Semiconductor Market & Technology Trends

2014 IEEE Semiconductor Wafer Test Workshop

Ken Hansen | VP & CTO

June.08.2014

freescale™

External Use

Key Messages

- The next wave of explosion in electronics will be applications at the edge of the Internet of Things
- Computational methods must change and will possibly change to operate more like the brain
- No need to close the patent office yet – plenty of innovation yet to come

What Do These Innovations All Have in Common?

2003

2004

2005

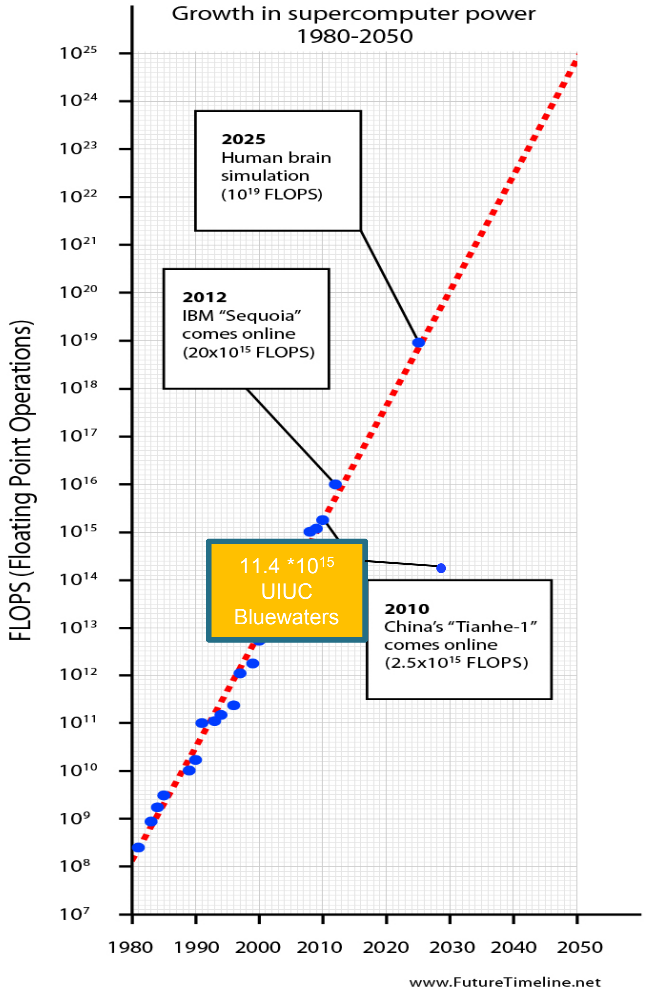
2006

2007

2008

These innovations didn't exist 10 years ago

2025+ : Hardware Approaching Human Brain Scale

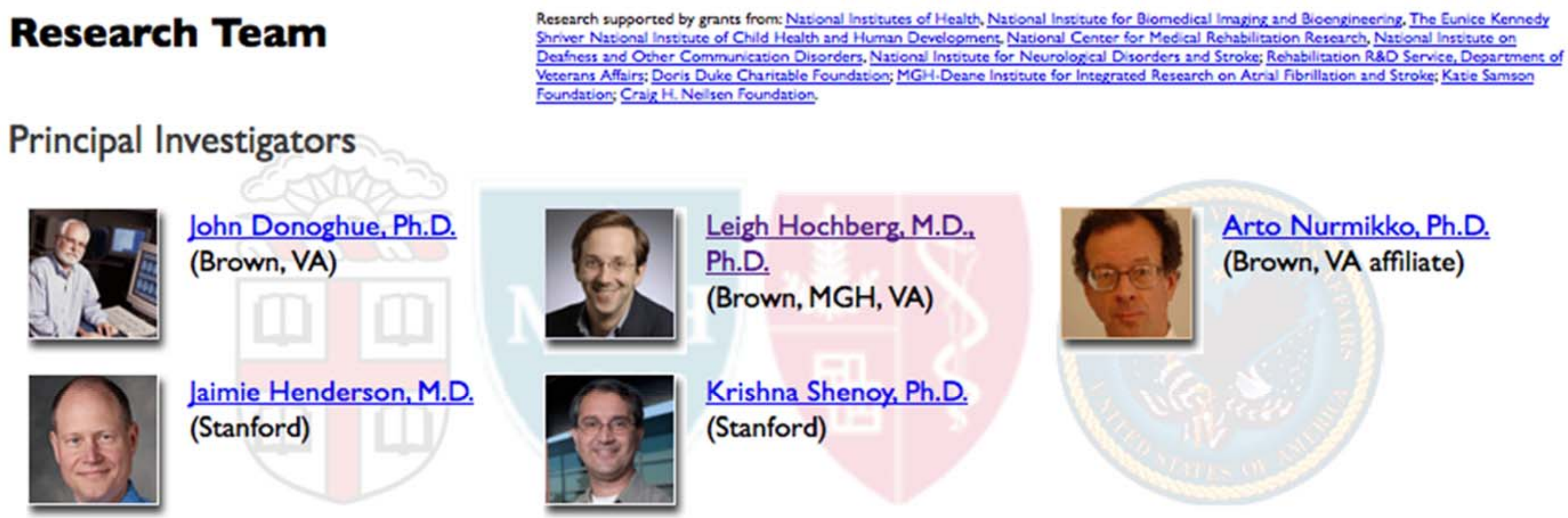


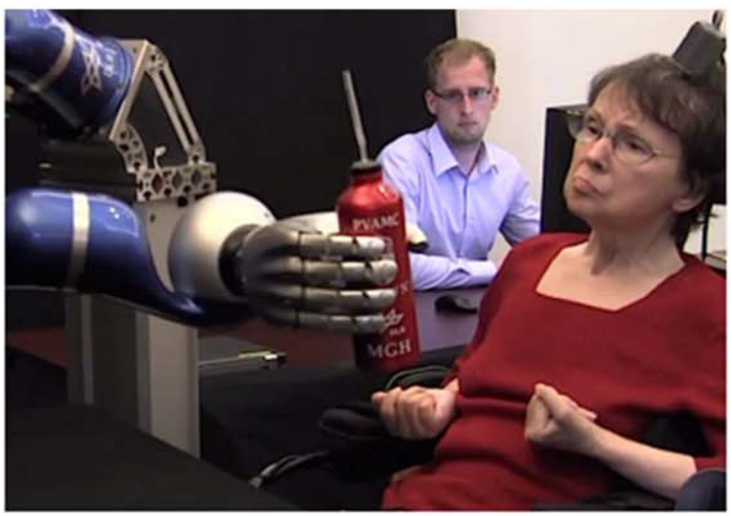
	Sandia Lab's ASCI Red	Sony Playstation 3
Date of Origin	1997	2006
Peak Performance	1.8 teraflops	1.8 teraflops*
Physical Size	150 square meters	0.08 square meter
Power Consumption	800,000 watts	<200 watts

Source: Peter Kogge

BrainGate

- http://venturebeat.com/2012/05/16/braingate-robotic-arm/





- Focused on developing technologies to restore
  - Communication
  - Mobility
  - Independence
- 96 electrodes implanted into motor cortex of the brain
  - Commands body movement

Non-invasive Brain Computer Interface (BCI)

- http://discover.umn.edu/news/science-technology/brain-computer-interface-allows-mind-control-robots

Biomedical engineering professor Bin He (standing, white shirt), researchers (l to r) Karl LaFleur, Brad Edelman, and Alex Doud, and their colleagues developed a system to control a robot with one's mind.

University of Minnesota

As a Leader in Embedded Processing Solutions

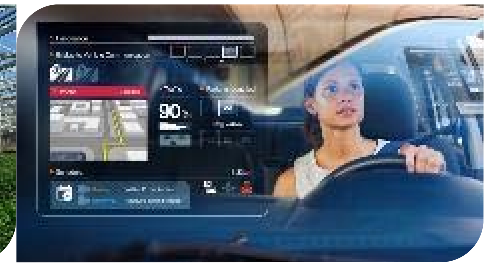
Freescale is Making the World a Smarter Place.

Four Key Market Trends


Internet of Things


Software Defined Networking


Sensor Fusion


Advanced Driver Assistance

Five Technology Trends


Multicore

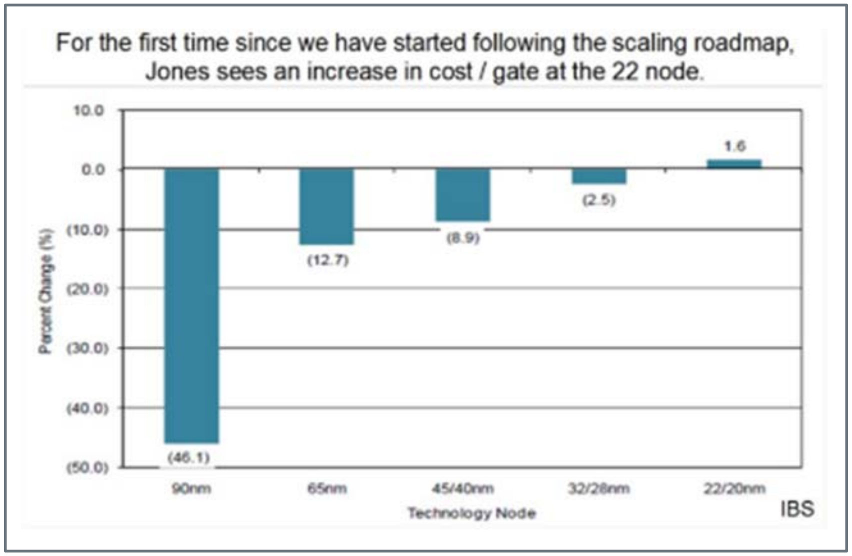

Security

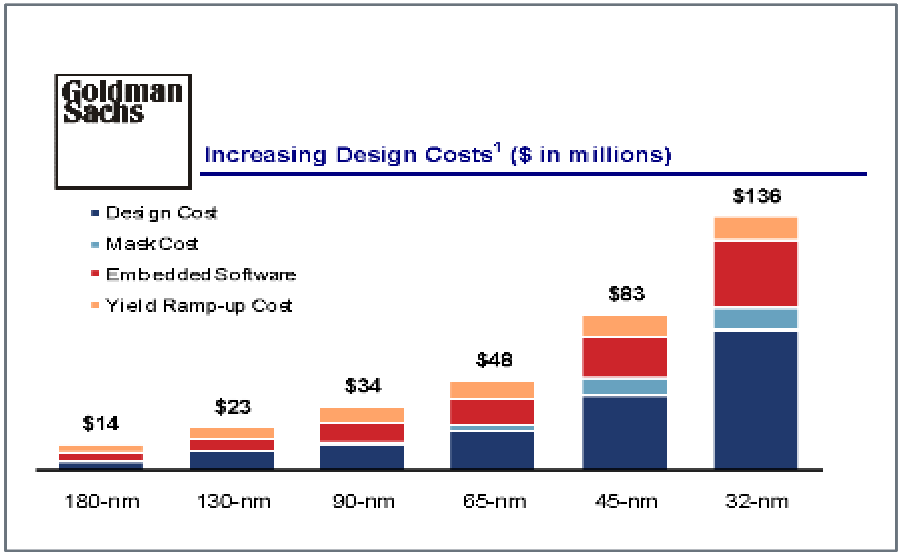

Ease of Use


Safety


Power Efficiency

Semiconductor Costs





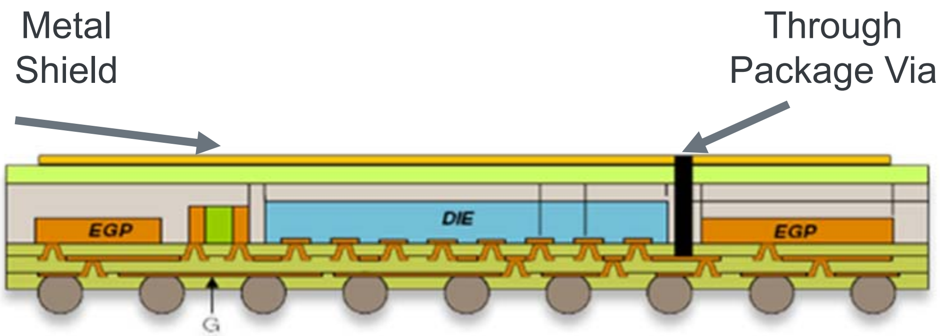
Basic premise that of declining cost/gate with advancing technology nodes is broken

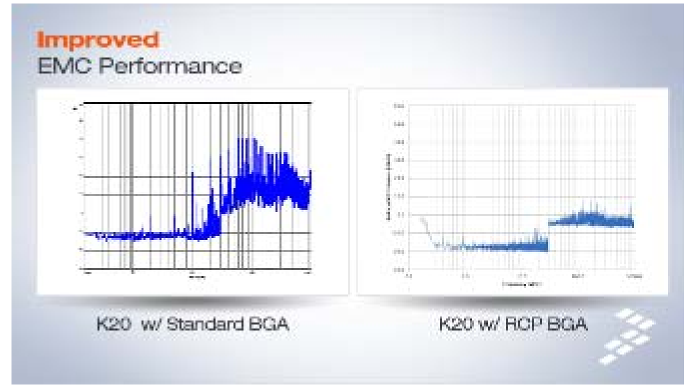
Development costs growing at ~1.65X per node

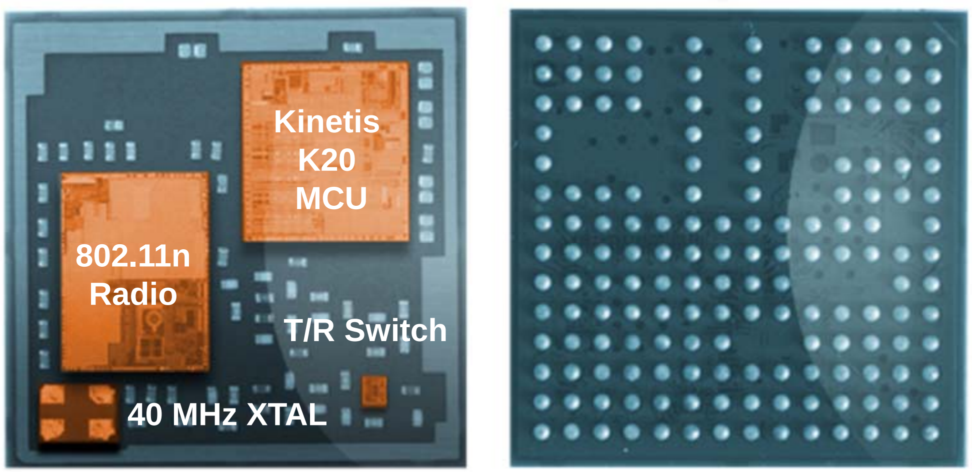
Conclusion

- 28 nm node will have a long life
- Push for advanced packaging for heterogeneous ICs

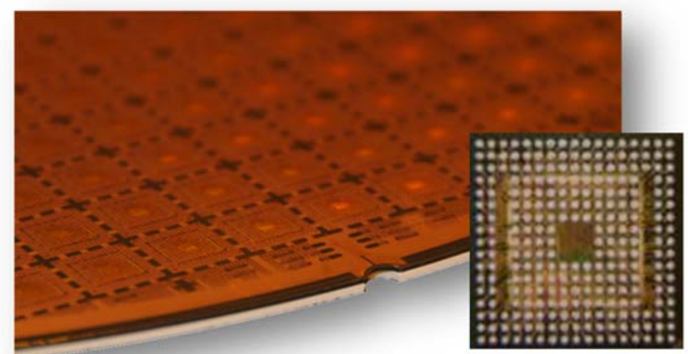
Freescale RCP Technology





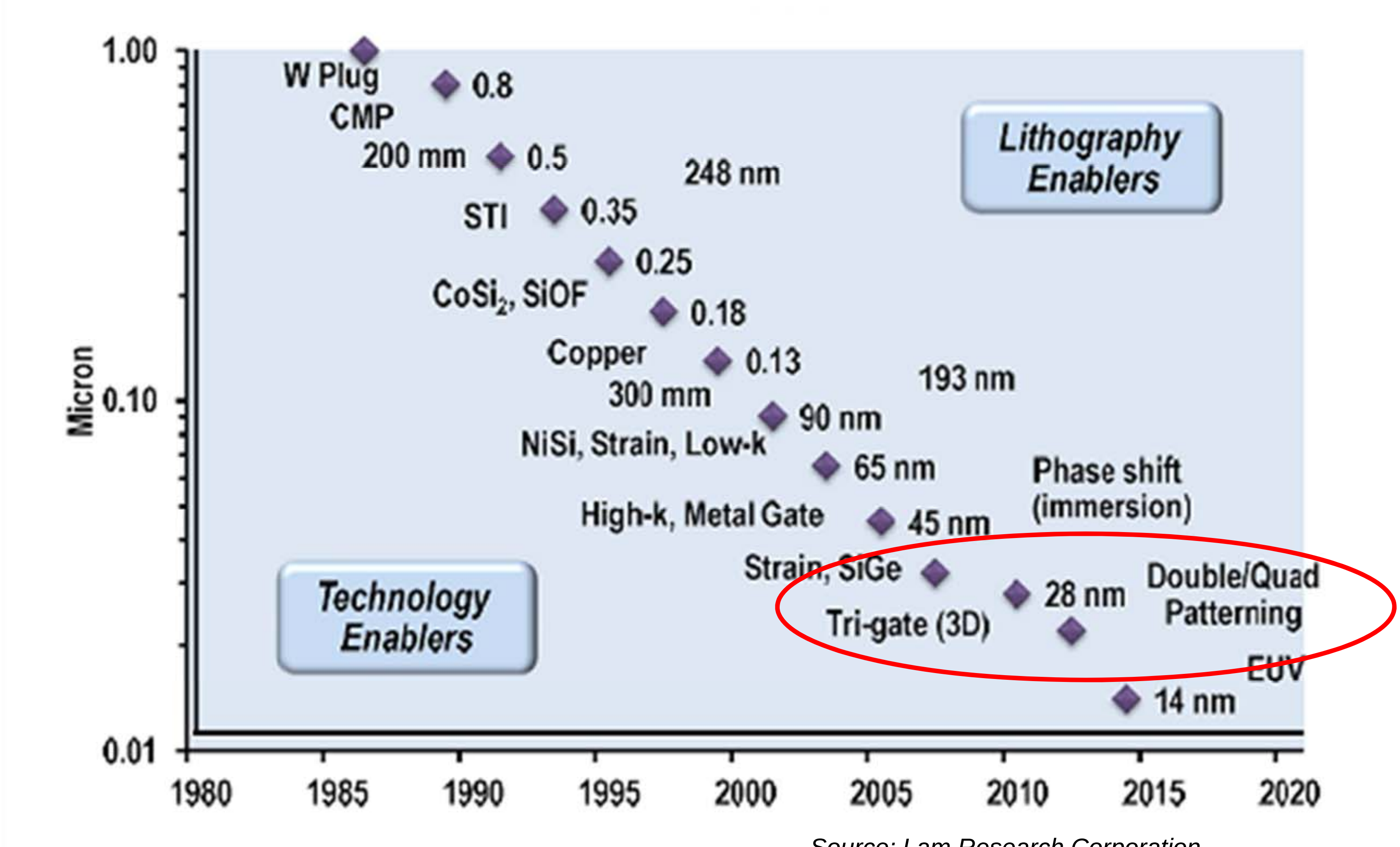


10x10x1mm^3, 802.11n radio + Kinetis MCU
3 ICs + 59 discretes



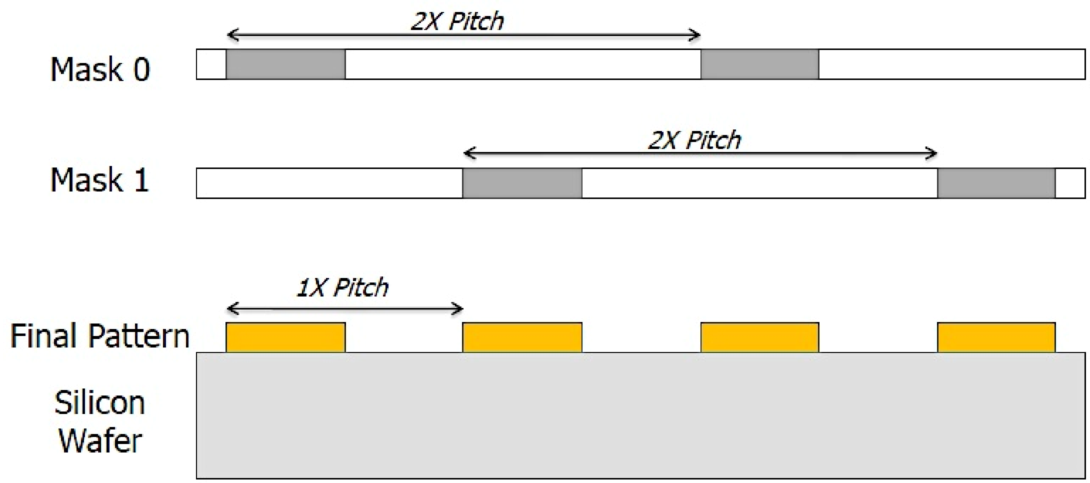
- SiP
- Volumetric Shrink
- High Performance
- Wafer scale assembly

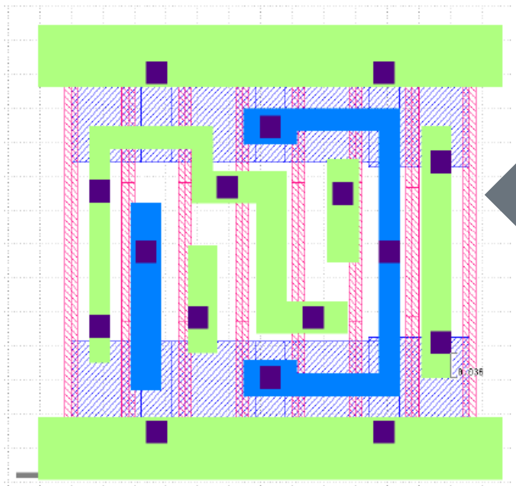
Continuous Innovation Enables Continuation of Moore's Law



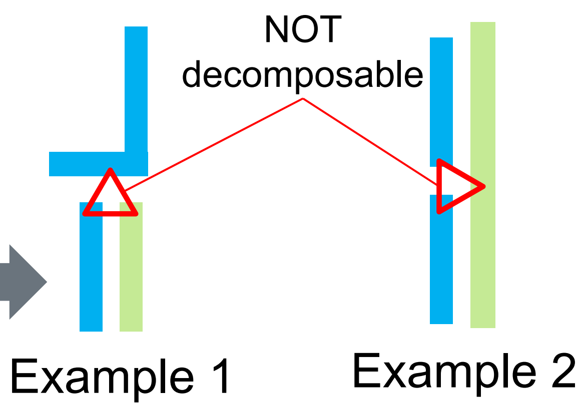
Source: Lam Research Corporation

Double Patterning of Metals





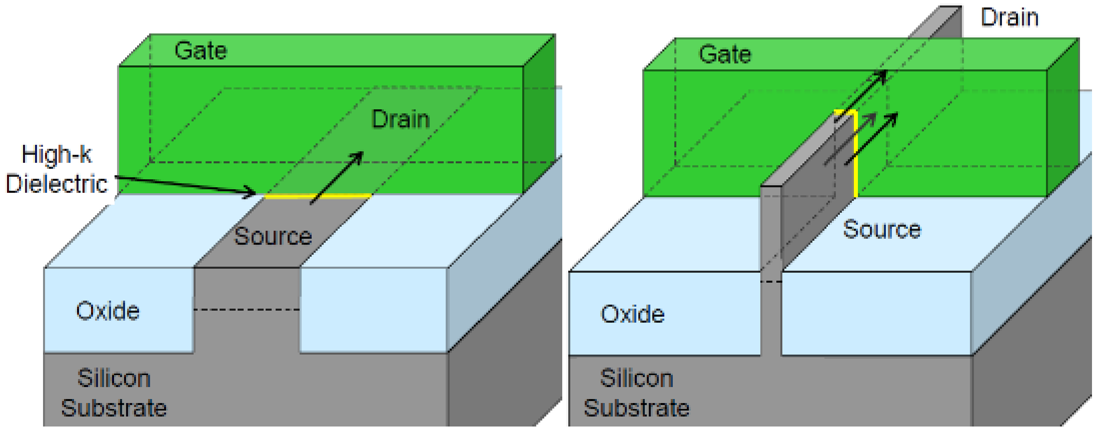
- Green/Blue colorization
  Decomposable layout
- 2 Examples of a non – decomposable layout



What is a FinFET?

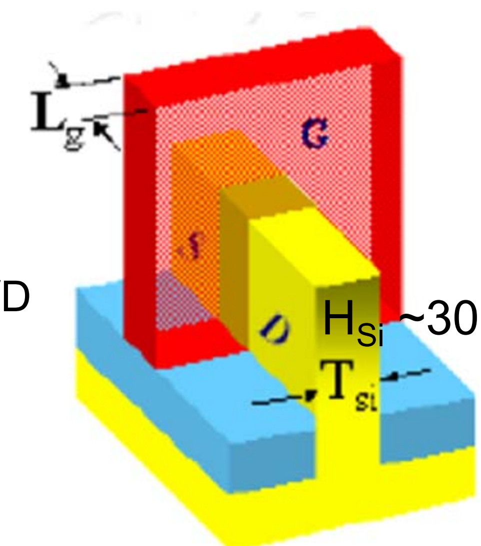
Planar Transistor

'Fin' Transistor



Quantized device width =
2 H_{si} + T_{si} ≈ 70nm

A thin fin (T_{Si}~10nm) provides FET body and S/D



Advantages

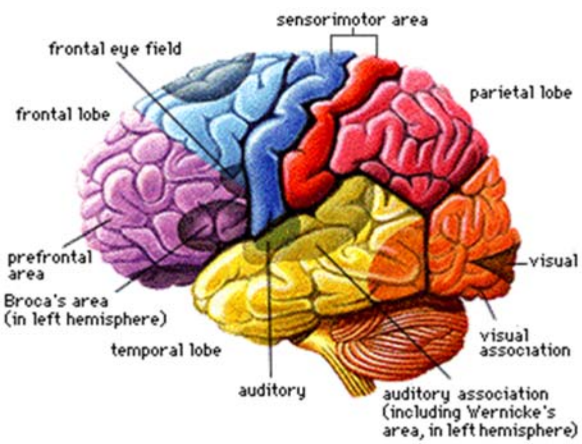
- 50% Lower Power Consumption
- Higher Drive Current for given silicon area
- Lower Vt / reduced Vdd due to better electrostatic control
  - (1) undoped channels → higher mobility
  - (2) Lower leakage (Ioff)
  - (3) Allows thicker oxide, wider channels
- Higher layout efficiency and higher speed / lower power
- Undoped channels → lower RDF (random dopant fluctuation) / variation → lower Vmin

Challenges

- Control of 'Fin' depth and width
- Product designed need in accommodate quantized transistor width due to discrete nature of the fins
- Device variability

Bio-Inspired Computing

- Exploit the properties of neural systems
- Utilize the properties of deeply scaled nanometer CMOS or post-CMOS devices
  - Organics, Carbon-nanotube, Graphene, MEMS, Spin, PCM, RRAM, etc.

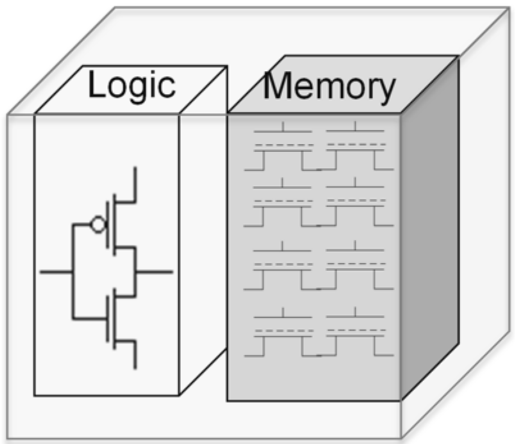


Human Brain

- Unreliable and noisy components yet reliable output
- Robustness in the presence of component failure and variations
  - Neural responses is highly variable (σ/μ≈1)
- Amazing performance with mediocre components
  - Auditory system: can tell difference of time arrival within 10 μs with cells having time constant of 1ms
- Adaptive – learns
- Seamless interaction with the analog world
- Massively parallel
- High computational power for low DC power consumption

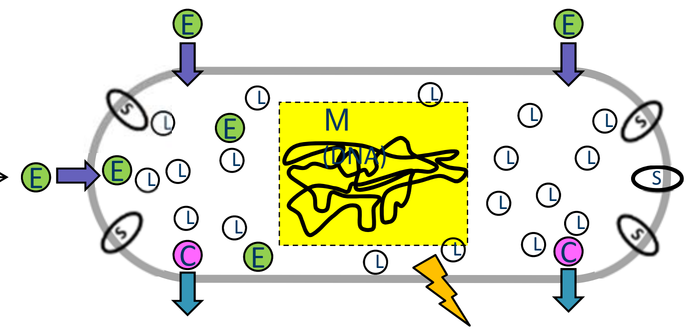
Comparison of a Si Cell to a Bio Cell

Si-µCell



← $V=1\mu m^3$ →

Bio-µCell



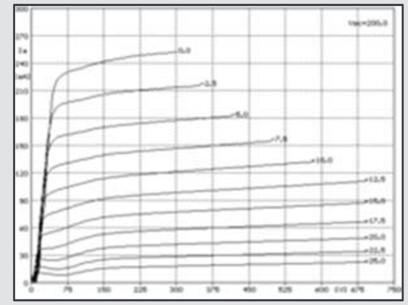
Memory:	~10^4bit
Logic:	~300–150,000 bit
Power:	~10^{-7} W
Heat:	~1 W/cm^2
Total energy/task*:	~10^{-2} J
Task time*:	510,000 s ~ 6 days

Memory:	10^7 bit
Logic:	>10^6 bit
Power:	10^{-13} W
Heat:	10^{-6} W/cm^2
Total energy/task*:	10^{-10} J
Task time*:	2400s=40min

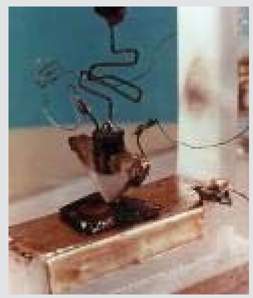
*Equivalent to 10^{11} output bits

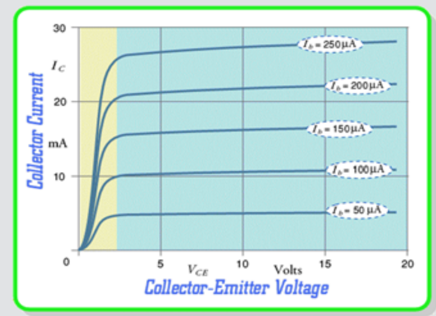
What Device is Next?

19TH and early 20TH century: vacuum tube pentode

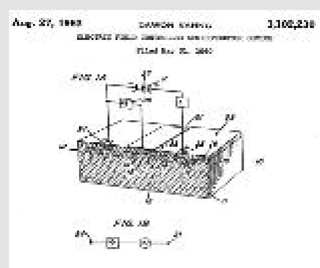


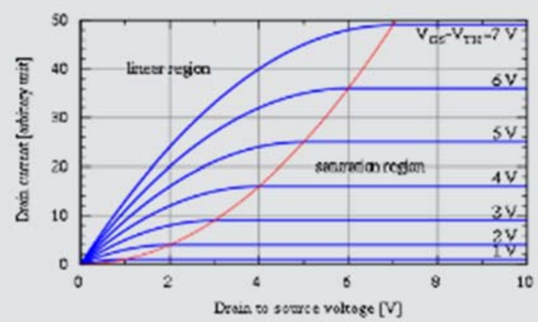
1947: First BJT Bardeen, Shockley, Brattain (Bell Labs)





1960: Atalla's MOSFET patent



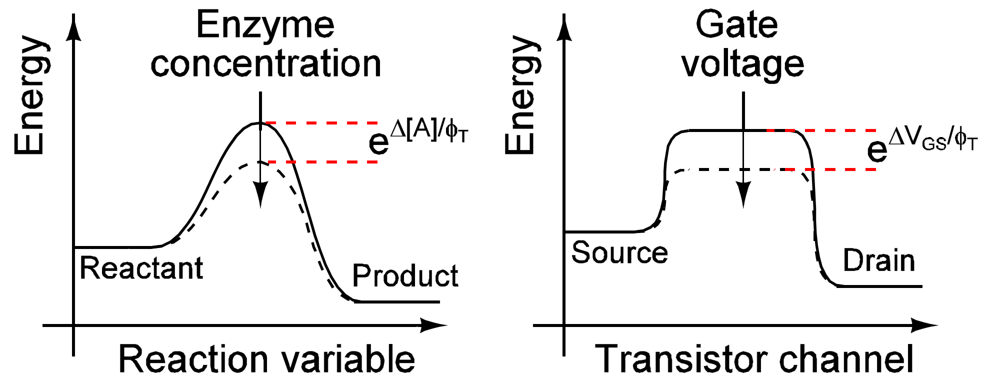


- Incredible base of knowledge in using devices that look like these
- Strategies to run circuits at low power, amplify signals, and reduce noise are well known

Similarities Between Chemistry and Electronics

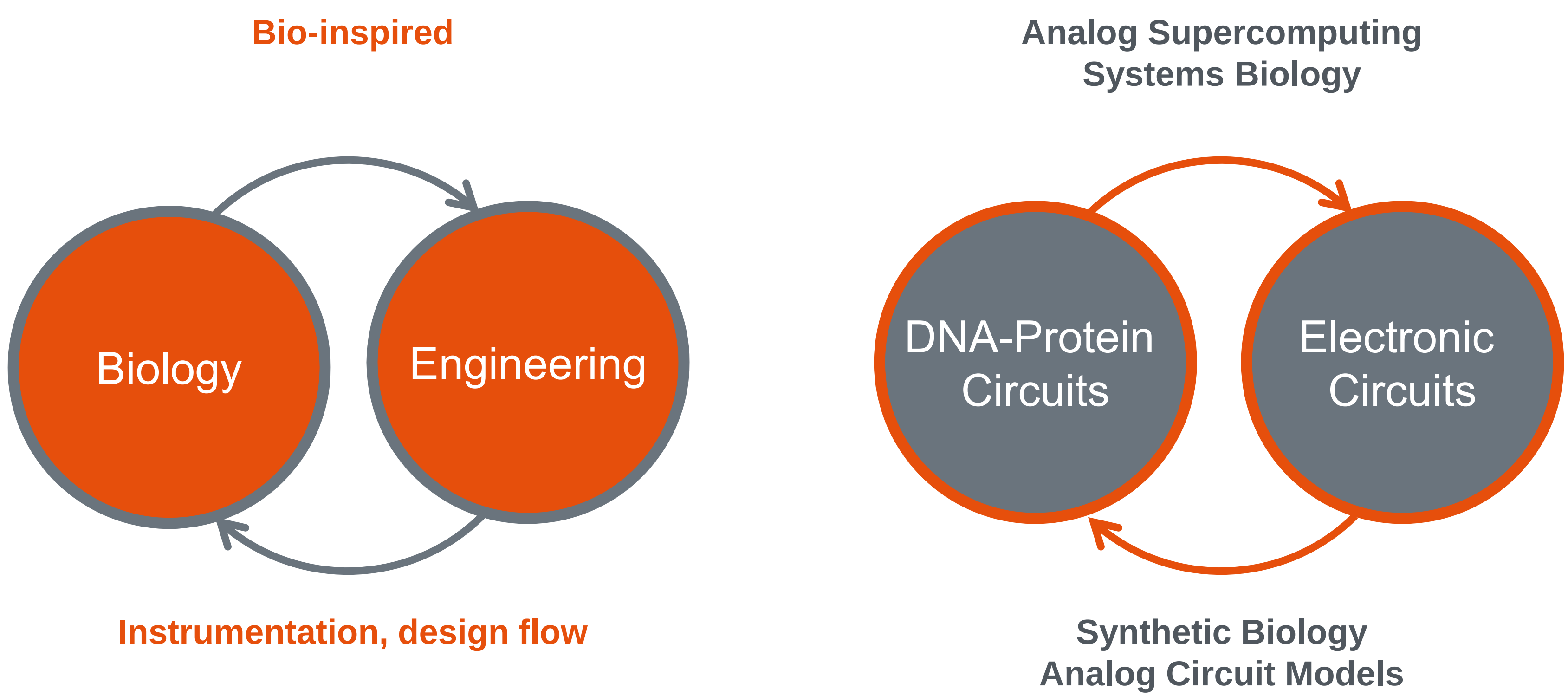
- Currents in a subthreshold electronic transistor versus molecular flows in a chemical reaction (exponential Boltzmann laws, forward and reverse currents)
- Poisson electron arrival statistics ↔ Poisson molecular flow statistics. Noise scaling is similar

Sources: Rahul Sarpeshkar
SRC SSB Workshop, Boston 2013



- Kirchoff's Current Law (KCL) ↔ Flux Balance Analysis (automatically satisfied)
- Kirchoff's Voltage Law (KVL) ↔ thermodynamic loop law on chemical potentials (automatically satisfied)
- Molecular flux = current; log(molecular concentration) = electrochemical voltage

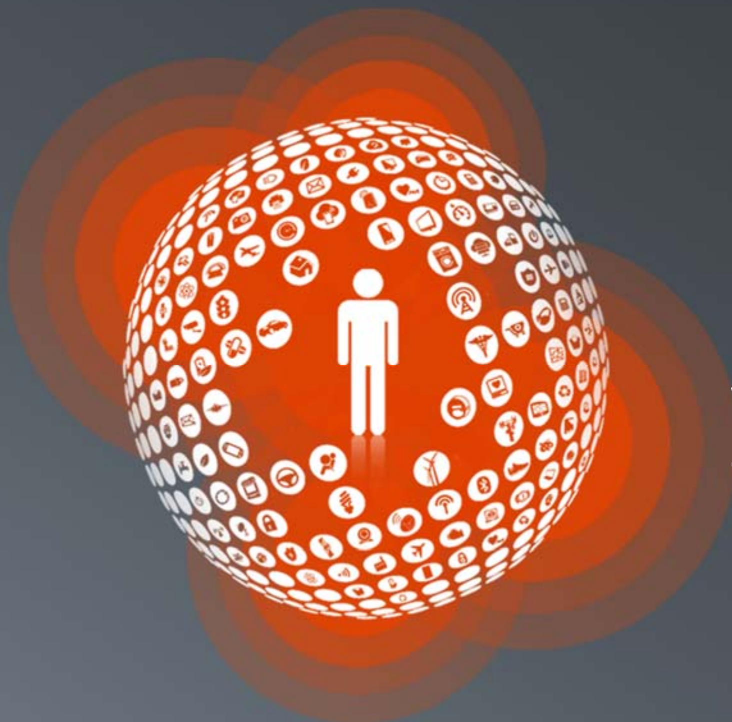
Increasing Relationship Between Biology and Engineering



Transition in the Semiconductor Industry

- Application driver
  - PC ➡ cell phone ➡ IoT (from the edge to the Big Data collection and analytics from anywhere, anytime
- Technology driver
  - Increased levels of integration to provide for layered intelligence requiring orders of magnitude more computational power
    - ex: analog ➡ GSM ➡ WCDMA ➡ OFDM
- Parametric driver
  - Power consumption (NMOS ➡ CMOS: single core, single threaded ➡ multicore, multithreaded: planar ➡ FinFET active vs. leakage current
- Technical threat
  - Security ➡ Privacy
- Adoption accelerator
  - Ease of Use

The Vision of the Internet of Things



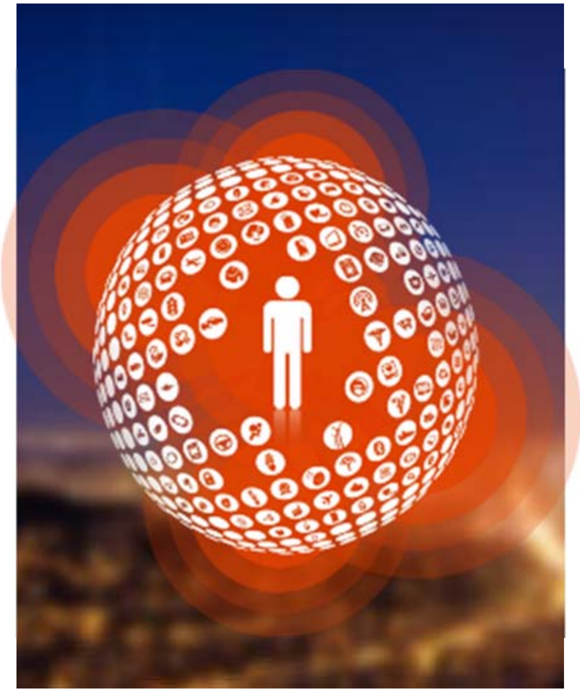
"Today computers—and therefore, the Internet—are almost wholly dependent on human beings for information. The problem is, people have limited, time, attention and accuracy—all of which means they are not very good at capturing data about things in the real world."

The solution is empowering devices to gather information on their own data, without human intervention.

—Kevin Ashton, 2009

… and convert data into information or the so-called "Big Data Analytics"

The Promise of the Internet of Things



- **2.4 billion** Internet users
- **12 billion** connected devices in 2013
- **5 billion** Internet users
- **50 billion** connected devices by 2020
- Devices talking to each other, all **connected** to the **cloud** and **servers**
- All communicating **securely**
- Opportunity to grow – IPv6/IPv4 = $\mathbf{2^{96}}$

Resulting in savings and value creation
Impact on U.S. GDP ~$1.4 trillion in 2025

Source: Cisco IBSG, Jim Cicconi, AT&T, Steve Leibson, Computer History Museum, CNN, University of Michigan, Fraunhofer, FSL Strategy

Infrastructure of the Internet of Things

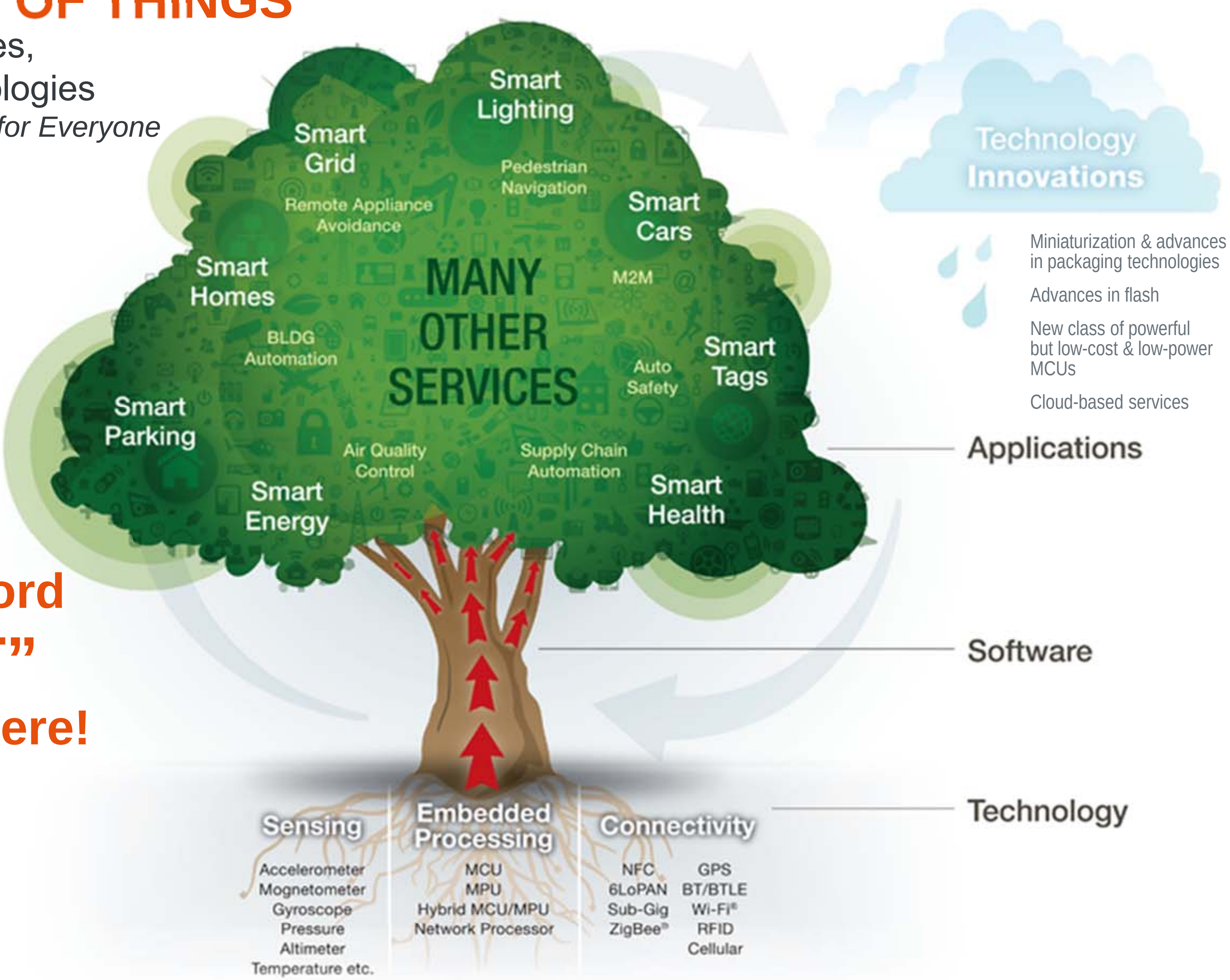
- SW to automate tasks and enable new classes of service
- Full security across the signal path

INTERNET OF THINGS

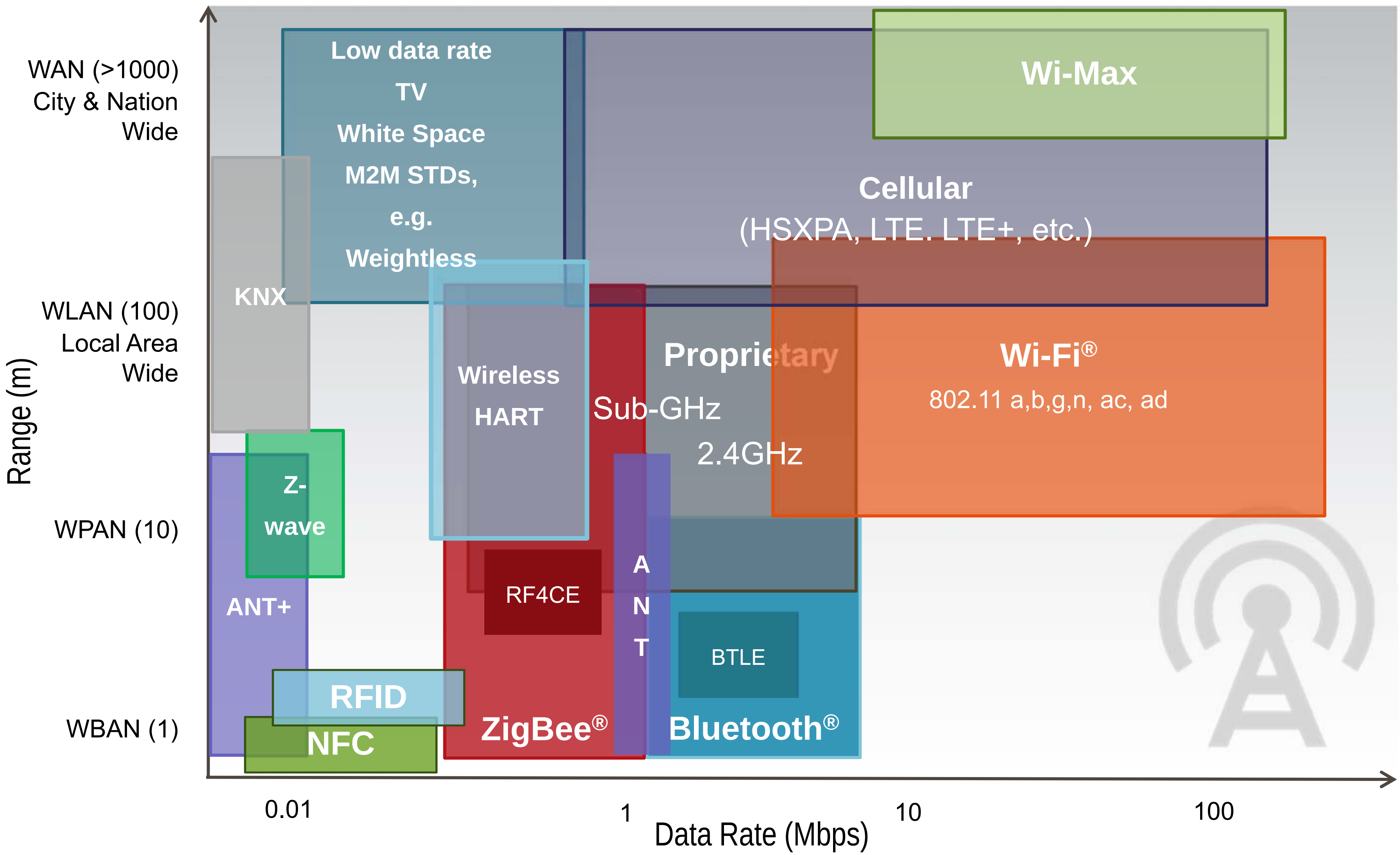
Different Services,
Different Technologies

Different Meanings for Everyone

And the Word "SMART" Is Everywhere!



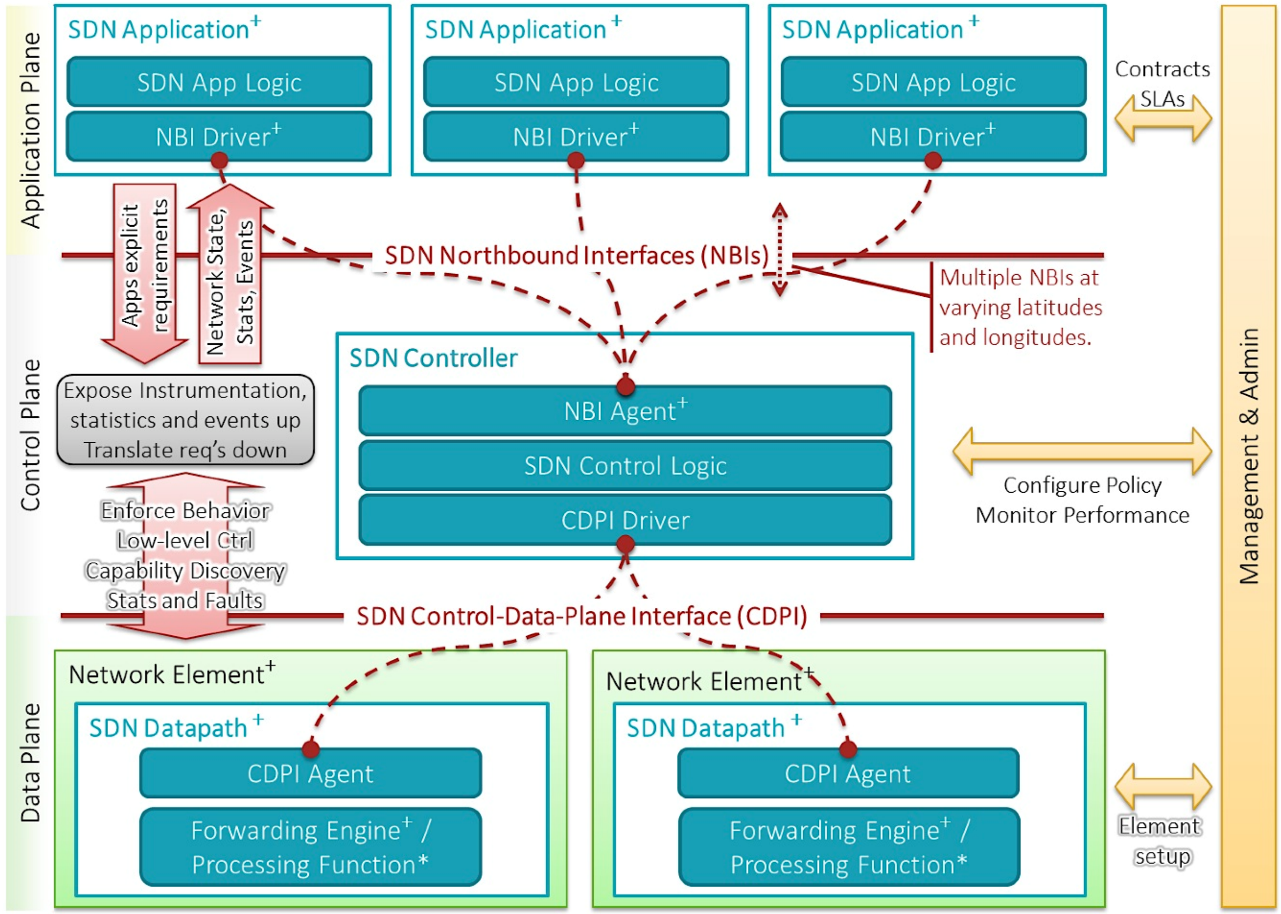
Today's Wireless Landscape



SDN Motivation

- Historical architecture supported single client to single server communication with protocols defined in isolation
- Today's applications access different databases and servers from a variety of devices requiring a dynamic virtualized network
  - Consumerization of IT – smartphones, tablets, notebooks
  - Rise of cloud services both public and private
  - Big data – massive parallel processing on thousands of servers

SDN Architecture



+ indicates one or more instances | * indicates zero or more instances

Figure 1: Overview of Software-Defined Networking Architecture

Benefits of SDN

- Ease of use for enterprises and carriers
- Greater rate of innovation
  - Ability to offer new services and network capabilities
  - Non-proprietary networking model
  - Common programming environment enabling rapid differentiation
- Increased network reliability
  - Fluid automation for datacenter traffic flow to reduce downtime, improved data resilience
  - No need to configure individual devices or wait for vendor releases
- Enhanced provisioning of services
  - Automated management tasks across real and virtual machines
  - Consistent policies for access, security, and QoS
- Agility
  - Unified control allows network operators to scale their networks at a pace commensurate with their business conditions
- Vendor independence
  - Standard, open interfaces

Sensor Fusion and ADAS

NEWS

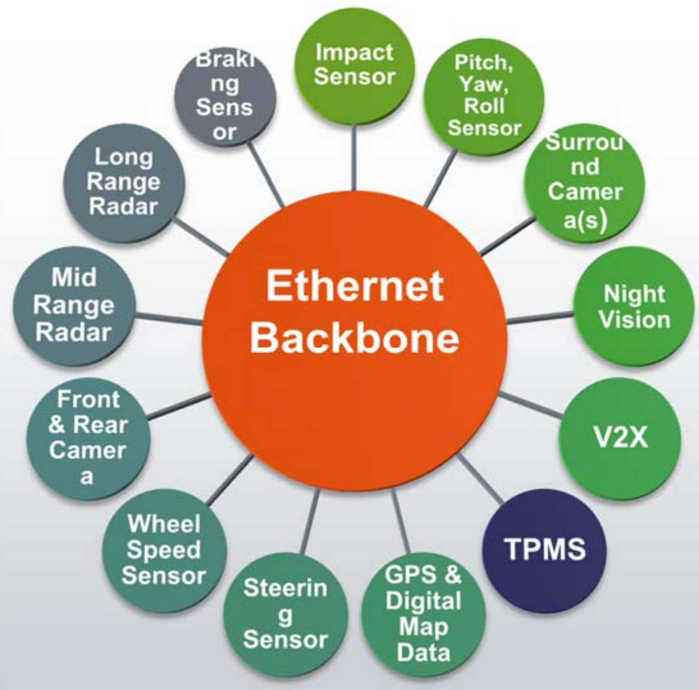
Cadillac XTS Getting 'Sensor Fusion' Driver Assistance Package

Cadillac, like other auto makers, is working towards the ultimate goal of self-driving cars. Computers, it seems, are far better at multi-tasking than humans, and aren't prone to cell-phone-induced distractions.

While self-driving cars are still potentially decades in the future, technology being developed towards that end can be implemented to make cars safer now. An example of this is the Driver Assistance Package in the 2013 Cadillac XTS, which was developed using what GM calls "sensor fusion."

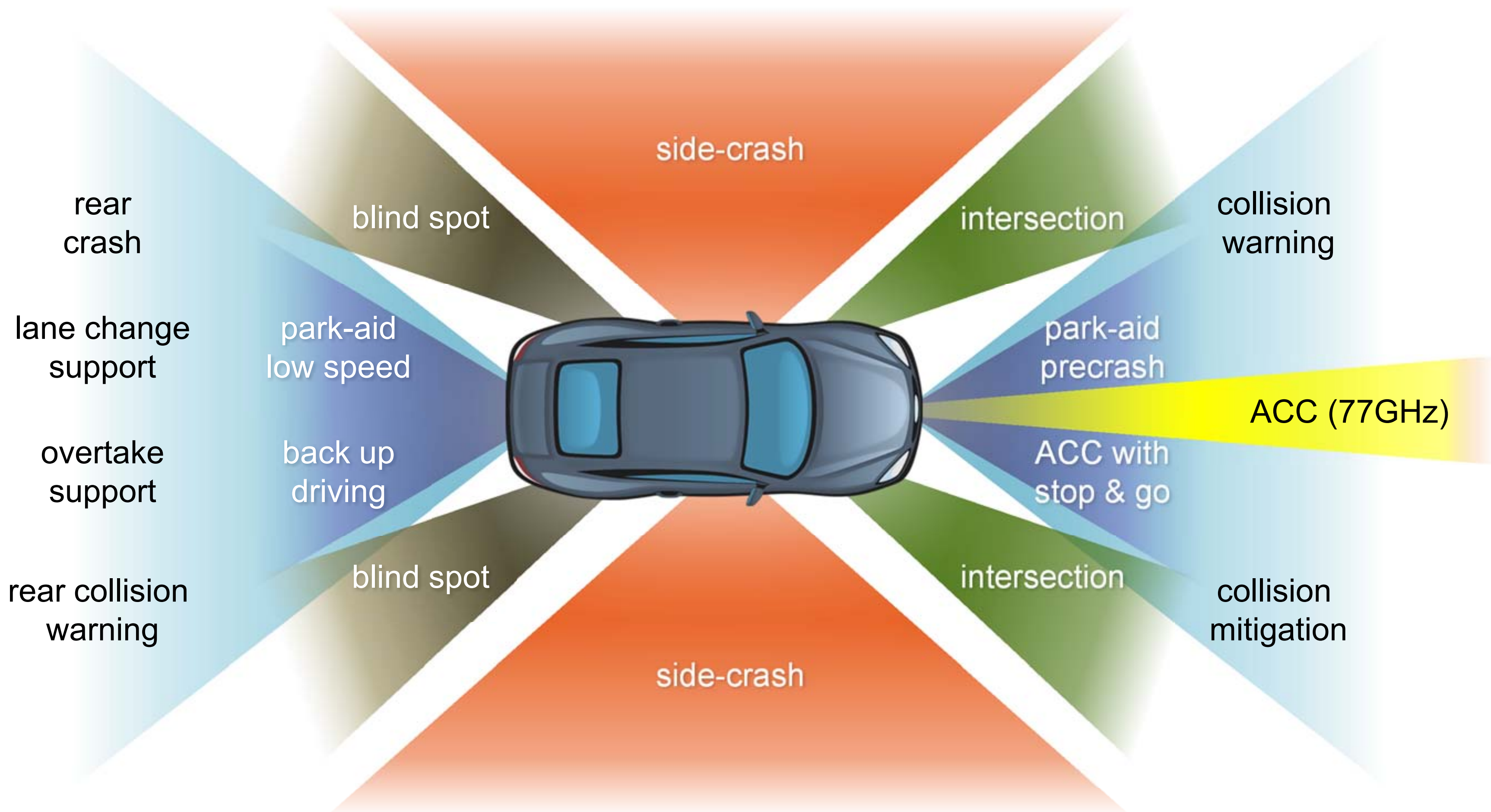
Sensor fusion may sound like something that requires repair under warranty, but it actually refers to the integration of various technologies that aid drivers in determining both position and potential dangers in the surrounding environment.

Cadillac's Driver Assistance Package will blend radar, cameras and ultrasonic sensors to provide owners with adaptive cruise control, forward collision alert, lane departure warning, automatic collision preparation, blind zone alert, rear cross traffic alert and a rearview camera with dynamic guidelines.

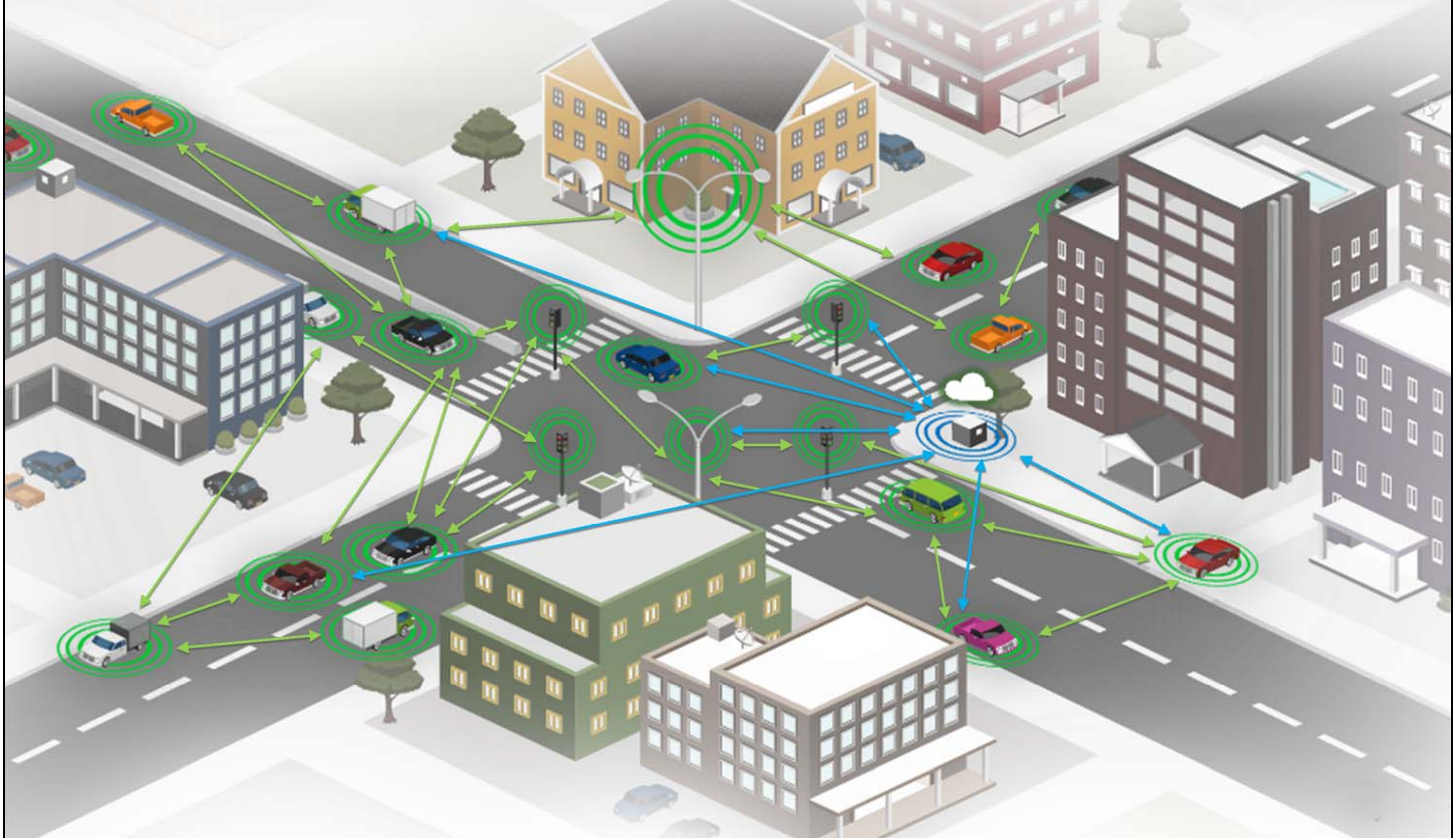


Source: Kurt Ernst of Motor Authority

Coverage Areas for Various Automotive Safety Applications



V2V & V2I Communications



Internet as a Top Security Concern

Intelligence Chiefs Warn that Cyber Attacks are Nation’s Top Security Threat

By Jordy Yager and Carlo Munoz – 03/12/13 4;00 PM ET

Testifying at the Senate Intelligence Committee’s annual hearing on worldwide threats, Director of National Intelligence James Clapper told lawmakers that terrorist groups are increasingly pursuing the ability to wage cyber attacks, which, if successful, could bring businesses and the government to a collapsing halt.

“Our statement this year leads with cyber, and it’s hard to overemphasize its significance,” said Clapper, reading a statement on behalf of himself, FBI Director Robert Mueller, CIA Director John Brennan and National Counterterrorism Center Director Matthew Olsen.

Despite the growing number of terror and nuclear related threats, officials and lawmakers concentrated much of their attention on cyber security — a signal that momentum is growing on Capitol Hill to try to pass another bill on the issue.

Security

- Unfortunately security will be broken
  - ~86,000 new pieces of malware/day
  - When value of break exceeds effort to break
    - Cyber risk = threats X vulnerabilities X consequences
  - Where humans are involved
- System level approach to security required from the sensing nodes through various layers of embedded processing to the data centers
  - System only as strong as its weakest link
  - IoT creates a pervasive network of entry points for attack
- Hugh area for research over the next decade
  - Tamper detection
  - Monitor prevention – privacy
  - What happens in the case of theft of a device
  - Mutual authentication
  - Data confidentiality as it passes across different communication protocols
  - Not only is the data uncorrupted, but has all the data made it
  - Etc.

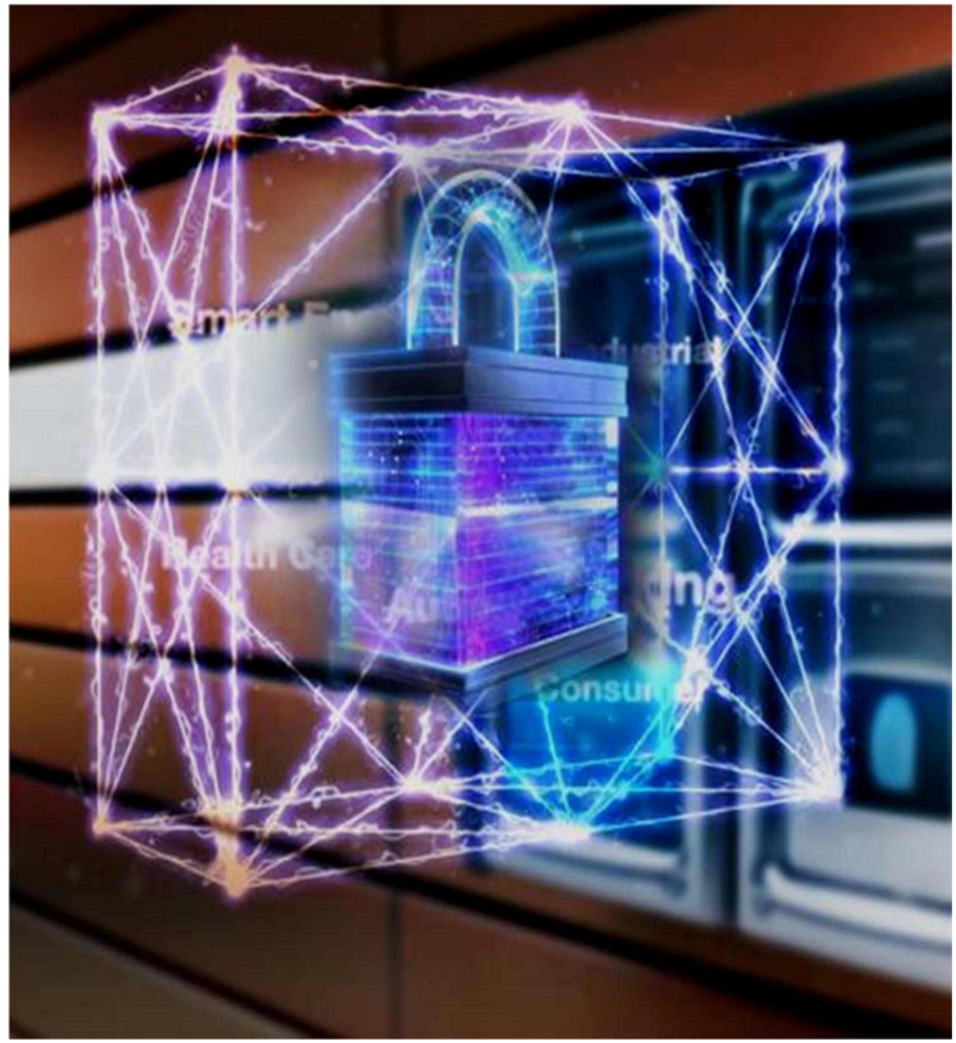
Infrastructure of the Internet of Things

Java technology to embrace the entire system and unify the Internet of Things, even down to the tiniest and most resource-constrained edge/sensing nodes

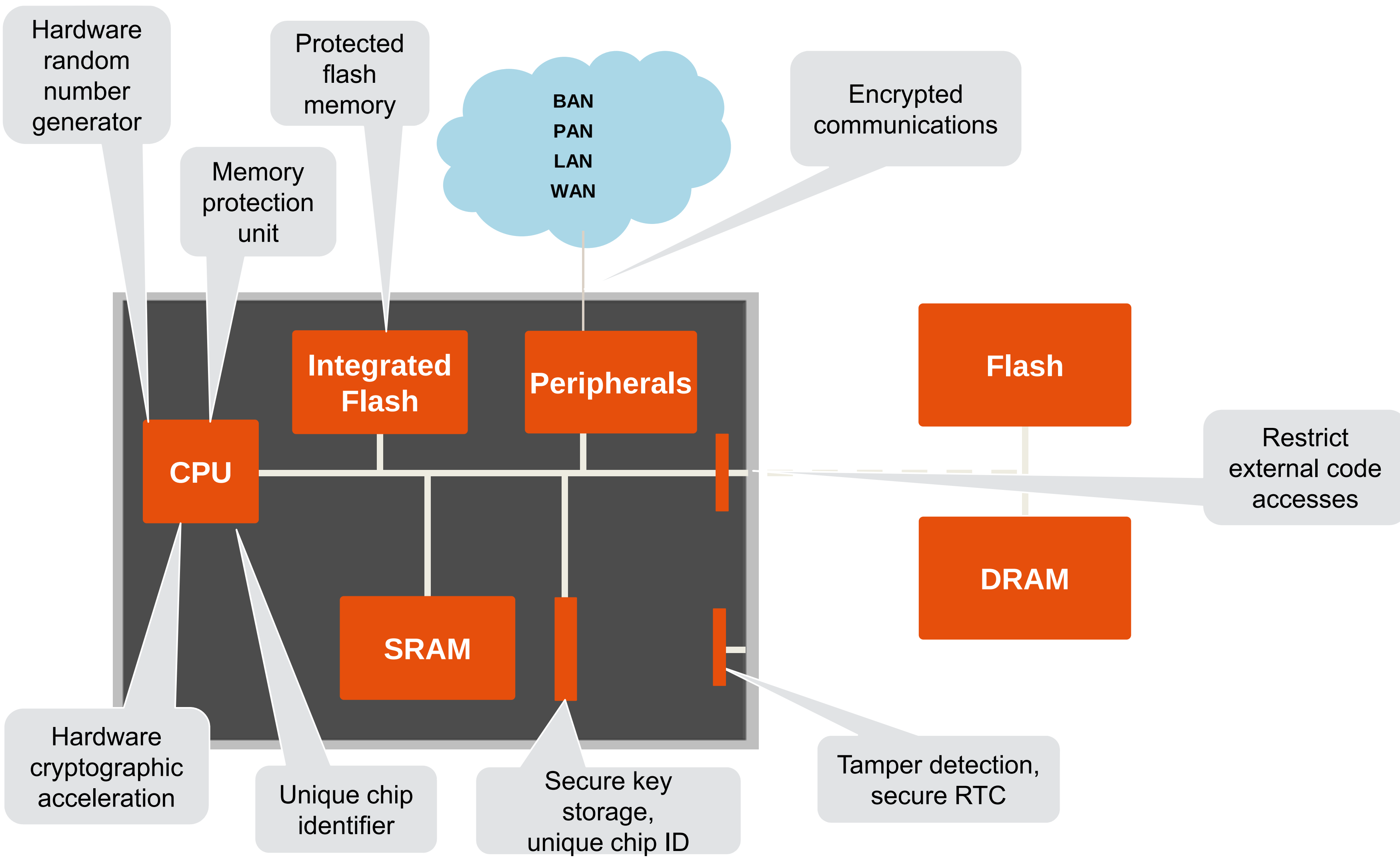
Hardware Security

- **THREATS**
  - Reverse engineering
  - Malicious IP
  - Trojan circuits
  - Tampered manufacturing
  - Counterfeits

- **COUNTERMEASURES**
  - Security architectures
  - Hardware primitives
  - Security specification and verification
  - Metrics and benchmarks
  - Design for security tools
  - Supply chain security



Example of MCU System Security



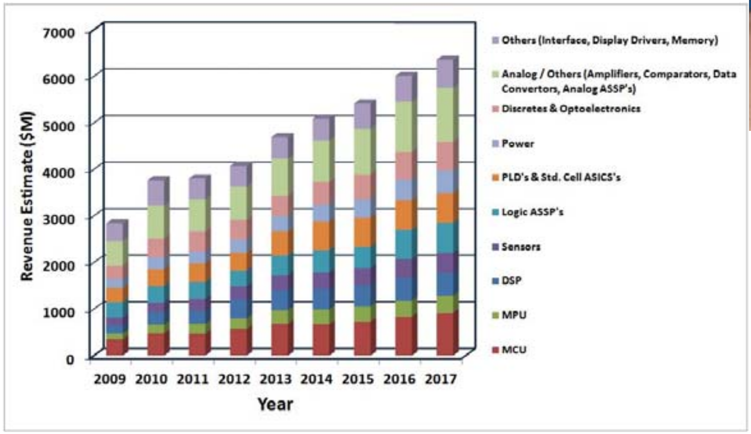
Recent Security Issues

- Target
  - Hack identified by FireEye security package, alarm sent, no action taken
- Edwin Snowden
- Heartbleed – 2 year breach before discovered
  - *"I was working on improving OpenSSL and submitted numerous bug fixes and added new features…In one of the new features, unfortunately, I missed validating a variable containing a length."*

Robert Seggelmann as told to Ben Grubb of the Sydney Morning Herald

1969

Semiconductors in medical electronics & the baby boomers



Source: databeans

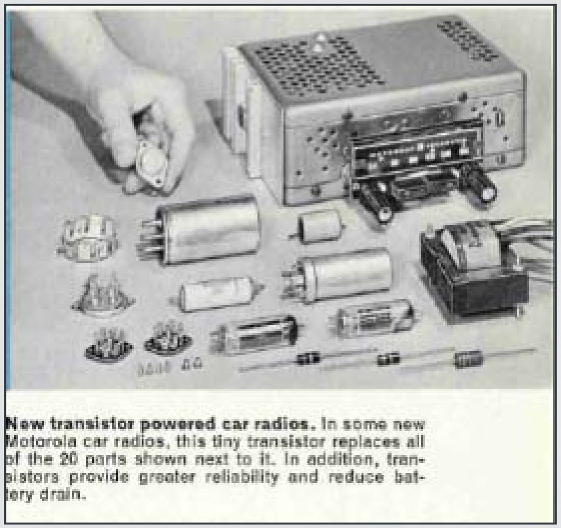
Creativity Toys

Of the Future

Ease of Use

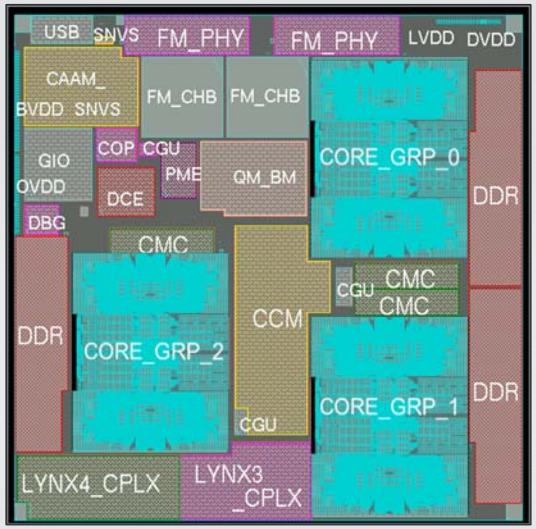
Semiconductor Evolution

1955



- 1 Transistor
- Replace 20 parts
- Greater reliability
- Reduce battery drain

2014



- ~ 2-3B transistors
  - control, dataplane, and services processing for SDN networks
  - 12 e6500 64-bit dual-threaded 1.8GHz cores
  - DPAA, PME, & DCE accelerators

2035

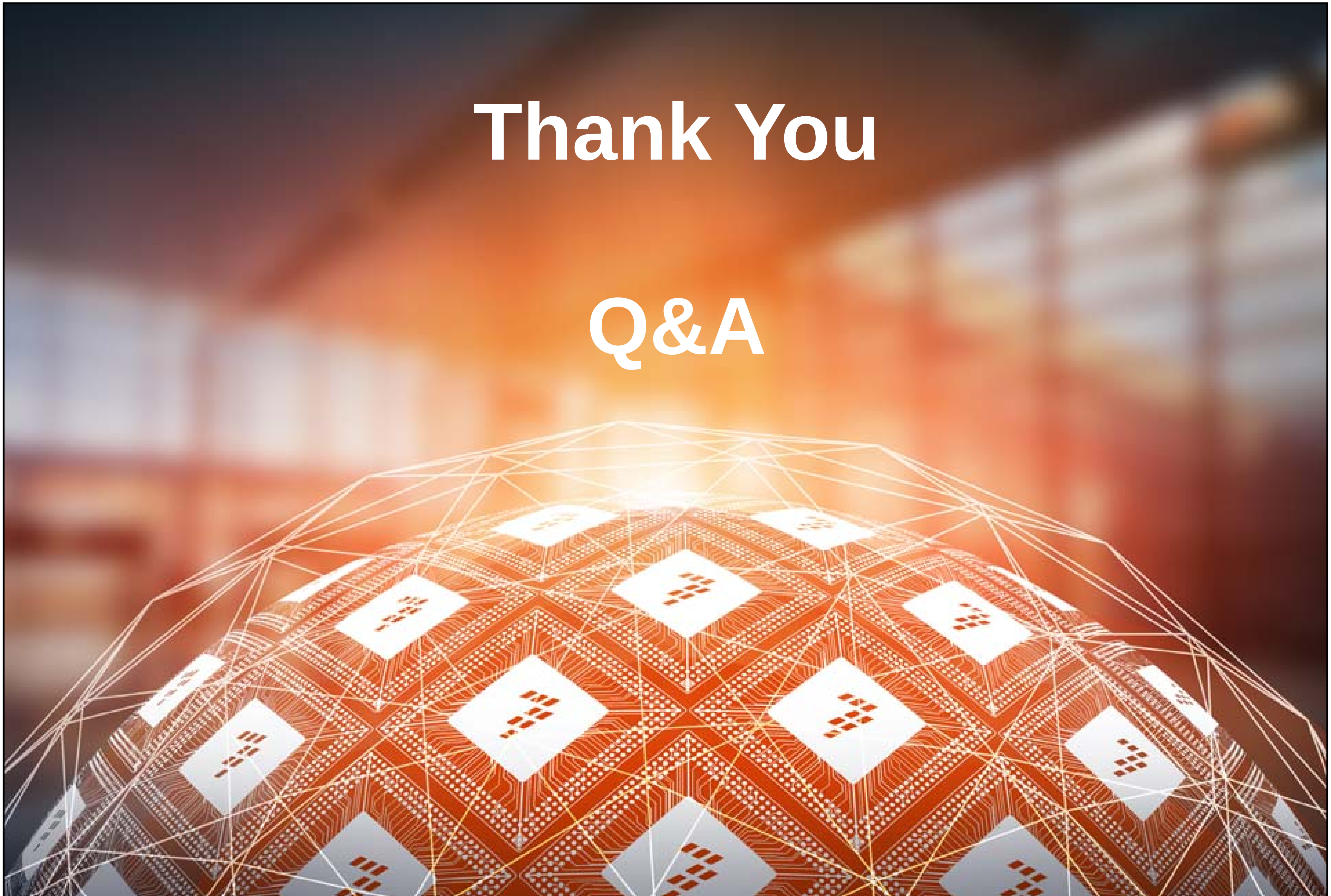
- ~1000B transistors
- Disciplined Imagination

"The vast stretches of the unknown and the unanswered and the unfinished still far outstrip our collective comprehension."

John F. Kennedy
Rice University
September 12, 1962

Thank You

Q&A



www.Freescale.com