The Key to the Internet-of-Things: Conquering Complexity One Step at a Time

IoT Workshop at IEEE PHM2017
June 19, 2017

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IEEE Internet of Things

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June 19, 2017

The Key to the Internet of Things
The Evolution of the Connected World

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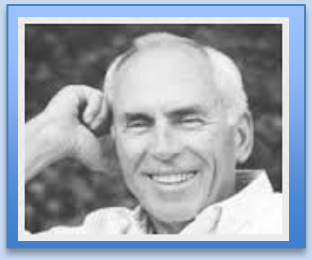
Outline

- *What is IoT?*
- *Where is IoT in its evolution?*
  - *A life Cycle View*
  - *Key ingredients*
  - *Dealing with Complexity*
- *What are the basic ingredients for IoT?*
- *Why are there so many Organizations working on IoT?*

  - Many many verticals and many differing requirements
  - Likely outcomes
  - The element of time
- *A few examples from the IoT front*

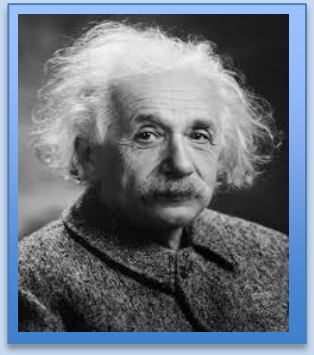
Where to Start?

Amara's Law: We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run.



Law of Parsimony (Occam's razor): "Entities must not be multiplied beyond necessity", "The simplest explanation is the best", "It is superfluous to suppose that what may be accounted for by a few principles has been produced by many."

A Corollary (Einstein's observation): "Everything should be made as simple as possible, but no simpler than necessary!"



What is IoT?

- The catch phrase “The Internet of Things” is a general term that evokes aspects of many ideas, made real in a multitude of forms, and that can bring value to a broad range of products, services, processes, and end use applications.
- What these have in common is:
  - Deep digitization – from analog to digital, mechanical to electronic,..
  - Use of an increasingly pervasive and globally accessible infrastructure
  - Connectivity ranging from local to global – approaching ubiquity
  - Long lived protocols and standards – preserving investment
  - Generation and gathering of “data” – from many sources in many forms
  - Exploitation of computing - analysis methods, algorithms, techniques
  - Progress in closing the “control loop” - automation by design

What is IoT?

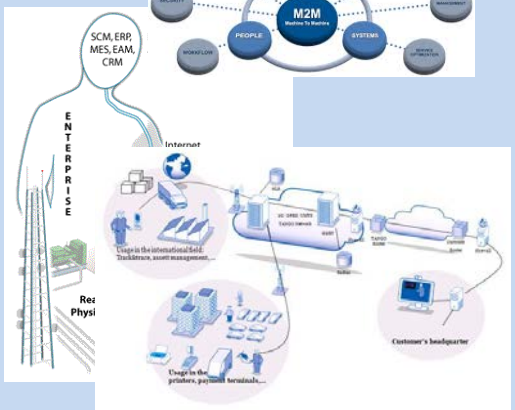
When talking about the “Internet of Things” you will often come across:

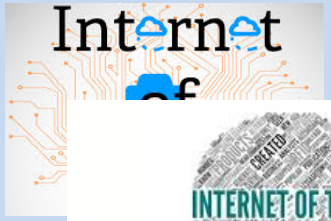
- Cyber-Physical Systems
- M2M – Machine to Machine Communications
- The Internet of Everything
- The Internet of Things
- The Industrial Internet
- Industry 4.0
- The Network of Things
- The Connected World
- The Networked World

And many similar “terms” that describe how applications and solutions, can be constructed to deliver specific functionality from common components, processes, techniques, and infrastructure and that rely on digitization, connectivity, computation, and decisions to create an outcome.

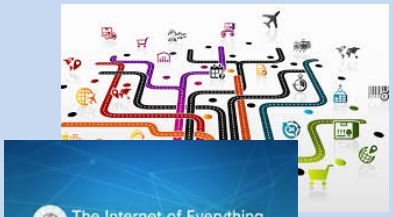
What is IoT?

M2M Communications
Common Carrier Network
Protocols for “Things”





The Internet of Everything
Things • Processes •People



The Internet of Things
The Catchall – Applications at the Core

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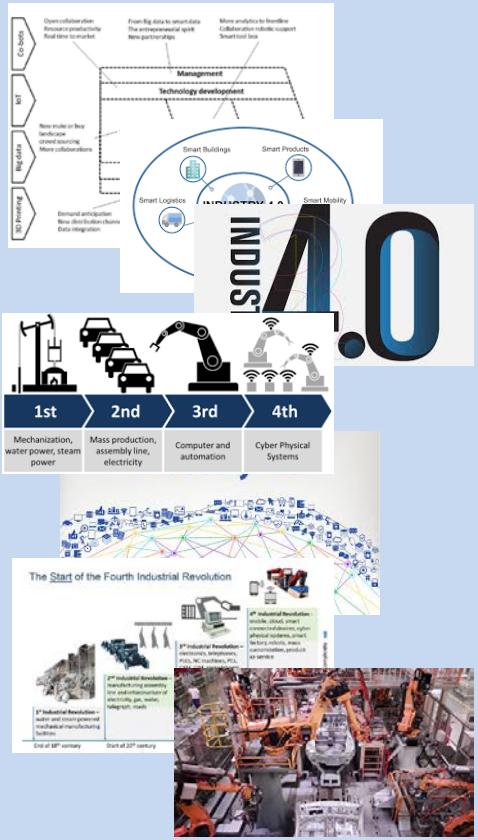
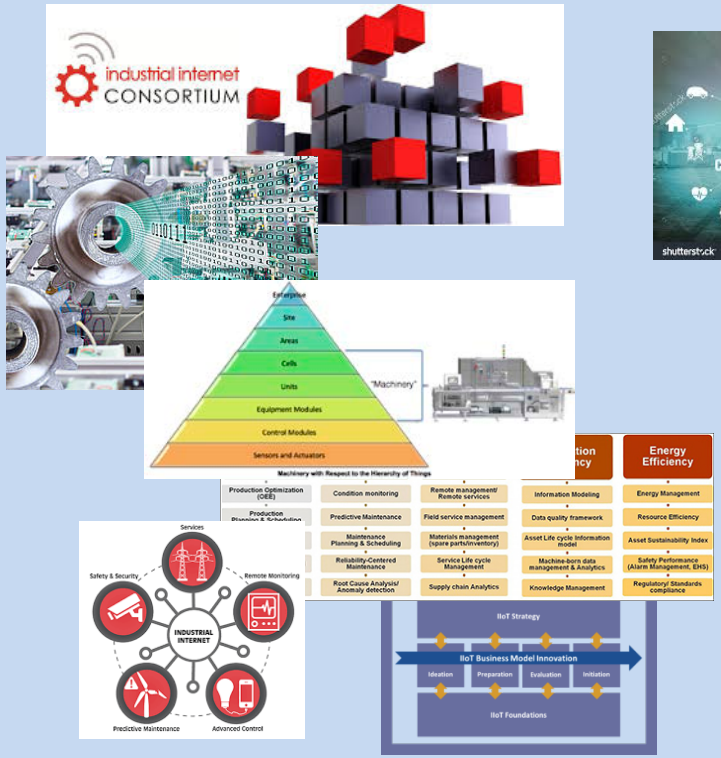
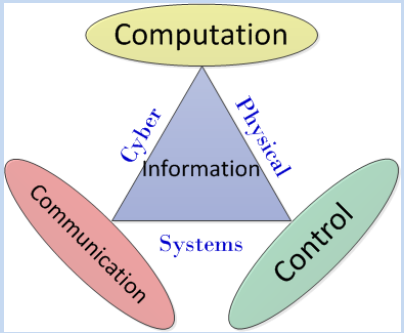
What is IoT?

Industry 4.0 –Life Cycle Framework



Cyber Physical Systems – Digitized Design





Industrial Internet – Operational Efficiency

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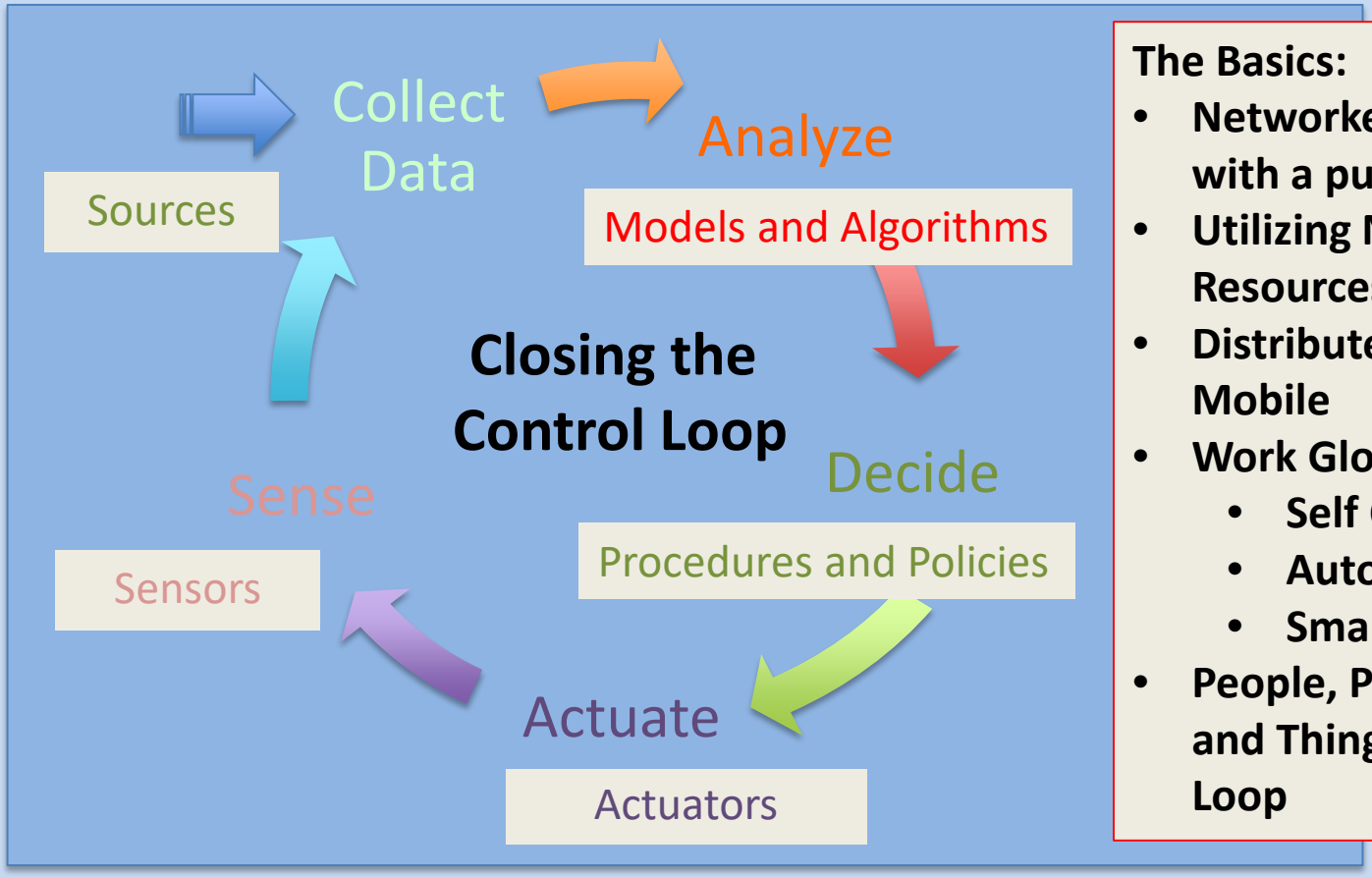
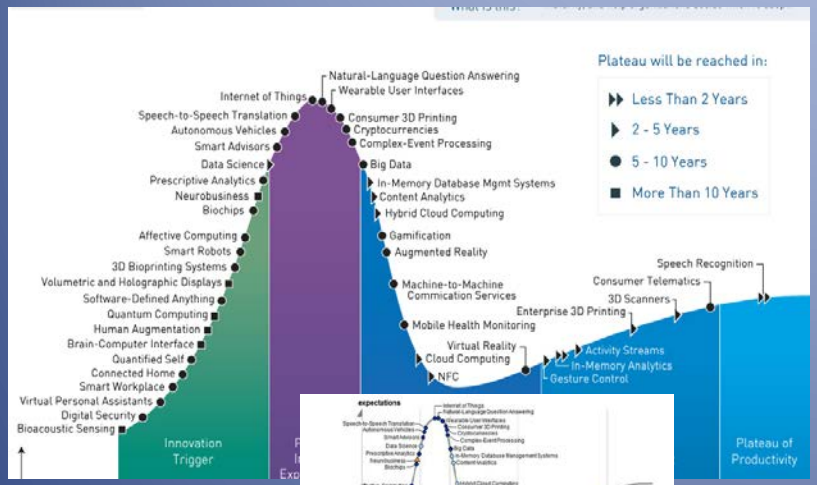
What is IoT?

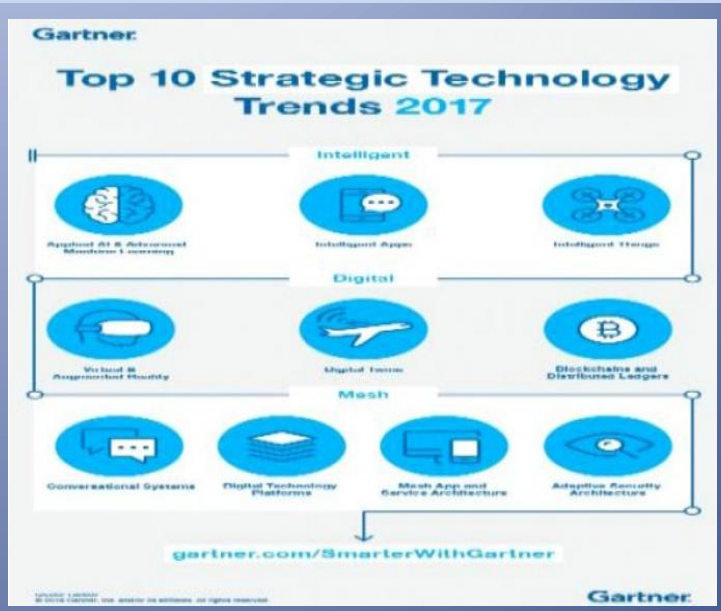


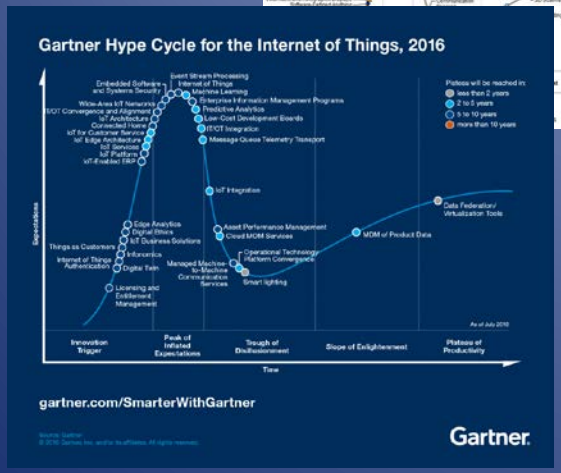
The Basics:

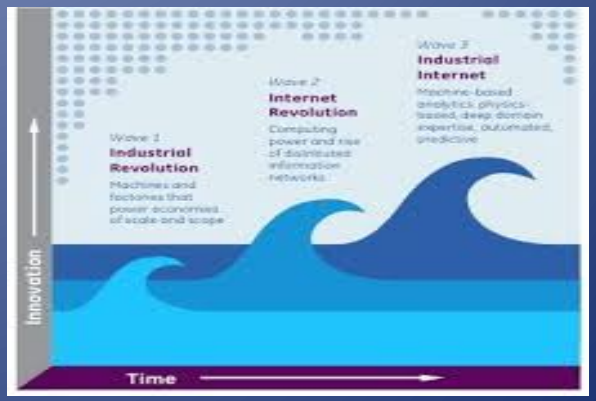
- **Networked System with a purpose!**
- **Utilizing Network Resources**
- **Distributed and Mobile**
- **Work Globally**
  - **Self Configuring**
  - **Automated**
  - **Smarts built in**
- **People, Processes, and Things in the Loop**

Where is IoT in its evolution?









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Where is IoT in its evolution?

Vertical Specific Applications

Core Multi-Vertical Platform

Common Components

- Computing
- Storage
- Connectivity
- Interfaces (APIs)
- Actuators
- Sensors
- Software, Data Management

Core Services

- Directory, Naming
- Billing
- Provisioning, Activation
- Deployment
- Monitoring, Optimization
- Maintenance
- Application Enablement
- Intellectual Property

End-End Attributes

- Security/Privacy
- Availability
- Reliability
- Scaling
- Distribution

Performance

- Latency
- Jitter
- Bandwidth
- Capacity

Vertical Specific End-System Implementations

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Where is IoT in its evolution?

Vertical Specific Applications

Enumerating the Space that IoT Spans		
Common Components	1,000,000s	Across Building Blocks
Core Services	100,000s	For Application Types
Performance Parameters	100,000s	Over all Verticals
Attributes	10,000s	For Range of Use Cases
Multiple (Hopefully few) Architectures Needed to Span the Space		

Vertical Specific End-System Implementations

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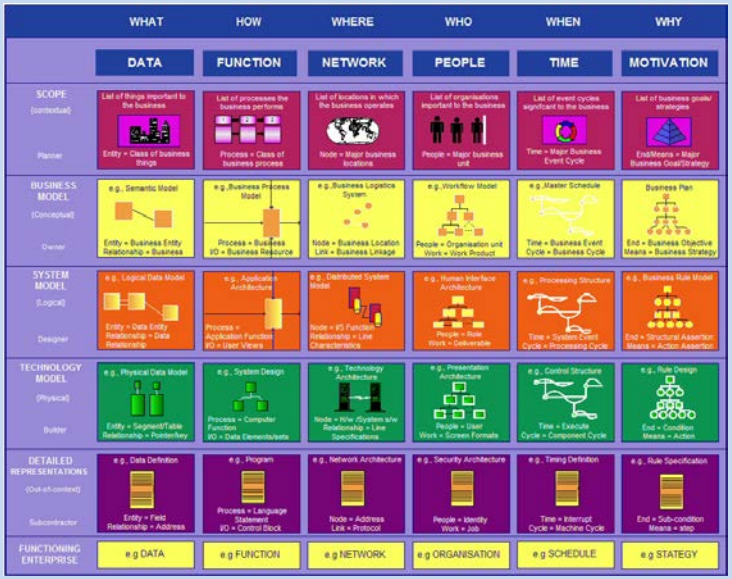
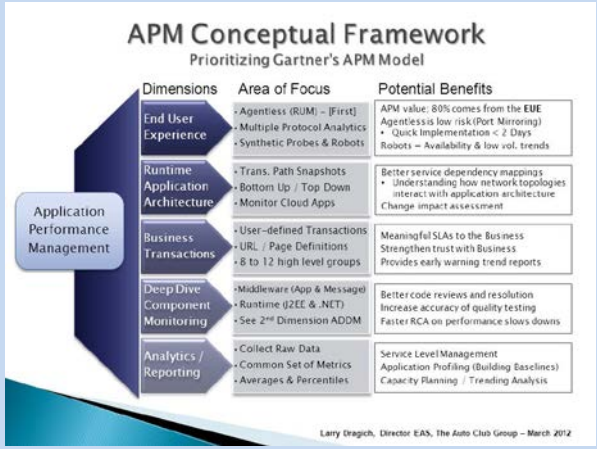
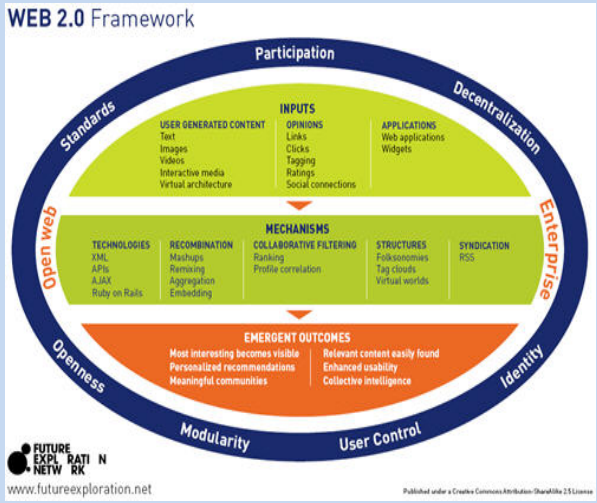
Where is IoT in its evolution?

- *Frameworks*







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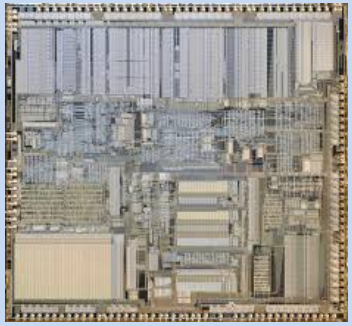
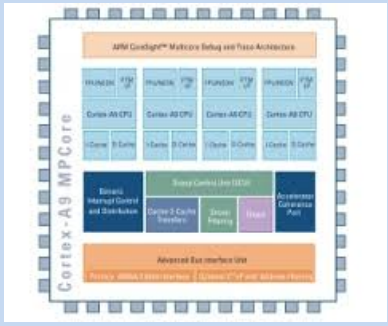
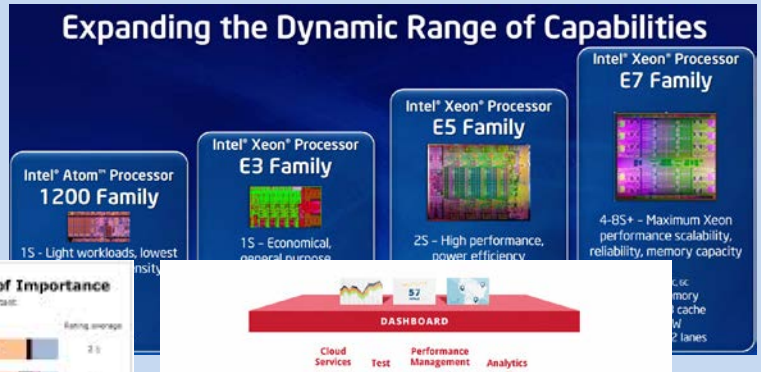
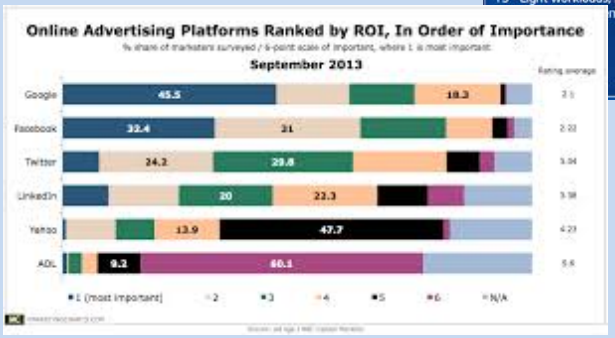
Where is IoT in its evolution?

- *Platforms*









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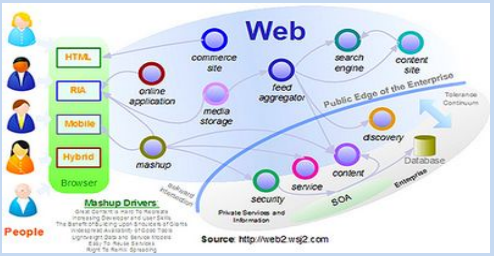
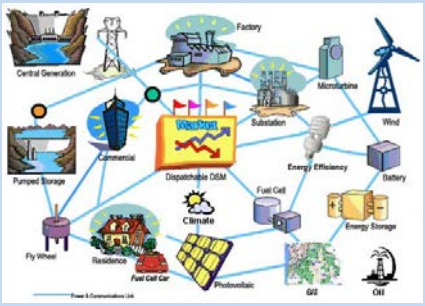
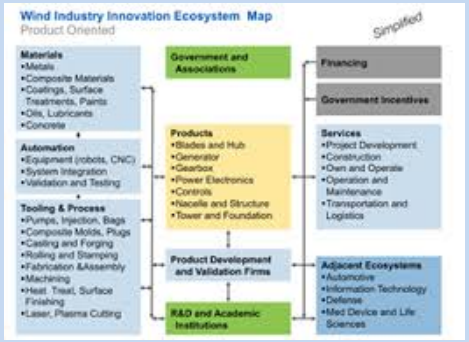
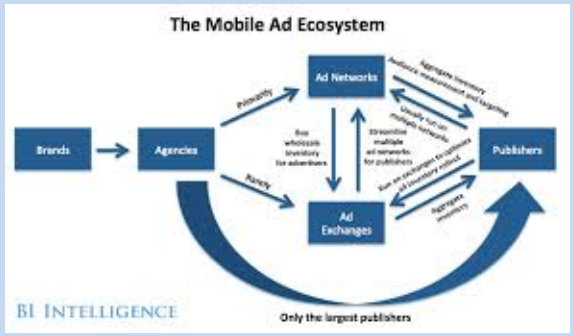
Where is IoT in its evolution?

- *Ecosystems*









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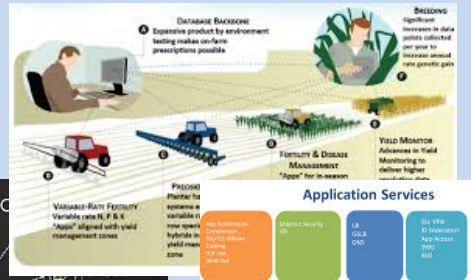
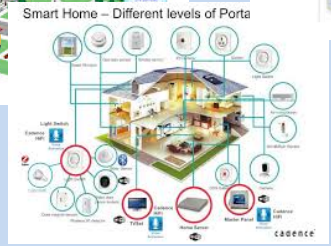
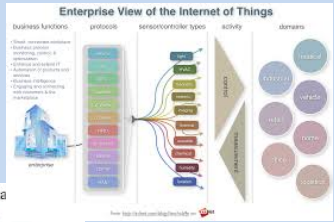
Where is IoT in its evolution?

- *Almost Every "Vertical" will be impacted by IoT*
  - *The existing stock of "solutions" has crossed a thresh-hold where the ROI from current deployments is positive – it's all about economics!*
  - *Most solutions are vertical specific, being developed within verticals, and have very different requirements.*
  - *We are learning what is common and what is not and that takes time and experimentation.*

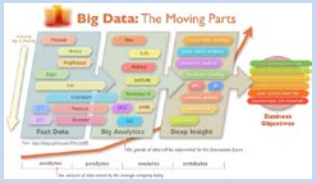






Where is IoT in its evolution?

- *Influence of major trends*
  - *Big data and analytics*
  - *Cloud based computing and storage (including edge/fog)*
  - *Mobility - LTE and precursors for 5G*
  - *Universal access with high bandwidth – copper, coax, and fiber.*



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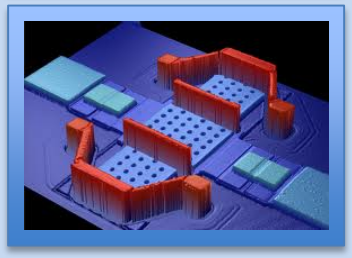
What are the basic ingredients of IoT?

- *Building Blocks and essential Ingredients*
  - *Computing*
  - *Storage*
  - *Connectivity*
  - *Sensors*
  - *Actuators*
  - *Interfaces – Humans in the Loop*
  - *Software and Algorithms*
  - *Power and Energy*
  - *Design and Integration Methods*
  - *Operational Technologies*








What are the basic ingredients of IoT?

- *Computing*
- *For IoT the intelligence is everywhere!!*
  - *Cloud*
  - *Fog/Edge*
  - *Embedded*

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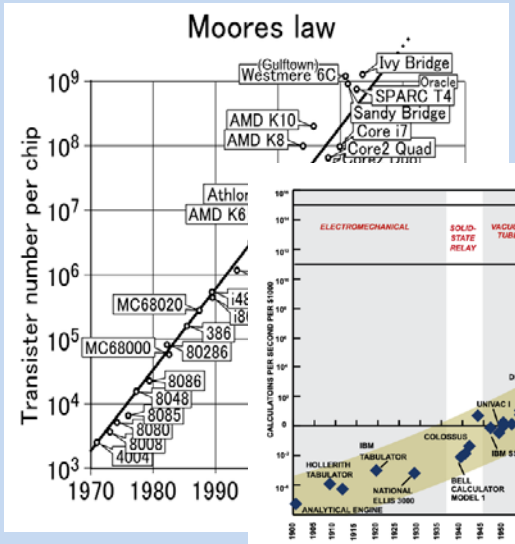
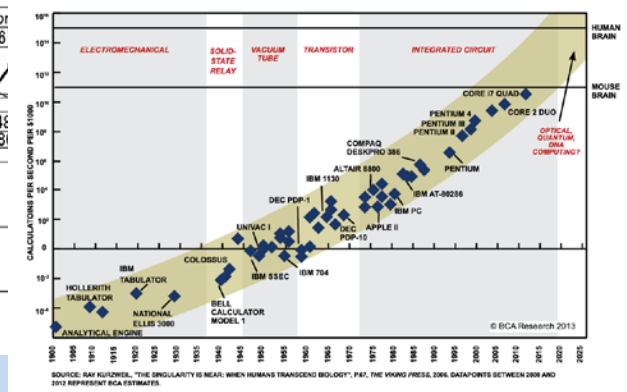
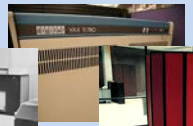
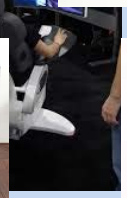
What are the basic ingredients of IoT?

- *Computing – Continue Advances!*









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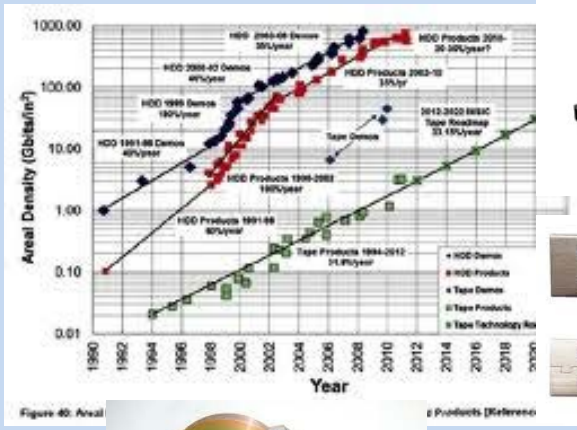
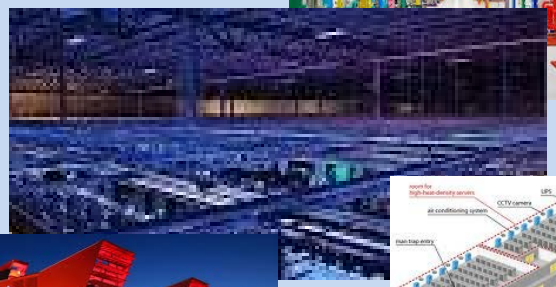
What are the basic ingredients of IoT?

- *Storage*

Kryder's Law

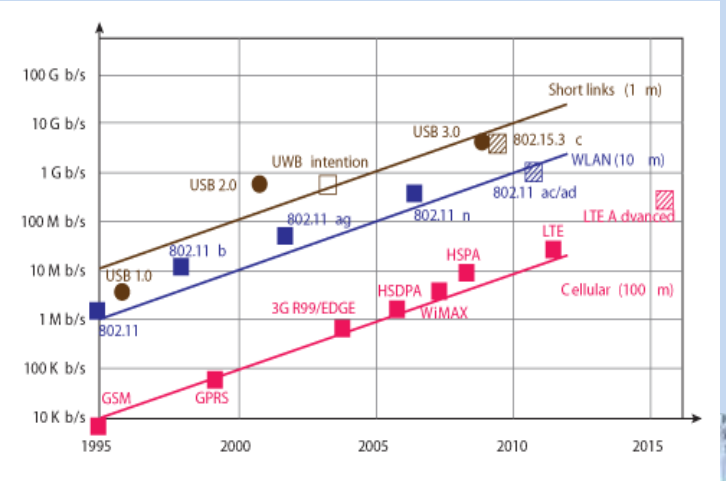
Distributed!!!

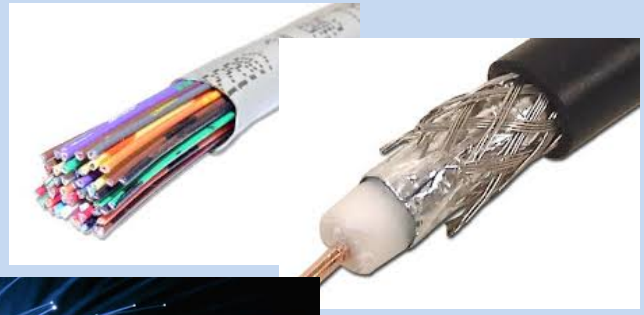


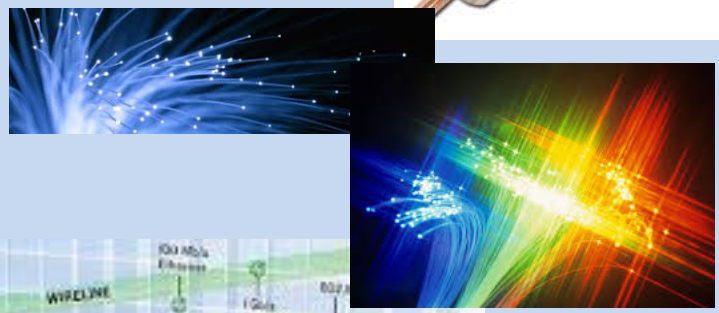


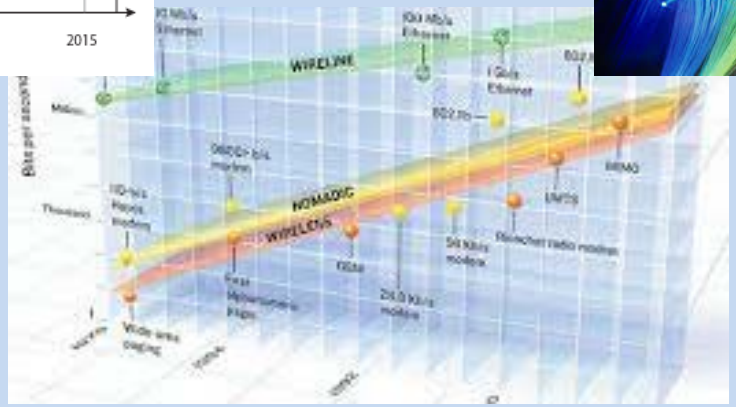
What are the basic ingredients of IoT?

- *Connectivity*









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What are the basic ingredients of IoT?

- *Communications*

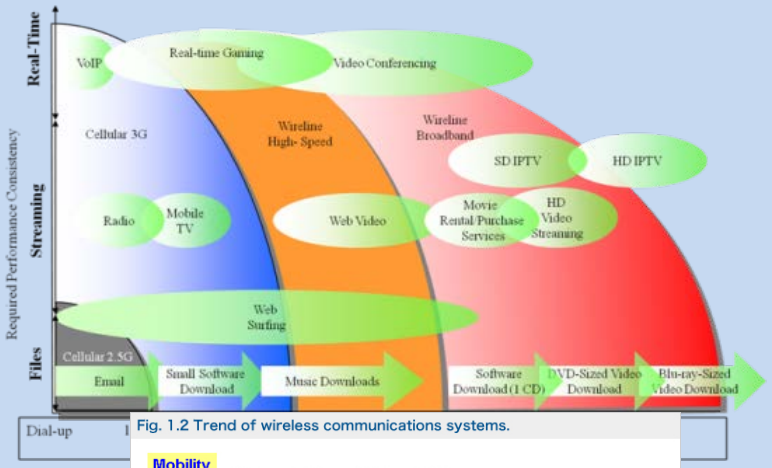
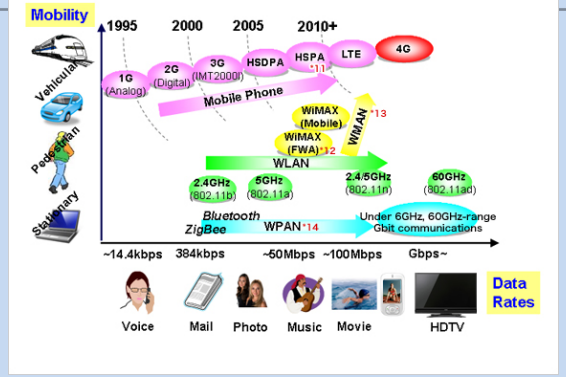
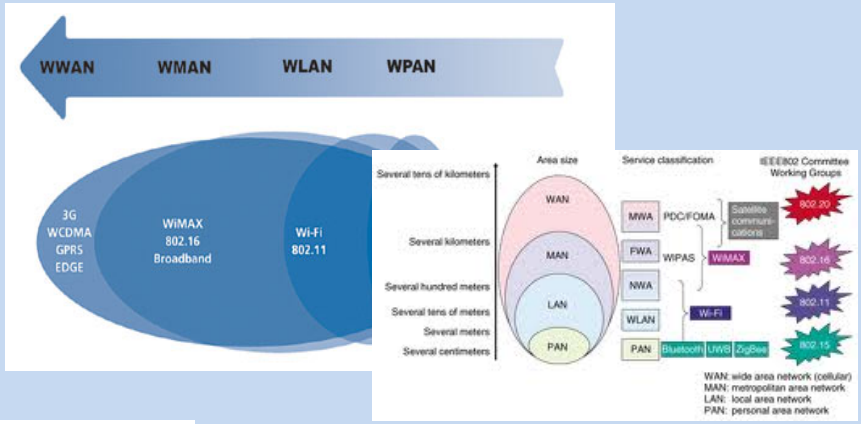


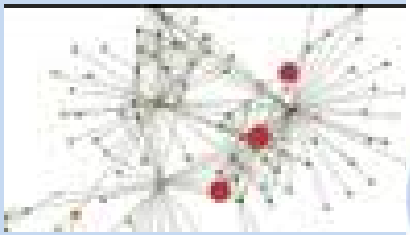
Fig. 1.2 Trend of wireless communications systems.



What are the basic ingredients of IoT?

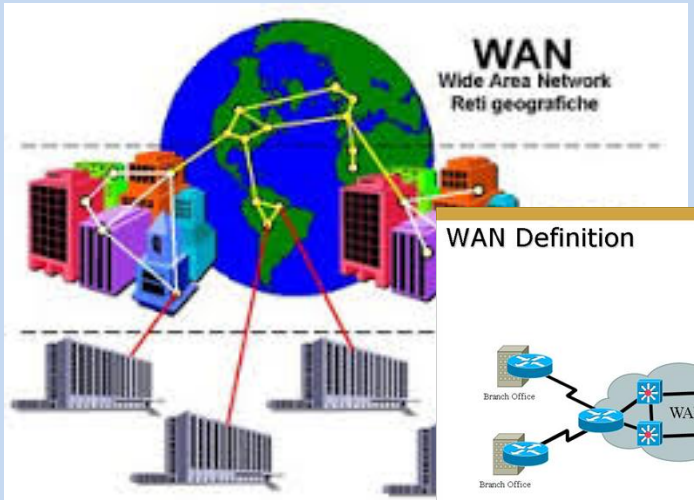
- *Communications - Hierarchy and Heterogeneity*

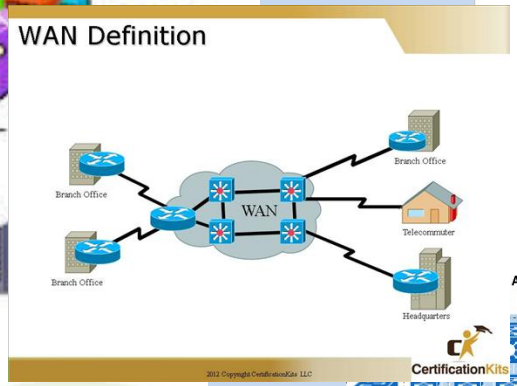


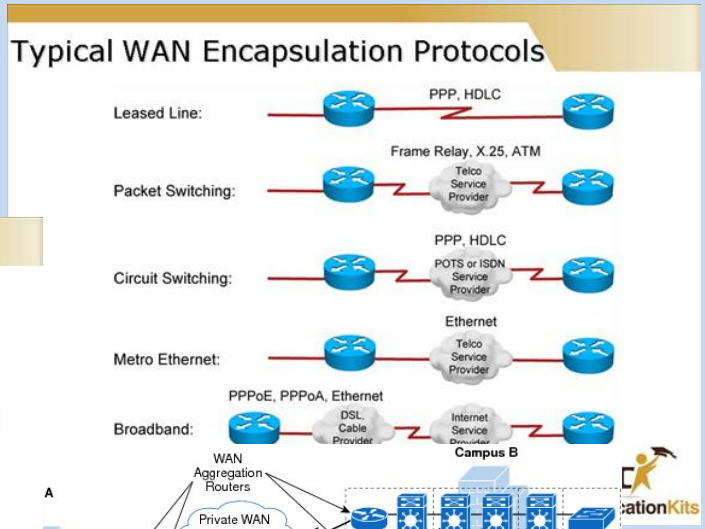


What are the basic ingredients of IoT?

- *Connectivity - Hierarchy and Heterogeneity - WAN*

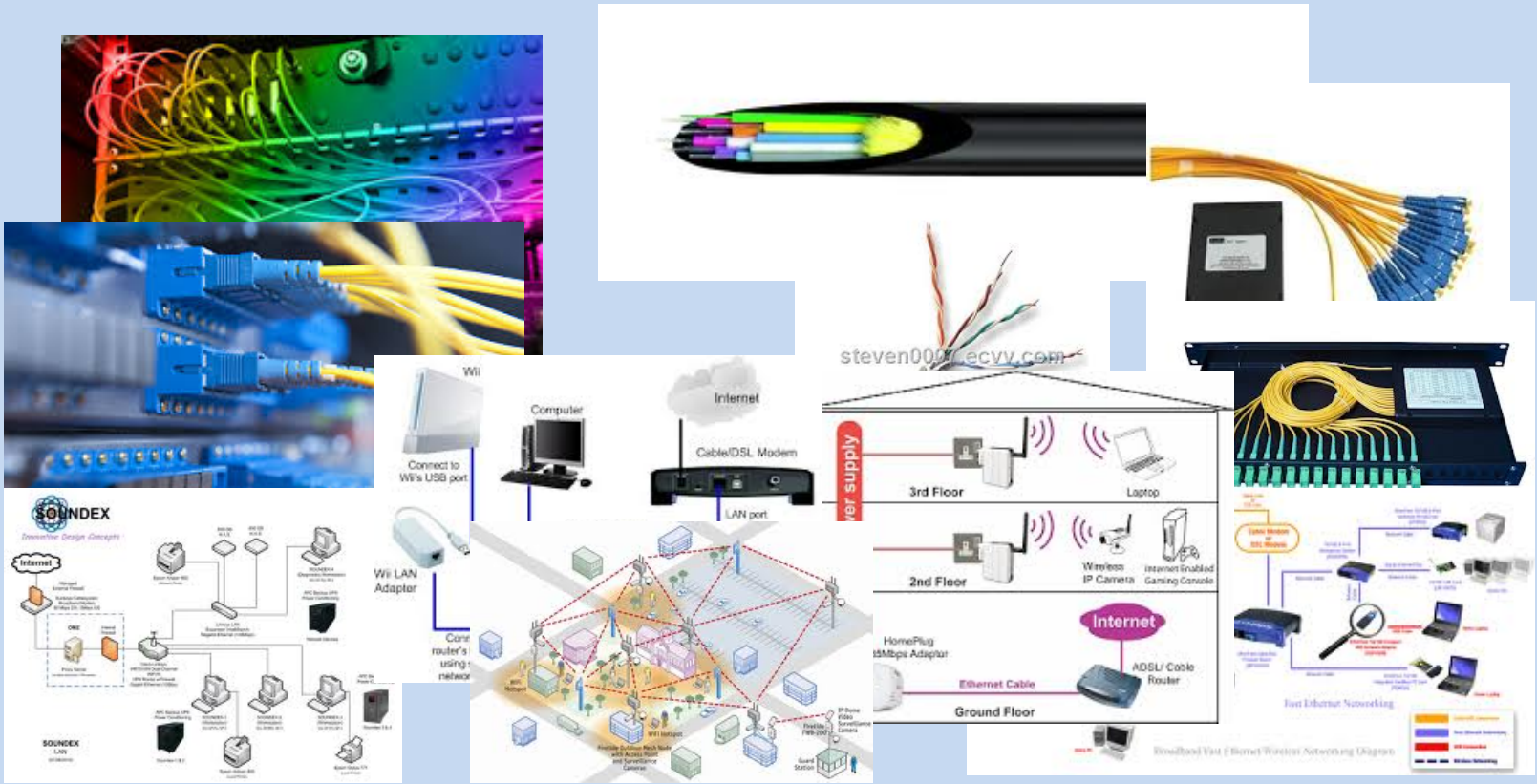






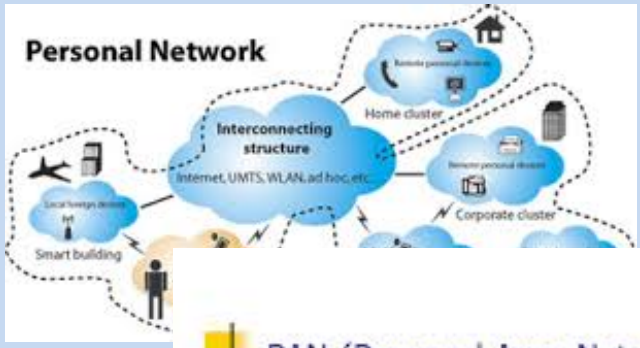
What are the basic ingredients of IoT?

- *Connectivity - Hierarchy and Heterogeneity - LAN*



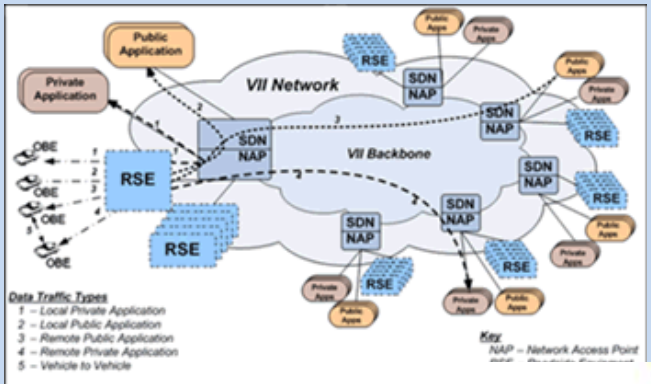
What are the basic ingredients of IoT?

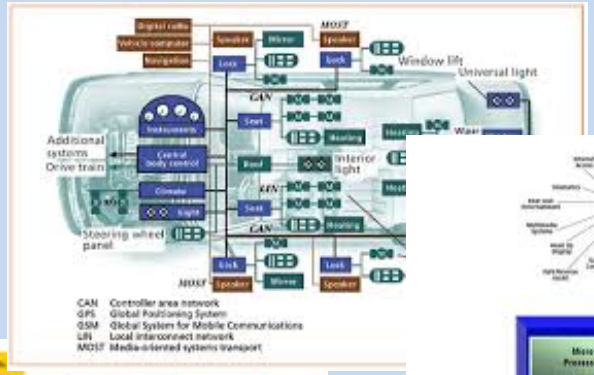
- *Connectivity - Hierarchy and Heterogeneity - PAN*

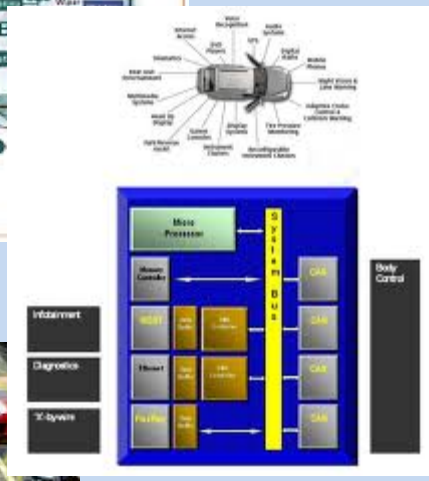


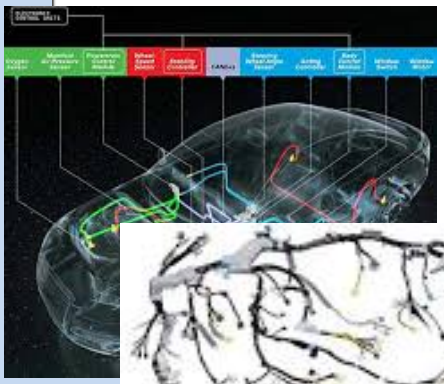
What are the basic ingredients of IoT?

- *Connectivity - Hierarchy and Heterogeneity - Automotive*









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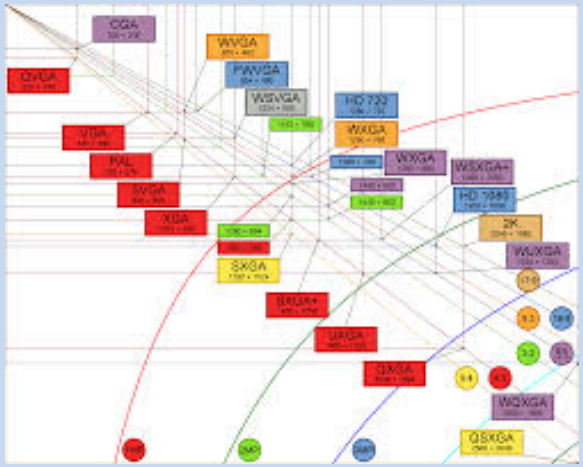
What are the basic ingredients of IoT?

- *Interfaces – Humans in the loop*

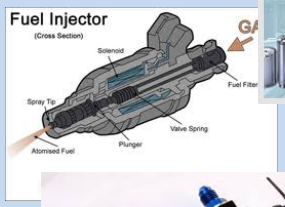


What are the basic ingredients of IoT?

- *Sensors*

What are the basic ingredients of IoT?

- *Actuators*

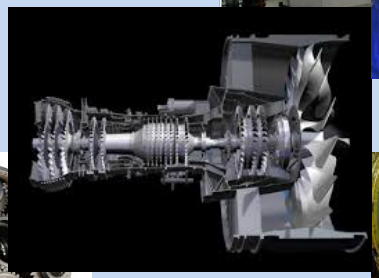





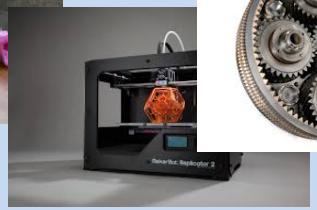
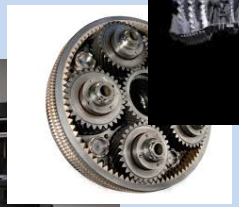








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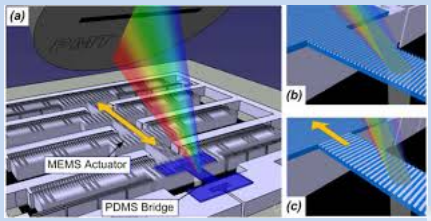
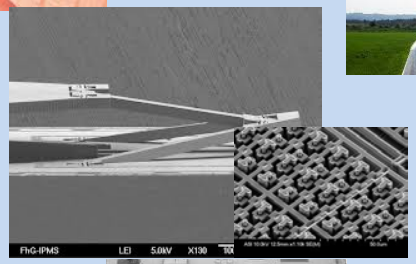
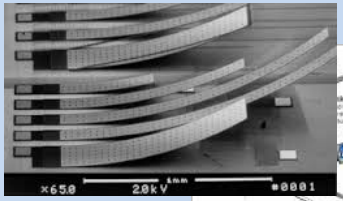
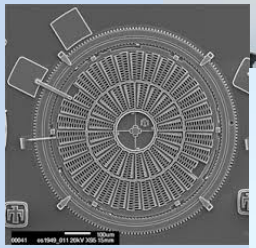
What are the basic ingredients of IoT?

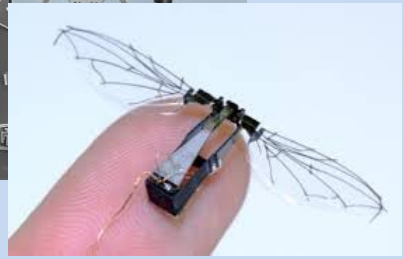
- *Actuators*

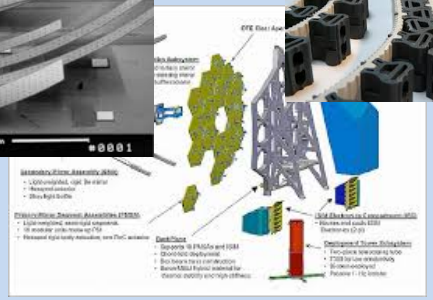












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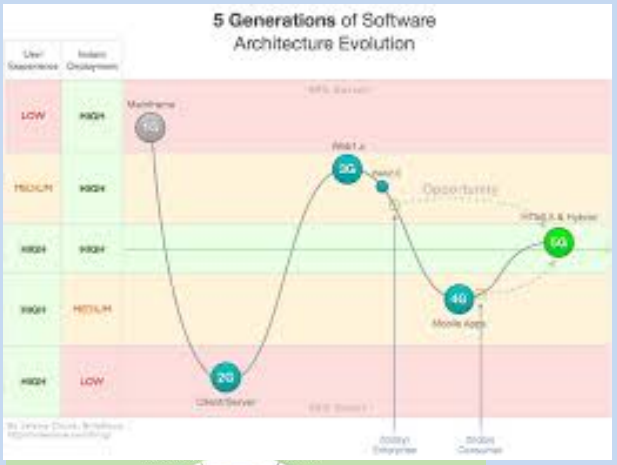
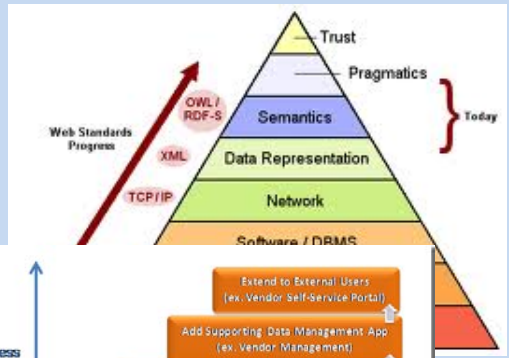
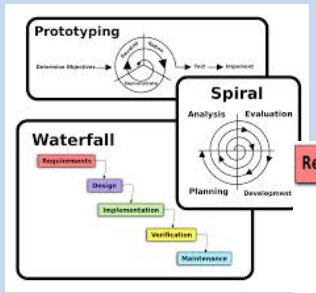
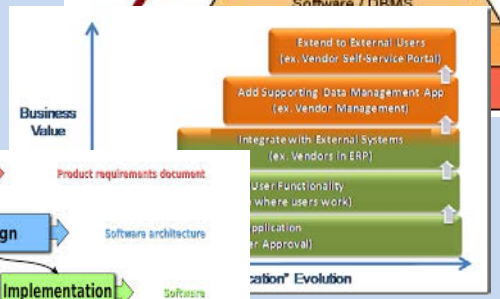
What are the basic ingredients of IoT?

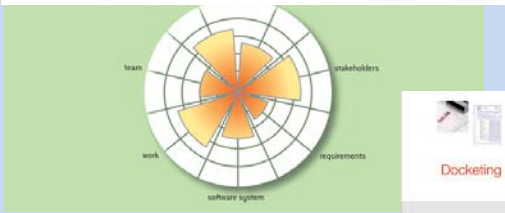
- *Software and Algorithms*











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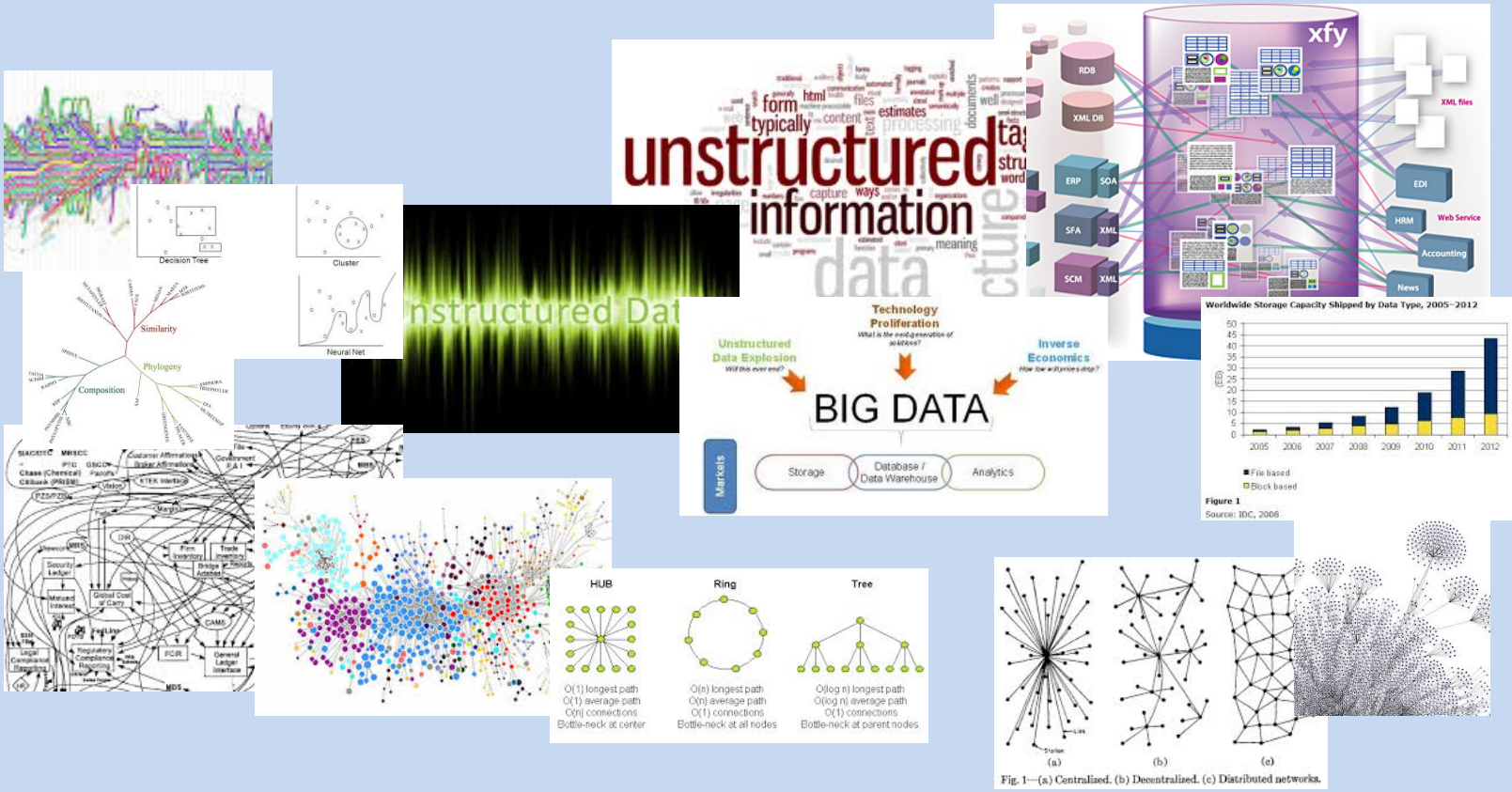
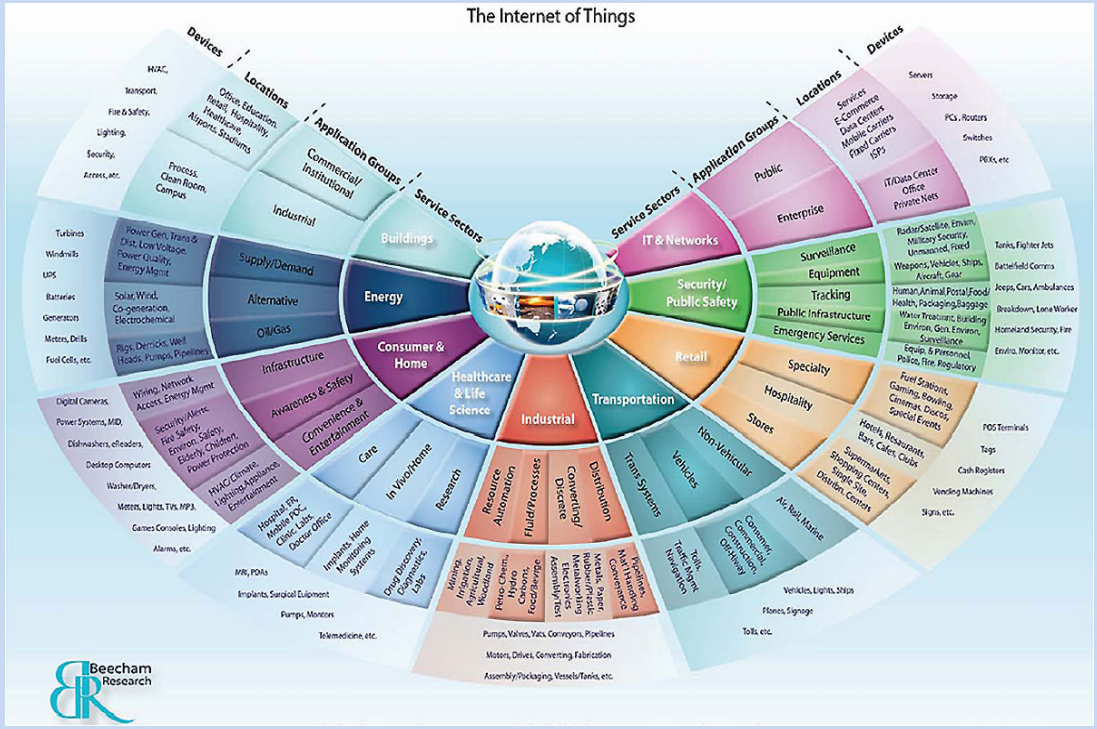
What are the basic ingredients of IoT?

- *Software and Algorithms*



Why are so many organizations working on IoT?

- *Its about Economics!!!!*



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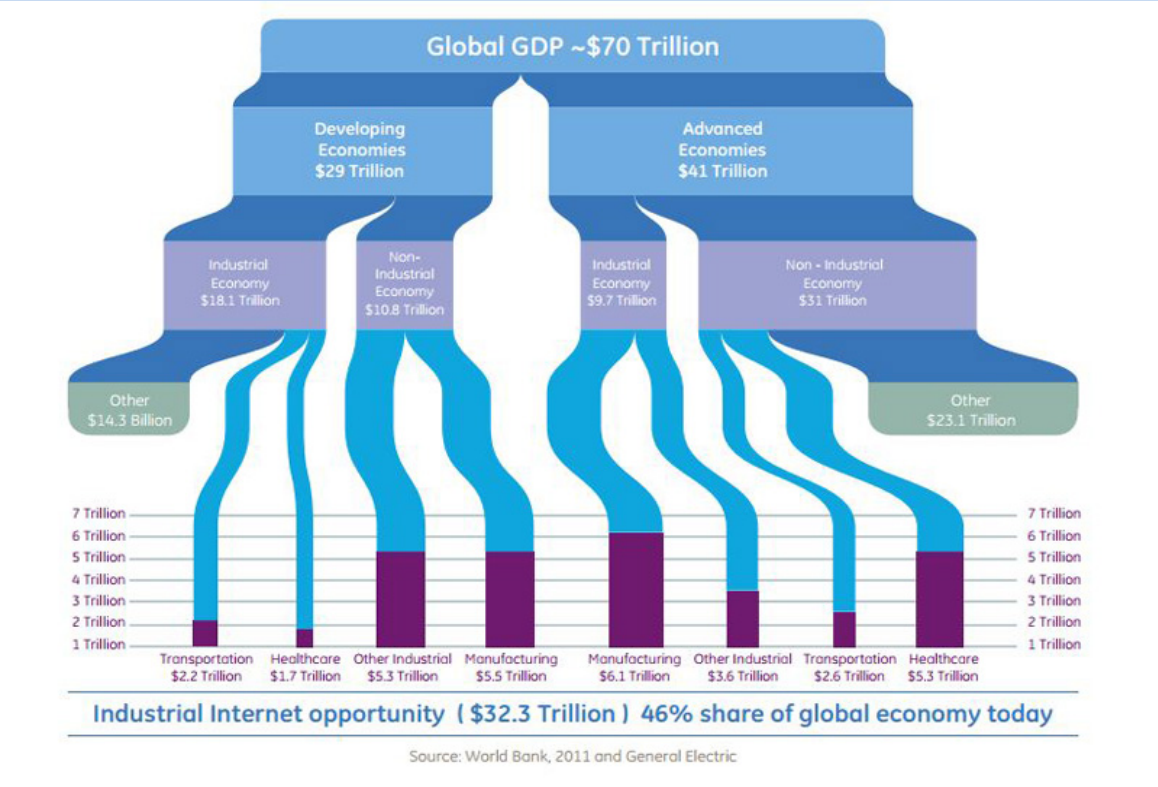
Why are so many organizations working on IoT?

- *Its about Economics!!!!*

From GE 2015 Annual Report



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Why are so many organizations working on IoT?

- *Element of Time*
  - *We are on a learning curve*
    - *Low thresh-hold solutions first*
    - *High value solutions next*
  - *Greater use of AI* → *Autonomy and Automation*
  - *Consolidation of Vertical Solutions and Emergence of a limited number of Dominant of IoT Architectures – hopefully a small number!*
  - *A trend that will roll out for the next 20-30 years.*

→ *The Biggest Gains Will Come From Refactoring*

A Few Examples

- *Many of the ideas behind IoT applications are not new*
- *The difference between then and now is:*

  In the past

  – *Each Application was built in isolation and for a limited number of uses*

  – *Often the cost required National means and was linked to an National goal or imperative*

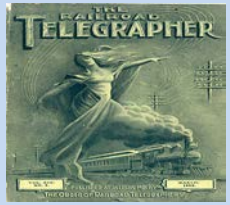
  Today

  – *The economics that drive IoT are driven by wide availability of IT, Communication, and Operational Technologies, that have benefited from the scale of global markets, and investments to continue improvements in performance (in many different ways)*

  – *The deployment of the infrastructure building blocks for IoT is deep and greatly drops the threshold for achieving an ROI.*

A Few Examples – From the Past

- *Impact from the introduction of the Telegraph an early implementation of IoT!!!*



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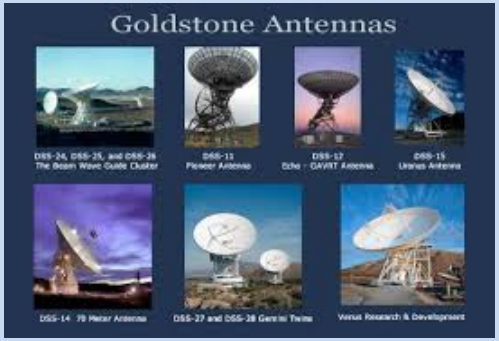
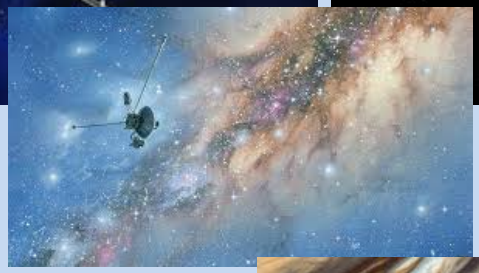
A Few Examples – From the Past

- *Space Exploration a high value IoT implementation!*





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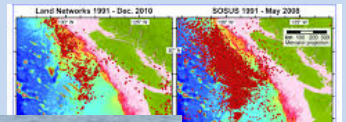
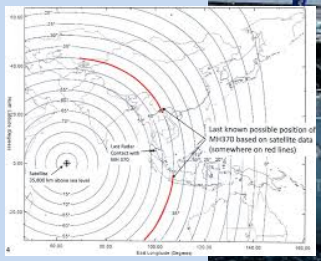
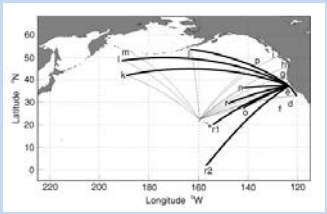
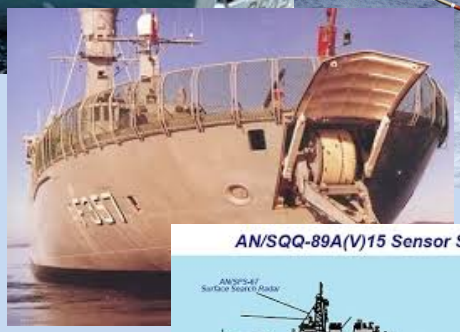
A Few Examples – From the Past

- *Cold War Submarine Tracking*
- *The SOSUS Array*









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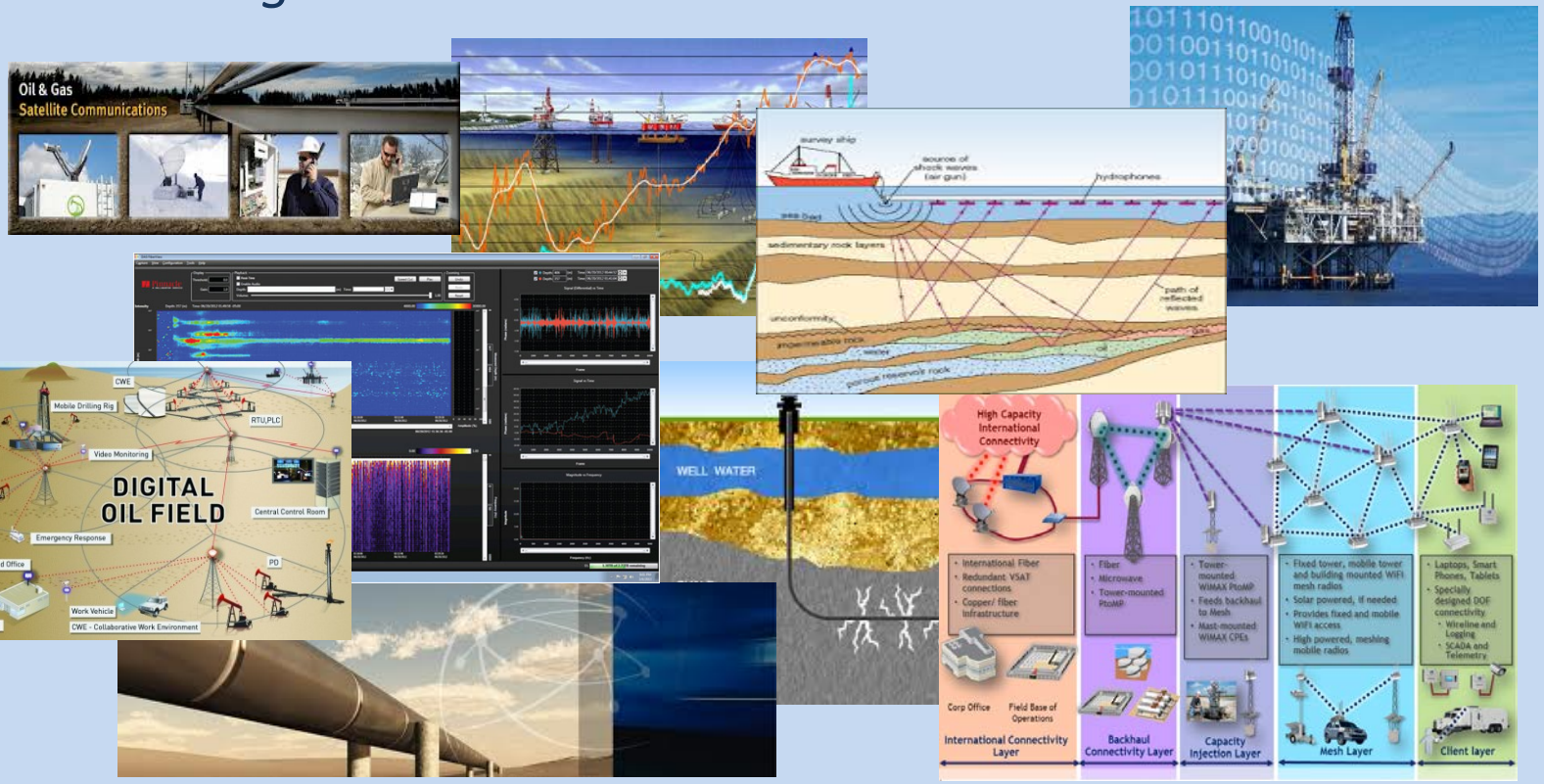
A Few Examples - Today

- *IoT Oil & Gas Exploration and Production*
- *The Digital Oil Field*



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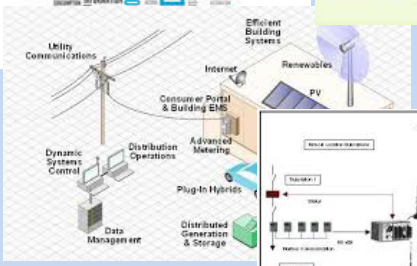
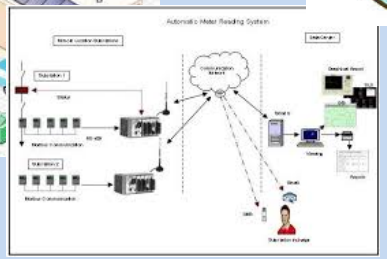
A Few Examples - Today

- *Smart Grid and Smart Utilities*





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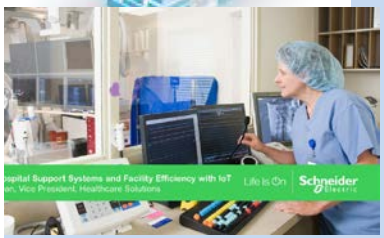
A Few Examples - Today

- *Healthcare*



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A Few Examples - Today

- *Precision Agriculture*
- *Smart Farming*

















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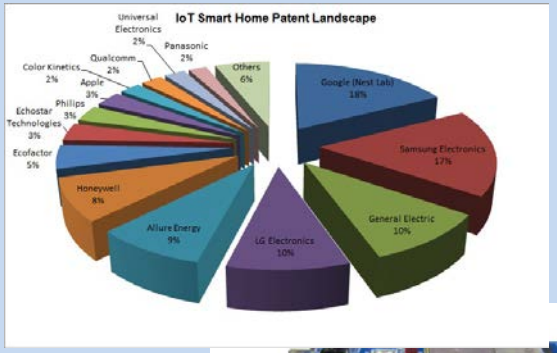
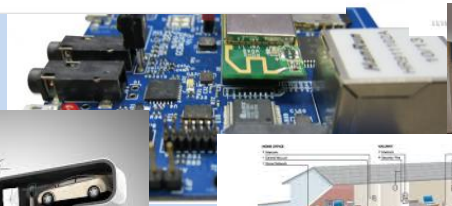
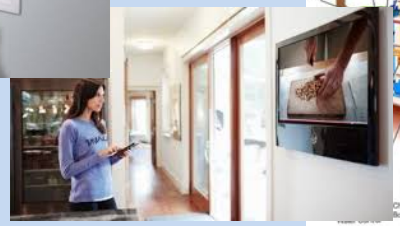
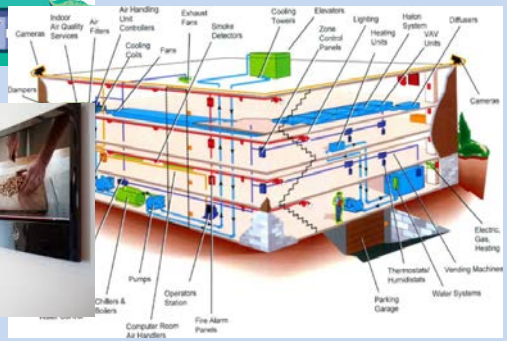
A Few Examples - Today

- *Smart Home*
- *Intelligent Home*
- *Home Automation*









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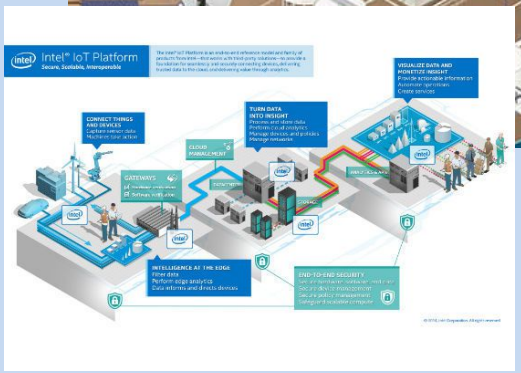
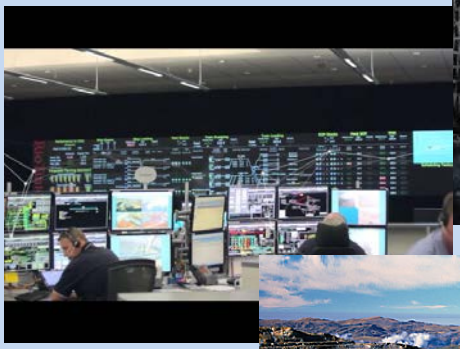
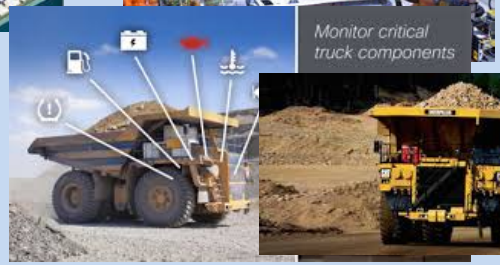
A Few Examples - Today

- *Mining and Natural Resources*







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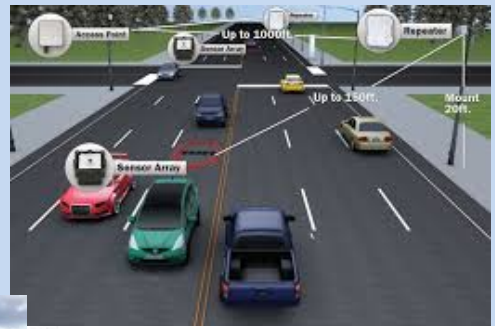
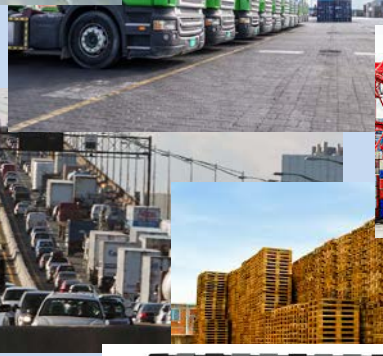
A Few Examples - Today

- *Transportation*













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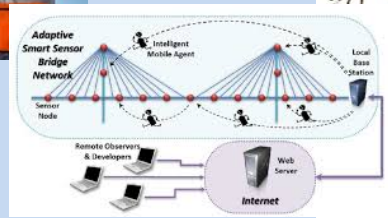
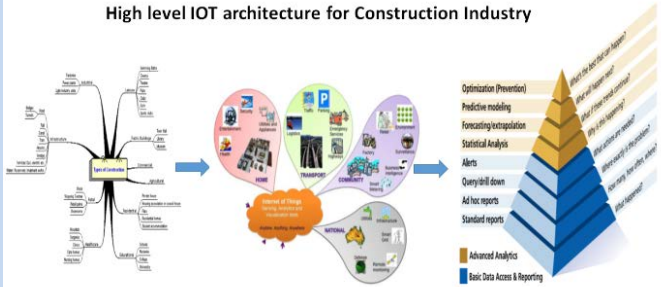
A Few Examples - Today

- *Construction*



High level IOT architecture for Construction Industry



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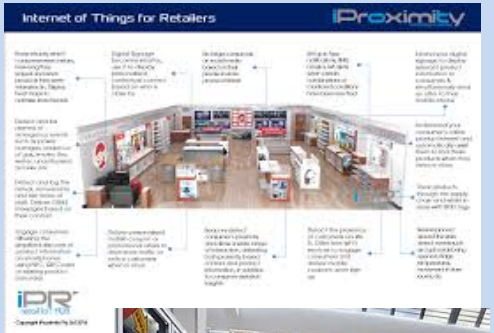
A Few Examples - Today

- *Retailing*



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A Few Examples - Standards

ALLSEEN ALLIANCE

Initiated by Qualcomm with over 100 members: APIs, interoperability and consumer electronics

IEEE Standard P2431

IoT Architectures

IEEE IoT

oneM2M

TIA

TTC Telecommunication Technology Committee

CCSA

atis

ARIB

TTA

ETSI World Class Standards

Cross Industry Telecommunication Standards: Led by seven SDOs

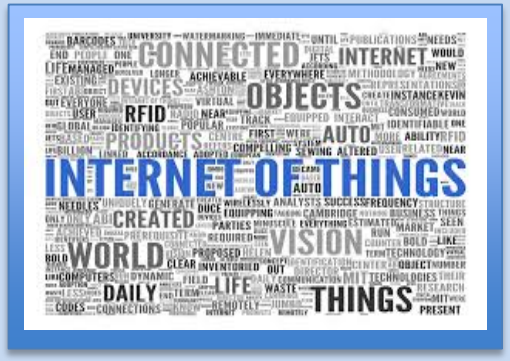
industrial internet CONSORTIUM

Founded by GE, Intel, IBM, Cisco, and AT&T: IoT for the Industrial World

Summary

- *The Internet of Things is complex and today involves many different IoT implementation.*
- *Standards play a key role in consolidating our knowledge and extending the reach of solutions. This in turn allow us to do new things and at the same time drive down the costs to accelerate adoption.*
- *The greatest gains will come from how we refactor the design of personal and infrastructure systems that are pervasive and affect us all.*

Thank you!



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