IoT: The Convergence of Information Technologies and Operations Technologies

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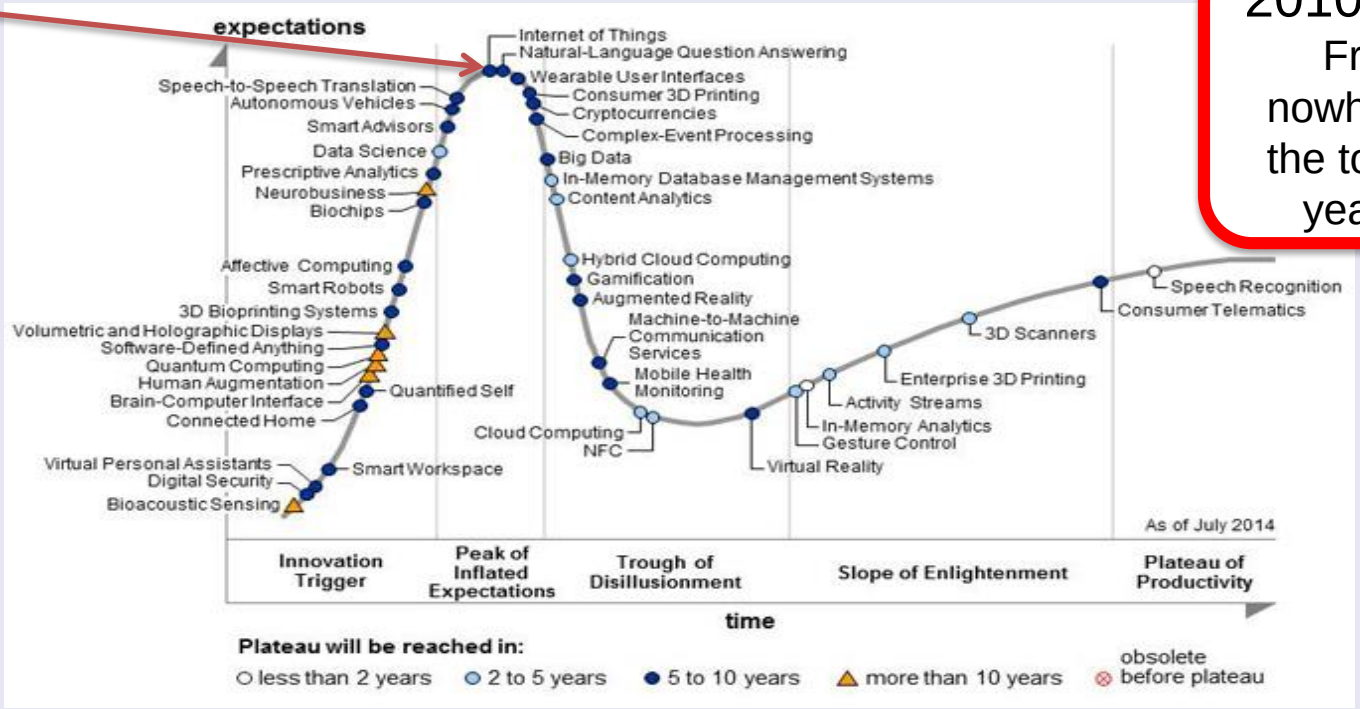
Agenda

- High Level Thoughts on IoT
- IoT : The Convergence of IT and OT
- Key IoT Technologies :
  - Communications
  - Distributed Computing and “Fog Computing”
  - Security and Privacy
  - Software!!!!
- Conclusions, in the Context of “Data on a Mission”

The IoT Hype Curve

- **IoT is at the Top of the Hype Curve**

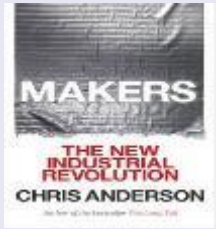


2010-2014
From nowhere to the top in 4 years!!!

The Internet of Things Key Challenge:

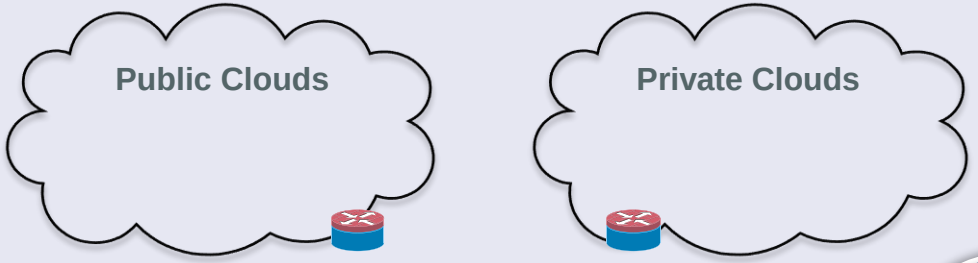
Meeting of Different Cultures, Generations, Worlds, and Models of Investment, Development and Commercialization

Different Requirements and Technologies !

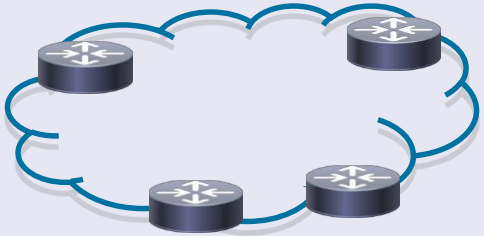


The IoT Infrastructure

The IT Infrastructure Evolving Towards IoT



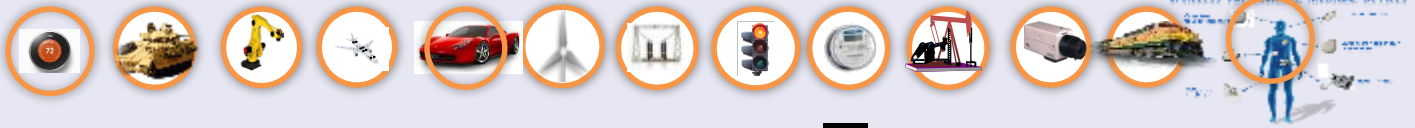
Public and Private Communications Infrastructure (Internet, Enterprise Ethernet, WiFi)



Enterprise Data Centers

Traditional IT end-points

Machines, devices, sensors, actuators, things (OT Devices)



IoT Objective: The Virtuous Information Cycle
"Data on a Mission"

MEANINGFUL DATA GRAPHICALLY EXPRESSED

BIG DATA ANALYTICS

REMOTE AND CENTRALIZED DATA VISUALIZATION

Communications, Data Interoperability, and Data Analysis, are Critical through-out the Cycle

INDUSTRIAL DATA SYSTEMS

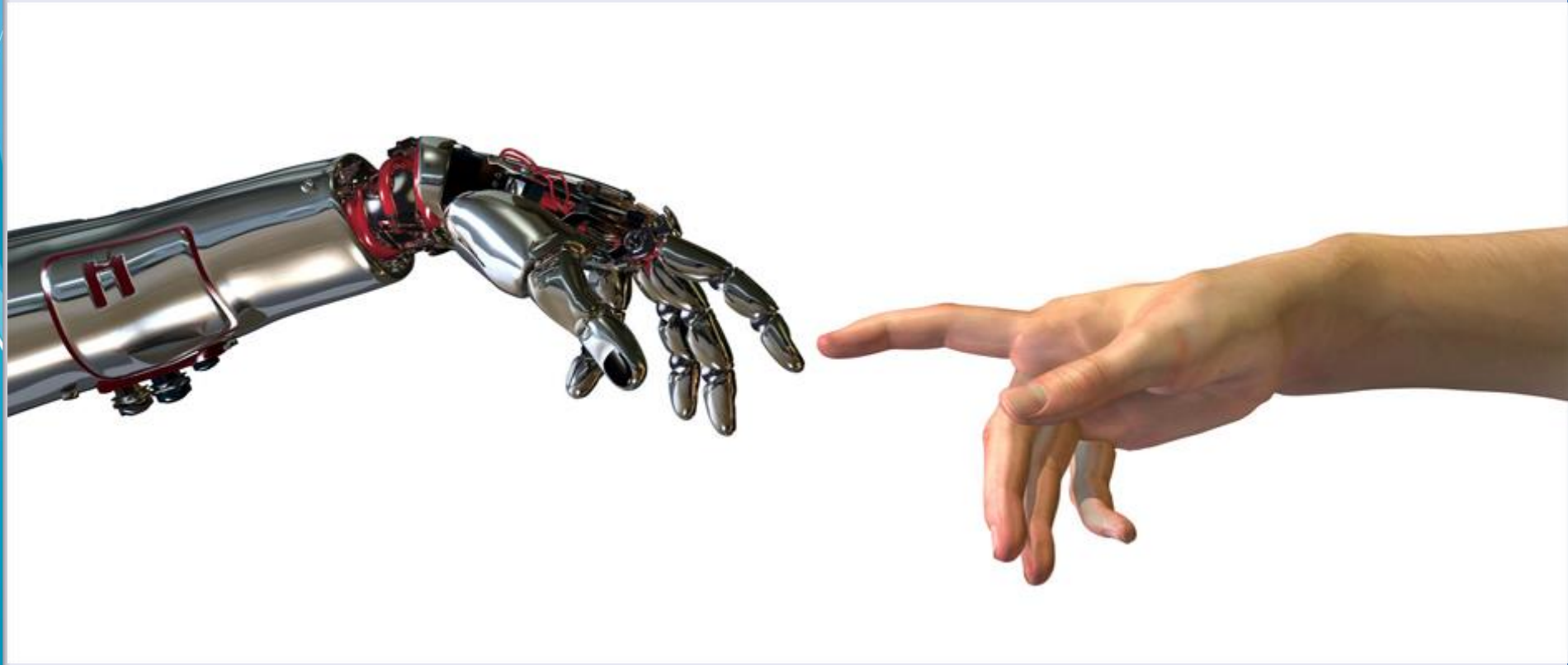
DECISIONS AND CONTROLS

INSTRUMENTED MACHINES, SENSORS AND HUMAN BEINGS

Courtesy of GE

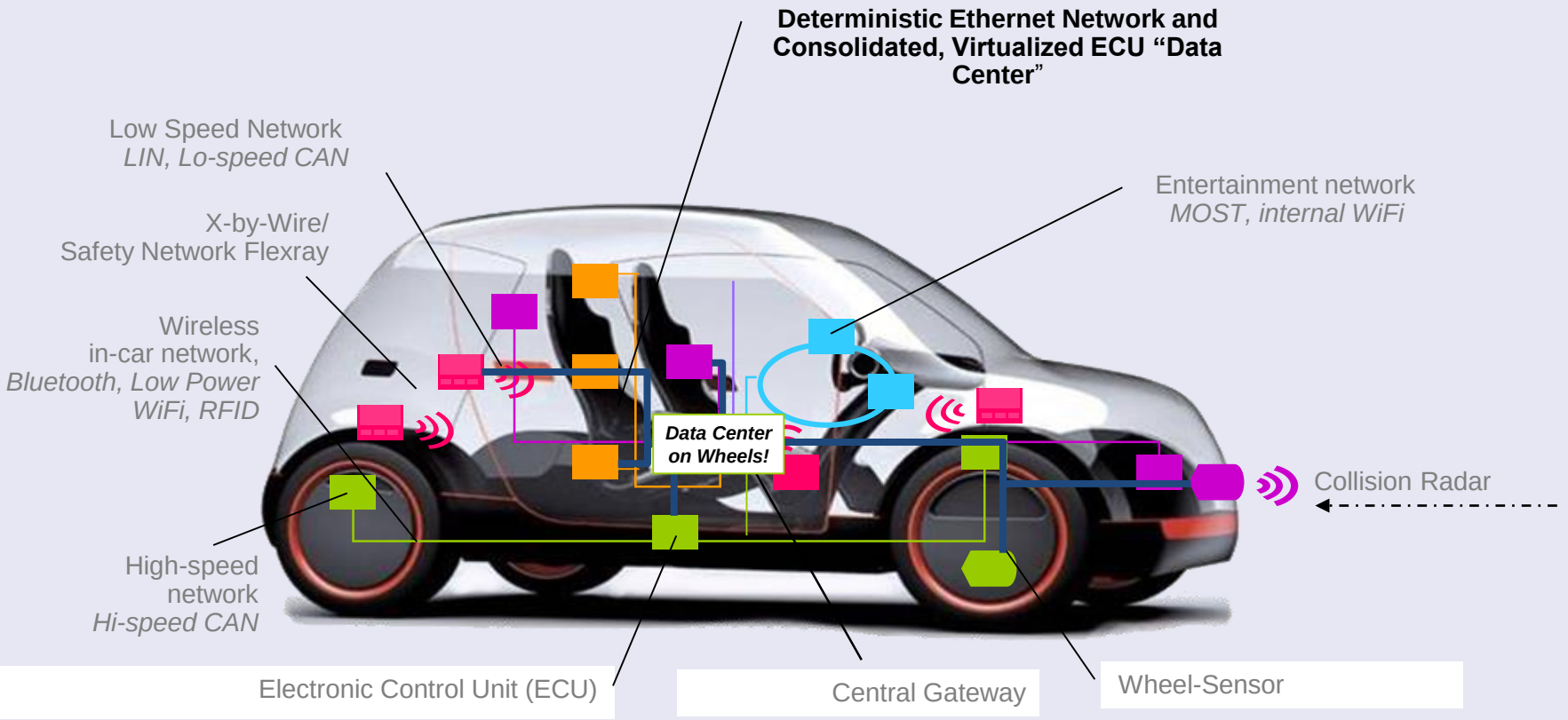
IT and OT Convergence: Industrial

IT and OT Convergence: Robot meets Human

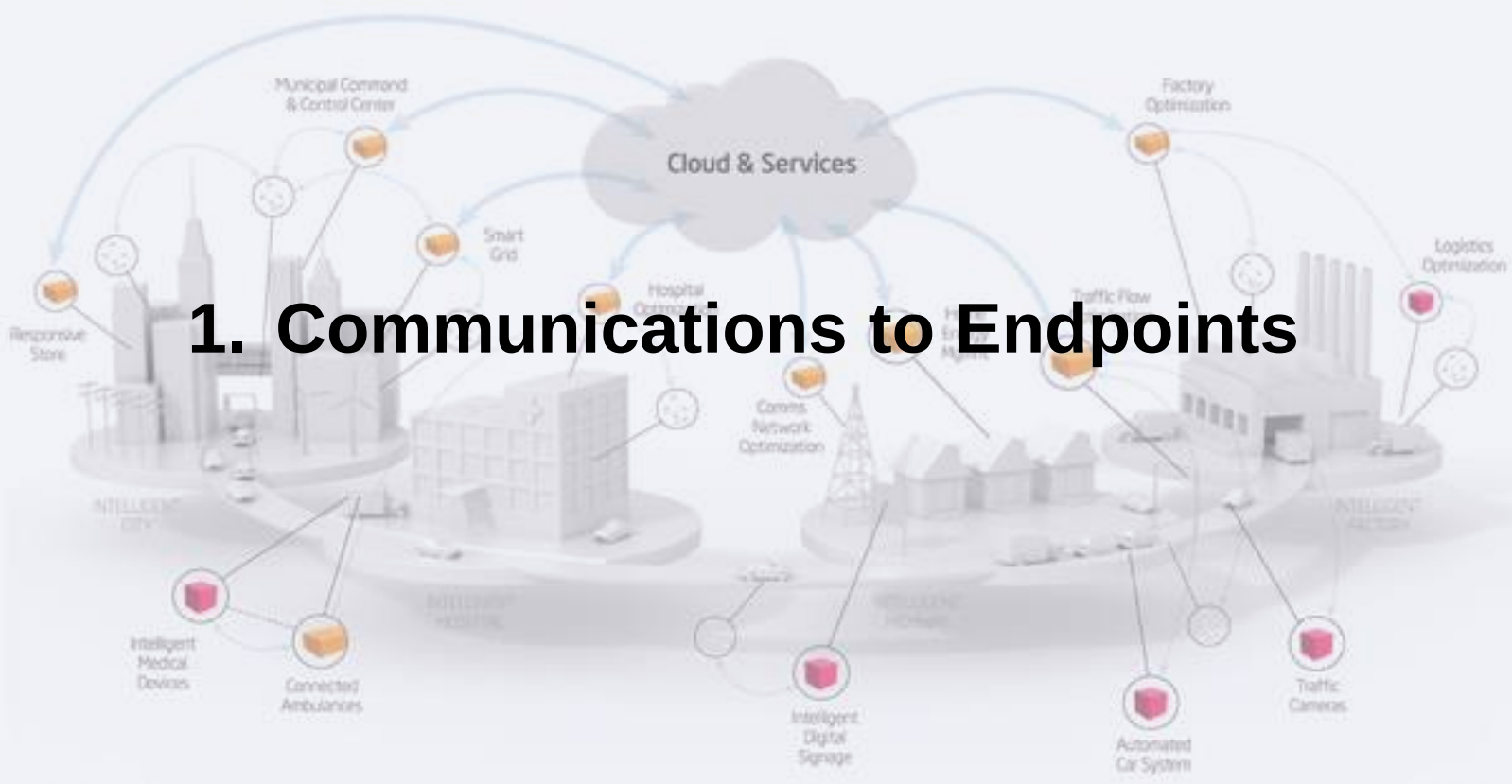


IT and OT Convergence: Transportation

IT and OT Convergence: Automobile Evolution



IT and OT Convergence: Key Technologies

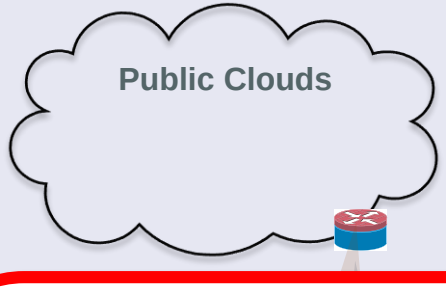


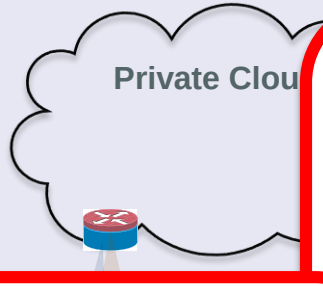
1. **Communications to Endpoints**

Evolving Communications and IoT

Wireless Technologies:

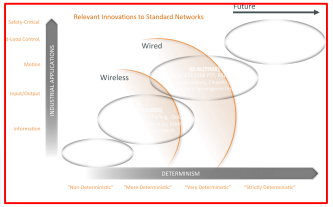
1. Bluetooth Low Energy (BLE)
2. LoRa (Low power, long range, low bandwidth)
3. IEEE 802.15.4 with 6TSCH
4. WiFi: Low Power, Deterministic, Vehicula (802.11.p)



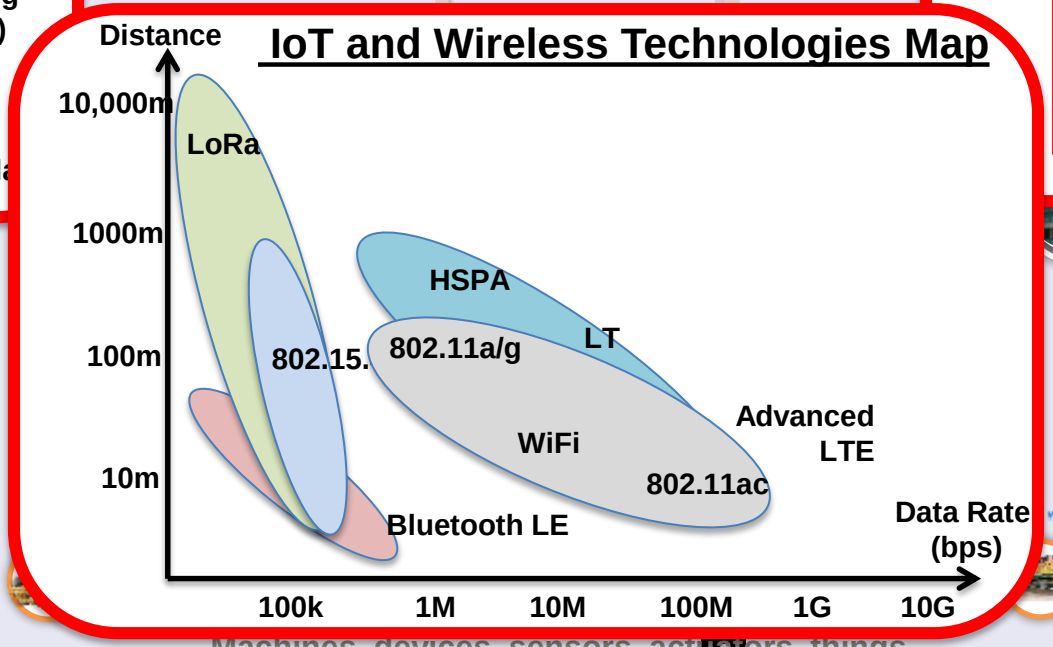


Wired Technologies:

1. Time Triggered Ethernet



Power Line Comm.



Data Center

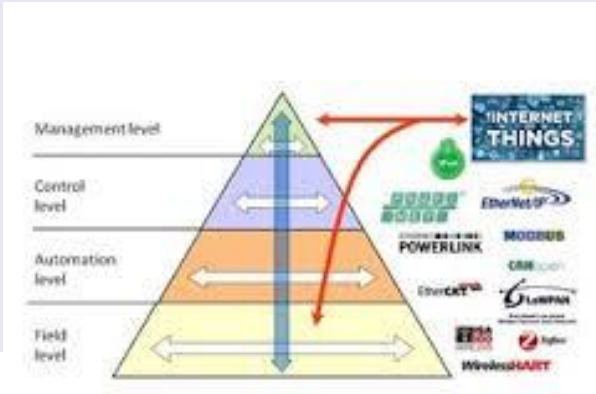
Machines, devices, sensors, actuators, things

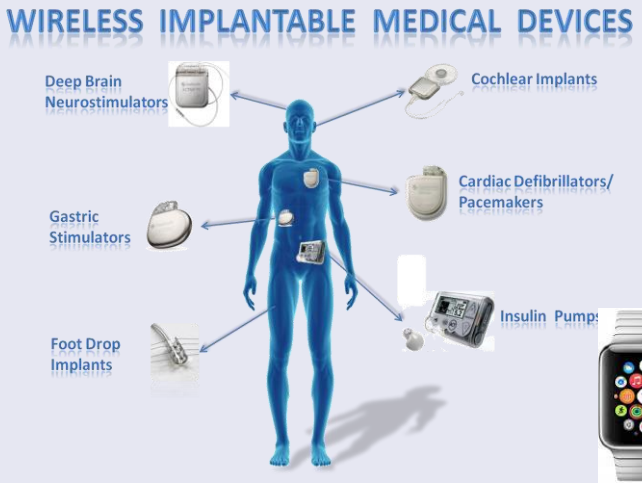
Evolving IoT Communications Technologies

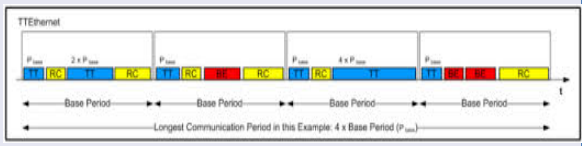
(Towards More Determinism)

Connectivity for IoT:

1. Bluetooth Low Energy (BLE)
2. Near Field (NFC)
3. LoRa (Low power, long range)
4. WiFi (also Deterministic, and V2V)
5. Cellular
6. Ethernet (Deterministic)
7. Over Power Line (PLC)



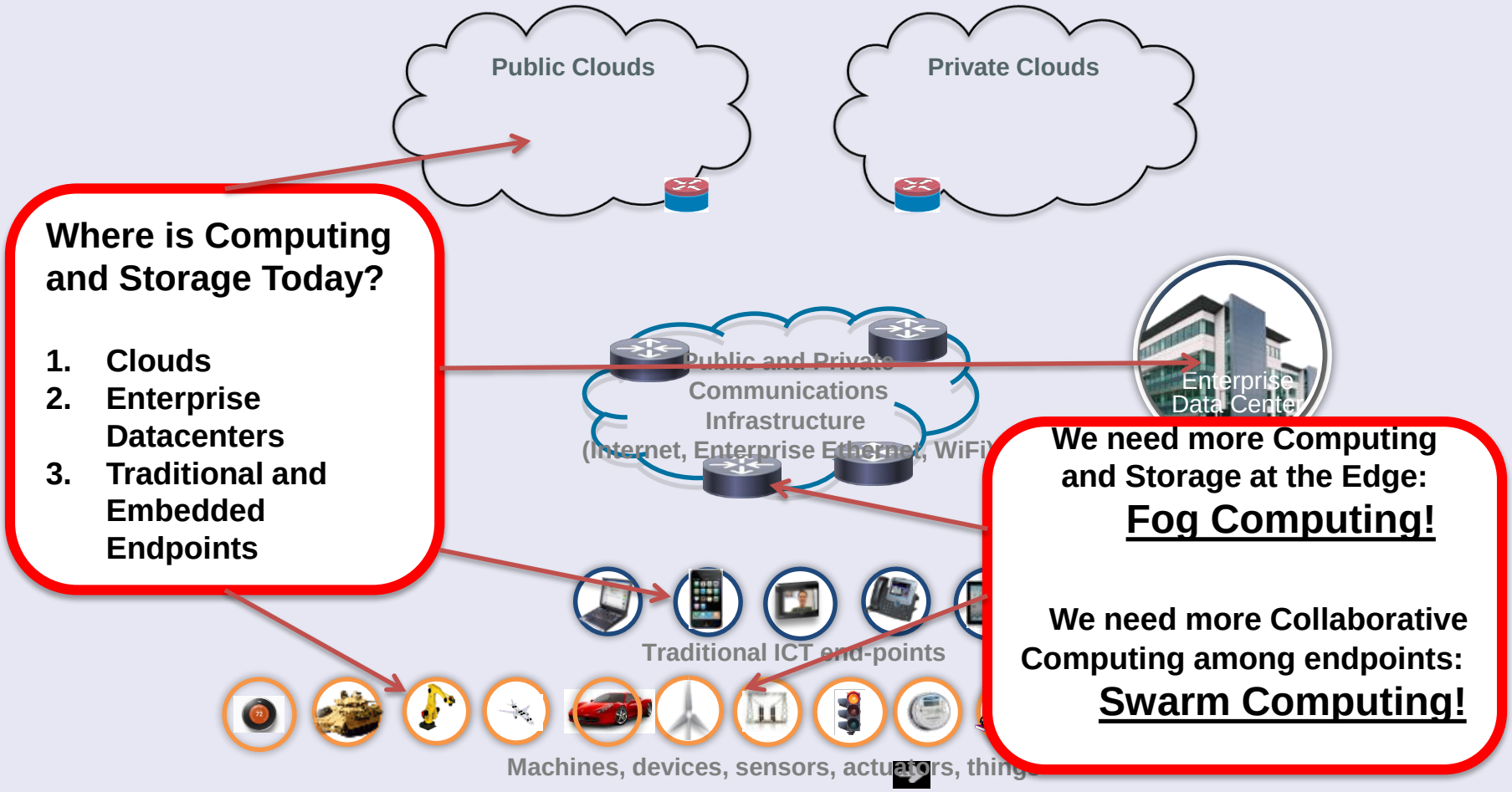




IT and OT Convergence: Key Technologies

2. Distributed Computing: and the Role of “Fog Computing”

The IoT Infrastructure and Fog Computing



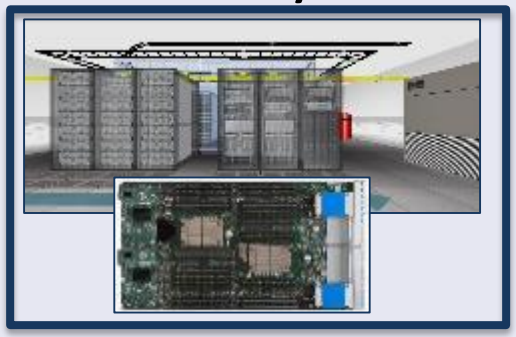
IoT: Networking, Computing and Storage Hierarchy

Fog Computing Key Motivations:

1. Real-time, local control
2. Communications “bridging”
3. Virtualization of all resources
4. Edge Data Management
5. Security and Privacy
6. Scalability
7. Edge application hosting
8. Reliability

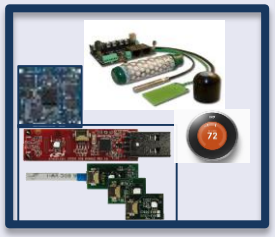
(Information Technologies)

IT



The meeting place of Internet, Cloud, (IT), and embedded world, (OT)

"The IoT Distributed Computer"



OT

(Operations Technologies)

Fog Computing Gaining Traction:

1. Industry and press acceptance
2. Academic acceptance

IoT: Distributed Applications over a Virtualized, Distributed Infrastructure

Integrated Intelligence and Collaboration

Application

Data Management

Communication

Distributed Application

Application

Data Management

Communication

Local Application

Application

Data Management

Communication

Sensing /actuating

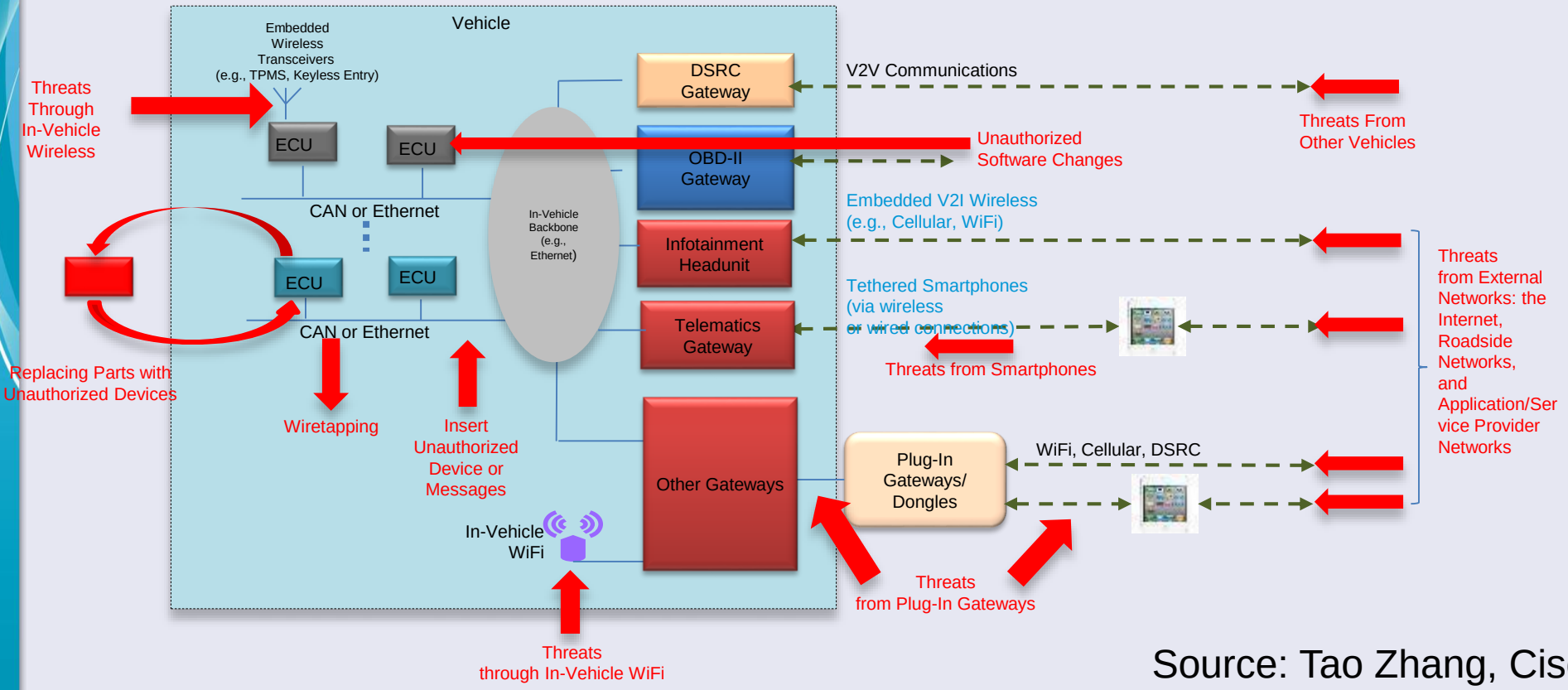
Dimension 1: where

Dimension 2: what

IT and OT Convergence: Key Technologies

3. Security and Privacy

IoT Security Example: Vehicles are Vulnerable to Security Attacks from Many Surfaces



Source: Tao Zhang, Cisc

This is Scary! What to Do ?

From T.S.Eliot, Four Quartets:

We need to "Fare Forward" rather than waiting to "Fare Well"….

- It will be an arms race. Start with what we have… Learn and borrow from Defense Industry
- Invest in Research and Innovation in Security
  - Progress on: Un-clonable devices, low power encryption, low power re-programmable devices, physical layer security
- Exploit the potential of Cloud and Fog Computing to support Security
- Prioritize threats, and trade carefully Security vs Efficiency and Utility
- Revisit SOFTWARE!!!!!!

CSRA
CYBER SECURITY
RESEARCH ALLIANCE

IoT and Security: Key Role of the Edge

Trusted Computing

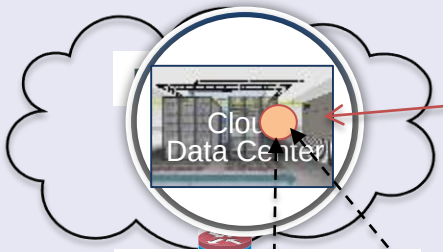
Full Virtualization

Security Analytics

Security proxy for lower layer

Higher layer traditional models of security

Traditional Certificate Authority



Long Distant, Expensive, intermittent, High Latency Higher Power, Mobile

Very resource expensive, often unavailable

Power/cost constrained Security Trust, Un-clonability

Routers, Gateways

Traditional ICT end-points

Local, Inexpensive, Intermittent, Low Latency, Low Power, Mobile

Machines, devices, sensors, actuators, things

IT and OT Convergence: Key Technologies

IoT: Software is Critical and yet Challenged!

IoT Software Challenges :

- Scale, Distribution, Real-time, Security and Safety
- Modularity, Automation, and Reusability
- Vertical Experts not Programmers !
- Languages Do Not Capture Behavior
- Software for a Complex, Interacting Ecosystem with Data at the Core

We May Need a Clean Slate Approach to Software Development!!

Clean Slate IoT Software: Cubicon

Purpose-Built Software Components for IoT Systems

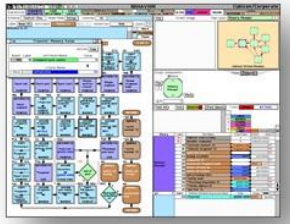
Sandy Klausner's gift:

- **85,000+ hours** - applied research
- **12,500+ frames** - animation (UI prototype)
- **6,000+ blueprints** - architectural specifications
- **1,200+ frames** - animation (technology primer)

Provenance

Graphical Programming Language

Integrated Development Environment



Cubicon
Create

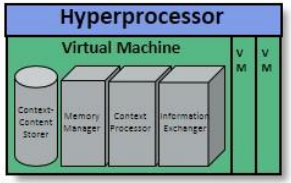
CubeID
Identify

CubeDesigner
Develop

CubeEngine
Execute

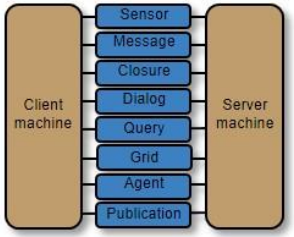
CubeProtocols
Transmit

Operating System



CubeWeb
Store, index, track, associate

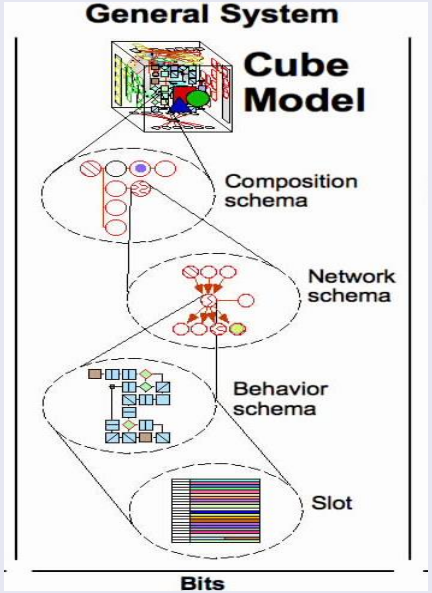
Internet Layer

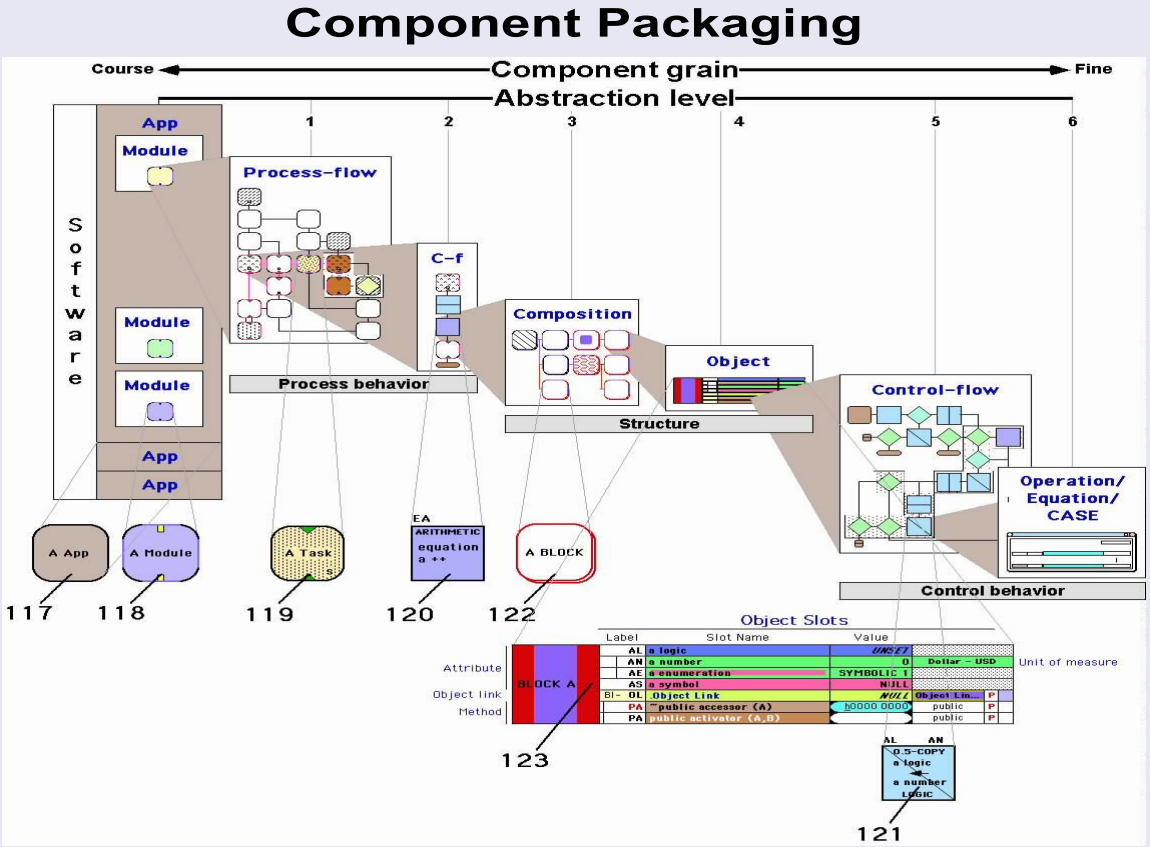


Protocols

Clean Slate IoT Software: Cubicon

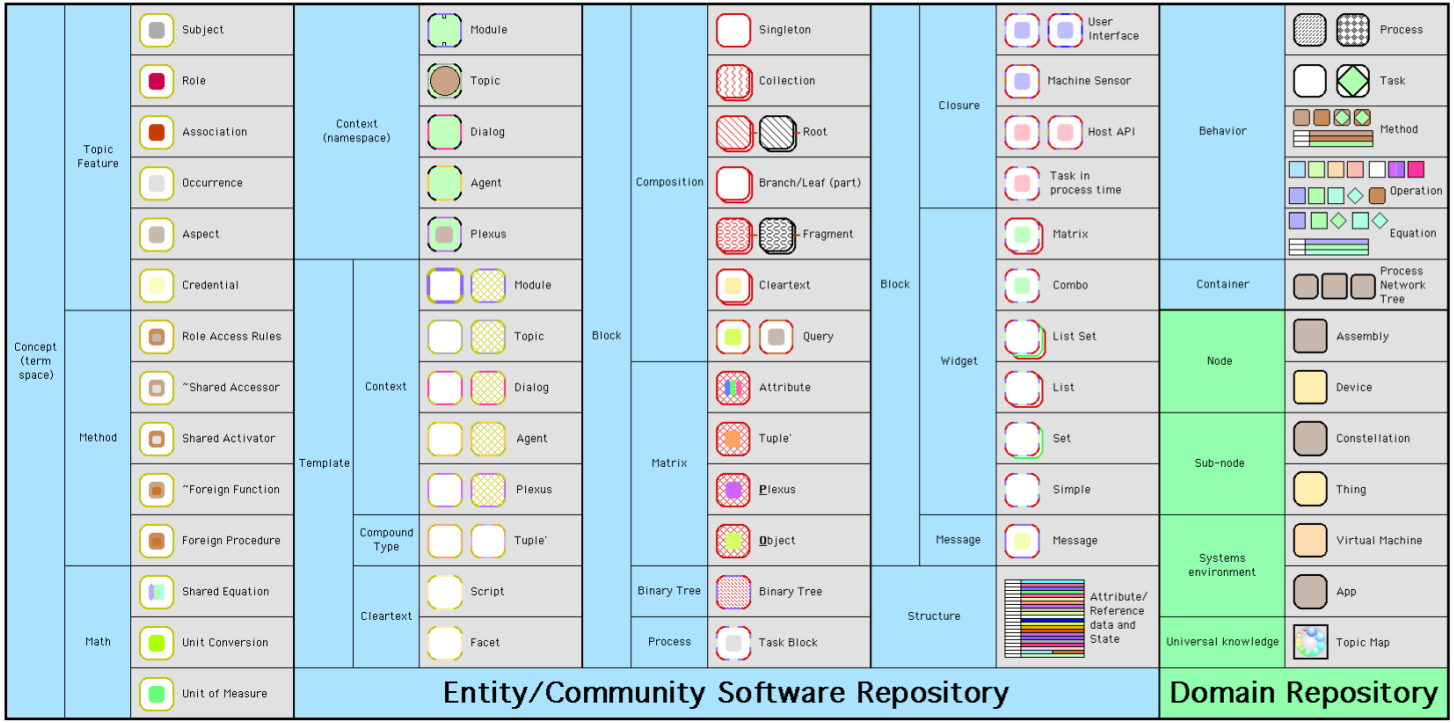
A Graphical, Multi-Perspective Approach to Computer Programming





Clean Slate IoT Software: Cubicon

64 Universal Computations Abstractions



Software component chart depicts
64 component types that recombine to form all Cubicon apps.

Conclusions

Data is Key!!!

MEANINGFUL DATA GRAPHICALLY EXPRESSED

BIG DATA ANALYTICS

REMOTE AND CENTRALIZED DATA VISUALIZATION

Communications, Data Interoperability, and Data Analysis, are Critical through-out the Cycle

INDUSTRIAL DATA SYSTEMS

DECISIONS AND CONTROLS

INSTRUMENTED MACHINES, SENSORS AND HUMAN BEINGS

Courtesy of GE

Data Needs Help to Accomplish its Mission!!!

- Data needs to be **extracted** efficiently, in motion, cheaply, securely
- Data needs to be **“objectified and contextualized”**, as soon as possible, needs to be **virtualized, securely stored, compressed, and analyzed hierarchically**.
- Data needs to be **moved, located, searched** efficiently, cheaply, securely, around the infrastructure
- Rich **Data awareness needs to be distributed from end-points to Clouds**

Data is Not the End of The Story!

- Data needs to be used to **Close the Control Loop!**
- Good Analysis leads to **Good Actions!**
- The Convergence of IT and OT needs to deliver more efficient, scalable, effective **Control of Systems**

FPGAs Have a Great Role to Play in IoT!

- **FPGA Technology can play a role in:**
  - **Supporting evolving standards in transport (e.g., Deterministic Ethernet (TSN)**
  - **Providing acceleration in data management and analytics (e.g., video analytics)**
  - **Acceleration in SDN applications at the Edge**
  - **Evolving security protocols**
  - **Storage evolving protocols**

- **FPGAs need to be made easier to program and more dynamic in their configuration**

- **FPGA main issue is COST!!!!!**