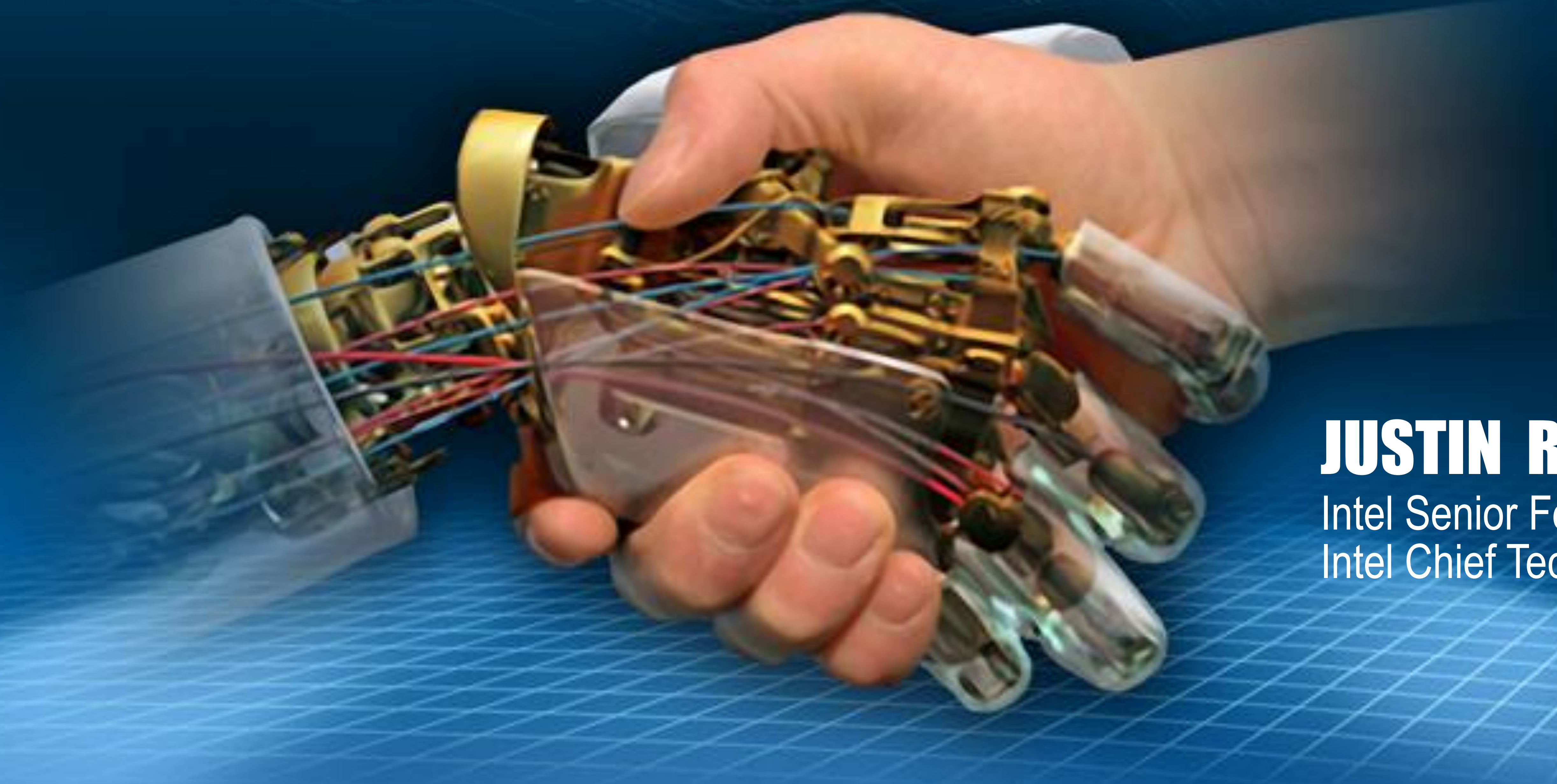
Intel Developer FORUM

Invent the new reality.

Crossing The Chasm Between

HUMANS and MACHINES

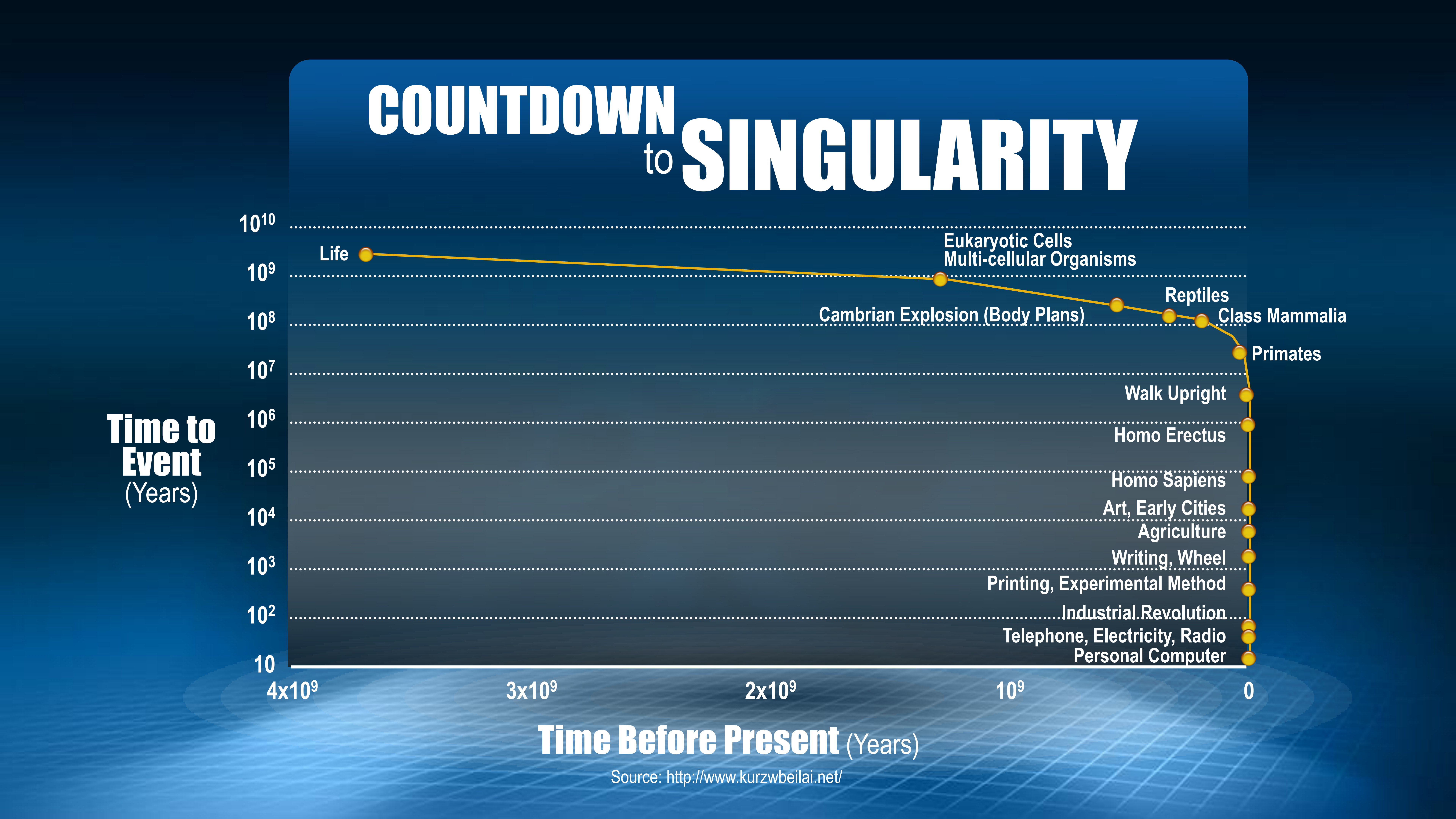
...the Next 40 Years

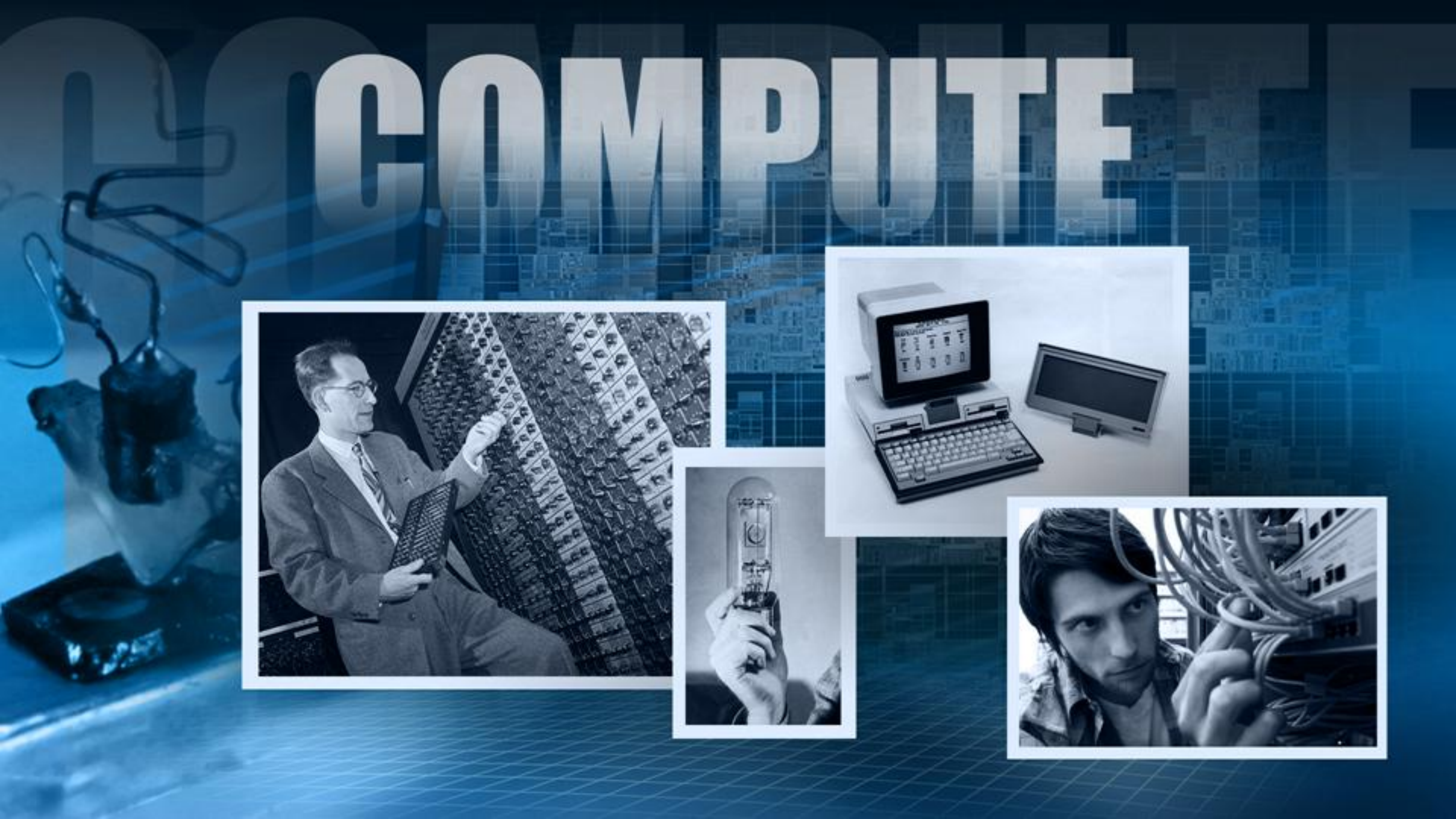


JUSTIN RATTNER

Intel Senior Fellow, Vice President

Intel Chief Technology Officer


COUNTDOWN to SINGULARITY
Time to Event (Years)
10^10
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10
Life
Eukaryotic Cells
Multi-cellular Organisms
Cambrian Explosion (Body Plans)
Reptiles
Class Mammalia
Primates
Walk Upright
Homo Erectus
Homo Sapiens
Art, Early Cities
Agriculture
Writing, Wheel
Printing, Experimental Method
Industrial Revolution
Telephone, Electricity, Radio
Personal Computer
4x10^9
3x10^9
2x10^9
10^9
0
Time Before Present (Years)
Source: http://www.kurzweilai.net/

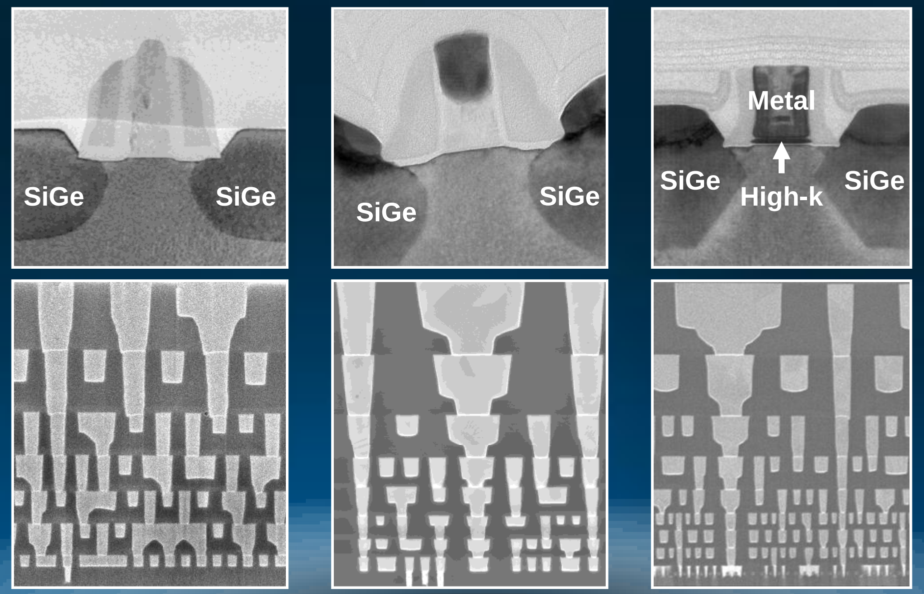

COMPUTE

Dimensional Scaling and BEYOND

TECHNOLOGY GENERATION

90nm	65nm	45nm	32nm
2003	**2005**	**2007**	**2009**

MANUFACTURING → DEVELOPMENT



SCALING BEYOND CMOS

C. Michael Garner, Ph.D
Program Manager of Emerging Materials Roadmap
Technology and Manufacturing Group

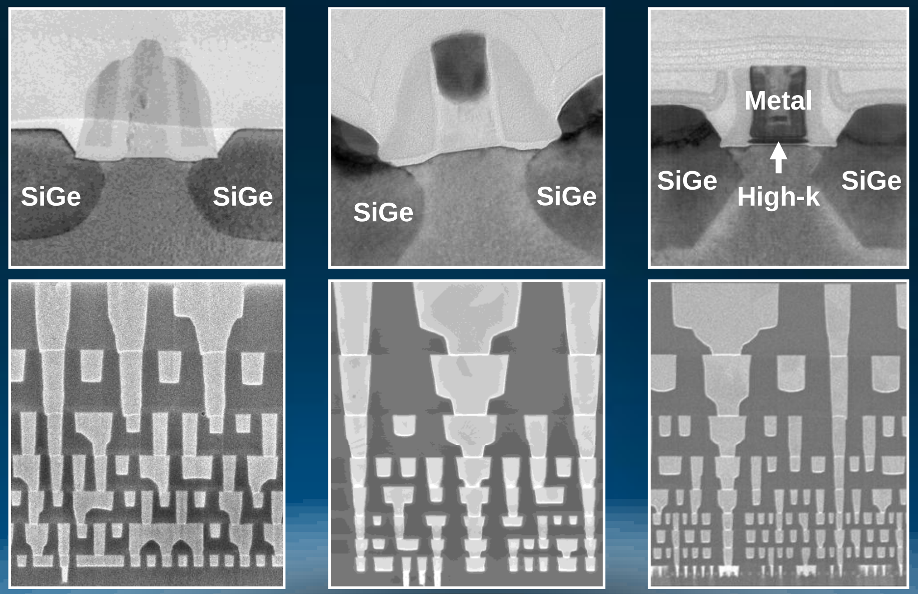
intel

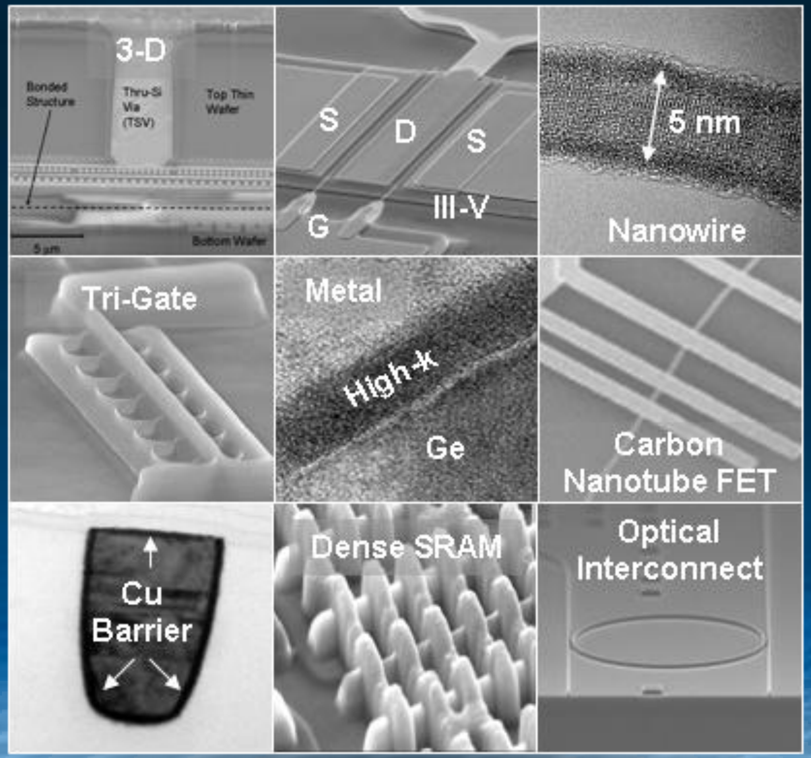
Dimensional Scaling and BEYOND

TECHNOLOGY GENERATION

90nm	65nm	45nm	32nm	22nm	16nm	11nm	Beyond
2003	**2005**	**2007**	**2009**	**2011**	**2013**	**2015**	**2020**

MANUFACTURING → DEVELOPMENT → RESEARCH





Future options subject to change

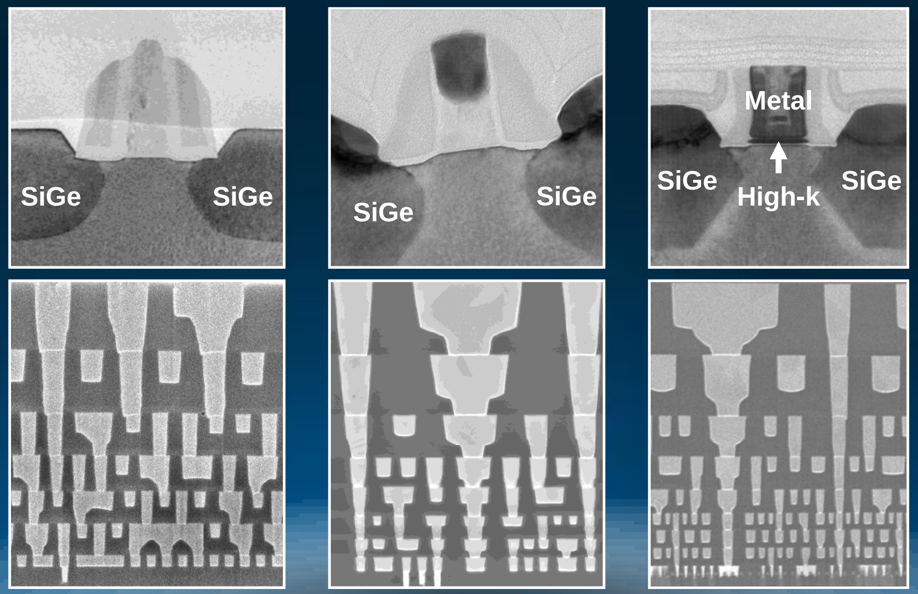
Scaled CMOS FET Remains the Optimum Electronic Logic Device!

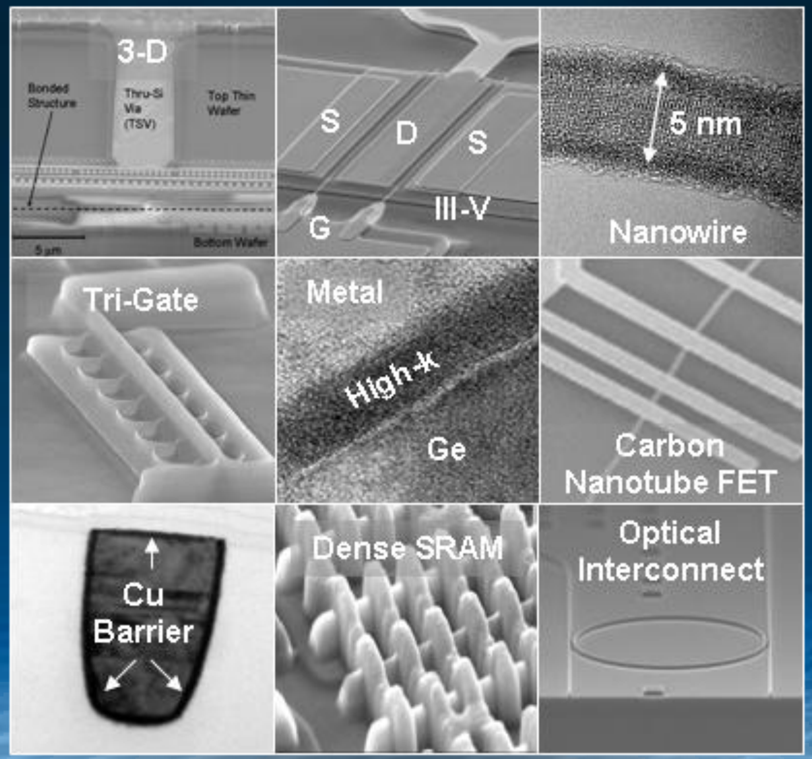
Dimensional Scaling and BEYOND

TECHNOLOGY GENERATION

90nm	65nm	45nm	32nm	22nm	16nm	11nm	Beyond
2003	2005	2007	2009	2011	2013	2015	2020

MANUFACTURING → DEVELOPMENT → RESEARCH

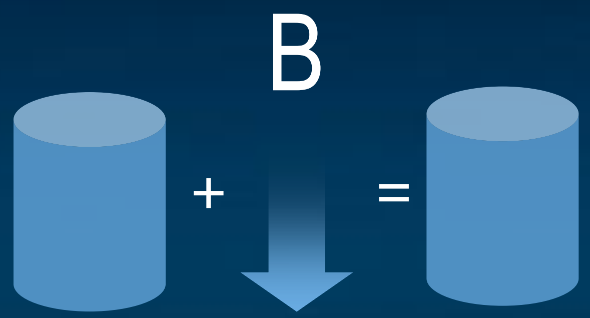




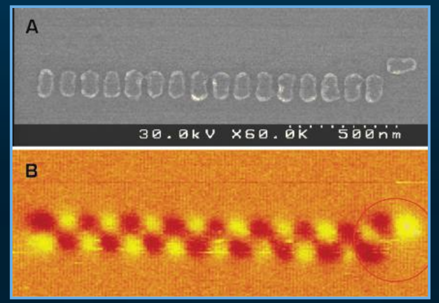
Future options subject to change

Alternative State Variable

Spin
Molecular
Optical
Phase
Quantum
?????

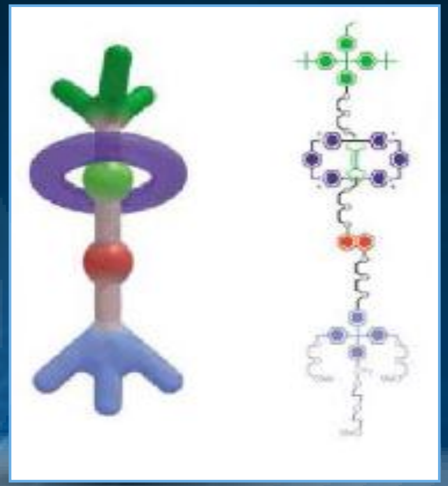


Single Spins



Magnetic Domains

Boolean, Non-Boolean Information Processing

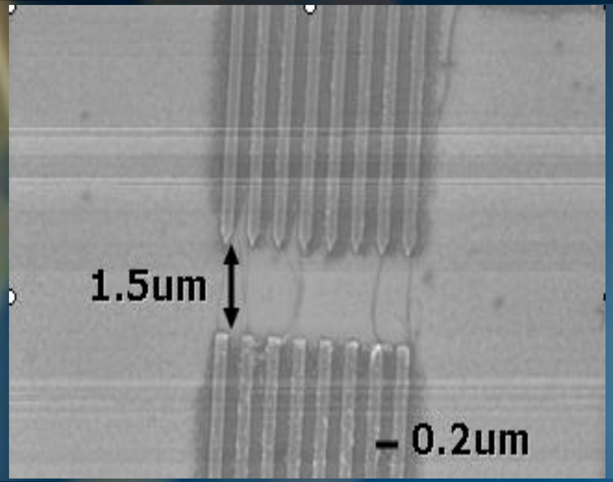


Molecular Conformation

Scaled CMOS FET Remains the Optimum Electronic Logic Device!

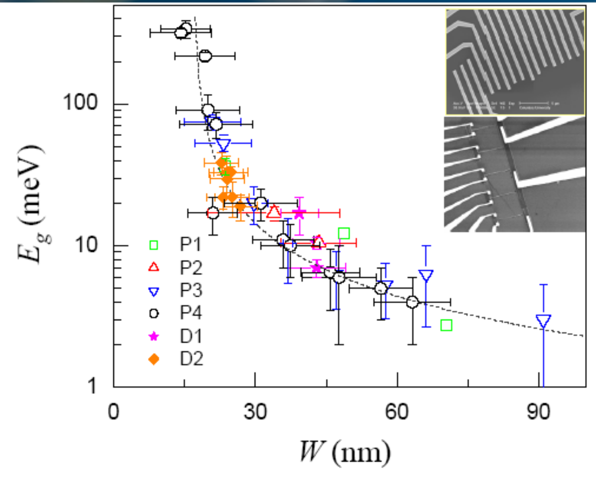
Beyond Silicon:

CARBON BASED DEVICES



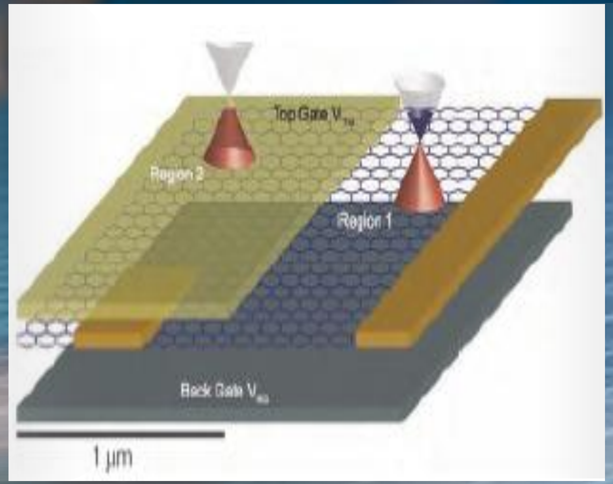
Carbon Nanotubes

- High mobility, high current densities
- Ballistic FET devices



Graphene Ribbons

- Creating bandgap in carbon based devices
- High performance FETs
- Dimensional modulation devices

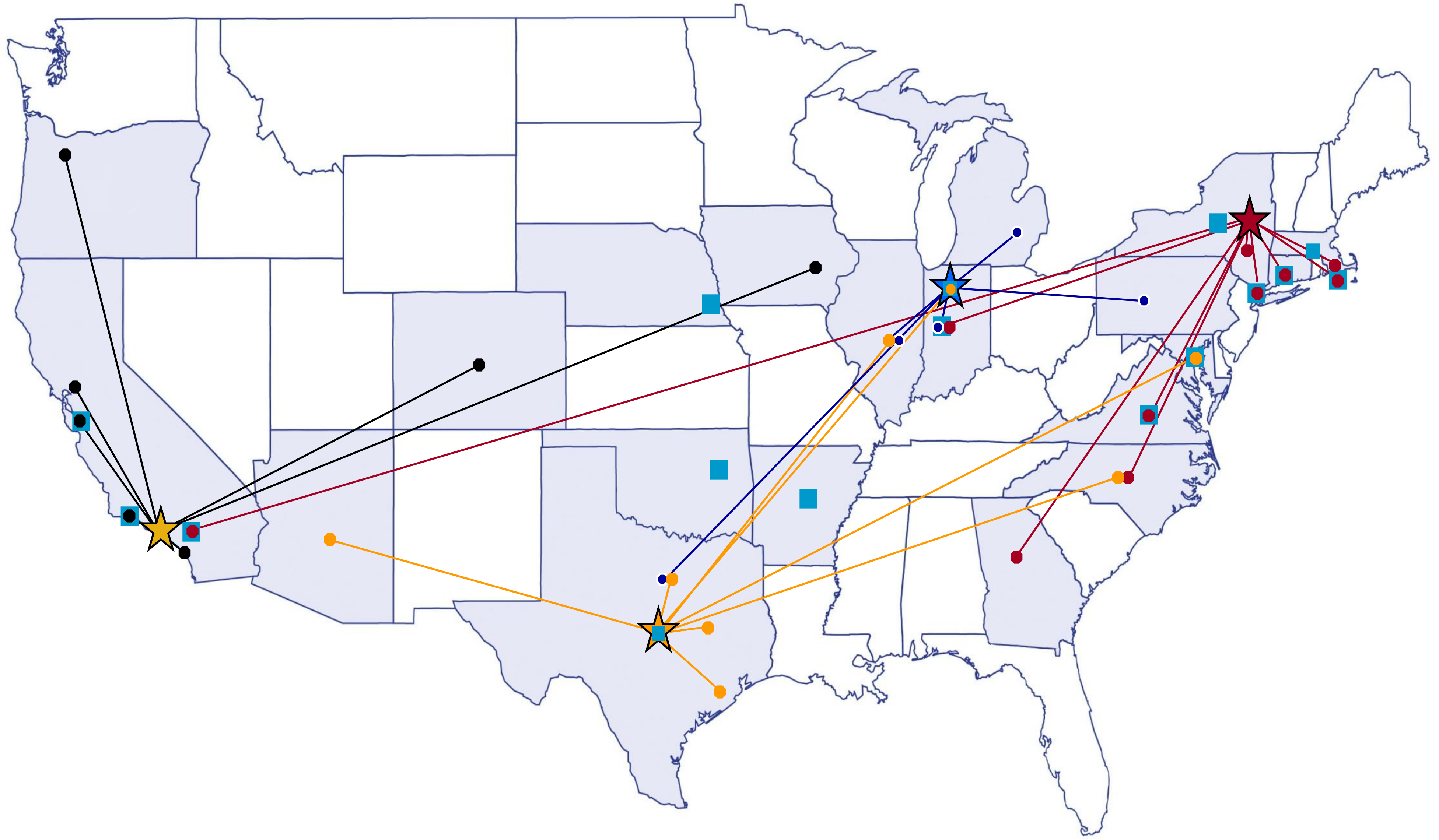


Bilayer Graphene

- Strong quantum interaction between layers
- Low loss coherent tunneling devices

Drive University Research
Through Consortia Such as

Nanoelectronics Research Initiative



35 Universities in 20 States

Midwest Institute of Nanoelectronics Discovery

Notre Dame
Illinois – UC State
Perdue
Penn

WIN Western Institute of Nanoelectronics

UC Los Angeles
UC Berkeley
UC Irvine
UC Santa Barbara
Stanford
U Denver
Portland State
U Iowa

INDEX INSTITUTE FOR NANOELECTRONICS DISCOVERY AND EXPLORATION

SUNY-Albany
Purdue
Caltech
Yale
GIT
RPI
MIT
UVA
Harvard
Columbia
NCSU

SWAN Southwest Academy of Nanoelectronics

UT Austin
UT Dallas
U. Maryland
Rice
ASU
NCSU
Texas A&M
Notre Dame
Illinois UC

NIST **NSF**

Columbia
Harvard
Purdue
UVA
Yale
UC Santa Barbara
Stanford
U. Mass
U. Arkansas
U. Oklahoma
Notre Dame
U. Nebraska/Lincoln
U. Maryland
Cornell
UT Austin
Caltech

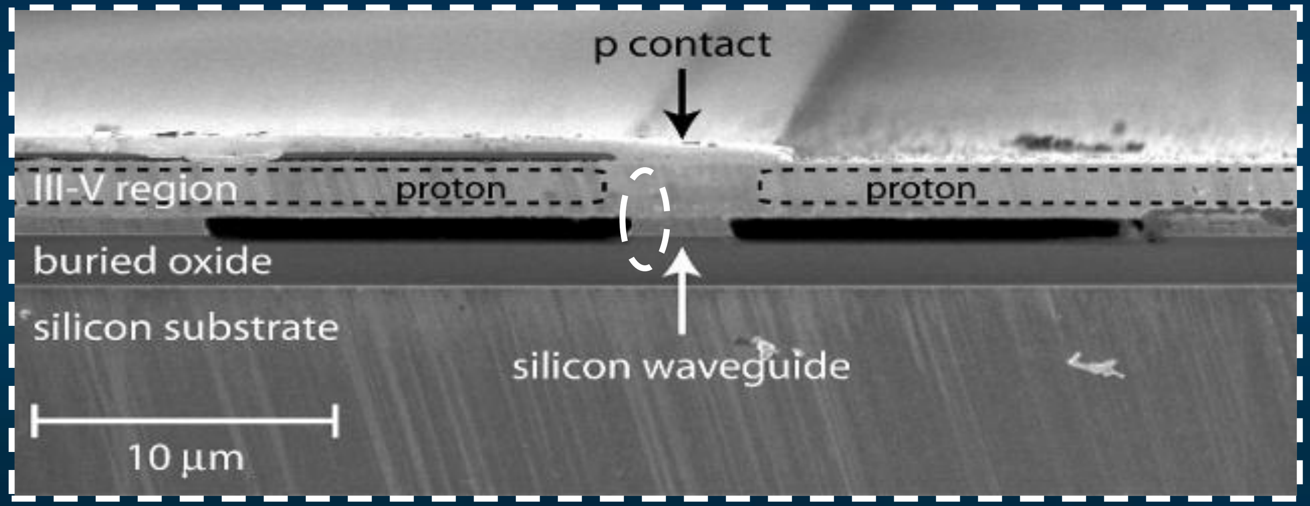

Saml. F. B. Morse
SIGNALING

SILICON PHOTONICS

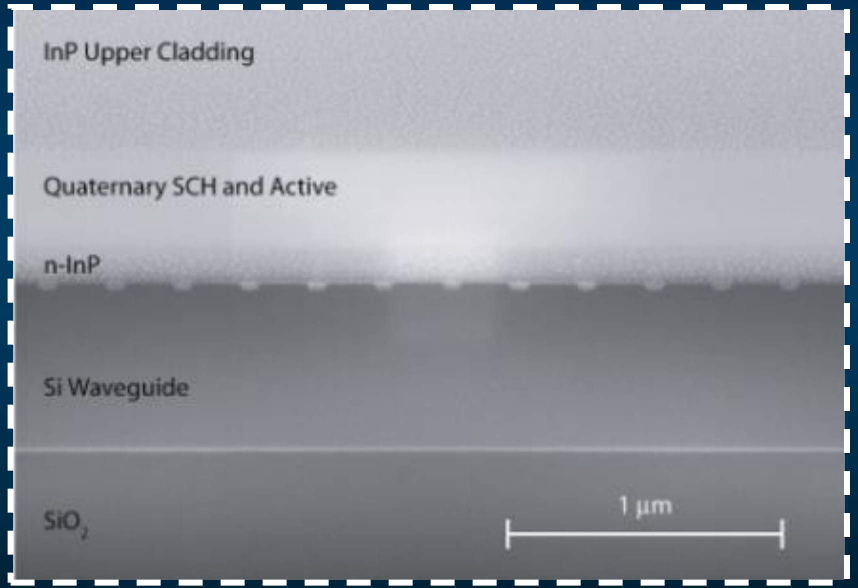
Brian Koch
Intern, Communications Technology Lab
Corporate Technology Group,
University of California, Santa Barbara

UCSB

Progress in Silicon Photonics



2006 ✓



TODAY

Forbes.com

Hybrid Silicon Laser

September 16, 2006

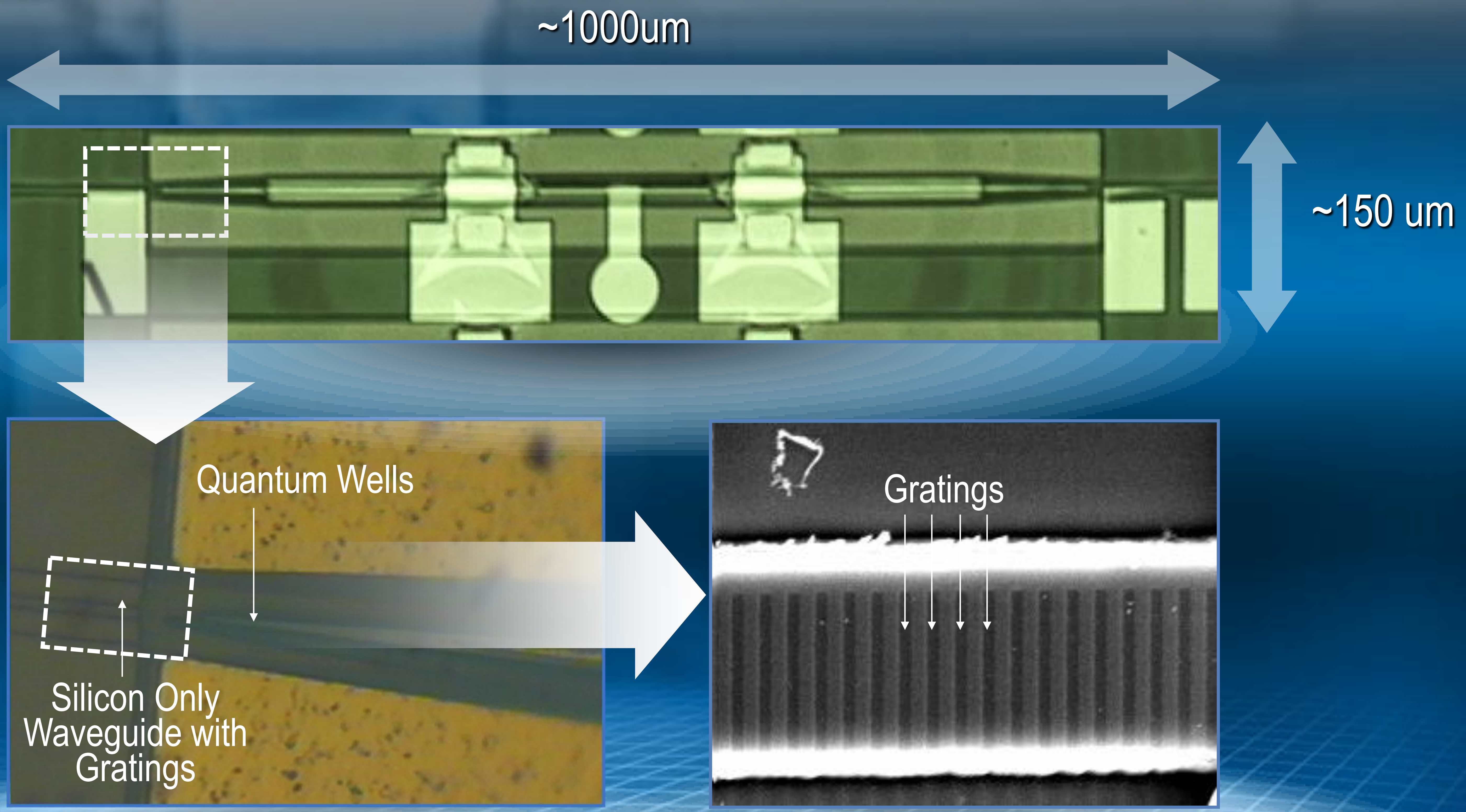
"… with technology investors excited by news of a research breakthrough in laser chips at Intel…"

Integrated Grating Mirrors

August 21, 2008

"… Intel makes next advancement in achieving tera-scale I/O goal…"

The DEVICE



Grating "Mirror" SEM of a Passive Gratings

Edge of the Laser Cavity

Next Step: Integrated SiP Transceiver

YESTERDAY ✓

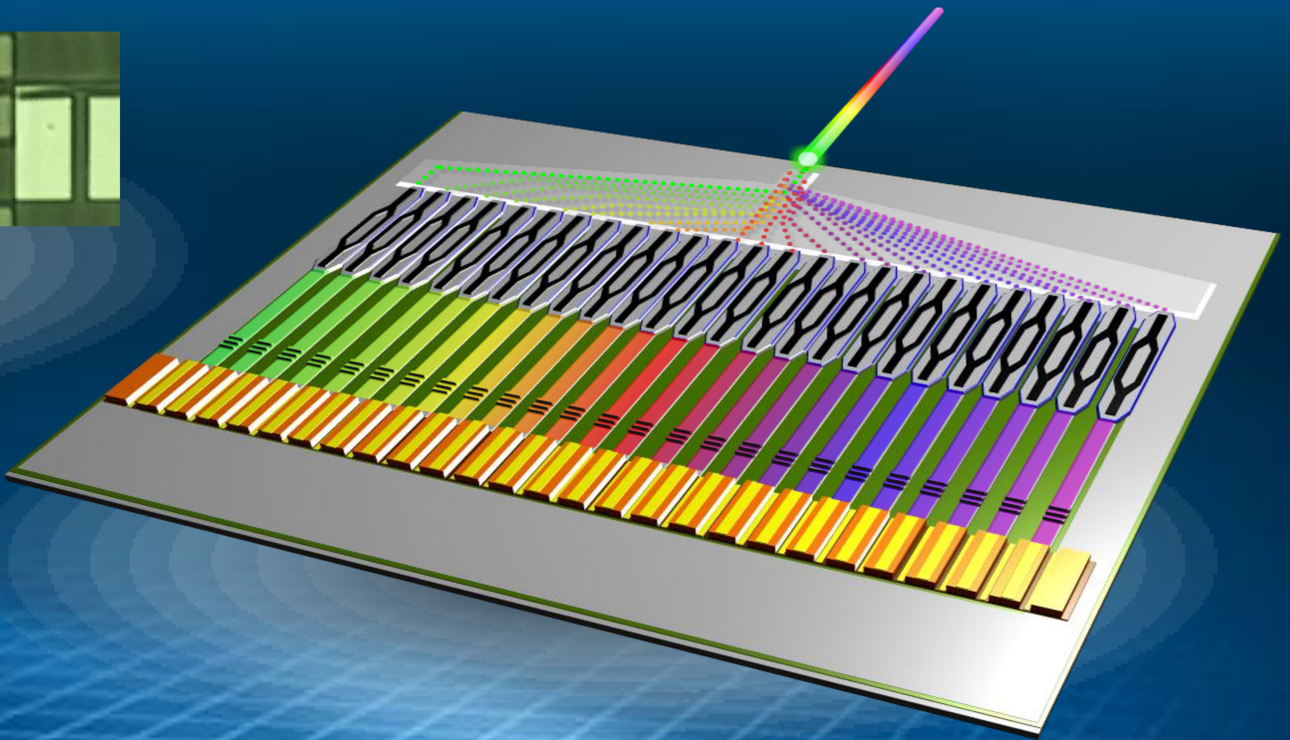
Modulators
at 40Gb/s

TODAY ✓

Hybrid Lasers with
Integrated Gratings

TOMORROW

Integrated Modulators and Hybrid
Lasers on Photonics chip




WIRELESS

Massively Simultaneous Wireless COMMUNICATIONS

Jan Rabaey

Donald O. Pederson Distinguished Professor

Department of Electrical Engineering and Computer Sciences

University of California at Berkeley

Towards a World with 1000 RADIOS *per Person!*

MULTI-MODAL CELLPHONES

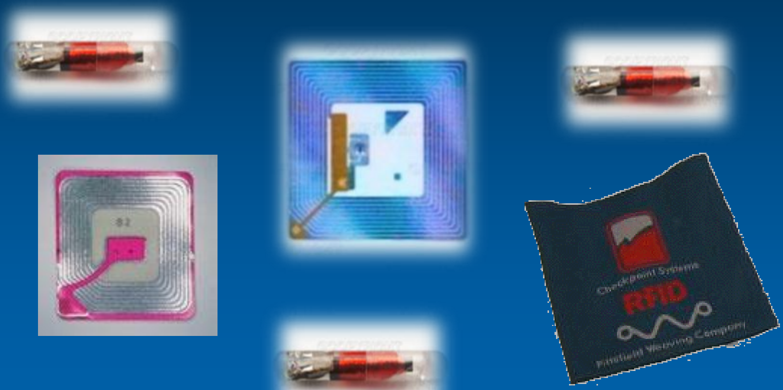
HEALTH AND MEDICAL

SMART HOMES

INTELLIGENT CARS

THE EARLY DAYS

RFID EXPLOSION



Reliable

UNIVERSAL COVERAGE at All Times

TOP STORY

CE’s wireless Babel: Connectivity strategies are all over the map

Now that consumer electronics are delivering a full suite of product to the digital living room, they are working out how to connect them.

EE Times
Jan. 14 2008

7 trillion radios quickly run out of spectrum …

Most devices energy-constrained

Wireless is notoriously unreliable

Heterogeneity causes incompatibilities

Imagine a

DIFFERENT WORLD

POINT OF VIEW

Digital Wireless—*Regulation and Control Free?*

BY PETER COCHRANE
Cochrane Associates, UK

Imagine for a moment that we had arrived at our present state of technological prowess without the discovery and implementation of wireless systems. Improbable and impossible, I know, but bear with me and also imagine that we had simultaneously missed out on the feast of the analog and copper era and had jumped straight to optical line systems entirely operating in digital mode. What a vastly different world it would be with near infinite bandwidth connecting every fixed node in our networks. A world where people never asked the question; why do people want bandwidth and what will they do with it? But also, a world without any form of mobility.

IEEE Proceedings, July 2008

How would you build your wireless network?

A World With

UNLIMITED WIRELESS BANDWIDTH

and Always-On Coverage

Cognitive

dramatic increase in attainable wireless data-rates

Collaboration

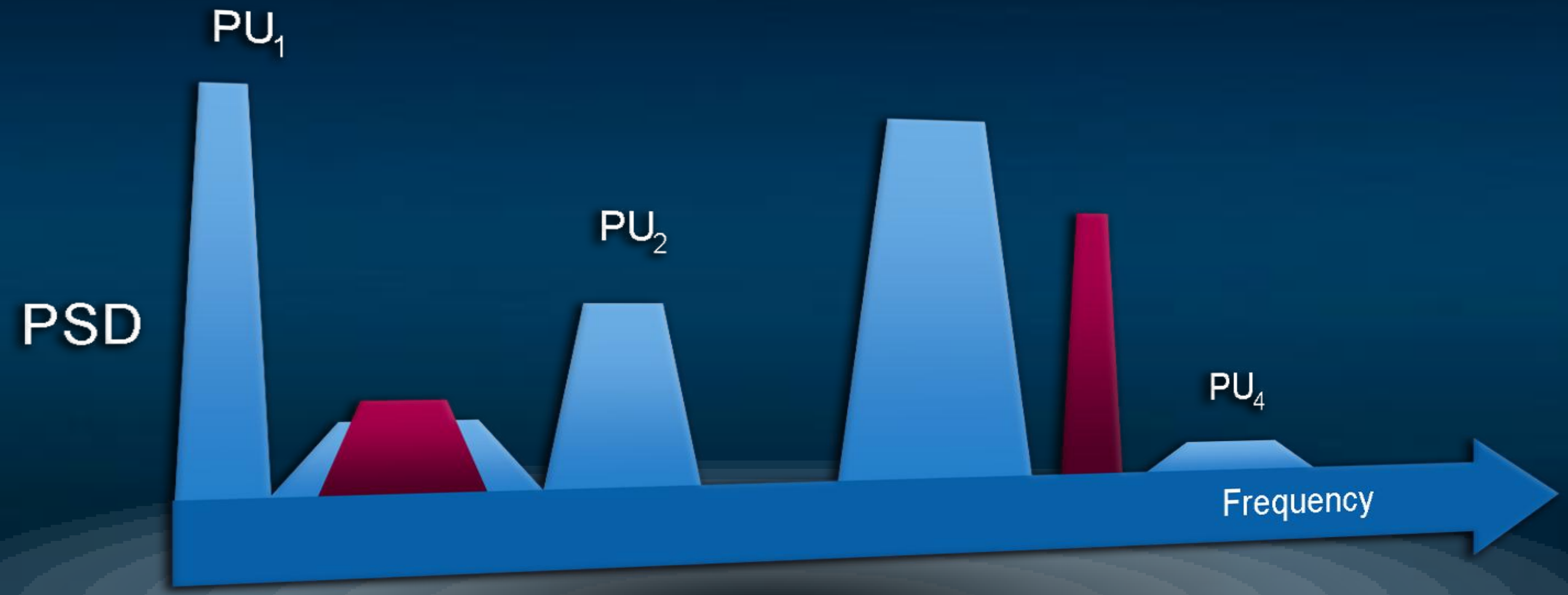
among terminals and infrastructure essential to accomplish cognitive promises

Connectivity Brokerage

as the new operational (as well as business) paradigm

A Fundamentally Disruptive Technology: Spectrum as a Tradable Commodity

Cognitive Radio to Enable Dynamic Spectrum Allocation



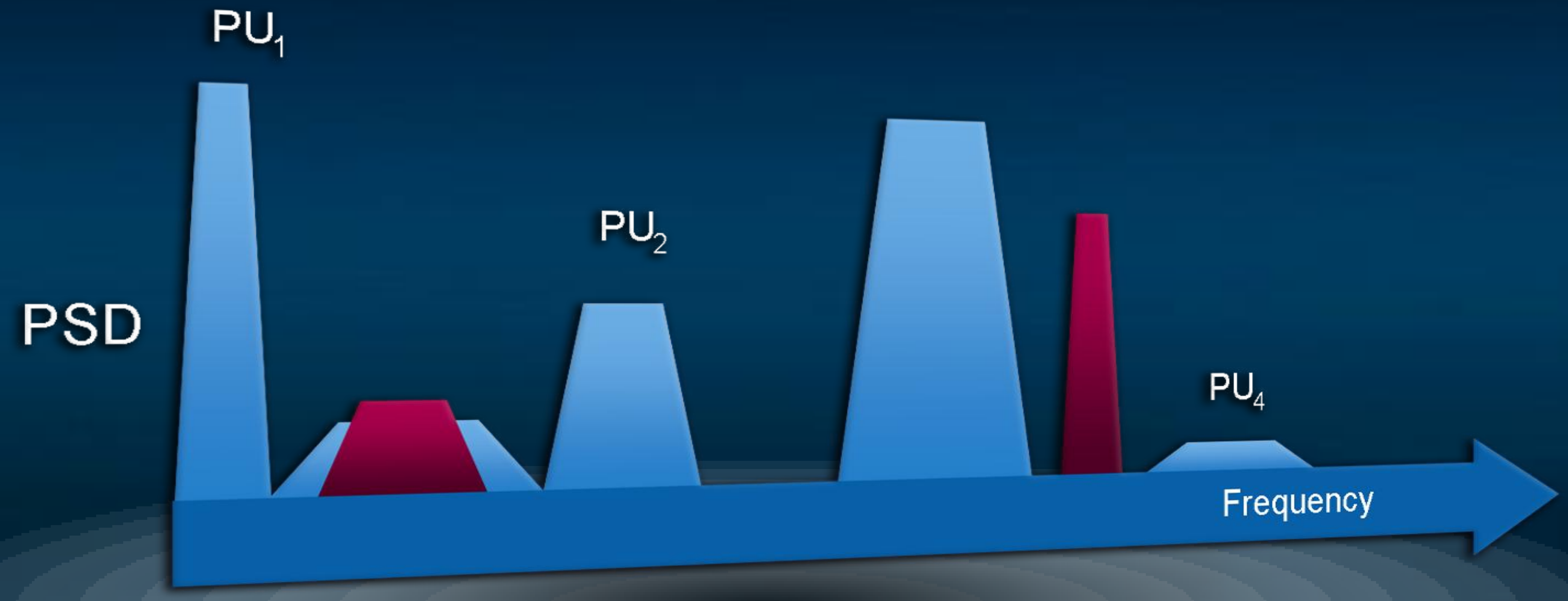
Sense spectral environment

Reliably **detect** users and/or interferers

Rules of sharing resources

Flexibility to adjust

Cognitive Radio to Enable Dynamic Spectrum Allocation



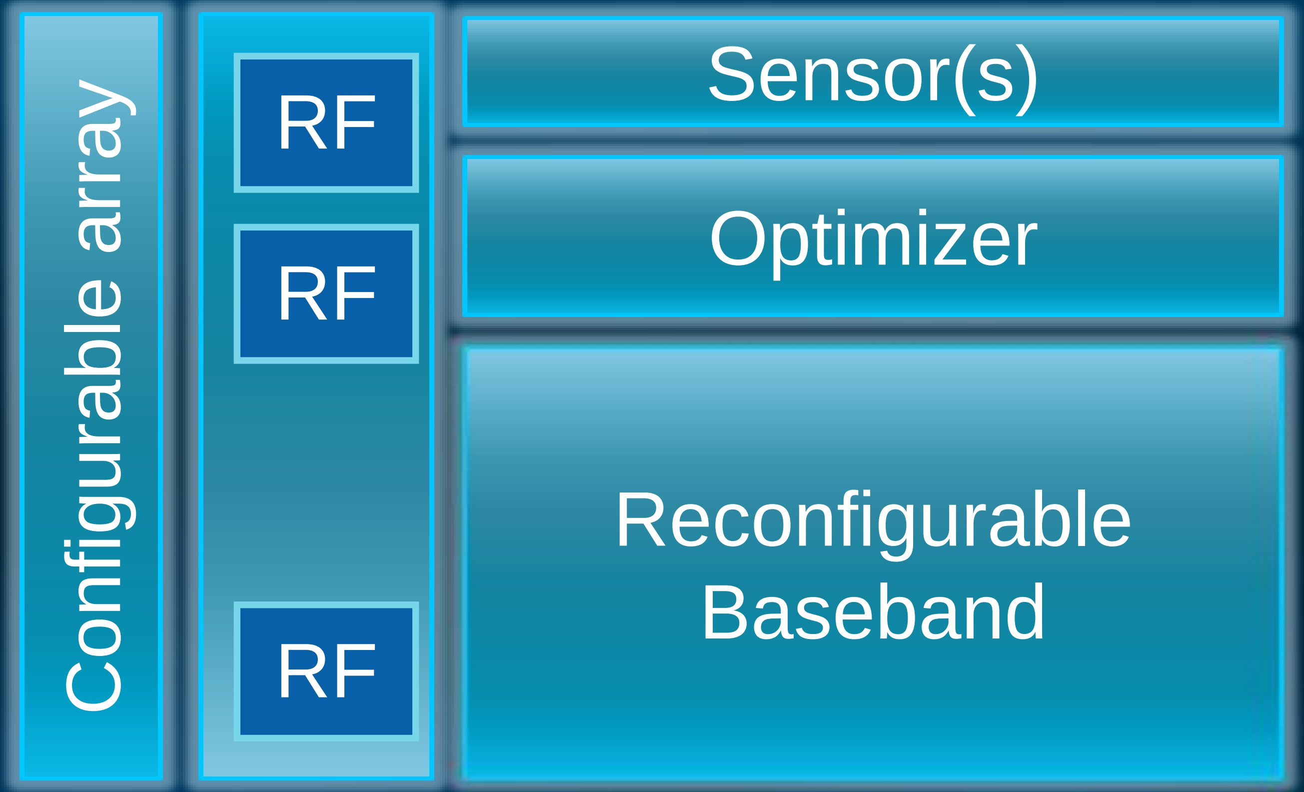
Sense spectral environment

Reliably **detect** users and/or interferers

Rules of sharing resources

Flexibility to adjust

First Experiment in Cognitive:
TV Bands @ 700 MHz
(IEEE 802.22)



Cognitive Terminal

Increased bandwidth availability reduces TX/RX energy cost

The Power of

COLLABORATION

Conventional wireless mindset:

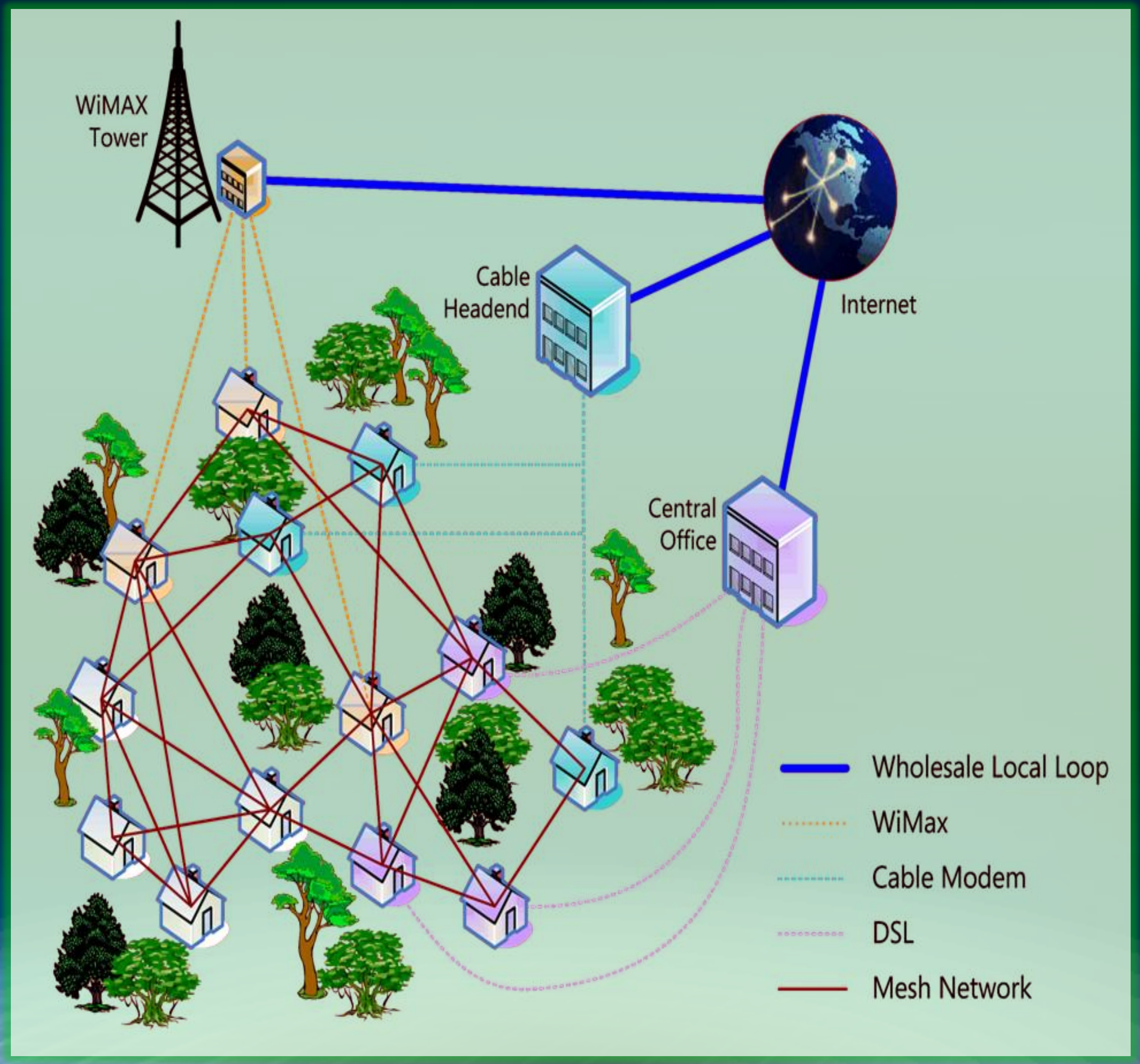
Services compete!

- Example: Bluetooth, WIFI and Zigbee
- Adding terminals degrades user capacity

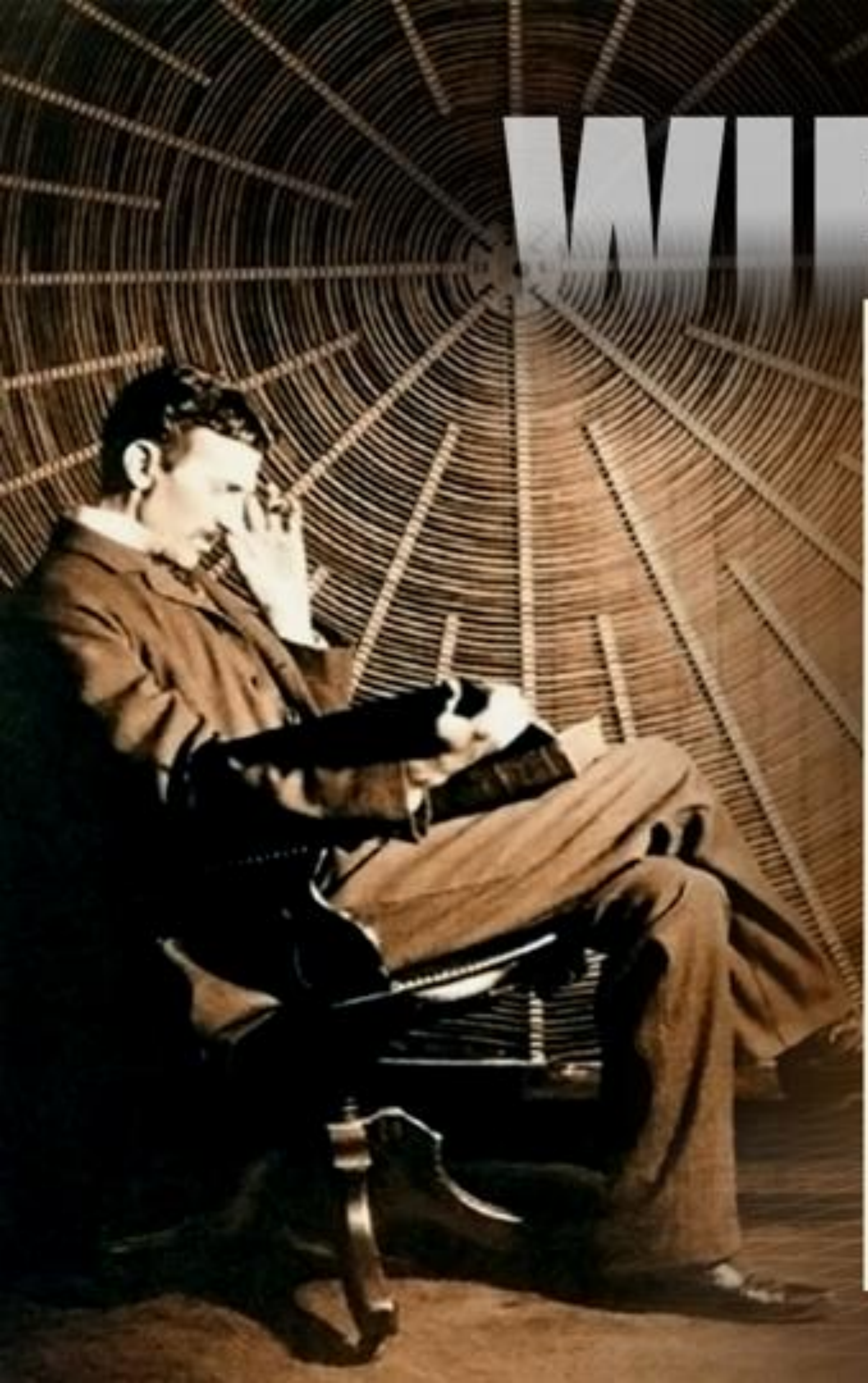
Collaboration as a means to improve spectrum utilization!

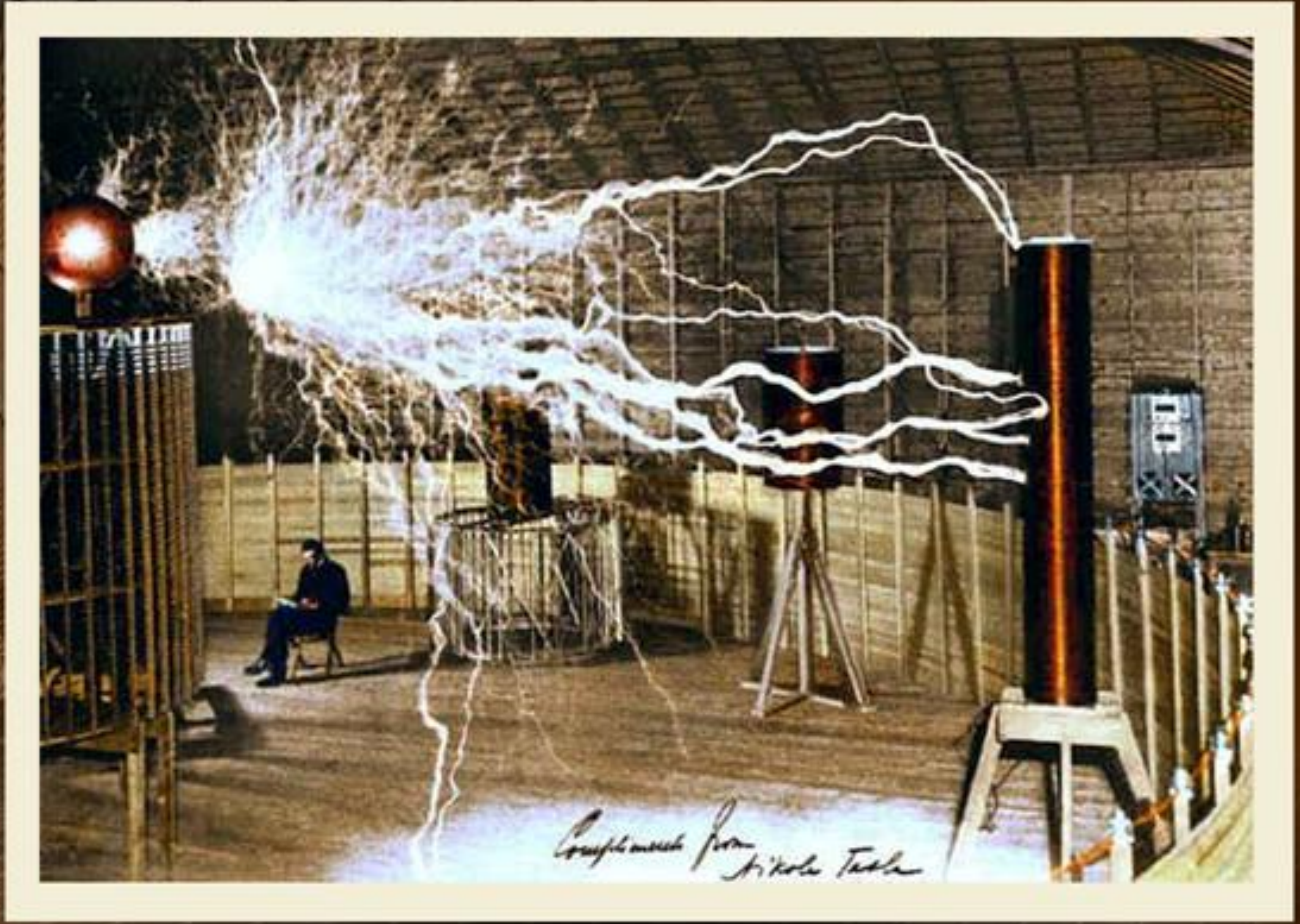
Working together leads to better *capacity*, *coverage*, *efficiency* and/or *reliability*

Examples: multi-hop, collaborative MIMO



WIRELESS POWER





Cutting the Cord

Wireless Power TRANSFER

Alanson Sample

Intern, Intel Research Seattle

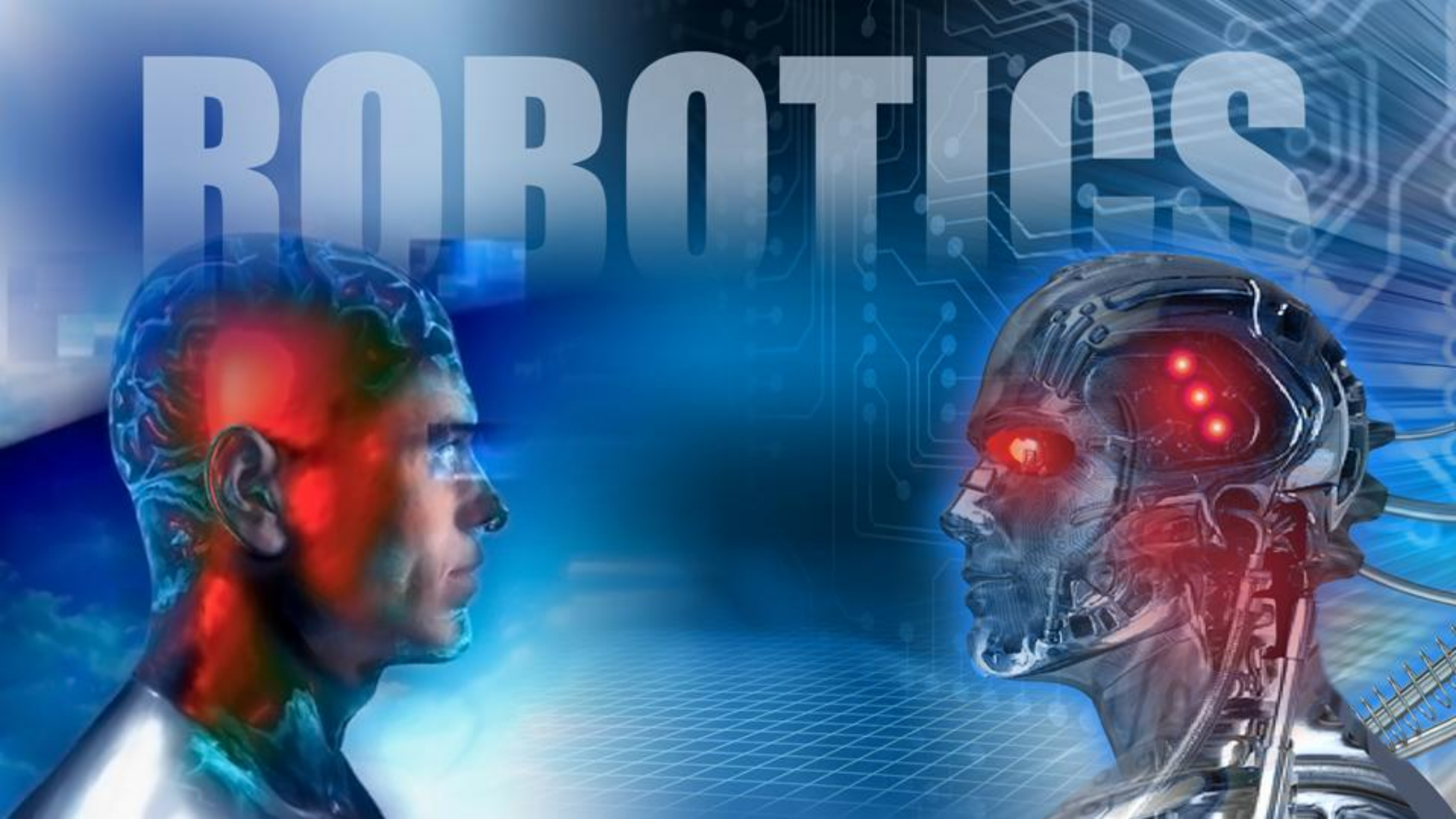
University of Washington,

Department of Electrical Engineering

VISION:
Wirelessly Powered (Recharged)
LAPTOP

Significant engineering challenges remain:

- More challenging loads:
  light bulb → laptop power supply
- Reduce antenna sizes
- Antenna orientation dependence


ROBOTICS

ROBOTICS Gets PERSONAL

Dave Ferguson
Siddhartha Srinivasa
Research Scientists
Intel Research Pittsburgh

Challenges

Navigation in Populated Environments

- Where am I? → *Mobile robot localization*
- What does the world look like? → *Mapping and obstacle detection*
- How do I get where I want to go? → *Navigation and obstacle avoidance*

Manipulation Under Uncertainty

- What and where is the object? → *Object shape and pose estimation*
- Where do I pick it up? → *Grasp planning for complex objects*
- How do I pick it up? → *Dynamic arm motion planning*

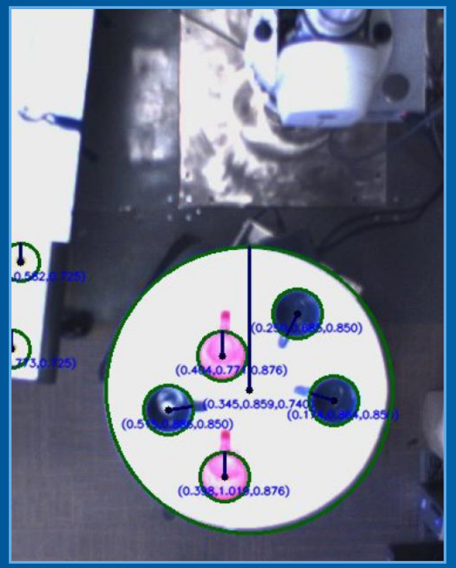
Robotic Components

Navigation

Localization and
Planning in
Populated
Environments

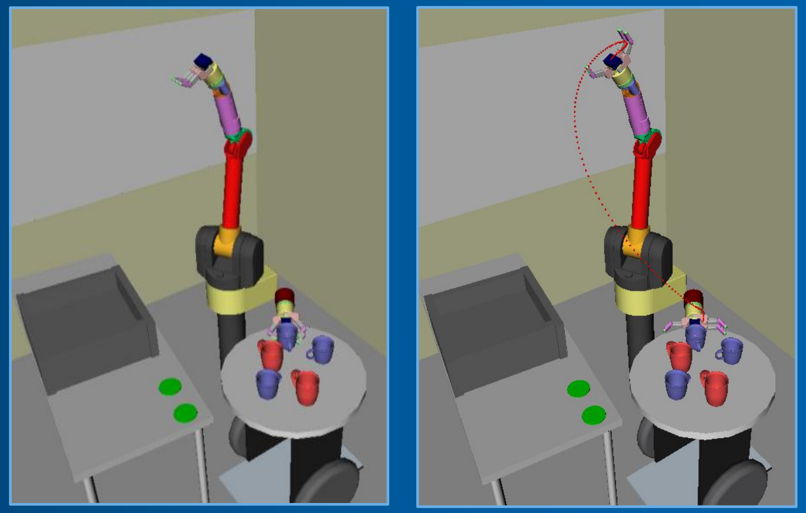
Perception

Robust Object
Recognition and
Pose Estimation



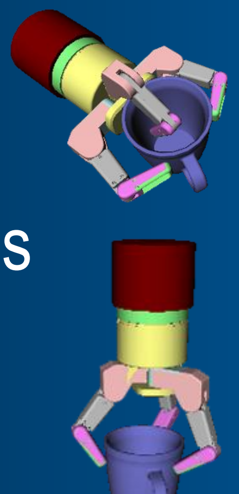
Arm Planning and Execution

Smooth Dynamic
Collision-Free
Trajectories



Grasping

Generating Grasps
in High Clutter at
Human Speeds



A New Approach to Sensing

Electric Field PRETOUCH

Joshua Smith
Principal Engineer
Intel Research Seattle

intel

Electric Field PRETOUCH

Black Ghost Knife Fish (*Apteronotus albifrons*)
1 KHz continuous wave

- E-Field Sensing is used by several species of fish but not humans
- Fish generates and detects a weak electric field (green)
- Objects (red) change detected electric field (lighter green line)

Electric Field PRETOUCH

Shorter Range Than Vision but Longer Range Than Touch

Tells a Machine When It's About to Touch Something


NEURAL INTERFACES

NEURAL INTERFACES

Tan Le

Cofounder and President, Emotiv Systems

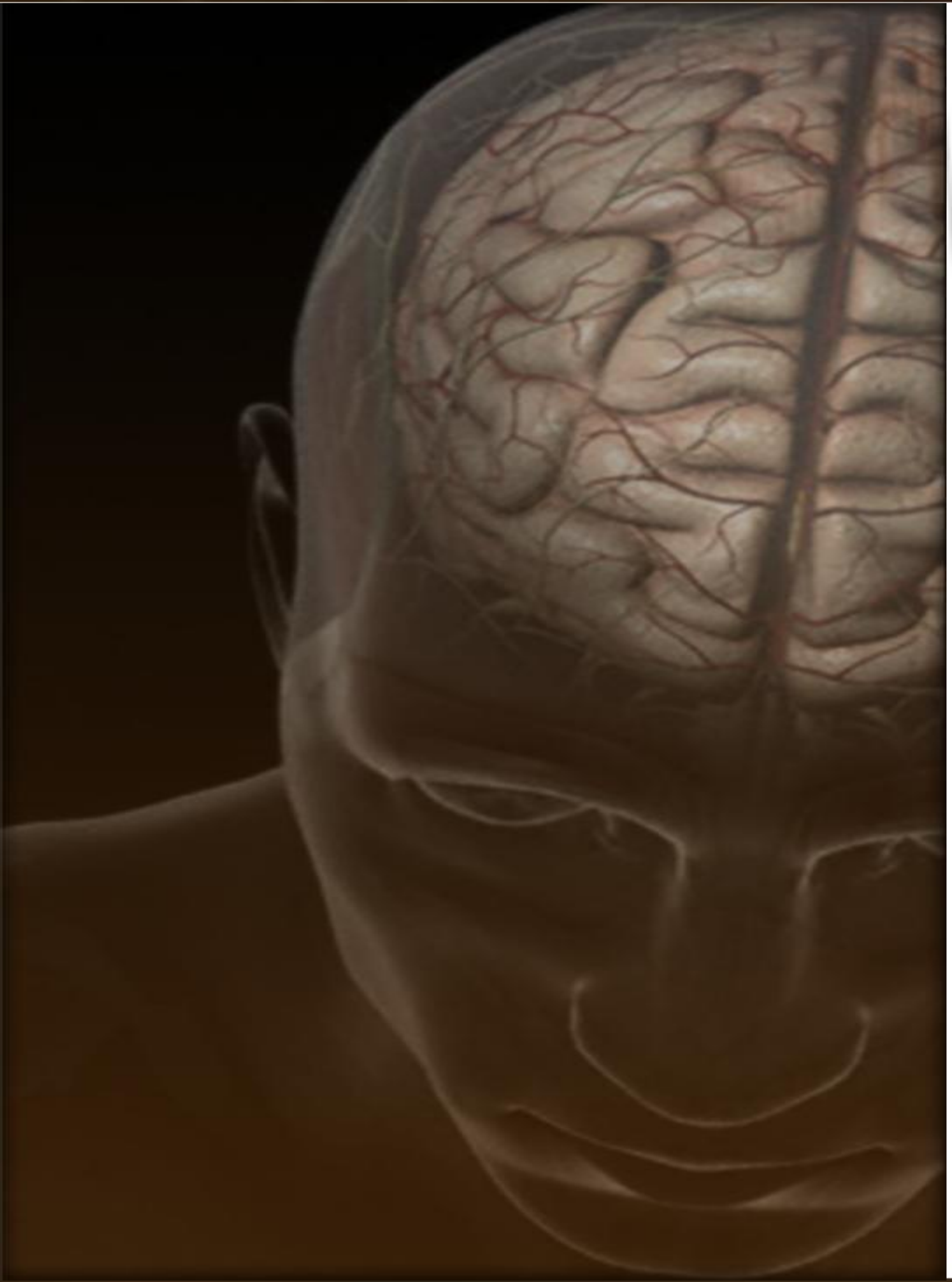
The interaction between humans and computers needs to evolve beyond the current limits of conscious input

MULTIDIMENSIONAL DATA POSES LARGE CHALLENGES

The explosion of content is becoming overwhelming to navigate

The current interface between humans and computers will not allow us to cope with the vast amount of information

A new form of interface must emerge that will help navigate through this information and content



The next wave of technology innovation will be around the way humans interact with computers.

Breakthrough neurotechnology is needed to enable interaction with information and applications using your brain

Computers can be made to understand:

- Cognitive Thoughts
- Facial Expressions
- Emotions

Enables a whole new realm of interaction by tapping into the electrical signals that naturally emit from our brain

A headset that provides a unique, immersive extension of the user experience

Naturally detect real-time facial expressions to make avatars come to life

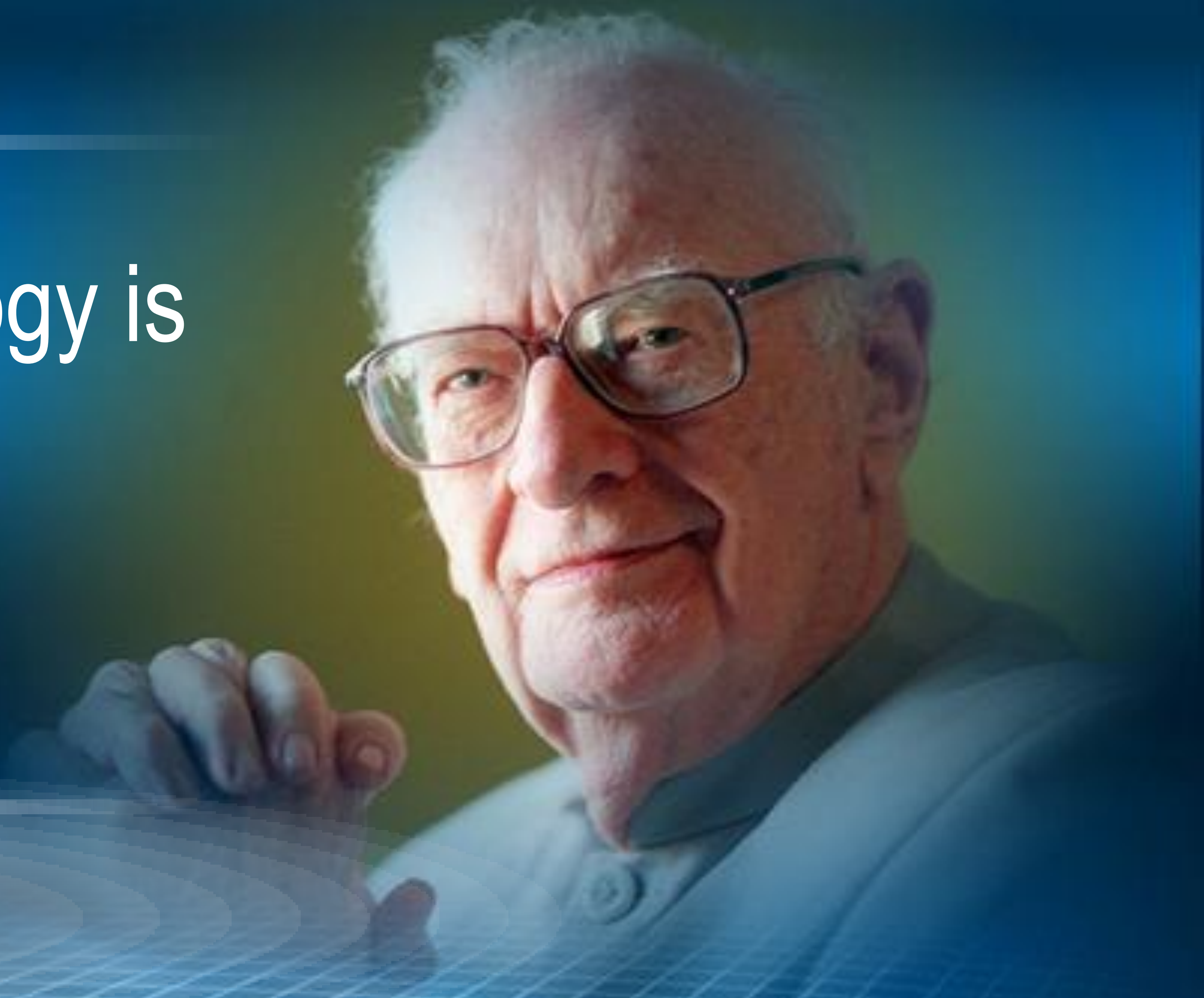
Dynamic content adjustment responding to users emotional state - excitement, engagement, calmness, tension, frustration

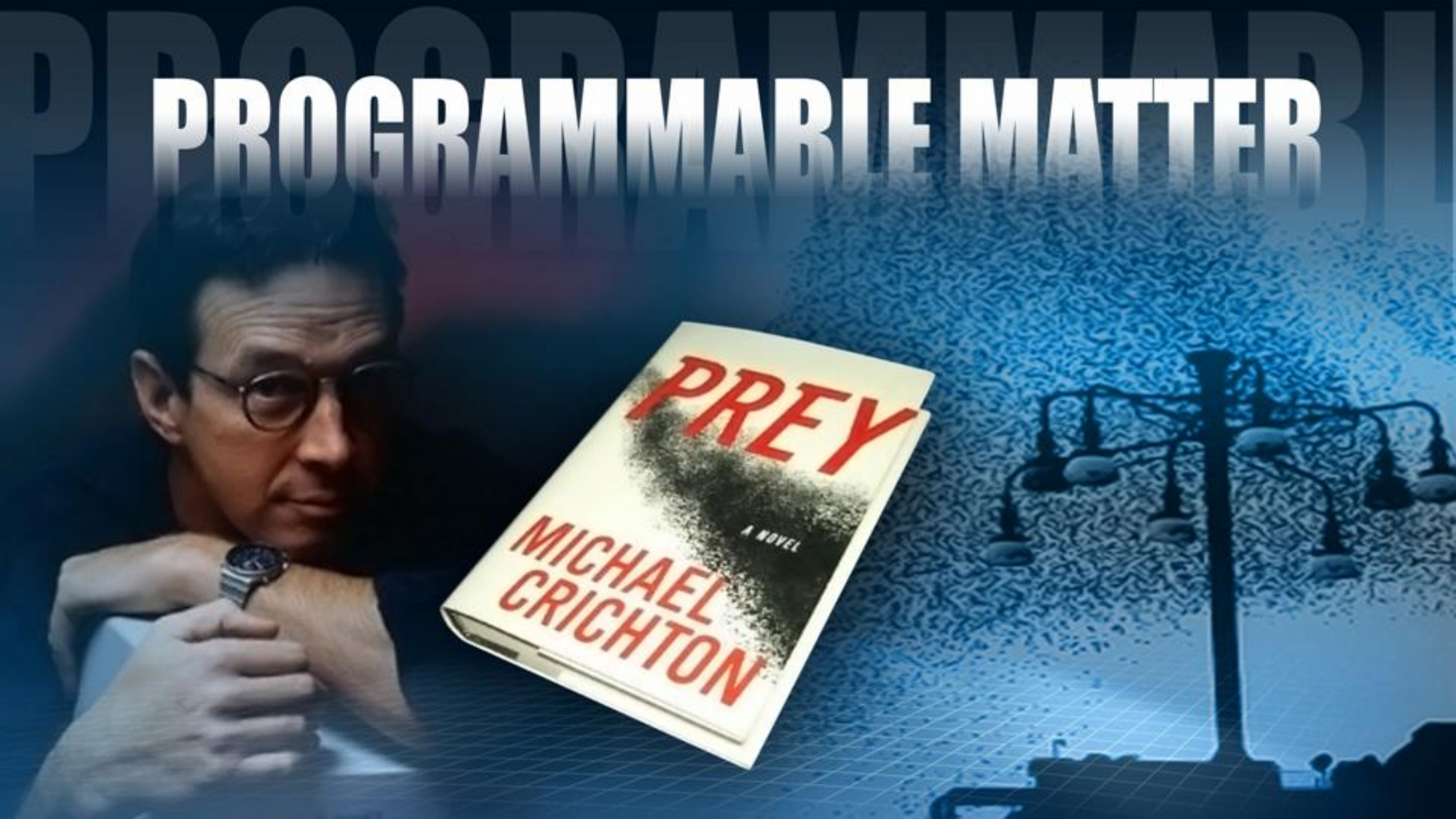
Control objects by thought, enabling players to have the power of "The Force"

"Any sufficiently advanced technology is indistinguishable from magic."

Arthur C. Clarke

1917 -2008




PROGRAMMABLE MATTER
PREY
A NOVEL
MICHAEL CRICHTON

PROGRAMMABLE MATTER

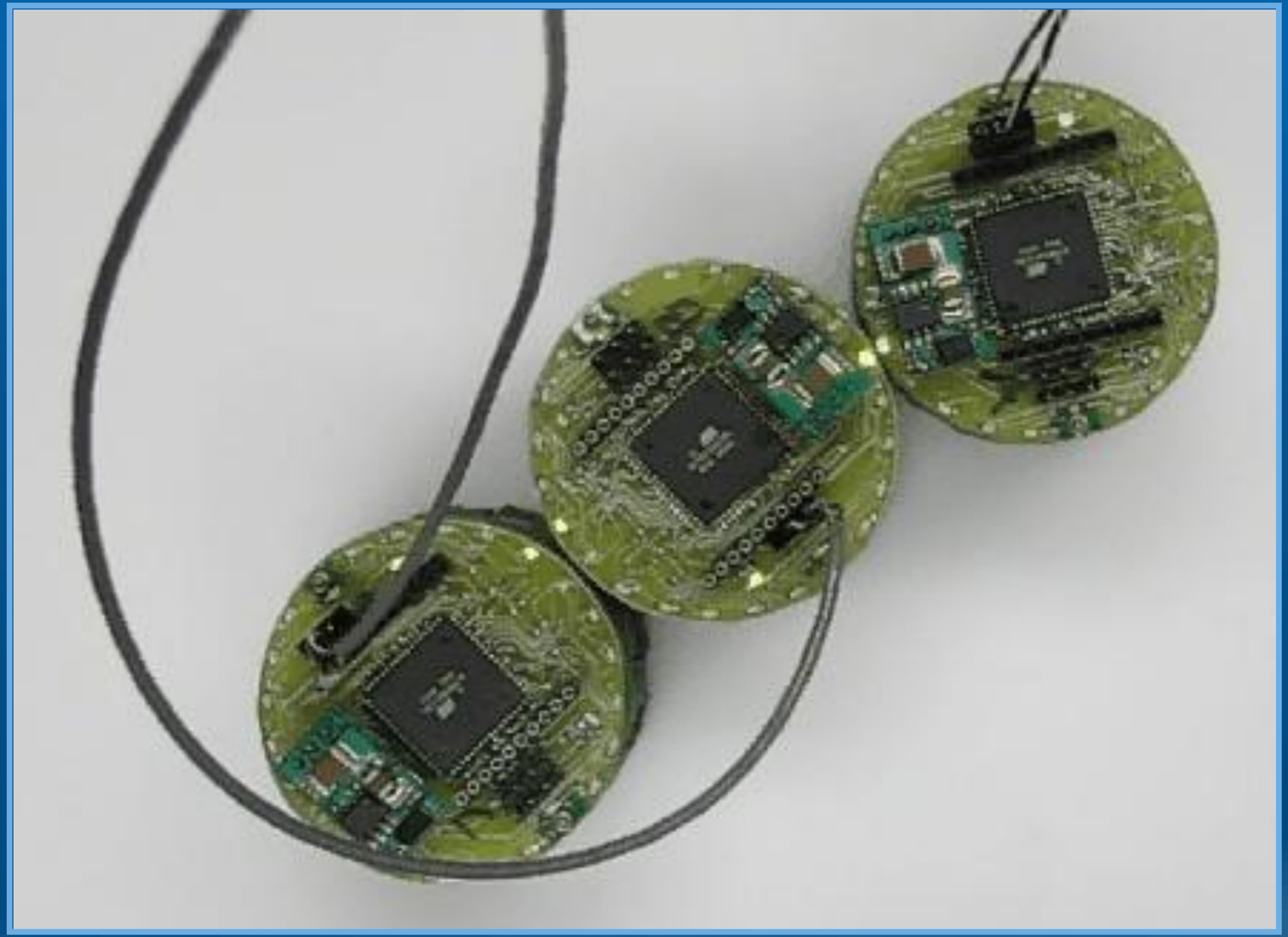
Jason Campbell

Senior Staff Research Scientist

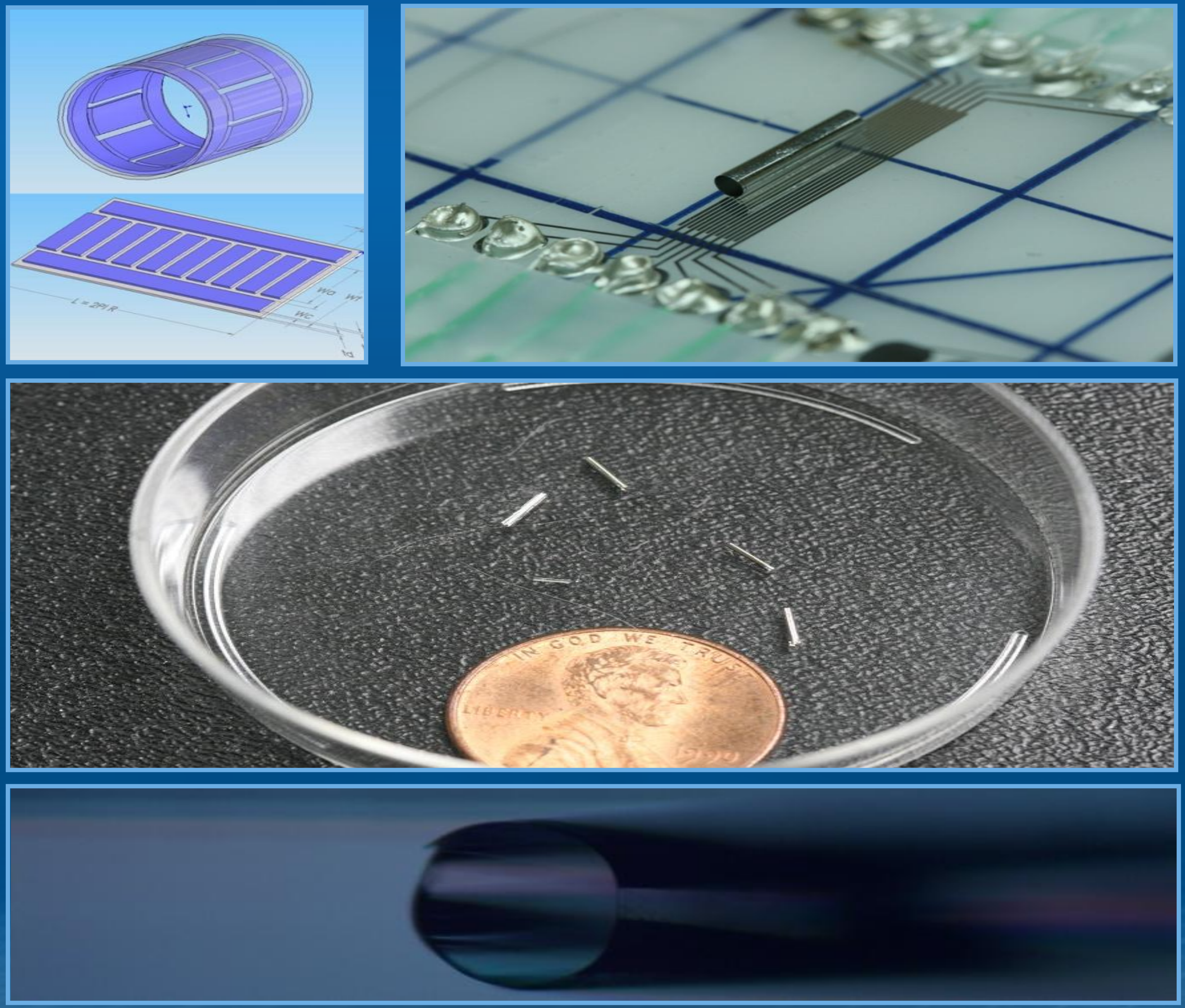
Intel Research

intel

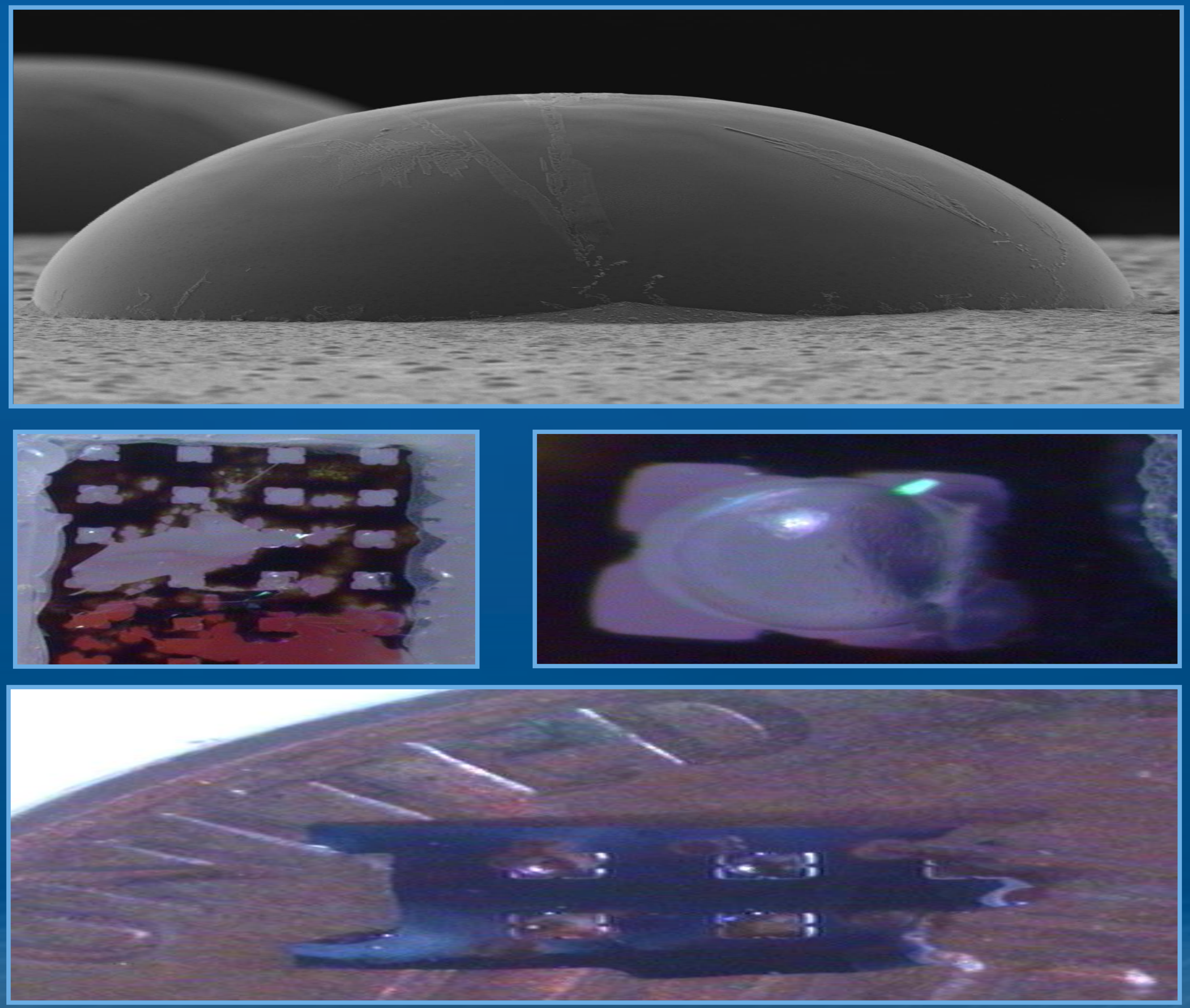
2D cm Catom – Electromagnetic



2D mm Catom – Electrostatic



3D mm Catom – Electrostatic




COUNTDOWN to SINGULARITY
The Last 40 Years…
The Next 40 Years…
and the
Accelerating Pace
of Technology

Intel Developer FORUM

Invent the new reality.