CPS and IoT Foundations Panel
2016 NSF CPS PI Meeting

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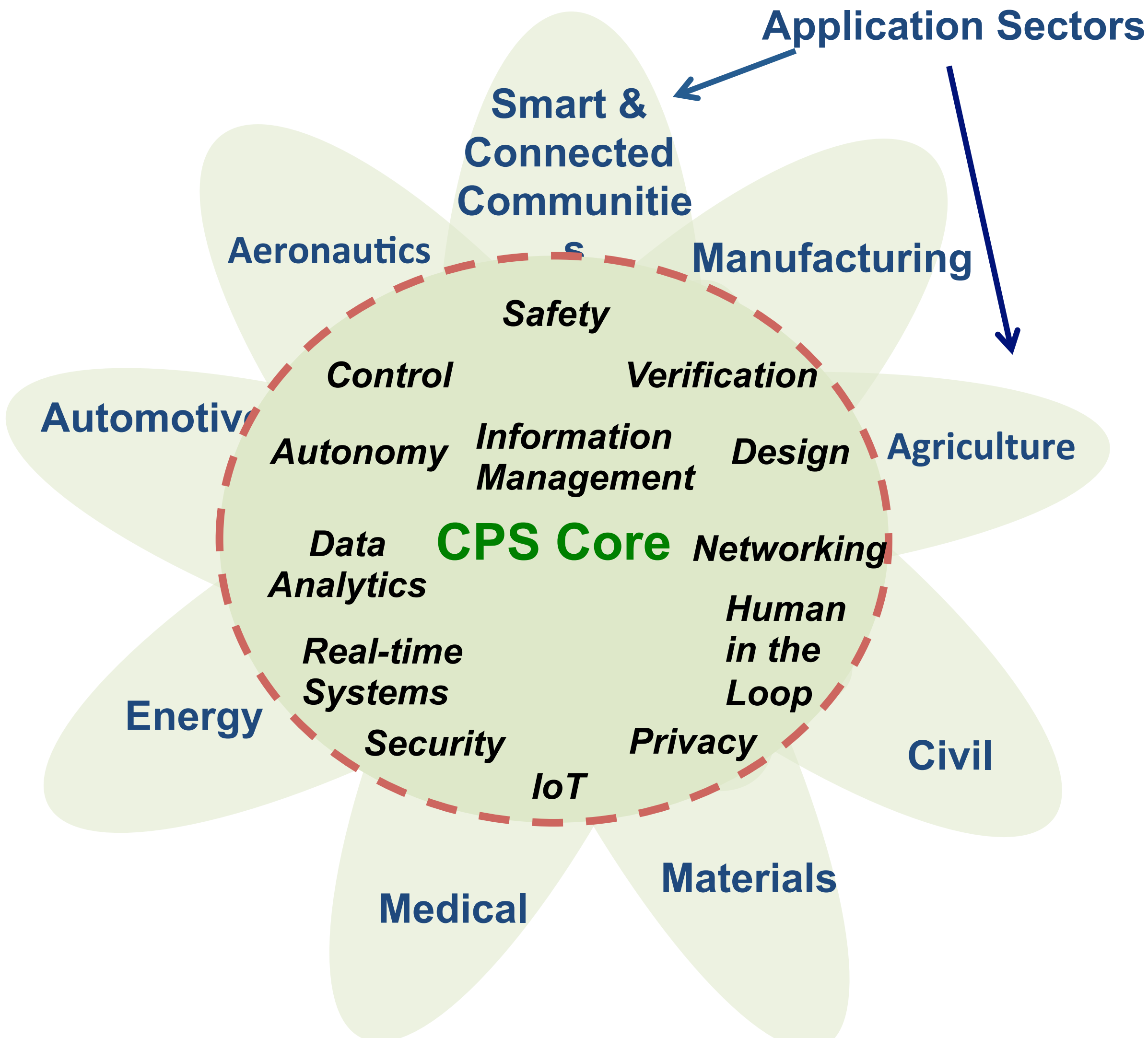
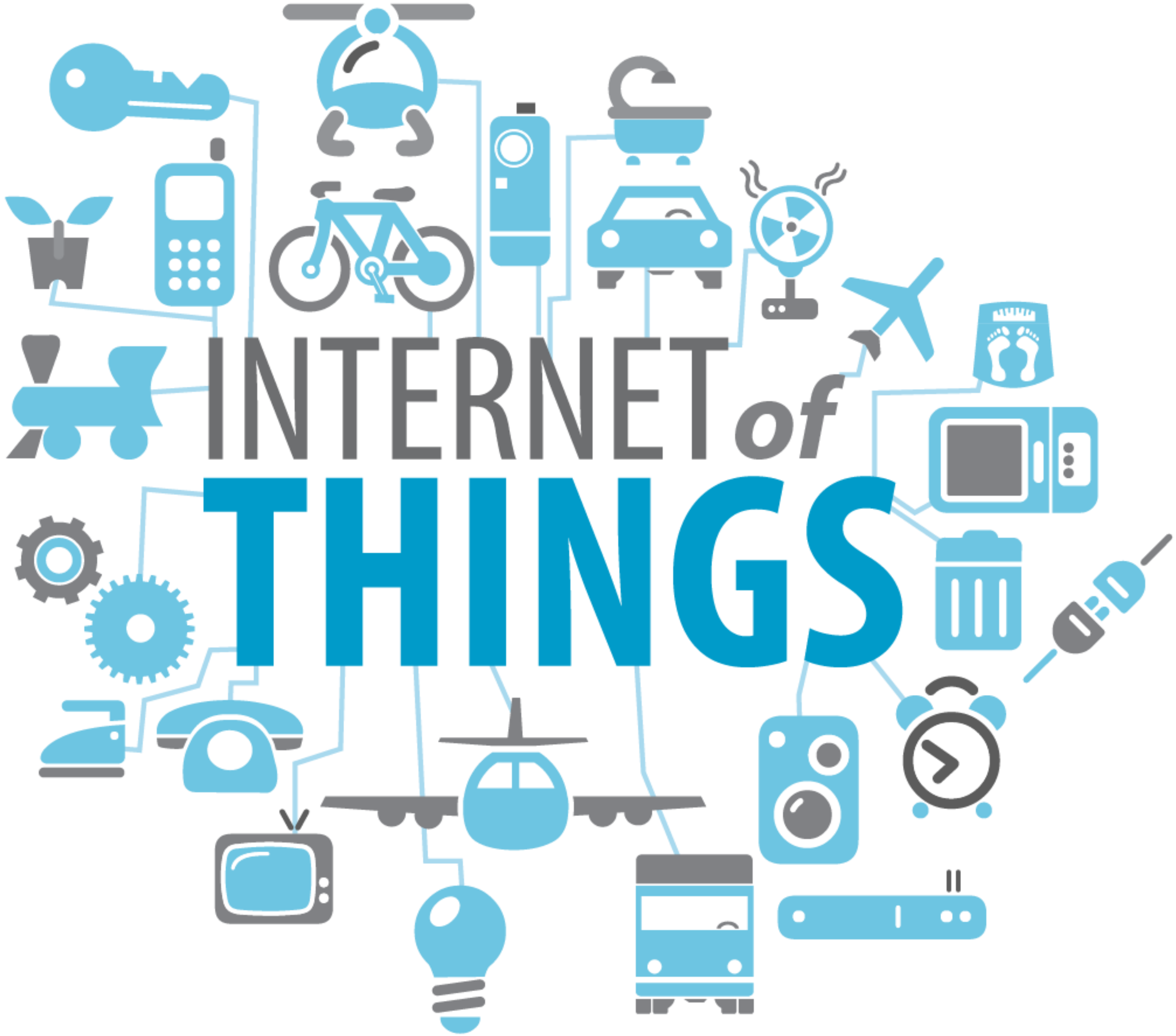
Cyber-physical systems



Internet of Things (IoT)

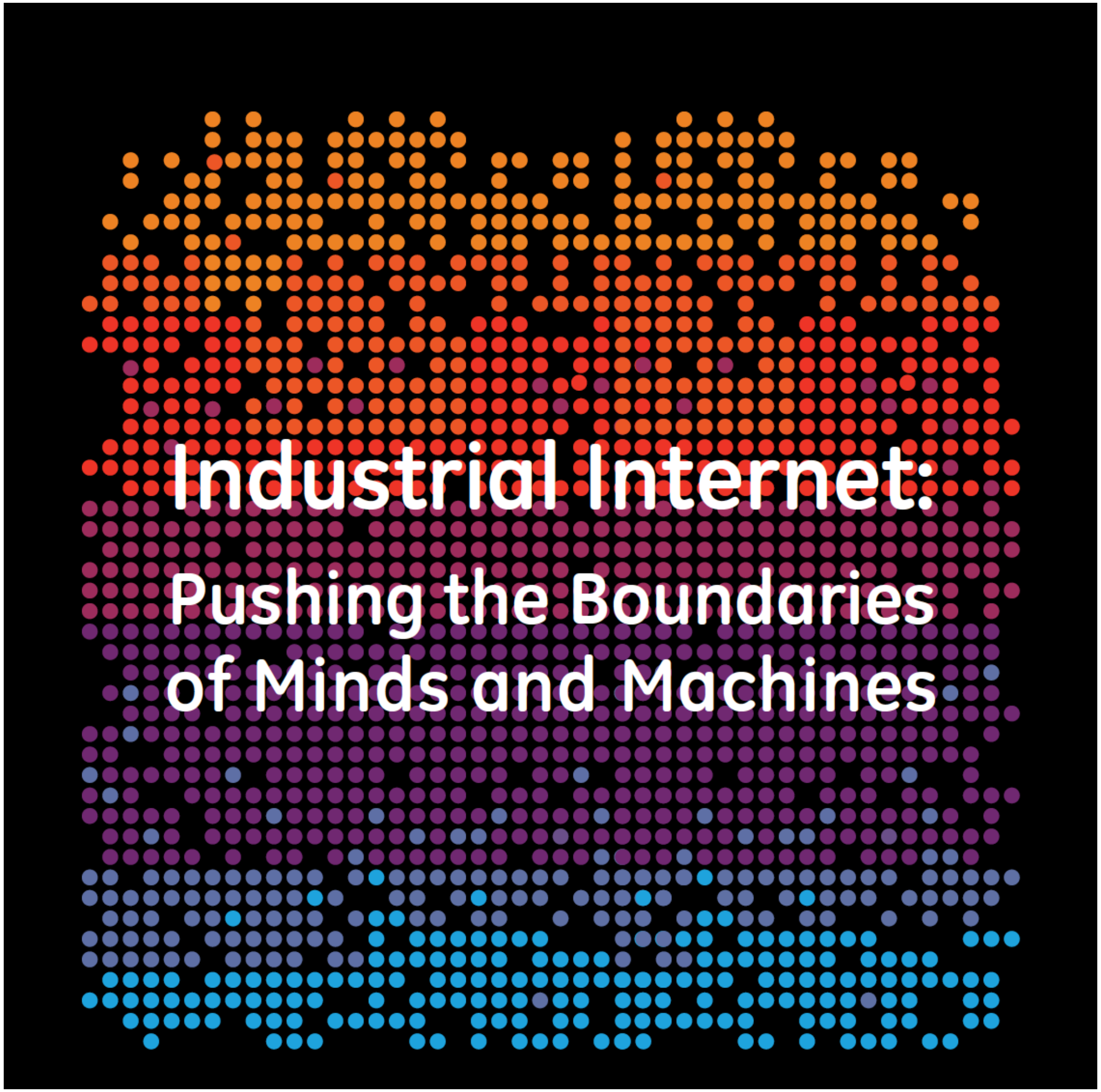


The trillion sensor challenge

- 5 Billion people to be connected by 2015 (Source: NSN)
- 7 trillion wireless devices serving 7 billion people in 2017 (Source: WWRF)
  - 1000 wireless devices per person?

[Courtesy: Niko Kiukkonen, Nokia]

General Electric's Industrial Internet



General Electric's Industrial Internet

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1 Intelligent Machines

Connect the world's machines, facilities, fleets and networks with advanced sensors, controls and software applications

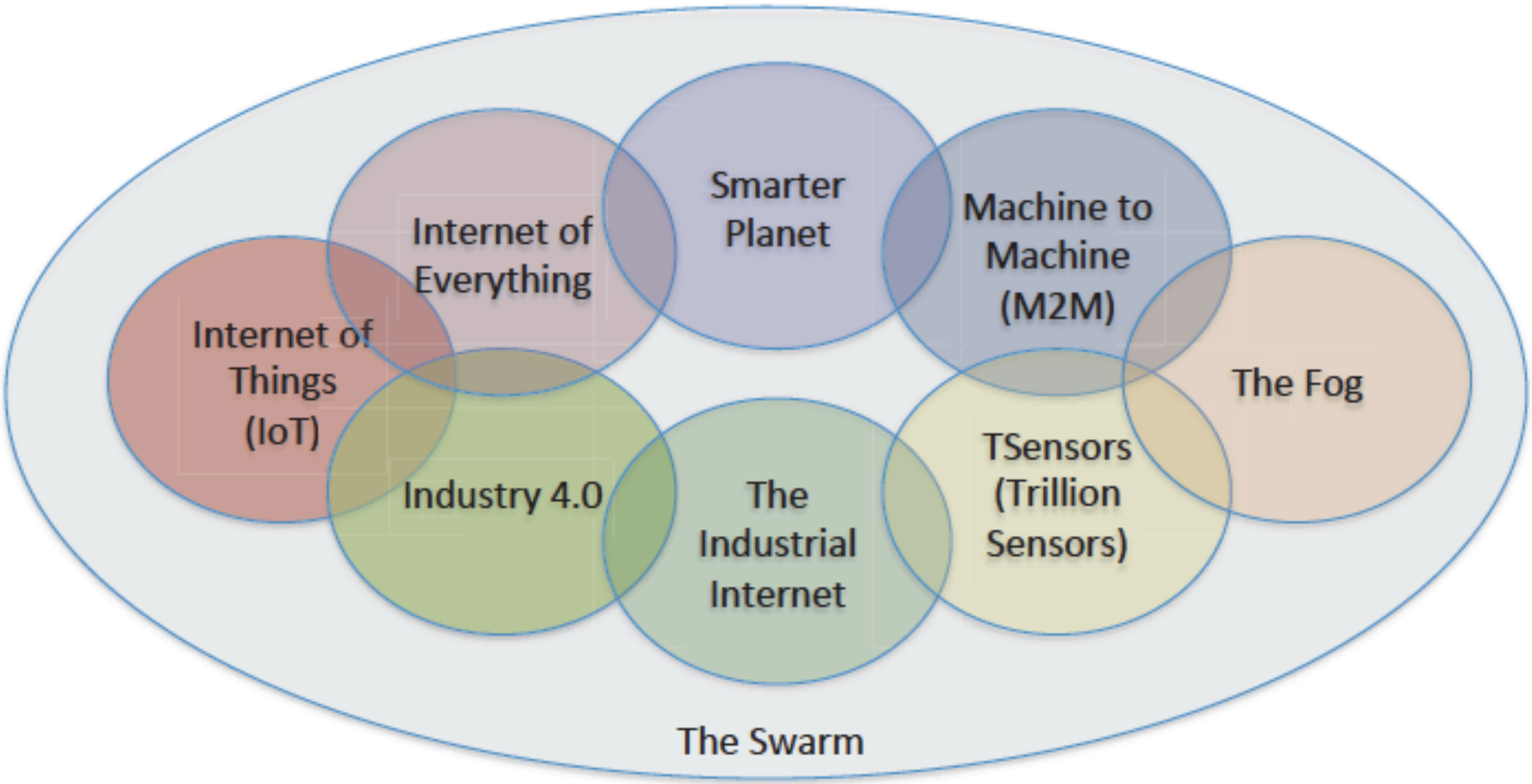
2 Advanced Analytics

Combines the power of physics-based analytics, predictive algorithms, automation and deep domain expertise

3 People at Work

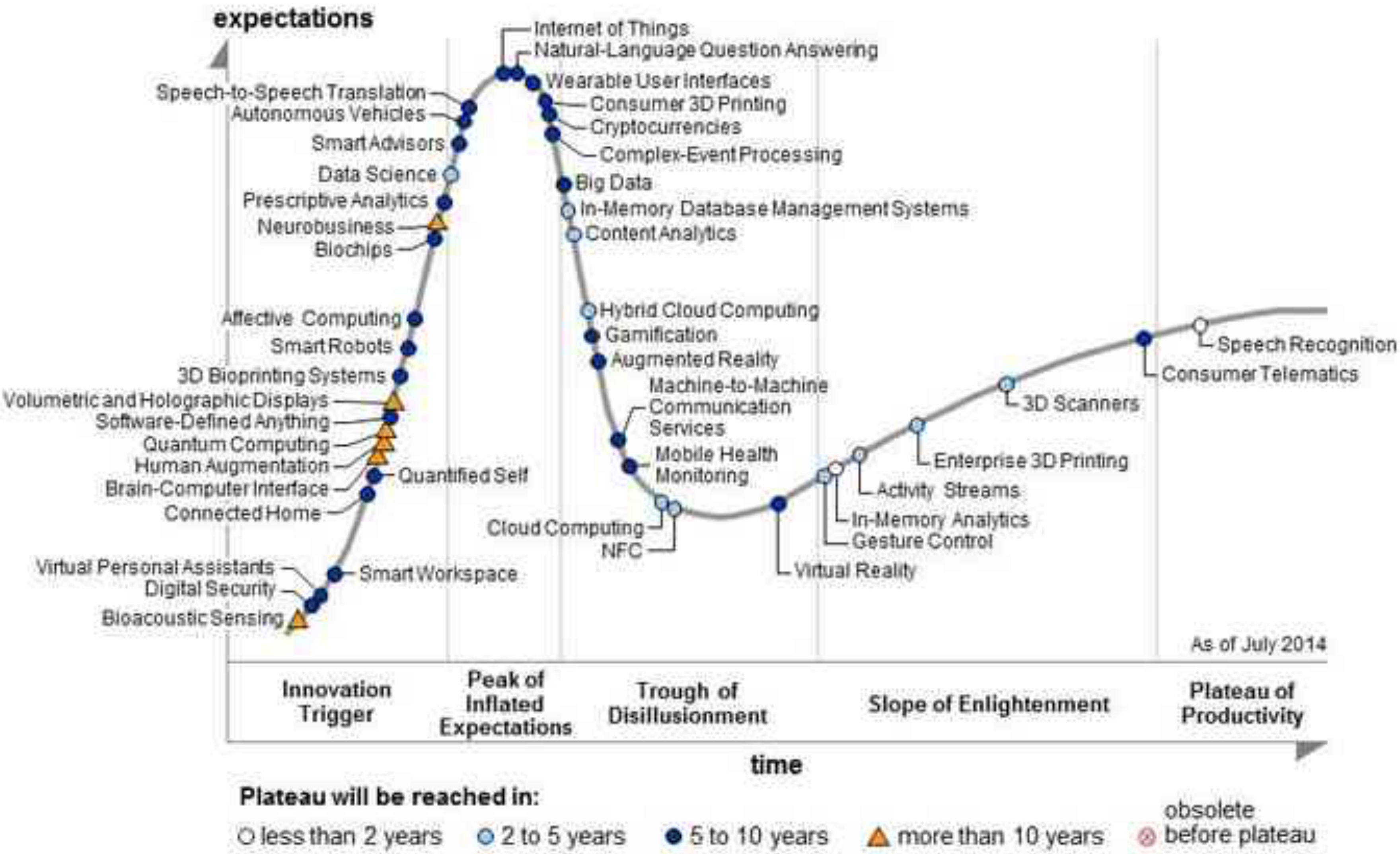
Connecting people at work or on the move, any time to support more intelligent design, operations, maintenance and higher service quality and safety

Industrial buzz



Cisco report: IoT creates $14.4T value at stake until 2022

Gartner Hype Cycle



What it is:

The TerraSwarm Research Center is addressing the huge potential (and associated risks) of pervasive integration of smart, networked sensors and actuators into our connected world.

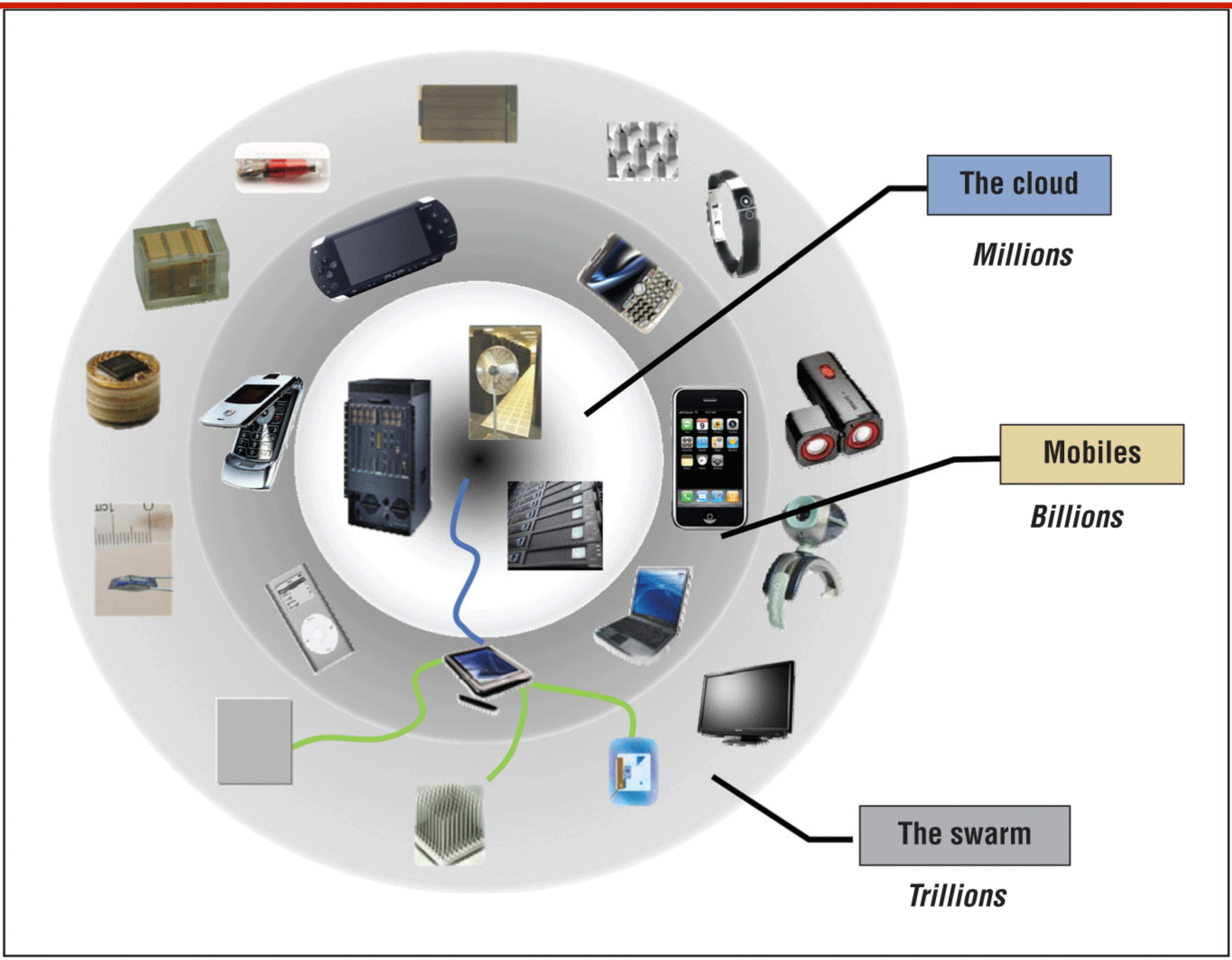
The Goal

To lead the world in development of the platforms, methodologies, and tools that enable invention of creative, secure, and sound applications using networked sensors and actuators.

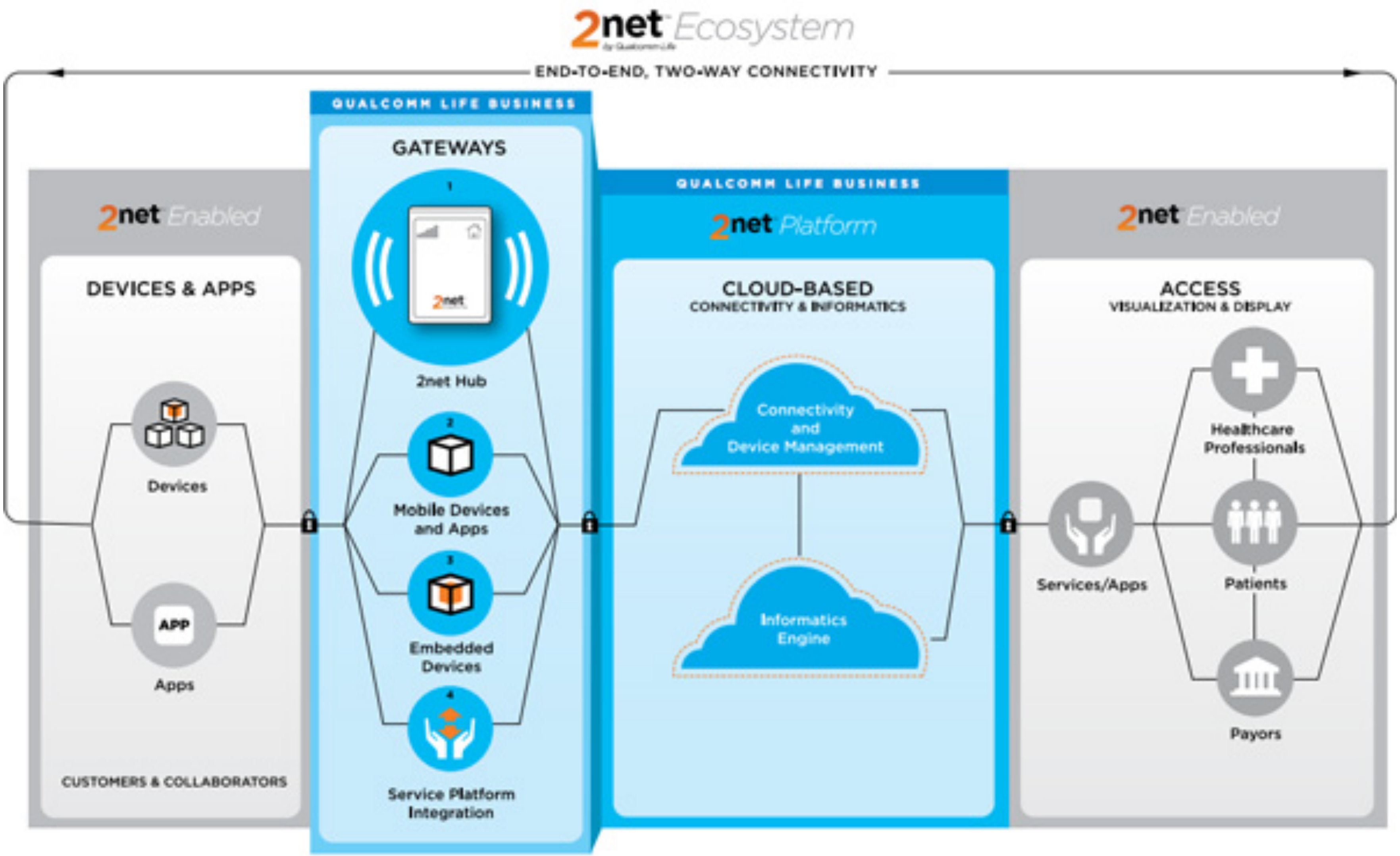
The Sponsors:

DARPA, GlobalFoundries, IBM, Intel, Micron, Raytheon, Texas Instruments, United Technologies

Emerging IoT architecture



Qualcomm Life



Research Challenges – Device level

Low power energy management, novel sensors

Connect to circuits people, MEMS, sensors

Energy-aware estimation and control

Use energy wisely as needed, energy harvesting

Hardware security and privacy at device level

Energy impact of security, cost of security

Machine learning with safety at device level

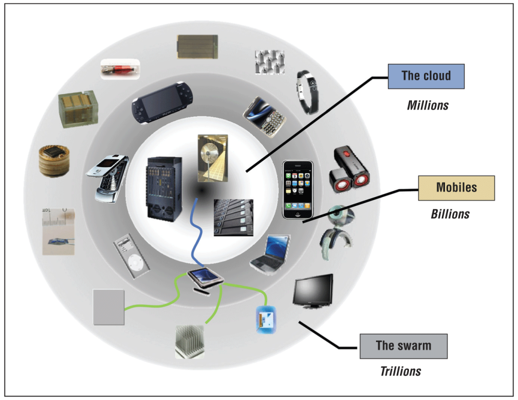
Safe learning, learning for safety

Blending learning with formal methods

Prove correctness in unknown environments/models

Safety of autonomous systems

Safe deep learning? Explainable?



Research Challenges –Connectivity level

Edge (fog) computing

Balance of local computing to cloud computing

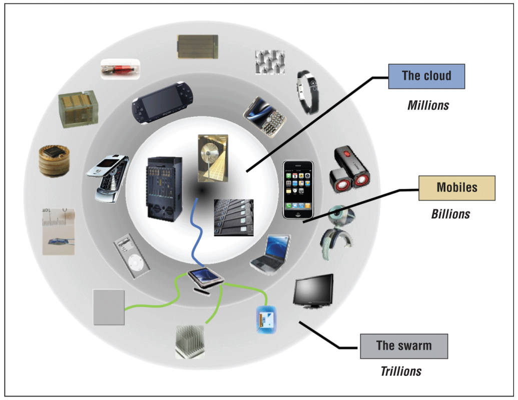
Bandwidth for seven trillion devices

Opportunistic, adaptive, reconfigurable connectivity

Discover and exploit services, time synchronization

Distributed control, estimation, learning over large networks

Connect to network science, cross-cutting



Network security and privacy

Resilient networks, secrecy, etc

Programmable cross-device abstraction model

What is the operating system? TCP/IP?

Programming across heterogeneous devices/robots

Research Challenges –Connectivity level

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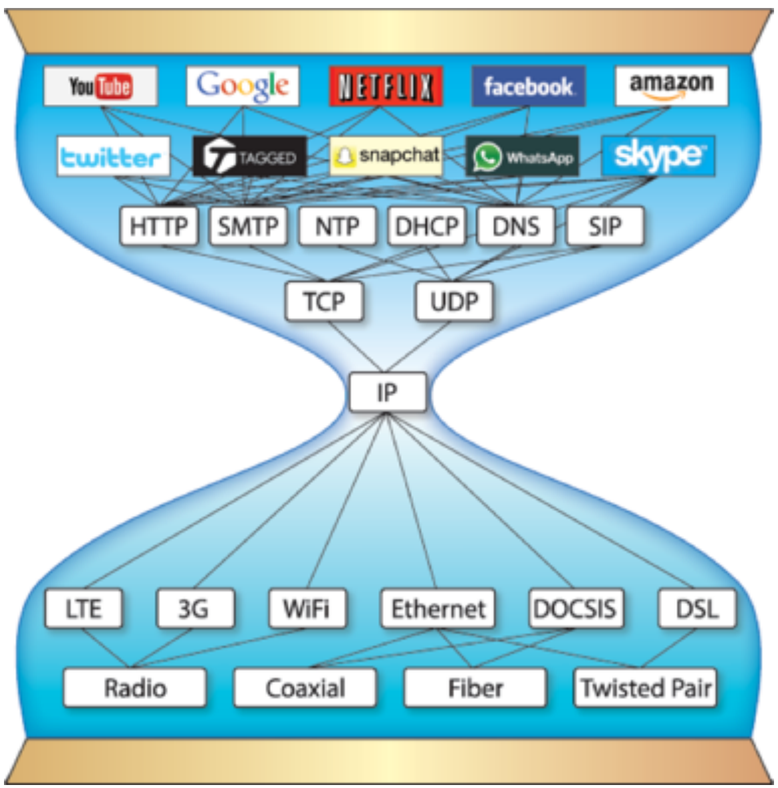
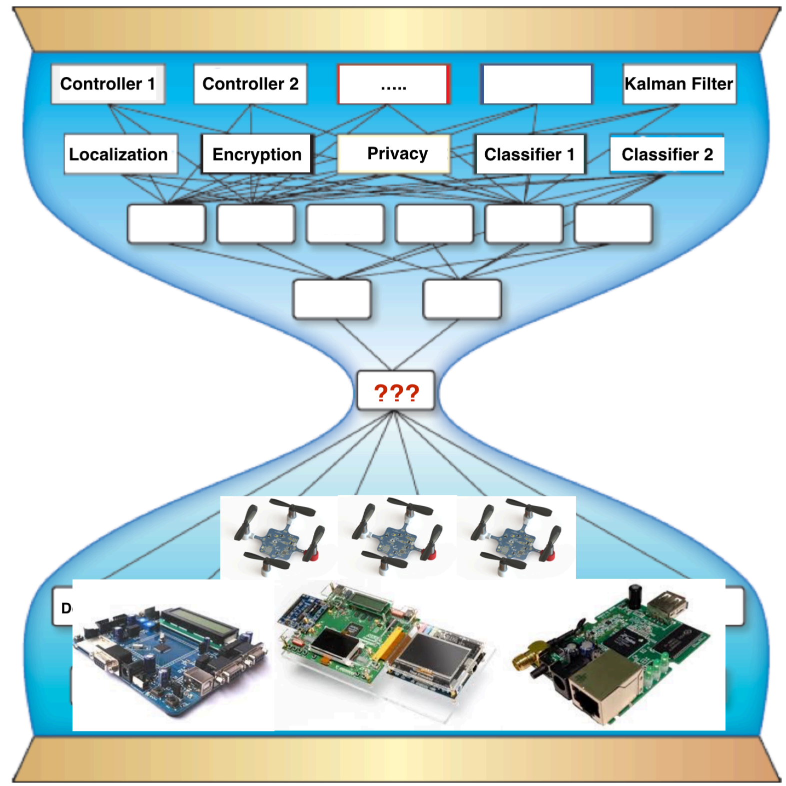




Research Challenges –Cloud level

Physical data

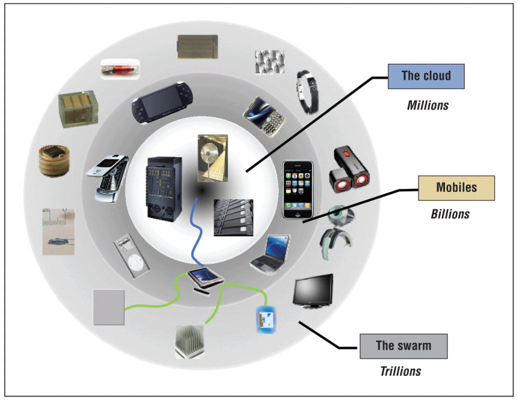
Big, real time, dynamic (space and time) but physical

Data driven learning/optimization/control

Not enough time to create accurate models, active learning

Scale & scaling laws

Linear operations are slow, sublinear operations



Data to information

We are interested in functions of the data

Security and privacy in the cloud

Differential privacy, homomorphic encryption, trusted cloud

Dependable Cloud with real time guarantees

Not necessarily for fast closed loop control, but for monitoring

Research Challenges – Cross cutting challenges

IoT Architecture

- Distribution of computation, control, learning, security
- Cross cutting design methodology (cloud/edge/device)

Models & Abstractions

- Heterogeneous System of Systems, models of computation for IoT
- Dynamic composition of device services (sensing/control)

Rigorous design and analysis tools

- Formal methods for the IoT engineer, specification languages

Security and privacy

- Holistic co-design across layers, trust management

Human interactions

- Human sensors, interactions with a swarm of robots, information overload

Educational Challenges – IoT curriculum

How do we educate the 21st century IoT engineer?

Devices :	Low power circuits, sensing & actuator, embedded systems, control systems, real time computing, robotics, signal processing, formal methods, heterogeneous systems
Connectivity:	Sensor networks, real time networks, software defined networks, network security, distributed systems, network science, information theory, 5G wireless
Cloud:	Data science, machine learning, optimization, data-driven control, privacy, algorithms, cloud computing, cloud security
Electives:	Application domains