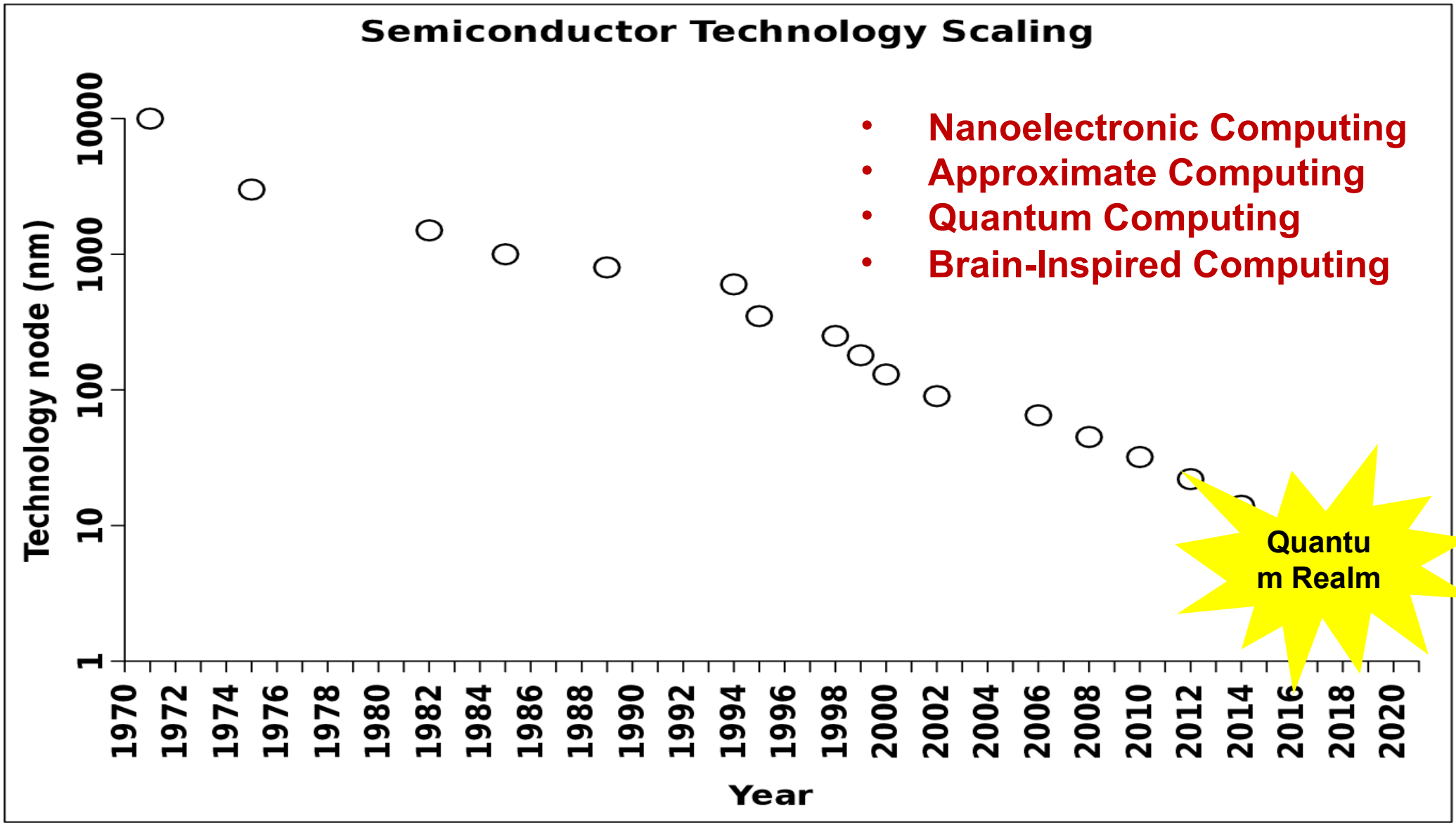
Horst Simon, Deputy Director,
U.S. Department of Energy's
Lawrence Berkeley National Laboratory

U.S. DEPARTMENT OF ENERGY

BERKELEY LAB
Bringing Science Solutions to the World

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New Computing Architectures Will Be Necessary In the Coming Decade



Graph source: www.iue.tuwien.ac.at/phd/filipovic/node20.html

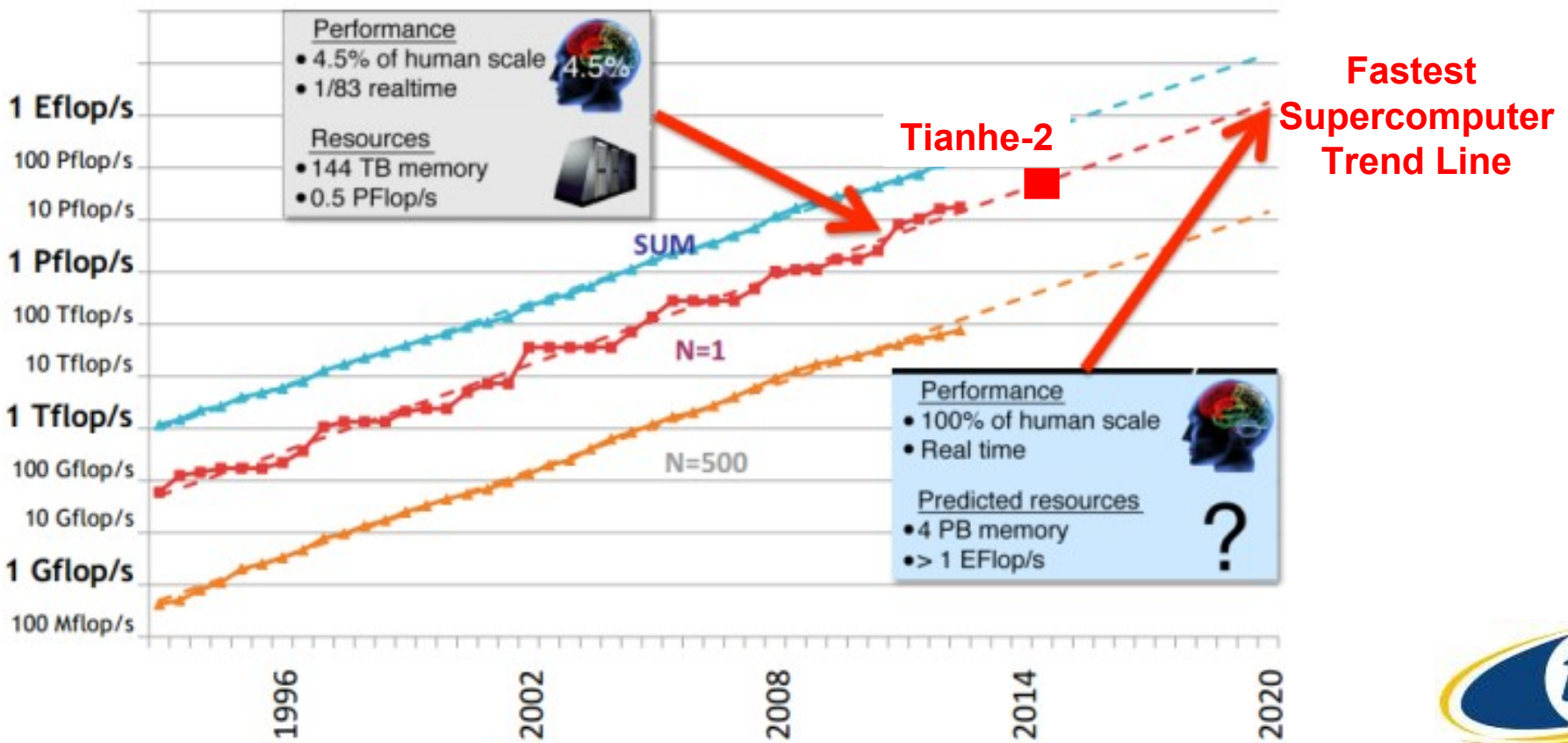
Realtime Simulation of Human Brain Possible Within the Next Ten Years With Exascale Supercomputer

IBM Simulates 4.5 percent of the Human Brain, and All of the Cat Brain

SCIENTIFIC AMERICAN™ October 25, 2011

Towards Exascale

Horst Simon, Deputy Director,
Lawrence Berkeley National Laboratory



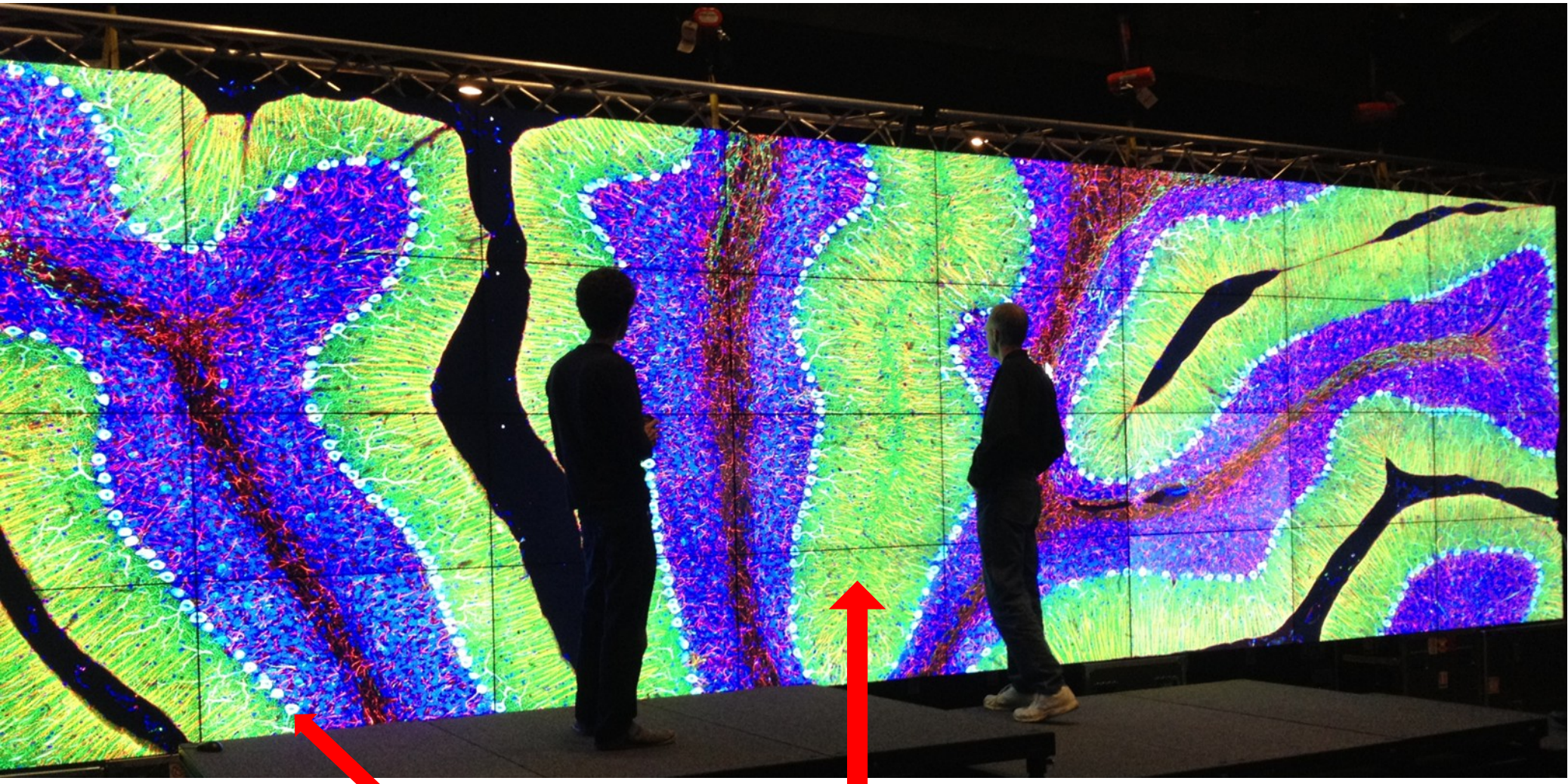
The Exascale Power Conundrum: Why We Have to Turn to Brain-Inspired Computers

- **Straightforward Extrapolation Results in a Real Time Human Brain Scale Simulation at 1–10 Exaflop/s with 4 PB of Memory**
- **A Digital Computer with this Performance Might be Available in 2022–2024 with a Power Consumption of >20–30 MW**
- **The Human Brain Runs on 20 W**
- **Our Brain is a Million Times More Power Efficient!**



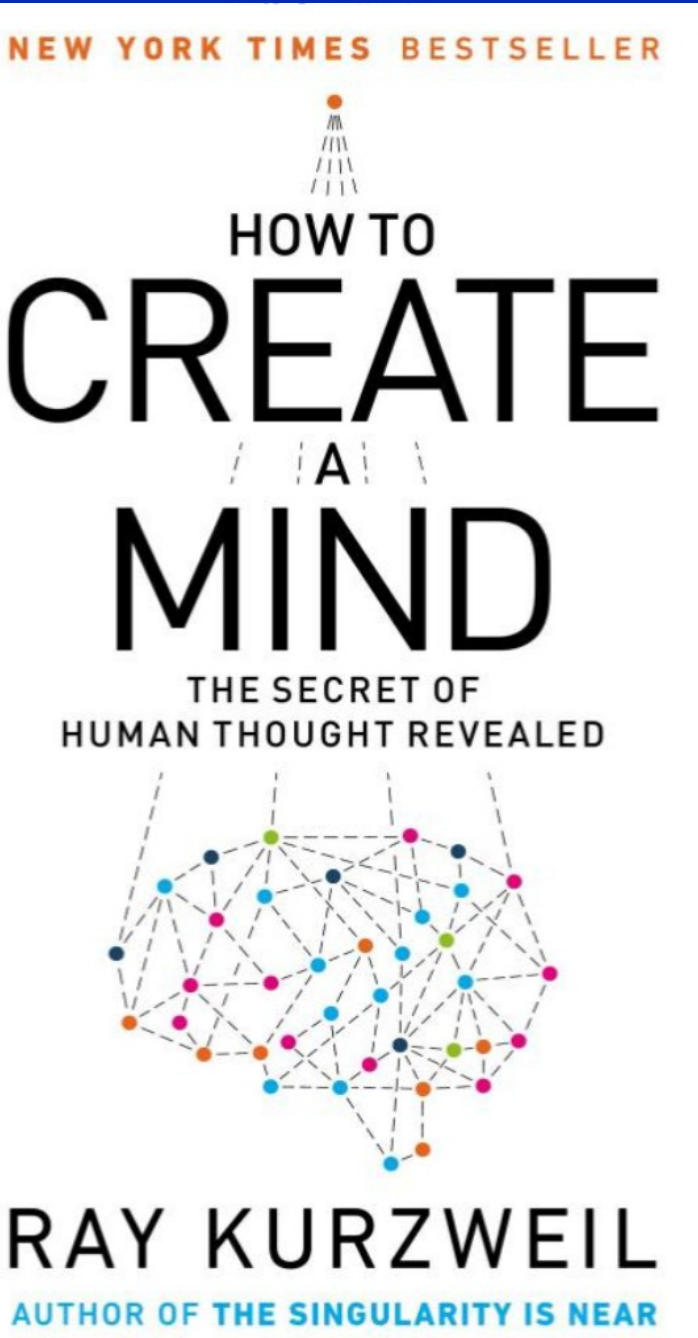
Horst Simon, Deputy Director,
Lawrence Berkeley National Laboratory

Large Scale Microscopy of Mammal Brains Reveals Complex Connectivity



Source: Rat Cerebellum Image, Mark Ellisman, UCSD

Kurzweil's Theory of Mind:
The Human Neocortex is a Self-Organizing Hierarchical System of Pattern Recognizers



November 13, 2012

"There are ~300M Pattern Recognizers in the Human Neocortex."

In the Emerging Synthetic Neocortex, "Why Not a Billion? Or a Trillion?"

Envisioning a New Era in Chip Design: The Brain-Inspired "Pattern Recognition Processor"

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The most accurate predictive report on technology and the global economy, read by leaders in industry, finance and government worldwide.

SNS Subscriber Edition Volume 16, Issue 6 Week of February 11, 2013

SNS

THE MOST IMPORTANT CHIP NOT YET INVENTED

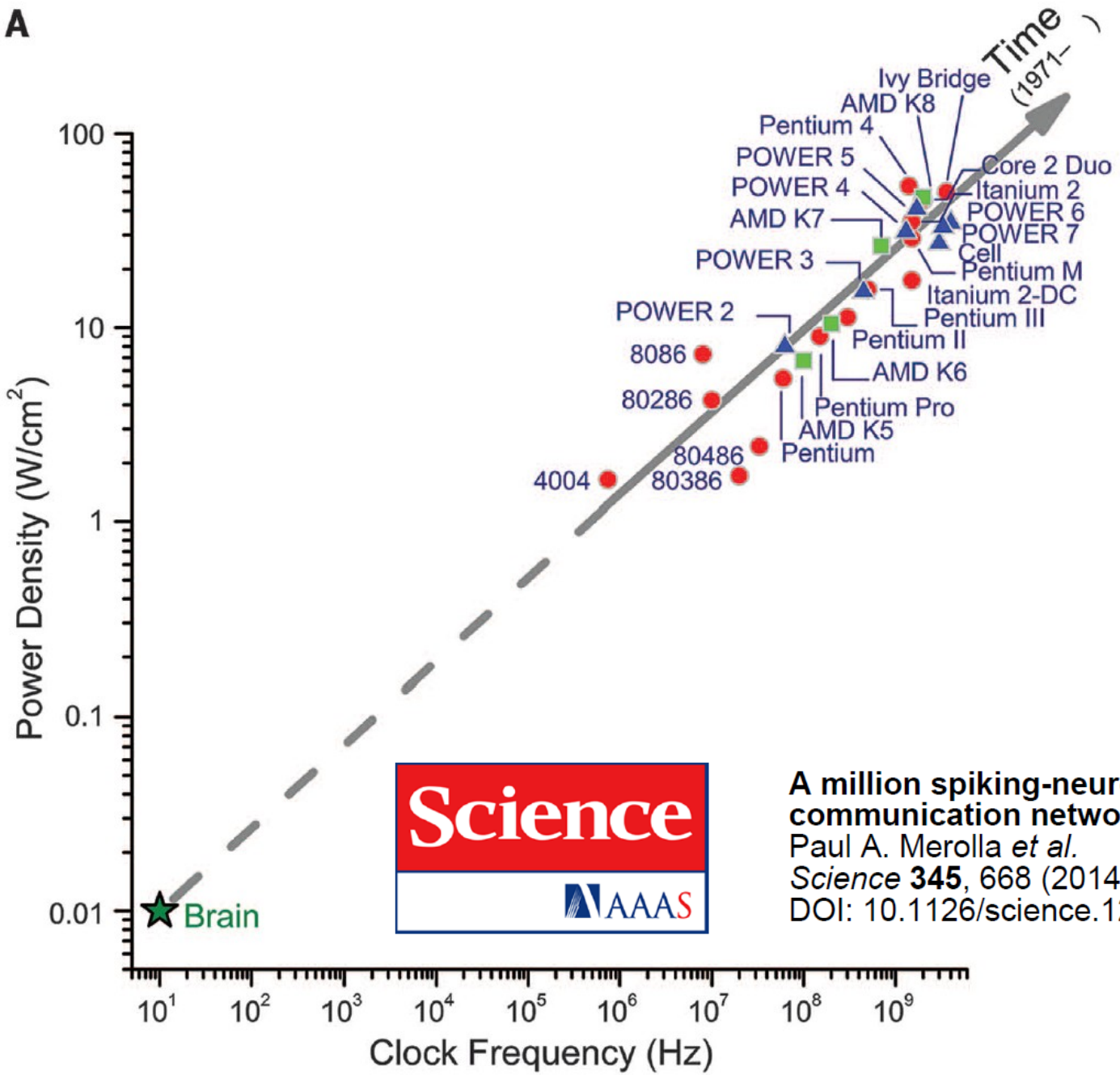
IN THIS ISSUE

FEATURE:
THE MOST IMPORTANT CHIP NOT YET INVENTED

"Since 1995 I have been recommending Pattern Recognition as the key attribute for human approaches to seeing the world clearly. …Perhaps we can help lay the foundation for a new era of understanding by inventing a new Pattern Recognition Processor."

Source: Mark Anderson, CEO SNS; Calit2 Advisory Board Member

Major Challenge to Current von Neumann Chips: Moving Away From the Brain's Efficiency



A million spiking-neuron integrated circuit with a scalable communication network and interface
Paul A. Merolla *et al.*
Science **345**, 668 (2014);
DOI: 10.1126/science.1254642

Massive Public Private Partnership to Accelerate Brain-Inspired Computers



Over $100 Million

DARPA SyNAPSE Program

HRL

GM BOEING

IBM

Jan/Feb 2014



Brainlike Computers, Learning From Experience

By JOHN MARKOFF

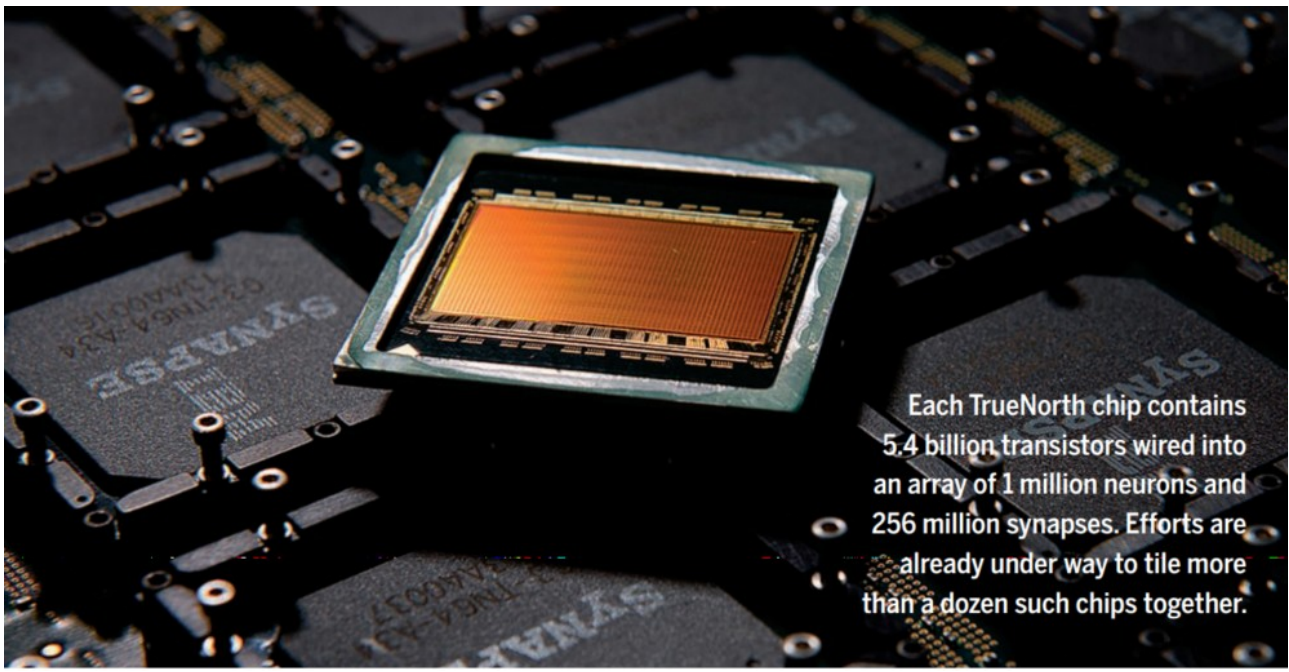
Published: December 28, 2013

The New York Times

it²

Brain-Inspired Processors
Are The Start of the non-von Neumann Architecture Era





IBM

August 8, 2014

"On the drawing board are collections of 64, 256, 1024, and 4096 chips.

'It's only limited by money, not imagination,' Modha says."

Source: Dr. Dharmendra Modha
Founding Director, IBM Cognitive Computing Group

Mark Anderson's Reaction to the IBM True North Science Paper

"Larry et al.-I am including the url to
perhaps the most important new chip design in many decades.

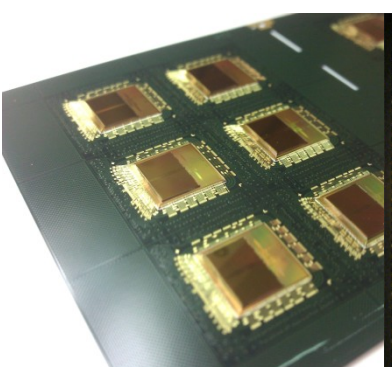
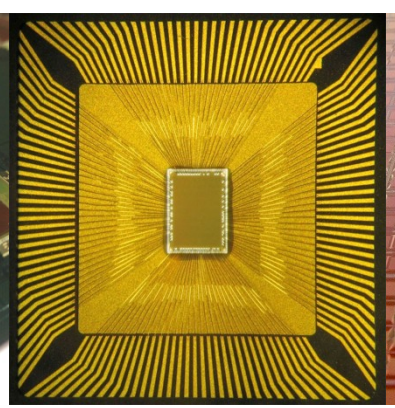
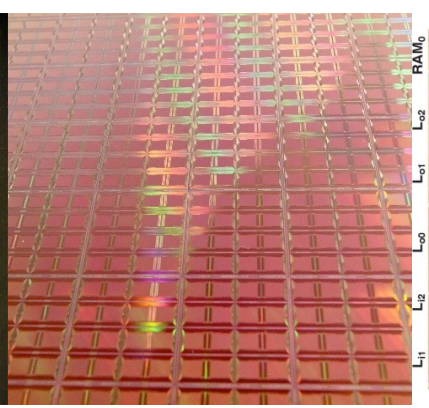
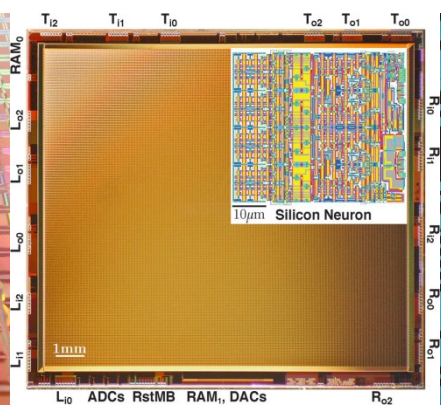
If you feel as though you had already read about it,
I would encourage going back to the 2.11.13 SNS,
called "The Most Important Chip Not Yet Invented."

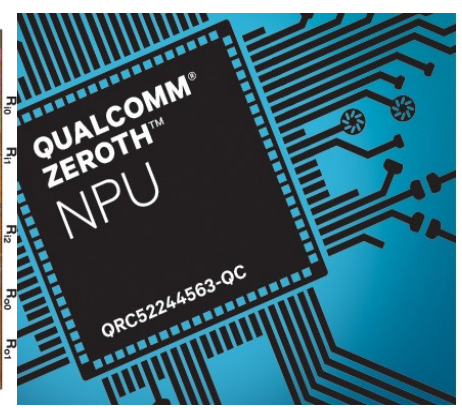
Now, it has been.
I think you'll find the descriptions almost amazingly identical."

Source: Mark Anderson Email 8/9/2014

Five Complementary Approaches to Neuromorphic Computing (Massively Parallel, Asynchronous Communication, Configurable):

- Custom Fully Digital (IBM Almaden)
- Commodity Microprocessors (SpiNNaker, HBP)
- Custom Mixed-Signal (BrainScaleS, HBP)
- Custom Subthreshold Analog Cells (Stanford, ETHZ)
- Custom Hybrid (Qualcomm)



Source: Horst Simon, LBL; after K. Meier, Nov. 2014

Pattern Recognition Co-Processors Coupled to Today's von Neumann Processors

"If we think of today's von Neumann computers
as akin to the "left-brain"
—fast, symbolic, number-crunching calculators,
then IBM's TrueNorth chip
can be likened to the "right-brain"
—slow, sensory, pattern recognizing machines."
- Dr. Dhamendra Modha, IBM Cognitive Computing

www.research.ibm.com/articles/brain-chip.shtml

Contextual Robots With Neuromorphic Processors That Can See and Learn Will Tie Into the Planetary Computer

"We think robotics is the killer app for neuromorphic computing."

Todd Hylton, Brain Corporation

brain CORPORATION

Qualcomm launches robotics accelerator

QUALCOMM

Qualcomm could add a "neural processing unit" to mobile-phone chips to handle sensory data and tasks such as image recognition.

MIT Technology Review

April 2014



Science 10 October 2014

it²

The Planetary Cloud Computer Is Connected to a Billion Cray-Speed Smartphones

Imagine Each Smartphone with a PRP!

1 Billion Smartphones Shipped In 2013

InformationWeek 1/28/2014

The iPad in Your Hand: As Fast as a Supercomputer of Yore

The New York Times

By JOHN MARKOFF MAY 9, 2011 3:45 PM 14 Comments

1988 Cray Y-MP



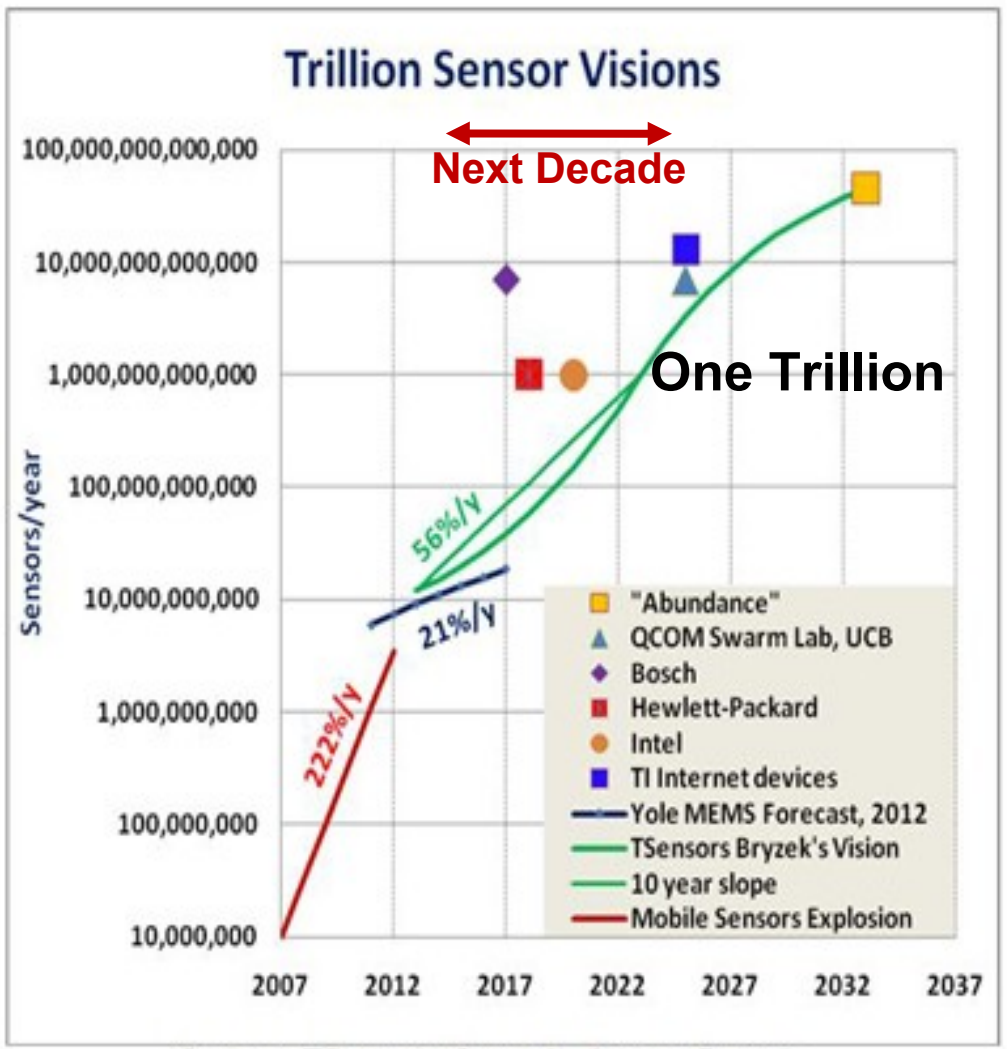
2010 ipad 2



Two Examples of $Trillion Markets That This Cyberinfrastructure Will Disrupt

- **Quantified Machines and the Industrial Internet**
- **Quantified Selves and Healthcare**

The Planetary-Scale Computer Fed by a Trillion Sensors Will Drive a Global Industrial Internet



Source: TSensors Summit, Janusz Bryzek



www.tsensorssummit.org

"Within the next 20 years the Industrial Internet will have added to the global economy an additional $15 trillion."
--General Electric

www.ge.com/docs/chapters/Industrial_Internet.pdf

ww-bsac.eecs.berkeley.edu/frontpagefiles/BSACGrowingMEMS_Markets_%20SEMI.ORG.html

A Vision for Healthcare in the Coming Decades

Using this data, the planetary computer will be able to build a computational model of your body and compare your sensor stream with millions of others. Besides providing early detection of internal changes that could lead to disease, cloud-powered voice-recognition wellness coaches could provide continual personalized support on lifestyle choices, potentially staving off disease and making health care affordable for everyone.

ESSAY | The New York Times | Science

An Evolution Toward a Programmable Universe

By LARRY SMARR

Published: December 5, 2011

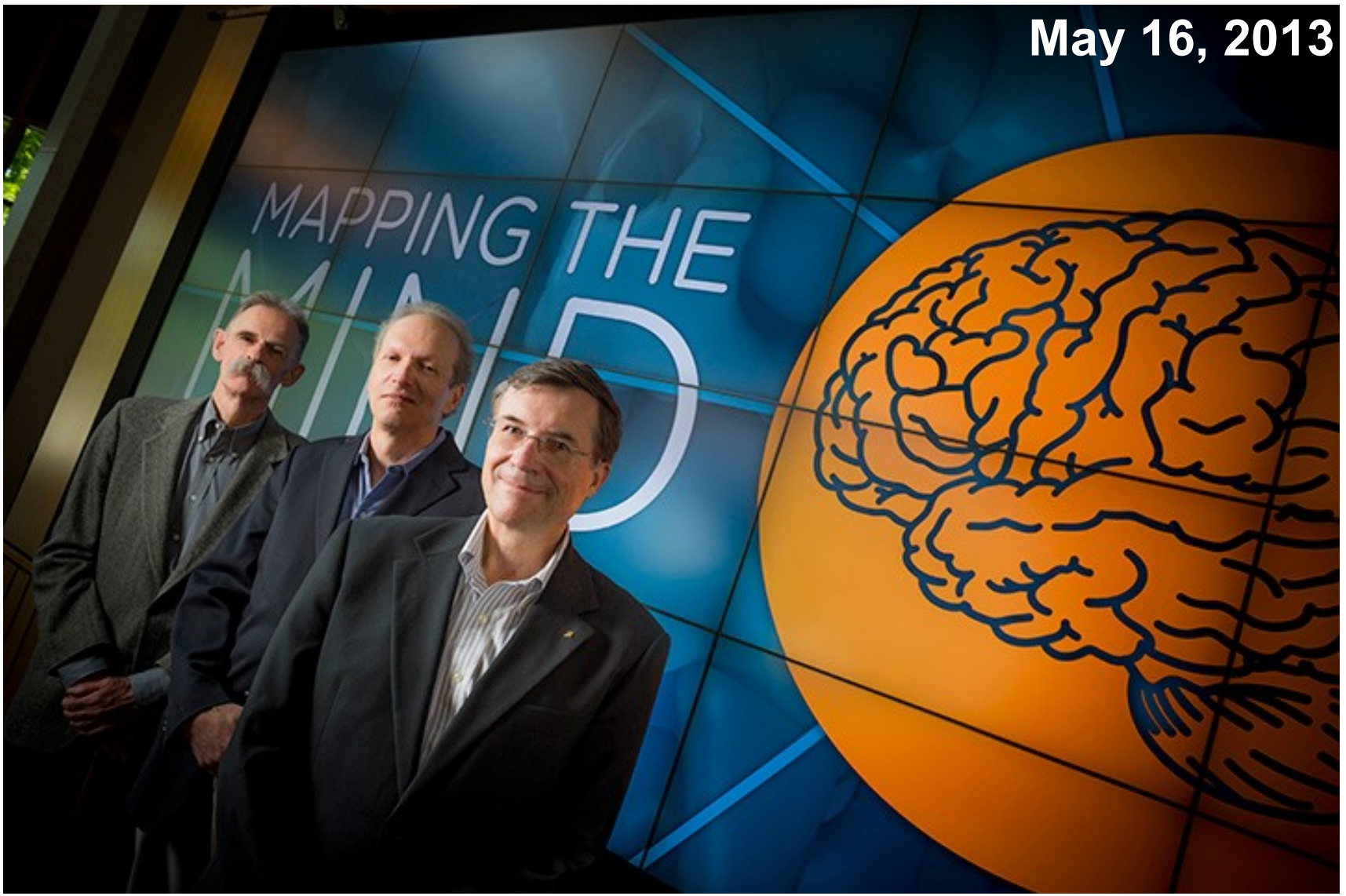
Reverse Engineering of the Brain Is Accelerating Under the Federal Brain Initiative



www.whitehouse.gov/infographics/brain-initiative

UC San Diego Creates Center for Brain Activity Mapping

http://ucsdnews.ucsd.edu/feature/uc_san_diego_creates_center_for_brain_activity_mapping



From left, Nick Spitzer, Ralph Greenspan, and Terry Sejnowski.
Photos by Erik Jepsen/UC San Diego Publications

Center for Brain Activity Mapping

cbam.ucsd.edu

of the KAVLI Institute for Brain and Mind at UCSD

SENSOR TECHNOLOGIES FOR THE NERVOUS SYSTEM

JUNE 4, 2014 8:00AM – 5:30PM

ATKINSON HALL, QUALCOMM INSTITUTE, UCSD

A Symposium Sponsored by
the Center for Brain Activity Mapping at UCSD
Registration at cbamsensor2014.eventbrite.com

The B.R.A.I.N. Initiative faces a major technological barrier in obtaining high resolution, real-time recordings of brain activity over large areas of the brain. Leading researchers will explore available and promising approaches to surmounting that barrier, exploring current work and future possibilities for the detection and recording of the range of relevant electrical and chemical signals in the nervous system.

speakers

ralph greenspan	*Opening Remarks*
adam cohen	*All-optical Electrophysiology with Microbial Rhodospins*
alan jasanoff	*Molecular Probes for Noninvasive Neuroimaging*
james schuck	*Optimizing Nanocrystals for Deep-Tissue Imaging*
erkki ruoslahti	*Targeting of the Brain and its Diseases with Nanoparticles*
ania bleszynski jayich	*Nanoscale Sensing with Diamond Spins: Prospects for Bio-sensing*
r. mark wightman	*Electrochemical Monitoring of Neurotransmitters and Metabolites*
paul weiss	*Developing Nanoscale Measurements for the Brain*

The Brain Initiative is Driving Nanosensors

A Totally New Information System is Being Invented to Read Out the Dynamic State of the Brain

Massive Amounts of Data Combined With Planetary-Scale Computing Leads to Deep Learning

How Ray Kurzweil Will Help Google Make the Ultimate AI Brain

BY STEVEN LEVY 04.25.13 | 9:30 AM | PERMALINK

WIRED

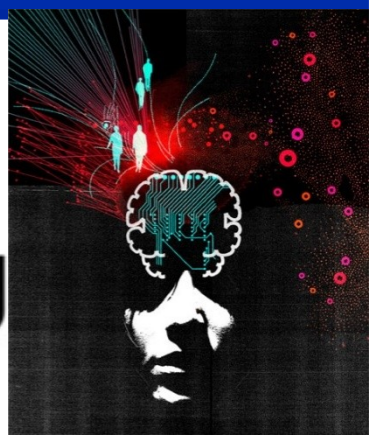
Facebook's Quest to Build an Artificial Brain Depends on This Guy

BY DANIELA HERNANDEZ 08.14.14 | 6:30 AM | PERMALINK

Exclusive: Google to Buy Artificial Intelligence Startup DeepMind for $400M

January 26, 2014, 4:25 PM PST ‹re/code›

Deep Learning



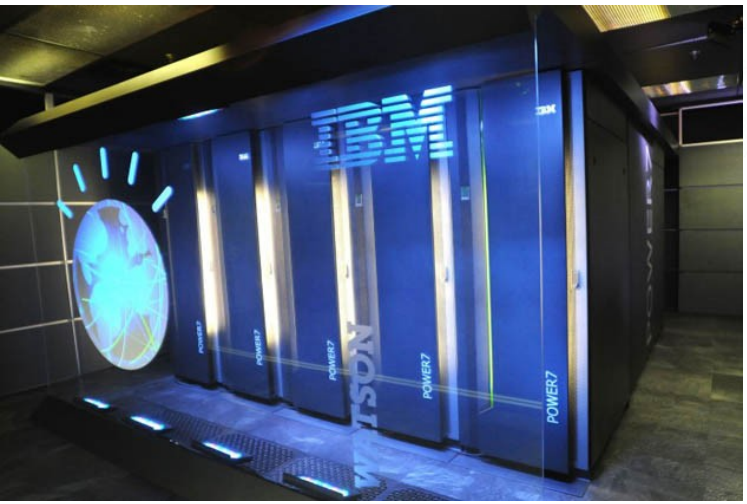
With massive amounts of computational power, machines can now recognize objects and translate speech in real time. Artificial intelligence is finally getting smart.

MIT Technology Review

April 2013

it²

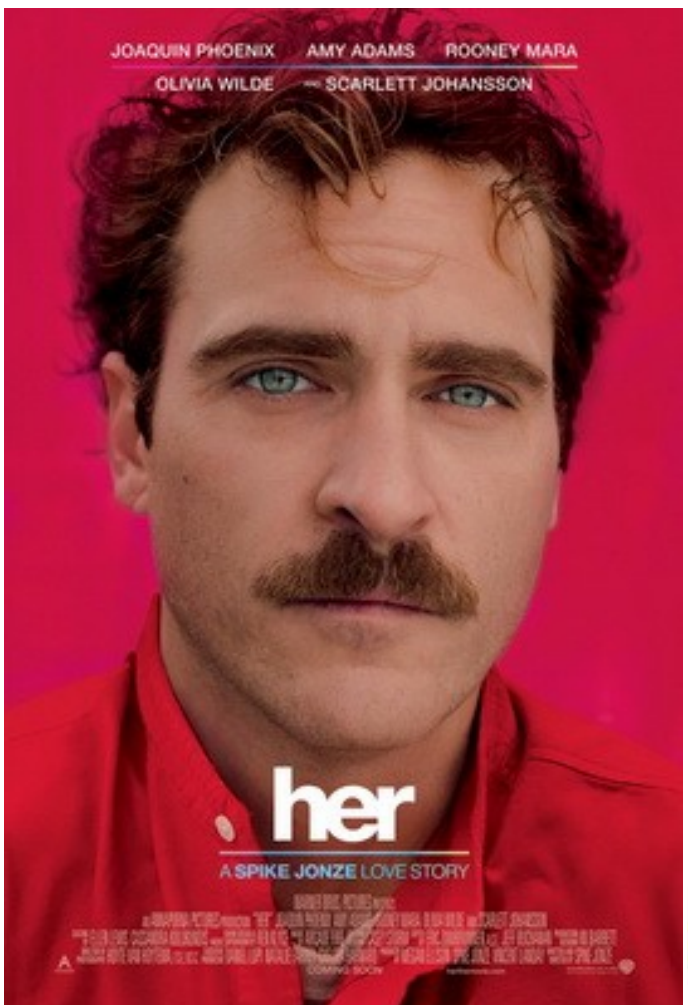
Deep Learning Will Provide Personalized Assistants to Each of Us



IBM's Watson supercomputer gets its own $1 billion business

IBN Live **January 10, 2014**

Where Personalized Coaching is Now



Where Personalized Coaching is Going

This Next Decade's Computing Transition Will Not Be Just About Technology



"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*



Elon Musk
@elonmusk

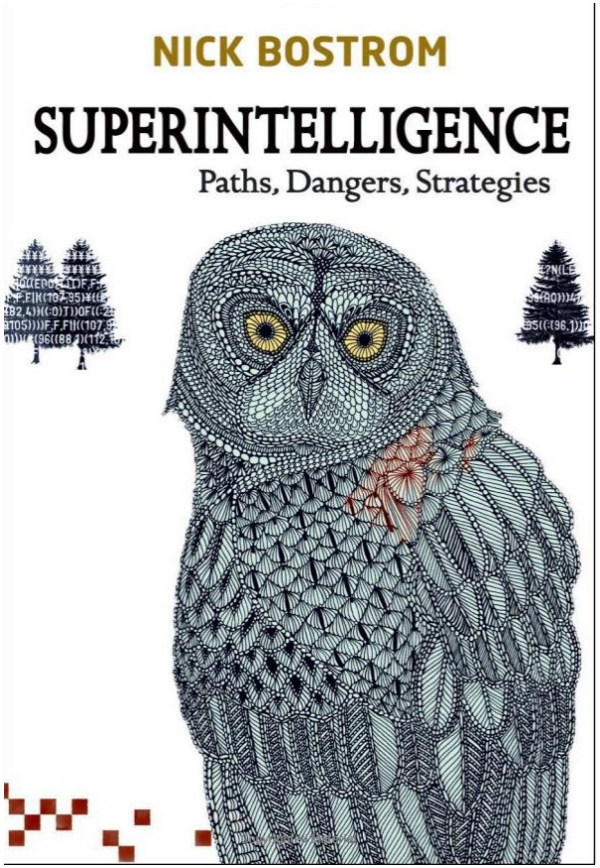
Follow

Worth reading Superintelligence by Bostrom. We need to be super careful with AI. Potentially more dangerous than nukes.

7:33 PM - 2 Aug 2014



If our own extinction is a likely, or even possible, outcome of our technological development, shouldn't we proceed with great





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*