"Advanced Cyberinfrastructure Enabled Services and Applications in 2021"

**Keynote Presentation
NSF Workshop on Applications and Services in 2021
Washington, DC
January 28, 2016**

Dr. Larry Smarr

Director, California Institute for Telecommunications and Information Technology

Harry E. Gruber Professor,

Dept. of Computer Science and Engineering
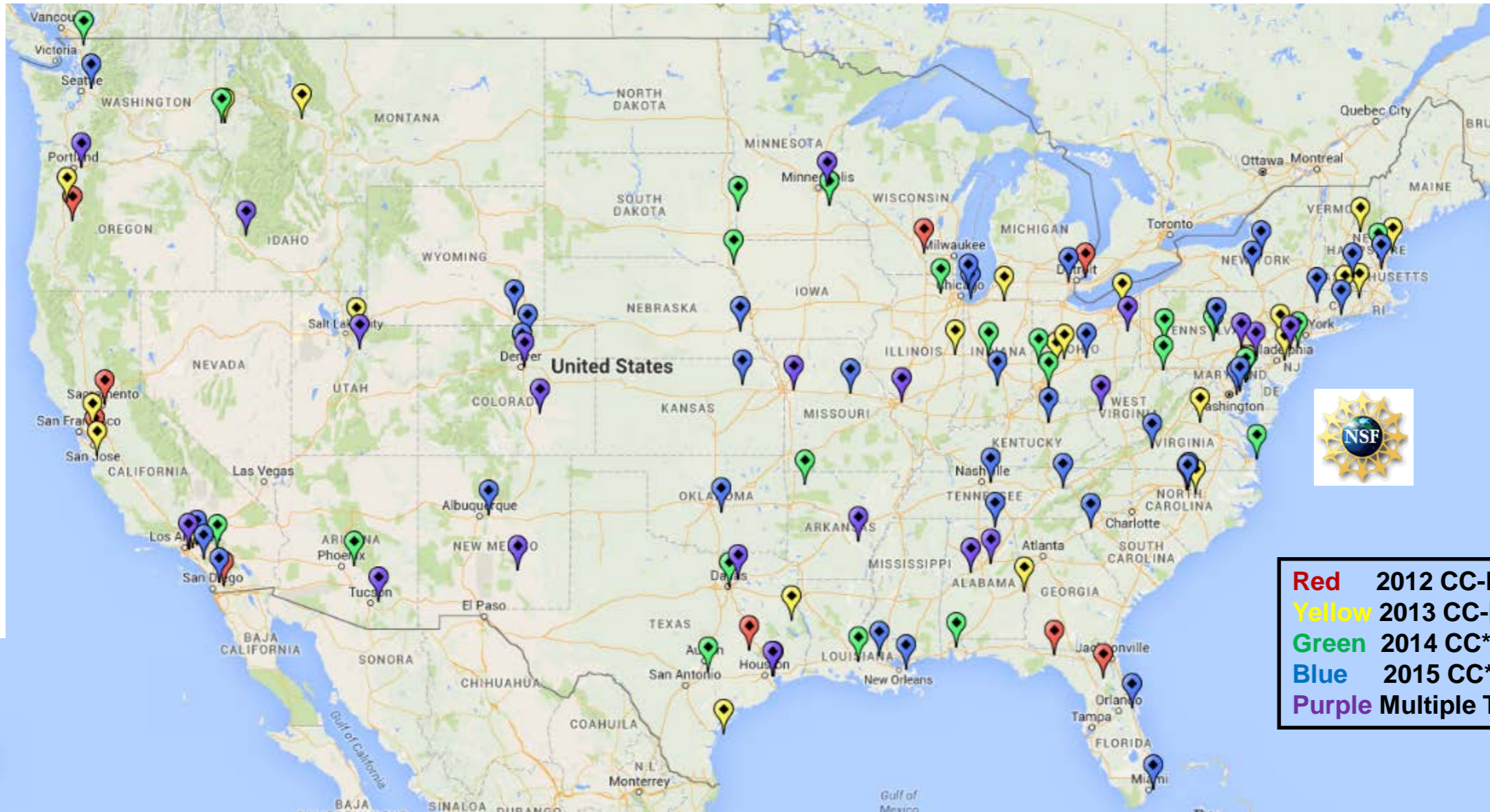
Jacobs School of Engineering, UCSD

The Cyberinfrastructure of 2021 Will Be Radically Different from 2016

- **Wired**

- **Wireless**

- **Sensors**

- **Computer Architecture**

- **Visualization**

# NSF Has Funded Over 100 Campuses to Build Local "Big Data" Optical Fiber Freeways 1000x Shared Internet Speed

Red 2012 CC-NIE Awardees
Yellow 2013 CC-NIE Awardees
Green 2014 CC*IIE Awardees
Blue 2015 CC*DNI Awardees
Purple Multiple Time Awardees

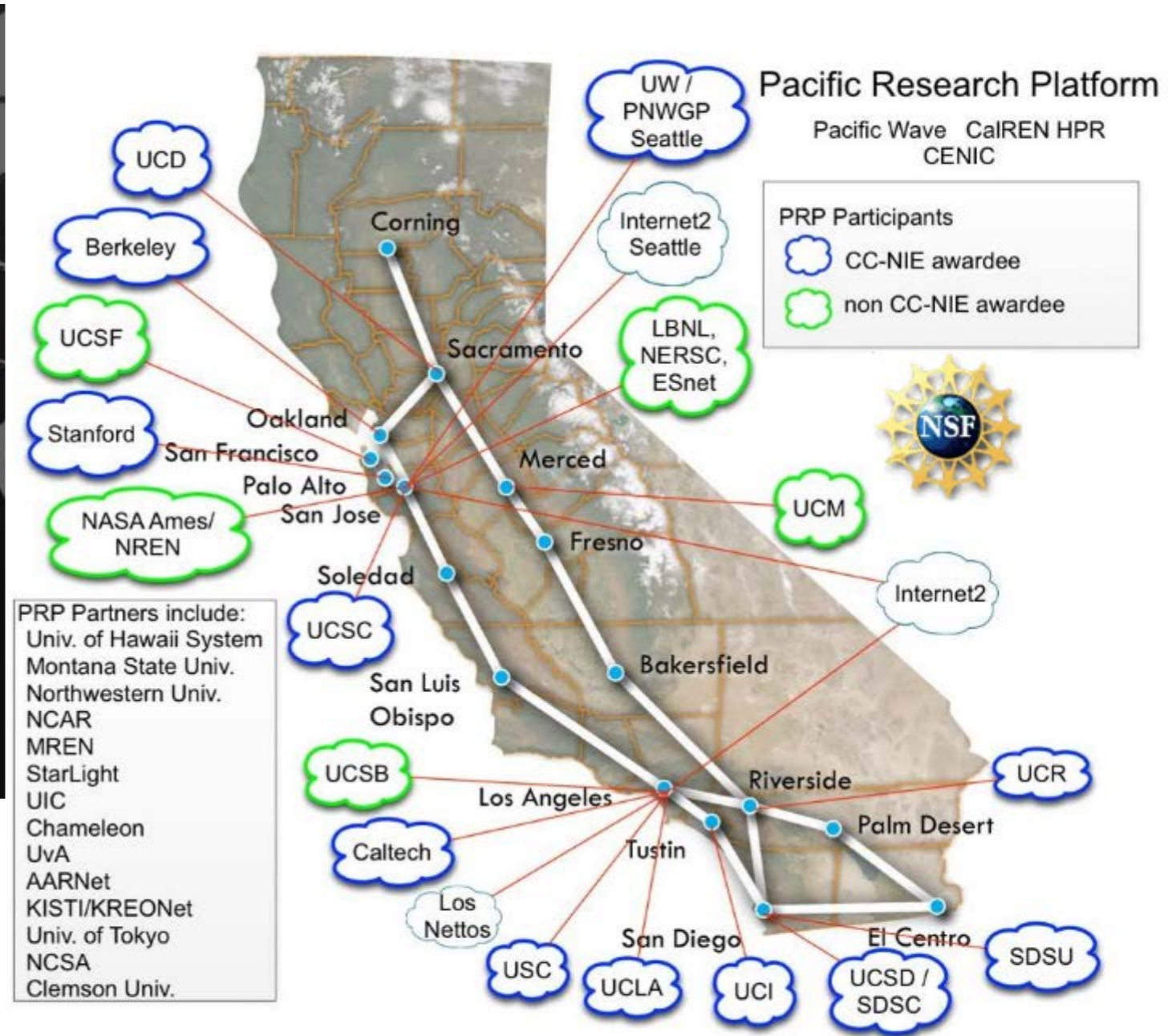**2012-2015 CC-NIE / CC*IIE / CC*DNI PROGRAMS**

Source: NSF

Optical Fibers Linking Big Data Researchers at 10-100Gbps in U.S., Australia, Korea, Japan, and the Netherlands
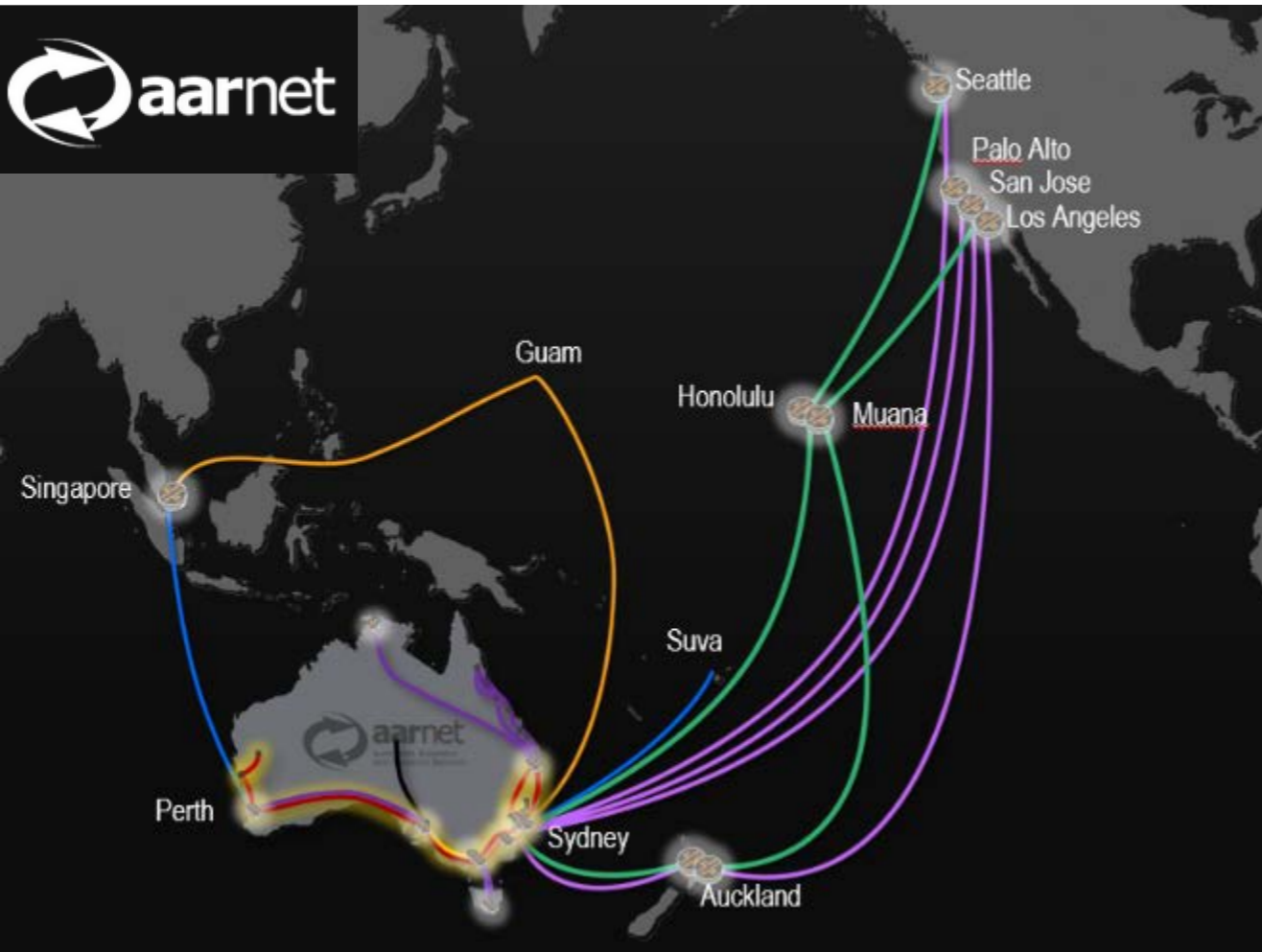
Australia forges US partnership to accelerate scientific discovery and innovation
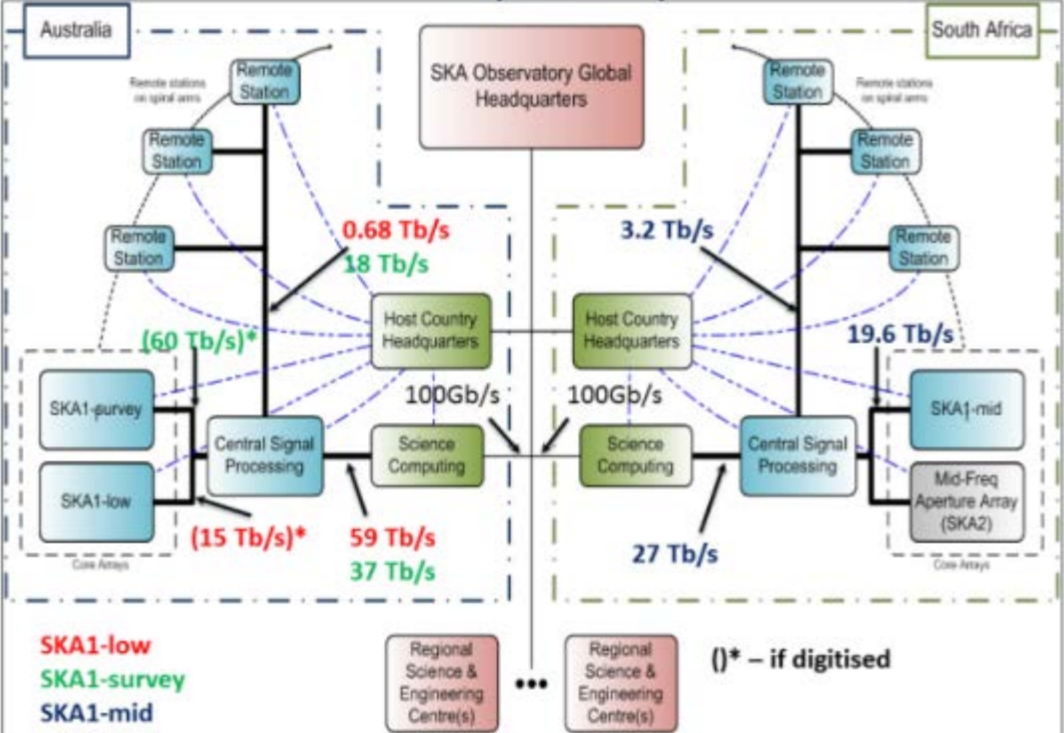
August 5, 2015

Global Scientific Instruments Will Produce Ultralarge Datasets Continuously: New Services and Applications Needed for Data Scientific Discovery

Square Kilometer Array

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

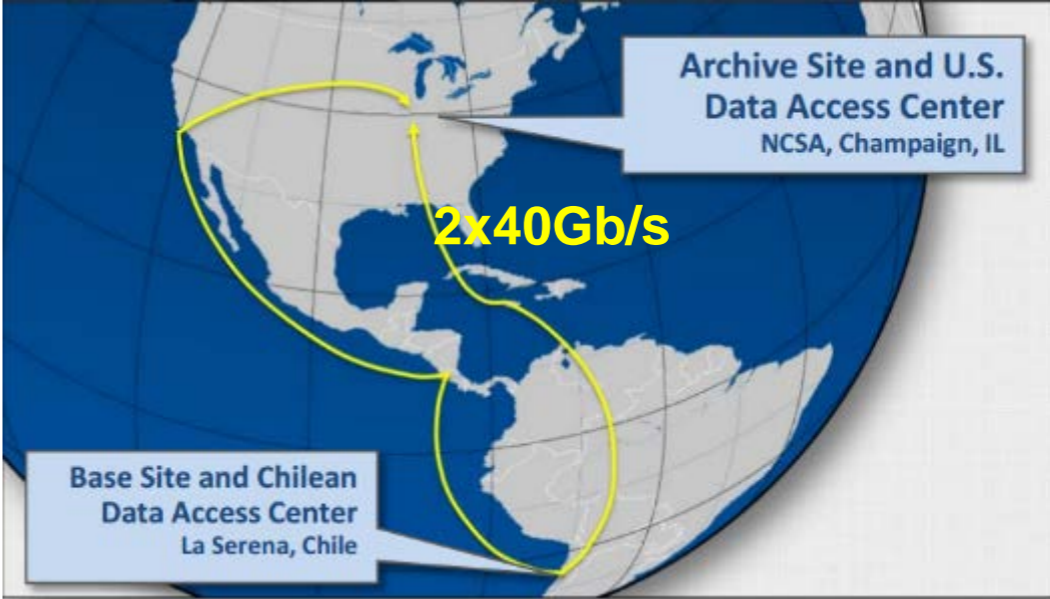By Sebastian Anthony on April 2, 2012 at 11:48 am | 8 Comments

Large Synoptic Survey Telescope

Tracks ~40B Objects, Creates 10M Alerts/Night Within 1 Minute of Observing

5G Will Enable a Wide Range of New Wireless Applications and Services Connecting People and Things

Higher user experienced data rate

Fiber-like access rate

Zero latency experience

Comparable to local operations

Vehicle

Dense zone

Train

Subway

Excellent experience under various scenarios

Consistent experience under diverse scenarios

Typical Services

Mobile Internet services

UHD Video Streaming

Cloud Storage

Augmented Reality

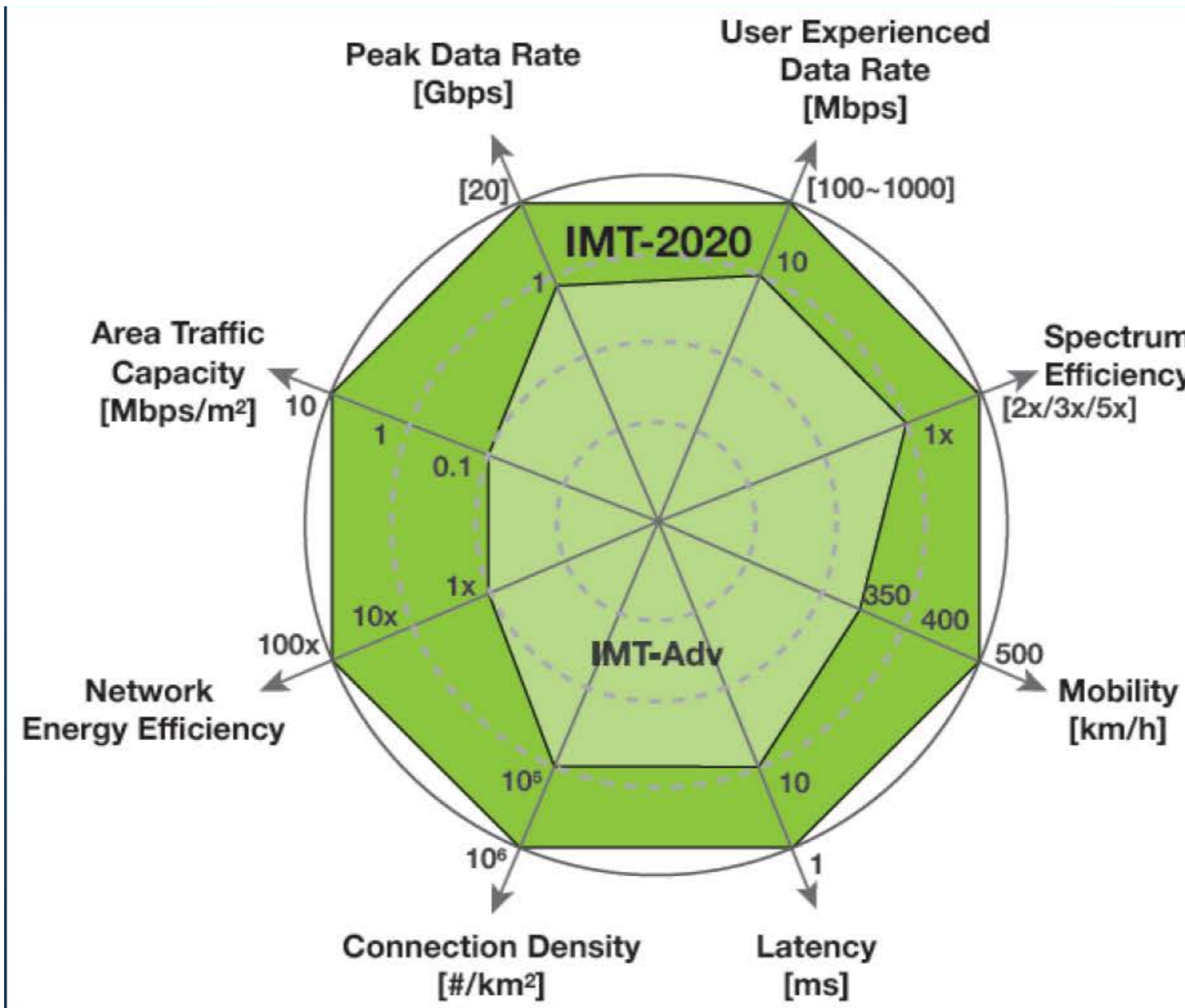Virtual Reality

IoT services

ITS
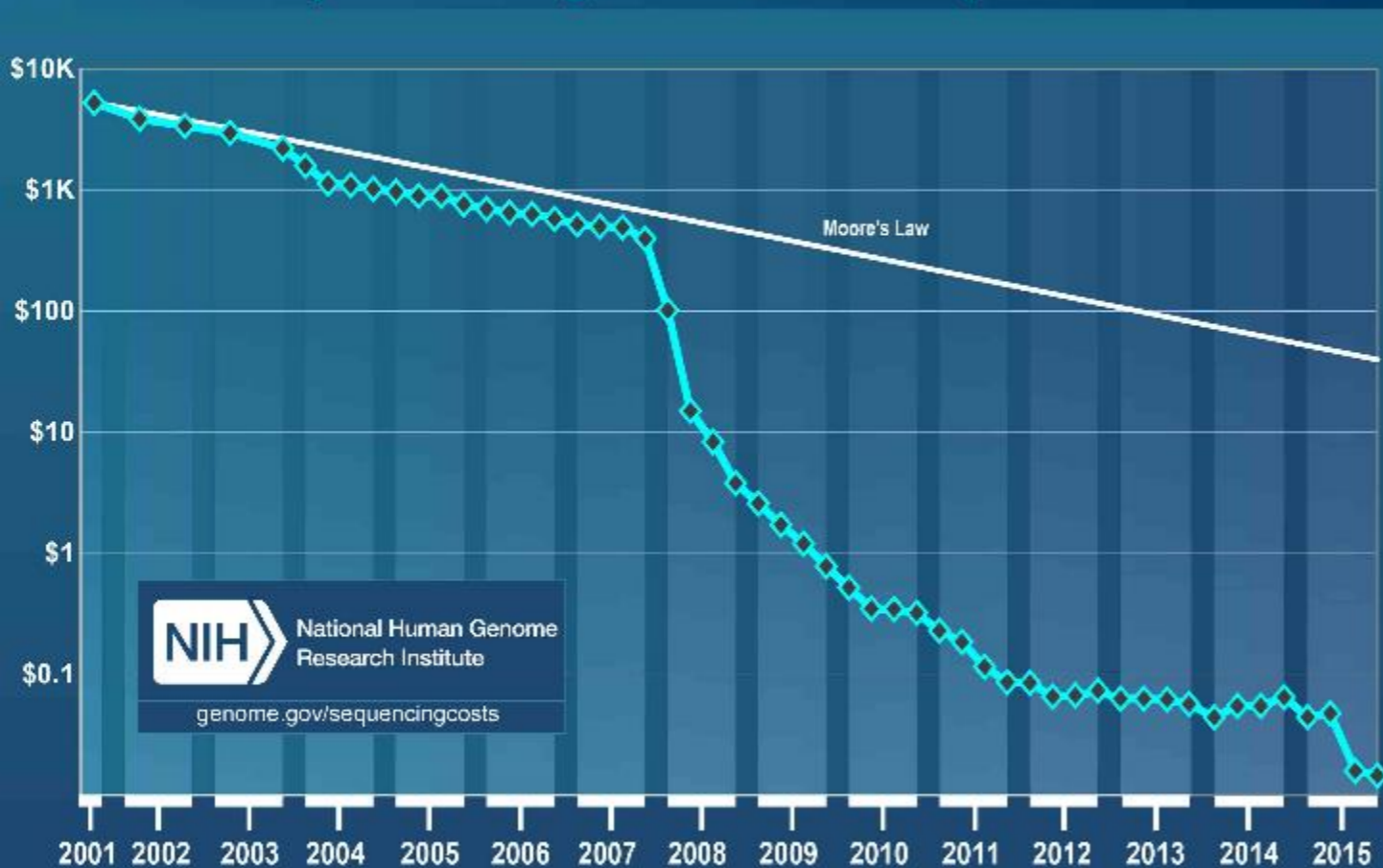
Smart Home

Surveillance

Smart Grid

The Jump from Wireless 4G to 5G Will Be Transformative: ITU's International Mobile Telecommunication (IMT) System

Massive Changes in Our Ability to Quantify the World
Simultaneously Explosively Decrease in Sensor Cost and Increase of Use
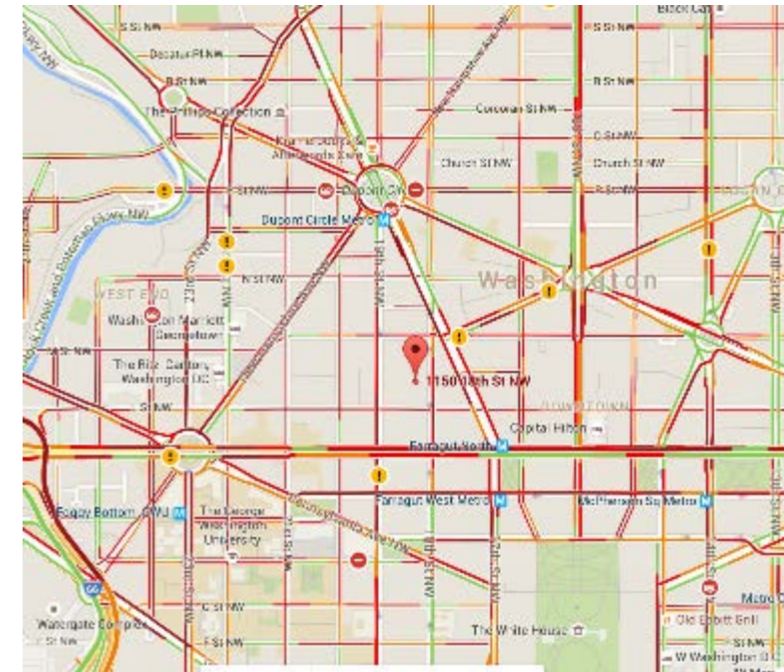
www.genome.gov/images/content/costperMb2015_4.jpg

New Computing Architectures Are Developing Rapidly From the End of Scaling Which Drove Moore's Law

Semiconductor Technology Scaling

- **Nanoelectronic Computing**
- **Approximate Computing**
- **Quantum Computing**
- **Brain-Inspired Computing**

Quantum Realm
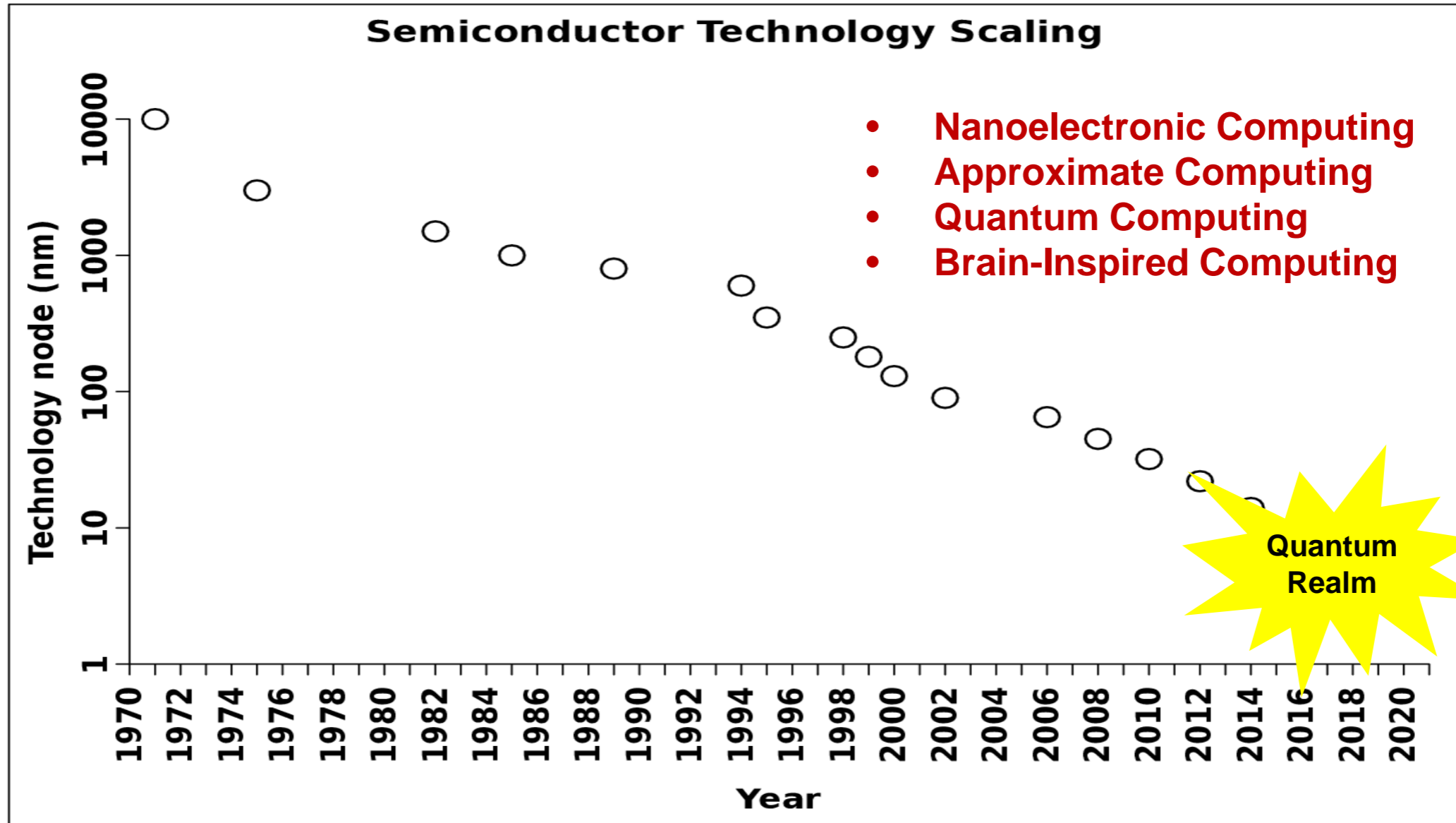
The Future of Supercomputing

**"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**

Adapted from D-Wave

Massive Public Private Partnership
to Accelerate Brain-Inspired Computers

Artificial Brains
The quest to build sentient machines

Over $100 Million

HRL

GM · BOEING

DARPA SyNAPSE Program

IBM

Jan/Feb 2014

Feature
Thinking in Silicon
By Tom Simonite

MIT Technology Review
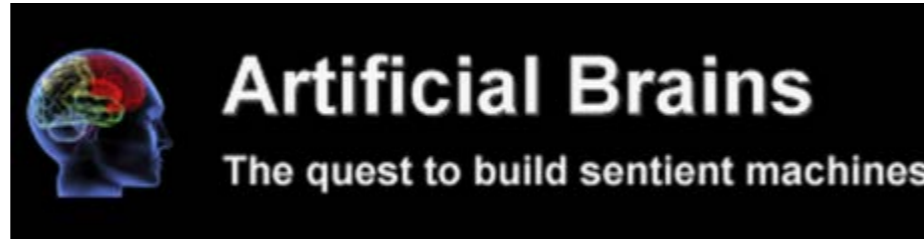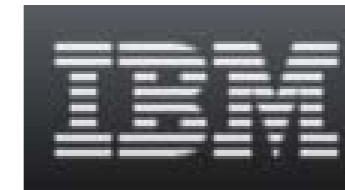
Brainlike Computers, Learning From Experience
By JOHN MARKOFF
Published: December 28, 2013

The New York Times

it²

Brain-Inspired Processors
Are Accelerating the non-von Neumann Architecture Era

Each TrueNorth chip contains 5.4 billion transistors wired into an array of 1 million neurons and 256 million synapses. Efforts are already under way to tile more than a dozen such chips together.

August 8, 2014
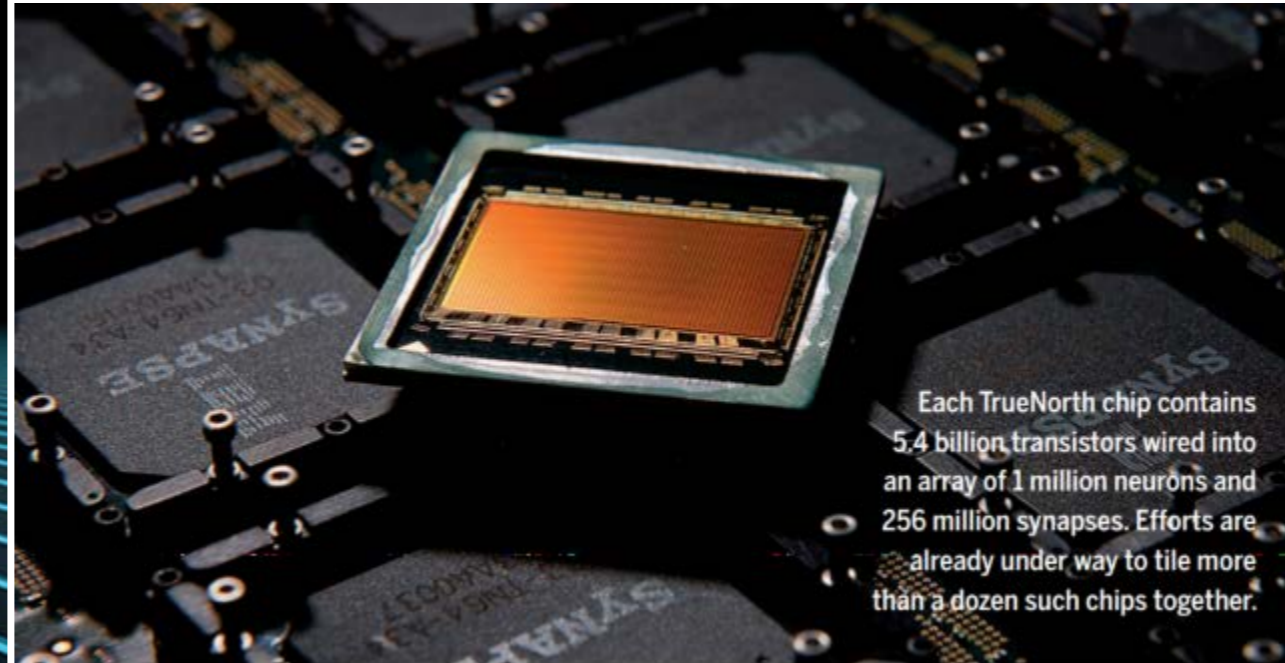
"On the drawing board are collections of 64, 256, 1024, and 4096 chips.
'It's only limited by money, not imagination,' Modha says."

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

"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.
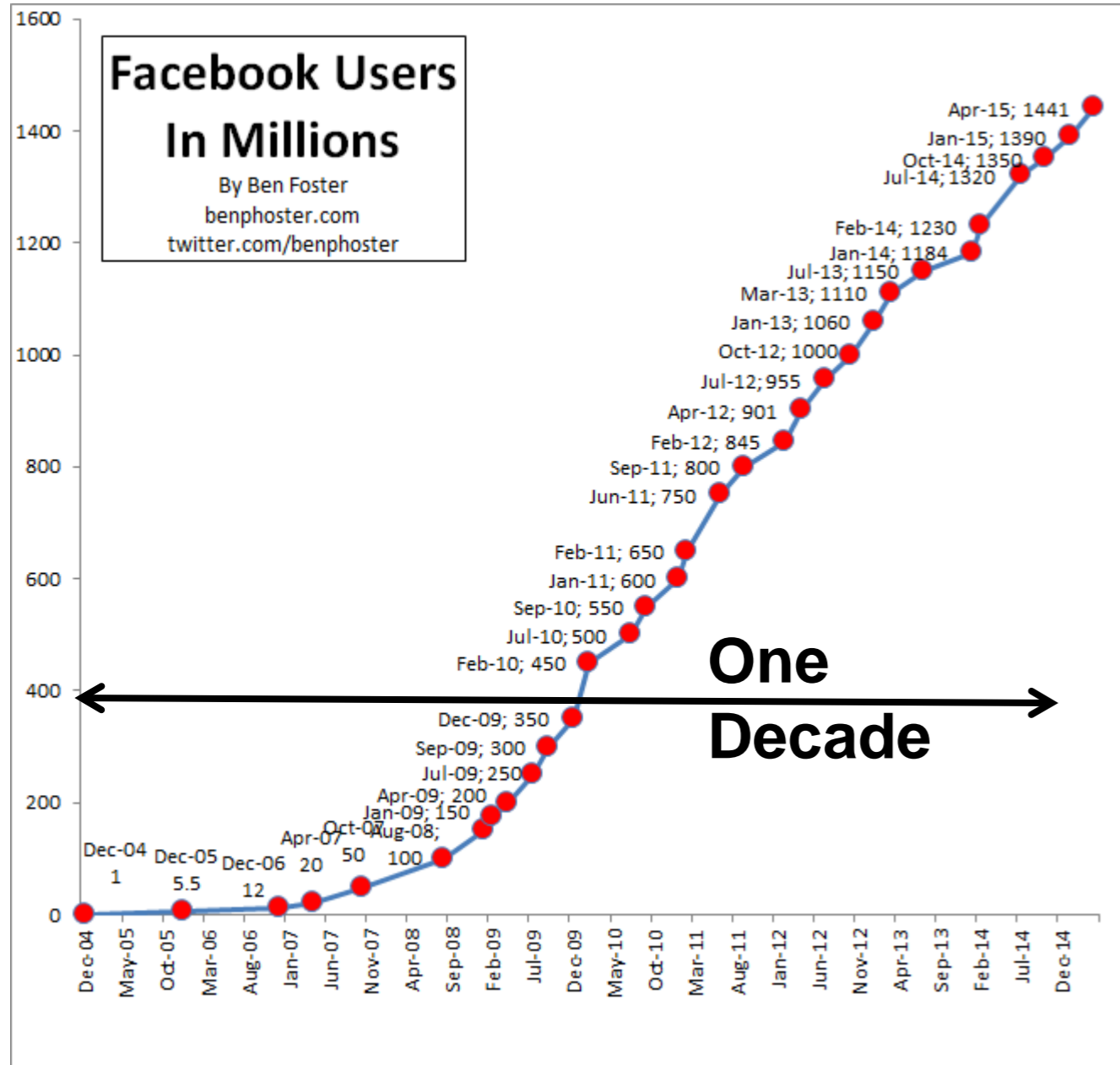
MIT Technology Review

April 2014

Minds of their own

Novel neuromorphic chips and software should provide robots with unrivaled perceptual skills

Science 10 October 2014

If You Are Planning New Applications and Services On a Ten Year Horizon, It Helps to See What Unexpected Change Can Happen In a Decade…

Facebook Users In Millions

By Ben Foster
benphoster.com
twitter.com/benphoster

Apr-15; 1441
Jan-15; 1390
Oct-14; 1350
Jul-14; 1320
Feb-14; 1230
Jan-14; 1184
Jul-13; 1150
Mar-13; 1110
Jan-13; 1060
Oct-12; 1000
Jul-12; 955
Apr-12; 901
Feb-12; 845
Sep-11; 800
Jun-11; 750
Feb-11; 650
Jan-11; 600
Sep-10; 550
Jul-10; 500
Feb-10; 450
Dec-09; 350
Sep-09; 300
Jul-09; 250
Apr-09; 200
Jan-09; 150
Oct-08; 100
Aug-08;
Apr-07; 50
Oct-07; 20
Dec-04; 1
Dec-05; 5.5
Dec-06; 12

One Decade

www.thesocialnetwork-movie.com

DEC 2004

1 000 046

From One Million to One Billion Users In Less Than 8 Years!

Facebook: One Billion and Counting

By GEOFFREY A. FOWLER
October 4, 2012

THE WALL STREET JOURNAL.

Calit2

EVL
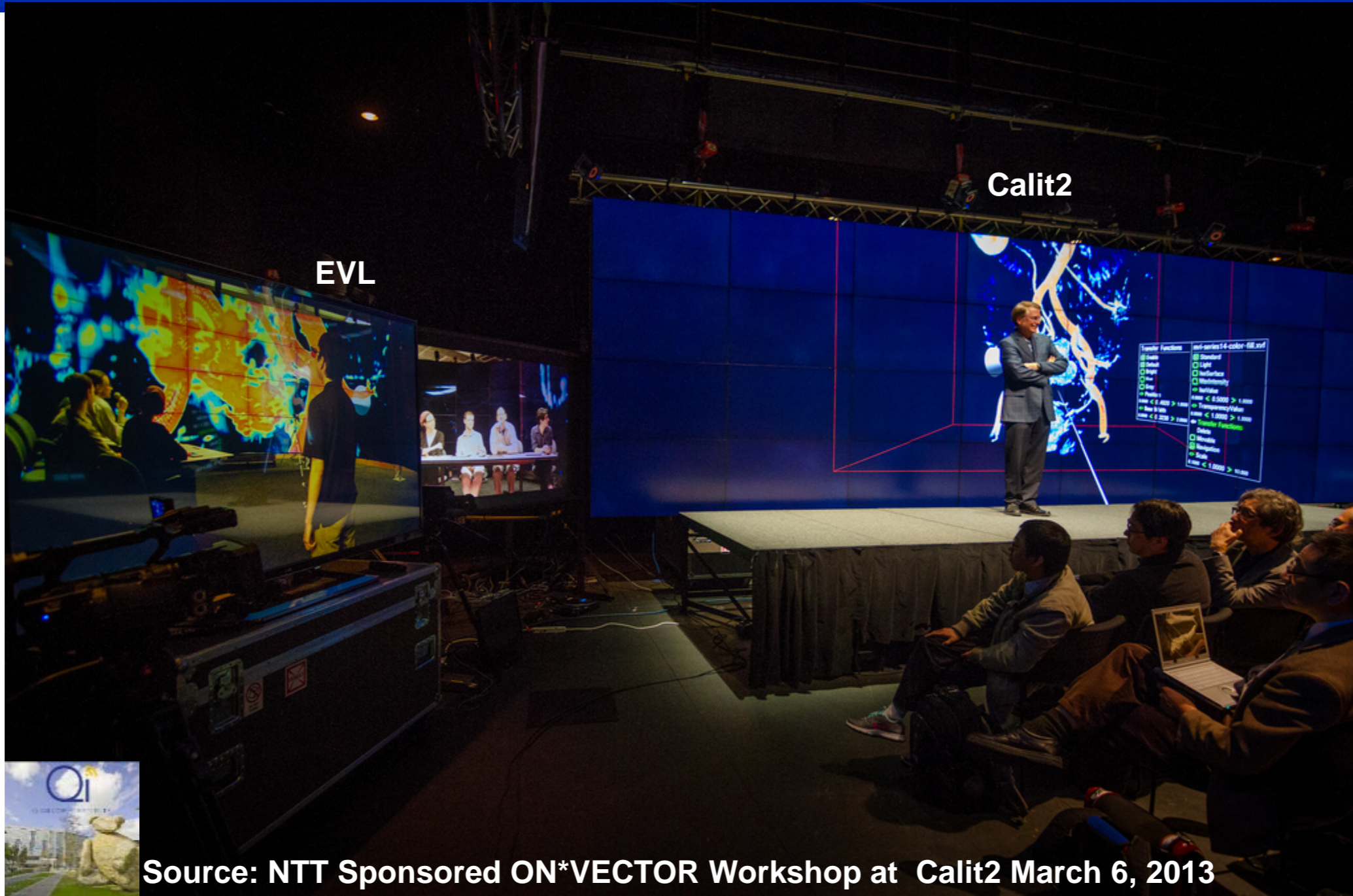
Source: NTT Sponsored ON*VECTOR Workshop at Calit2 March 6, 2013

Why Would a Social Network Company Buy a Consumer Virtual Reality Company?

TIME

Facebook Buying Oculus Virtual-Reality Company for $2 Billion

March 25, 2014

Step into the Rift

Q1 2016

One Year Later…

"We're working on VR because I think it's the next major computing and communication platform after phones…"
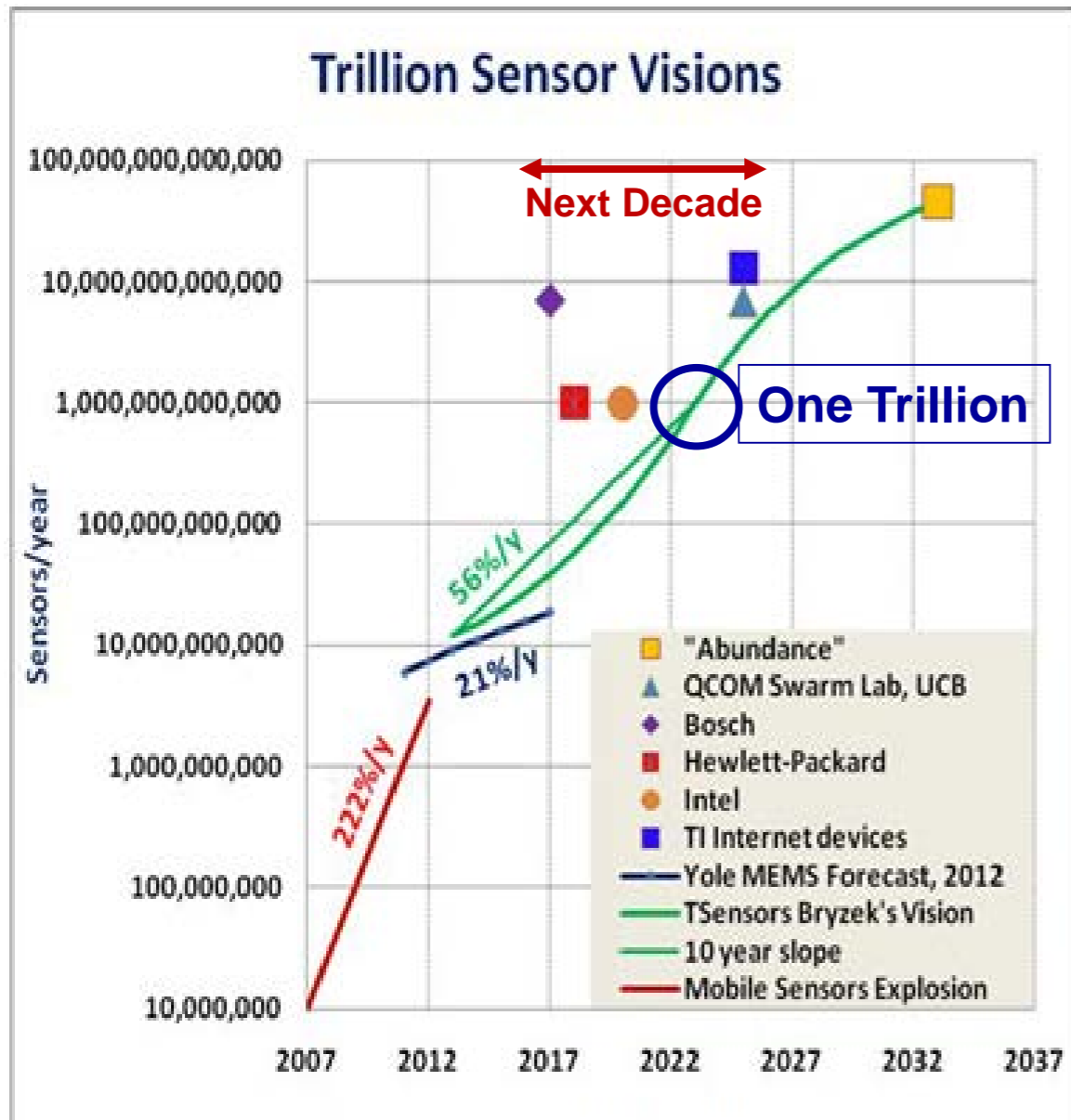**-Mark Zuckerberg, Facebook CEO**
July 1, 2015

Examples of Massive Markets That Are Being Disrupted by a Combination of These Cyberinfrastructure Advances

- **Quantified Machines Lead to the Industrial Internet**

- **Quantified Cars and Drones Lead to Self-Driving Vehicles**

- **Quantified Houses Lead to the Smart Electric Grid**

- **Quantified Selves Lead to Personalized Preventive Healthcare**

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

Trillion Sensor Visions

Sensors/year

- 100,000,000,000,000
- 10,000,000,000,000
- 1,000,000,000,000
- 100,000,000,000
- 10,000,000,000
- 1,000,000,000
- 100,000,000
- 10,000,000

Next Decade

One Trillion

56%/y
21%/y
222%/y

Legend:
- ☐ "Abundance"
- ▲ QCOM Swarm Lab, UCB
- ◆ Bosch
- ■ Hewlett-Packard
- ● Intel
- ■ TI Internet devices
- — Yole MEMS Forecast, 2012
- — TSensors Bryzek's Vision
- — 10 year slope
- — Mobile Sensors Explosion

2007 2012 2017 2022 2027 2032 2037

Source: TSensors Summit, Janusz Bryzek

The Industrial Internet

Bring together Brilliant Machines, Advanced Analytics and People at Work

"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

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

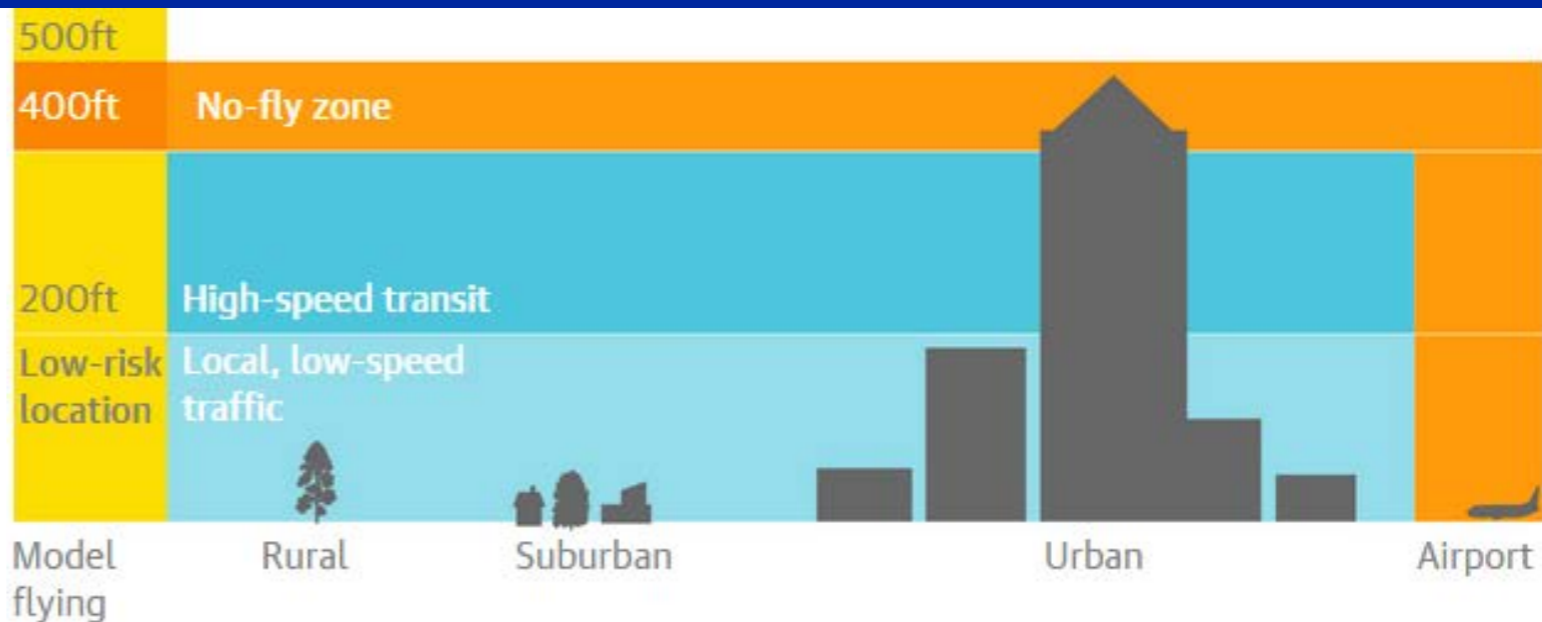Realtime Data Mapping Will Transform The Transportation Industry

Traffic Control for Drone Air Delivery
is Under Development by NASA, Amazon, & Google

theguardian

Amazon proposes drones-only airspace to facilitate high-speed delivery

500ft
400ft — No-fly zone
200ft — High-speed transit
Low-risk location — Local, low-speed traffic

Model flying   Rural   Suburban   Urban   Airport

Guardian graphic   Source: Amazon

QUALCOMM

First public demo of Snapdragon Flight robotics dev platform in one of world's smallest 4K drones   SEP 10, 2015

Drone traffic control? NASA, Amazon, Google partner to manage self-driving swarms

JULY 28, 2015   **FORTUNE**

By Matt O'Brien | mobrien@mercurynews.com

San Jose Mercury News
BUSINESS

it²

The Electric Grid Is Becoming
More Like the Internet

San Diego Vows to Move Entirely to Renewable Energy in 20 Years

By MATT RICHTEL   DEC. 15, 2015   The New York Times

Electric Grid, You Have Software Updates Available

SCIENTIFIC AMERICAN™

By Martin LaMonica on May 20, 2014

Researchers are developing software that will let renewable energy flow into and out of a decentralized power grid like data on the Internet

Power Grid Cyber Attacks Keep the Pentagon Up at Night

By Michael McElfresh, The Conversation on June 8, 2015
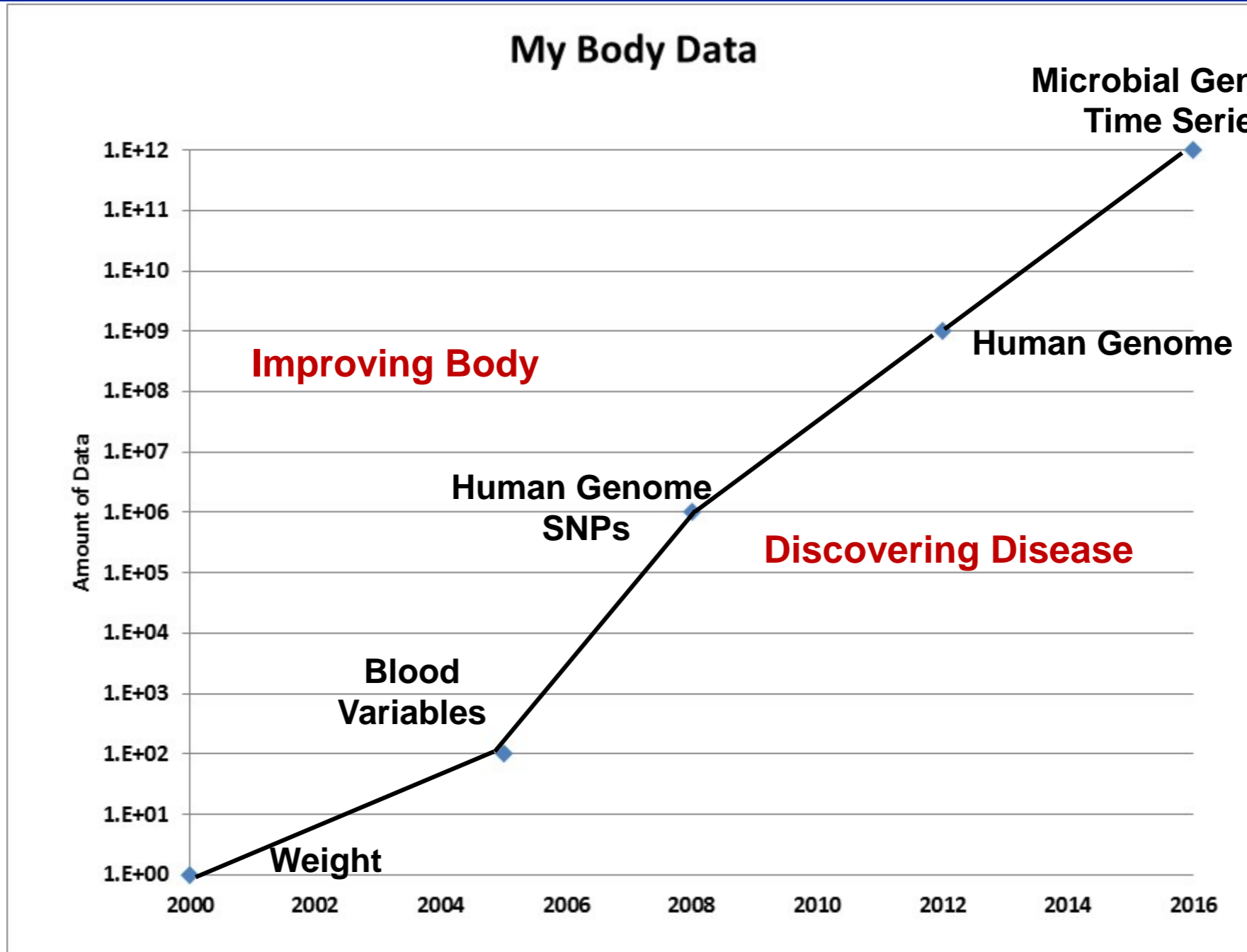
SCIENTIFIC AMERICAN™

You think the power grid isn't sexy? Think again.

by Barb Darrow   @gigabarb   SEPTEMBER 29, 2015

FORTUNE

it²

From One to a Trillion Data Points Defining Me in 15 Years: The Exponential Rise in Body Data

My Body Data

I Decided to Track My Internal Biomarkers
Just As I Did My External Body

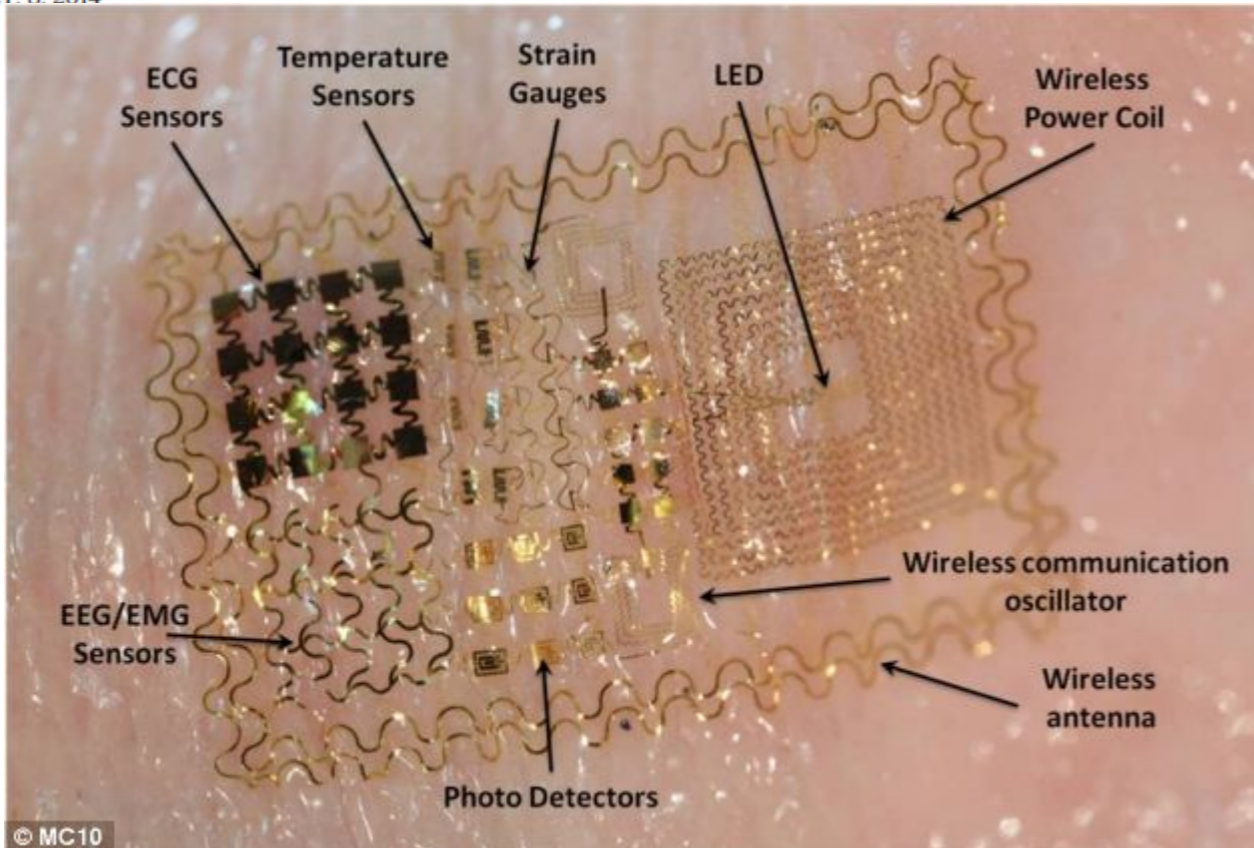Calit2 64 Megapixel VROOM

One Blood Draw For Me

A New Generation of Human Body Sensors Will Provide Continuous Readouts

FASHION & STYLE | DISRUPTIONS
The New York Times
Wearable Technology That Feels Like Skin
By NICK BILTON OCT. 8, 2014

nature
Linda Geddes
27 January 2016

Wearable sweat sensor paves way for real-time analysis of body chemistry

ECG Sensors
Temperature Sensors
Strain Gauges
LED
Wireless Power Coil
EEG/EMG Sensors
Wireless communication oscillator
Wireless antenna
Photo Detectors
© MC10

Startup MC10 Working With UIUC

Consumer Internal Self-Tracking Tools Are Growing Rapidly

Blood Variable Time Series

Stool Variable Time Series
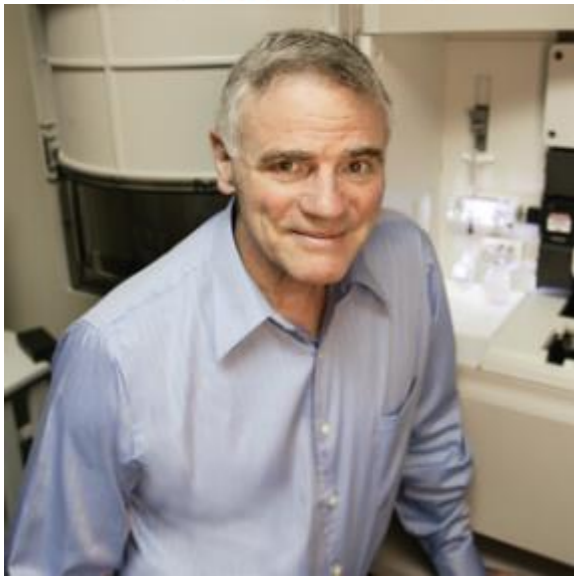
Integrated Wellness

Human Genetic Variations
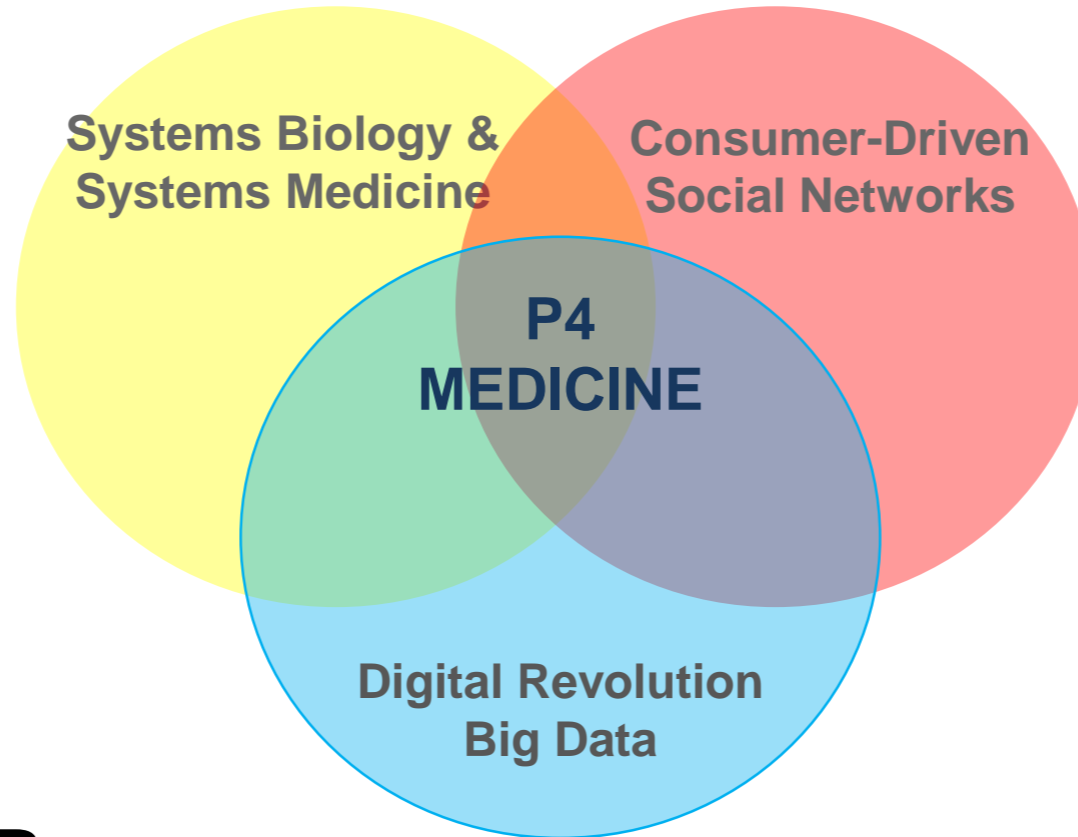
Human Microbiome

How Will the *Quantified Consumer*
Be Integrated into Healthcare Systems?

Systems Biology &
Systems Medicine

Consumer-Driven
Social Networks

P4
MEDICINE

Digital Revolution
Big Data

The secret to
wellness isn't a
secret. It's science.

Arivale

Lee Hood, Director ISB

The 100K Person Wellness Project:
A Data-Rich Longitudinal
Study for the Digital Age

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.**

The New York Times

ESSAY

Science

An Evolution Toward a Programmable
Universe
By LARRY SMARR
Published: December 5, 2011

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

IBNLive   **January 10, 2014**

Where Personalized Coaching is Now

JOAQUIN PHOENIX   AMY ADAMS   ROONEY MARA
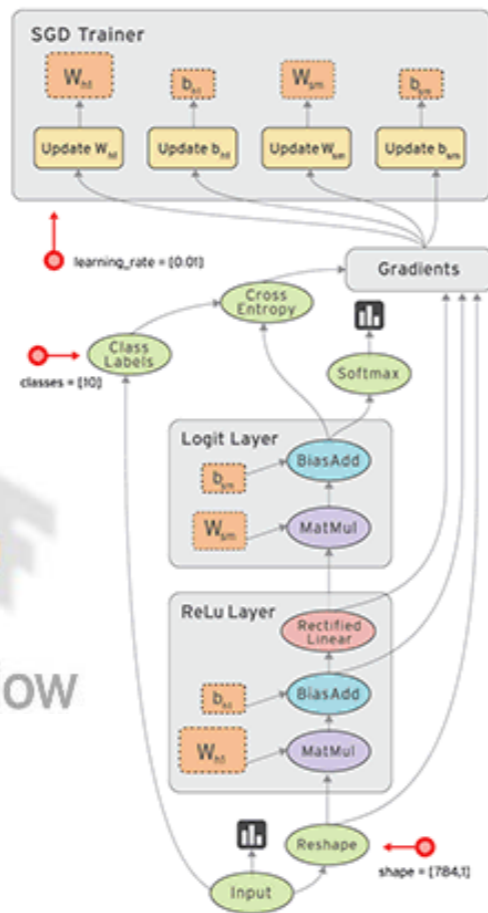OLIVIA WILDE   SCARLETT JOHANSSON

her

A SPIKE JONZE LOVE STORY

Where Personalized Coaching is Going

Is the Release of Google's of TensorFlow as Transformative as the Release of C?

TensorFlow is an Open Source Software Library for Machine Intelligence

From Programming Computers
Step by Step To Achieve a Goal
To Showing the Computer
Some Examples of
What You Want It to Achieve
and Then Letting the Computer
Figure It Out On Its Own
--Jeremy Howard, Singularity Univ.
2015

AI is Advancing at a Amazing Pace:
Deep Learning Algorithms Working on Massive Datasets

ALAN LEVINOVITZ   BUSINESS   05.12.14   6:30 AM   WIRED

THE MYSTERY OF GO, THE ANCIENT GAME THAT COMPUTERS STILL CAN'T WIN

‹re/code›

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

January 26, 2014, 4:25 PM PST

1.5 Years!

Training on 30M Moves, Then Playing Against Itself

ADE METZ   BUSINESS   01.27.16   1:00 PM   WIRED

IN A HUGE BREAKTHROUGH, GOOGLE'S AI BEATS A TOP PLAYER AT THE GAME OF GO

the WHITE HOUSE

PRESIDENT OBAMA IS CALLING ON THE SCIENCE COMMUNITY
TO JOIN HIM IN PURSUING A GRAND CHALLENGE

BRAIN INITIATIVE

BRAIN RESEARCH
THROUGH ADVANCING
INNOVATIVE
NEUROTECHNOLOGIES

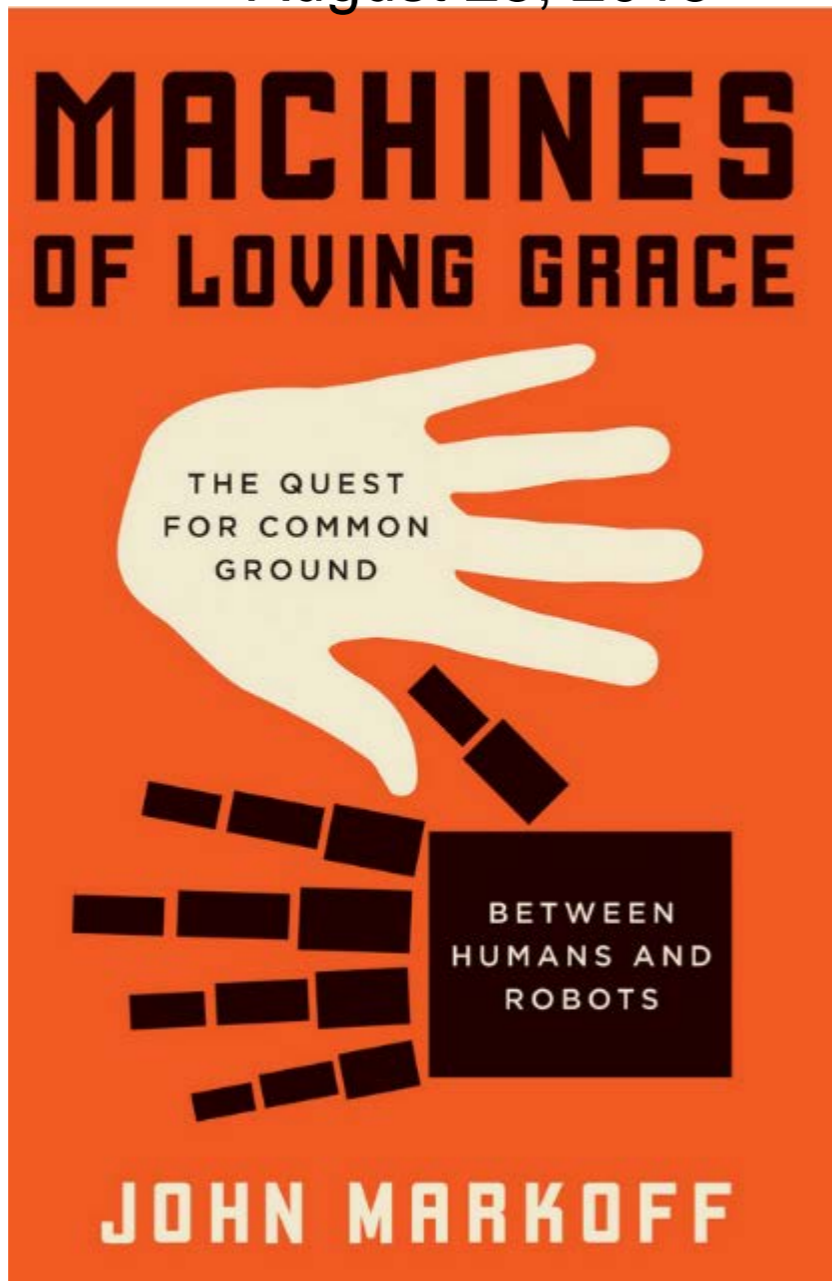**www.whitehouse.gov/infographics/brain-initiative**

November 13, 2012

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

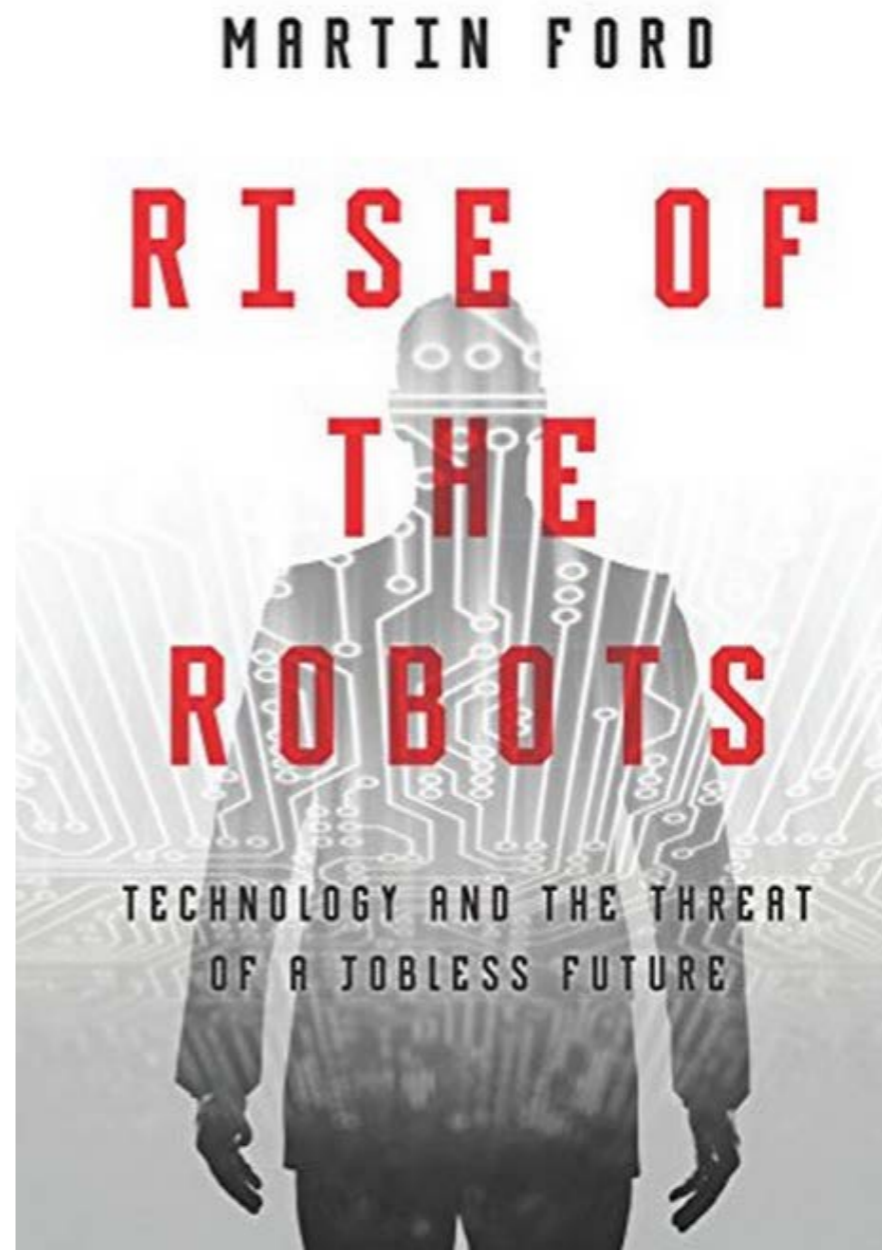**In the Emerging Synthetic Neocortex, "Why Not a Billion? Or a Trillion?"**

August 25, 2015

May 5, 2015

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

NICK BOSTROM
SUPERINTELLIGENCE
Paths, Dangers, Strategies

If our own extinction is a likely, or even possible, outcome of our technological development, shouldn't we proceed with great caution? – *Bill Joy*
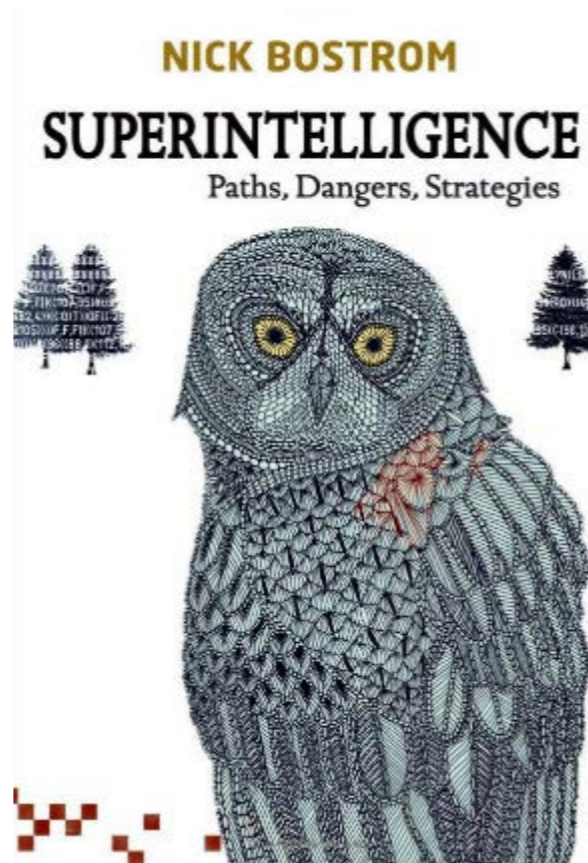
Success in creating AI would be the biggest event in human history. Unfortunately, it might also be the last, unless we learn how to avoid the risks.
– *Steven Hawking*

it²