# Paradox to Paradigms

IMPERFECTLY CATALYZED BY CYBERPHYSICAL SYSTEMS AND INTERNET OF THINGS

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- THE ORIGIN OF THE TITLE

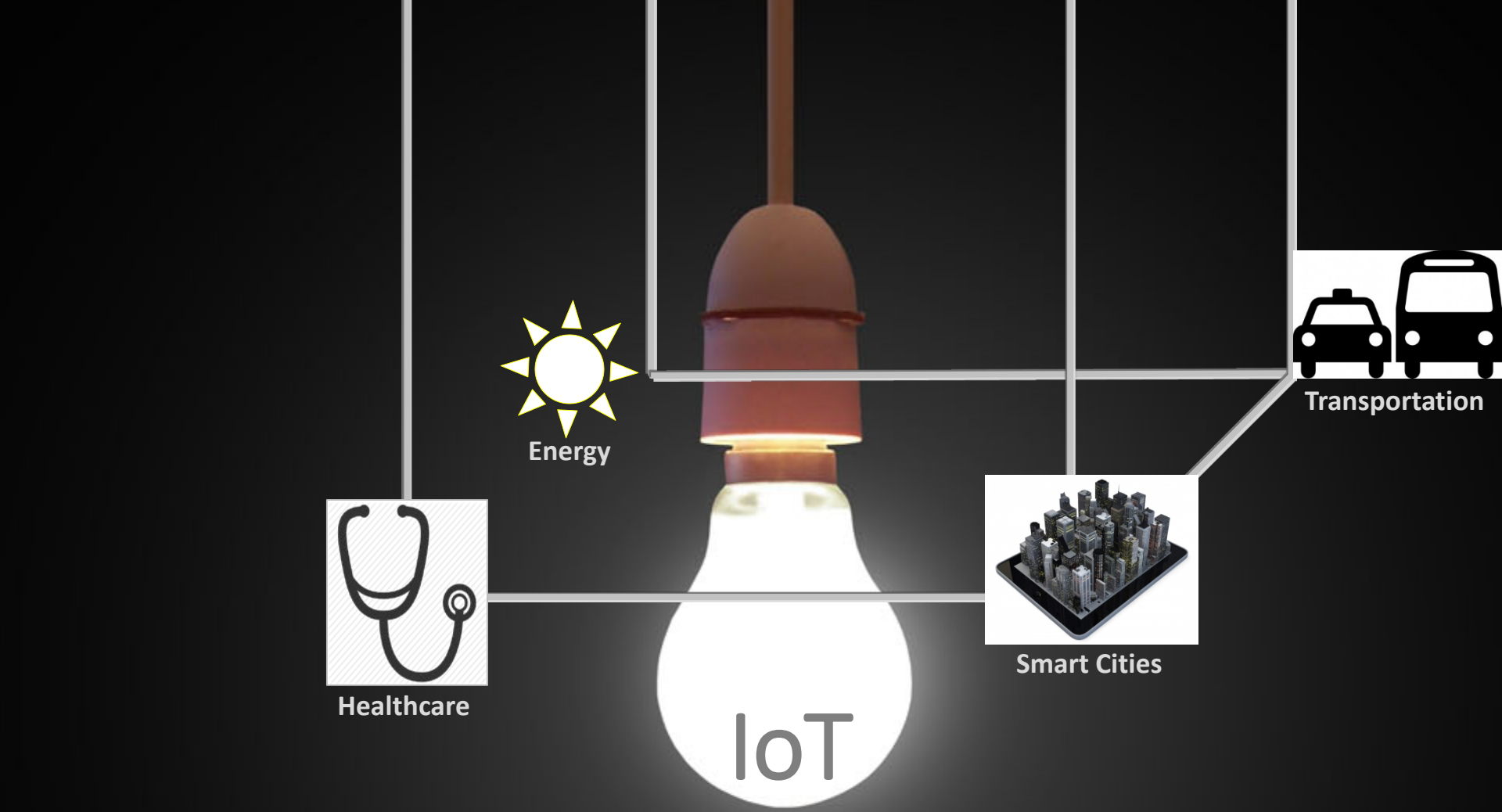
**The Nobel Prize in Physics 2004**

David J. Gross, H. David Politzer, Frank Wilczek

# Nobel Lecture

## Asymptotic Freedom: From Paradox to Paradigm

Frank Wilczek held his Nobel Lecture December 8, 2004, at Aula Magna, Stockholm University. He was presented by Professor Sune Svanberg, Chairman of the Nobel Committee for Physics.



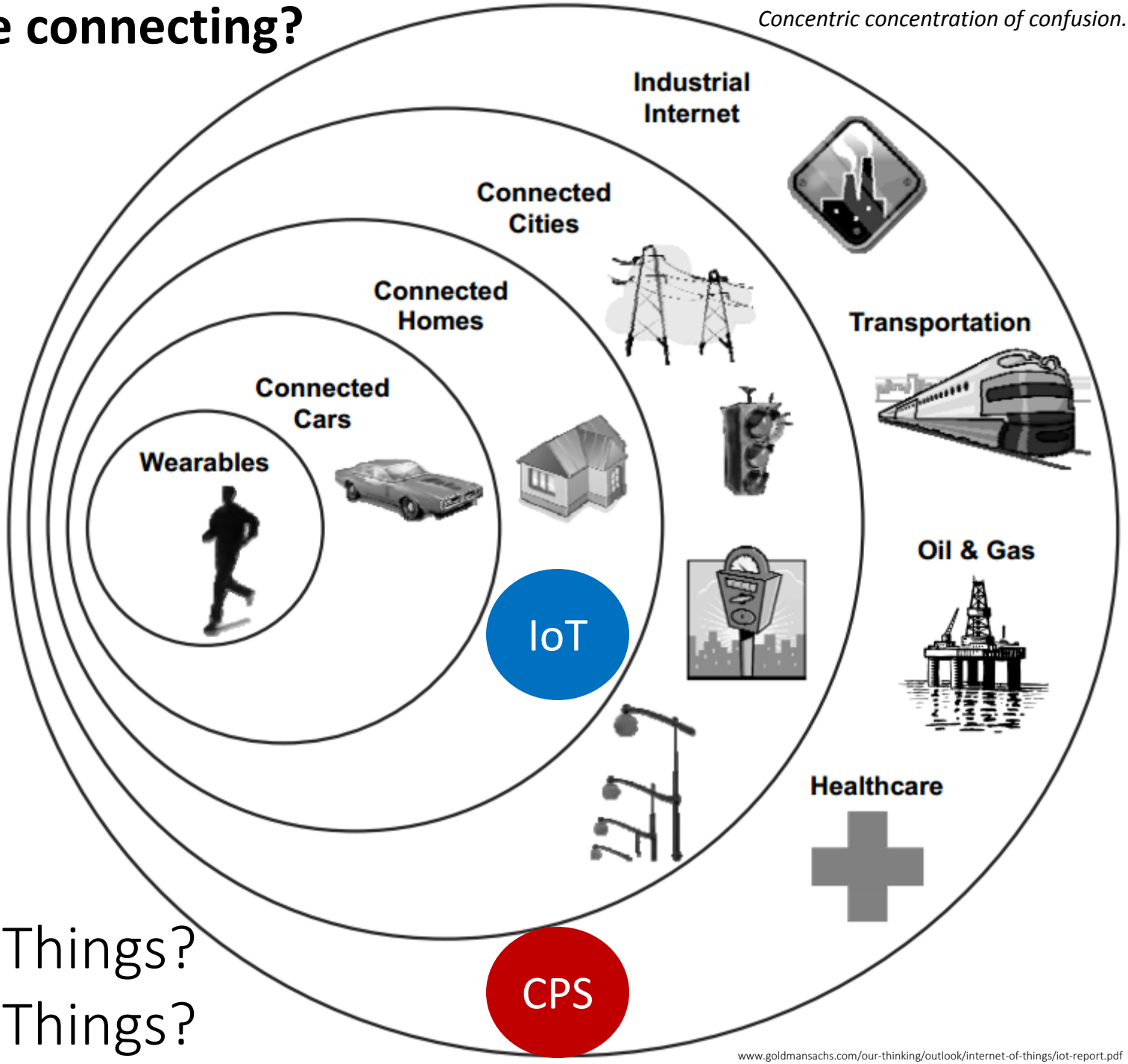

# Grand Challenges



I invented nothing new. I simply assembled into a car the discoveries of other men behind whom were centuries of work ▪ HENRY FORD

# What are we connecting?

*Concentric concentration of confusion.*



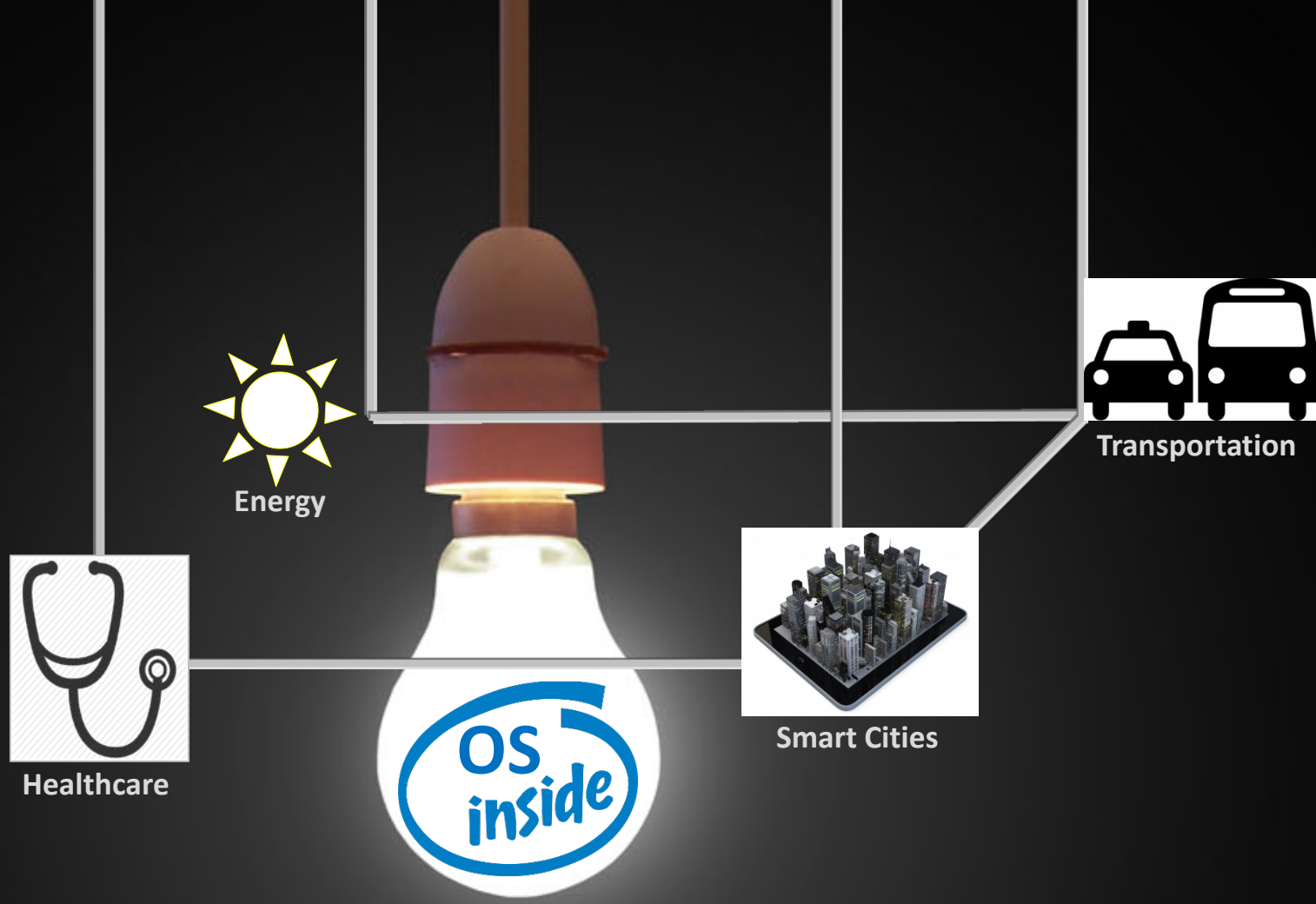

Atoms?

Bits?

Data of Things?

Big Data of Things?

www.goldmansachs.com/our-thinking/outlook/internet-of-things/iot-report.pdf




# Grand Platforms

Platforms

# Something to stand on

**Proliferating digital platforms will be at the heart of tomorrow's economy, and even government**

Jan 18th 2014 | From the print edition

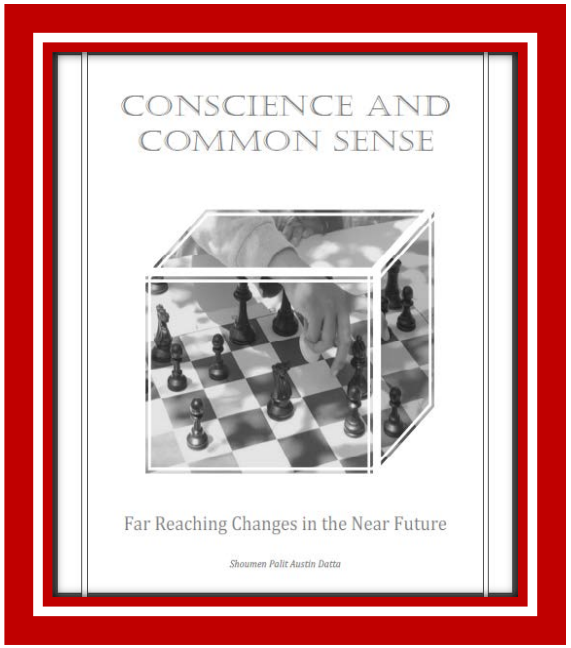
Dr Shoumen P Austin Datta ● Research Affiliate, School of Engineering, MIT ● SVP, Industrial Internet Consortium ● shoumen@mit.edu

# Paradox to Paradigms to Platforms

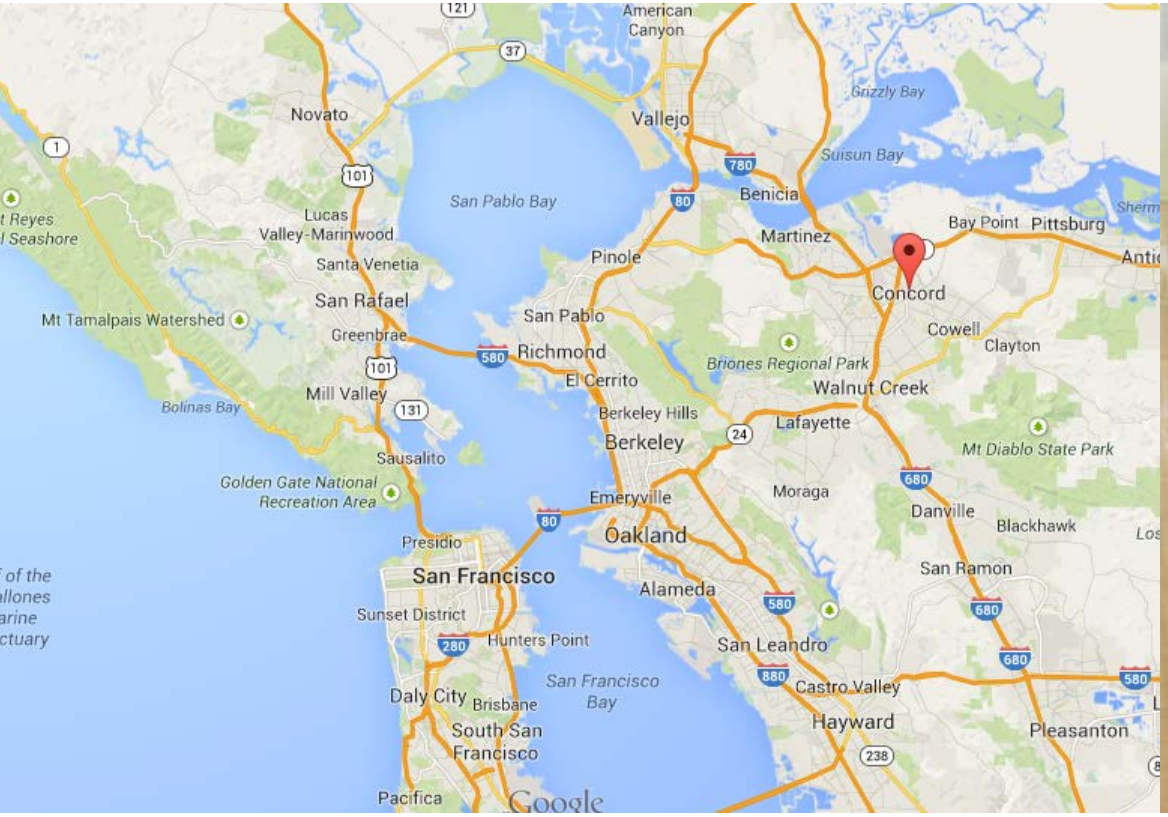
- Paradox to Paradigms to Platforms ☑ http://bit.ly/MIT-IOT

- Vision, Mission and Opportunities

- Challenges
  - ☑ Autonomous Transportation
  - ☑ Global Smart Cities
  - ☑ Healthcare
  - ☑ Data



# Diffusion of the Internet - NetDay 1996





President Bill Clinton installing computer cables with Vice President Al Gore on NetDay at Ygnacio Valley High School (Concord, CA - Mar 9, 1996)

# IoT – Internet of Things – let us start at the beginning

The grand vision of the Industrial Internet may have started circa 1988 with the work of Mark Weiser of Xerox Palo Alto Research Center (XPARC) who predicted that computers may *"weave themselves into the fabric of everyday life"* and influence the future of business as well as lifestyle technologies, in his 1991 article in the *Scientific American*. The release of the commercial internet in 1995 paved the way for the Industrial Internet of the future. In 1998, Sanjay Sarma (MIT) extended the idea of using RFID tags on objects for track and trace purposes. To make it feasible for businesses to use RFID tags in the management of their supply chains, the price of the RFID tag had to be reduced, significantly. Sarma suggested RFID tags contain only a reference number (electronic product code) rather than any actual data about the object. It was against the conventional wisdom. At the time, RFID tags were used and designed to contain data about the object or product. By eliminating need for data storage on the tag, the cost of the RFID tags were reduced. Sarma designed the EPC to act as an unique URL to access the object data stored on the Internet. In 1999, Sarma along with colleagues David Brock and Sunny Siu co-founded the Auto ID Center to transform this vision made possible by the "emerging" medium and the platform of the internet. The internet was still in its infancy and immature to act as a catalyst to augment business processes and industrial productivity. Sarma, Brock and Siu were later joined by Kevin Ashton who was loaned to the Auto ID Center at MIT from Proctor & Gamble. Auto ID Center at MIT developed the EPC and other technical concepts and standards prevalent today in the global RFID industry. Sarma, Brock and Ashton coined the term Internet of Things which envisioned objects /things connected to object-specific data on the internet which could be accessed using the unique EPC on the tag attached to the object. IoT is a vision, not a technology. In 2000, a paper by Sarma *et al* gave birth to that IoT concept. Please download (MIT-AUTOID-WH-001) *THE NETWORKED PHYSICAL WORLD* from this link http://tinyurl.com/Industrial-Internet (this folder contains many papers). Professor Sarma talked about the IoT at the MIT Sloan Symposium. It is on YouTube http://tinyurl.com/MIT-IoT-1998

I was a part of the Auto ID initiative since 2000 as a member of the Technology Board at Auto ID Center.

# • The Birth of the Internet of Things and the nascent Industrial Internet

**1953**

In my story "Sally," published in 1953, I described computerized cars that had almost reached the stage of having lives of their own. In the last few years, we do indeed have computerized cars that can actually talk to the driver. (*Robot Dreams* by Isaac Asimov aka Isaak Ozimov)

**1987**

Herbert Simon (June 15, 1916 – February 9, 2001) in his paper "*The Steam Engine and the Computer: What makes technology revolutionary*" framed his thoughts about the computer, "*you have to make friends with it, talk to it, let it talk to you.*"

**1991**

Mark Weiser (July 23, 1952 – April 27, 1999) of Xerox Palo Alto Research Center coined the term "ubiquitous computing" and suggested in 1988 that computers may *"weave themselves into the fabric of everyday life"* and influence the future of business (*Scientific American, 1991*).

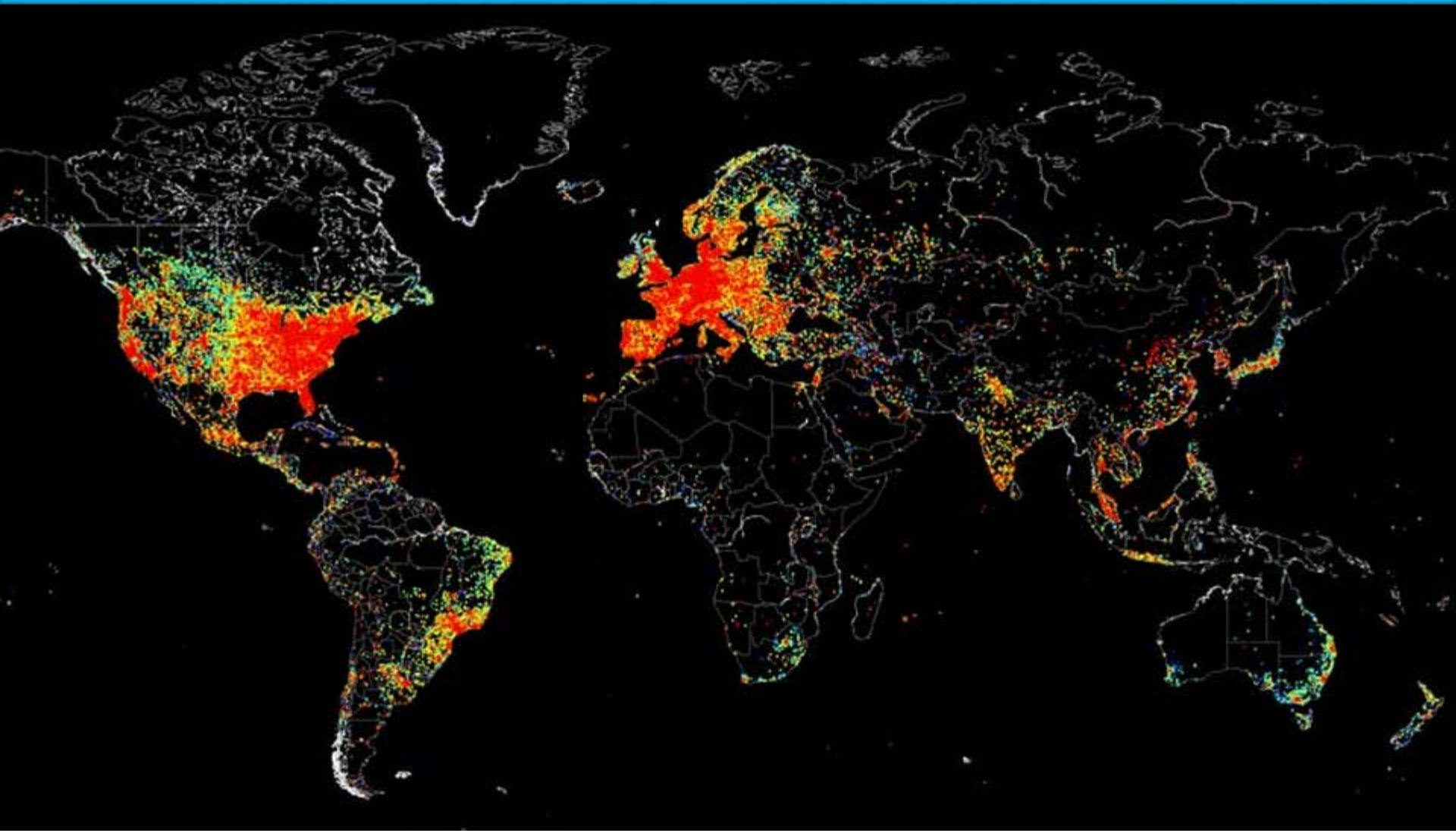
**2000**

The seminal paper *The Networked Physical World* by Sanjay Sarma *et al* spread the concept of the Internet of Things (IoT) through the creation of the Auto ID Center at MIT.

**2013**

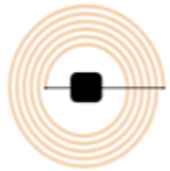
After sixty years of *Robot Dreams*, the evolution of the internet and the industrial revolution merged to conceive and create the Industrial Internet Consortium (03/27/2014) to catalyze global economic growth (www.iiconsortium.org). Sponsored by 5 founders with $1T market cap.

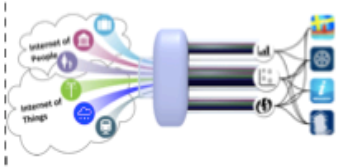
# THE NETWORKED PHYSICAL WORLD



Map of every device connected to the internet on the evening of 2 August 2014 (Shodan). John Matherly pinged all IP addresses of devices online on 2 August (11pm UK). It took about 5 hours. Map represents all the devices (red = many) that pinged back in 12 hours using matplotlib.

# A Short History of the Development of the Internet of Things starts with the re-invention of RFID





1994~1999

RFID based solutions

early 2000

WSAN oriented, Distributed WSANs, Communication technologies, Smart meter …

mid 2000

Smart Devices/ Web-enabled Apps/Services, initial products, vertical applications, concepts and demos, …

~2010

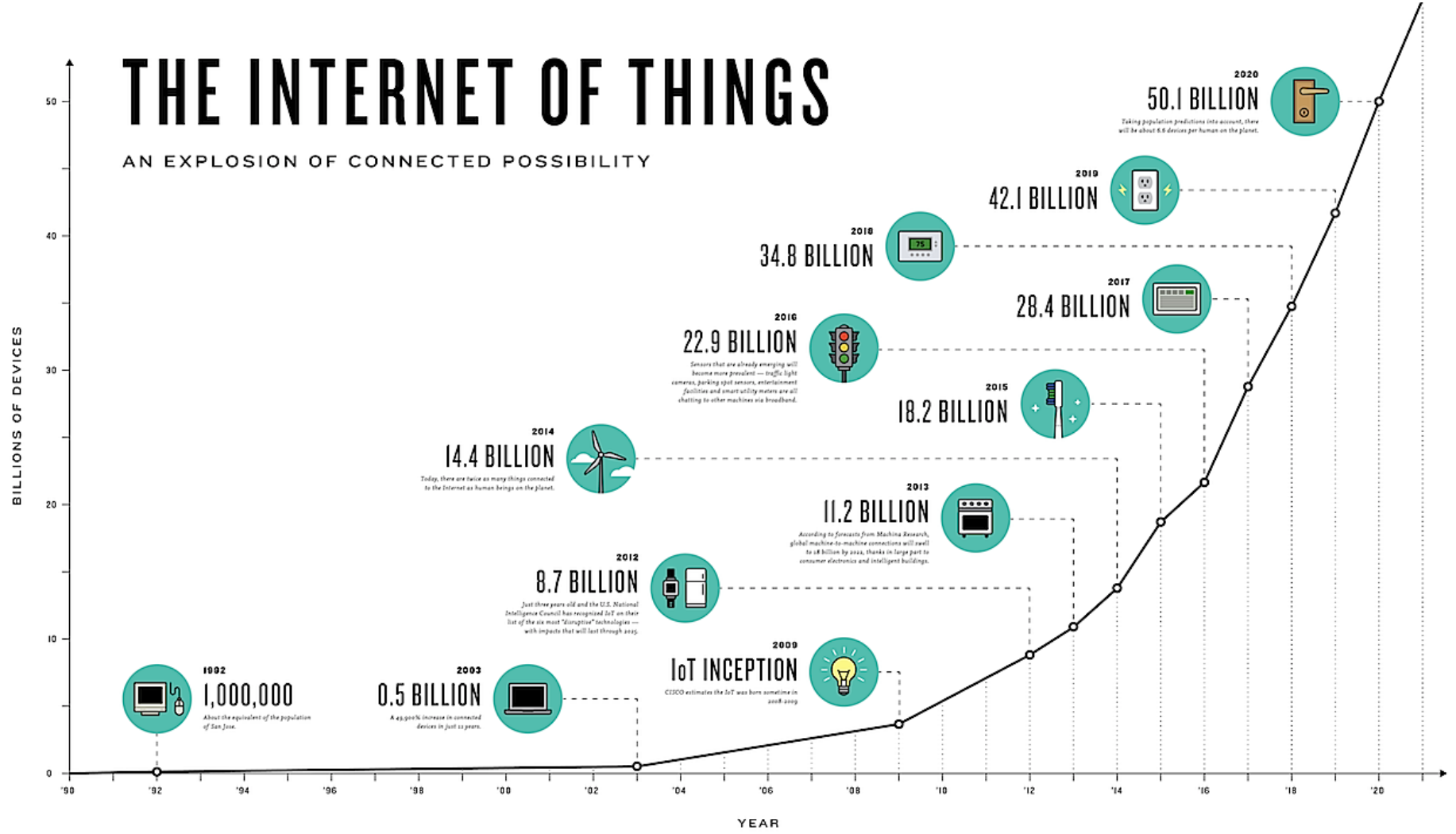
Physical-Cyber-Social Systems, Linked-data, semantics, More products and services (e.g. Smart Buildings), more heterogeneity, control and monitoring applications, …

~2020

Cloud platforms, Big (IoT) Data analytics, Mature IoT applications with actionable information, Multimodal fusion and intelligent data processing, Enhanced cellular/ wireless com. for IoT, Operational use-cases and commercial services/ applications, more Standards…

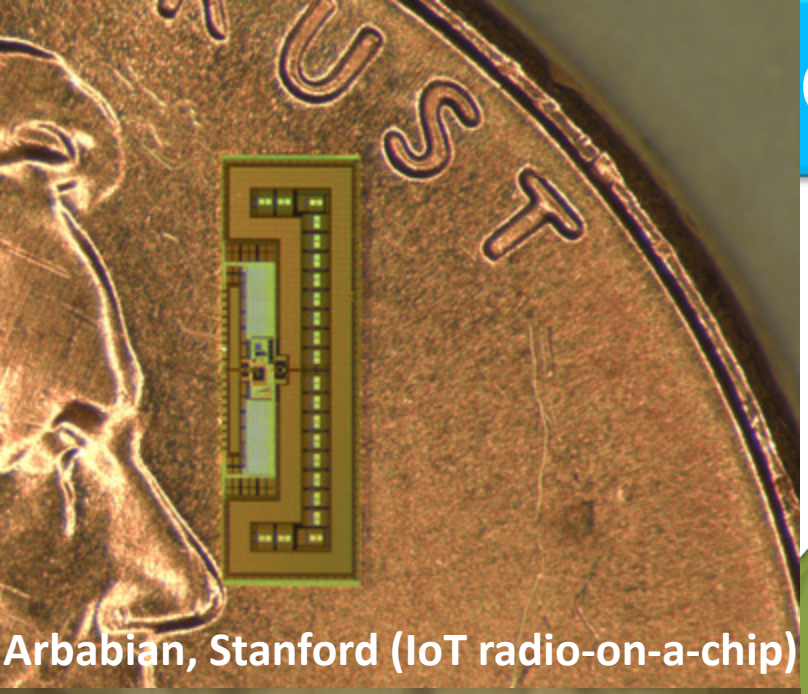
http://iot.ieee.org/images/files/newsletter/201409-barnaghi-figure1.png

# THE NETWORKED PHYSICAL WORLD

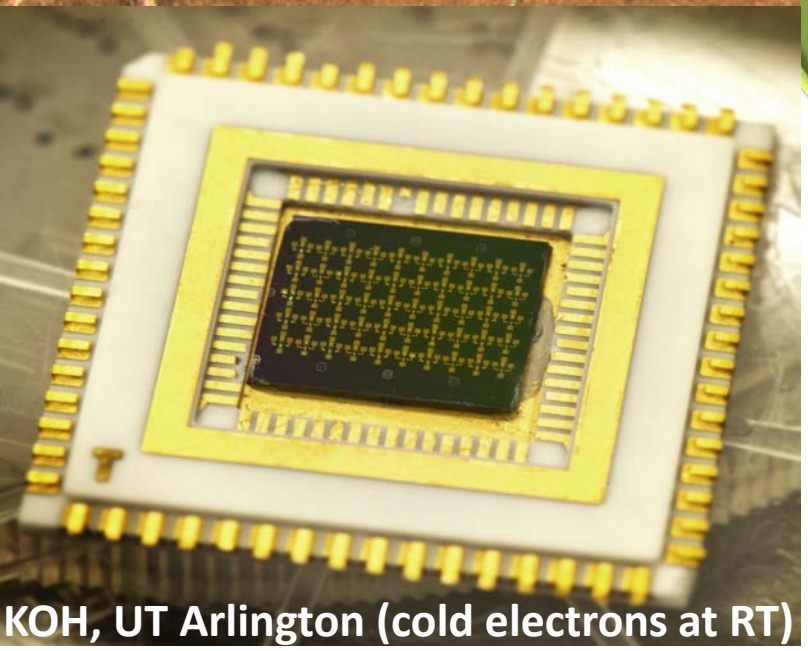



# ECONOMIC GROWTH ENGINES

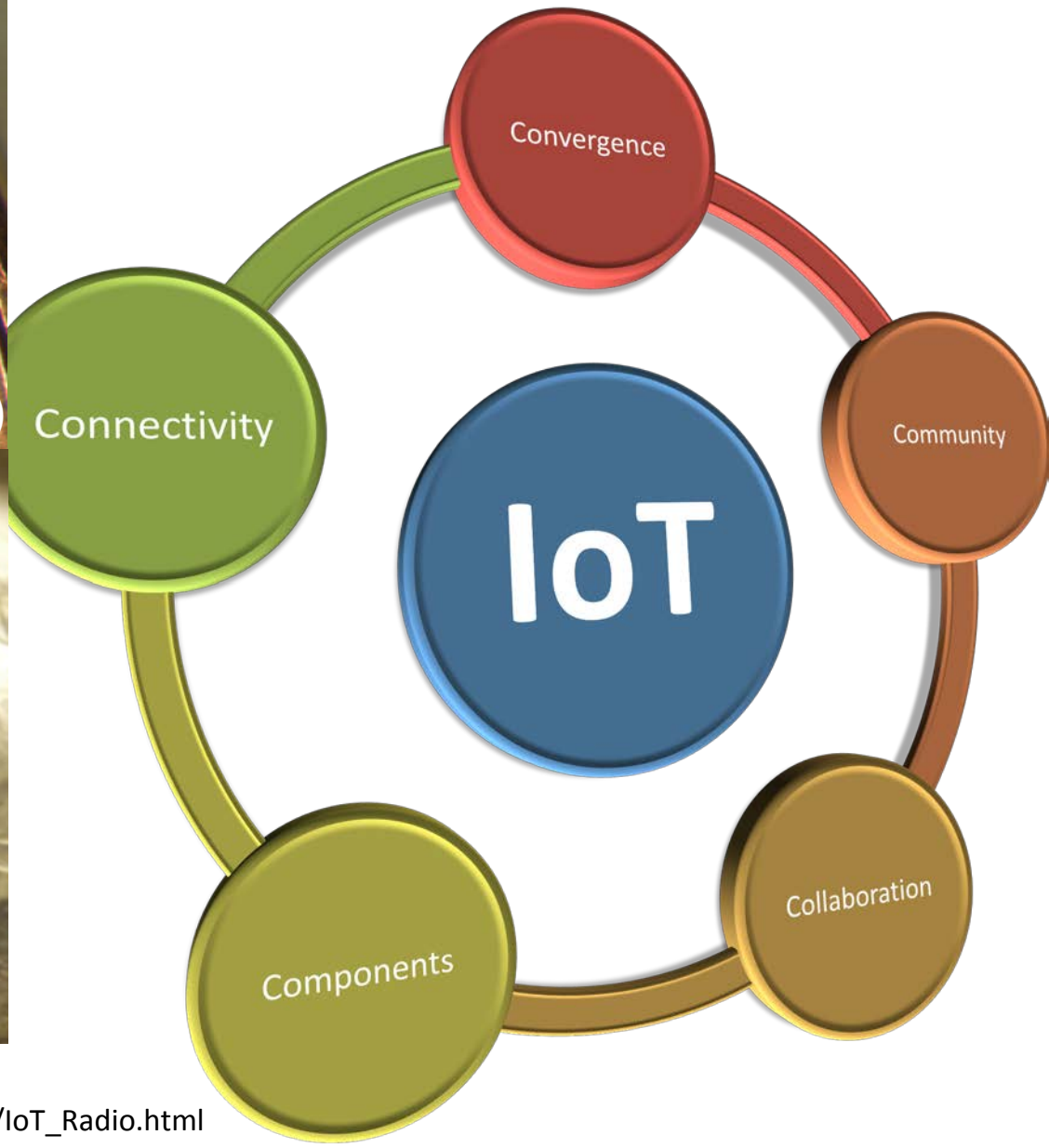
# COMBINE THE TWO 2 CONNECT



Arbabian, Stanford (IoT radio-on-a-chip)



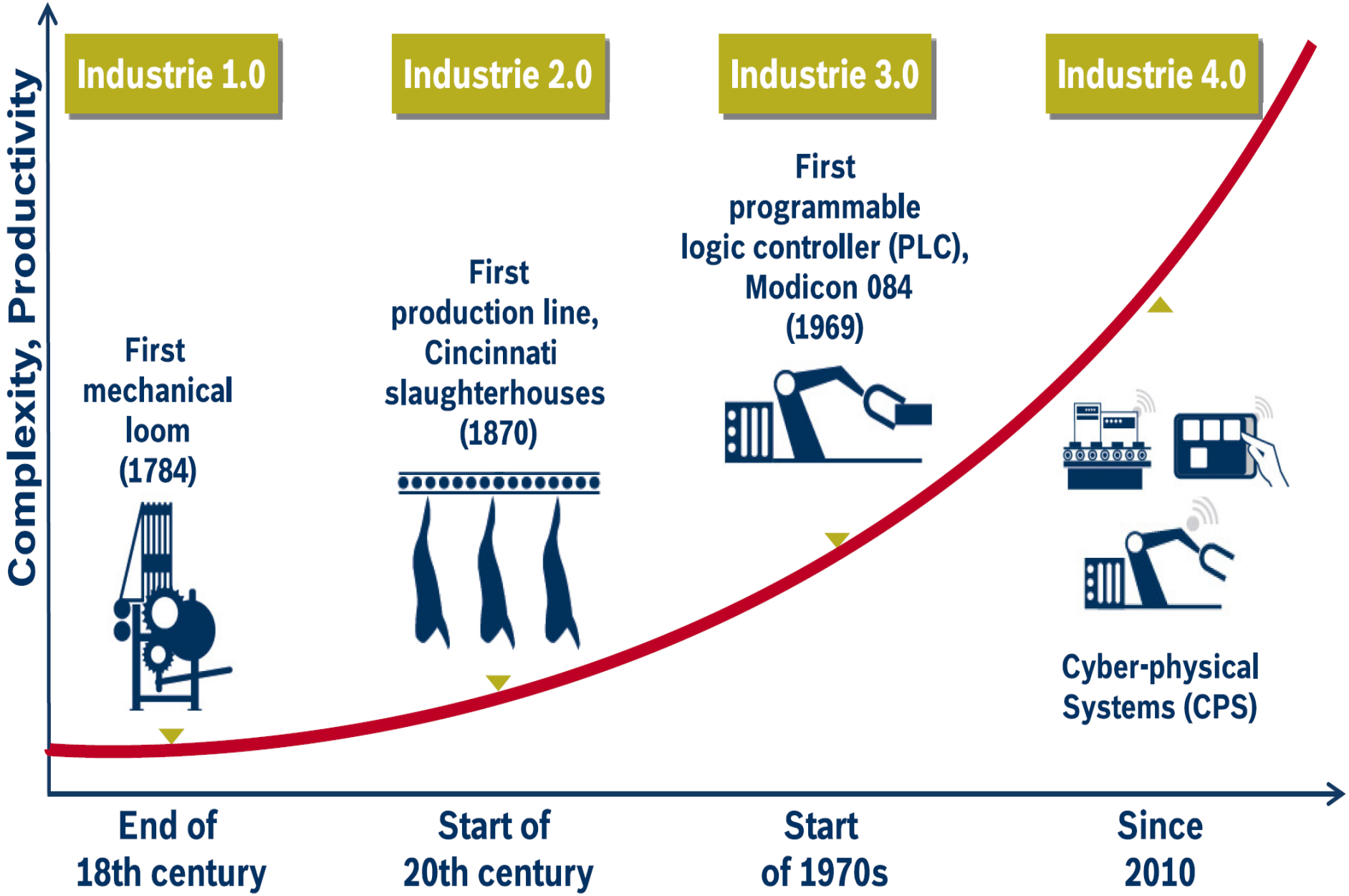
KOH, UT Arlington (cold electrons at RT)



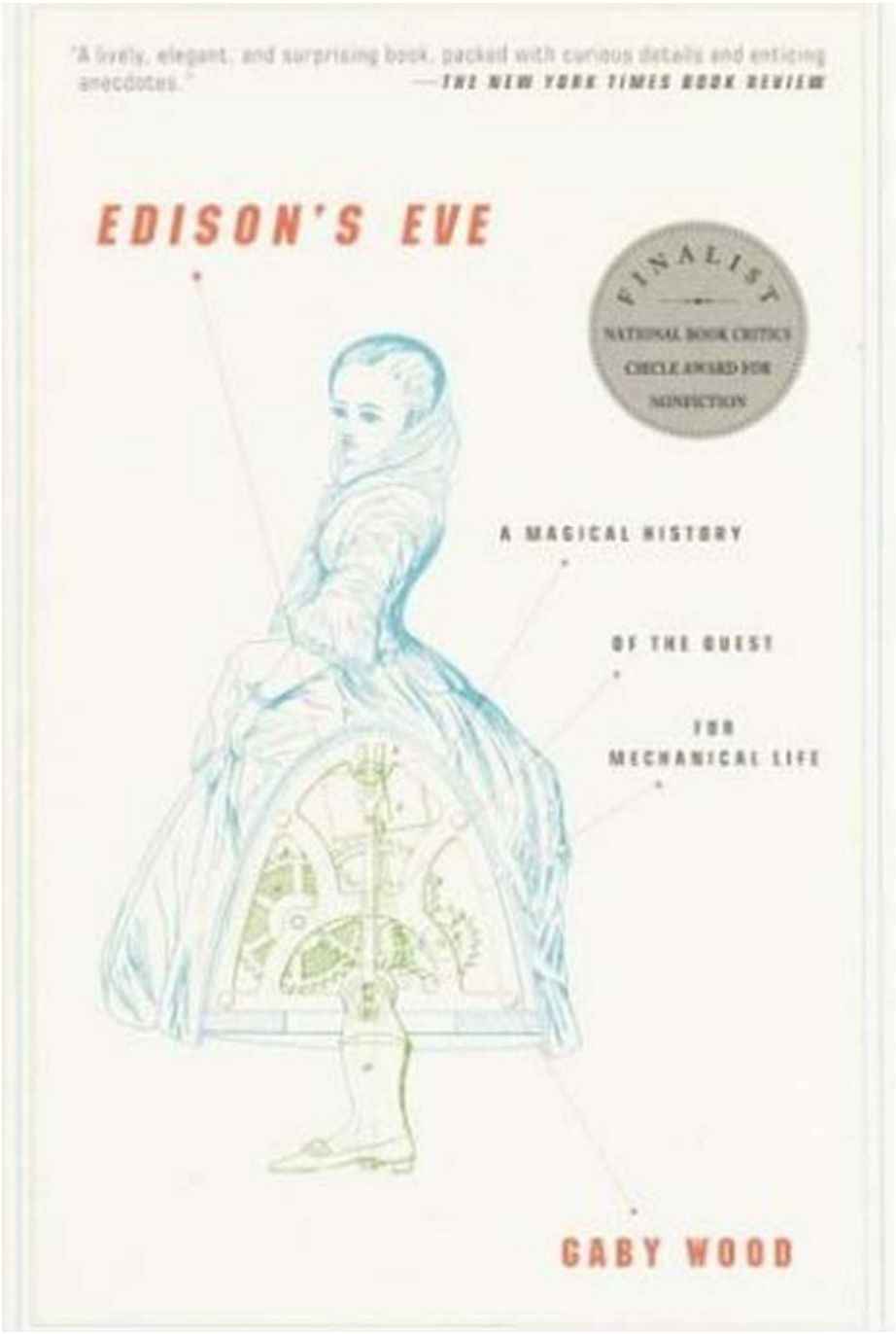

KOH●DOI: 10.1038/ncomms5745

ARBABIAN●http://web.stanford.edu/~arbabian/Home/IoT_Radio.html

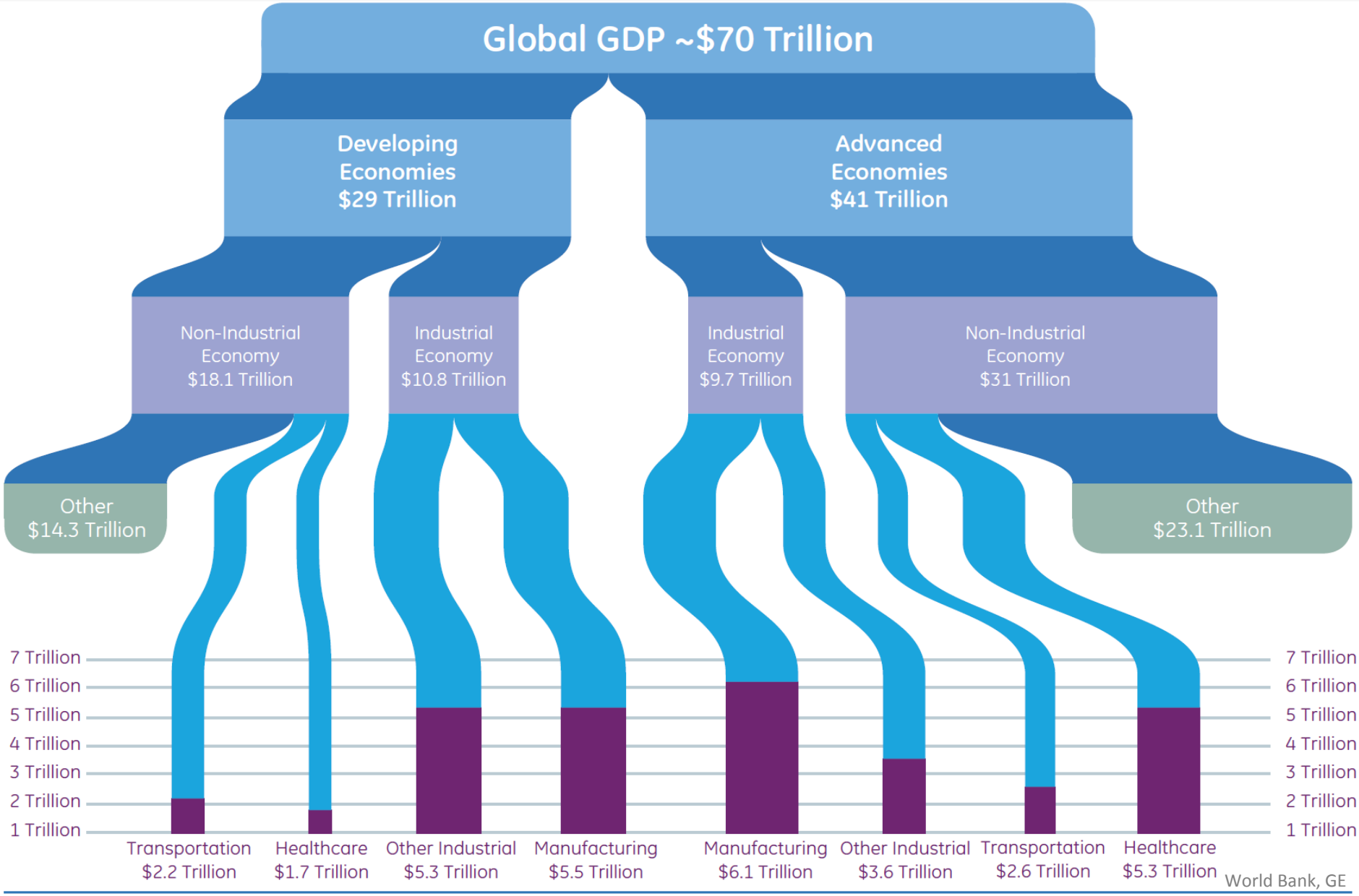
# THEN PREPARE FOR THE NEXT REVOLUTION



# A Brief History of Automaton



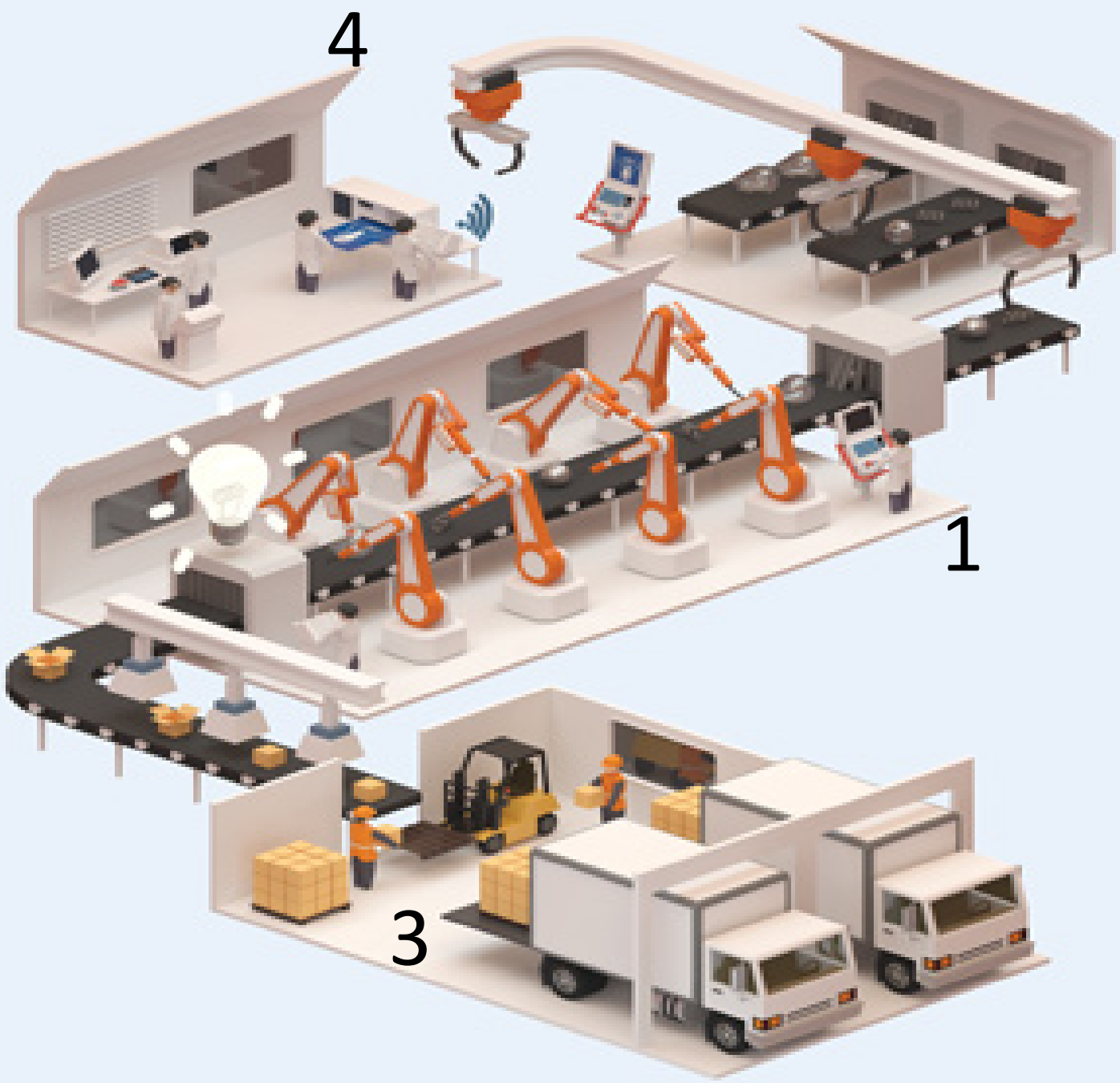
# Projected Economic Impact of The Industrial Internet




**Industrial Internet opportunity ( $32.3 Trillion ) 46% share of global economy today**

Design to Delivery

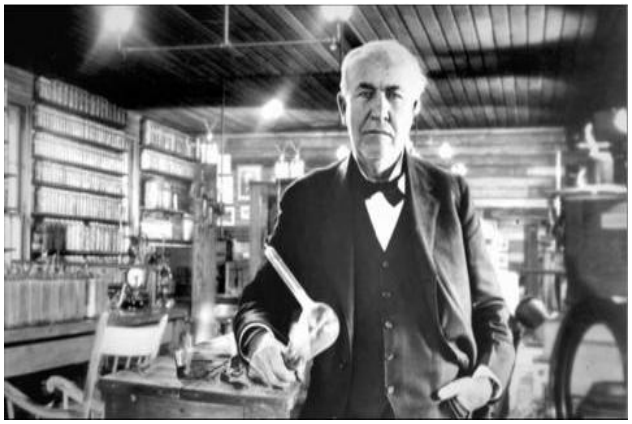
# D2D



# Mission

# Disrupt

## Total energy under the curve



*The concept of energy under the curve is directly analogous to an economy's money supply at a given time. Both the energy and the money supply are known amounts. The money is going to be spent by someone (device is going to output its energy). The key is for the money to be spent where it has the most benefit (the light bulb must produce visible light).*

In engineering parlance, there is a phrase called 'energy under the curve.' This refers to the total energy output of a device—light bulb, acoustic transducer —as measured on a graph across a range of frequencies. While every effort is made to maximize the amount of energy output from that device, in the end it's still a finite amount. The key to best performance is getting the device to deliver energy that is ***usable***. A light bulb may produce x lumens of energy, but it won't do much good if its output is predominately at ultraviolet frequencies that are invisible to the human eye. An acoustic transducer (speaker) can be modified to produce more or less energy at different frequencies, but the total acoustic energy produced by that specific speaker is finite. The engineers can move the energy output from one frequency region to another, but the 'total energy under the curve' remains the same. The key to a speaker's useful performance, of course, is for it to produce its energy at frequencies that are audible and useful to humans, not bats.

www.americanthinker.com/2004/09/the_light_bulb_economy.html

# Re-engineer Transaction Cost

## TRANSACTION COST THEORY

Ronald Coase (1937) posed two Nobel-prize puzzles :

- Why do any firms emerge in a market economy?
- Why not just One Big Firm for whole economy?

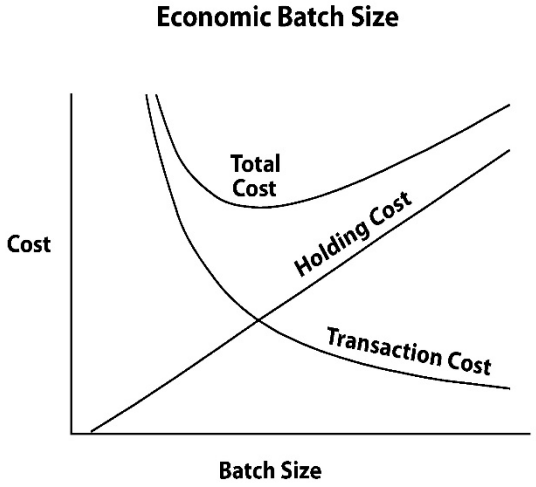
Neoclassical economics treats the firm as a production function that efficiently transforms land, labor & capital inputs into goods & services. Competitive markets coordinate buyer-seller exchanges via price signals.

Coase argued that market mechanism not cost-free, but involves transaction costs: time & money to search for sellers & buyers, negotiate exchange terms, write contracts, inspect results, enforce deals

Firms will emerge if an "economizing" organization can reduce its production + transaction costs < market prices

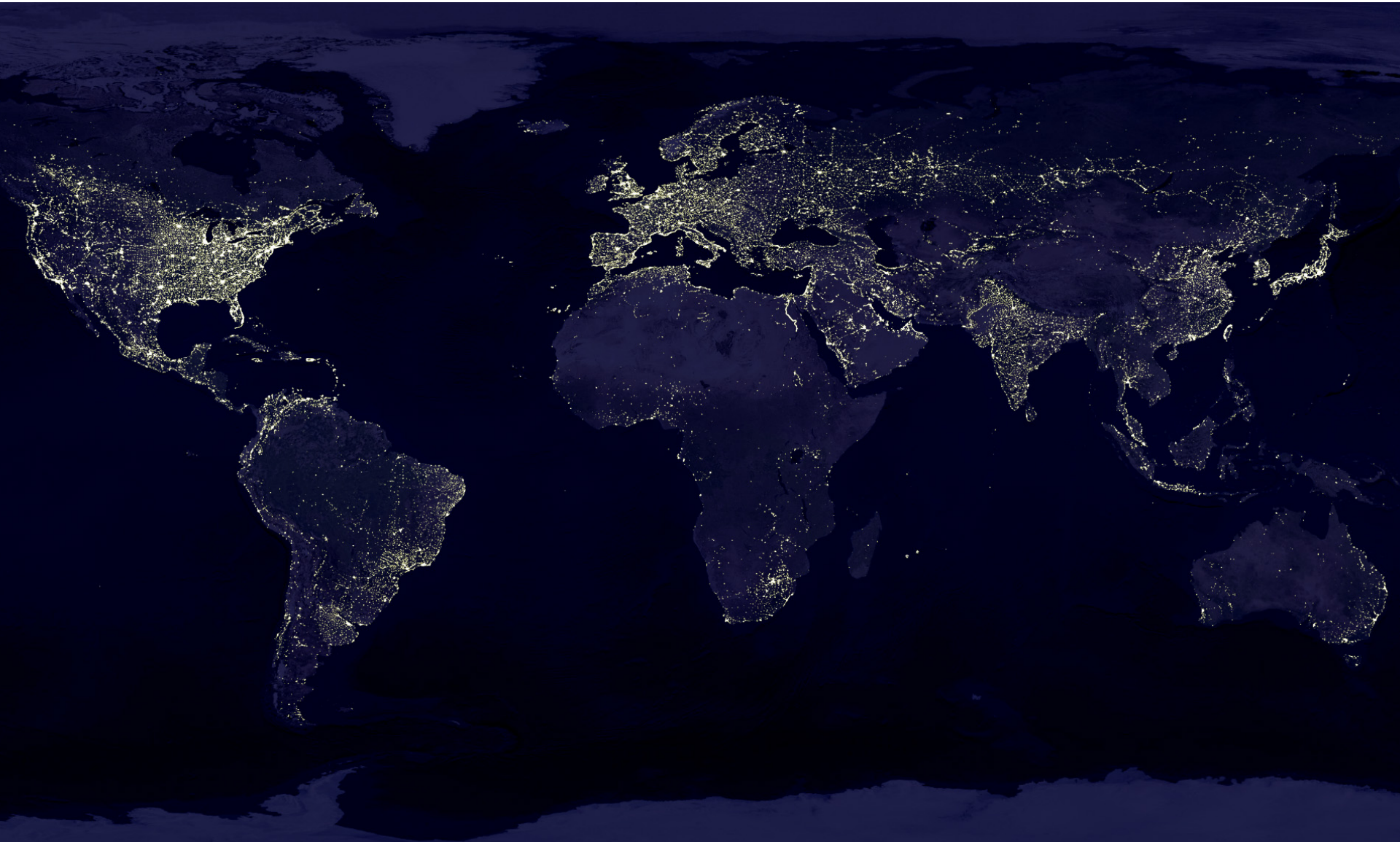
Firm expansion halts when intra-org'l TC > market prices

## Transaction Cost Economics

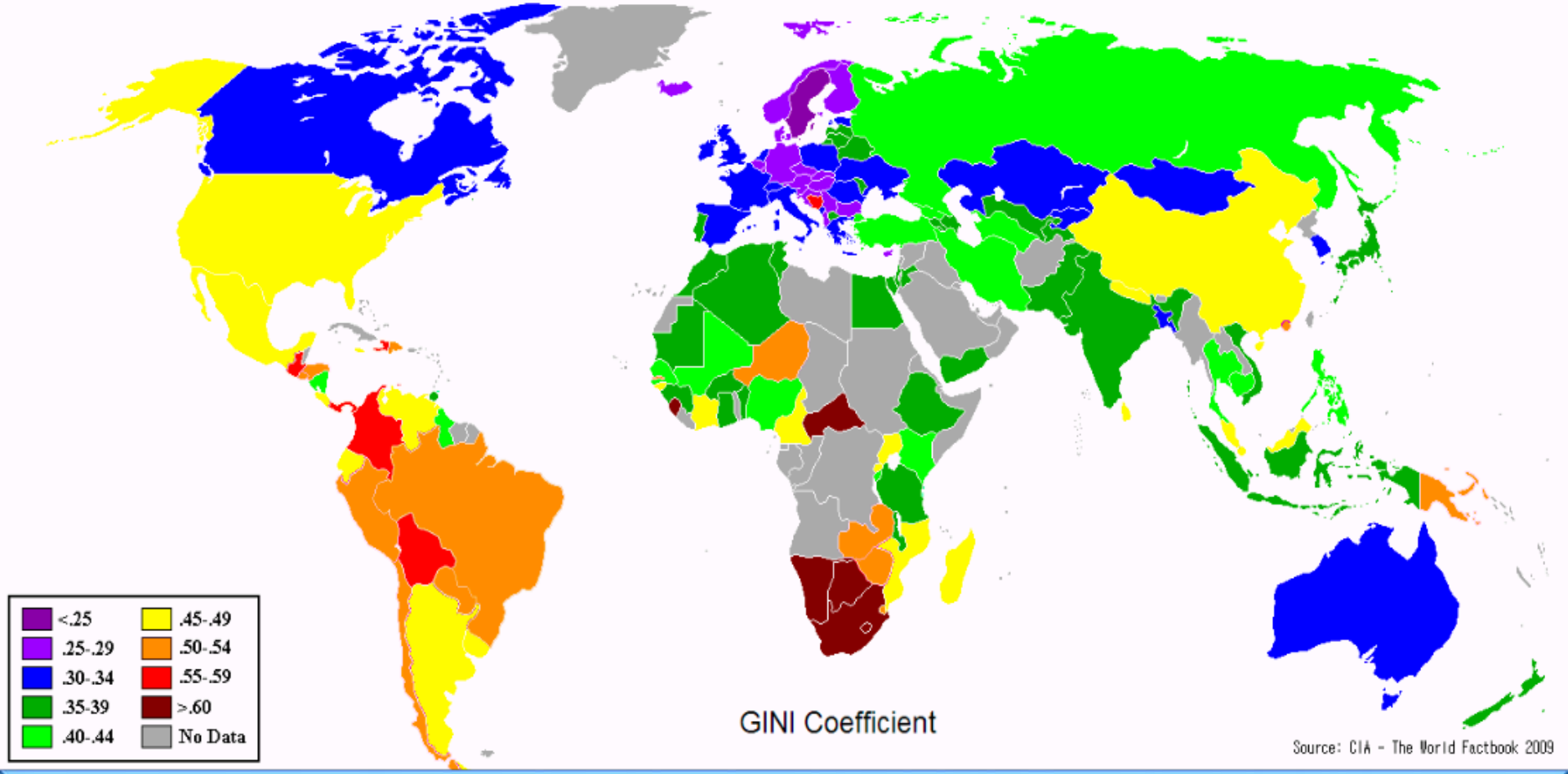



From "The Principles of Product Development Flow," by Donald G. Reinertsen. Celeritas Publishing: 2009. Copyright 2009, Donald G. Reinertsen

# Re-engineer Resource Utilization

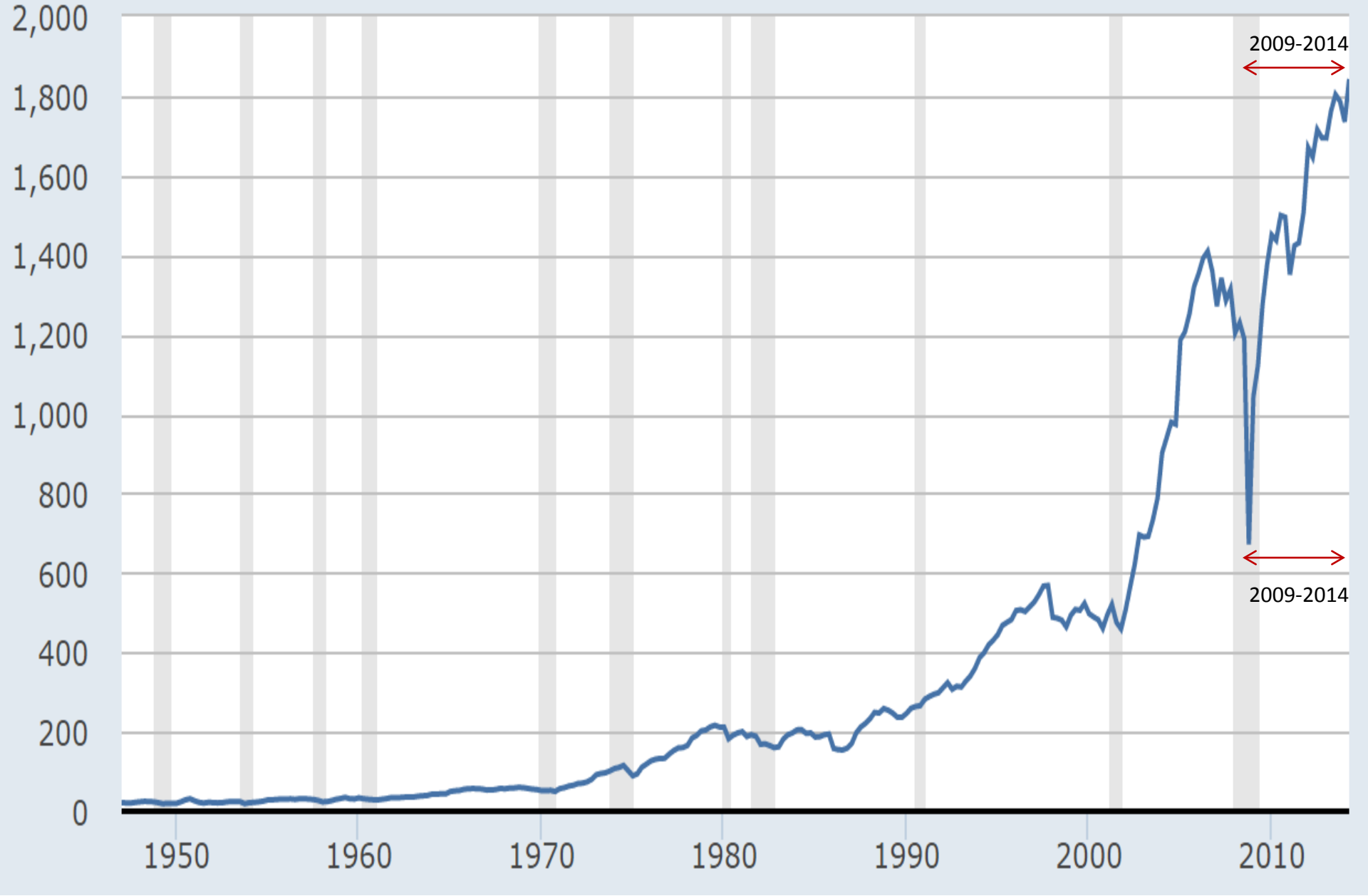


# Re-engineer GINI Coefficient




Gini coefficient measures the inequality among values of a frequency distribution (for example levels of income). Coefficient = zero expresses perfect equality (everyone has an exactly equal income). Coefficient = 1 expresses maximal inequality (where only 1 person has all the income).

# US Corporate Profits after Tax ($B) · Greatest increase in a 5 year period 2009-2014




http://research.stlouisfed.org/fred2/series/CP/

# Child Laborers in India

| | 2001 | 2011 |
|---|---|---|
| Uttar Pradesh | 1.92 million | 0.89 million |
| Andhra Pradesh | 1.36 | 0.4 |
| Rajasthan | 1.26 | 0.25 |
| Bihar | 1.11 | 0.45 |
| Madhya Pradesh | 1.06 | 0.28 |
| West Bengal | 0.85 | 0.23 |
| Karnataka | 0.82 | 0.24 |
| Maharashtra | 0.76 | 0.49 |
| Gujarat | 0.48 | 0.25 |
| Tamil Nadu | 0.41 | 0.15 |

qz.com

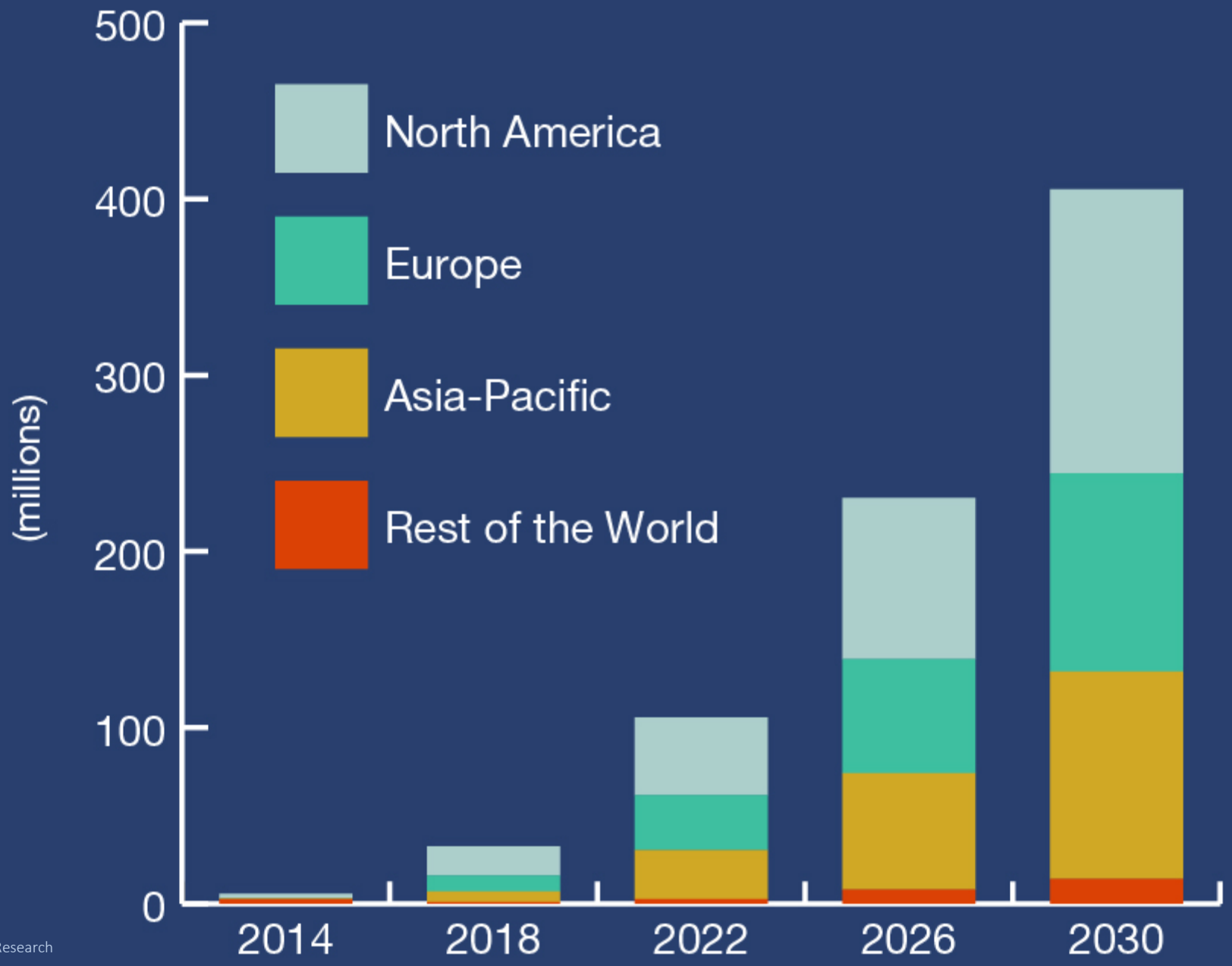
# To Disrupt

Deploy

- Paradox to Paradigms to Platforms ☑ http://bit.ly/MIT-IOT

- Challenges
  - ☑ Autonomous Transportation
  - ☑ Global Smart Cities
  - ☑ Healthcare
  - ☑ Data

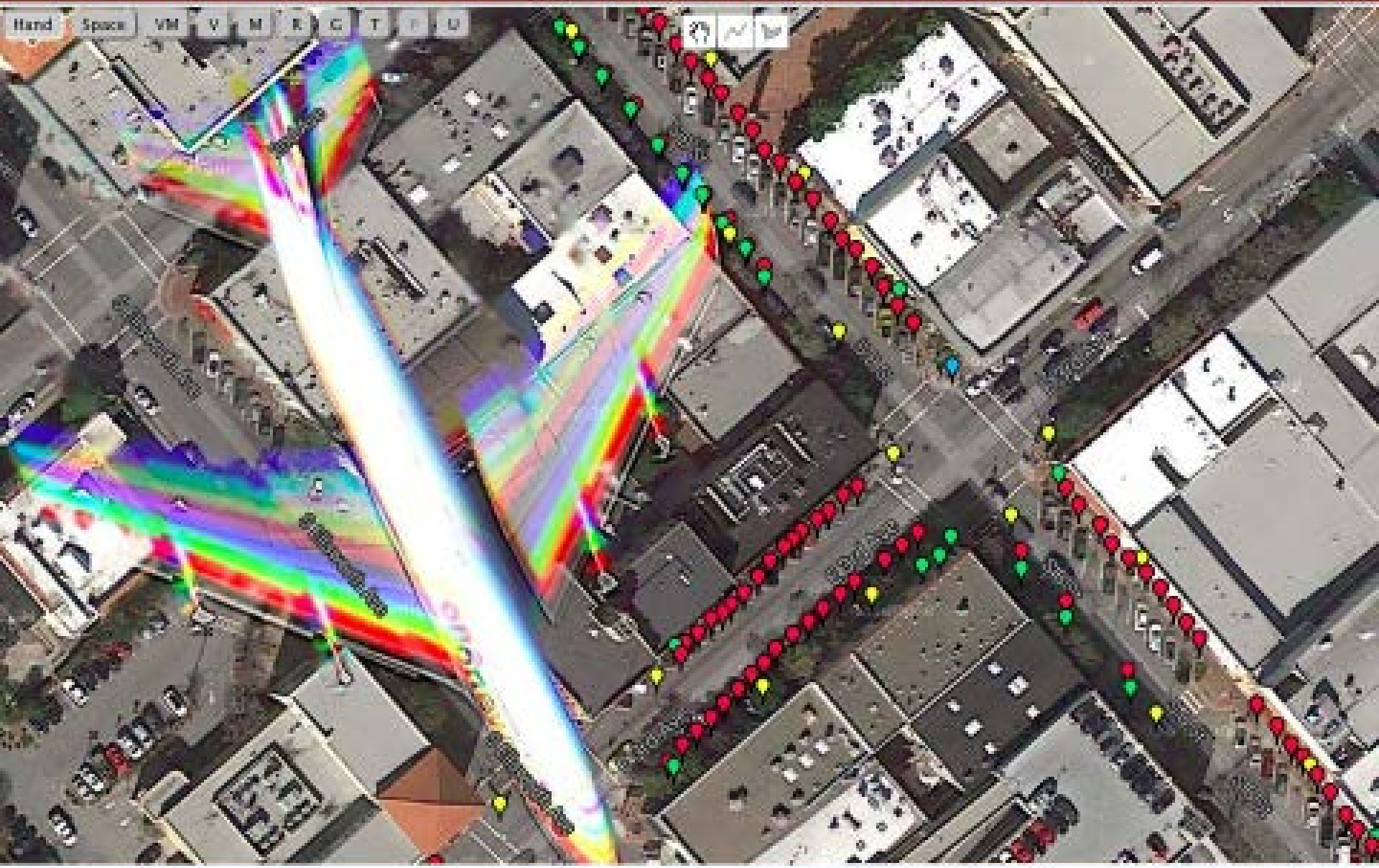
# Forecast → Vehicles with IoT Applications



# Industrial Internet – IoT – Services Ecosystem → Convergence



# Industrial Internet ← IoT Services → Parking Spaces Talks to Cars



Google Earth photo of a plane flying over downtown San Jose, CA. Parking space sensors showing available car parking spaces using Parker™ by Streetline (Photo courtesy of Zia Yusuf, President & CEO, Streetline Inc)

# Goal

Man on the Moon

www.homeofheroes.com/presidents/speeches/kennedy_space.html

# Goal

## "Man on the Moon" Address

**President**
**John F. Kennedy's**

***A Special Address to Congress***
***On The Importance of Space***

**May 25, 1961**

**I therefore ask the Congress, above and beyond the increases I have earlier requested for space activities, to provide the funds which are needed to meet the following national goals:**

**First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish.**

JFK

# Goal

- Deployment of Semi-Autonomous Freight Transportation

# SAFTI

## *Semi-Autonomous Freight Transportation Initiative*

- **Public domain deployment**

  Refrigerated truck transporting cargo containers with perishable grocery arrives at an intermodal operation (for transportation by sea or air or rail or cross-dock)

  – *Driver disembarks at a Hilton (prior to security perimeter)*

  – *Truck shifts to autonomous mode and enters secure zone*

  – *Unloads / uploads cargo (informs supply chain partners)*

  – *Exits secure zone and arrives at Hilton to pick-up driver*

  – *Truck driver continues to warehouse / distribution center*

# SAFTI

## *Semi-Autonomous Freight Transportation Initiative*

Decompose scenario to broad deployment packages (BDP)

– TRUCKS

– INFRASTRUCTURE

– TRANSPORTATION OF DATA

# SAFTI

## *Semi-Autonomous Freight Transportation Initiative*

### Decompose scenario to broad deployment packages (BDP)

- *The semi-autonomously operable fleet of trucks or lorries (approx 1000-2000 physical units of freight carrier vehicles) invulnerable to cyber attacks.*
- *Operational infrastructure deployment in an environment where roads, traffic lights, bridges, tunnels, housing zones, pedestrian crossings are equipped to communicate (GIS, GPS, RF, DSRC) with autonomous objects as well as autonomous vehicle operation with mixed vehicles (eg FedEx). Transmission and analysis of data from users and operators (supply chain of goods, status of roads/bridges and cybersecurity) per SAE.J2735/J.2745*
- *Intermodal port operator environment where these autonomous vehicles interact with humans and non-autonomous vehicles. Robotic handling of cargo containers (off-load, re-load) between ships to rail head and ground transportation and air cargo). Data transmission and monetization of pay per use analytics from users and operators (supply chain of goods, status of roads/bridges, security of goods in containers, micro-localization and highly granular identification of objects by products, containers, vehicles, distribution, logistics handling, DHS CBP compliant e-manifest and SOX409)*

# Further decomposition of BDP

***Let us break down each work package to large segments***

# SAFTI

## *Semi-Autonomous Freight Transportation Initiative*

## Decompose "goal/scenario" to broad deployment package (BDP)

- *The semi-autonomously operable fleet of trucks or lorries (approx 1000-2000 freight carrier vehicles) invulnerable to cyber attacks.*
  - *Calls for global partnership and globally interoperable standards*
  - *Pre-competitive standards based approach to vehicle "brain"*
  - *Semi-autonomous "brain" of the vehicle (robotic navigation) should be able to operate in Pittsburgh, Long Beach, Schiphol or Kaohsiung. In other words, traffic signal compliance in any country and collision avoidance in any geographic terrain under diverse range of weather.*
  - *Standard cybersecurity for run-time intruder detection and repulsion*
  - *Data flow/analytics about vehicle, environment and infrastructure*
  - *Network standards and compliance – worldwide interoperability*
  - *Funded by global partners*

# SAFTI

## *Semi-Autonomous Freight Transportation Initiative*

## Decompose "goal/scenario" to broad deployment package (BDP)

- *Operational infrastructure deployment in an environment where roads, traffic lights, bridges, tunnels, housing zones, pedestrian crossings are equipped to communicate (GIS, GPS, RF, DSRC) with autonomous objects as well as autonomous vehicle operation with mixed vehicles (eg Fedex ground hub). Transmission and analysis of data from users and operators (supply chain, status of roads/bridges, cyber-security) using interoperable standards (SAE).*
  - *Communications protocols with interoperable standards and cybersecurity*
  - *Physical infrastructure upgrades and equipment installation / monitoring*
  - *Logistics operators as a part of the real-world deployment to provide access to non-autonomous fleet of trucks/lorries for data acquisition*
  - *Data convergence from agencies dealing with traffic, weather, emergency*
  - *Monetization incentives for contribution of data and pay per use analytics*
  - *Deployment funded by each nation or country on their own soil but uses the semi-autonomous fleet of vehicles developed as a global partnership*

# SAFTI

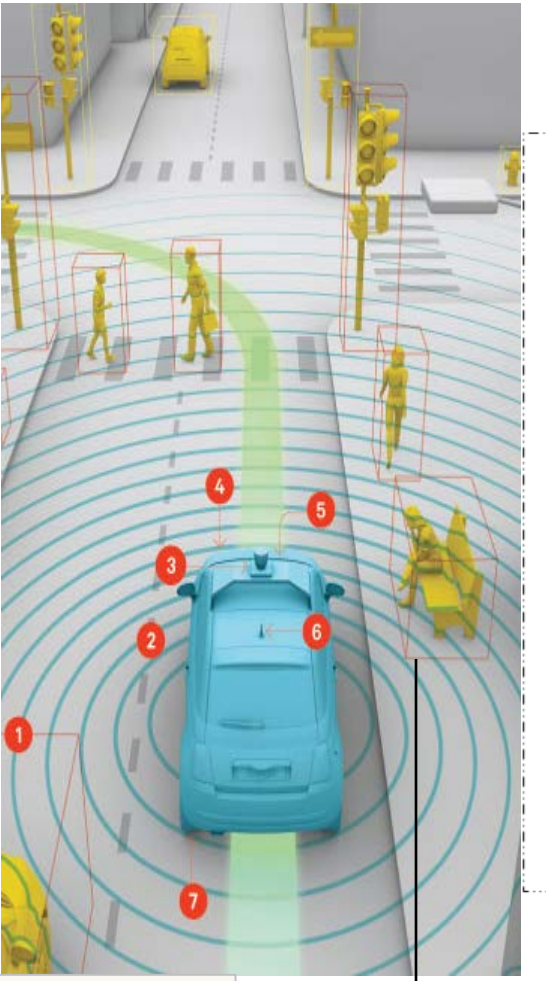
## *Semi-Autonomous Freight Transportation Initiative*

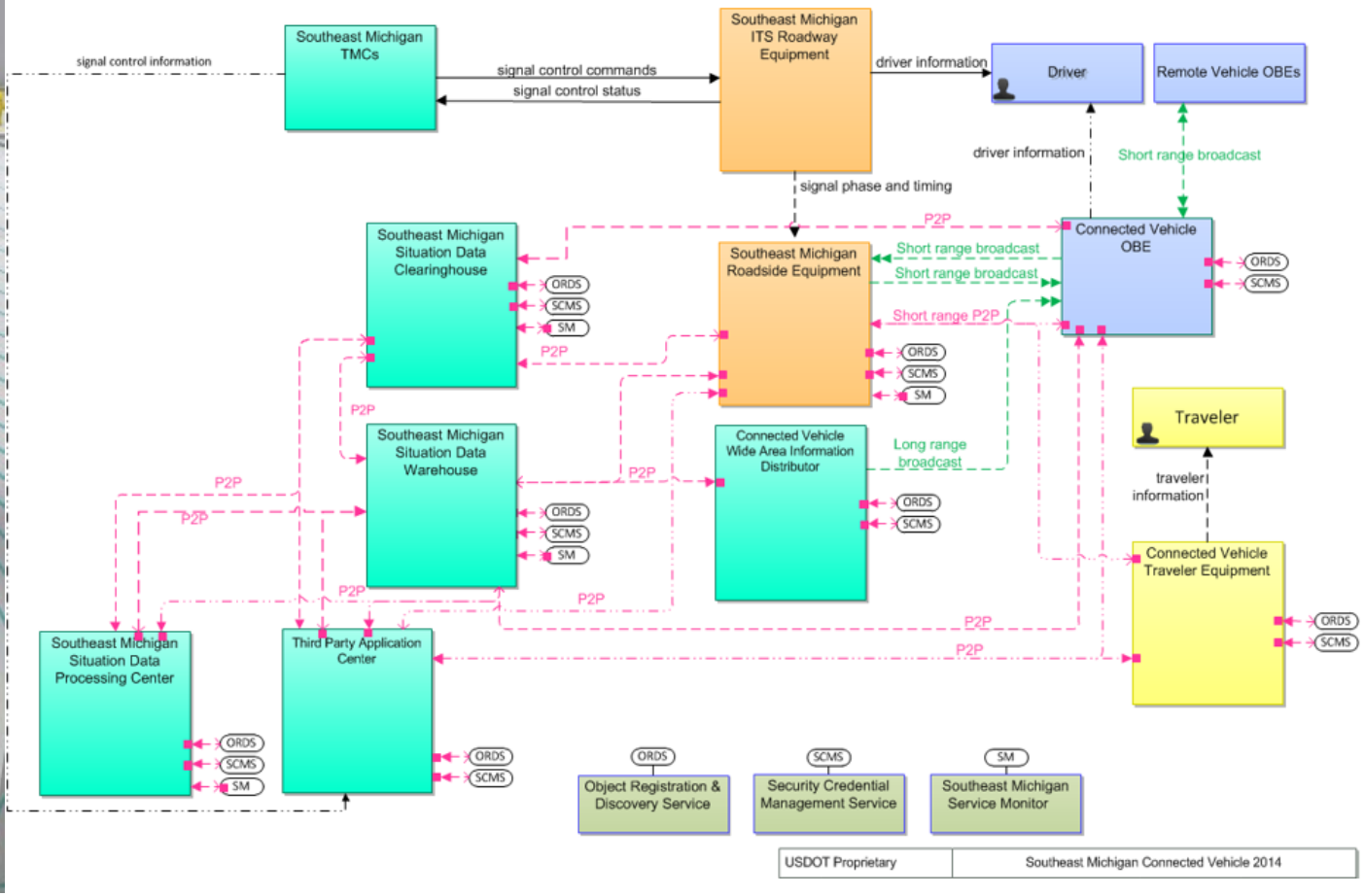
## Decompose "goal/scenario" to broad deployment package (BDP)

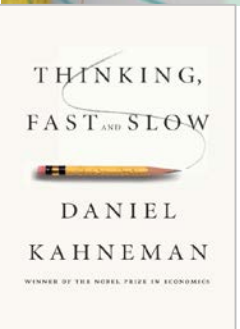
- *Intermodal port operator environment where these autonomous vehicles interact with humans and non-autonomous vehicles. Robotic handling of cargo containers (off-load, re-load) between ships to rail head and ground transportation (and air cargo). Data transmission and monetization of pay per use analytics from users and operators (supply chain of goods, status of roads/bridges, security of goods in containers, micro-localization and highly granular identification of objects by products, containers, vehicles, distribution, logistics handling, DHS CBP compliant e-manifest, regulatory framework eg SOX-409 and other country specific regulations)*

  - *Funded by each nation on their soil as a joint effort by an air/sea port operator + group lead with technological expertise*
  - *Robotic handling, precision transfers and secure transport A to B to C (ship to rail)*
  - *Highly granular data acquisition from operation for commercial visibility and transparency to enhance security as well as status of goods (perishable food)*
  - *Data analytics & monetization model as the business driver for data exchange*

# Hellabytes of data per second from deployment of autonomous vehicles






Uncertainty Estimation?

# Temporary Summary

# Semi-Autonomous Freight Transportation Initiative

# SAFTI

The current goal of this initiative is
[1] to create a coalition of distinguished academia, global corporations, local standards organizations and government agencies
[2] to catalyze a highly credible global public-private partnership (PPP)
[3] to collectively work to deploy and integrate semi-autonomous freight vehicles for intermodal cargo operations within the business ecosystem of freight transportation.

Project commences when pre-competitive global PPP begins construction of ~1000 units based on standards or interoperable standards (old, new, to be designed) which will be tested for operational safety, cyber security and communications compatibility.

Semi-autonomous vehicles produced by the global PPP will be deployed by country specific PPP on public roads in different geographies (US, EU, APAC) to integrate with existing freight transportation operations. Pre-deployment of local infrastructure (global standards of communications, networks, data) for semi-autonomous vehicle integration.

# Temporary Evidence

## Semi-Autonomous Freight Transportation Initiative

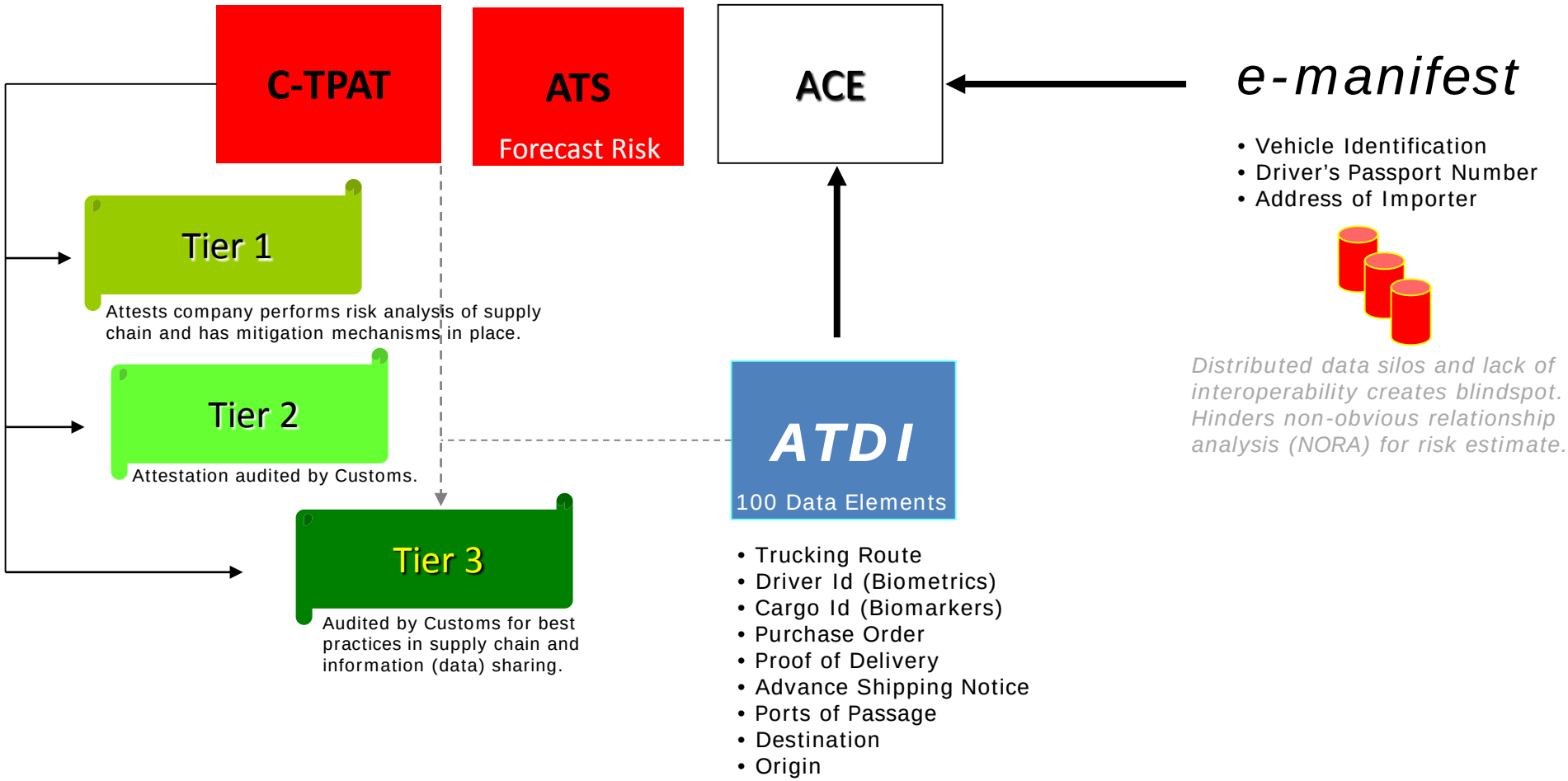
# SAFTI


http://bit.ly/MB-AutoTruck


Ecosystem Example

*Homeland Security*

# Autonomous Transportation ● Operation Safe Commerce



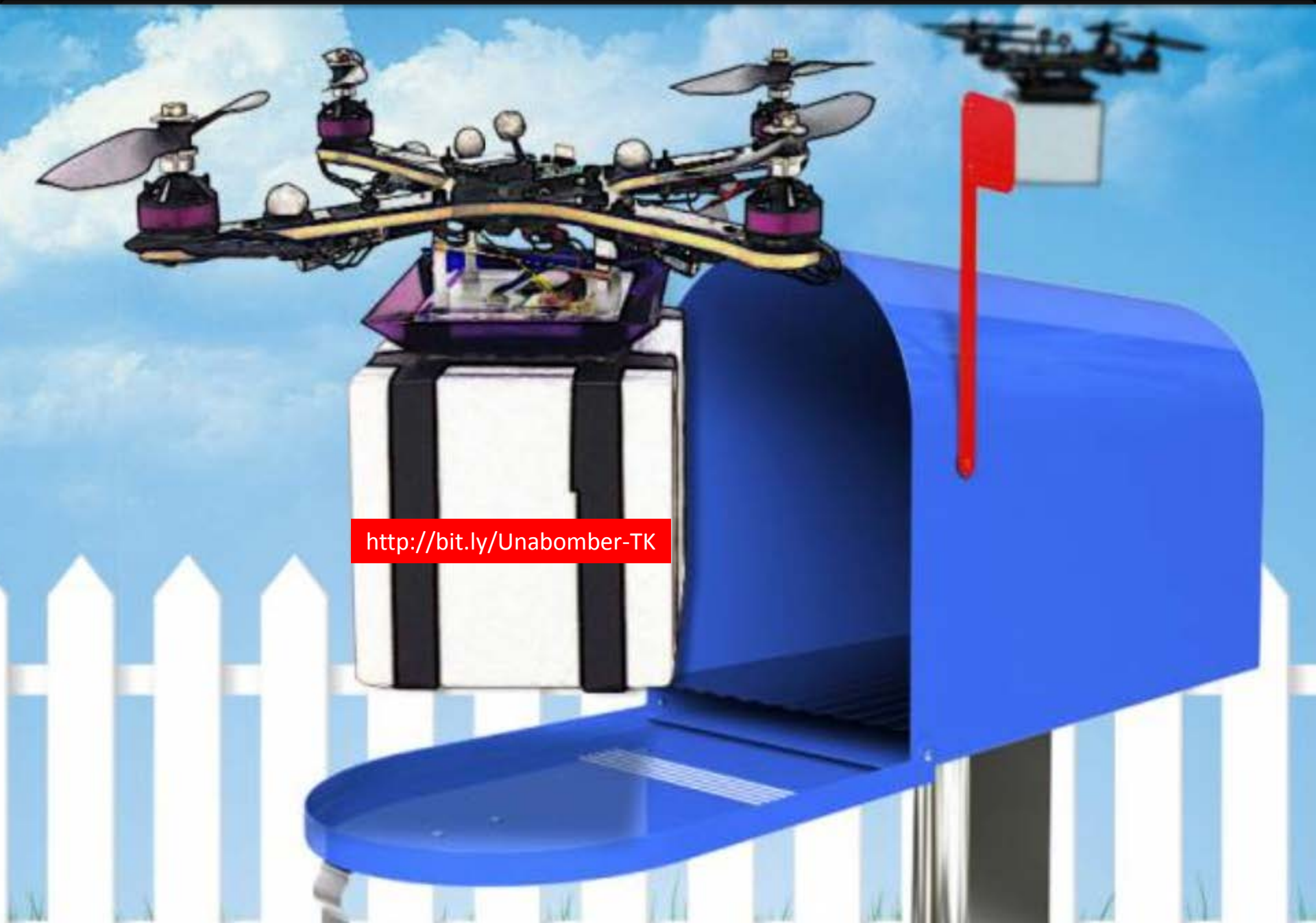

C-TPAT > Customs-Trade Partnership Against Terrorism
ACE > Automated Commercial Environment (the enterprise system equivalent)
ATDI > Advanced Trade Data Initiative (necessary for C-TPAT Tier 3)
ATS > Automated Targeting System (in operation since 1990's)

# SAFTI

Ecosystem Example

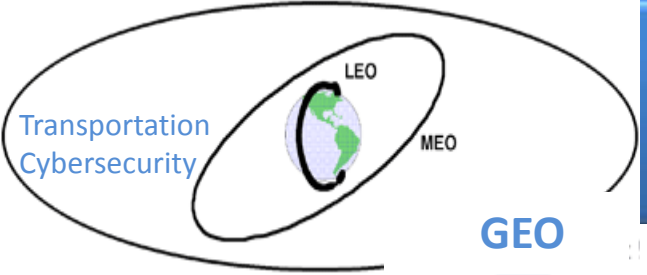
*Network Disruption*

# THEODORE KACZYNSKI'S 'DRONACHARYA' DELIVERS TO YOUR DOOR-STEP er MAIL BOX



# How baby-sitting may be automated in the future …

# What happens if the network is disrupted ?

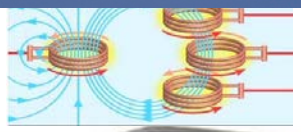



3

4

1

2



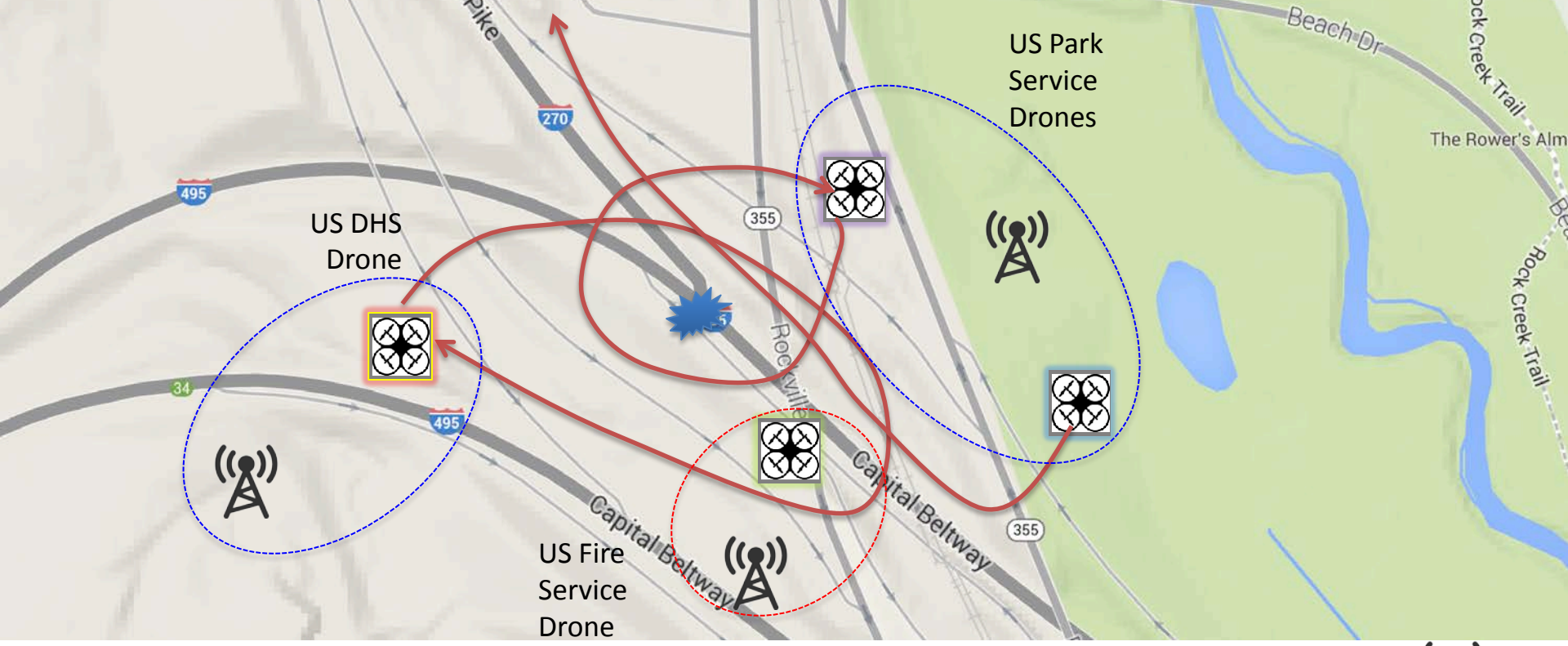


5

## Truck equipped with **Droneport**

- [1] Drones on board using HACMS and fitted with UWB transceivers to create *ad hoc* radio network
- [2] Roof-top wireless electricity charging pad for droneport provided by WiTriCity
- [3] Drones transmit signal to LEO, MEO, HEO or GEO satellites in range
- [4] Satellite re-transmits to safe zones for communication / update
- [5] Responds with message and/or guidance to autonomous vehicle

# Terrestrial Transportation – Emergency “Crash to Care” Response System


US Park
Service
Drones
US DHS
Drone
US Fire
Service
Drone
Capital Beltway
Capital Beltway
Rock Creek Trail
Beach Dr
The Rower's Alm
270
495
355
34
Time, Sensors, Network
& Data Synchronization


Mobile Time Synchronization
NSF Funded Grand Challenge
Announced on June 13, 2014

Approved for OTI




News
News From the Field
For the News Media
Special Reports
Research Overviews
NSF-Wide Investments
Speeches & Lectures
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Chemistry & Materials
Computing
Earth & Environment
Education
Engineering
Mathematics
Nanoscience
People & Society
Physics

Email Print

Press Release 14-074

# Revolutionizing how we keep track of time in cyber-physical systems

**New five-year, $4 million Frontier award aims to improve the coordination of time in networked physical systems**


NSF announces five-year, $4 million award to tackle the challenge of time in cyber-physical systems.
Credit and Larger Version

**June 13, 2014**

The National Science Foundation (NSF) today announced a five-year, $4 million award to tackle the challenge of synchronizing time in cyber-physical systems (CPS)--systems that integrate sensing, computation, control and networking into physical objects and infrastructure.

Examples of cyber-physical systems include autonomous cars, aircraft autopilot systems, tele-robotics devices and energy-efficient buildings, among many others.

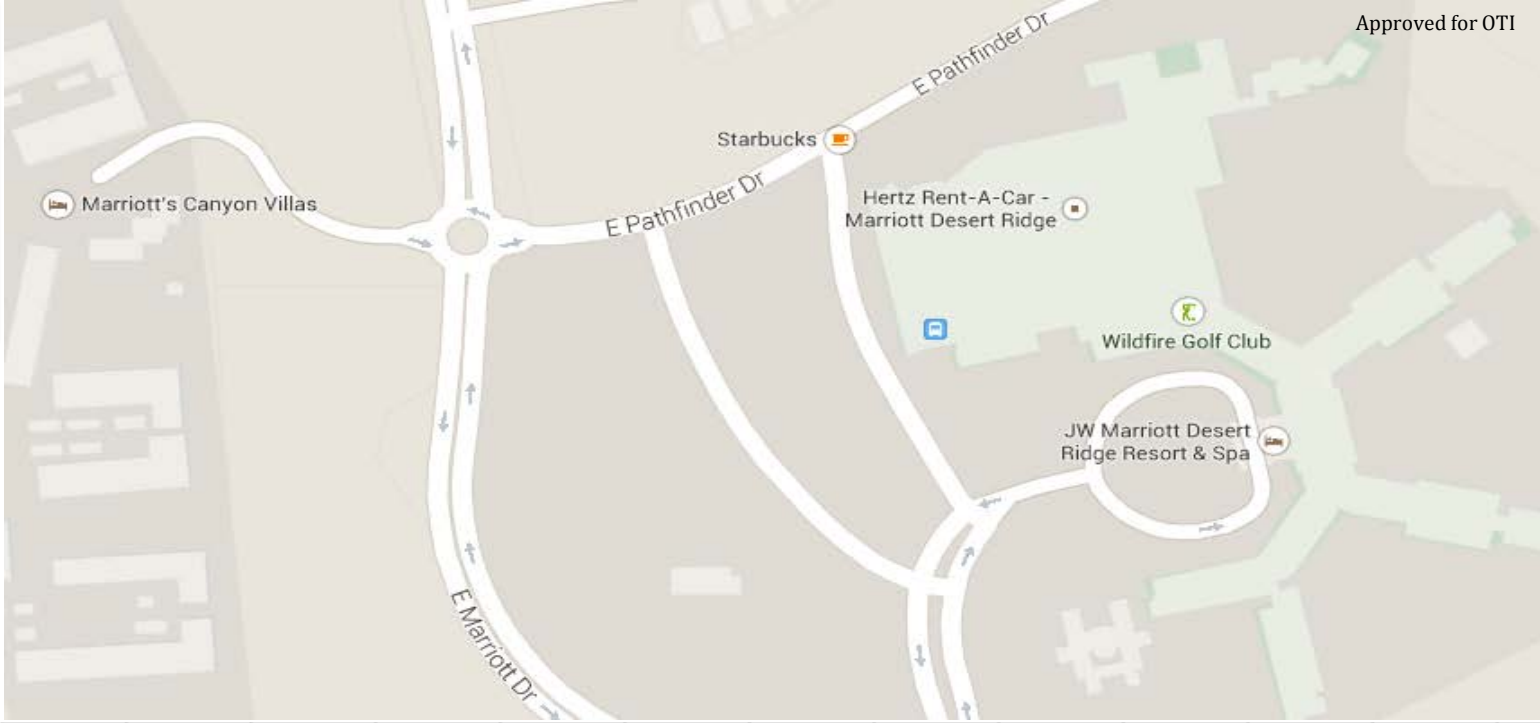
The grant brings together expertise from five universities and establishes a center-scale research activity to improve the accuracy, efficiency, robustness and security with which computers maintain knowledge of time and synchronize it with other networked devices in the emerging "Internet of Things."

Time has always been a critical issue in science and technology. From pendulums to atomic clocks, the accurate measurement of time has helped drive scientific discovery and engineering innovation throughout history. For example, advances in distributed clock synchronization technology enabled GPS satellites to precisely measure distances. This, in turn, created new opportunities and even entirely new industries, enabling the development of mobile navigation systems. However,

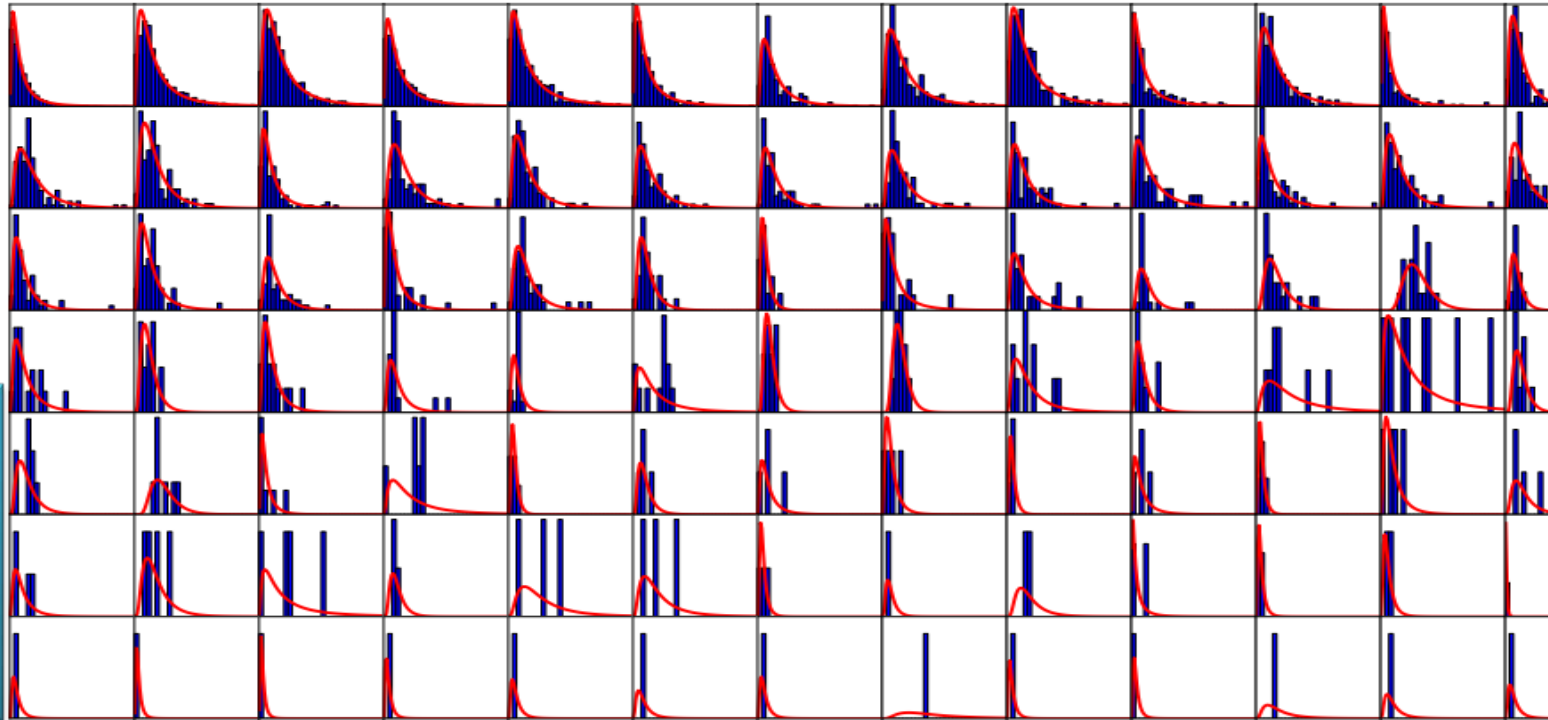

Ecosystem Example

*Autonomous Vehicle Guidance*

# Streets




# Streetlets



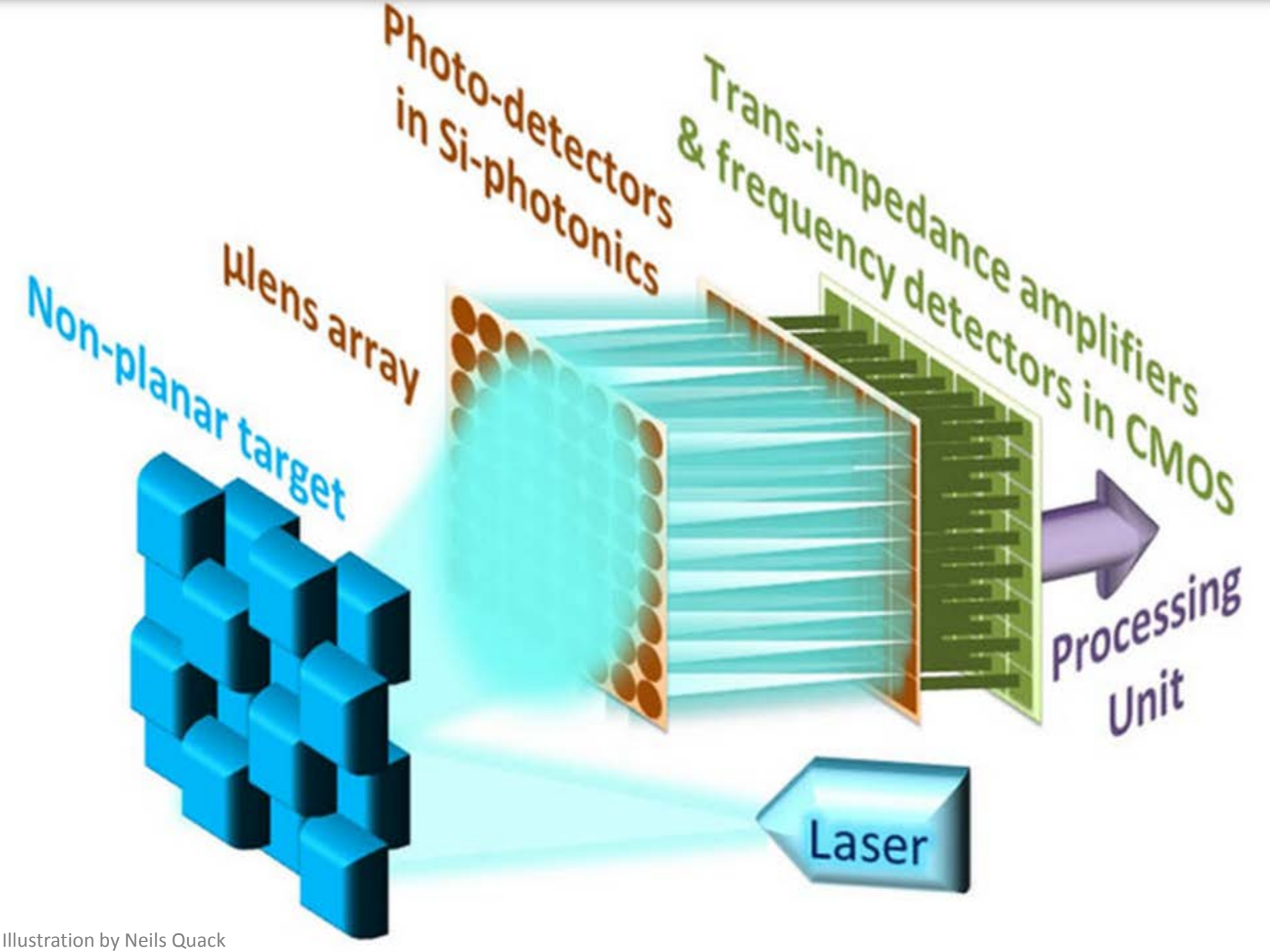
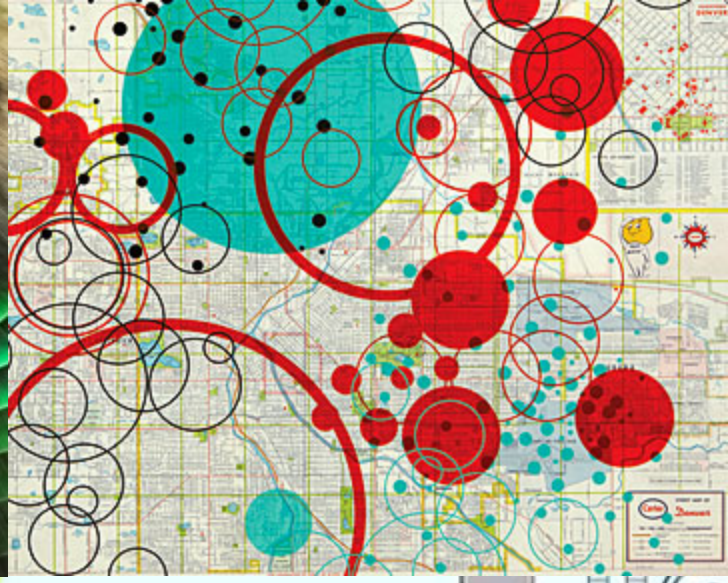
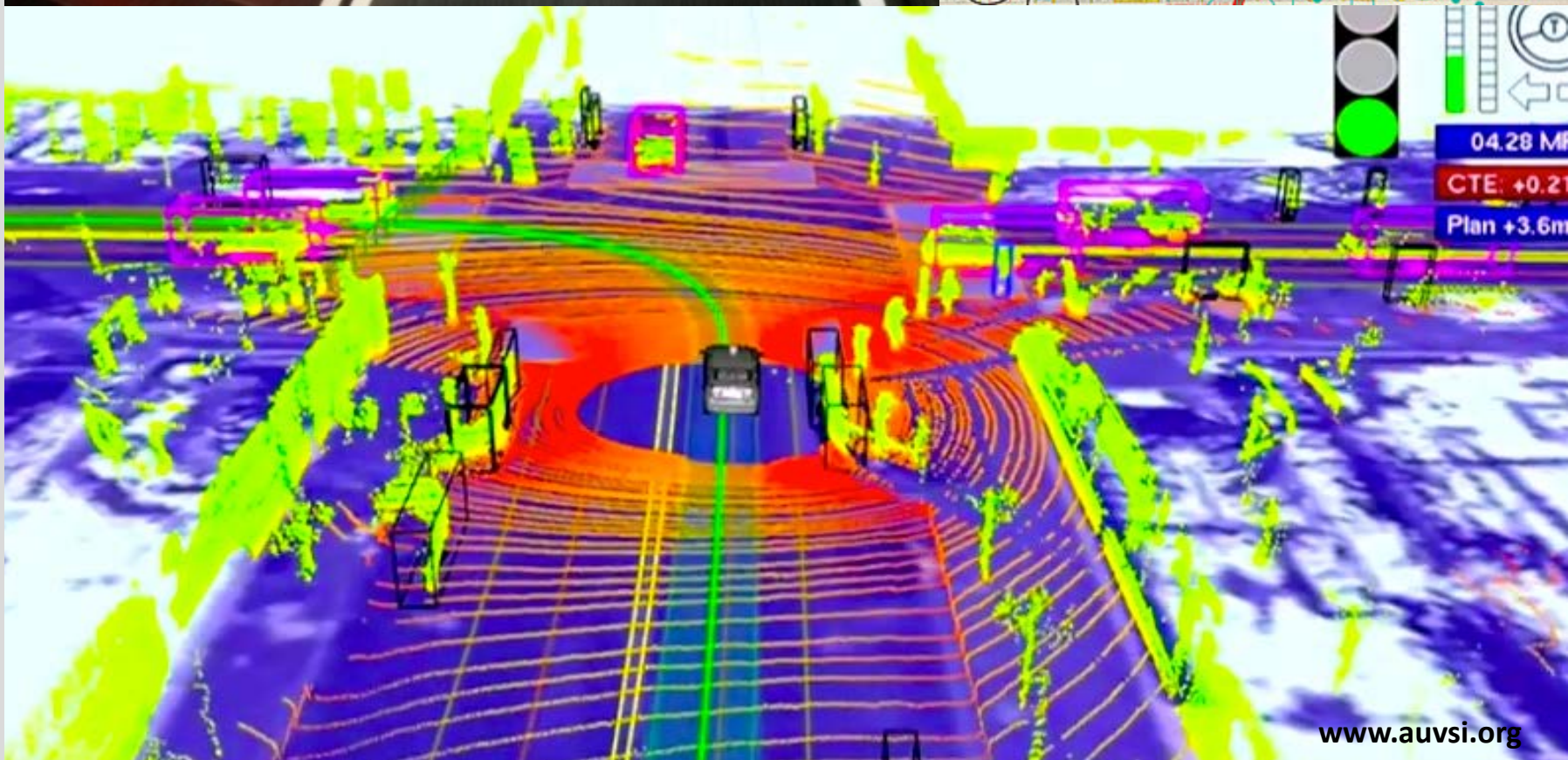



Illustration by Neils Quack

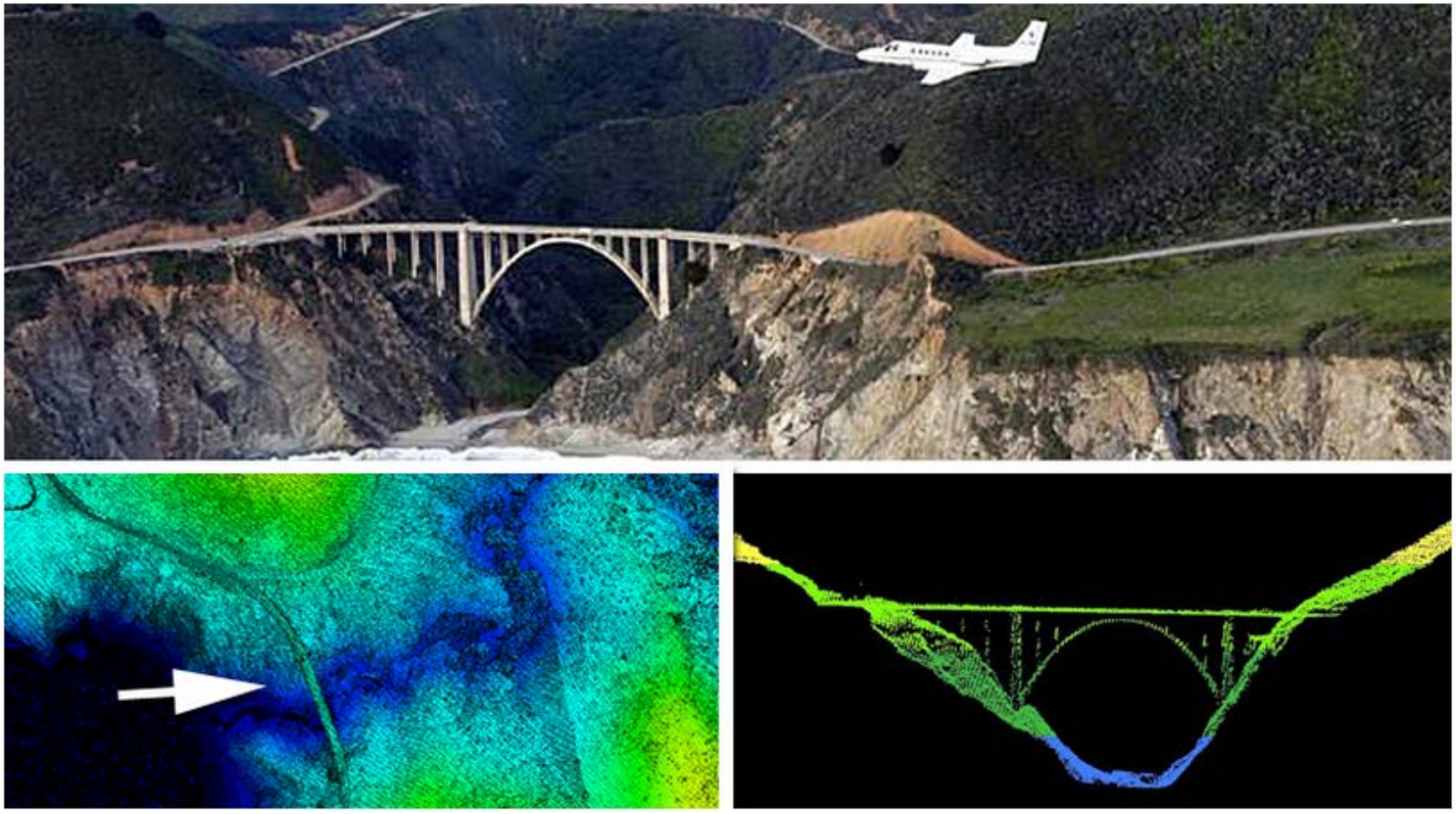
# AUTONOMOUS VEHICLES






www.auvsi.org

# LIDAR is one part of the HD 3D Point Cloud for Immersive Mapping



LIDAR data is often collected by air, such as with this NOAA survey aircraft (top) over Bixby Bridge in Big Sur, Calif. Here, LIDAR data reveals a top-down (bottom left) and profile view of Bixby Bridge. NOAA scientists use LIDAR-generated products to examine both natural and manmade environments. LIDAR data supports activities such as inundation and storm surge modeling, hydrodynamic modeling, shoreline mapping, emergency response, hydrographic surveying, and coastal vulnerability analysis.

# HD 3D Point Cloud for Immersive Mapping of road segmentation, obstacle detection, situation awareness, uncertainty estimation

# SAFTI

Ecosystem Example

*Precision Farming ?*

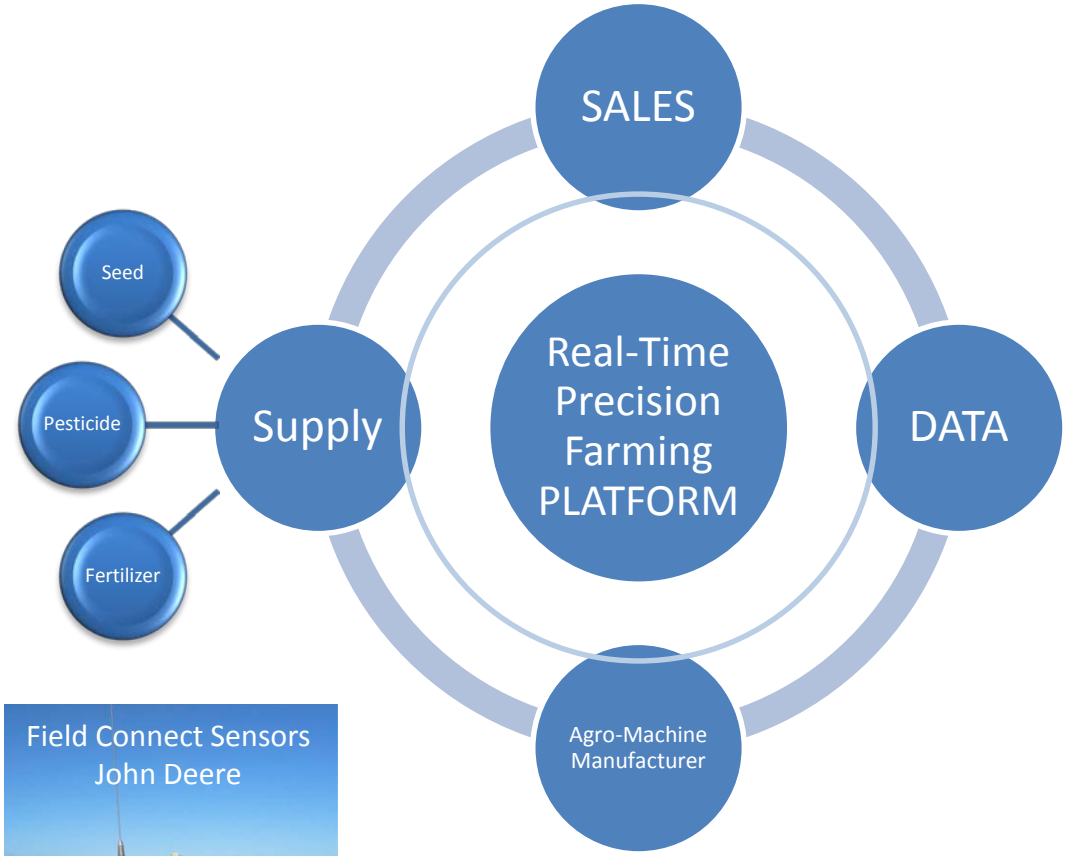
# Grand Challenge – Convergence of ecosystem of inter-dependent systems

The potential convergence of Precision Farming ecosystem
- Seed to Mouth (S2M)
- Farm to Fork (F2F)

with other ecosystems, such as:
- Smart Cities
- Autonomous Transportation and operations management for trusted and secure supply chain network of partners. Compliance with SOX-409 type regulations and DHS e-manifest are a part of this scenario. Additional links to energy and environmental systems are also obvious. Food safety, security, nutrition, availability and consumption are inextricably linked with global health, malnutrition, infant mortality and healthcare, in general.

*Farming in California alone is a $50 billion industry*

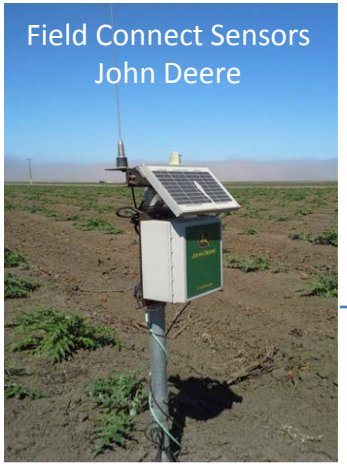
Retail Supply Chain – Sourcing / Distribution / Warehouse / Transportation
Track & Trace – Commodity Traders – Risk Management – Regulators (FDA)




-Measure, understand and apply
-Impact of data on quality & yield

-Weather data
-GPS micro-localization data
-Soil chemistry (GCMS) specifics
-Seed (sterile unless cultivated)
-Fertilizers (catalytic vs toxicity)
-Protection (pesticide, herbicide)
-Storage, shelf-life and waste
-Country of origin - goods supply

Leverage data to run long and short term simulations to plan for "what if" to optimize profit
- Weather patterns
- Demand uncertainty
- Export and import
- Tariff, cost, excise
- Regulatory policy




- Optimize MRO to improve asset uptime
- Mobile data collection and dissemination
  - soil sample / nutrient analysis (GCMS)
  - moisture monitors / field connect data
  - temperature / dielectric constant
  - color and chemistry of crops
  - growth rate / fertilizer distribution
  - weather micro-impact / acidity-alkalinity

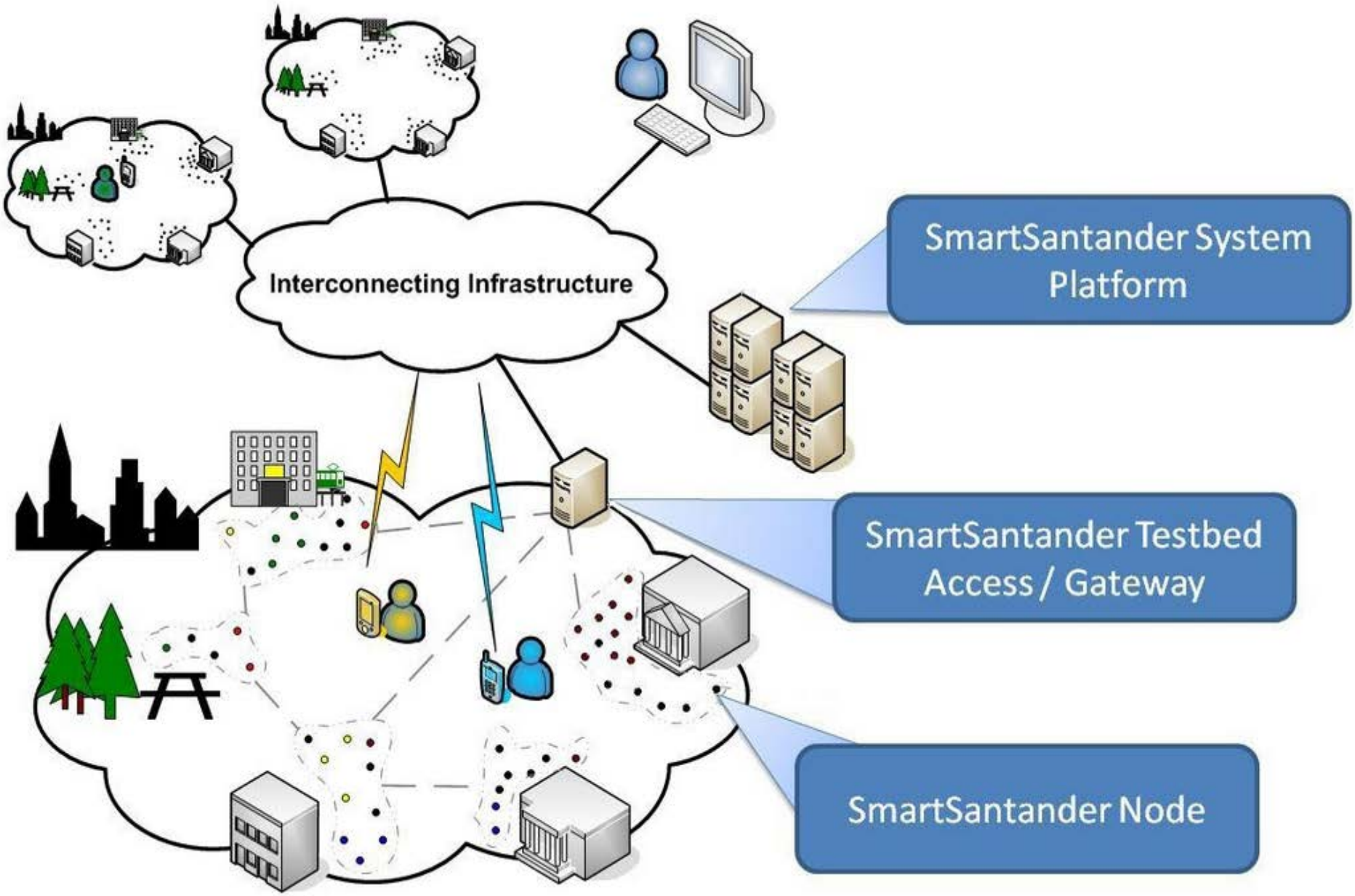
NASA Soil Moisture Active Passive (SMAP)

- Paradox to Paradigms to Platforms ☑ http://bit.ly/MIT-IOT

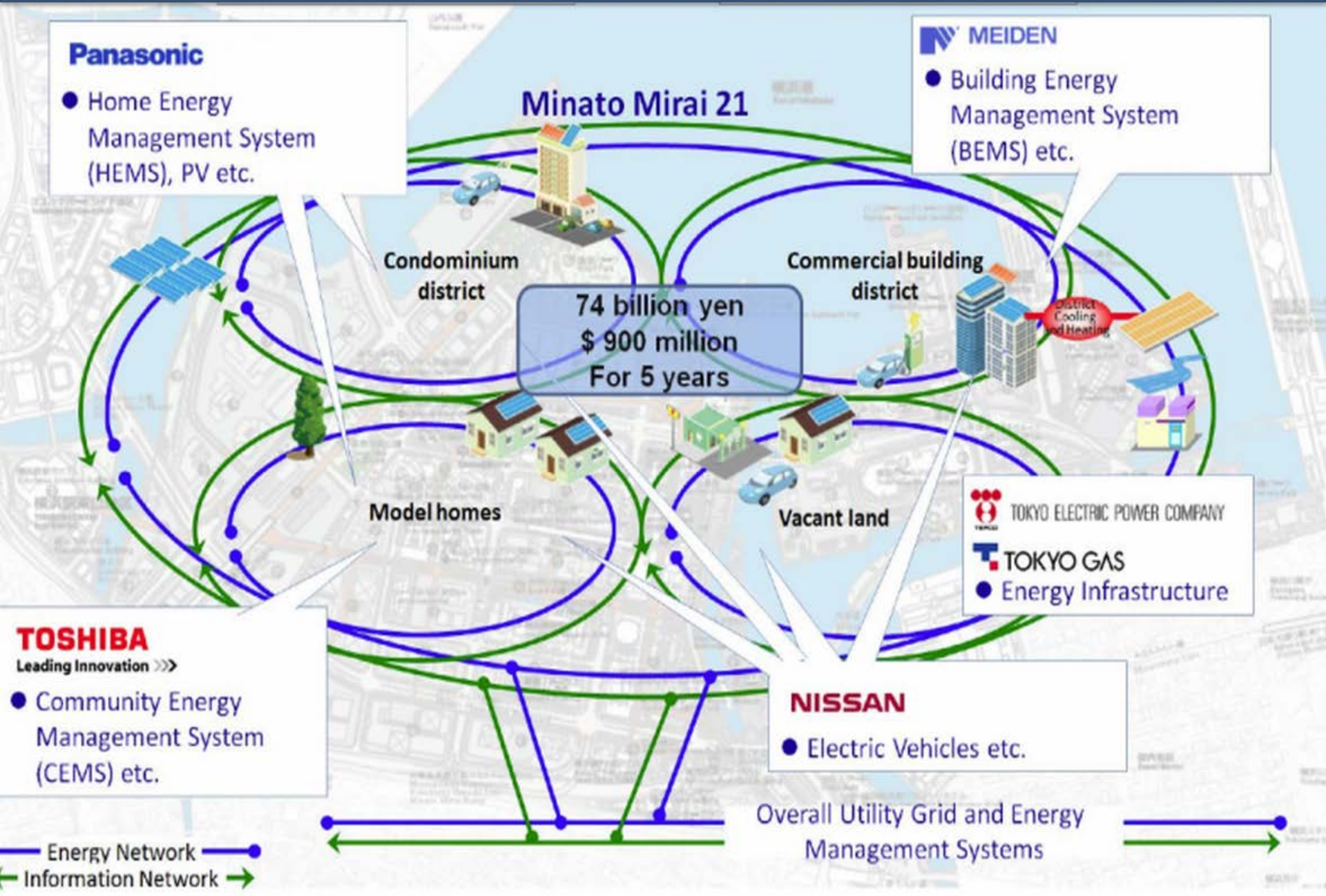
- Vision, Mission and Opportunities

- Challenges
  - ☑ Autonomous Transportation
  - ☑ Global Smart Cities
  - ☑ Healthcare
  - ☑ Data

# • Smart City ● Santander



# • Smart City ● Yokohama



# A SMARTER PLANET begins with SMART CITIES

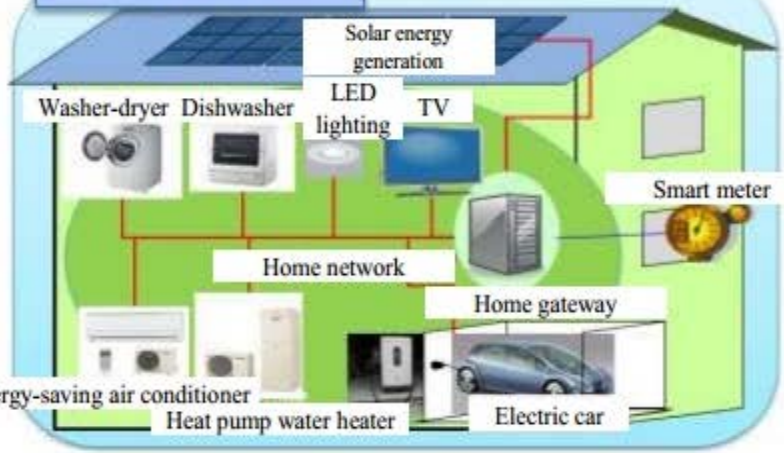
**Control center**

Control center that optimizes supply and demand of energy for the region

**A new transport infrastructure integrated with the energy network**

Drastically lowering carbon emissions and providing solutions for traffic accidents and traffic jams, by exchanging information between EVs and electric buses.


**Smart houses**




**Electric bus (to be changed into streetcars in the future)**

Electric buses with replacement-type batteries. Multiple buses will be connected to become a streetcar in the future.


METI
Ministry of Economy, Trade and Industry

Smart Cities Ecosystem

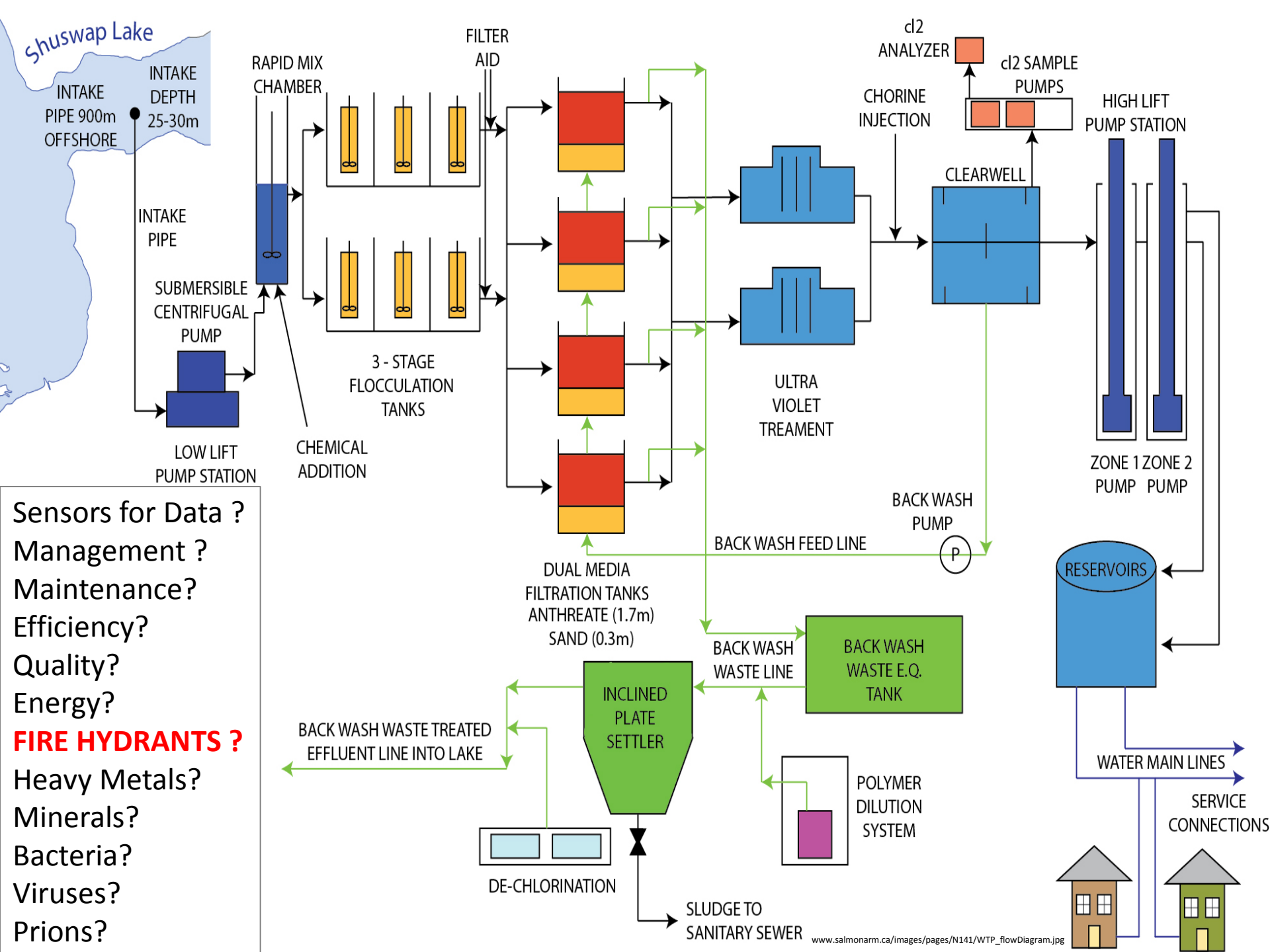
*Water*

# Reality Check ☑ Water

# Reality Check ☑ Water

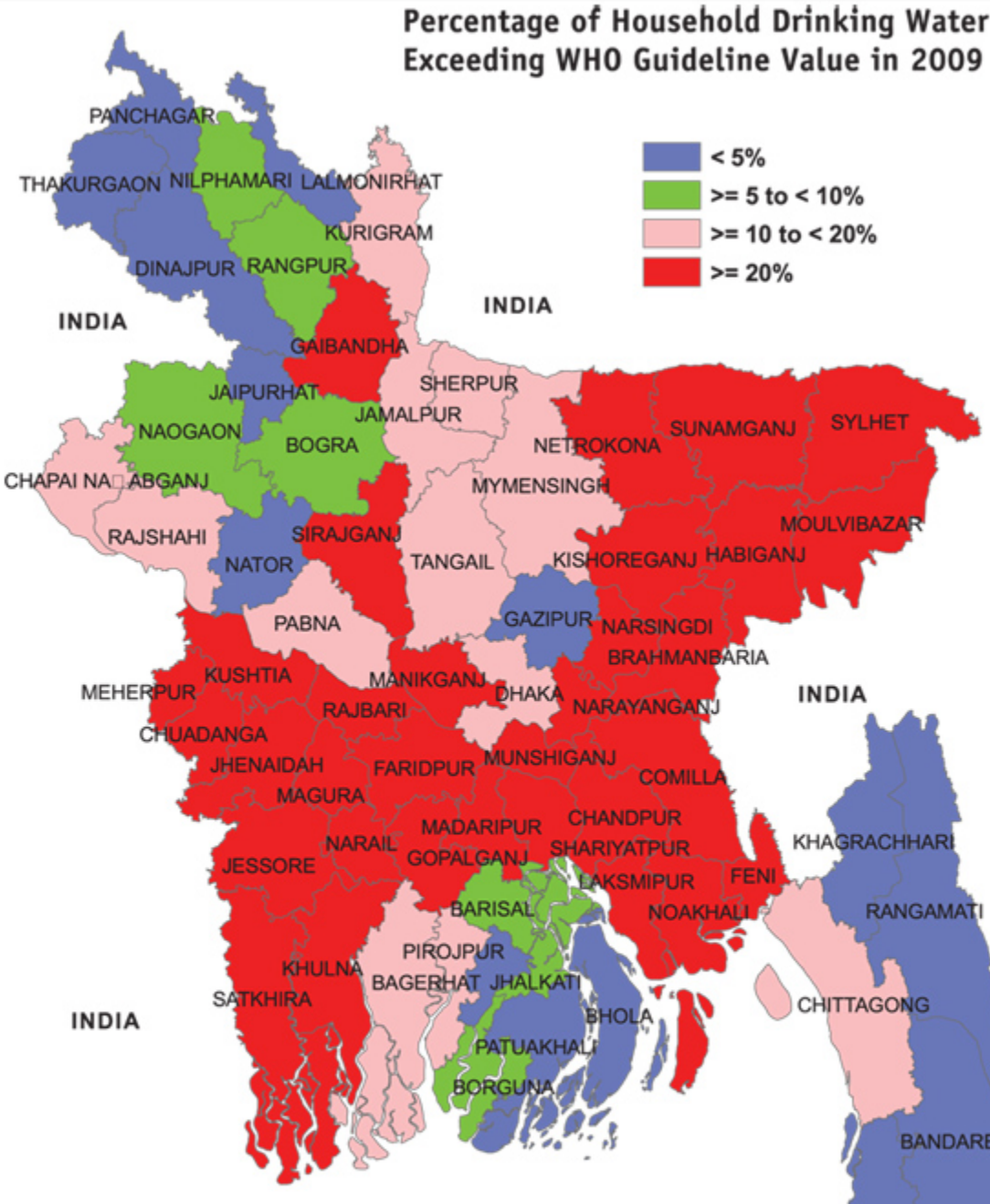
| | |
|---|---|
| 884 million | people lack access to safe water supplies — approximately one in eight people |
| 6 kilometres | is the average distance African and Asian women walk to fetch water |
| 3.6 million | people die each year from water-related diseases |
| 98 per cent | of water-related deaths occur in the developing world |
| 84 per cent | of water-related deaths are in children ages 0–14 |
| 43 per cent | of water-related deaths are due to diarrhoea |
| 65 million | People are at risk of arsenic poisoning in the Bangladesh, India and Nepal area |

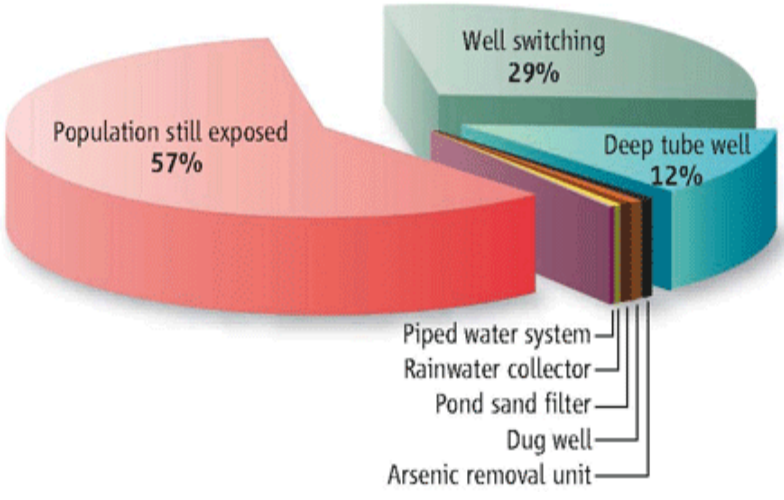
www.scidev.net/en/features/nanotechnology-for-clean-water-facts-and-figures.html




Sensors for Data ?
Management ?
Maintenance?
Efficiency?
Quality?
Energy?
**FIRE HYDRANTS ?**
Heavy Metals?
Minerals?
Bacteria?
Viruses?
Prions?

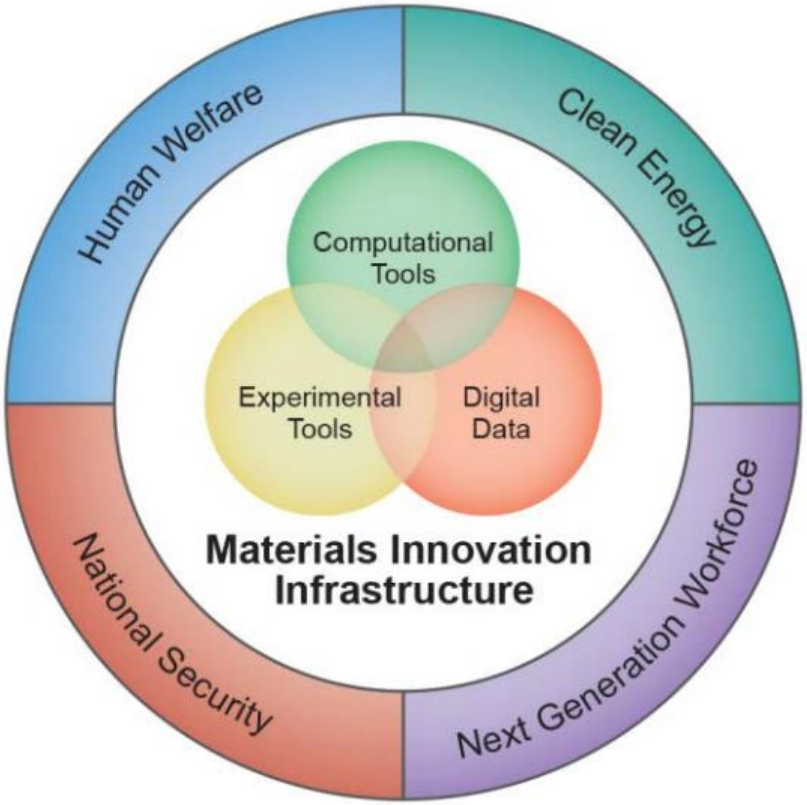
# Reality Check ☑ Arsenic in Water, Bangladesh



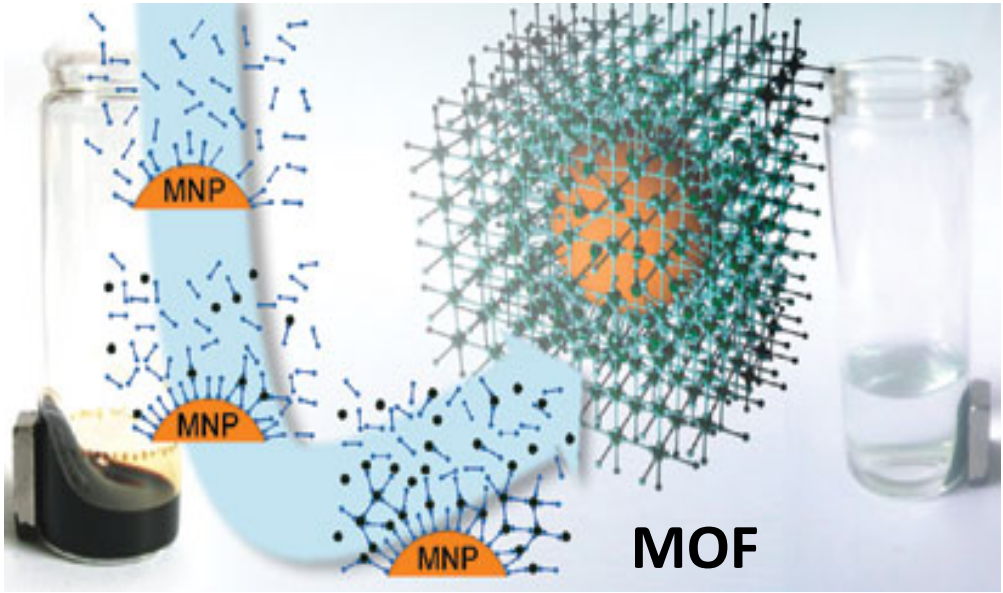



# Reality Check ☑ Arsenic in Water, Bangladesh

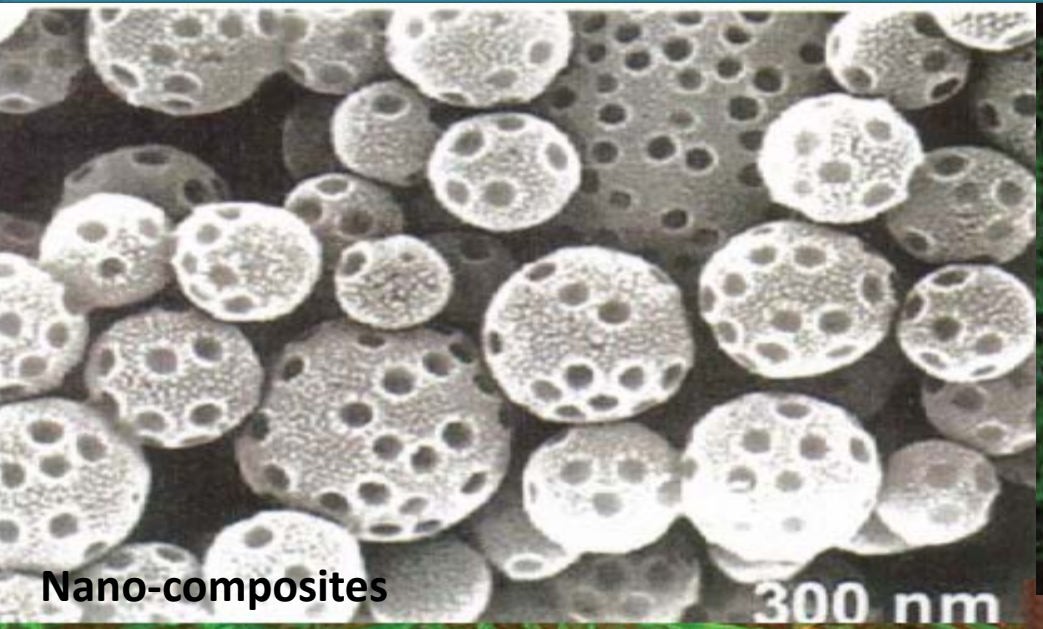
# We live in a material world – think graphene, think metal-organic frameworks



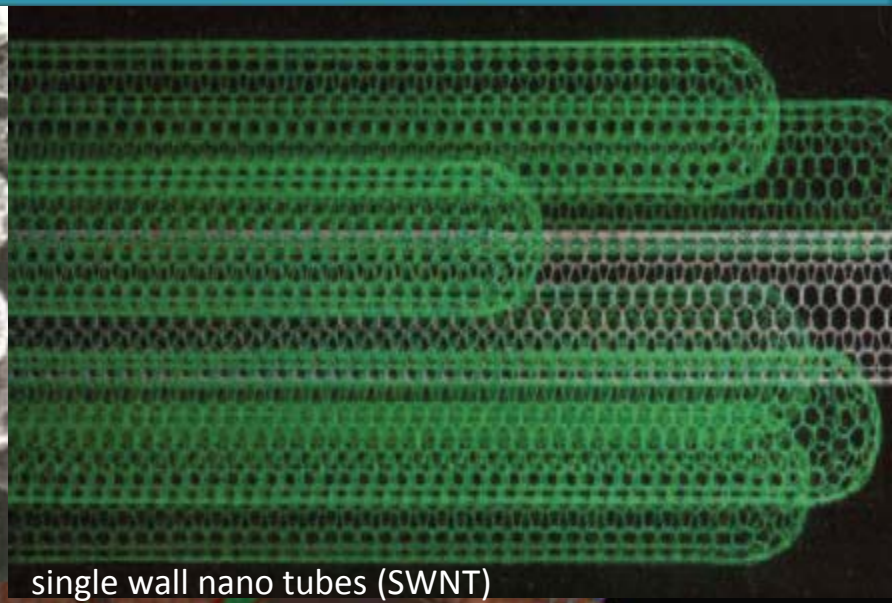

Material Genome Initiative (White House, June 2014)



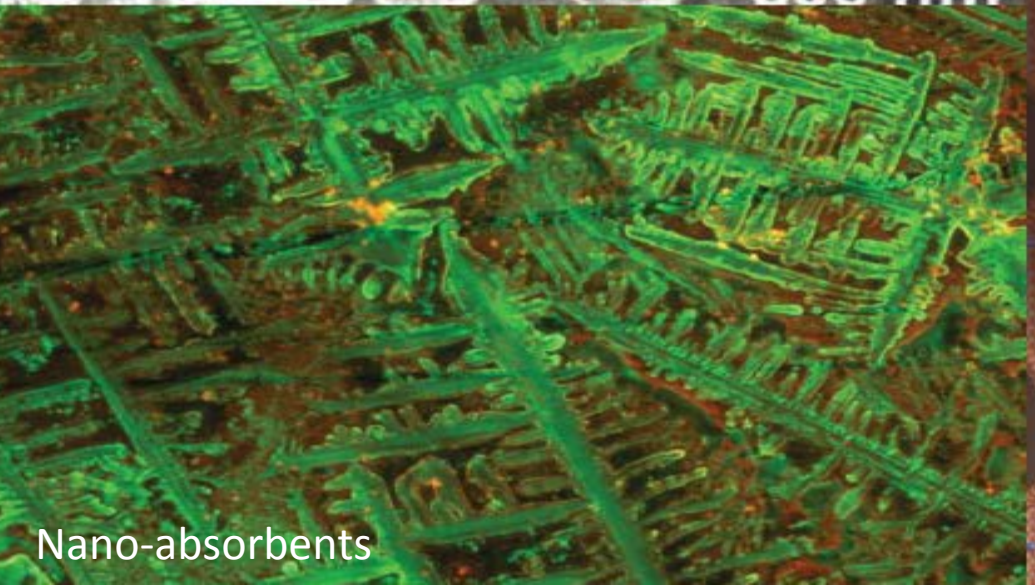
# Think Water – The Next Oil – Purification, Desalination & Waste Water Management



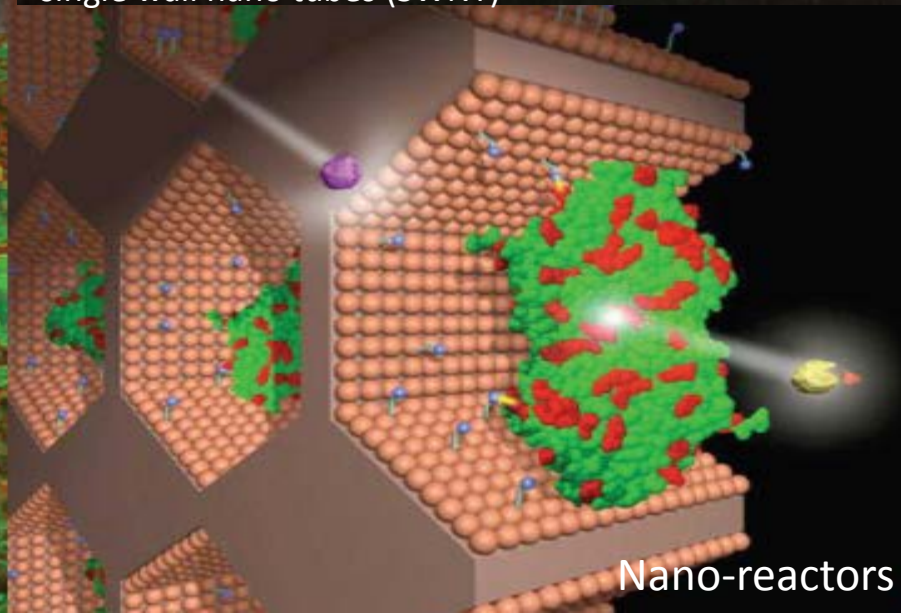

**Nano-composites**



single wall nano tubes (SWNT)

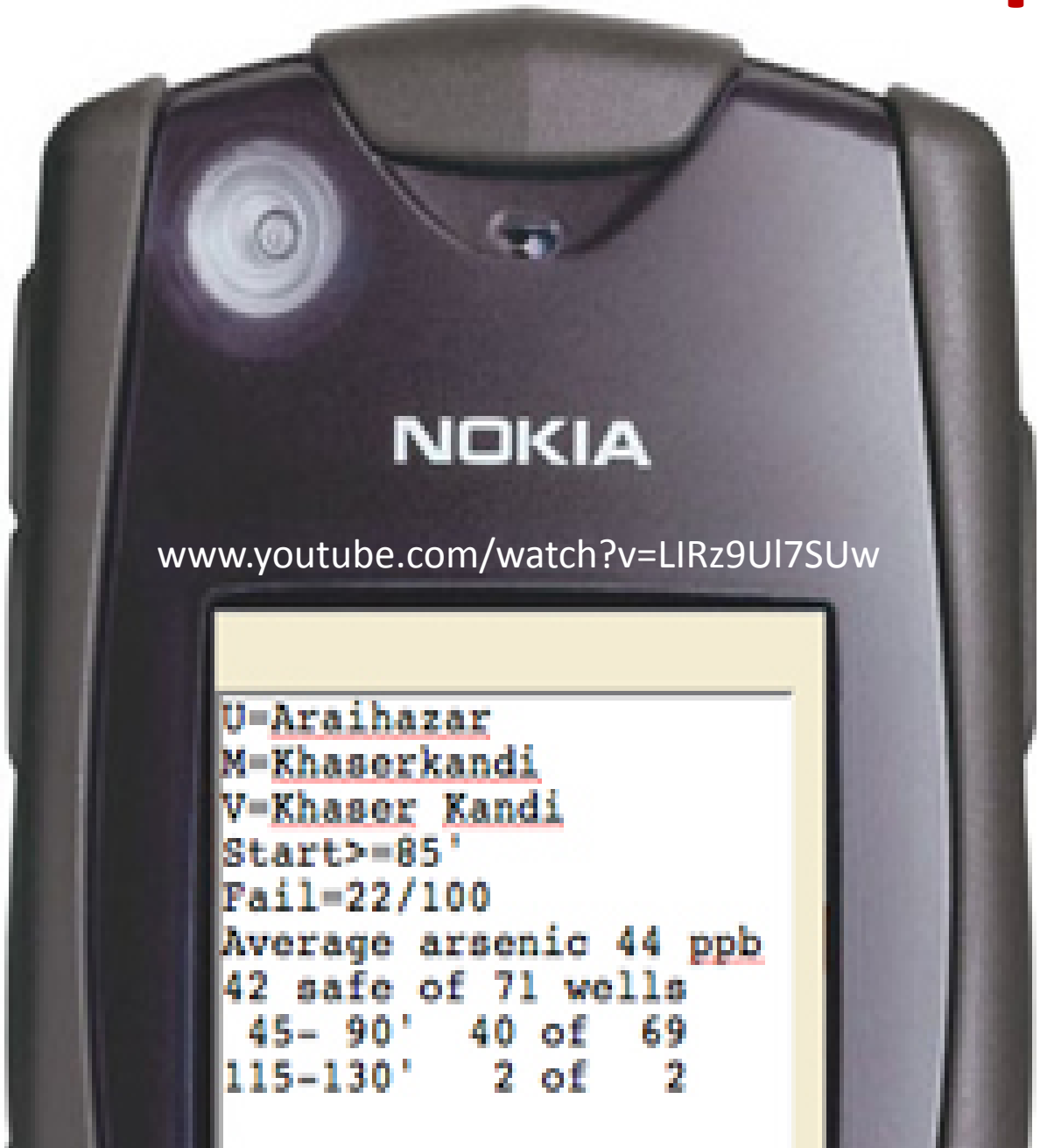


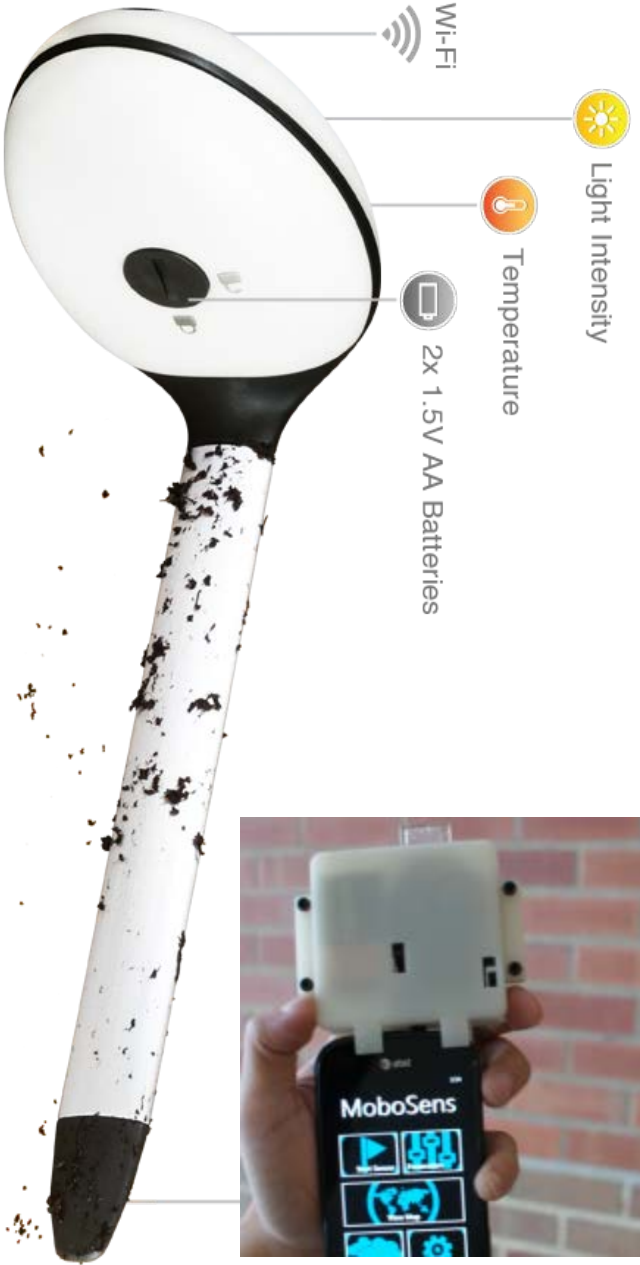
Nano-absorbents



Nano-reactors

# Socio-Economic Impact of IoT ?



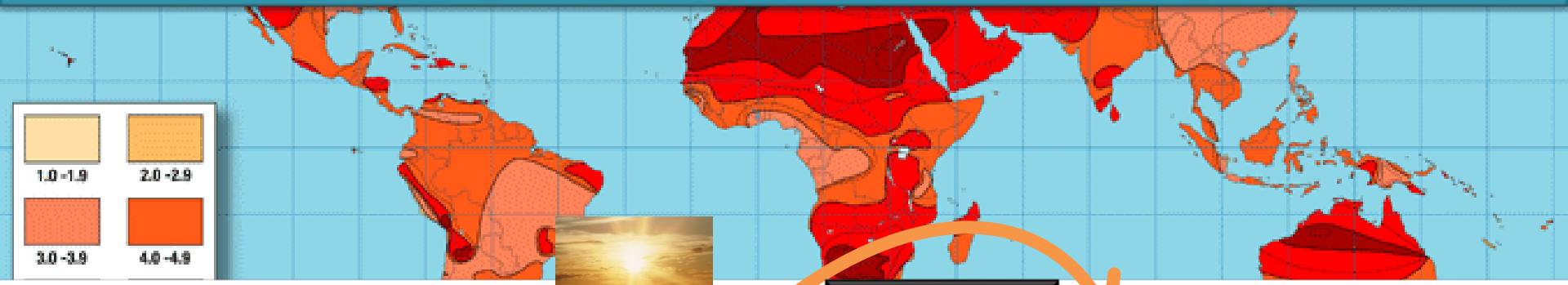



Smart Cities Ecosystem

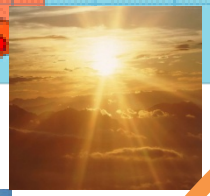
*Energy*

# MICRO-GRIDS?


# Renewables – Domestic Micro-Manufacturing Non-fossil Carbon-Neutral Liquid Fuel



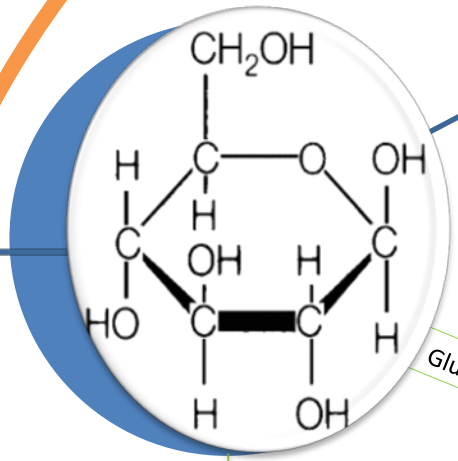




High Insolation

Micro Algae

Cyano Bacteria




Glucose

Liquid Fuel Generator

C 4
C 5

**Butanol**
**Pentanol**

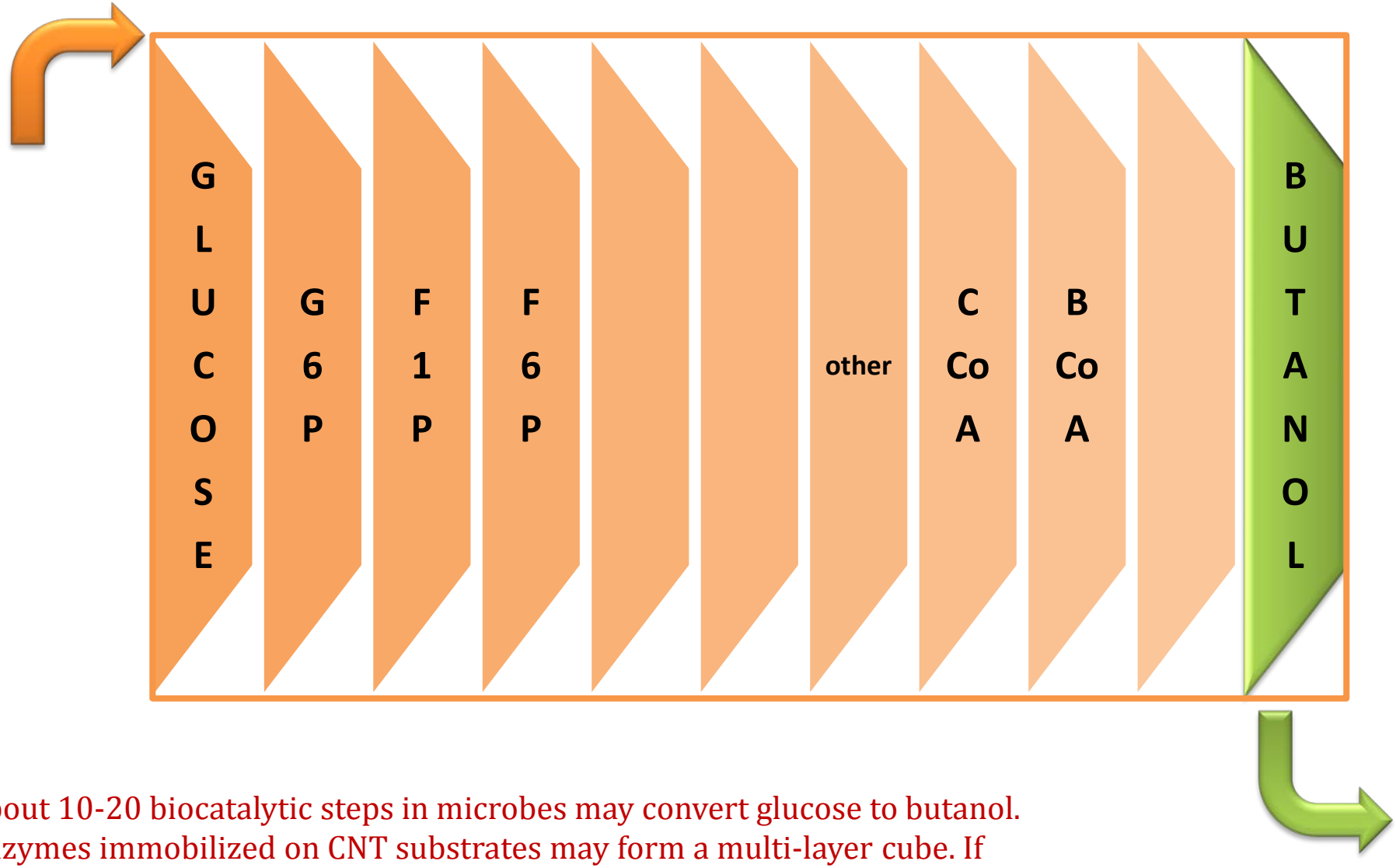
Glucose

C 6

**Glucose**

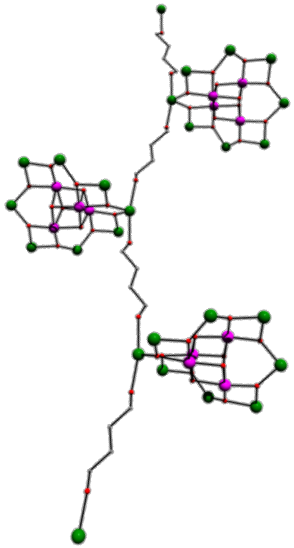
Low Insolation Commodity

# Butanol Battery 2050 • Enzymes adsorped on CNT may catalyze glucose to butanol

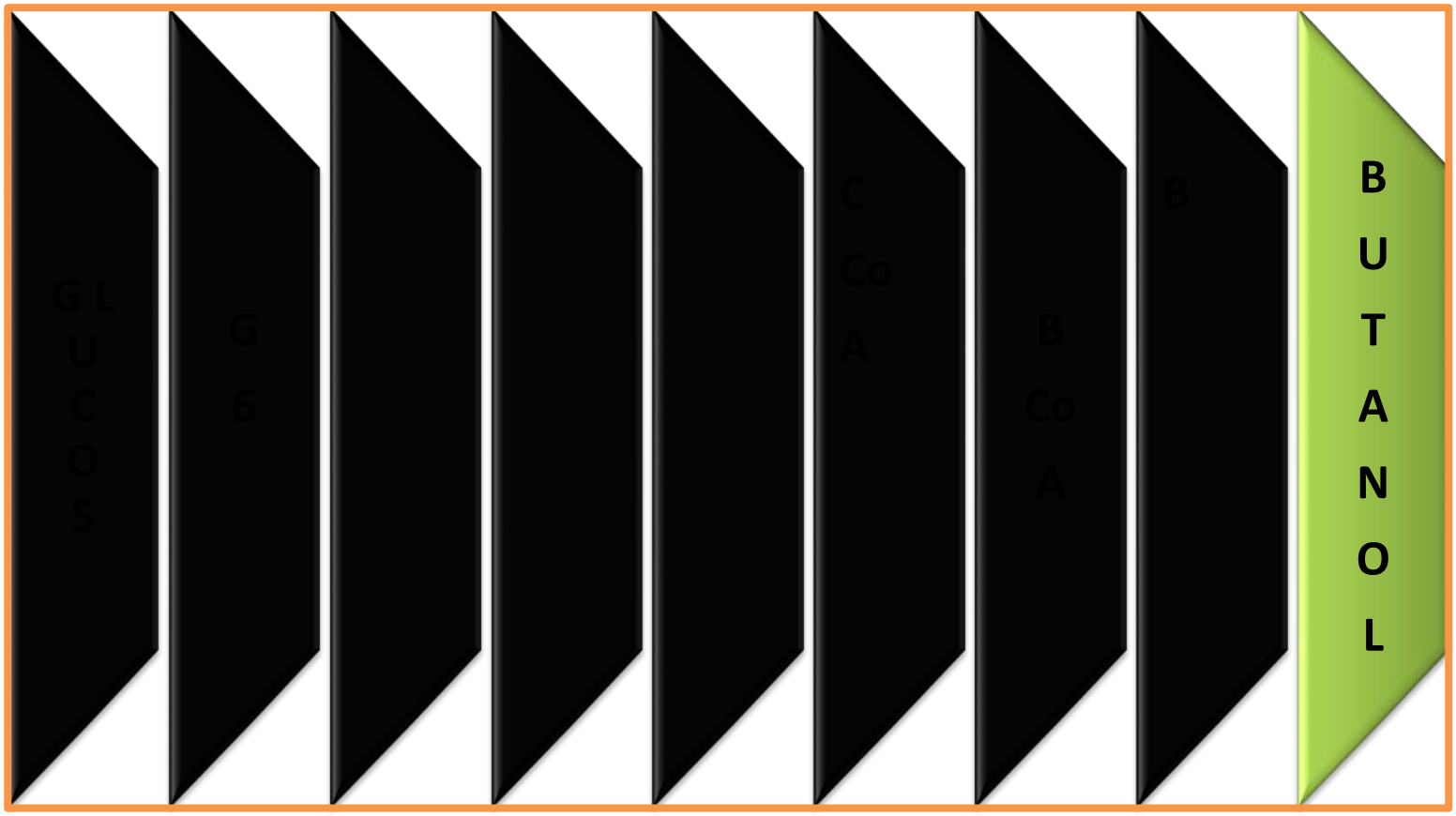



About 10-20 biocatalytic steps in microbes may convert glucose to butanol. Enzymes immobilized on CNT substrates may form a multi-layer cube. If functional, the cascade may convert glucose (commodity) directly to butanol.

# 2100 → Mass Manufactured Nano-Chloroplasts ← Nano-Molecular Switched MOF

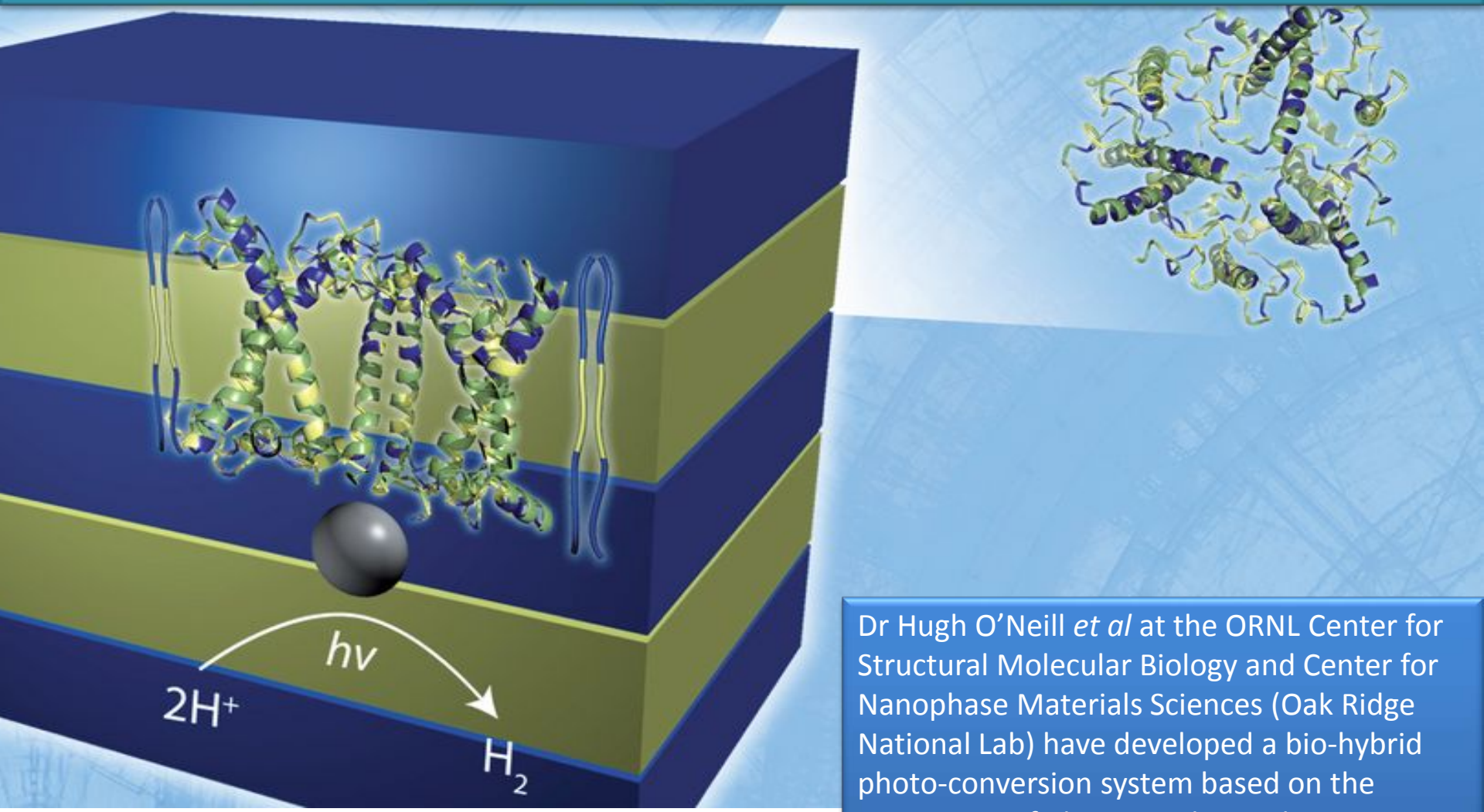


Transition metal nano cluster
Kelley, Datta, Lampropoulous,
http://tinyurl.com/Nano-Cluster




Light-dependent (photosystem I and II) and light-independent reactions
of photosynthesis may be difficult (but not impossible) to functionalize
due to the vast number of integral proteins in thylakoids in chloroplasts.
Black boxes [ ? ] → embedded proteins in nano-clusters or metal organic frameworks (MOF)

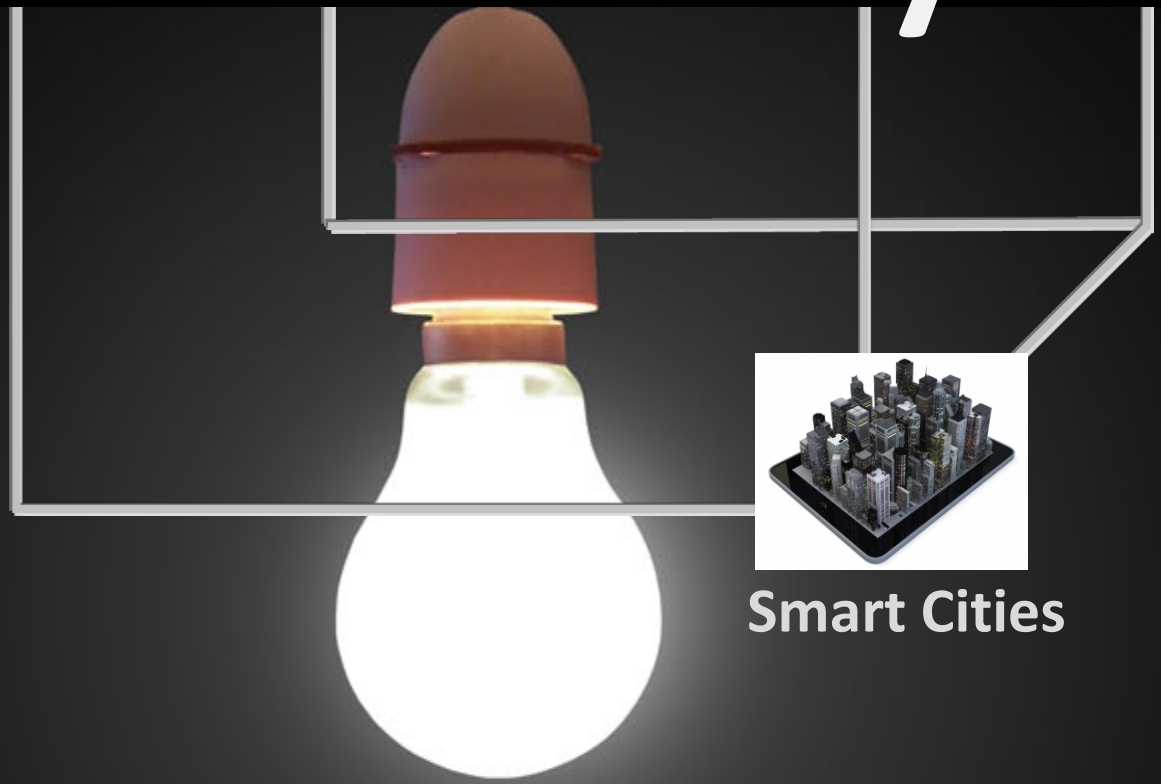
# Supra-molecular Assembly of Bio-hybrid Photo-conversion System → To Nano-Chloroplast ?




Supramolecular Assembly of Biohybrid Photoconversion Systems
Mateus B. Cardoso, Dmitriy Smolensky, William T. Heller, Kunlun Hong and Hugh O'Neill
Energy and Environmental Science (2011) **4** 181-188
DOI: 10.1039/C0EE00369G

Dr Hugh O'Neill *et al* at the ORNL Center for Structural Molecular Biology and Center for Nanophase Materials Sciences (Oak Ridge National Lab) have developed a bio-hybrid photo-conversion system based on the interaction of photo-synthetic plant proteins with synthetic polymers which can convert visible light into hydrogen fuel.

# Grand Unifying





Smart Cities

# Challenge



I invented nothing new. I simply assembled into a car the discoveries of other men behind whom were centuries of work ▪ HENRY FORD

# GLOBAL SMART CITIES – GRAND UNIFYING IoT CHALLENGE ?

**Smart parking**

**Smart homes**

**Smart healthcare**

**Smart transportation and traffic management**

**Smart energy and electricity micro-grid network**

**Smart water and waste water treatment**

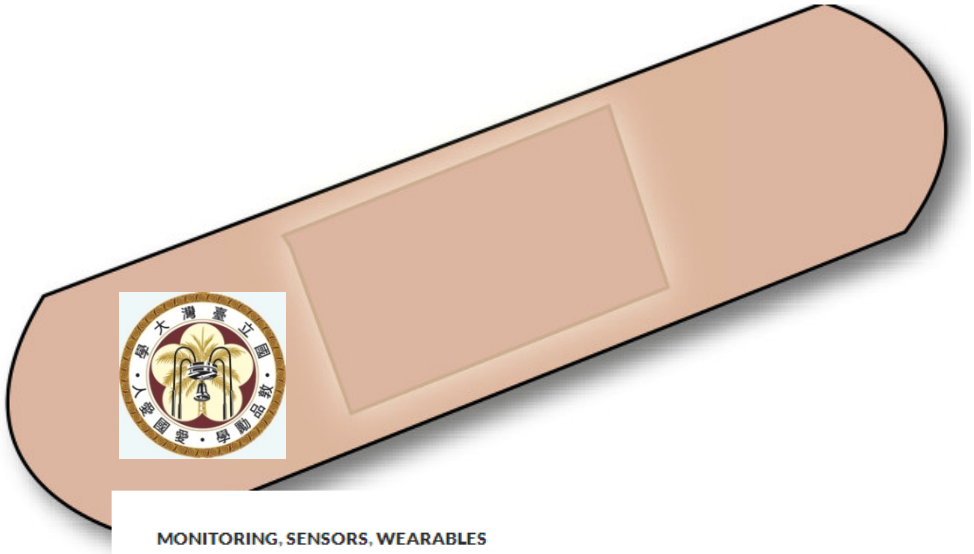
**Smart data and connectivity**

**Smart waste management**

**Smart maintenance and infrastructure**


# Grand Challenges

# • Paradox to Paradigms to Platforms ☑ http://bit.ly/MIT-IOT



MONITORING, SENSORS, WEARABLES

## SENSOR / 3D PRINTING / BANDAGE COMBINATION FOR CONTINUOUS MONITORING

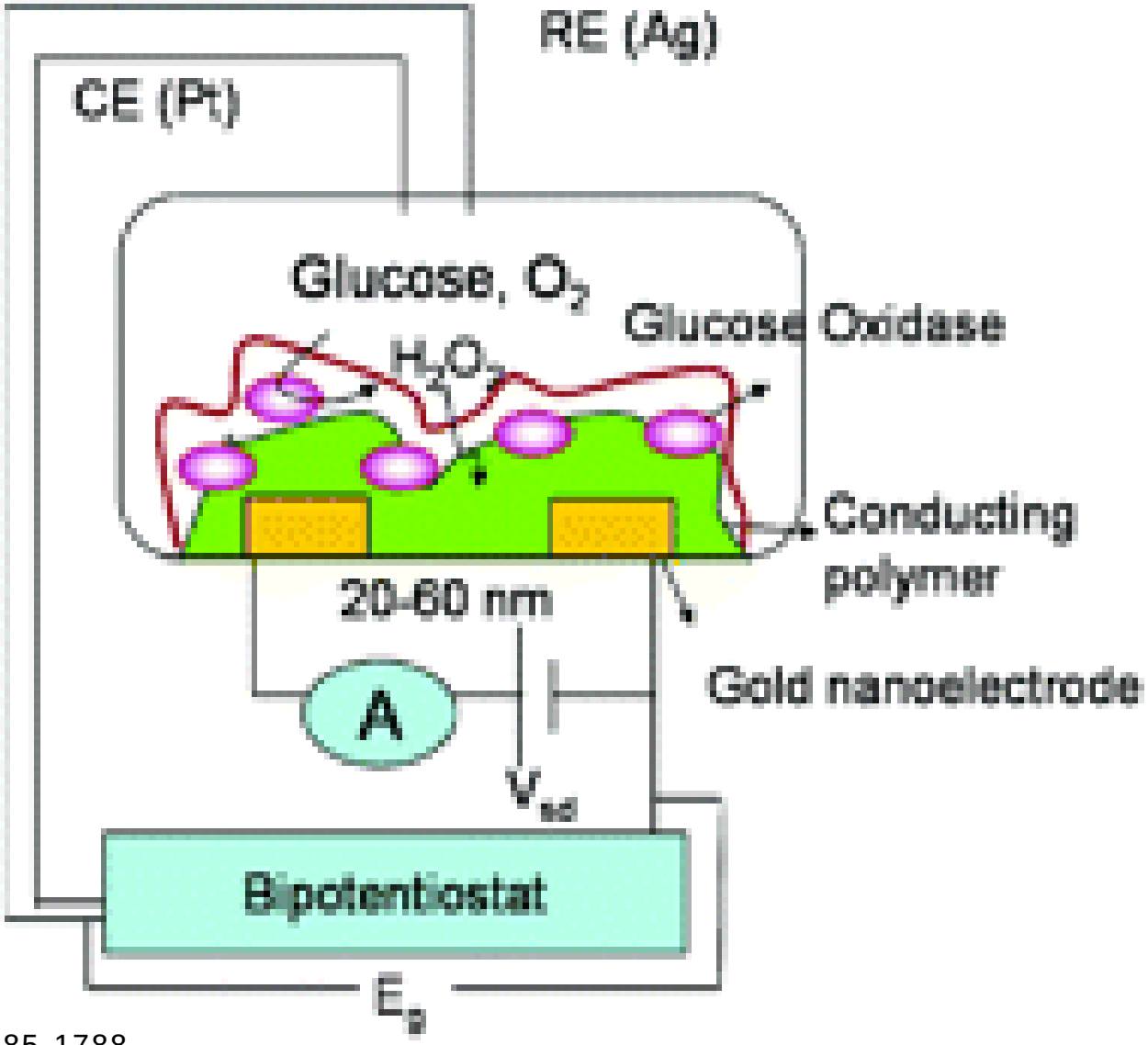
JULY 18, 2014 LISAWEINER

Bioscope bandages, developed at the National Taiwan University, wirelessly transmit temperature, heart rate, movement and vital sign data to doctors to monitor or remotely diagnose.

The bandage comes with an integrated thermometer, accelerometer, and sensors to measure electrical activity. A microphone can track organ sound patterns to detect disease. The area holding the modules is 3D printed for easy sensor additions or changes.

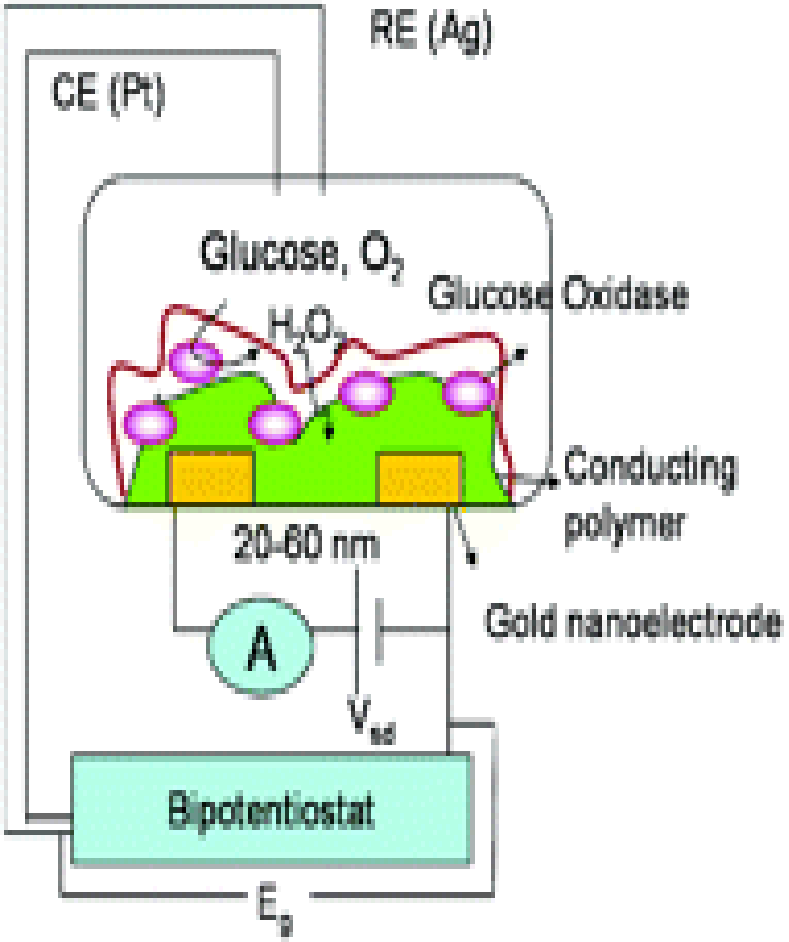

Laughter is the best indicator of this disease but the wireless sensors to detect laughter is not covered by your insurance

# Domain Specific Anchor for Internet of Health and Wellness – Glucose NanoSensor



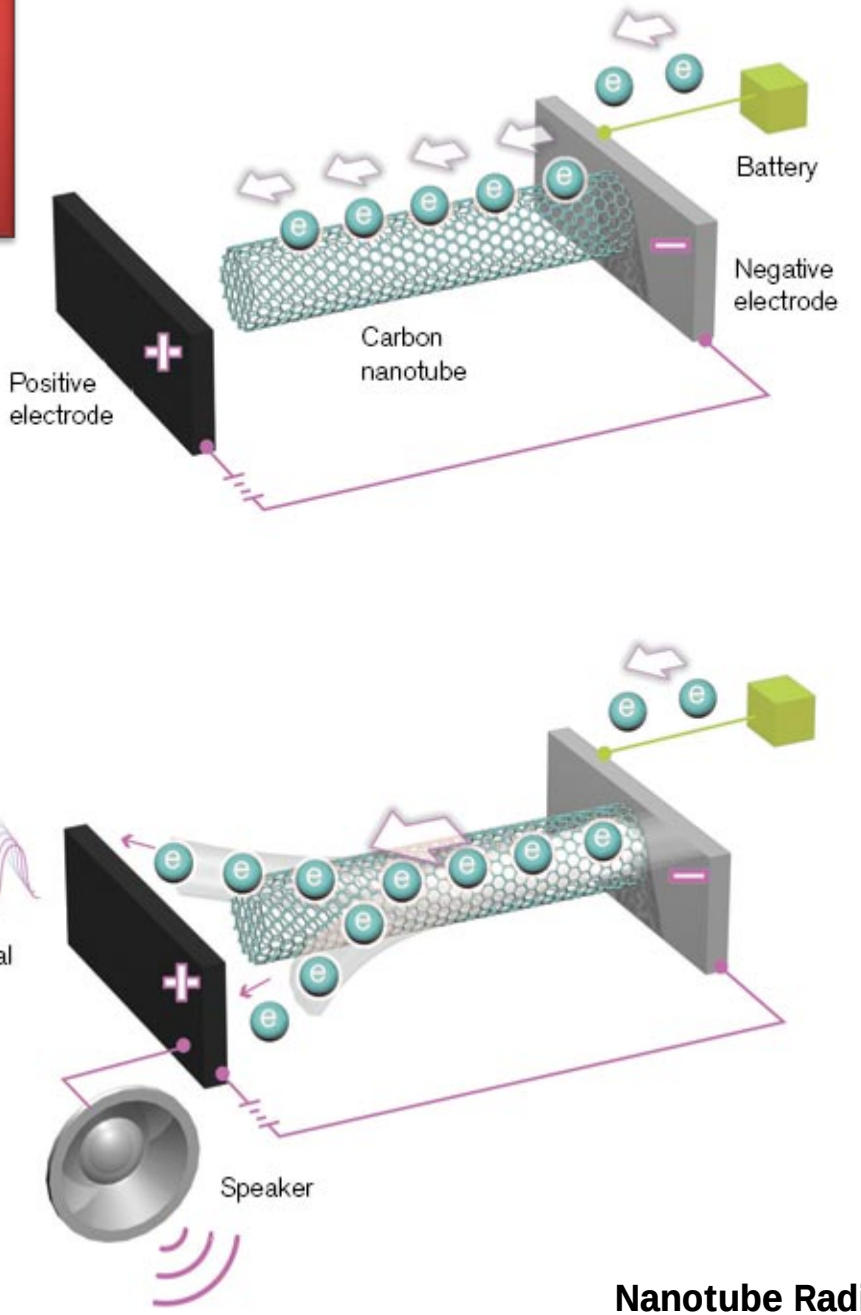

NanoLetters (2004) 4 1785-1788

# The Industrial Internet
# The Industrial Internet of Things
# The Industrial Internet of Healthcare




**Blood Glucose Nano-sensor**

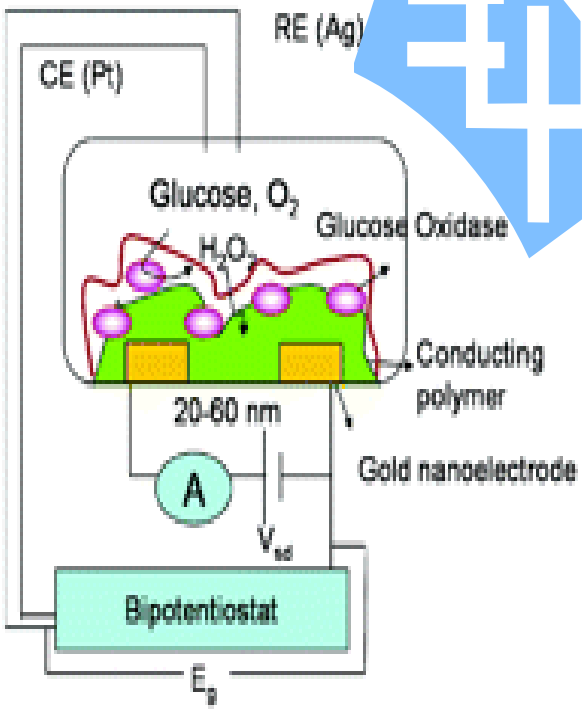
NanoLetters (2004) 4 1785-1788




**Nanotube Radio**

NanoLetters (2007) 7 3508-3511

# Integrated Glucose NanoSensor NanoRadio




Hypothetical (S. Datta)

***Diabetes affects 25.8 million people***

***8.3% of the U.S. population***

**DIAGNOSED**

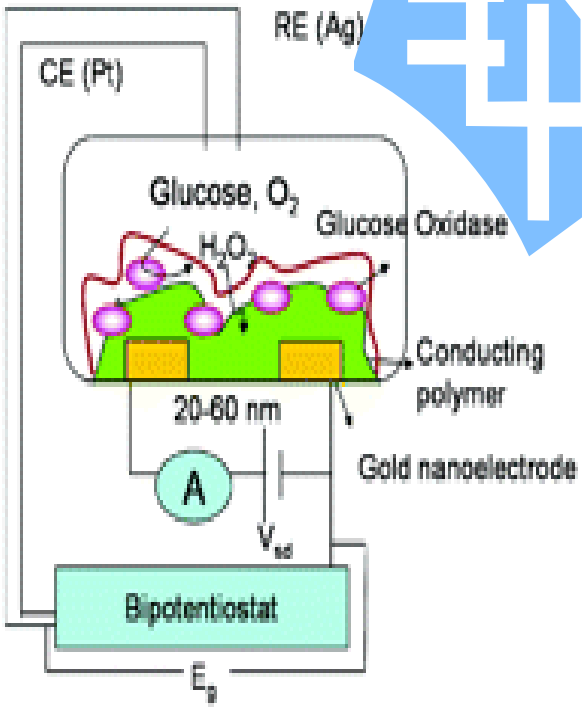
***18.8 million people***

**UNDIAGNOSED**

***7.0 million people***

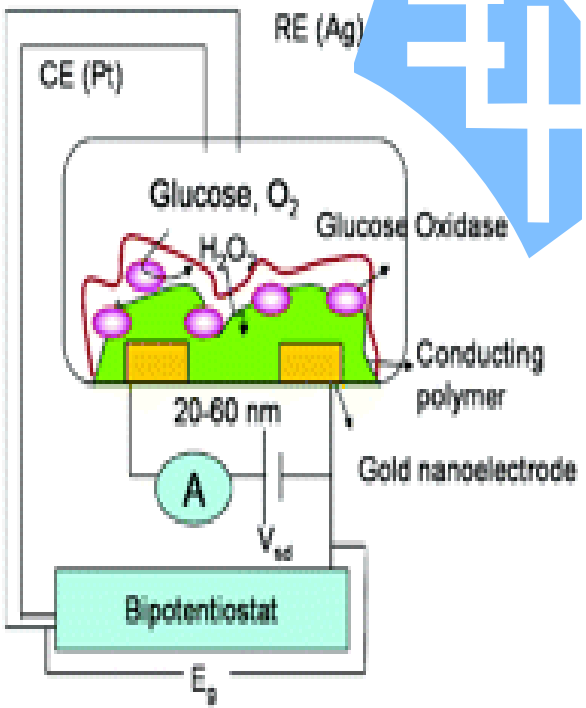
http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2011.pdf

# Industrial Internet - Remote Heath Monitoring




May I implant a glucose nano-sensor nano-radio chip on your shoulder? You are fat. You could become diabetic.

# Glucose NanoSensor NanoRadio
# Ecosystem of healthcare monitoring




**About 30 million individuals in US affected by diabetes**

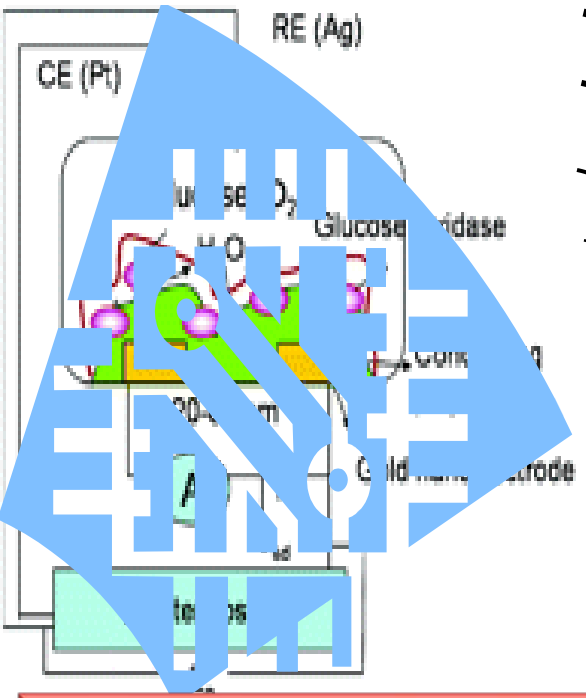

1. Implanted wireless sensor transmits blood glucose data from home or office or airport (WiFi/WAN/gateway)

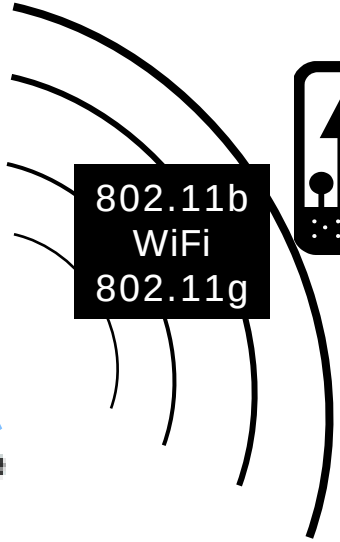
2. Data travels from you to your hospital or clinic (MAN)

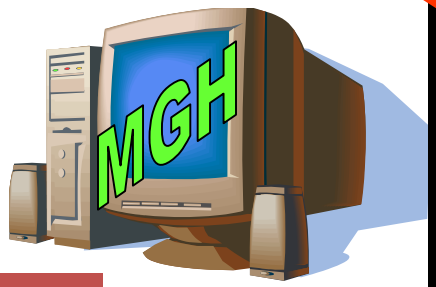
3. Blood glucose data updates risk and patient profile

4. If you need medical attention or insulin or other treatment then auto-responder sends message or calls

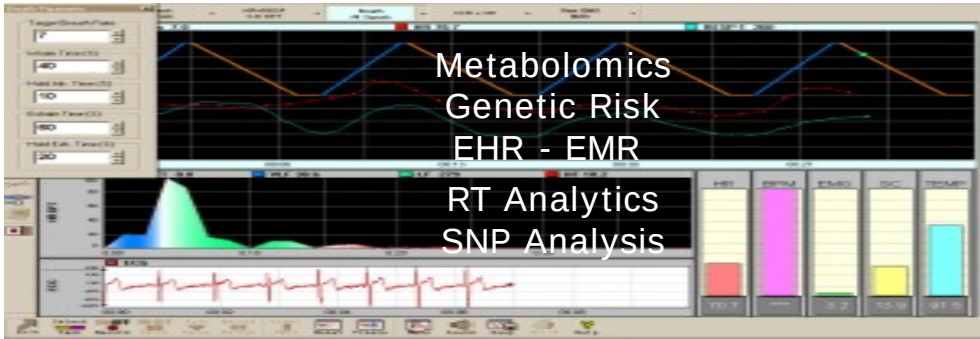
http://www.cdc.gov/nchs/fastats/diabetes.htm

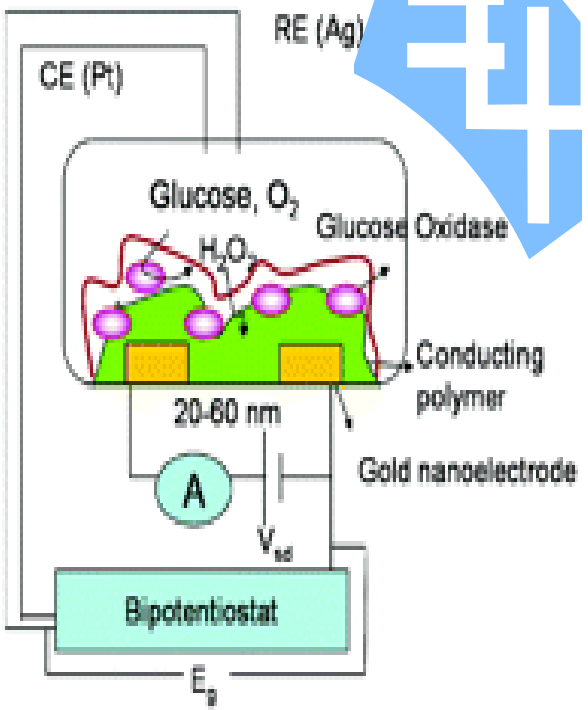



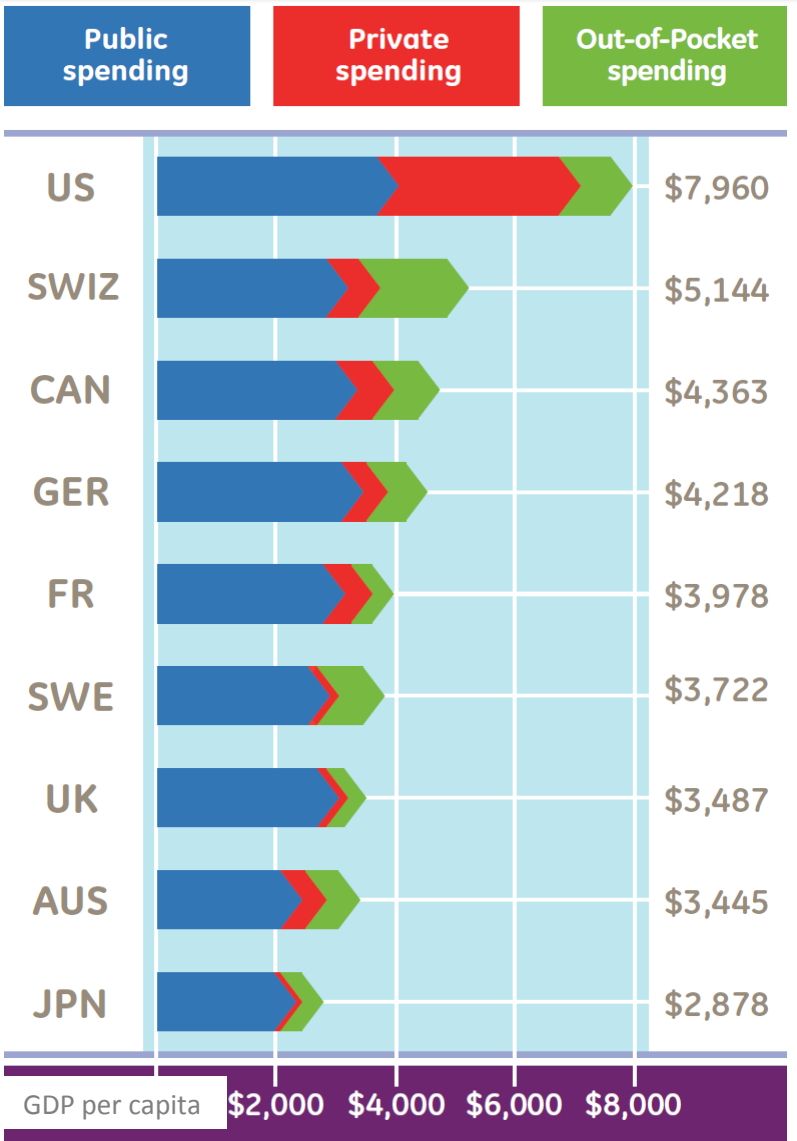

802.16a


Improved healthcare services, savings, create jobs from new products, new services and potential to create as well as capture new emerging markets of billions (BRICS)

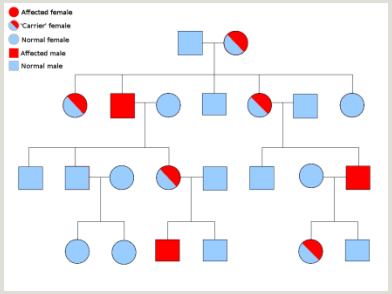
# Glucose NanoSensor NanoRadio ecosystem of health-care monitoring may have a major economic impact




http://www.cdc.gov/nchs/fastats/diabetes.htm

# Human Genomics in the IoT era - Is your genome connected to mine?




Genome

Transcriptome

Proteome

Metabolome

Microbiome

Epigenome

Exposome

Social graph

Biosensors

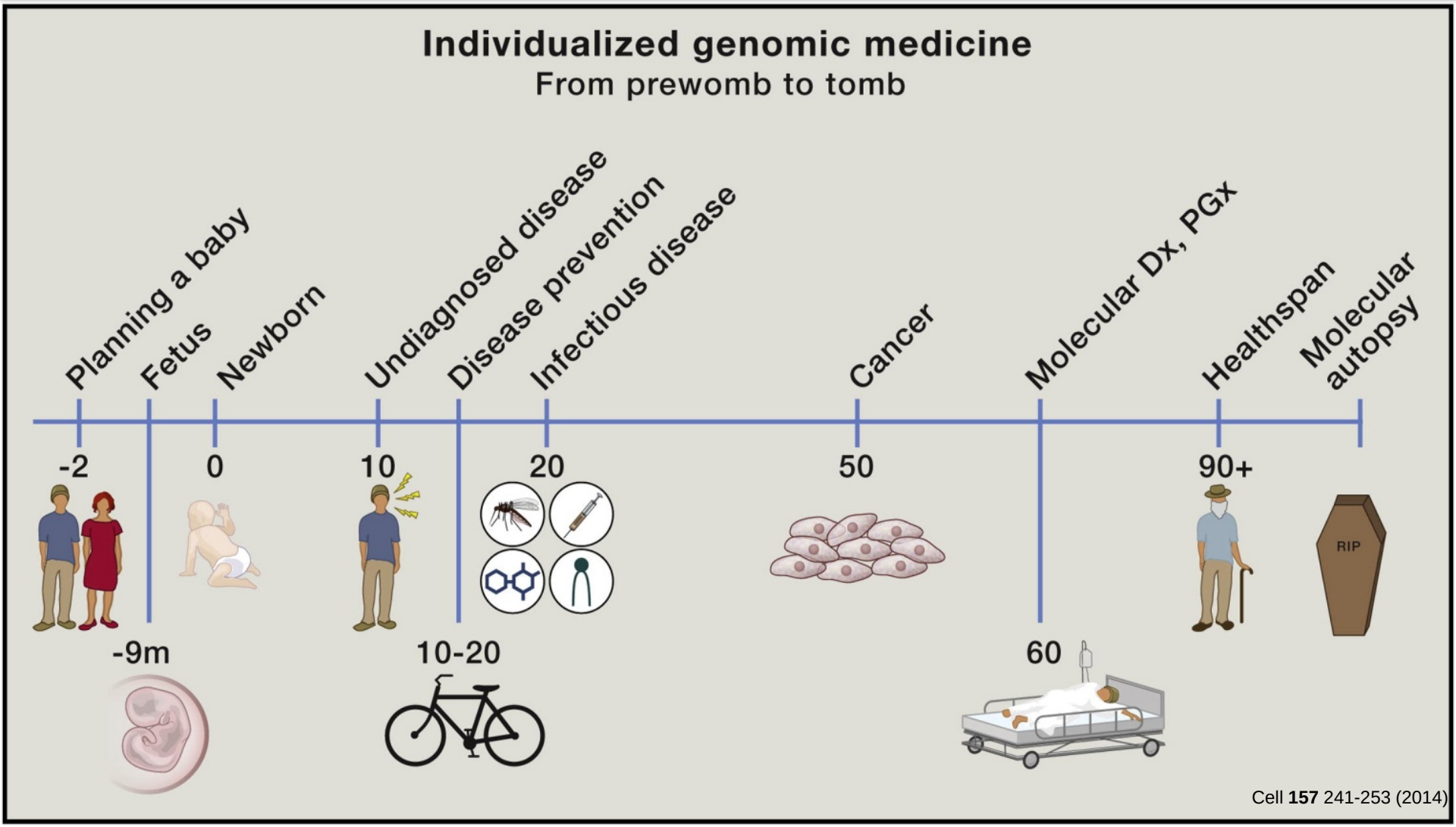
Imaging


Glucose
NanoSensor
NanoRadio

Cell **157** 241-253 (2014)

Mendelian Inheritance in Man: A Catalog of Human Genes and Genetic Disorders by Victor A. McKusick

# Human Genomics in the Wireless Hospital




Cell **157** 241-253 (2014)

# *Domain Specific Scenario*

Early Detection and Prevention

# Sensor enabled wearables - appropriate attributes may improve preventive medicine



**Hands-Free**

- Voice / gesture control

**Always-On**

- Low power consumption
- Instant wake
- Background working / sensing

**Environment -Aware**

- GPS
- Accelerometer
- Compass
- Camera
- Microphone
- Other Sensors

**Connected**

- Wi-Fi
- 3G / 4G
- Bluetooth
- NFC

**Attention-Getting**

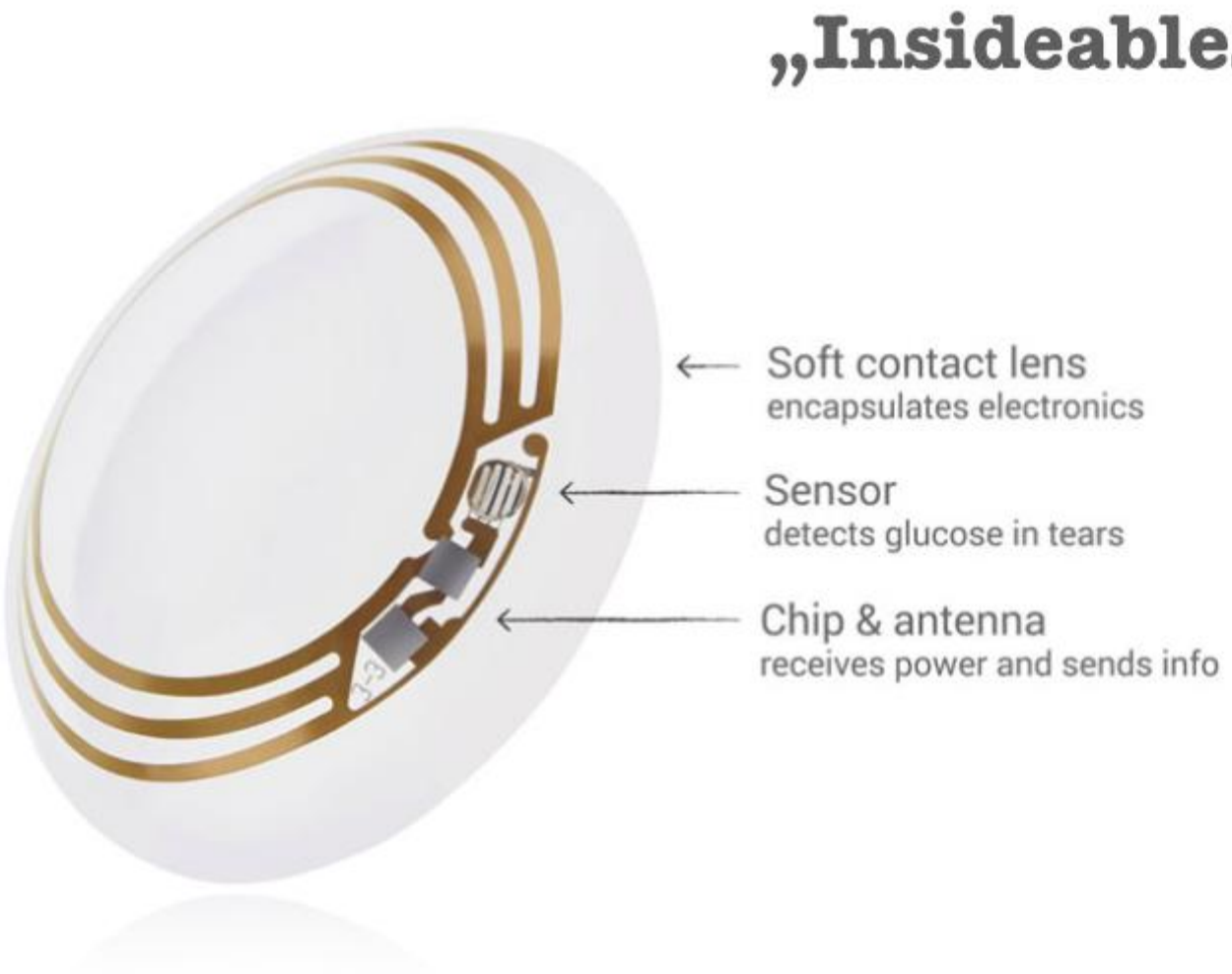
- Less distracting when receiving alerts / reminders / messages

**Development Platform**

- 3rd party apps
- API partners
- Accessories

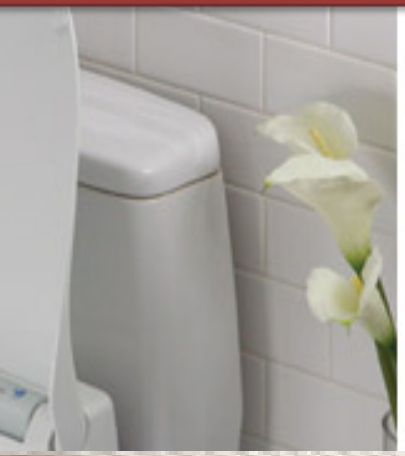
MIT

# Glucose Sensors can reduce the morbidity due to Glaucoma

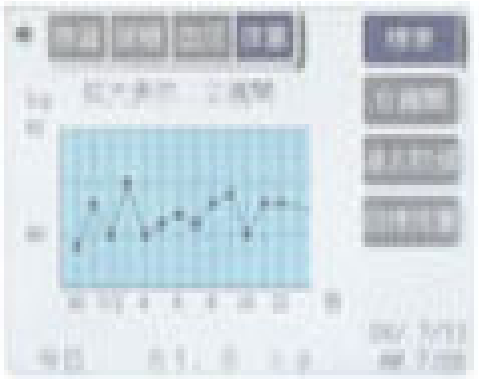



umcn.nl

# Pay-Per-Pee Home Health – IoT Wireless Toilet Bowl Connected to Health Informatics







Weigh-scale, BMI, FOBT, urine analysis, sugar, ketone body analysis, blood pressure monitor, pulse oximeter, networked to phone via WiFi and/or Bluetooth with biometrics and face recognition for secure communication with physician and hospital or clinic, globally.

Walgreens Specials - $1.99 for 24-pack Diet Coke • $1.99 for Bone Density • $1.99 Mammogram

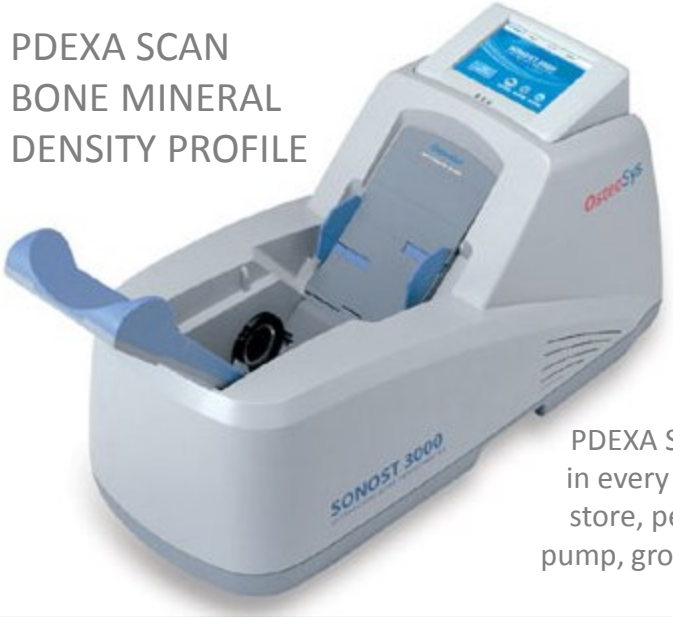

PDEXA SCAN
BONE MINERAL
DENSITY PROFILE

Value Network Ecosystem Testbed

Walgreens – Retail Healthcare
GE – Equipment
Cisco – IPv6 Routers
AT&T – Data Transmission
Intel – MIPS
IBM – Data Analytics
Samsung – Diagnostic Apps
Walmart – Grocery Supply Chain

# CVS Specials - $0.99 for 1-quart Milk • $1.99 for Bone Density • $2.99 Mammogram

PDEXA SCAN
BONE MINERAL
DENSITY PROFILE




PDEXA SCAN
in every drug
store, petrol
pump, grocery

**Osteoporosis**

EU → 28 million in 2010 to 34 million in 2025 (increase of 23%)

US → 44 million (represents 55% of people aged 50+)

Brazil → 10 million (1 in every 17)

India → 36 million (2013)

China → 70 million (50+). Cost of treatment USD1.5 billion in 2006.
Estimated US$12.5 billion in 2020 and US$265 billion in 2050.

In 2008, Indonesia had 34 DXA machines, half of them in Jakarta (population 237 million) which translates to 0.001 machine per 10,000 population. The equivalent recommended number for Europe is 0.11 (per 10,000)

http://bit.ly/BONE-HEALTH

*Health data without de-identification*

CONNECT

GROCERY STORE
PURCHASE LOG


Integrated system detects fall in bone density and correlates with reduced purchase of milk. Prevention for osteoporosis starts early. Avoids trauma and/or morbidity from broken bones. Connected healthcare data.

# US Healthcare spending nears $4 trillion (2013)

| Spending category | Costs estimated in NHEA categories (in billions) | | Costs estimated with sources other than NHEA (in billions) | | | |
|---|---|---|---|---|---|---|
| | Direct Costs | | Direct Costs | | Indirect/ Imputed costs | |
| **Hospital care** | Hospital care | $814 | | | | |
| **Professional services** | Physician and clinical services | $516 | | | | |
| | Dental services | $105 | | | | |
| | Other professional services | $68 | | | | |
| | Other personal health care | $129 | | | | |
| | | | All other ambulatory | $19 | | |
| | | | CAM practitioner costs | $31 | | |
| | | | Weight-reducing centers | $2 | | |
| **Long-term care (LTC)** | Home health care | $70 | | | | |
| | Nursing home care | $143 | | | | |
| | | | Homes for the elderly | $17 | | |
| **Prescription drugs** | Prescription drugs | $259 | | | | |
| **Retail products and services** | Durable medical equipment | $38 | | | | |
| | Other non-durable medical products | $45 | | | | |
| | | | CAM products | $2 | | |
| | | | Health publications | $2 | | |
| | | | Nutrition/supplements | $56 | | |
| **Direct administrative costs** | Total non-personal health care | $408 | | | | |
| **Supervisory care** | | | | | Supervisory care | $492 |
| **Total** | | $2,594 | | $129 | | $492 |

# Low Cost of Healthcare in India leaves billions in the dust without access to healthcare

**Cancer Treatment**

**$2,900** HCG Oncology, India

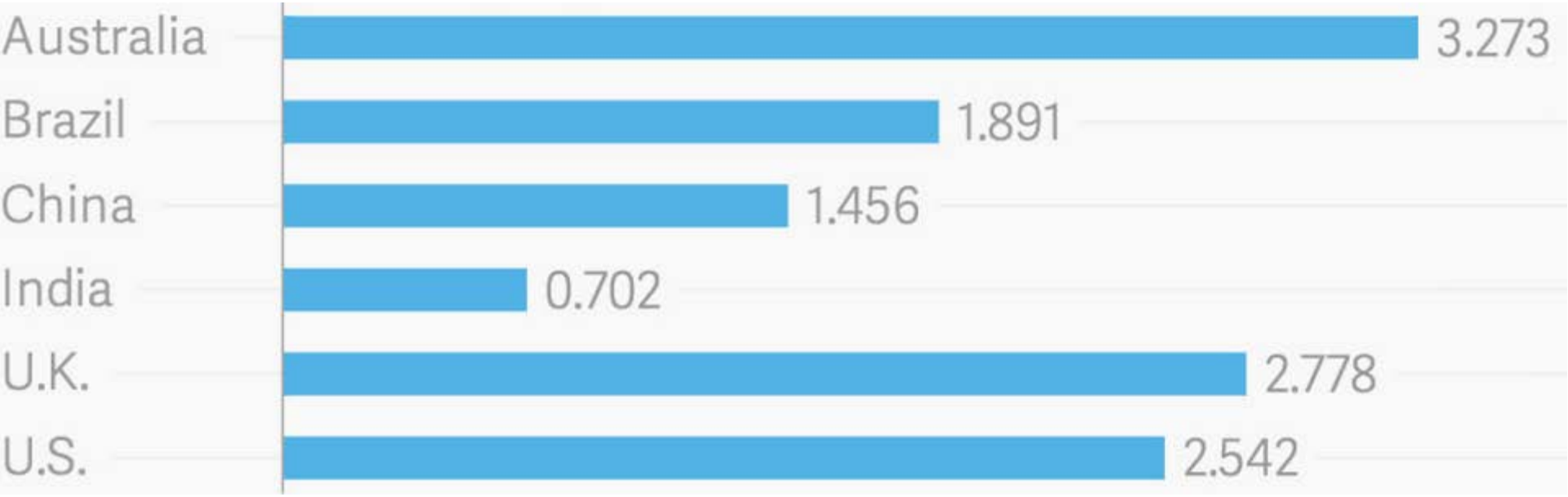
**$22,000** U.S. average

**Kidney Dialysis**

**$12,000** Deccan Hospital, India

**$66,750** U.S. average

# Density of Doctors per 1000 people (WHO, 2011)




| | |
|---|---|
| Population of India | 1,252,000,000 |
| Number of doctors in India | 750,000 |
| Number of new cervical cancer patients in India | 70,000 |
| Number of new gynecological cancer specialist each year in India | 1 |

http://qz.com/269394#2/why-you-have-to-share-a-doctor-with-1424-other-people/

# Fast Forward → Penny Per Person Per Use Per Day

$1 - Bone density

$1 - Mammogram

at the corner of Happy and Healthy in every zip code in India, China, Indonesia

data transmitted to specialists and reports sent to individuals, doctor and clinic

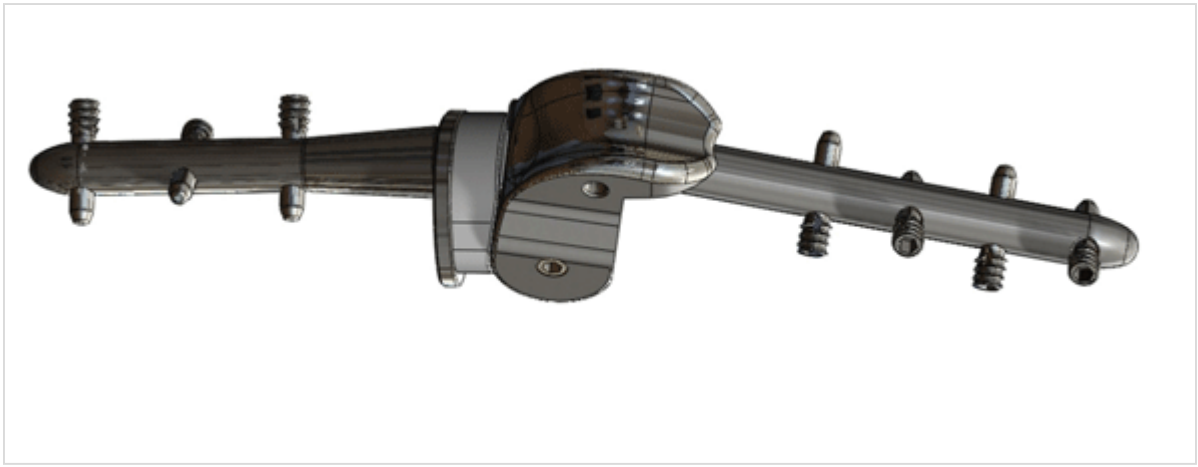
The micro-revenue earnings potential with 10% penetration for population of 3+ billion & aging!

# *Domain Specific Scenario*

3-D Printing in Healthcare

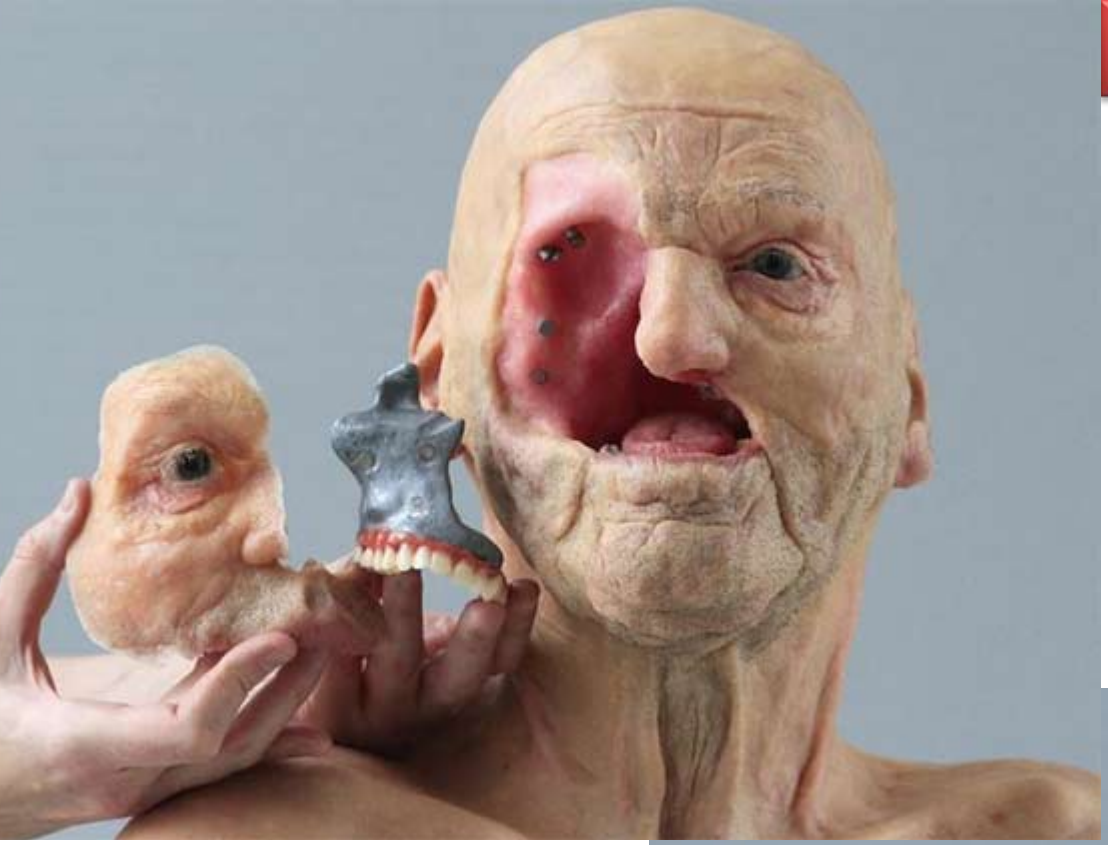
Innovation in manufacturing and digital design

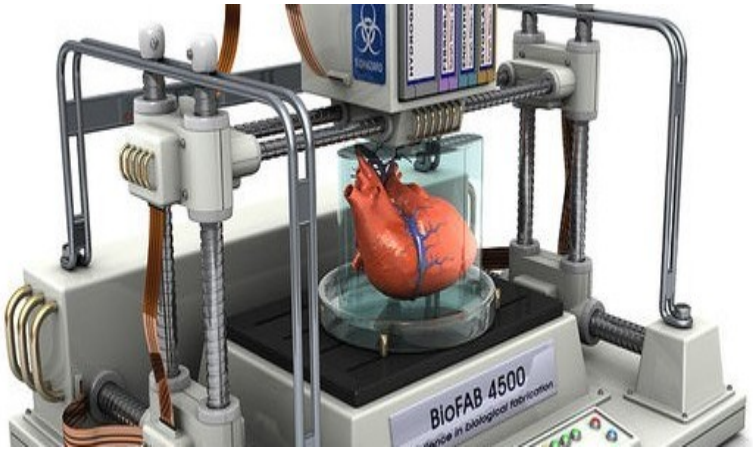
# 3-D Printing
# Design of Prosthetics and Orthopedic Imaging



Cyrano L. Catte II (above) is the first feline to receive a total knee arthroplasty (TKA). Femoral and tibial components were created with a direct metal laser sintering (EOS).

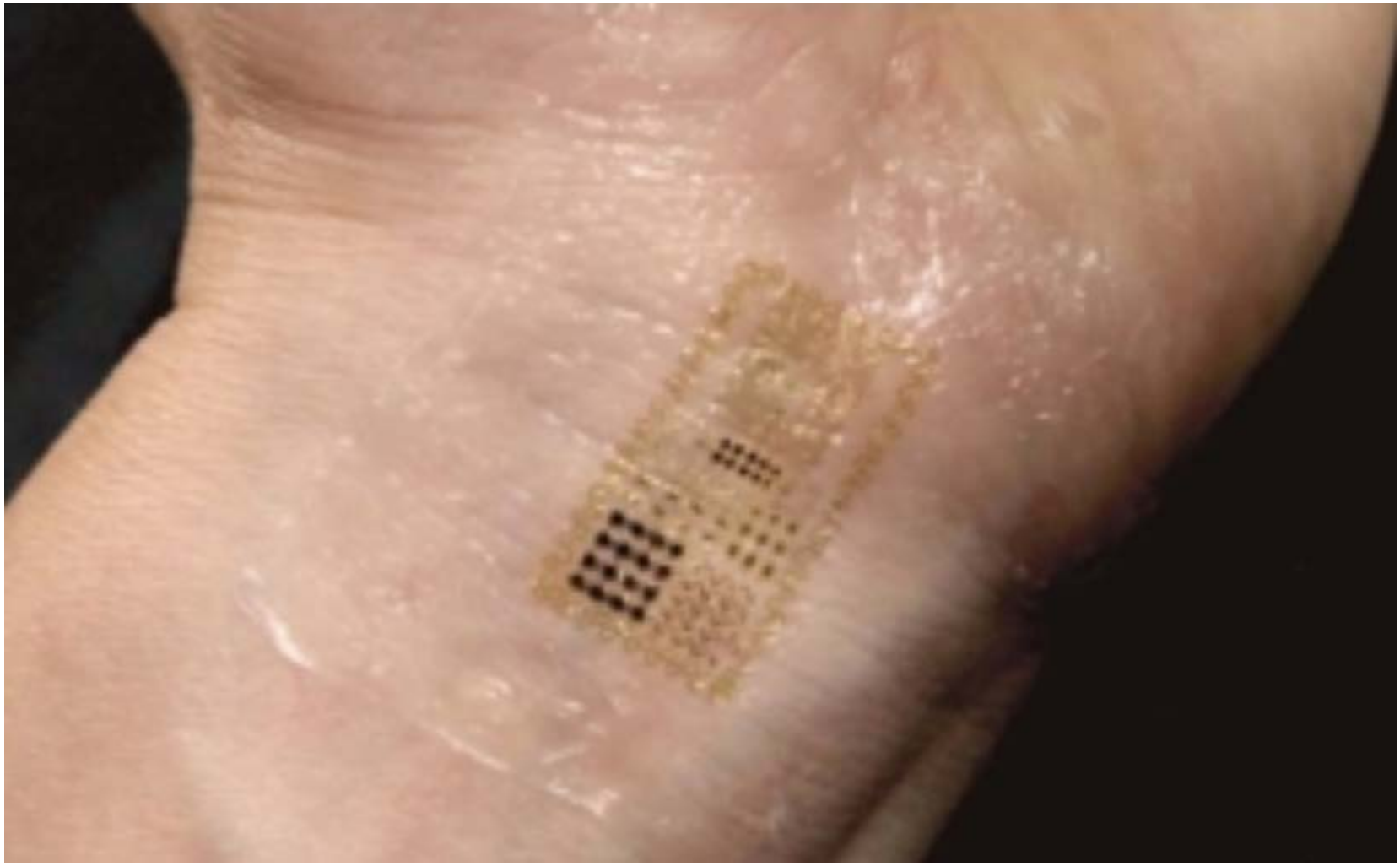
# 3-D Printing of Medical Devices






http://bit.ly/3D-Print-A-Tooth
http://bit.ly/3D-Print-Medical-Devices

# Artificial Skin with embedded sensory surface talks to smart phone via capacitive sensing using Touchcode adapted for printed i-Skin

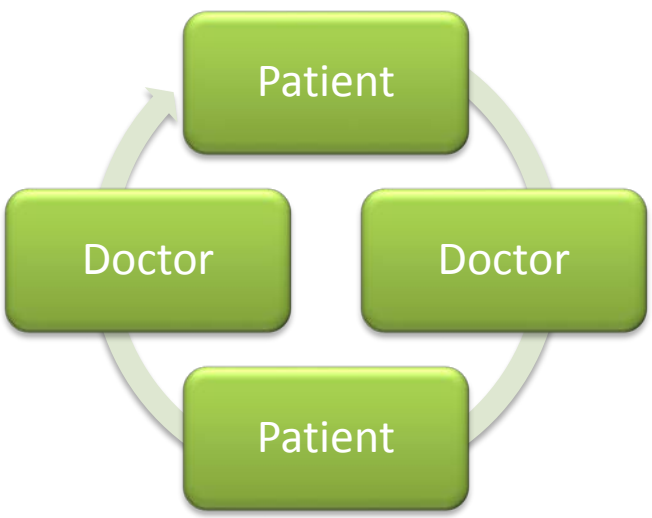


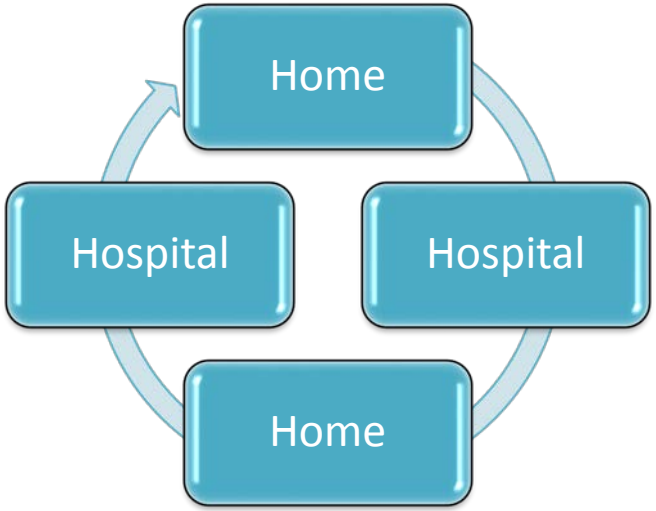
Your medicine can inform your doctor about its kinetics, bio-availability and side effects. It can alert your pharmacist about potential over-dose if multiple medications contain same or similar active ingredients. Your medicine can query and adjust dosage.

# *Domain Specific Scenario*

Healthcare Management

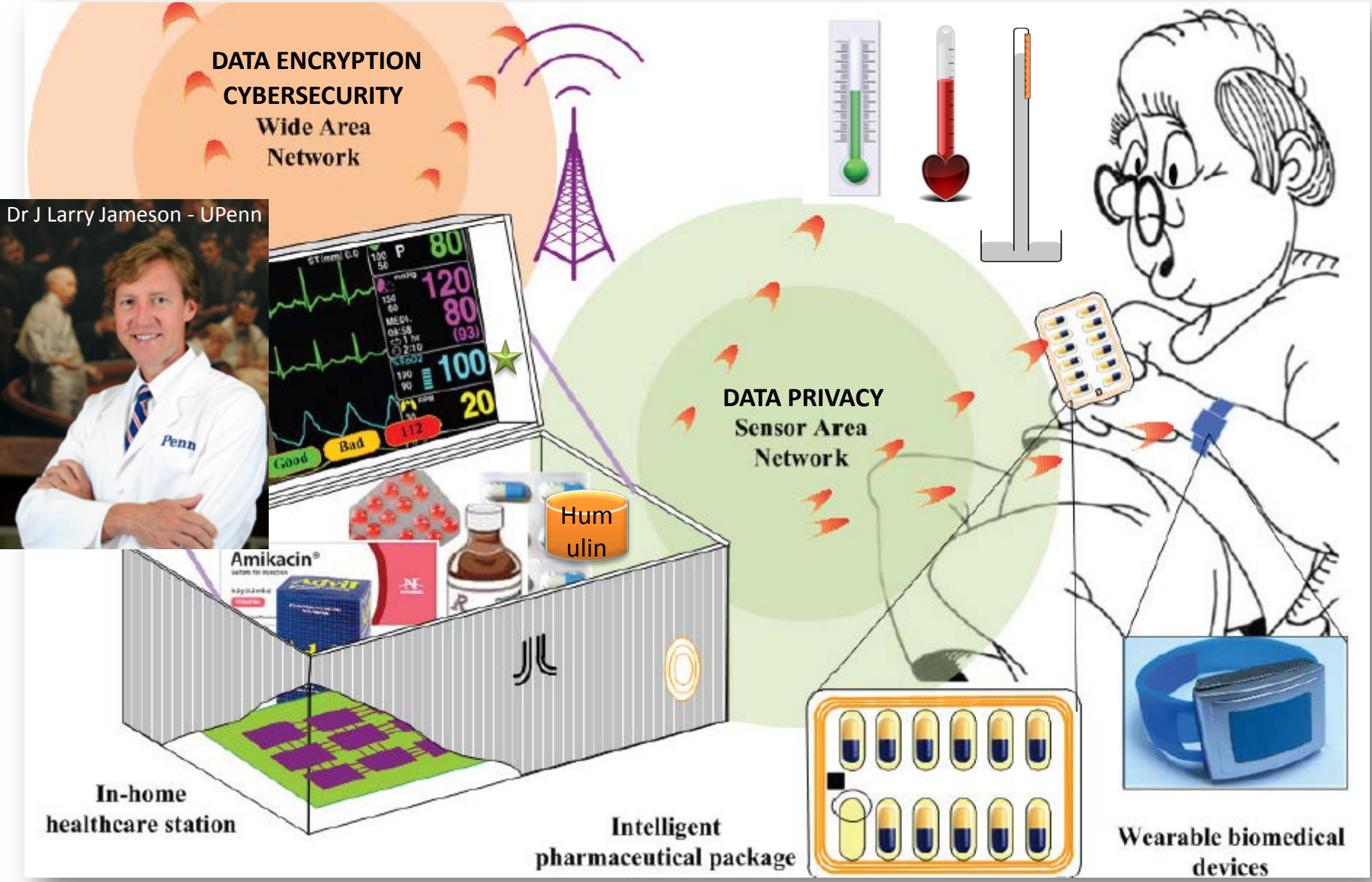
# Healthcare Management - Fundamentally Closed Loop & Quintessentially Patient Specific




The buzz of “innovation” in healthcare often fails to differentiate between tools and services. Tools and technologies used to deliver healthcare are easy targets for innovation, modularity and scalability. This is innovation in health related tools, ***not healthcare***. Innovation in healthcare is about ***delivery*** of healthcare which is a closed loop management system uniquely focused on one patient (not scalable) and relevant tools must converge at the point of care. The infrastructure (data, transmission, security, privacy) to deliver healthcare may be scalable but innovation to enhance the quality, functionality and reliability of the infrastructure may or may not have an impact on the QoS of healthcare delivery at POC.

# Harry at home with hypercholesterolemia : Hi Dr Jameson - Do I need Lipitor today?



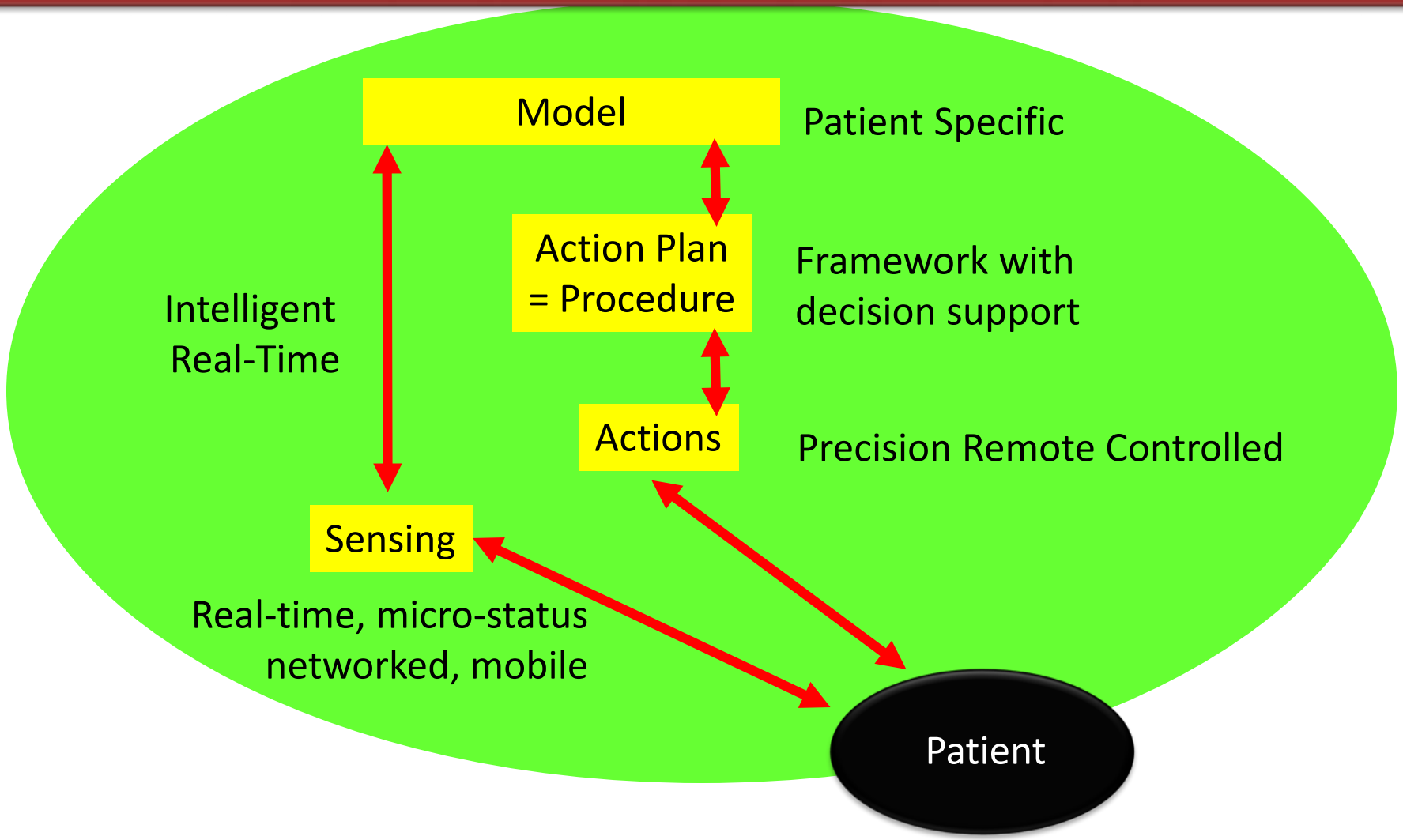

Dr J Larry Jameson: Thanks for avoiding KFC. Your LDL-VLDL ratio looks good. No Lipitor today.

# *Domain Specific Scenario*

Medical Device Integration

Data Interoperability

# 2004 CIMIT – Sense, ***then***, Respond – Future Integrated Healthcare Monitoring




*The distinction between healthcare and other industry is in differentiation of scalability. Patient centricity as a service is not scalable but patient centric infrastructure (architecture) is scalable.*

- Medical Device Interoperability?

# How Many Die From Medical Mistakes in U.S. Hospitals?

www.propublica.org/article/how-many-die-from-medical-mistakes-in-us-hospitals

- 1999 – IOM published “To Err Is Human” up to 98,000 die each year because of mistakes.
- 2010 – OIG US HHS: bad hospital care caused 180,000 deaths in Medicare in a given year.
- 2013 – Journal of Patient Safety: between 210,000 and 440,000 patients suffer some type of ***preventable*** harm that contributes to their death.
- That would make medical errors the third-leading cause of death in the US, behind heart disease, which is the first and cancer, which is second.

http://journals.lww.com/journalpatientsafety/Fulltext/2013/09000/A_New,_Evidence_based_Estimate_of_Patient_Harms.2.aspx

# Autonomous Control of Morphine Infusion Pump – Medical Device Integration Model

Infusion Pump

Capnometer

Patient Simulator
Ventilator

Intelligent Monitor


Vital Signs Monitor

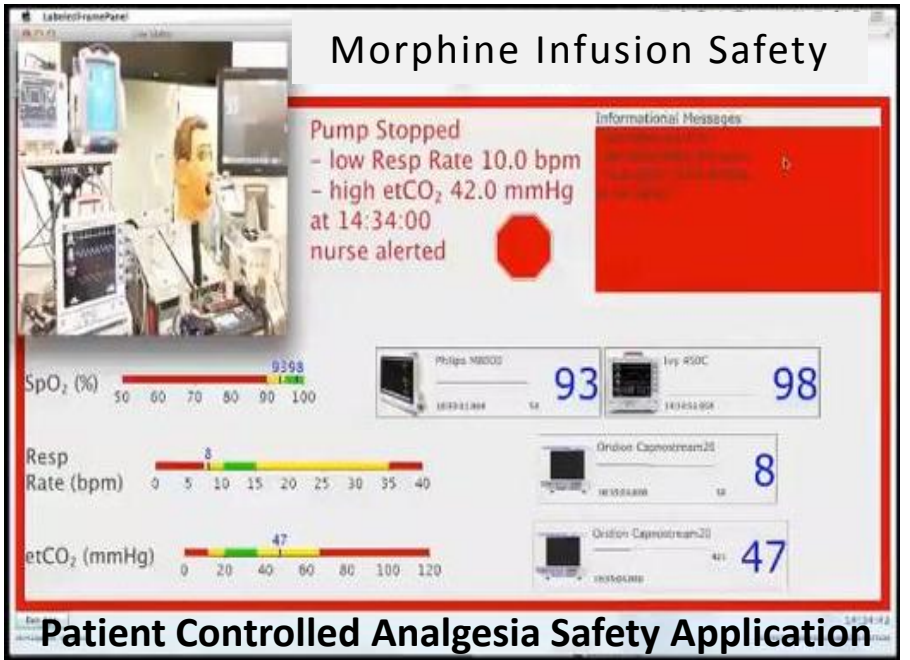
Simulator connected to vital signs monitor

Fluke ProSim 8 connected to intelligent monitor

*Approx 6,875 serious <u>preventable</u> PCA-related adverse events pa.*
*Annual Economic impact $15-145M ($13,803 per injured patient)*

- ↓ $O_2$ Saturation
- ↓ Respiratory Rate
- ↑ end-tidal $CO_2$

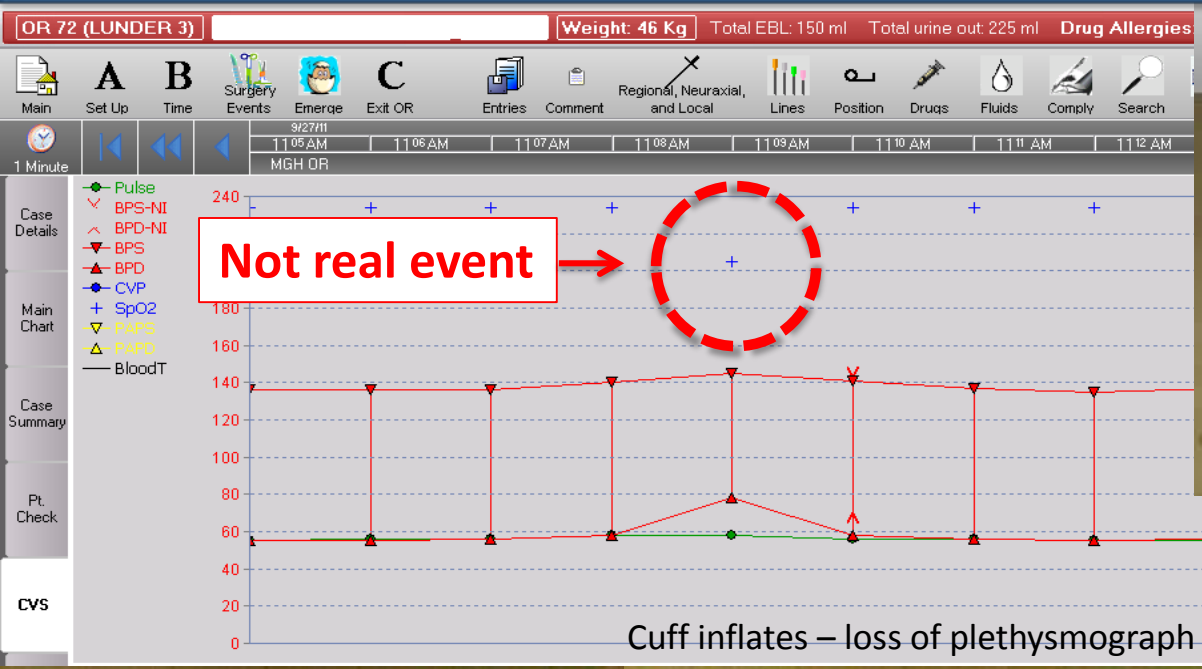
Connected Data
Collective Analysis
Automated Response




**Patient Controlled Analgesia Safety Application**

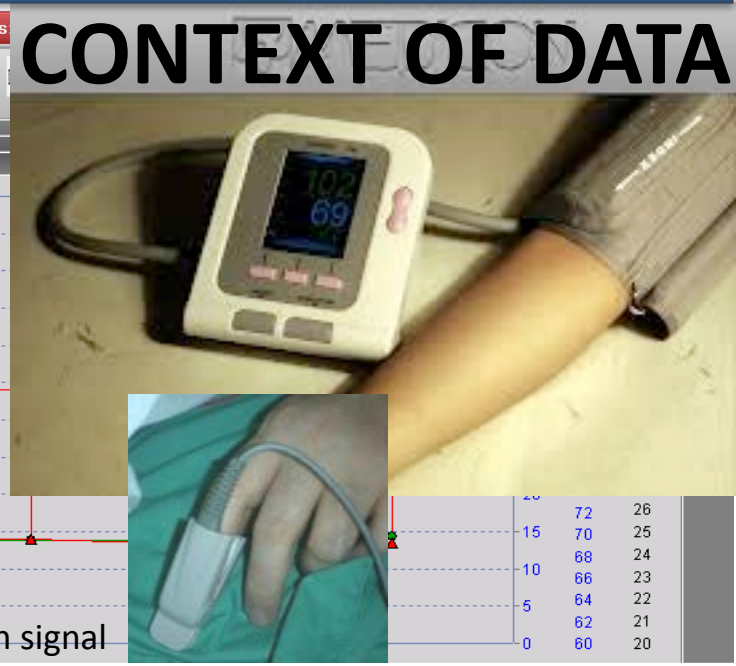
Julian Goldman MD (MDPnP.org and Partners.org)
Massachusetts General Hospital, Harvard Medical School
Harvard – MIT Center for Integrative Medicine and Information Technology

# Blood Pressure Cuff and Pulse Oximeter




Cuff inflates – loss of plethysmograph signal

## CONTEXT OF DATA

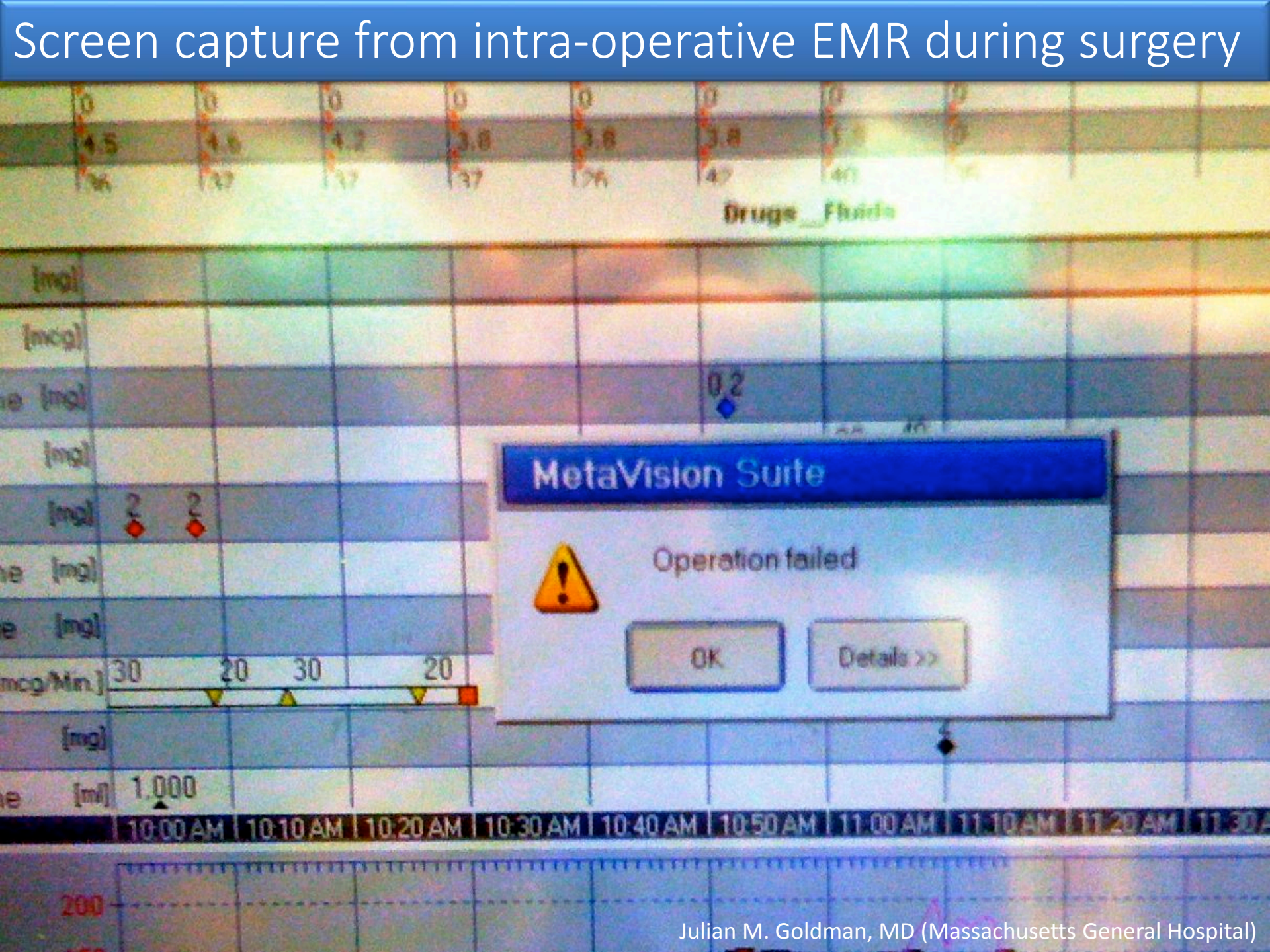



Julian Goldman MD

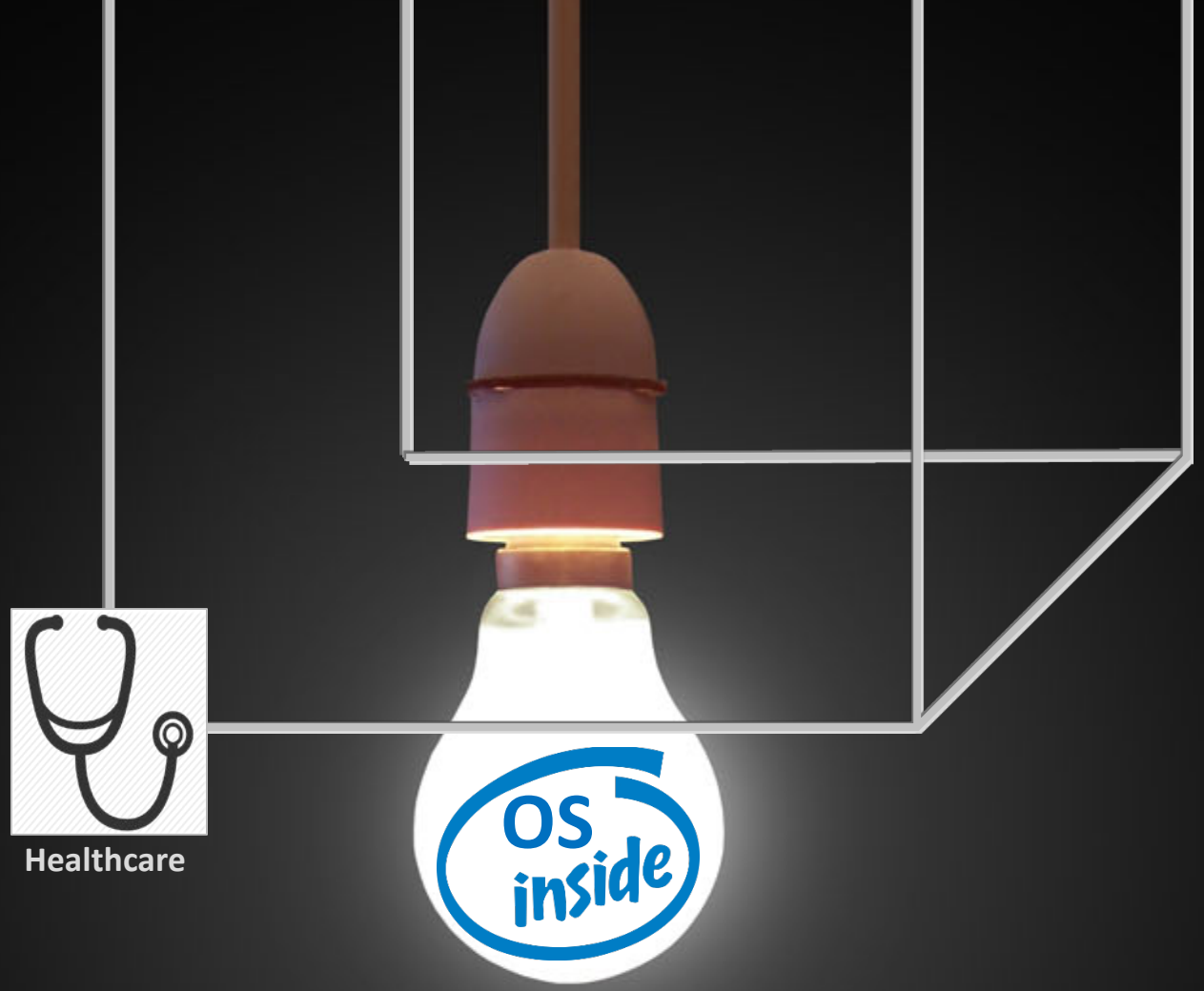
# Infusion pumps in use on ONE patient

1. Decision support?
2. Prevent contra-indicated infusion?
3. Consolidate data for adverse event analysis?
4. Check device status and software version?
5. Device update via SDN?

# Screen capture from intra-operative EMR during surgery



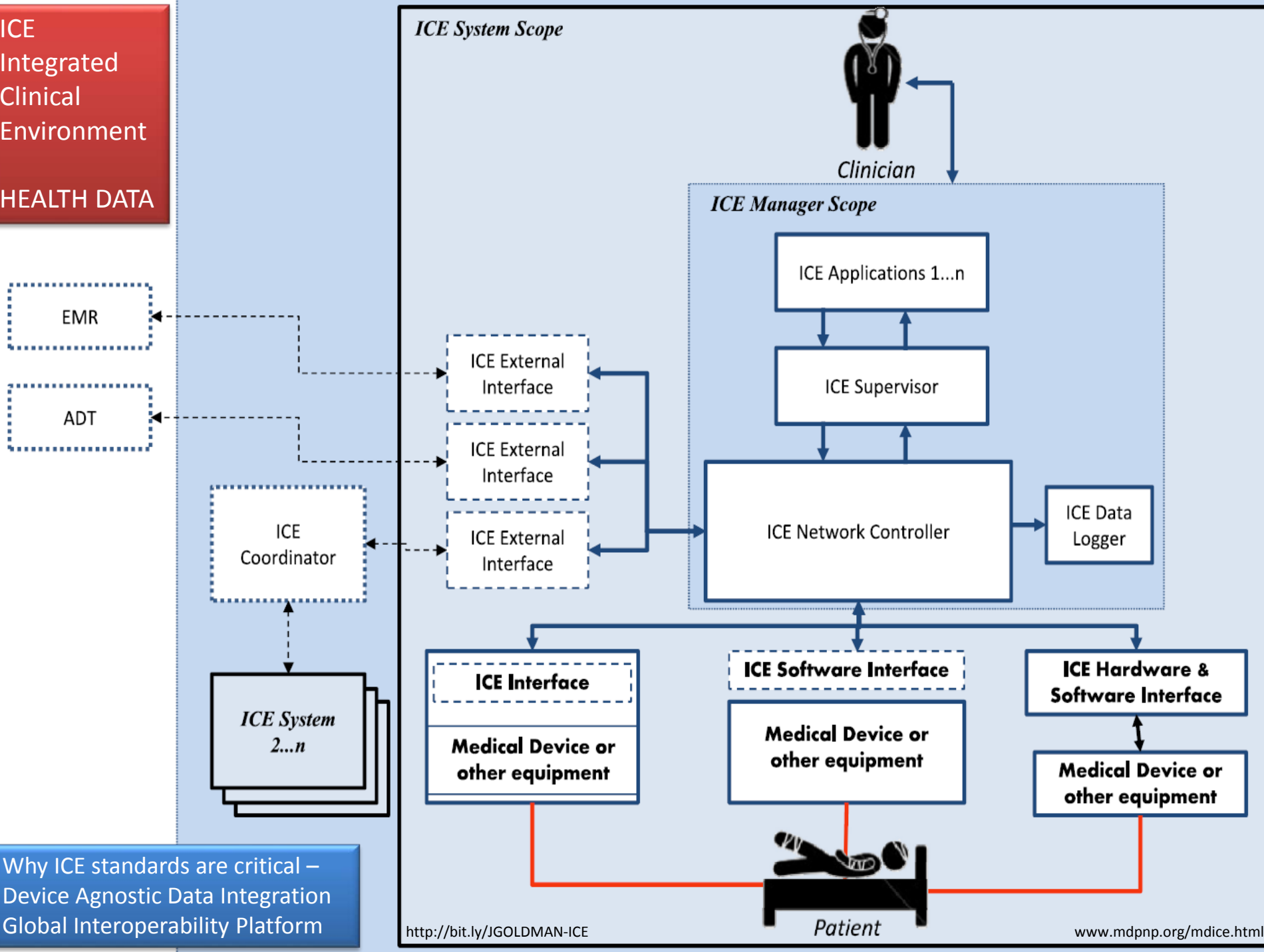

Julian M. Goldman, MD (Massachusetts General Hospital)




# Grand Platforms

ICE Integrated Clinical Environment

HEALTH DATA




Why ICE standards are critical – Device Agnostic Data Integration Global Interoperability Platform

# Integrated Healthcare Platform

## Data Logging and Access via Secure Interoperable Standards

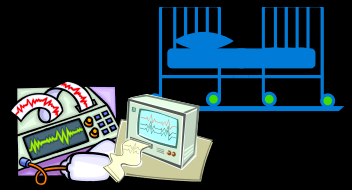

Imaging

EHR-Admin

EMR-Physician

Clinical Devices

Medical History



Clinic - Ward


Pharmacy

Laboratory

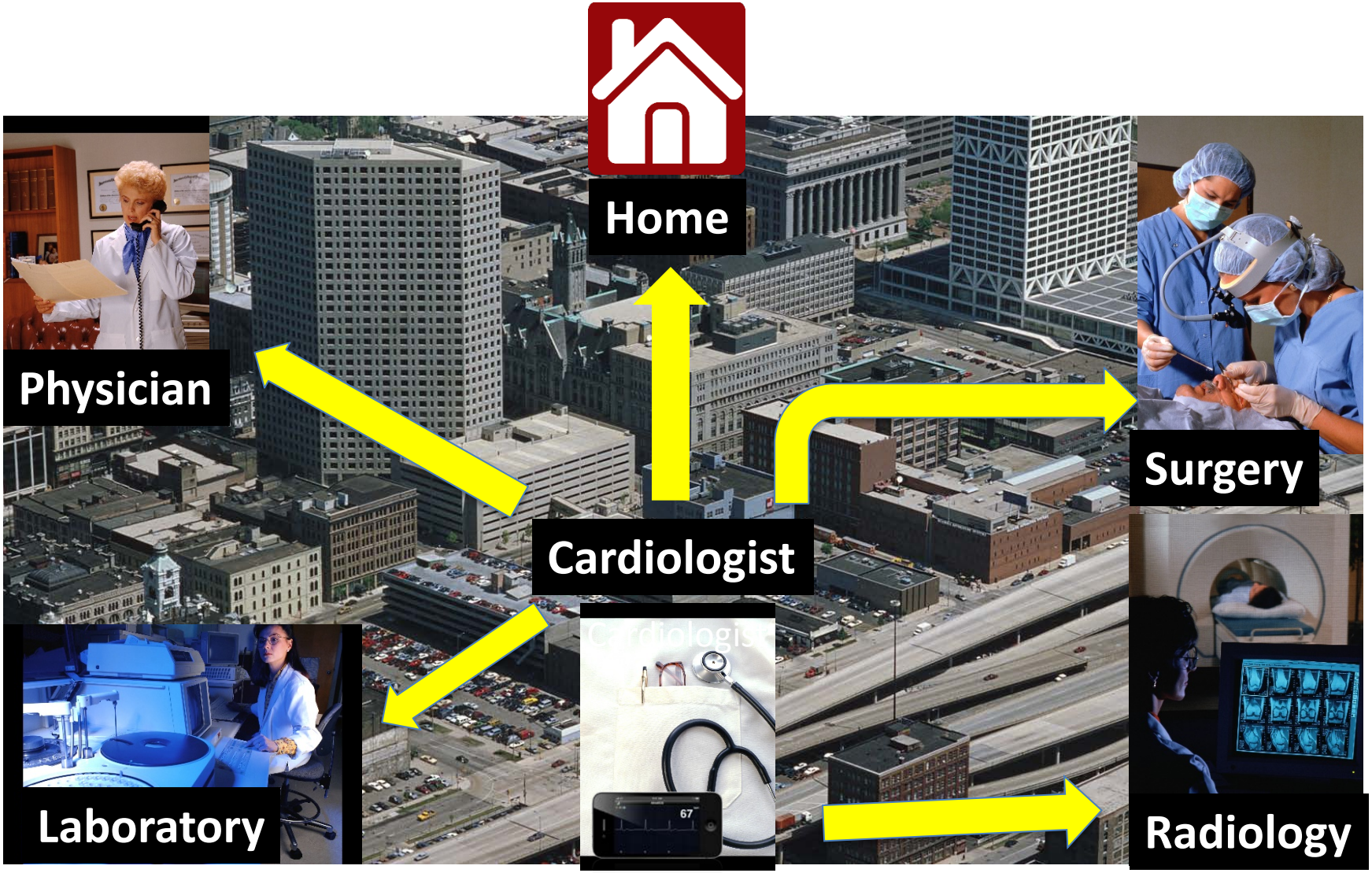
Exchanges

Devices

Homecare

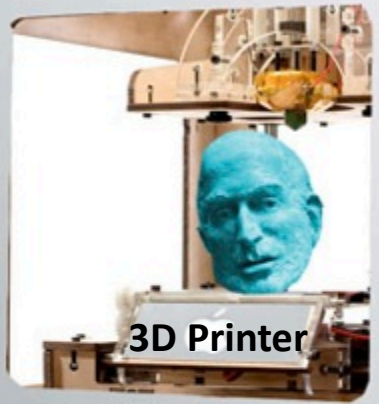
# Integrated Healthcare Platform

## n-Directional Data Access via Secure Interoperable Standards



# Hamburger wrapped in touch-code paper predicts CHF


Your burger calls your doctor to report that you are eating too many burgers.




# Congestive Heart Failure

*Why should CHF claim about 5 million lives in the US?*

- About 5.1 million people in the United States have heart failure.
- About half of people with CHF die within 5 years of diagnosis.
- CHF costs the nation an estimated $32 billion each year.

www.cdc.gov/dhdsp/data_statistics/fact_sheets/fs_heart_failure.htm

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2004 MIT experiment - 100 students and Nokia 6600 by Nathan Hale + Alex (Sandy) Pentland

- cell tower location data
- call data record (CDR)

Analytics – Predicted with high accuracy what you would do around 6pm if you get up at 10am

# Congestive Heart Failure

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- About half of people with CHF die within 5 years of diagnosis.
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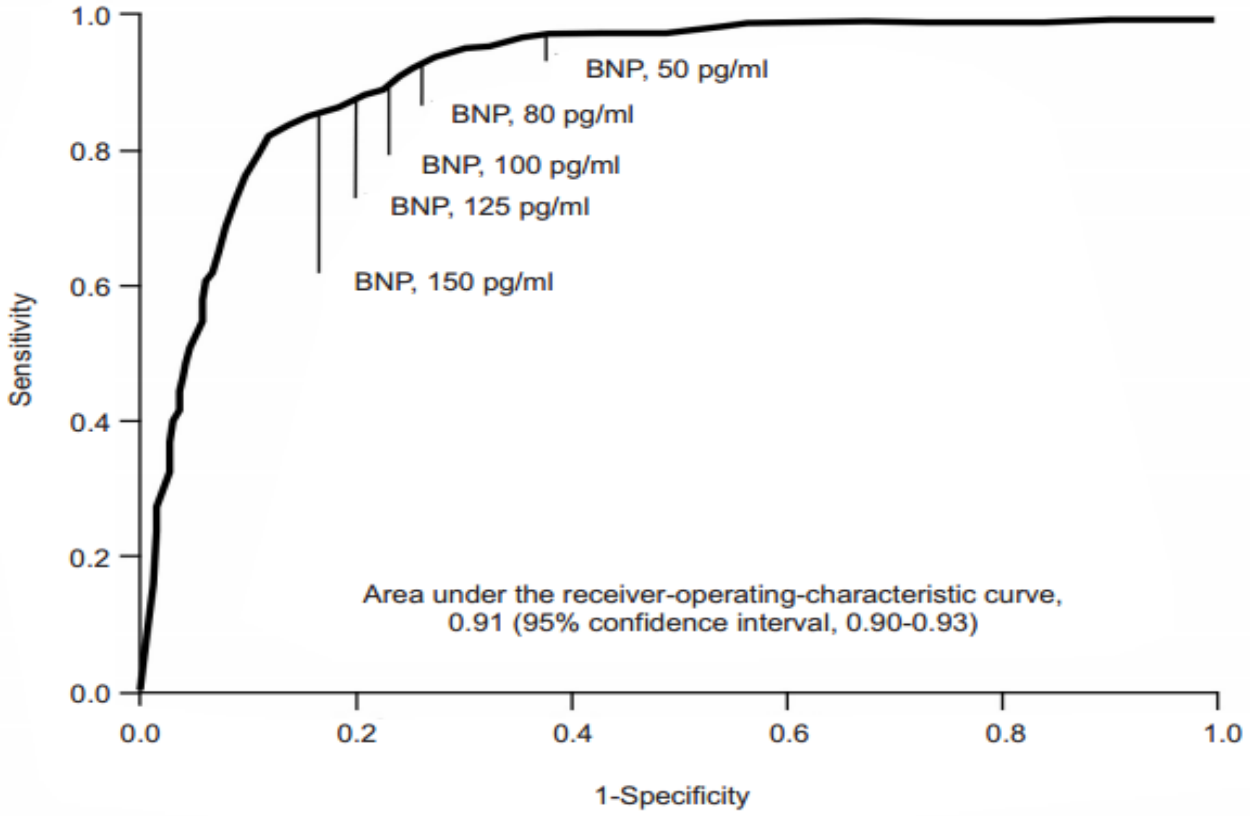
Abundance of prognostic biochemical markers –

- C-reative protein (CRP5 / CRP6) – 1954 and Framingham Heart Study
- Tumour necrosis factor alpha (TNFα)
- Brain Natriuretic Peptide (1981) BNP <100 pg/ml CHF unlikely and >400 pg/ml CHF likely
- N-terminal (NT) pro-BNP <300 pg/ml CHF unlikely and >400-900 pg/ml CHF likely (age related)

**48,629 patients of acute decompensated heart failure found linear correlation between BNP levels and in hospital mortality. Failure of BNP to decline during hospitalization predicts death and re-hospitalization while discharge levels of 250pg/ml or less predicts event free survival.**

http://bit.ly/CHF-US
http://bit.ly/CHF-IN
http://bit.ly/CHF-JP

www.cdc.gov/dhdsp/data_statistics/fact_sheets/fs_heart_failure.htm

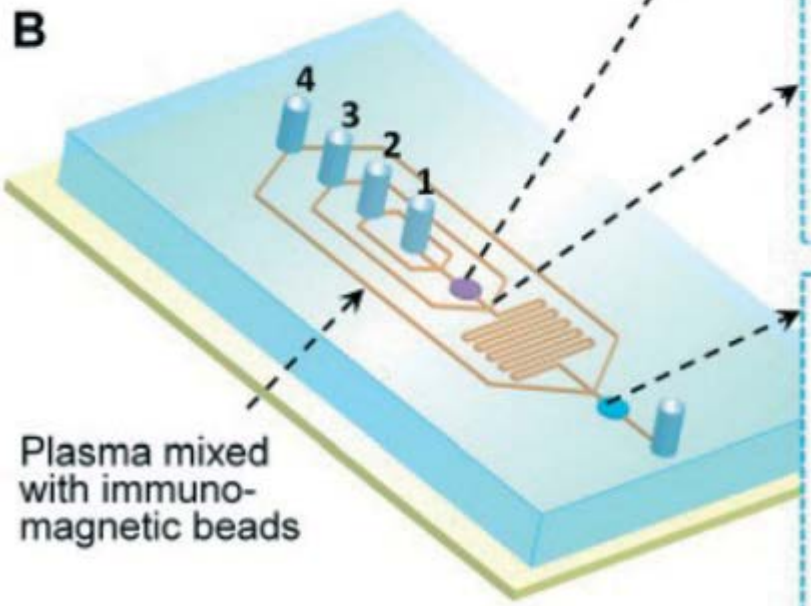


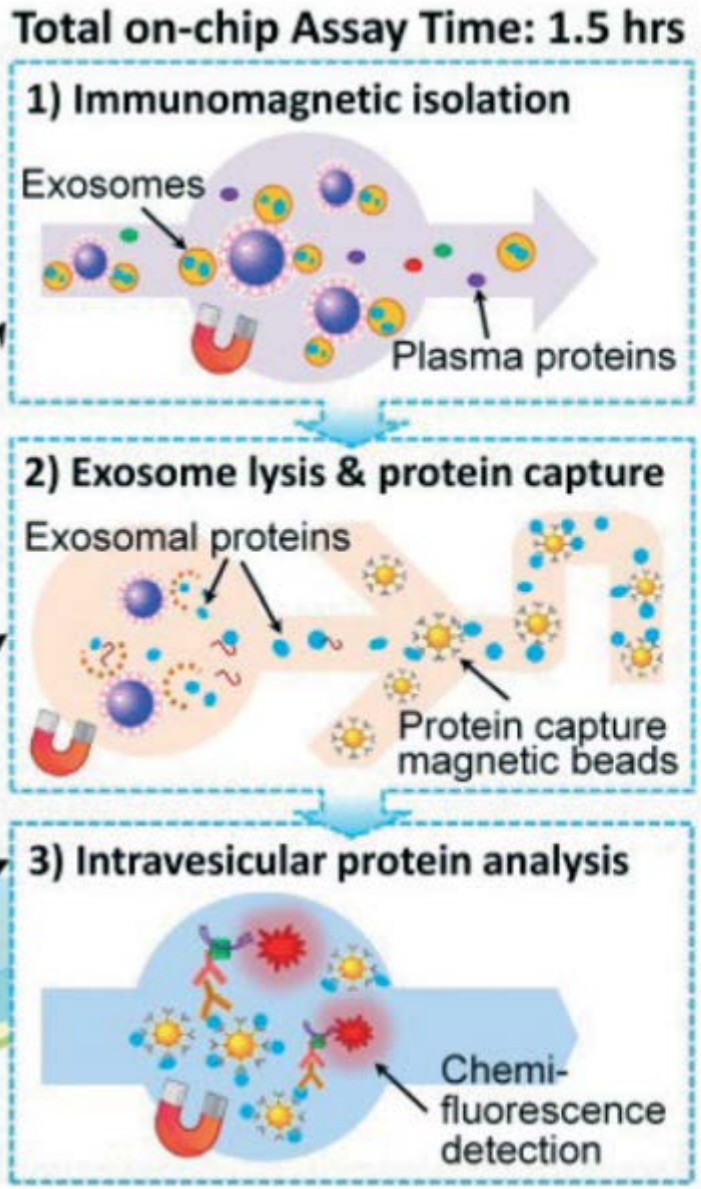

| BNP pg/ml | Sensitivity | Specificity | Positive Predictive Value | Negative Predictive Value | Accuracy |
|---|---|---|---|---|---|
| 50 | 97% | 62% | 71% | 96% | 79% |
| 80 | 93% | 74% | 77% | 92% | 83% |
| 100 | 90% | 76% | 79% | 89% | 83% |
| 125 | 87% | 79% | 80% | 87% | 83% |
| 150 | 85% | 83% | 83% | 85% | 84% |

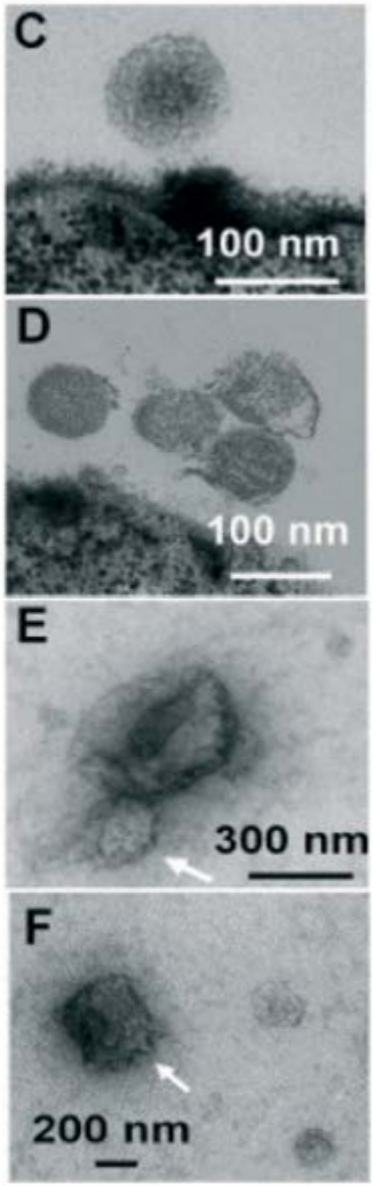
**Figure 3-1A** Receiver Operator Characteristic (ROC) Curve for B-type Natriuretic Peptide Testing in the Diagnosis of Heart Failure with Acute Dyspnea *(68)*. With permission from Maisel A, et al. "Rapid measurement of B-type natriuretic peptide in the emergency diagnosis of heart failure." *N Engl J Med* 2002; 347(3): 161–7; Copyright © 2002 Massachusetts Medical Society. All rights reserved. http://bit.ly/CHF-US

# Lab on a Chip - Detection of Non-Small Cell Lung Cancer (C) and Ovarian Cancer (D)



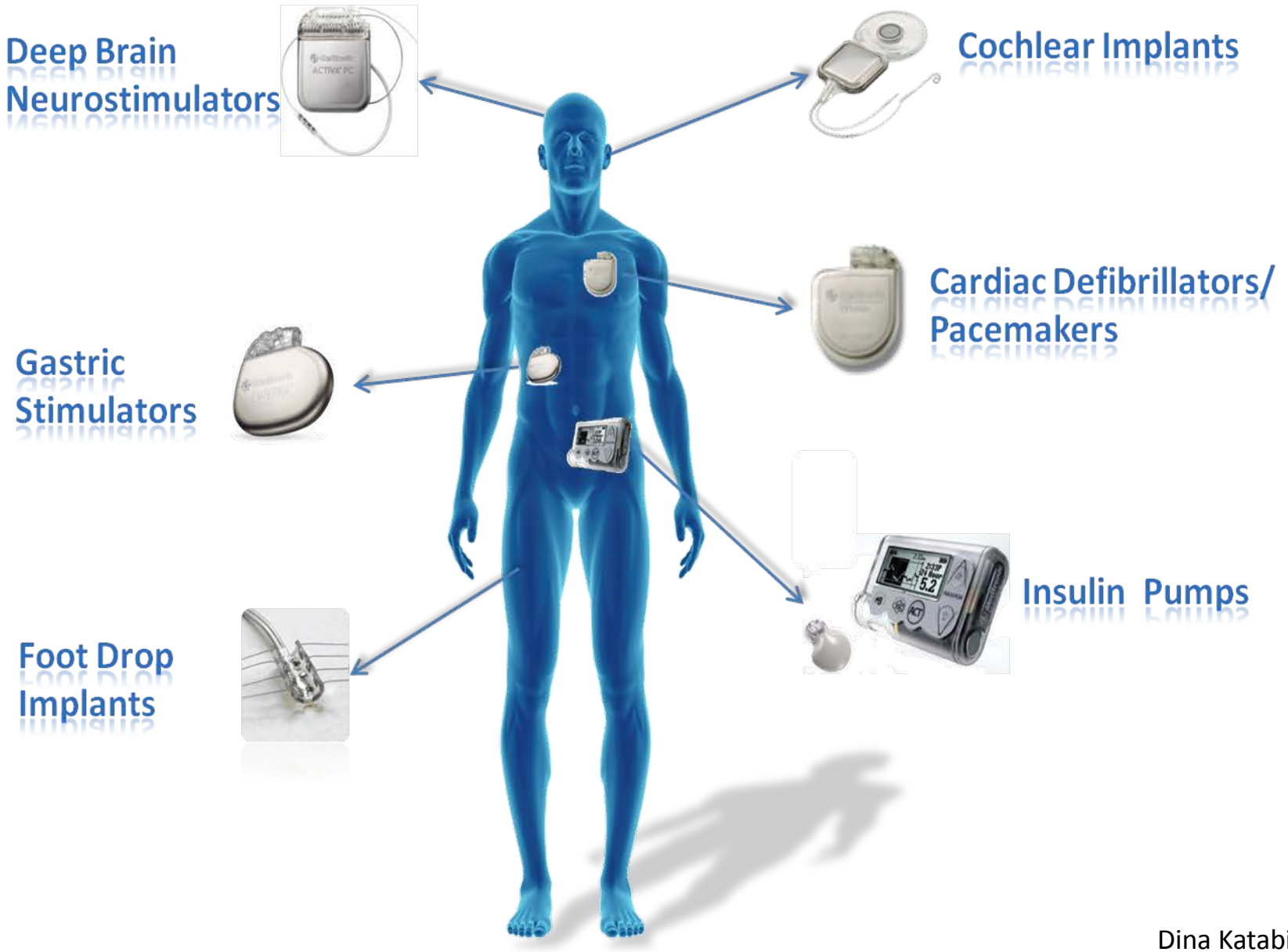



http://pubs.rsc.org/en/content/articlepdf/2014/LC/C4LC00662C

# WIRELESS IMPLANTABLE MEDICAL DEVICES




Dina Katabi, MIT

# SENSE, ANALYZE, ALERT

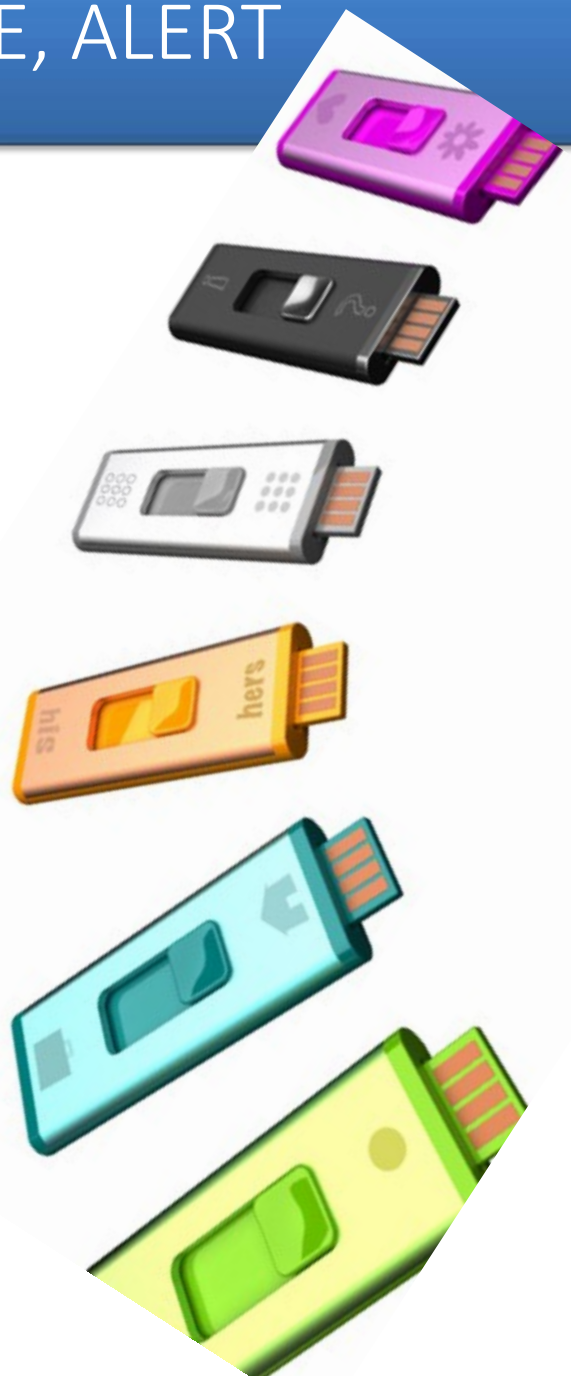
pH Sensor

CO Sensor

BNP Sensor

Glucose Sensor

Cholesterol Sensor

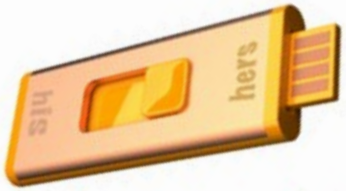



# CONNECT BILLIONS

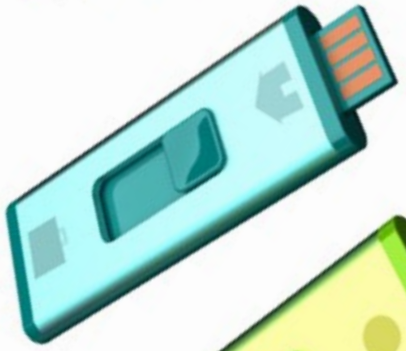

pH Sensor

CO Sensor

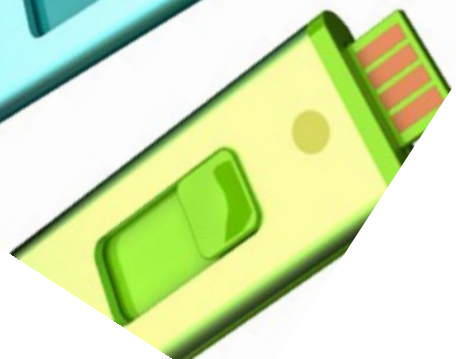
BNP Sensor




Glucose Sensor



Cholesterol Sensor




# Pay 1c Per Analytics Apps, Data Distribution Service

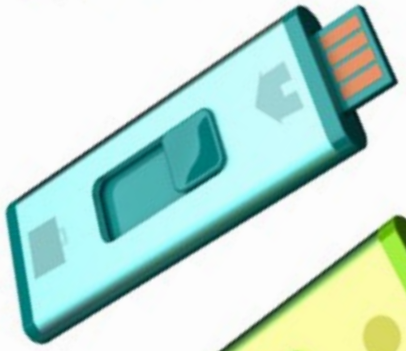
pH Sensor

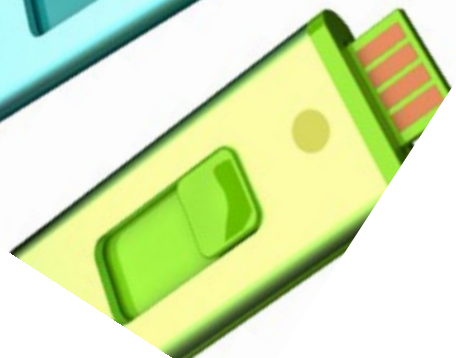
CO Sensor

BNP Sensor

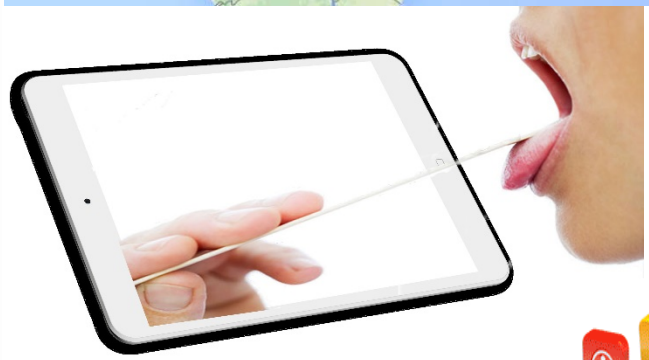
Glucose Sensor

Cholesterol Sensor



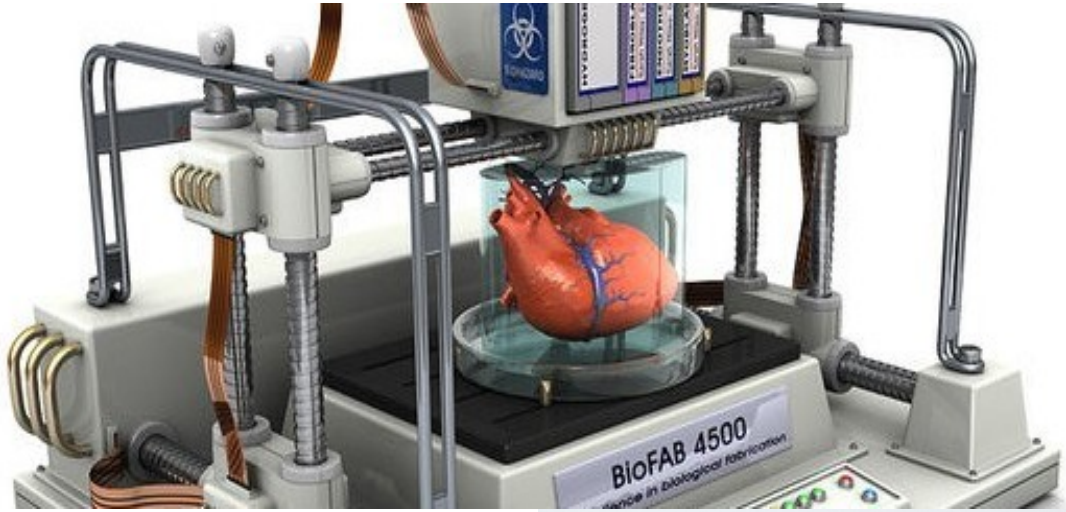
What does the data suggest about my health?

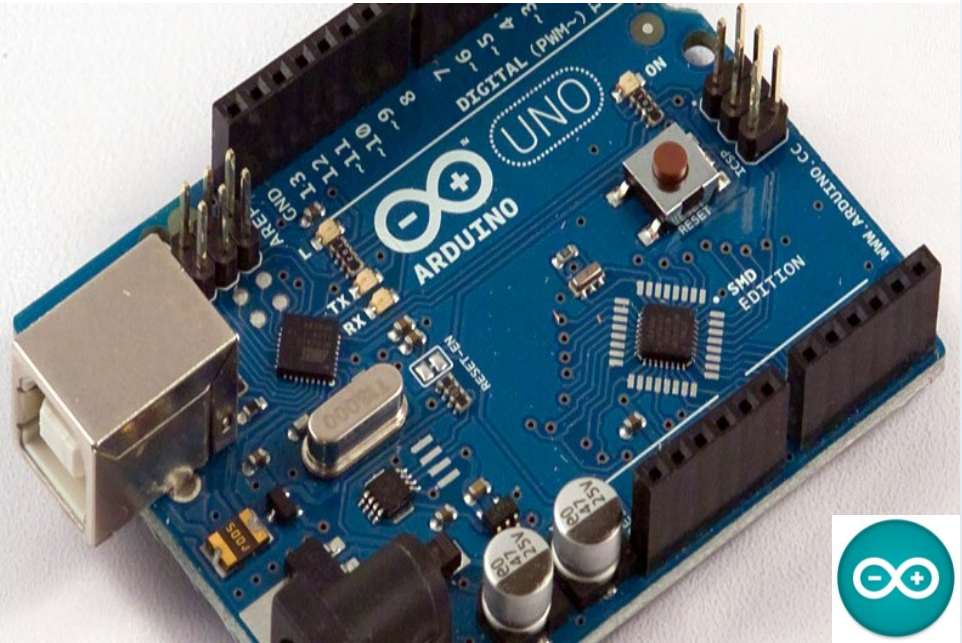



# Proprietary Data – Prevents Interoperability

# Global Healthcare Economics – Paradigm Shift ?

## 3D Printed Medical Devices + OS Hardware / Software

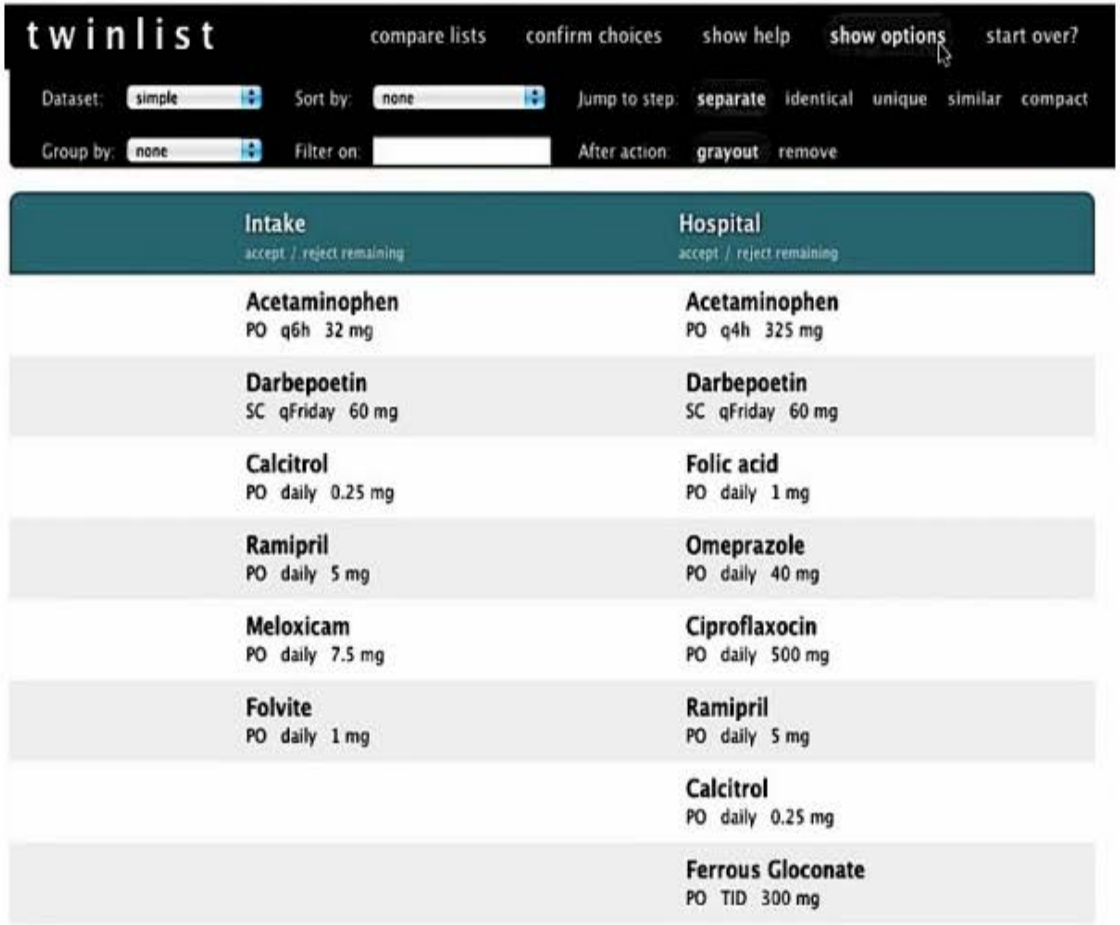



# Proprietary Healthcare Systems ?

EHR, EMR, Data Silos and
Medication Reconciliation

# PHARMACEUTICAL CONVERGENCE : MEDICATION RECONCILIATION LIST ?




www.youtube.com/watch?v=YoSxlKl0pCo

# Role of ONC FHA US HHS ?

# ONC FHA US HHS ? Standards and Interoperability ?

- Multilevel Decision Support Systems
- Security and Privacy Regulatory Policies
- Sensors, Tracking and Communication
- Ontologies for Objects and Events
- Predictive Analytics
- Data Mining and Pattern Identification
- Architecture for Storage and Services

# ONC HIT Certification Program

# Test Results Summary for 2014 Edition EHR Certification

Allscripts Enterprise Electronic Health Record

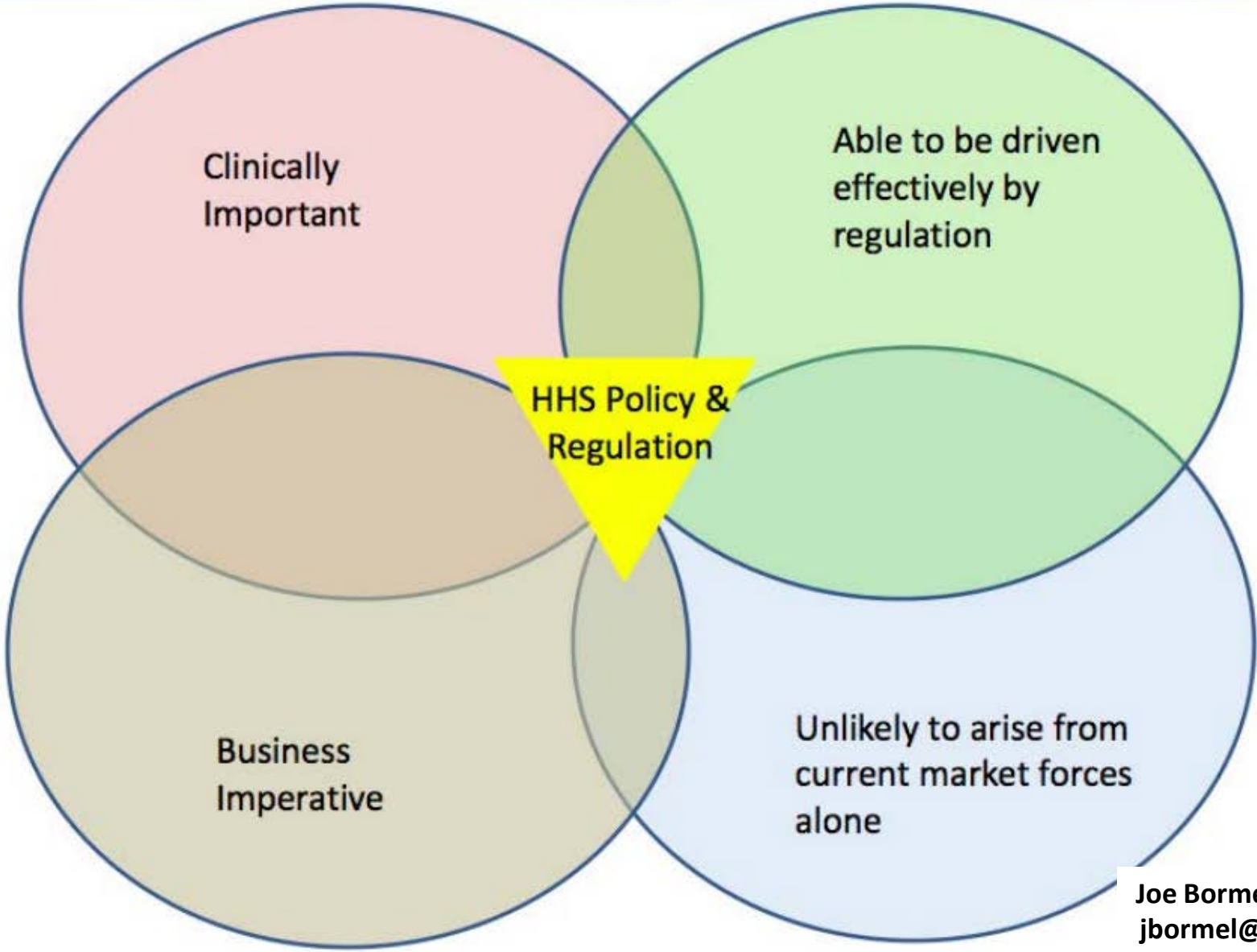
## Meaningful Use 2
## User-Centered Design Report

NISTIR 7742

**Customized Common Industry Format Template for Electronic Health Record Usability Testing**

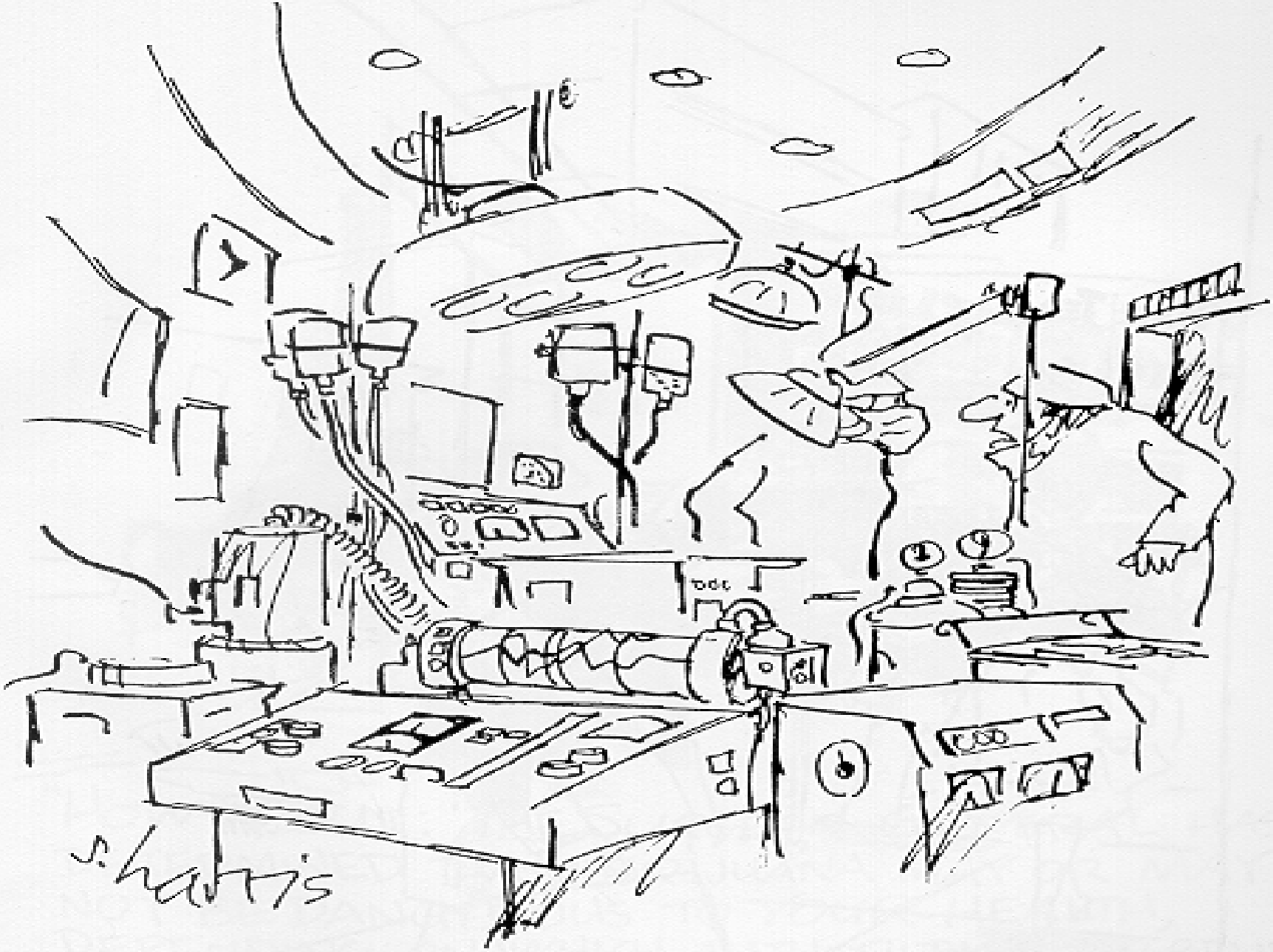
# Optimum Strategic Position for ONC to Leverage its Regulatory Authority for Change

Health IT Policy Committee
A Public Advisory Body on Health Information Technology to the National Coordinator for Health IT




Joe Bormel MD MPH
jbormel@gmail.com

# Operating Room: Today



"I GIVE UP. WHERE'S THE PATIENT?"

# Operating Room of the Future - Dr Julian Goldman MD


*Ascent of the Wireless Hospital*

- Paradox to Paradigms to Platforms ☑ http://bit.ly/MIT-IOT

- Vision, Mission and Opportunities

- Challenges
  - ☑ Autonomous Transportation
  - ☑ Global Smart Cities
  - ☑ Healthcare
  - ☑ Data

*All data are not created equal*

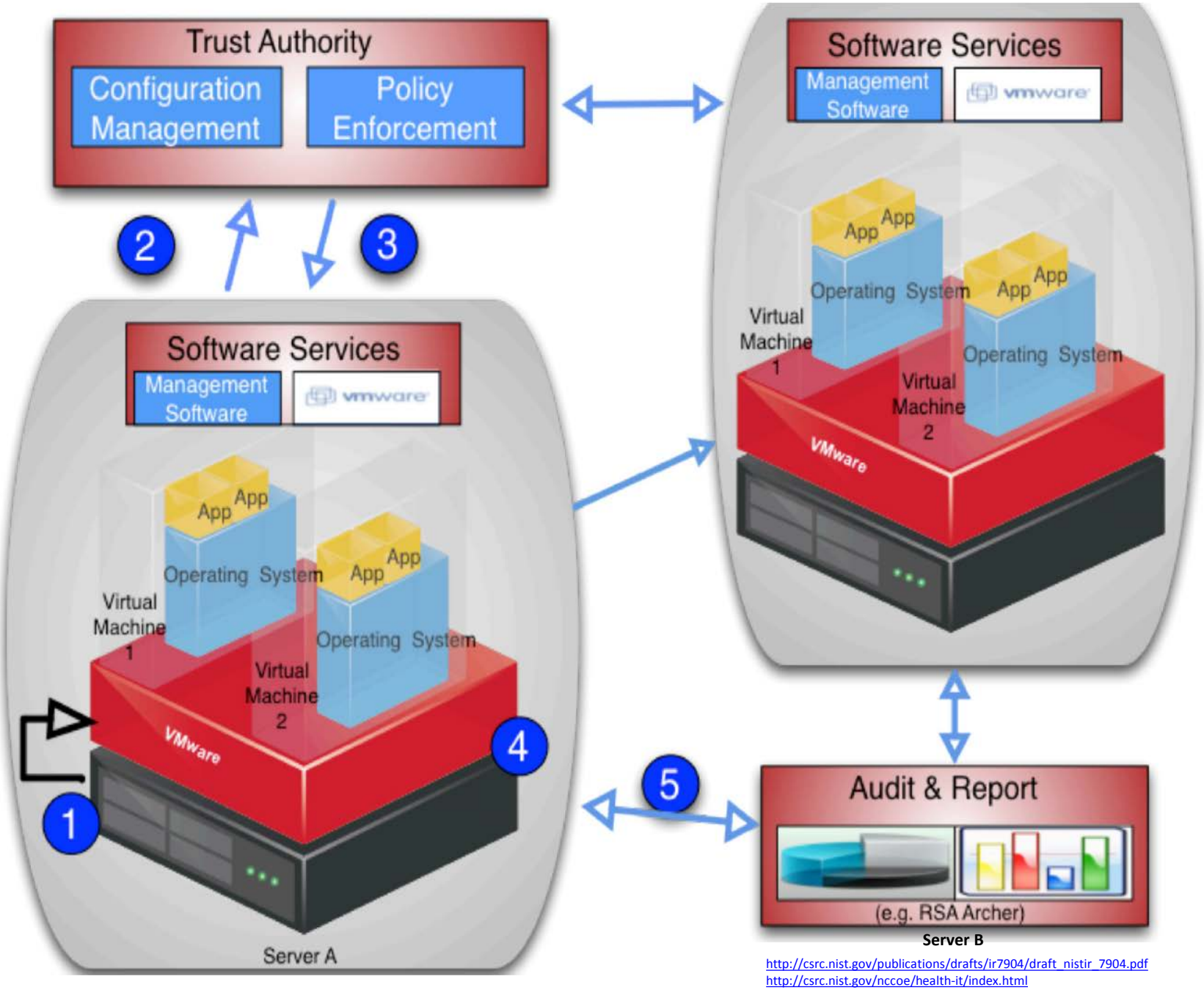
# DON’T USE MY DATA

"Before I write my name on the board, I'll need to know how you're planning to use that data."

*Healthcare Data Neutering*

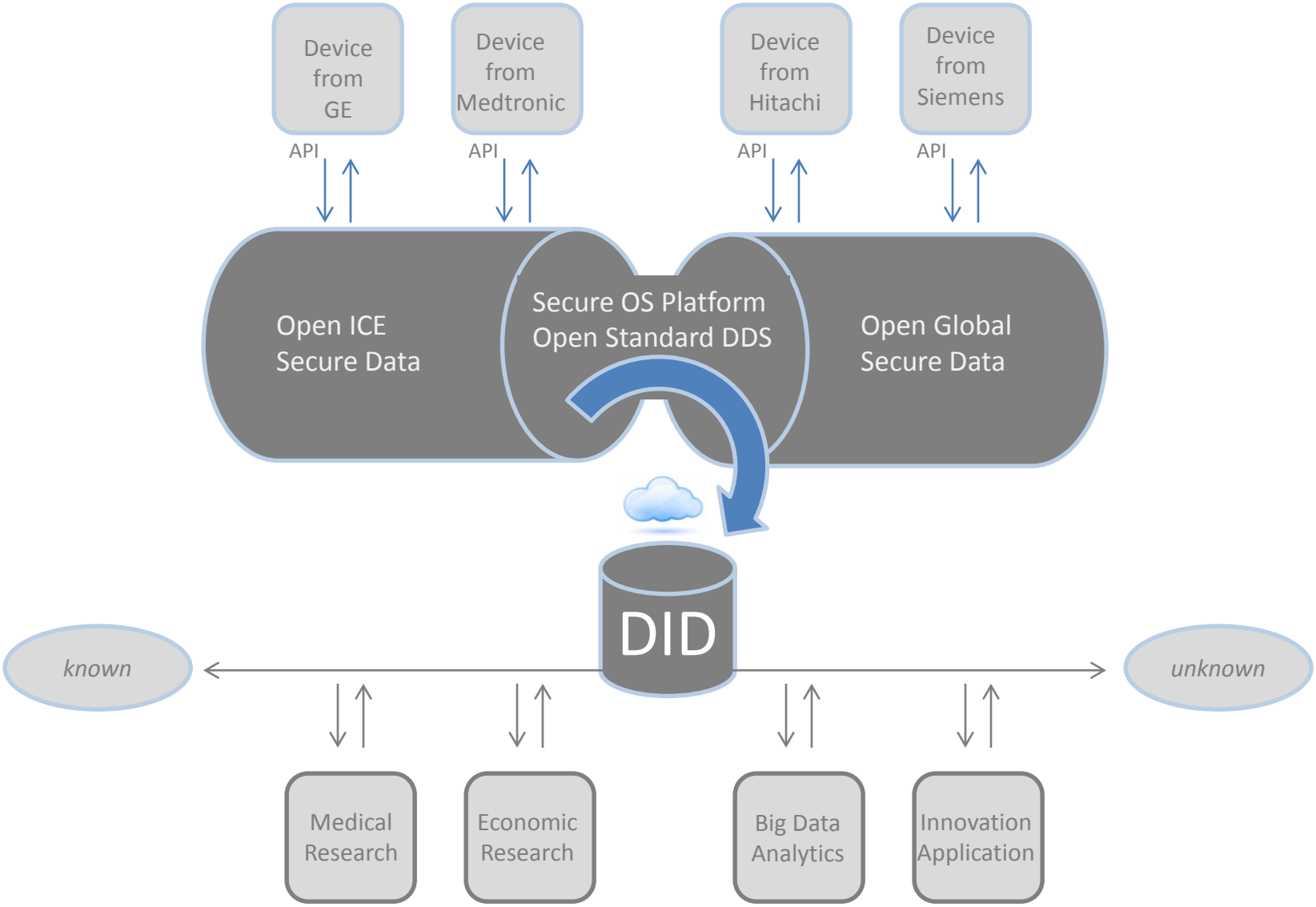
# De-Identified Data

# Trusted GeoLocation in the Cloud (NIST NCCOE) – Is this an adequate solution for health data?




http://csrc.nist.gov/publications/drafts/ir7904/draft_nistir_7904.pdf
http://csrc.nist.gov/nccoe/health-it/index.html

# De-identified Data (DID) will drive Research – Management Science – Policy – Funding




*Note: In certain instances, CPS related time constraints may render traditional cloud based D2D architecture unacceptable [QoS] due to latency.*

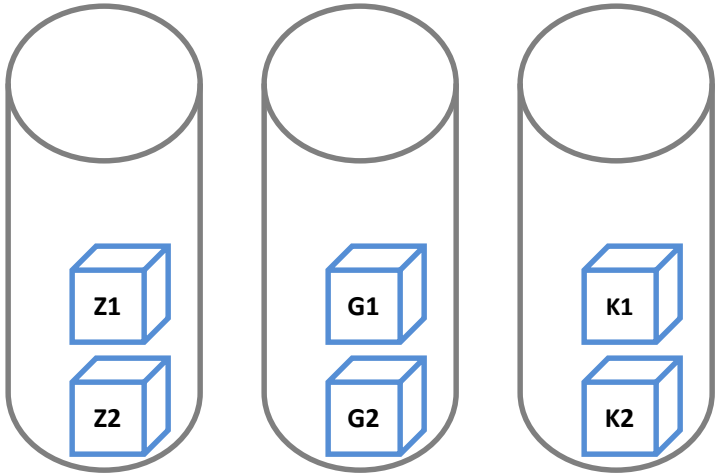
# Data Dissociation using meta data to identify/label data type

**Clinic VIEW**

| Name | SSN-UID | Street Address | Zip Code | Blood Glucose | Weight in kg |
|---|---|---|---|---|---|
| Jane Does<br>Tag N1 | 123-45-6789<br>Tag S1 | 77 Mass Ave<br>Tag A1 | 02139<br>Tag Z1 | 190 mg/dl<br>Tag G1 | 190<br>Tag K1 |
| John Does-Not<br>Tag N2 | 123-45-6790<br>Tag S2 | 86 Brattle St<br>Tag A2 | 02138<br>Tag Z2 | 109 mg/dl<br>Tag G2 | 159<br>Tag K2 |

**DID VIEW**

| Name | SSN-UID | Street Address | Zip Code | Blood Glucose | Weight in kg |
|---|---|---|---|---|---|
| | | | 02139<br>Tag Z1 | 190 mg/dl<br>Tag G1 | 190<br>Tag K1 |
| | | | 02138<br>Tag Z2 | 109 mg/dl<br>Tag G2 | 159<br>Tag K2 |




## Data Re-association using De-Identified Data (DID) Stack

Same data but ask a different

# QUESTION

# Same Data ← Different Questions → Extracting Information from DID

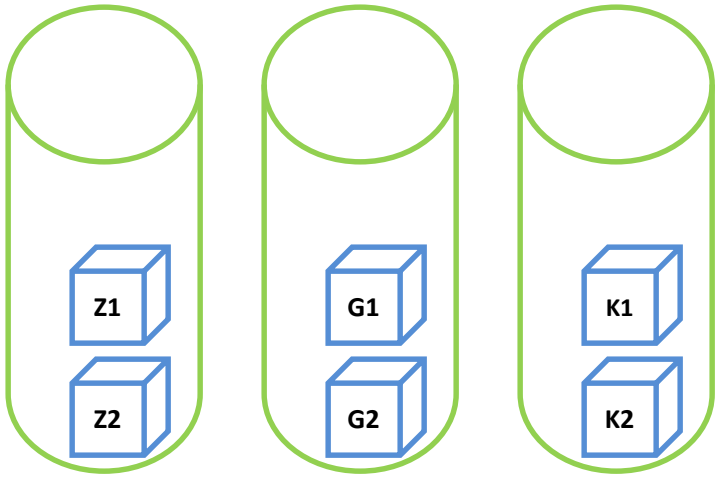
- Epedimiologists
- Economists
- Physician

*What is the distribution of potential diabetics by zip code?*

*Is there a relationship between per capita income and body fat?*

*Can we correlate high blood glucose with increased body weight?*

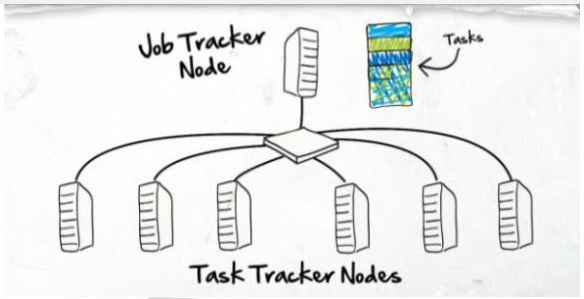
| Name | SSN-UID | Street Address | Zip Code | Blood Glucose | Weight in kg |
|---|---|---|---|---|---|
| | | | 02139<br>Tag Z1 | 190 mg/dl<br>Tag G1 | 190<br>Tag K1 |
| | | | 02138<br>Tag Z2 | 109 mg/dl<br>Tag G2 | 159<br>Tag K2 |

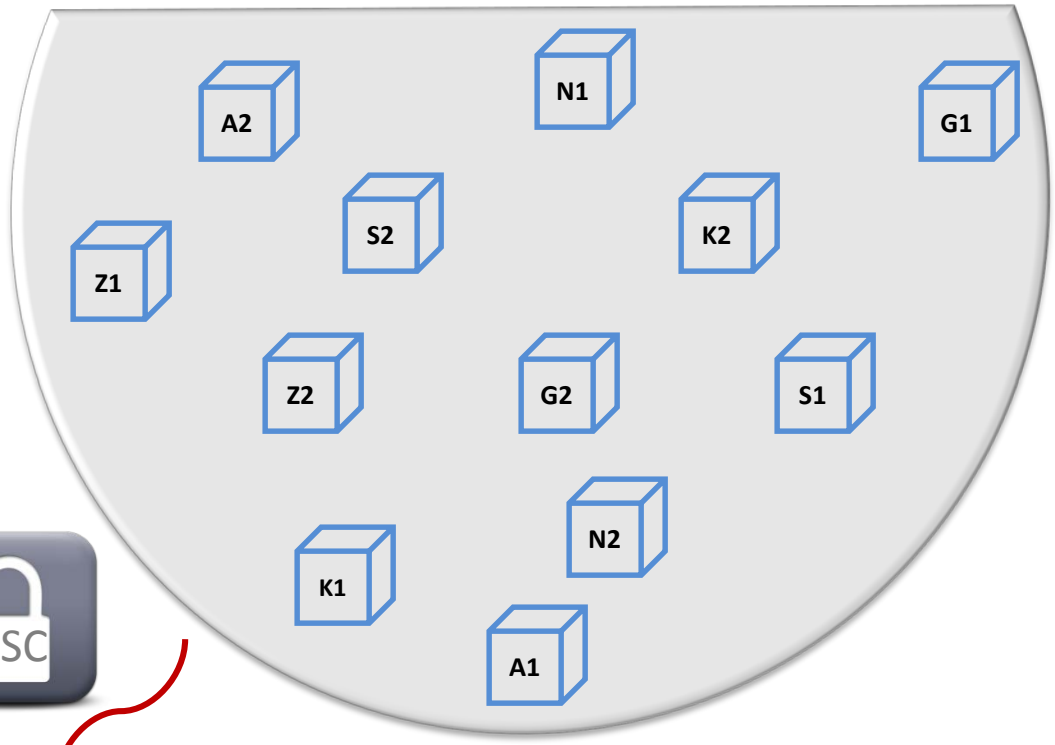



*This is a suggestion by the author. Not a proven concept in practice.*

# Secured Data <> Re-association of De-Identified Data (DID)

Re-sequence DID → HADOOP-esque concept ?





| Name | SSN-UID | Street Address | Zip Code | Blood Glucose | Weight in kg |
|---|---|---|---|---|---|
| Jane Does<br>Tag N1 | 123-45-6789<br>Tag S1 | 77 Mass Ave<br>Tag A1 | 02139<br>Tag Z1 | 190 mg/dl<br>Tag G1 | 190<br>Tag K1 |
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*This is a suggestion by the author. Not a proven concept in practice.*

## Re-stitch De-Identified Data - create Secure Sequencing Code (SSC)

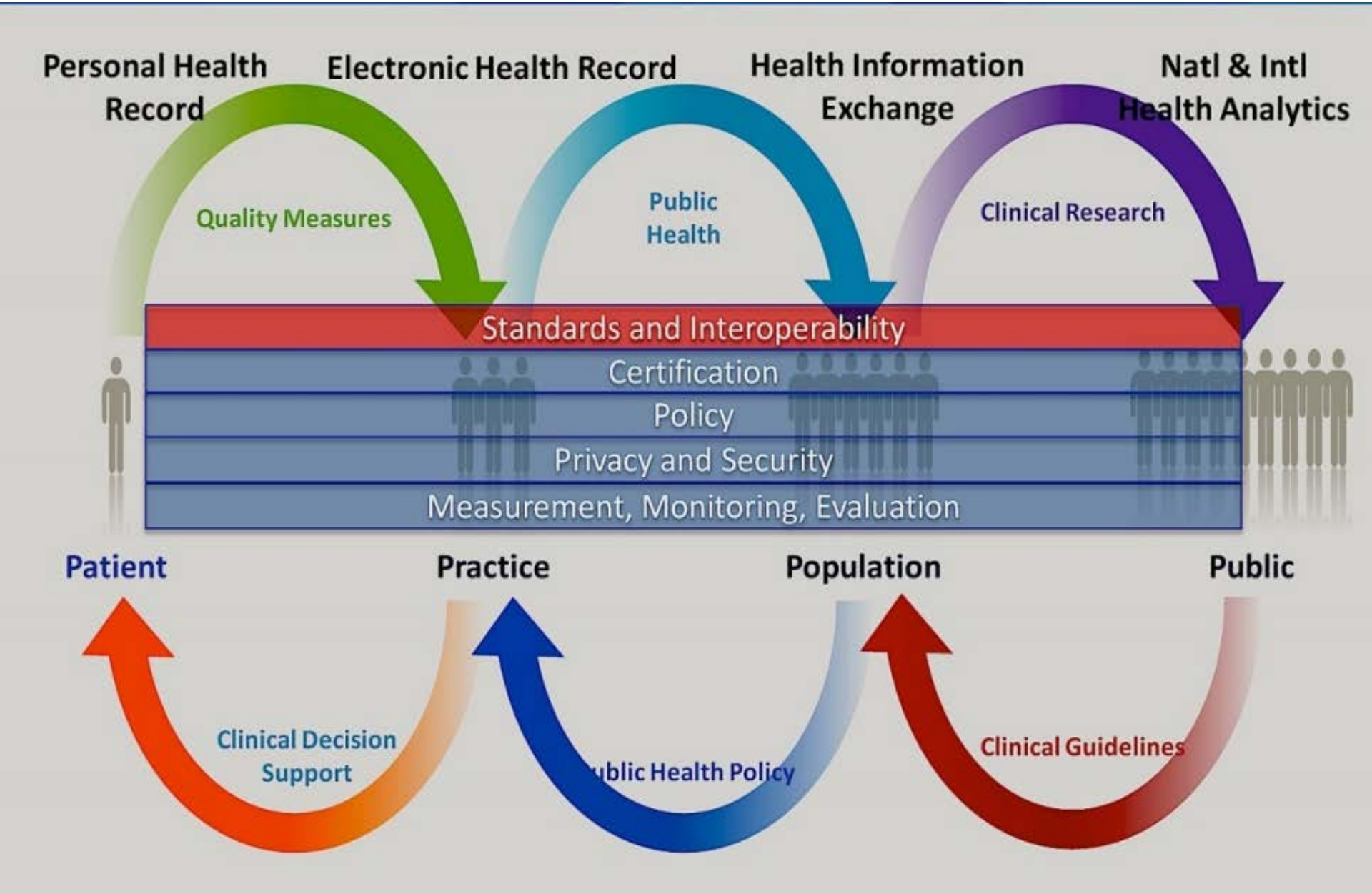
# PRIVACY

Privacy is a complex topic; there's no black and white. … The question becomes: Are providers of the service trustworthy? This idea stretches back to Shakespeare and beyond. In *Othello*, Iago spells out the importance of reputation:

*Good name in man and woman, dear my lord,*
*Is the immediate jewel of their souls:*
*Who steals my purse steals trash; 'tis something, nothing;*
*'Twas mine, 'tis his, and has been slave to thousands;*
*But he that filches from me my good name*
*Robs me of that which not enriches him*
*And makes me poor indeed.*

In this world of data and information, both people and companies must maintain their reputations. People will be very reluctant to transact with those they can't trust. Reputation, I think, will guide the kinds of decisions people make in the future.

# Platform for Trusted Data Access via Secure Standards and Interoperability



# The Inhibitor for Progress in Healthcare

**Lack of Semantic Interoperability**

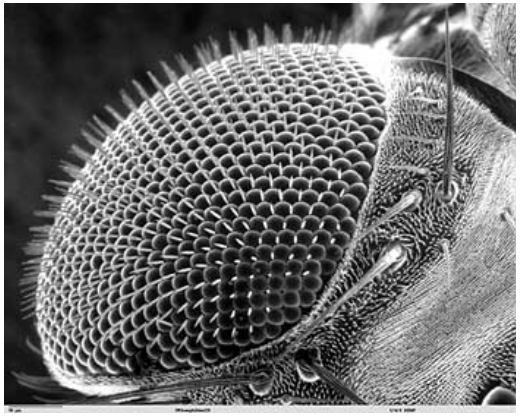
**Lack of OS Health Data Platform**

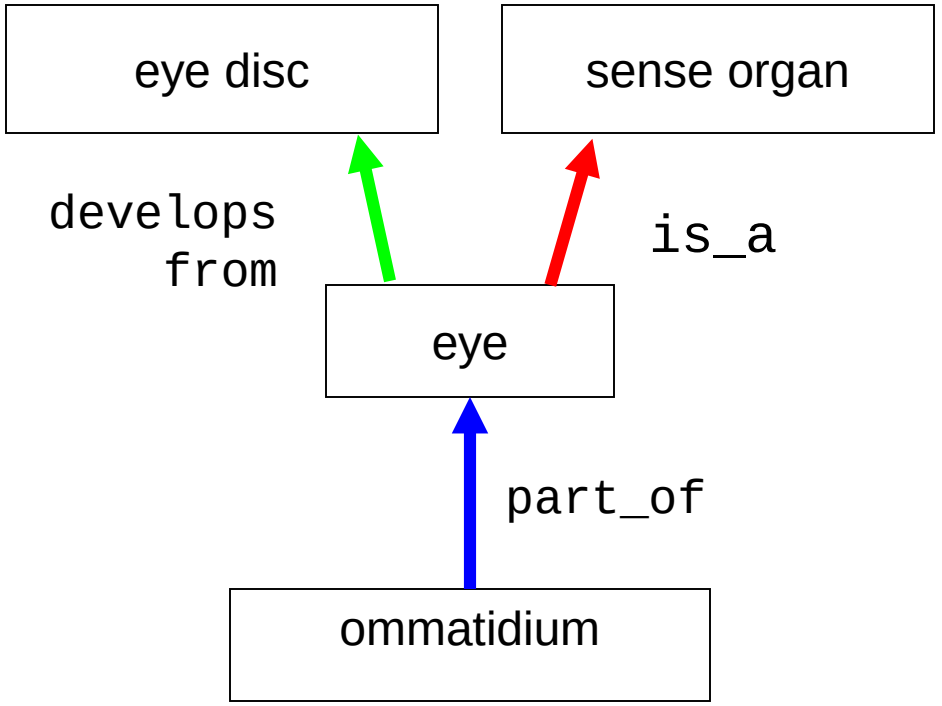
# At the heart of the matter ?

Ontology and Semantics
Interoperability Issues ?

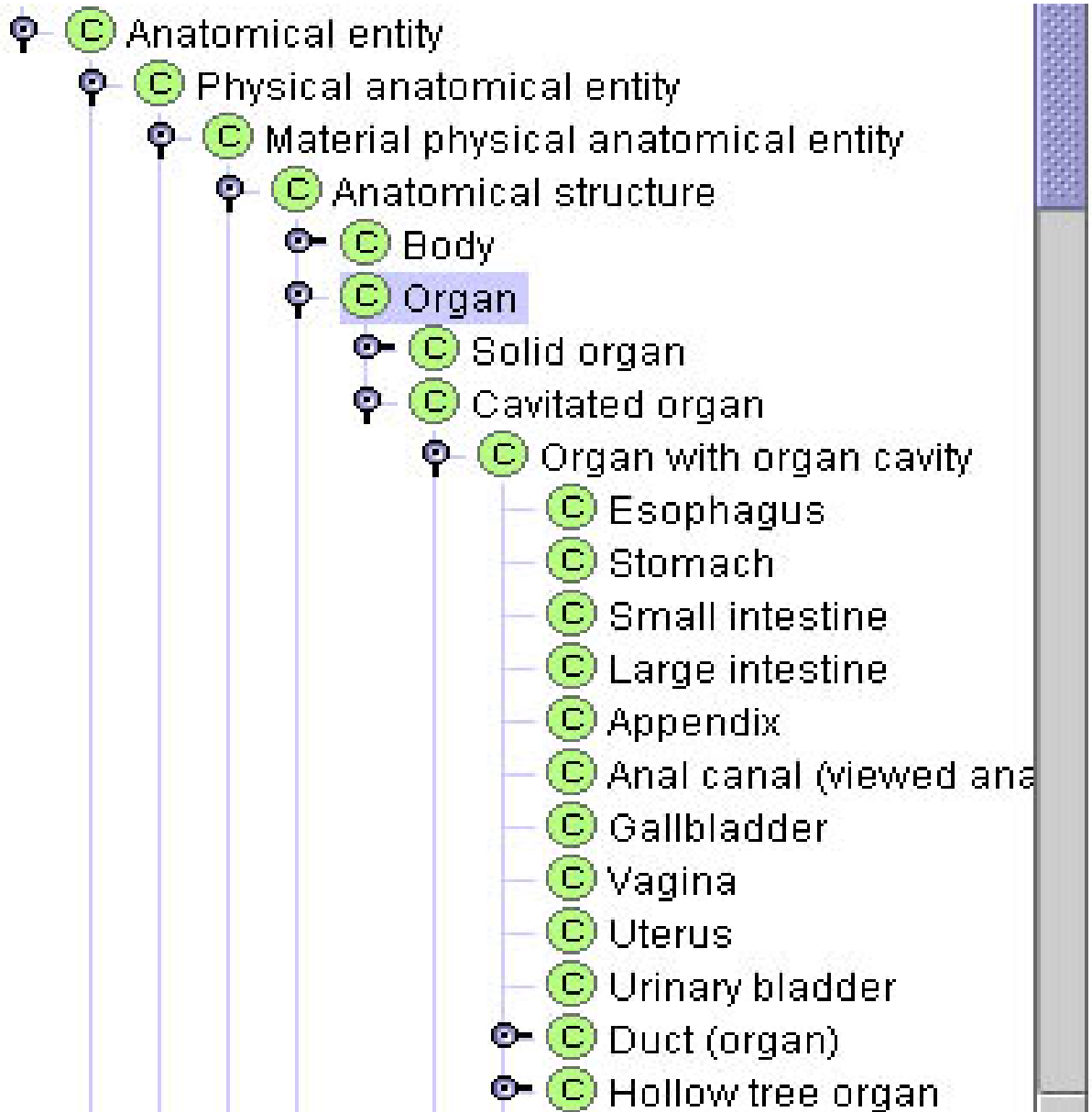
# Ontology

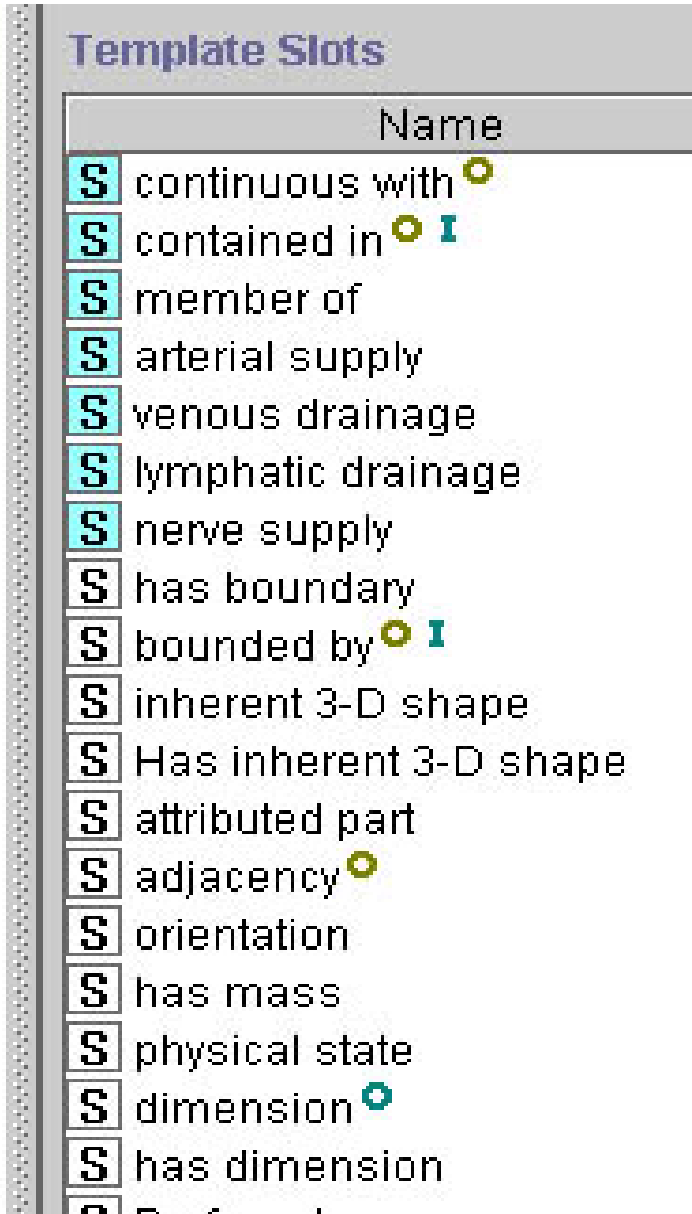
- A machine interpretable representation of relationship in the context of reality



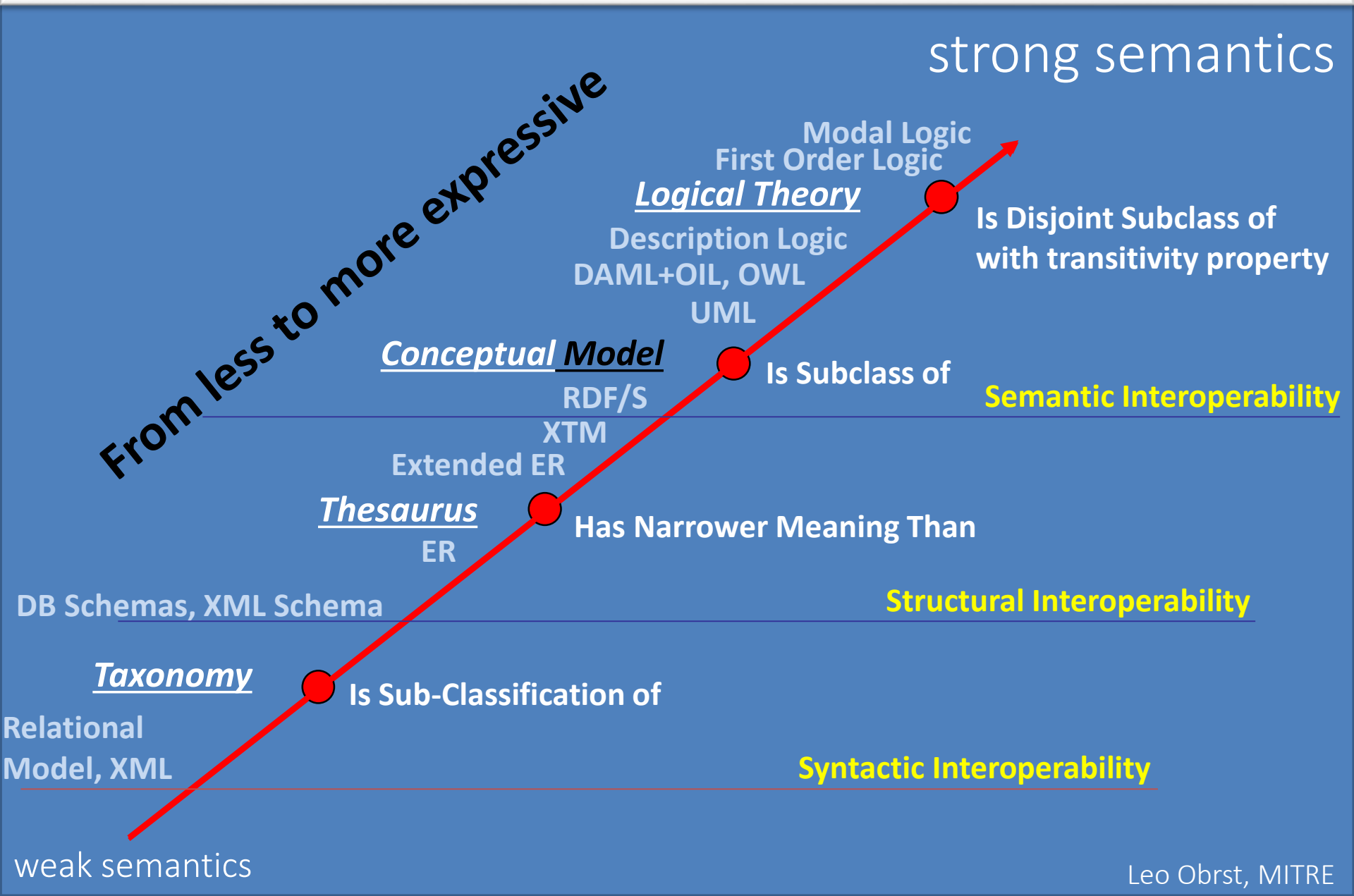


# The Foundational Model of Anatomy



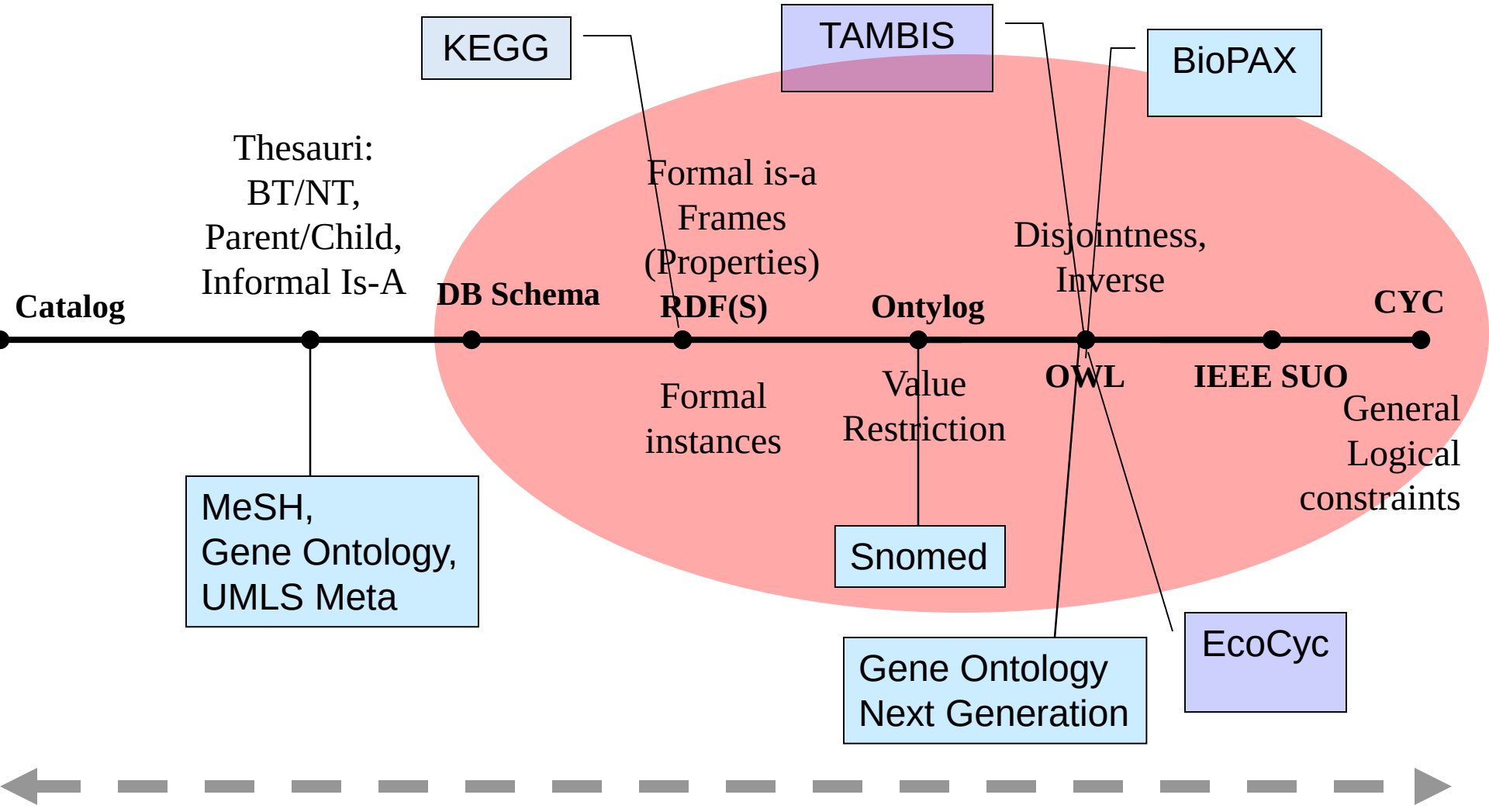



# Ontology Spectrum




Leo Obrst, MITRE

# Ontologies – A Broader Perspective – Ram Sriram, NIST



# Structure, Relations

```
<CompanyData>
   <CompanyName>
    MIT
   </CompanyName>
   <Location>
    Cambridge
   </location>
   <CallData>
     <RecordDate>
      Thu 7 Jun 2007
     </RecordDate>
     <CallsPerDay>
          536
     </CallsPerDay>
   </CallData>
</CompanyData>
```

# Structure, Relations, Syntax

"CallsPerDay"

```
<CompanyData>
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   </CompanyName>
   <Location>
    Cambridge
   </location>
   <CallData>
     <RecordDate>
      Thu 7 Jun 2007
     </RecordDate>
     <CallsPerDay>
          536
     </CallsPerDay>
   </CallData>
</CompanyData>
```

# Structure, Relations, Syntax, Semantics

```
<CompanyData>
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    MIT
   </CompanyName>
   <Location>
    Cambridge
   </location>
   <CallData>
     <RecordDate>
      Thu 7 Jun 2007
     </RecordDate>
     <CallsPerDay>
          536
     </CallsPerDay>
   </CallData>
</CompanyData>
```

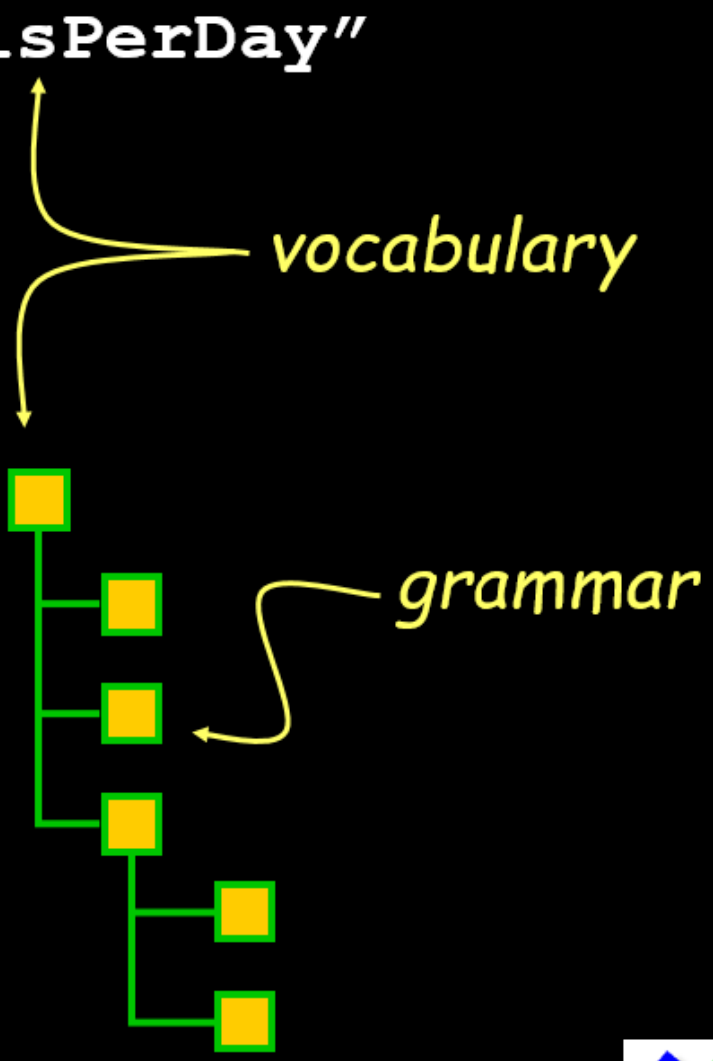

# Data, Structure, Relations, Syntax, Semantics

```
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   </CompanyName>
   <Location>
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   <CallData>
     <RecordDate>
      Thu 7 Jun 2007
     </RecordDate>
     <CallsPerDay>
          536
     </CallsPerDay>
   </CallData>
</CompanyData>
```
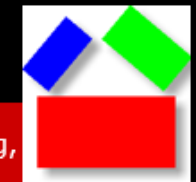

"CallsPerDay"

*vocabulary*

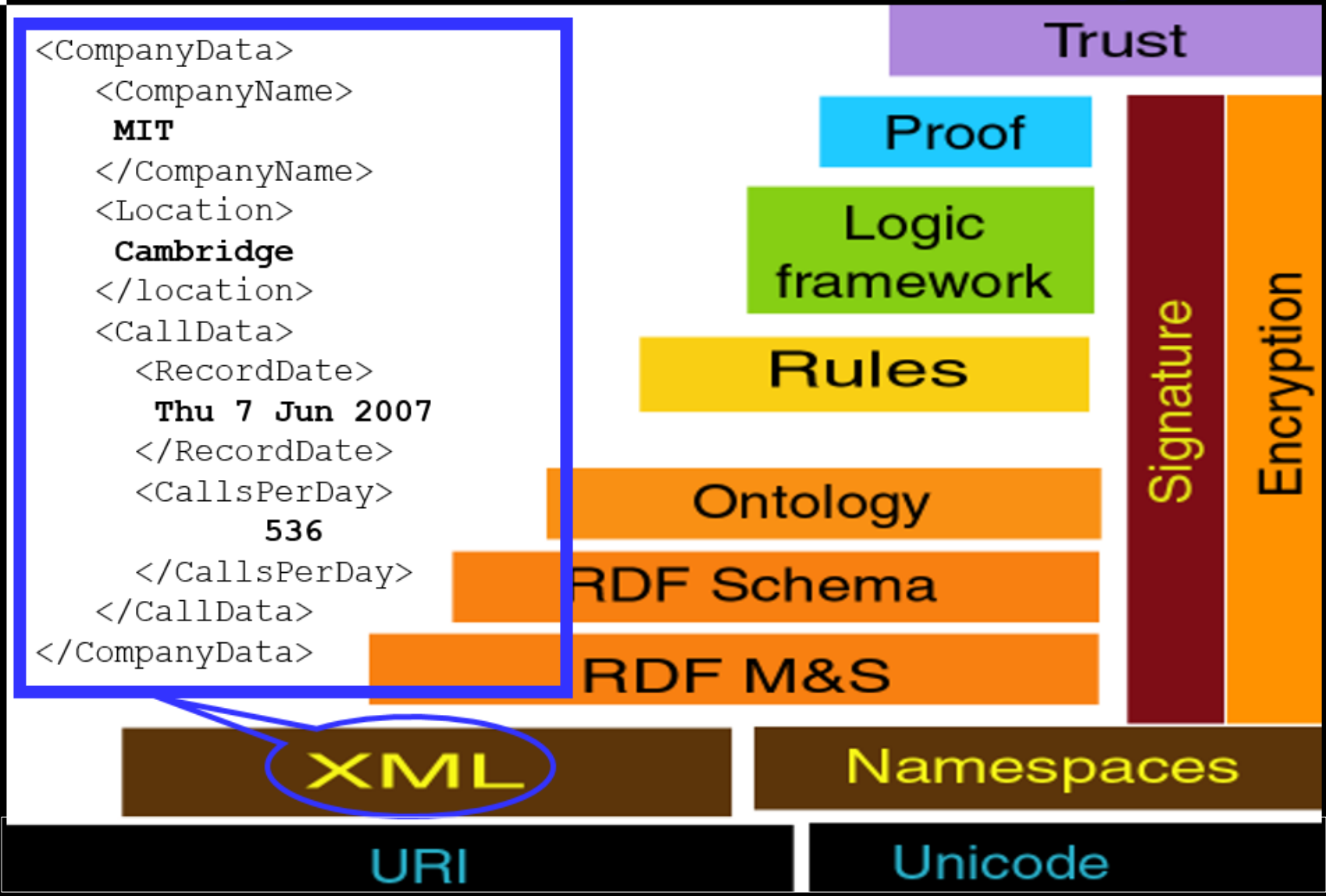
*grammar*

*data*



# Semantic Layers

## Tim Berners-Lee, MIT




# XML Evolution

2003 Ontology Working Language (OWL) DAML + OIL
DARPA Agent Markup Language + Ontology Inference Layer

1999 XML-based Physical Markup Language (PML)
RFID Object Description Language (AIDC, MIT)

1998 eXtensible Markup Language (XML)
World Wide Web Consortium (W3C)

1996 eXtensible Markup Language (XML)
World Wide Web Consortium (W3C) Initiative

1993 HTML Browser Mosaic - Marc Andreessen
National Center for Supercomputing Applications (NCSA) University of Illinois

1989 HyperText Markup Language (HTML) - Tim Berners-Lee, CERN

1986 SGML - International Organization for Standardization (ISO)

1983 SGML Computer Graphics Association (CGA)

1978 Standard General Markup Language (SGML) ANSI Initiative

1975 Document Composition Facility (DCF)

1971 Document Type Definition (DTD)

1969 General Markup Language (GML) - Charles Goldfarb, Ed Mosher, Ray Lorie

Compiled by: David Brock


# Houston, do we have a problem?

4ML
AML
AML
AML
AML
AML
AML
ABML
ABML
ACML
ACML
ACAP
ACS X12
ADML
AECM
AFML
AGML
AHML
AIML
AIML
AIF
AL3
ANML
ANNOTEA
ANATML
APML
APPML
AQL
APPEL
ARML
ARML
ASML
ASML
ASTM
ARML
ARML
ASML

ARML
ARML
ASML
ASML
ASTM
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ATML
ATML
ATML
AWML
AXML
AXML
AXML
AXML
BML
BML
BML
BML
BML
BML
BannerML
BCXML
BEEP
BGML
BHTML
BIBLIOML
BIOML
BIPS
BizCodes
BLM XML
BPML
BRML
BSML
BCXML
BEEP
BGML
BHTML

BiblioML
BCXML
BEEP
BGML
BHTML
BIBLIOML
BIOML
BIPS
BizCodes
BLM XML
BPML
BRML
BSML
CML
xCML
CaXML
CaseXML
xCBL
CBML
CDA
CDF
CDISC
CELLML
ChessGML
ChordML
ChordQL
CIM
CIML
CIDS
CIDX
xCIL
CLT
CNRP
ComicsML
CIM
CIML
CIDS

CIDX
xCIL
CLT
CNRP
ComicsML
Covad xLink
CPL
CP eXchange
CSS
CVML
CWMI
CycML
DML
DAML
DaliML
DaqXML
DAS
DASL
DCMI
DOI
DeltaV
DIG35
DLML
DMML
DocBook
DocScope
DoD XML
DPRL
DRI
DSML
DSD
DXS
EML
EML
DLML
EAD
ebXML

eBIS-XML
ECML
eCo
EcoKnow
edaXML
EMSA
eosML
ESML
ETD-ML
FieldML
FINML
FITS
FIXML
FLBC
FLOWML
FPML
FSML
GML
GML
GML
GXML
GAME
GBXML
GDML
GEML
GEDML
GEN
GeoLang
GIML
GXD
GXL
Hy XM
HITIS
HR-XML
HRMML
HTML
HTTPL

HTTP-DRP
HumanML
HyTime
IML
ICML
IDE
IDML
IDWG
IEEE DTD
IFX
IMPP
IMS Global
InTML
IOTP
IRML
IXML
IXRetail
JabberXML
JDF
JDox
JECMM
JLife
JSML
JSML
JScoreML
KBML
LACITO
LandXML
LEDES
LegalXML
Life Data
LitML
LMML
LogML
LogML
LTSC XML
MAML

MatML
MathML
MBAM
MISML
MCF
MDDL
MDSI-XML
Metarule
MFDX
MIX
MMLL
MML
MML
MML
MoDL
MOS
MPML
MPXML
MRML
MSAML
MTML
MTML
MusicXML
NAML
xNAL
NAA Ads
Navy DTD
NewsML
NML
NISO DTB
NITF
NLMXML
NVML
OAGIS
OBI
OCF
ODF

ODRL
OeBPS
OFX
OIL
OIM
OLifE
OML
ONIX DTD
OOPML
OPML
OpenMath
Office XML
OPML
OPX
OSD
OTA
PML
PML
PML
PML
PML
PML
PML
P3P
PDML
PDX
PEF XML
PetroML
PGML
PhysicsML
PICS
PMML
PNML
PNML
PNG
PrintML

PrintTalk
ProductionML
PSL
PSI
QML
QAML
QuickData
RBAC
RDDl
RDF
RDL
RecipeML
RELAX
RELAX NG
REXML
REPML
ResumeXML
RETML
RFML
RightsLang
RIXML
RoadmOPS
RosettaNet PIP
RSS
RuleML
SML
SML
SML
SML
SAML
SABLE
SAE J2008
SBML
Schemtron
SDML
SearchDM-XML
SGML

SHOE
SIF
SMML
SMBXML
SMDL
SDML
SMIL
SOAP
SODL
SOX
SPML
SpeechML
SSML
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STEP
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SVG
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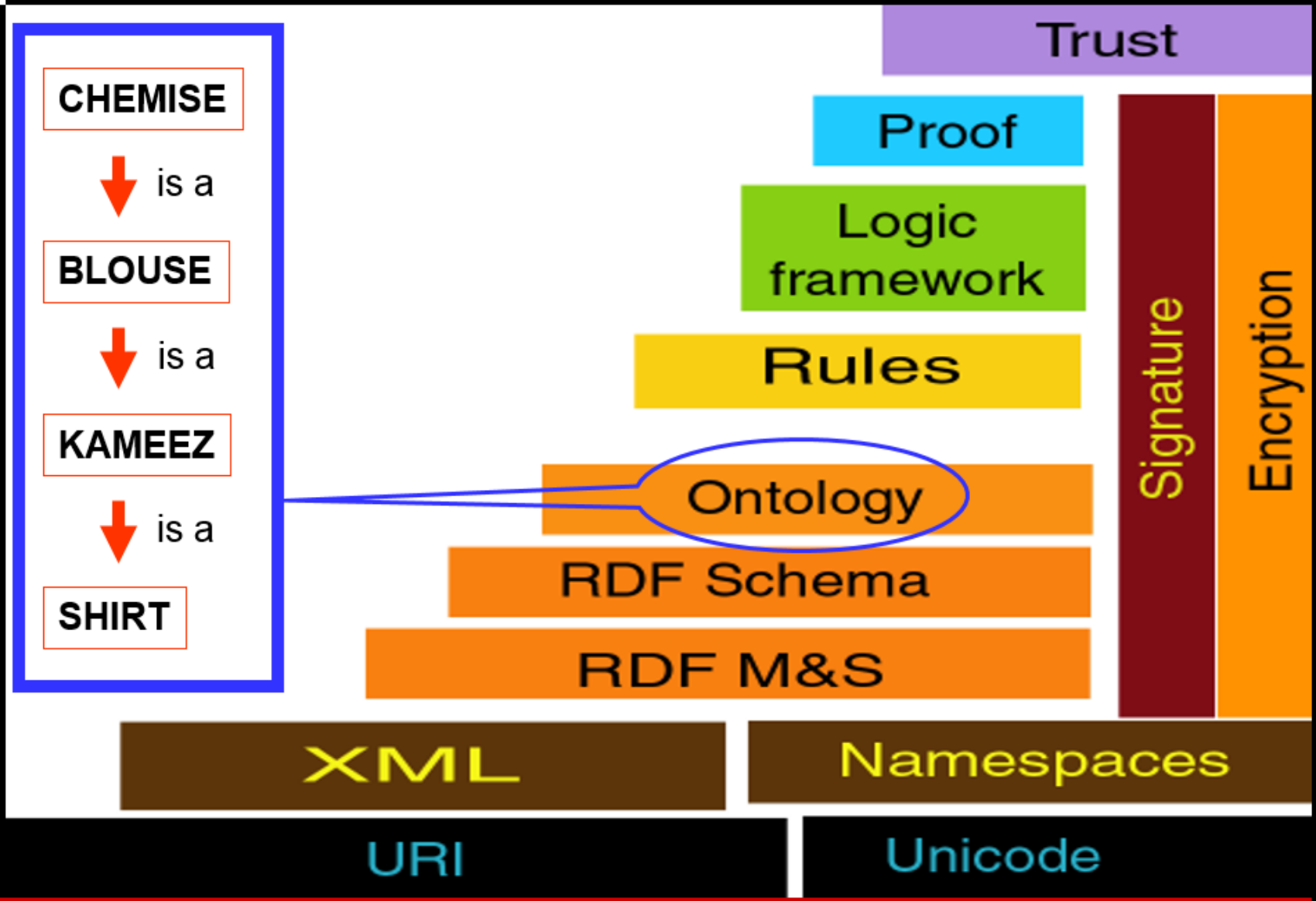
TML
TalkML
TaxML
TDL
TDML
TEI
ThML
TIM
TIM
TMML
TMX
TP
TPAML
TREX
TxLife

UML
UBL
UCLP
UDDI
UDEF
UIML
ULF
UMLS
UPnP
URI/URL
UXF
VML
vCalendar
vCard
VCML
VHG
VIML
VISA XML
VMML
VocML
VoiceXML
VRML
WAP
WDDX
WebML
WebDAV
WellML
WeldingXML
Wf-XML
WIDL
WITSML
WorldOS
WSML
WSIA
XML
XML Court
XML EDI

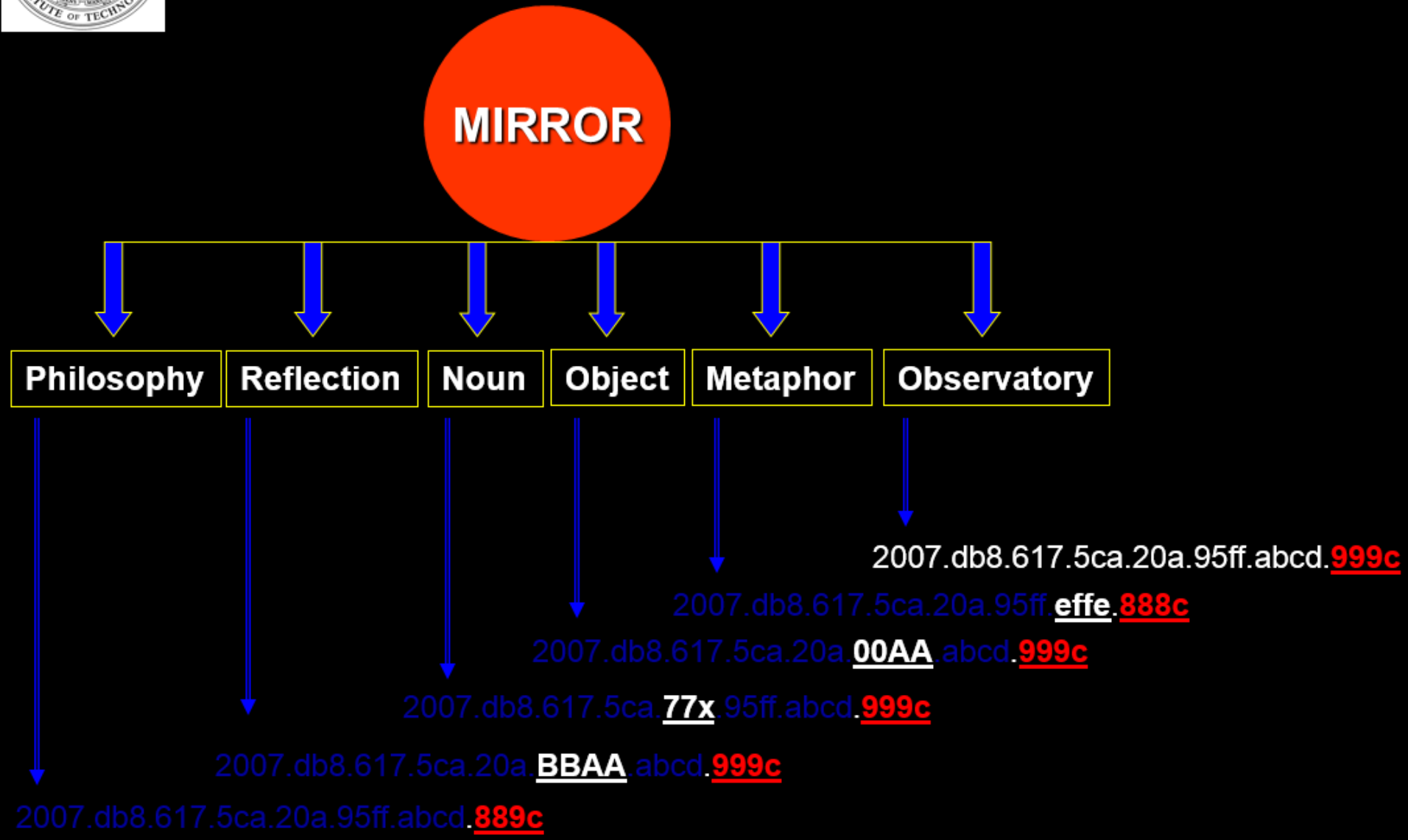
XML F
XML Key
XMLife
XML MP
XML News
XML RPC
XML Schema
XML Sign
XML Query
XML P7C
XML TP
XMLVoc
XML XCI
XAML
XACML
XBL
XSBEL
XBN
XBRL
XCFF
XCES
Xchart
Xdelta
XDF
XForms
XGF
XGL
XGMML
XHTML
XIOP
XLF
XLIFF
XLink
XMI
XMSG
XMTP
XNS

Dr Shoumen Datta http://dft.ba/-shoumen (fmr Research Director, Forum for Supply Chain Innovation, School of Engineering, MIT)

# Semantic Ontology



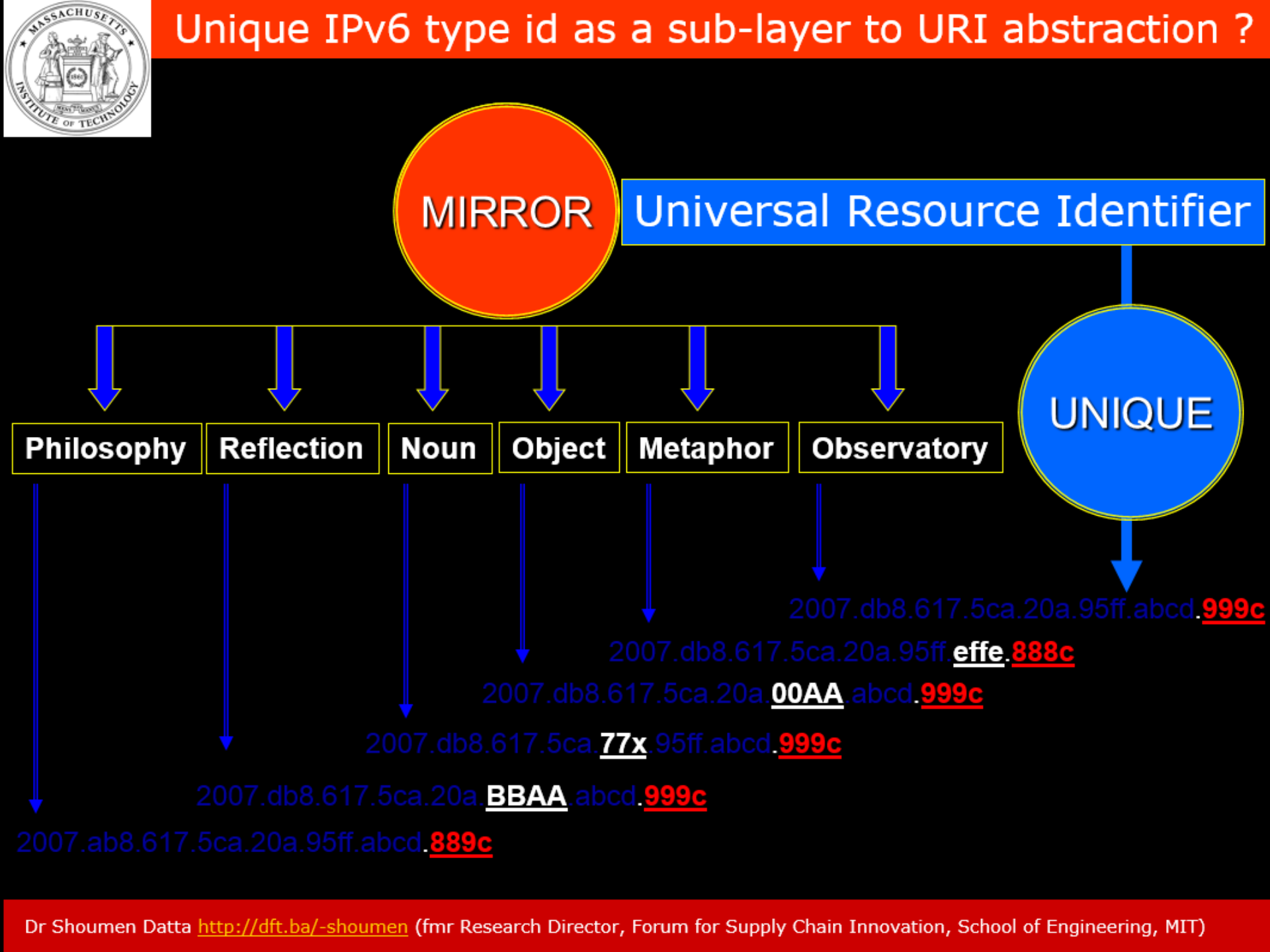
# Digital Semantics – Ontological UID with IPv6 type format



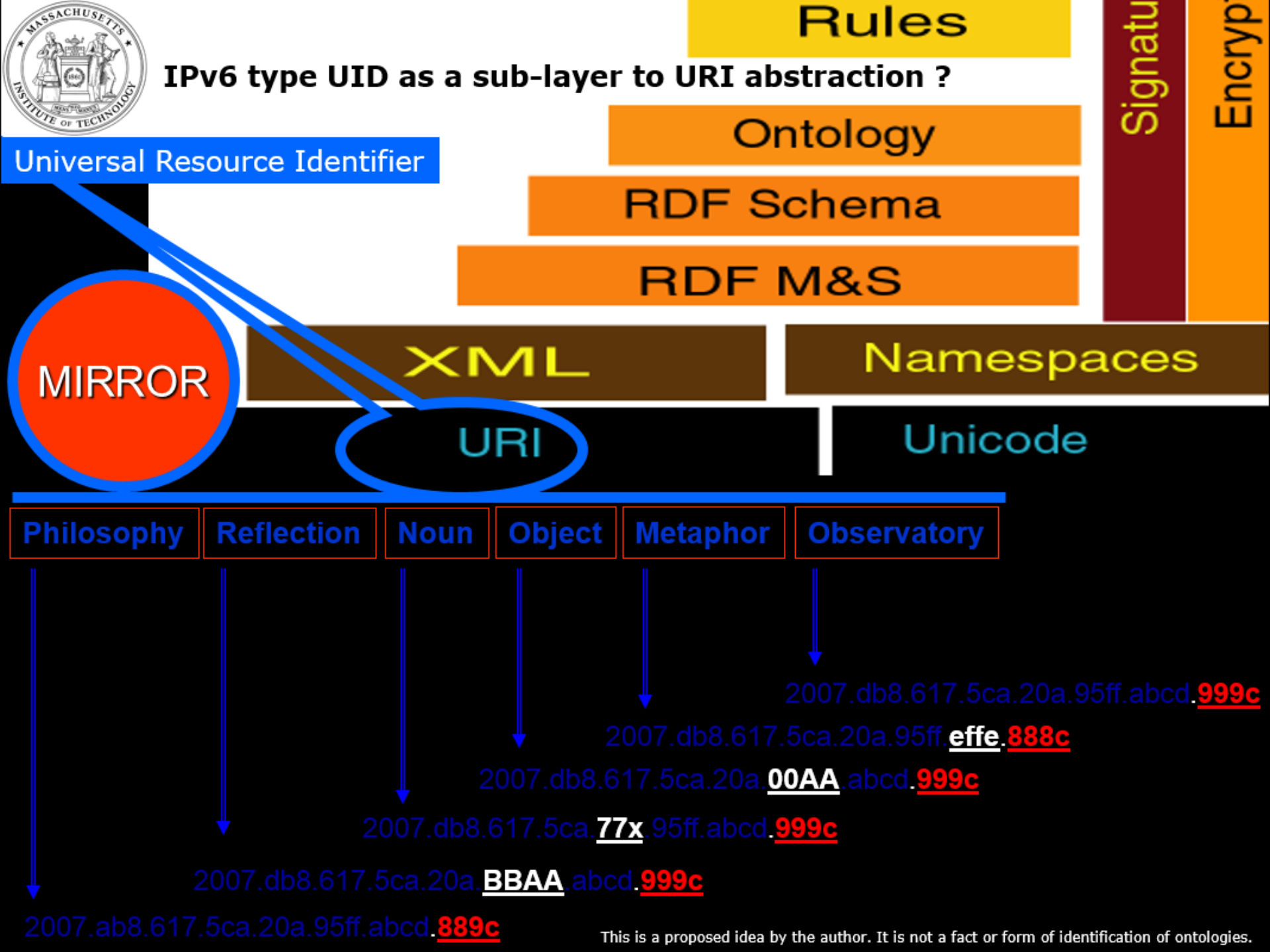

*This is an idea proposed by the author. It is not a fact or form of identification of ontologies, in practice, yet (2006).*

Dr Shoumen Datta http://dft.ba/-shoumen (fmr Research Director, Forum for Supply Chain Innovation, School of Engineering, MIT)

# Unique IPv6 type id as a sub-layer to URI abstraction ?




Dr Shoumen Datta http://dft.ba/-shoumen (fmr Research Director, Forum for Supply Chain Innovation, School of Engineering, MIT)


IPv6 type UID as a sub-layer to URI abstraction ?
Rules
Ontology
RDF Schema
RDF M&S
Universal Resource Identifier
MIRROR
XML
Namespaces
URI
Unicode
Philosophy
Reflection
Noun
Object
Metaphor
Observatory
2007.db8.617.5ca.20a.95ff.abcd.999c
2007.db8.617.5ca.20a.95ff.effe.888c
2007.db8.617.5ca.20a.00AA.abcd.999c
2007.db8.617.5ca.77x.95ff.abcd.999c
2007.db8.617.5ca.20a.BBAA.abcd.999c
2007.ab8.617.5ca.20a.95ff.abcd.889c
This is a proposed idea by the author. It is not a fact or form of identification of ontologies.

# Why is it necessary to define ontology class with UID ?

- Global Semantic Interoperability
- Reduce natural language ambiguity

Class

Upperbody Outerwear

# *Why is it necessary to define ontology class with unique id ?*

CHEMISE

is a

BLOUSE

is a

SHIRT

is it a ?

KAMEEZ

is a ?

KIMONO

## Western Ontology Classification

Kimono

is a

Shirt

Class

Upperbody Outerwear

# *Why is it necessary to define ontology class with unique id ?*


**Japanese Ontology Classification**

**Kimono**

**is a**

**Traditional Garment**

# Unique id eliminates semantic ambiguity

Class

Upperbody Outerwear

CHEMISE

is a

BLOUSE

is a

SHIRT

is it a ?

*KAMEEZ*

is a ?

*KIMONO*

2007.db8.617.5ca.20a.95ff.203f.8080

***Unique id enables classification agnostic application***

Western Ontological Framework

Japanese Ontological Framework

**Subclass or a Separate Class:**
Japanese Traditional Outer Garments
**Range:**
2007.db8.617.5ca.20a.95ff.202a.7777
to
2007.db8.617.5ca.20a.95ff.210f.9999

Shoumen Datta, MIT

# Semantic Ambiguity


**Call 1**
**Loud cry, shout**

喊叫

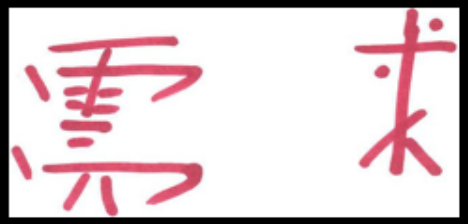
**Call 2**
**Animal's call**

嚎叫

**Call 3**
**Telephone call**

电话

**Call 4**
**House visit**



需求

# Semantic Ambiguity ⇸ Semantic Interoperability

**Call 1**
**Loud cry, shout**

喊叫

**Call 2**
**Animal's call**

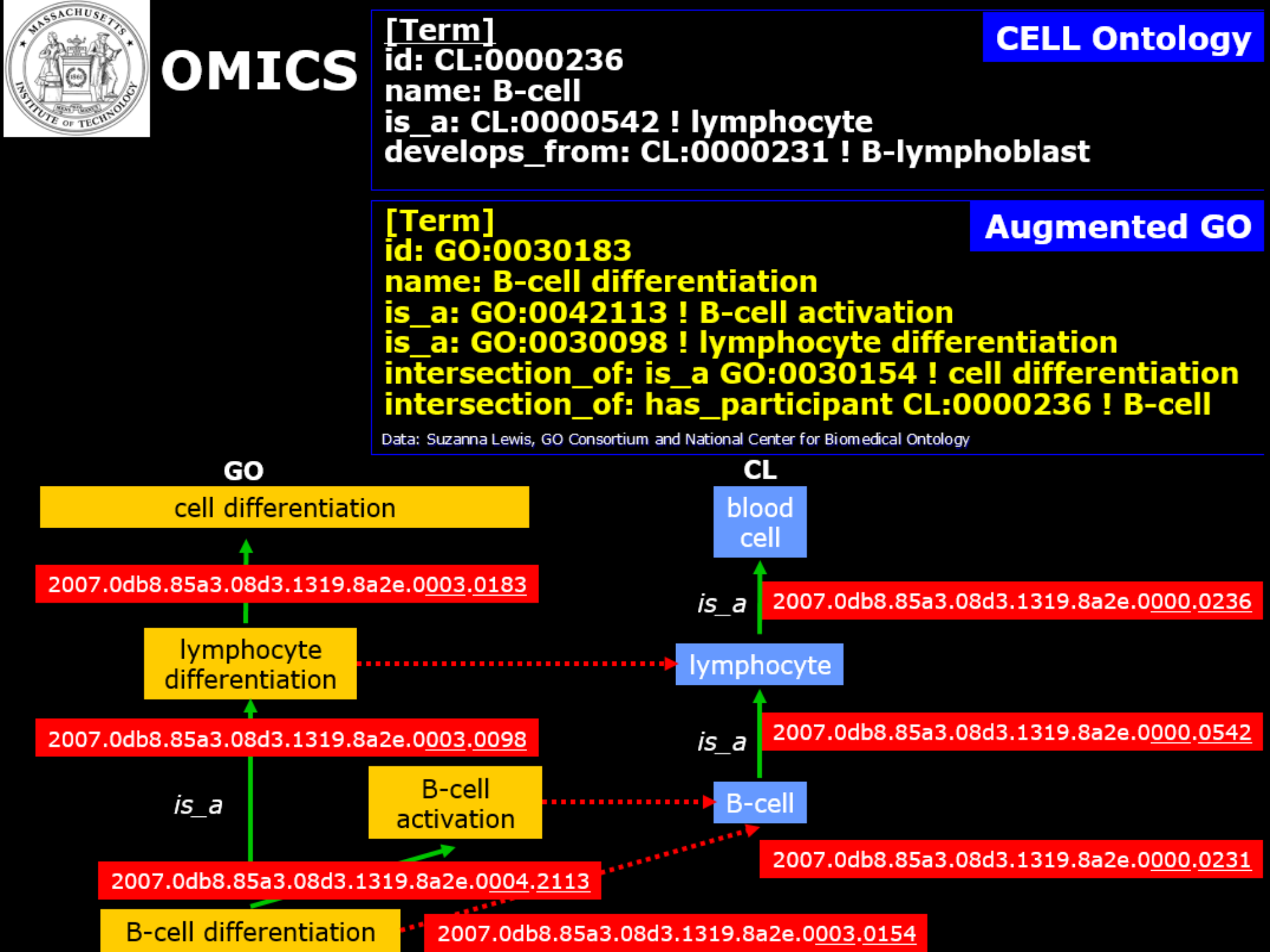
嚎叫

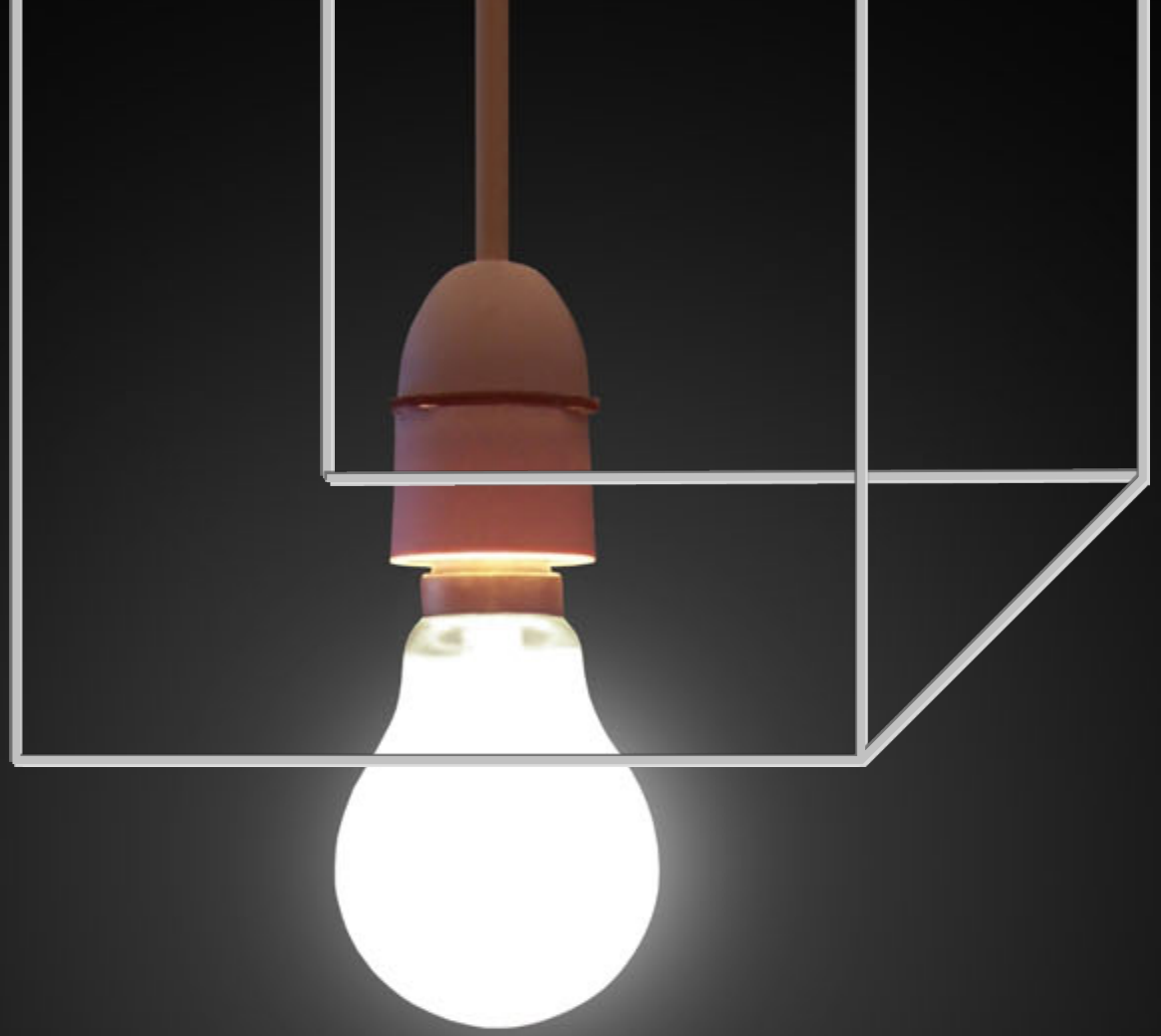
**Call 3**
**Telephone call**

电话

**Call 4**
**House visit**

需求

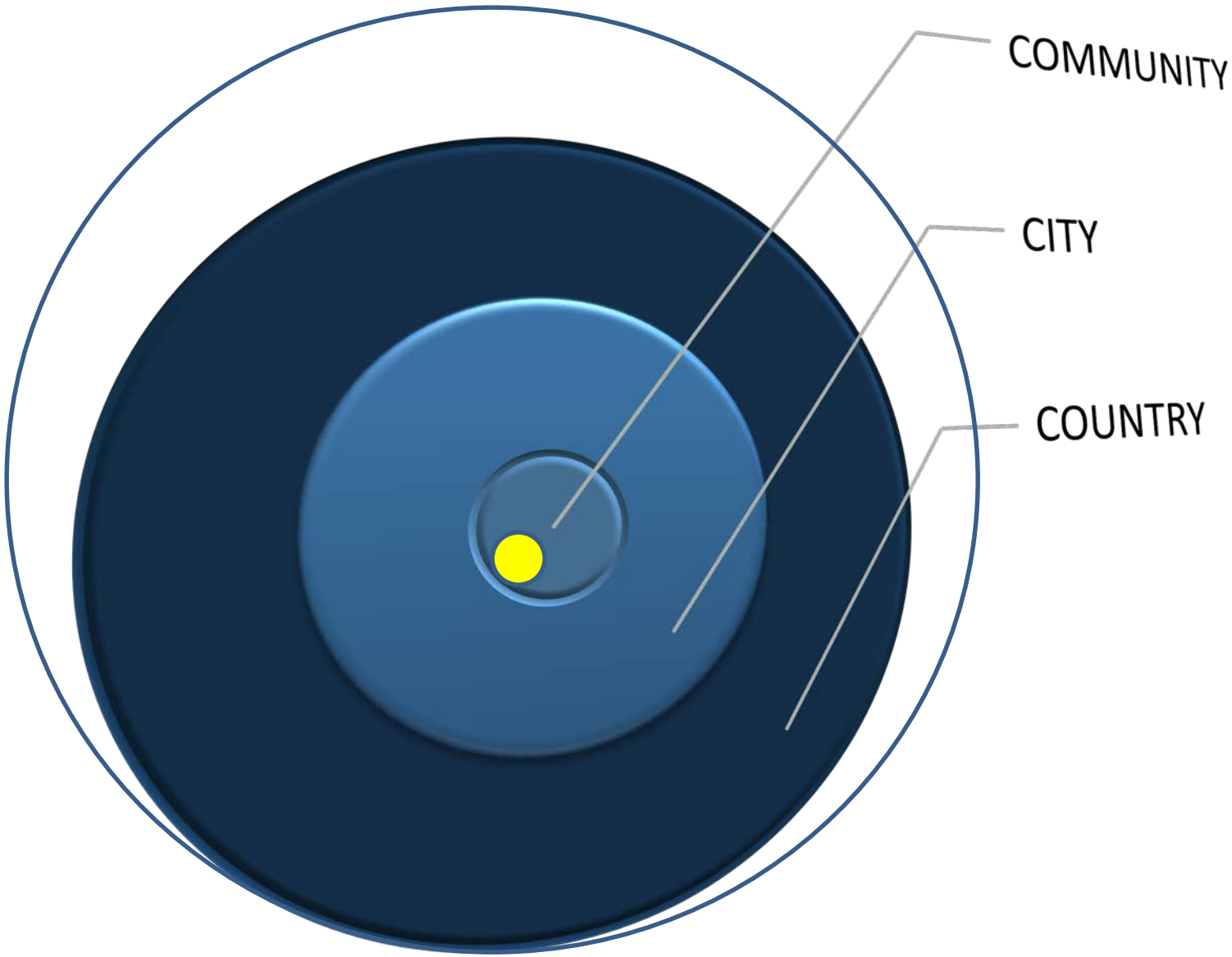

OMICS
[Term]
id: CL:0000236
name: B-cell
is_a: CL:0000542 ! lymphocyte
develops_from: CL:0000231 ! B-lymphoblast
CELL Ontology
[Term]
id: GO:0030183
name: B-cell differentiation
is_a: GO:0042113 ! B-cell activation
is_a: GO:0030098 ! lymphocyte differentiation
intersection_of: is_a GO:0030154 ! cell differentiation
intersection_of: has_participant CL:0000236 ! B-cell
Augmented GO
Data: Suzanna Lewis, GO Consortium and National Center for Biomedical Ontology
GO
CL
cell differentiation
blood cell
2007.0db8.85a3.08d3.1319.8a2e.0003.0183
is_a
2007.0db8.85a3.08d3.1319.8a2e.0000.0236
lymphocyte differentiation
lymphocyte
2007.0db8.85a3.08d3.1319.8a2e.0003.0098
is_a
2007.0db8.85a3.08d3.1319.8a2e.0000.0542
is_a
B-cell activation
B-cell
2007.0db8.85a3.08d3.1319.8a2e.0000.0231
2007.0db8.85a3.08d3.1319.8a2e.0004.2113
B-cell differentiation
2007.0db8.85a3.08d3.1319.8a2e.0003.0154



# Data of Things – Forecast Cloudy

*With current technology you can find the haystack but with big data you can find the needle - Nils Herzberg, SAP AG*

# BIG DATA = SMALL DATA + SMALL DATA + SMALL DATA + ● ● ●



# Healthcare Data Interoperability Standards ?

***… semantics, data dictionaries, billing codes …***

- Terminology
  - SNOMED, LOINC
- Classification Systems
  - ICD10, CPT
- Devices
  - IEEE 11073
- EHR-Related
  - DICOM, HL7 (CDA)
- Interoperability
  - DICOM, HL7 Messaging, HIPAA Transactions, NCPDP
- Language Formats
  - XML, X12

# • DIAGNOSIS CODES for SPRAINED and STRAINED ANKLES

## ICD-9

**845.00** Sprain and strain of ankle unspecied site
**845.01** Sprain and strain of ankle, Deltoid ligament/ Internal collateral ligament
**845.02** Sprain and strain of ankle, Calcaneobular (ligament)
**845.03** Sprain and strain of ankle, Tibiobular (ligament) distal

## ICD-10

**S93.401A** Sprain of unspecied ligament of right ankle – initial encounter
**S93.401D** Sprain of unspecied ligament of right ankle – subsequent encounter
**S93.401S** Sprain of unspecied ligament of right ankle – sequela
**S93.402A** Sprain of unspecied ligament of left ankle – initial encounter
**S93.402D** Sprain of unspecied ligament of left ankle – subsequent encounter
**S93.402S** Sprain of unspecied ligament of left ankle – sequela
**S93.409A** Sprain of unspecied ligament of unspecied ankle – initial encounter
**S93.409D** Sprain of unspecied ligament of unspecied ankle - subsequent encounter
**S93.409S** Sprain of unspecied ligament of unspecied ankle – sequela
**S93.412D** Sprain of calcaneobular ligament of left ankle – subsequent encounter
**S93.412S** Sprain of calcaneobular ligament of left ankle – sequela
**S93.419A** Sprain of calcaneobular ligament of unspecied ankle – initial encounter
**S93.419D** Sprain of calcaneobular ligament of unspecied ankle – subsequent encounter
**S93.419S** Sprain of calcaneobular ligament of unspecied ankle
**S93.431A** Sprain of tibiobular ligament of right ankle – initial encounter
**S93.431D** Sprain of tibiobular ligament of right ankle – subsequent encounter
**S93.431S** Sprain of tibiobular ligament of right ankle – sequela
**S93.432A** Sprain of tibiobular ligament of left ankle – initial encounter
**S93.432D** Sprain of tibiobular ligament of left ankle – subsequent encounter
**S93.432S** Sprain of tibiobular ligament of left ankle – sequela
**S93.439A** Sprain of tibiobular ligament of unspecied ankle – initial encounter
**S93.439D** Sprain of tibiobular ligament of unspecied ankle – subsequent encounter
S93.439S Sprain of tibiobular ligament of unspecied ankle – sequela
**S93.491A** Sprain of other ligament of right ankle (Internal collateral/ talobular) initial encounter
**S93.491D** Sprain of other ligament of right ankle (Internal collateral/ talobular) subsequent encounter
**S93.491S** Sprain of other ligament of right ankle (Internal collateral/ talobular) sequela
**S93.492A** Sprain of other ligament of left ankle, initial encounter
**S93.492D** Sprain of other ligament of left ankle subsequent encounter
**S93.492S** Sprain of other ligament of left ankle sequela
**S93.499A** Sprain of other ligament of unspecied ankle initial encounter
**S93.499D** Sprain of other ligament of unspecied ankle subs encounter
**S93.499S** Sprain of other ligament of unspecied ankle (Internal collateral/talobular) sequela
**S96.211A** Strain of intrinsic muscle and tendon at right ankle and foot level initial encounter
**S96.211D** Strain of intrinsic muscle and tendon at right ankle and foot level subsequent encounter
**S96.211S** Strain of intrinsic muscle and tendon at right ankle and foot level sequela
**S96.212A** Strain of intrinsic muscle and tendon at left ankle and foot level initial encounter
**S96.212D** Strain of intrinsic muscle and tendon at left ankle and foot level subsequent encounter
**S96.212S** Strain of intrinsic muscle and tendon at left ankle and foot level sequela
**S96.219A** Strain of intrinsic muscle and tendon at ankle and foot level, unspecied side initial encounter
**S96.219D** Strain of intrinsic muscle and tendon at ankle and foot level, unspecied side subs encounter
**S96.219S** Strain of intrinsic muscle and tendon at ankle and foot level, unspecied side
S96.811A Strain of other muscles and tendons at right ankle and foot level initial encounter
**S96.811D** Strain of other muscles and tendons at right ankle and foot level subsequent encounter
**S96.811S** Strain of other muscles and tendons at right ankle and foot level sequela
**S96.812A** Strain of other muscles and tendons at left ankle and foot level initial encounter
**S96.812D** Strain of other muscles and tendons at left ankle and foot level subsequent encounter
**S96.812S** Strain of other muscles and tendons at left ankle and foot level sequela
**S96.819A** Strain of other muscles and tendons at ankle and foot level, unspecied side initial encounter
**S96.819D** Strain of other muscles and tendons at ankle and foot level, unspecied side subs encounter
**S96.819S** Strain of other muscles and tendons at ankle and foot level, unspecied side sequela
**S96.911A** Strain of unspecied muscle and tendon at right ankle and foot level initial encounter
**S96.911D** Strain of unspecied muscle and tendon at right ankle and foot level subs encounter
**S96.911S** Strain of unspecied muscle and tendon at right ankle and foot level sequela
**S96.912A** Strain of unspecied muscle and tendon at left ankle and foot level initial encounter
**S96.912D** Strain of unspecied muscle and tendon at left ankle and foot level subs encounter
**S96.912S** Strain of unspecied muscle and tendon at left ankle and foot level sequela
**S96.919A** Strain of unspecied muscle and tendon at ankle and foot level, unspec. side initial encounter
**S96.919D** Strain of unspecied muscle and tendon at ankle and foot level, unspec. side subs encounter
**S96.919S** Strain of unspecied muscle and tendon at ankle and foot level, unspec. side sequela

# CONVERGENCE : DIAGNOSIS CODE and SEMANTIC INTEROPERABILITY ?

## ICD-9

**845.00** Sprain and strain of ankle unspecied site
**845.01** Sprain and strain of ankle, Deltoid ligament/ Internal collateral ligament
**845.02** Sprain and strain of ankle, Calcaneobular (ligament)
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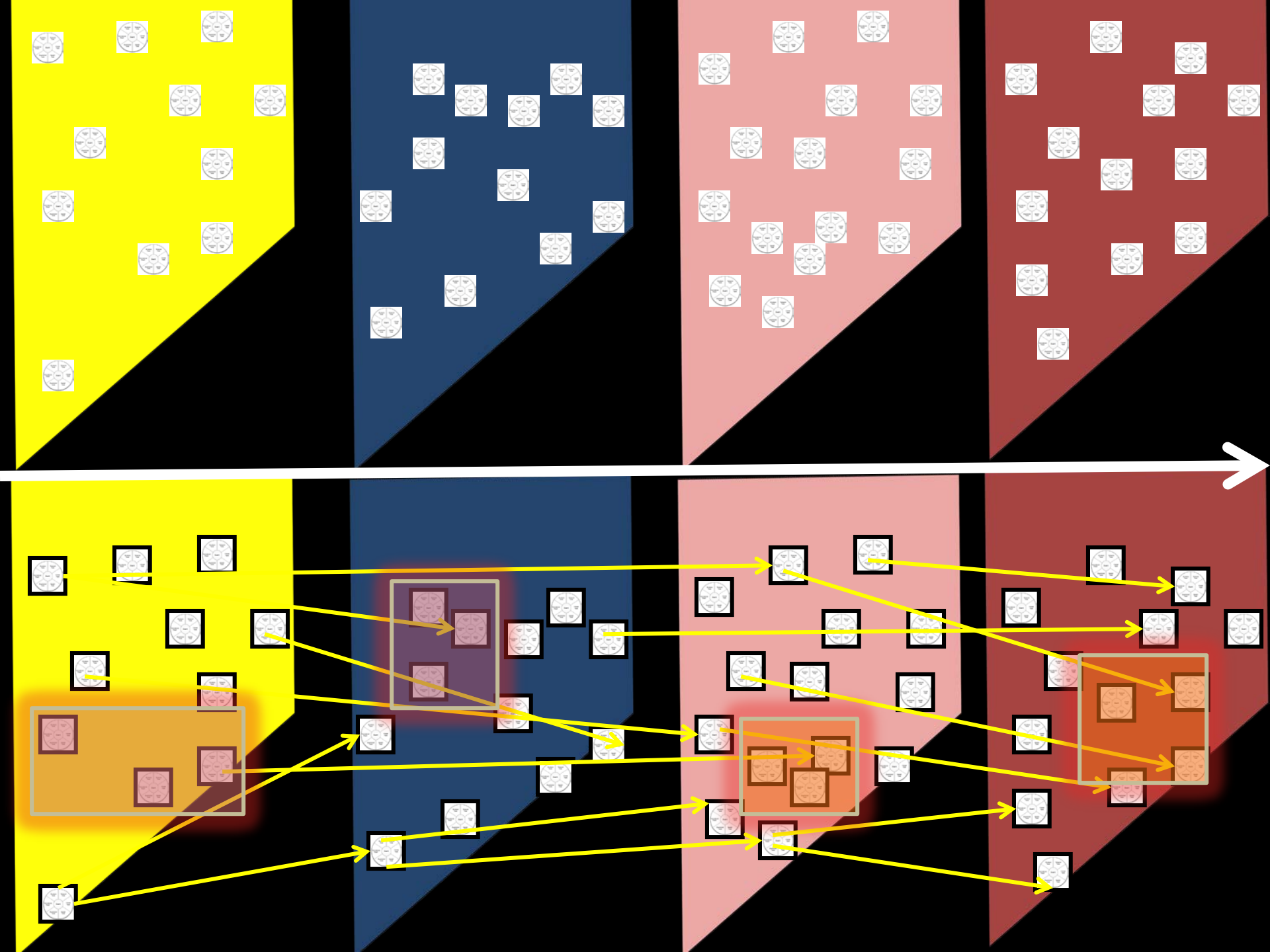
**S93.412D** Sprain of calcaneobular ligament of left ankle – subsequent encounter
**S93.412S** Sprain of calcaneobular ligament of left ankle – sequela
**S93.419A** Sprain of calcaneobular ligament of unspecied ankle – initial encounter

Proprietary closed semantic data dictionaries (EPIC) and heterogeneity of billing codes are contributors to lack of semantic interoperability and inhibitor for OS platforms

# Build bridges to create secure healthcare data platforms?

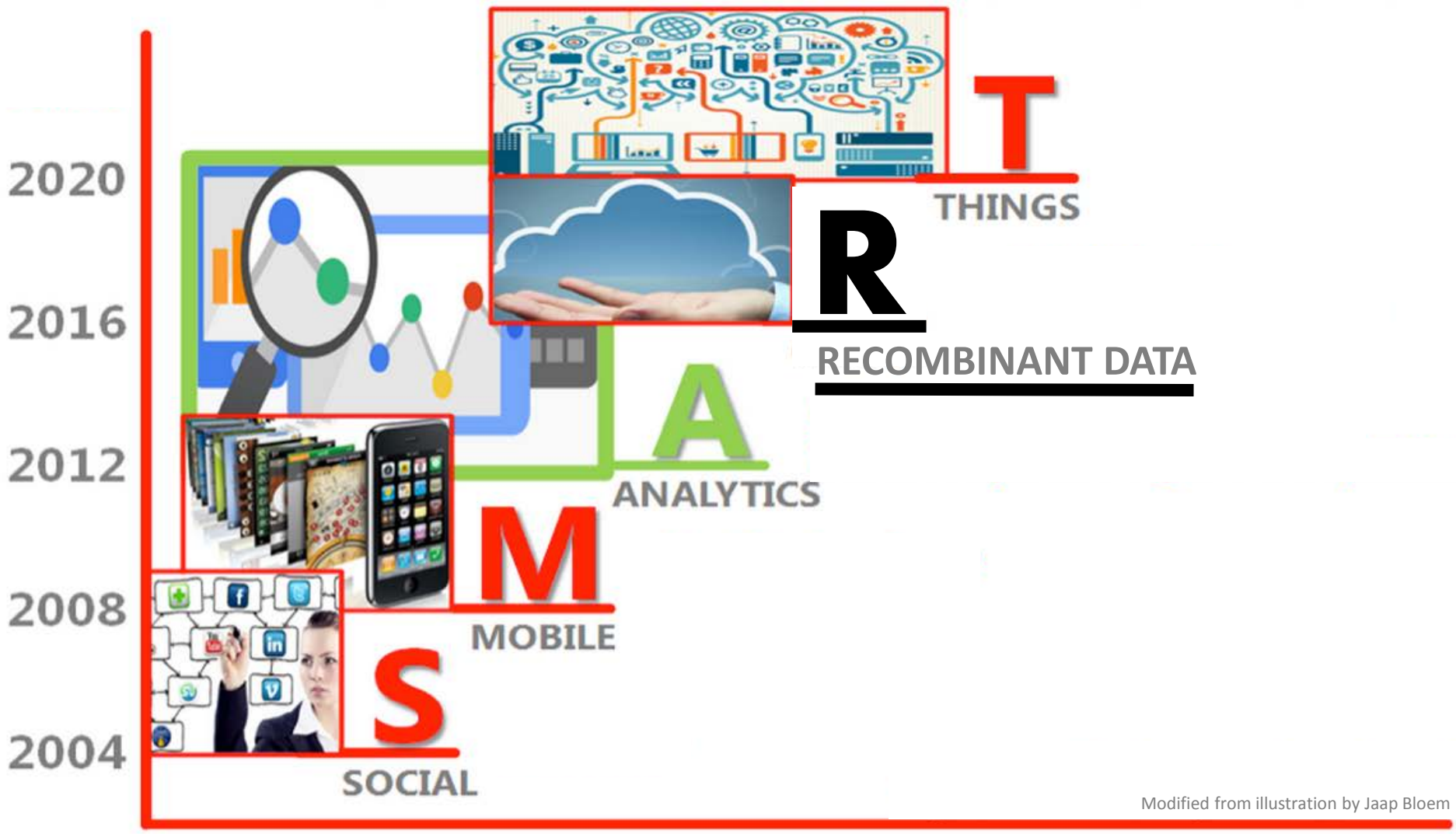
The complexity of healthcare is inextricably linked with regulatory compliance, security and privacy. The top down approach to create interoperable systems may be short of impossible but the bottom up approach to create bridges for data interoperability may help vendors continue with their system sales but enables practitioners to use the data, via data platforms, effectively.



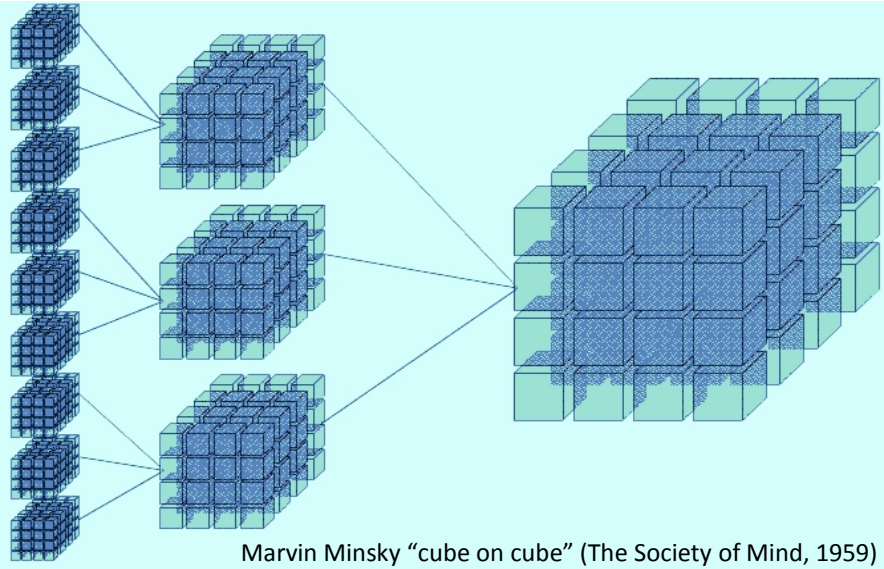
# Recombinant Data

Data (by itself – in one silo) is of limited value unless analyzed in conjunction with other data in context of the application or in context of the problem-question (eg healthcare, prevention)

# How smart can you make SMART ?? Depends on Recombinant Data

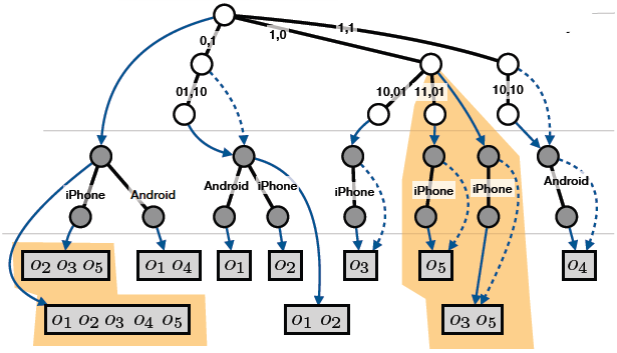


# Paradigm Shift in Data Analytics ?

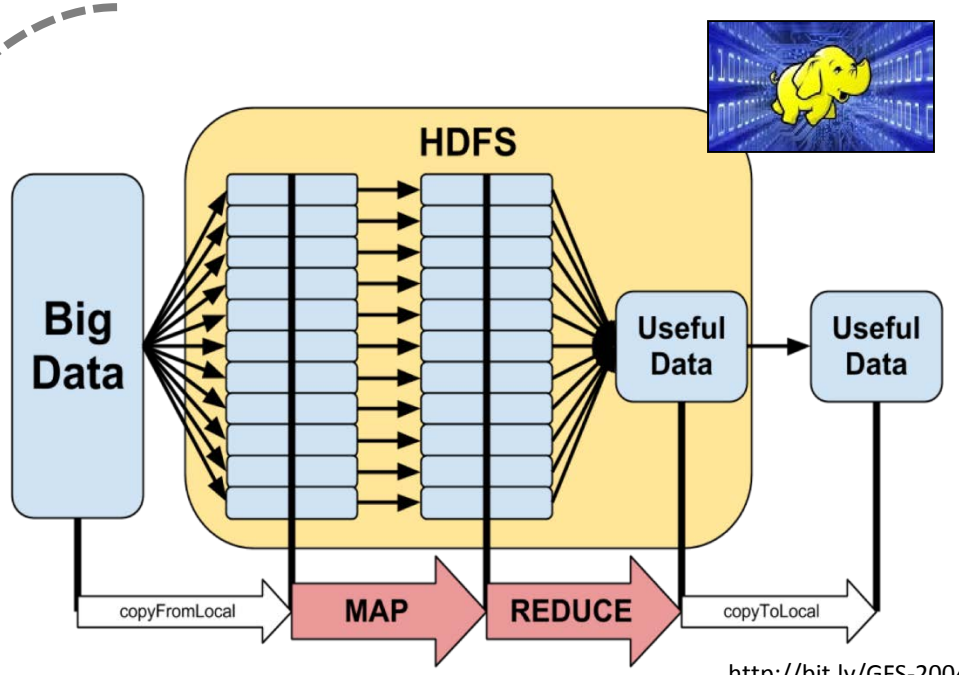


Marvin Minsky “cube on cube” (The Society of Mind, 1959)

nanocubes

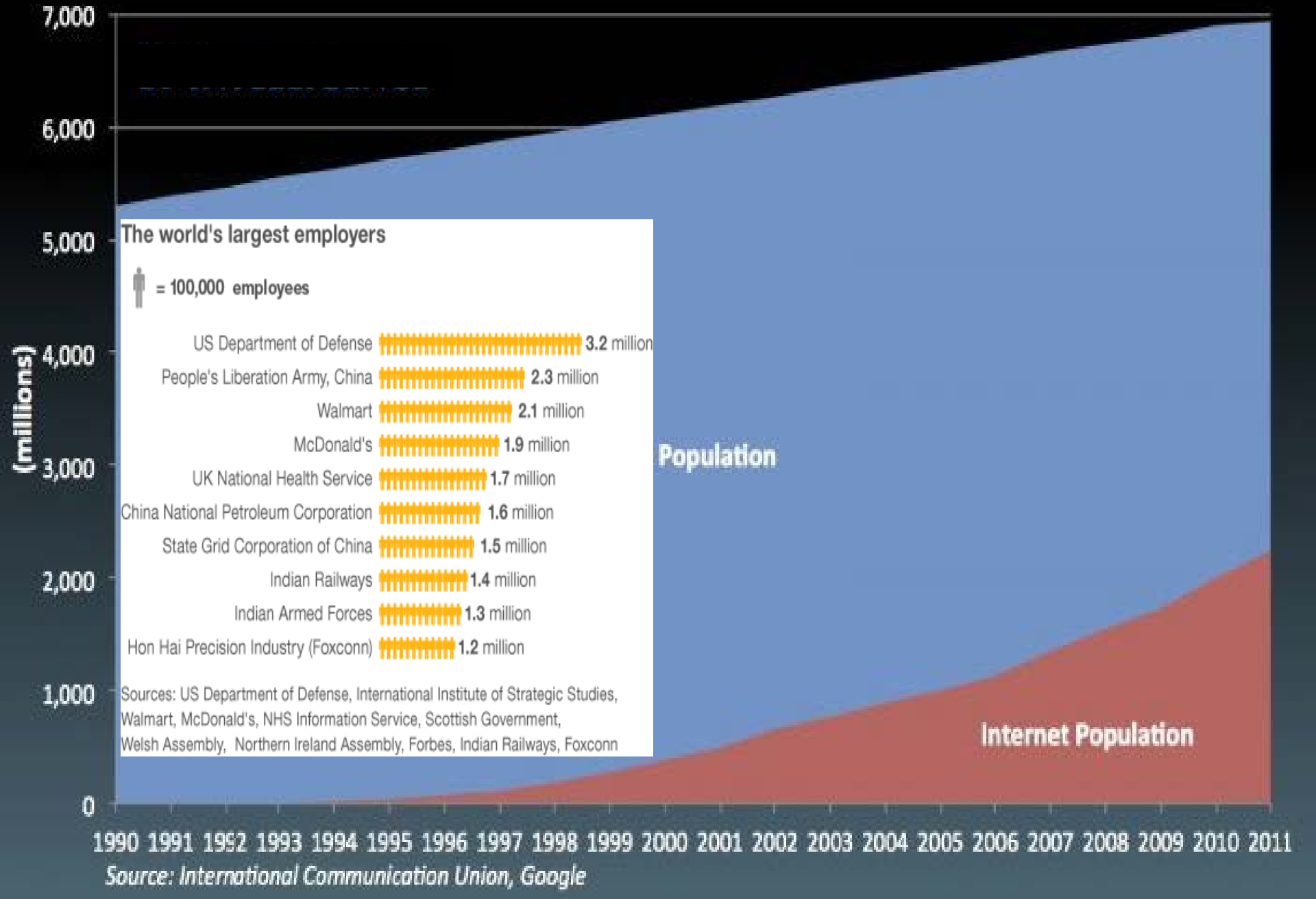



www.nanocubes.net/assets/pdf/nanocubes_paper.pdf

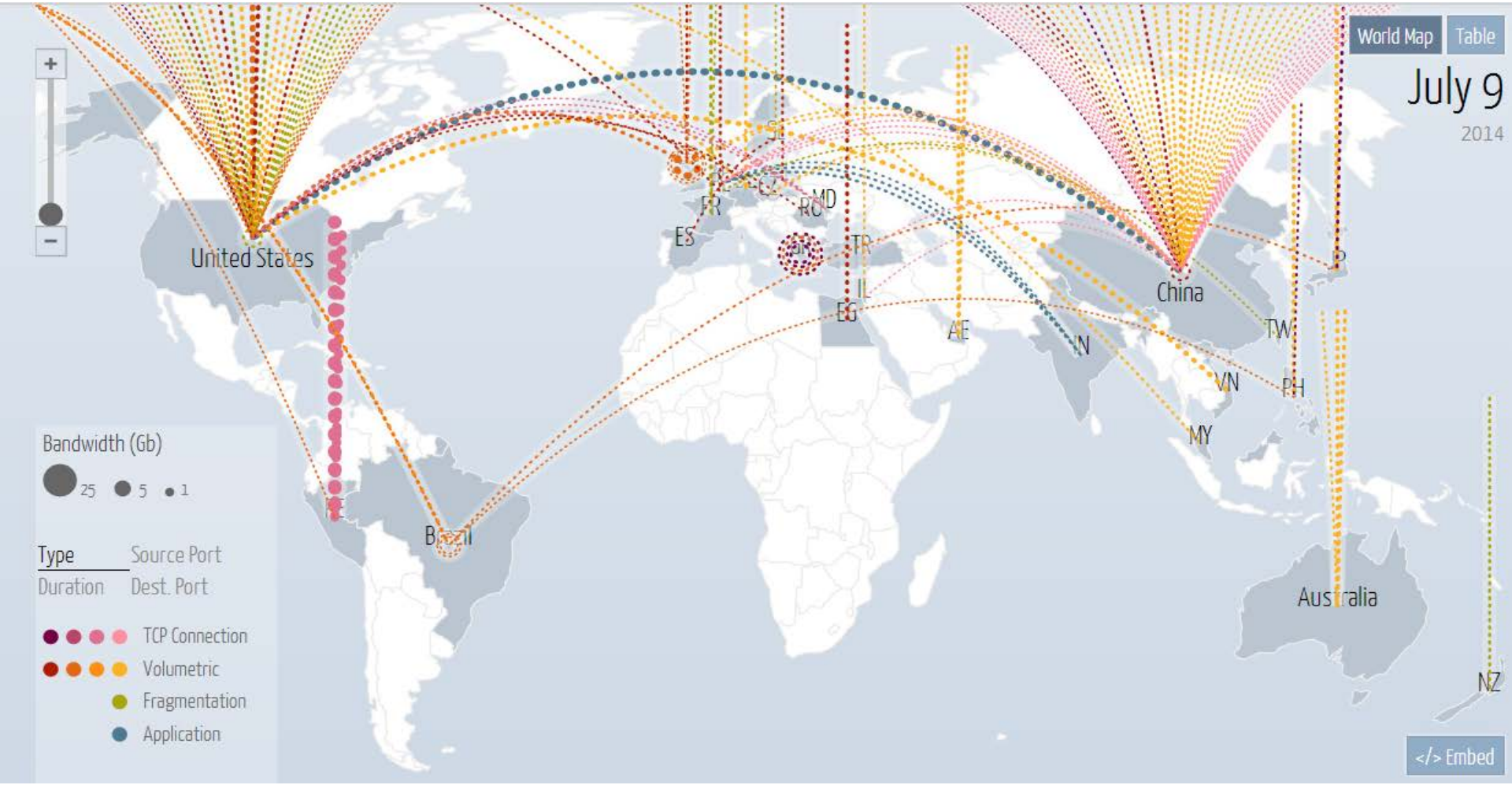



http://bit.ly/GFS-2004

# Data – Imagine what happens if 50% of the population were connected



# Data Cybersecurity – Digital Attack Map – The Prelude to Cyber Warfare



- EQM – Elusive Quest for Monetization (pre-proposal available on request)

- **Connect, Converge, Combine → Obvious vs Non-Obvious**

  [a] Space-time-node engine

  [b] Stigmergic computation

  [c] Cognitive matrices

  [d] Dynamic networks

  [e] Semantics of time

  [f] CLA + temporally integrated software / embedded systems

  [g] Artificial retina pattern recognition algorithm

  [h] Conventional (time series, GARCH, OR, AI, machine learning)

In 1854, Ferdinand de Lesseps obtained a concession from Sa'id Pasha, the Khedive of Egypt and Sudan, to create a company to construct a canal open to ships of all nations. De Lesseps convened the *Commission Internationale pour le percement de l'isthme des Suez* consisting of 13 experts from seven countries. The commission produced a unanimous report in December 1856 containing a detailed description of the canal complete with plans and profiles. The Suez Canal Company (*Compagnie universelle du canal maritime de Suez*) came into being on 15 December 1858 and work started on the shore of the future Port Said on 25 April 1859. International opinion was sceptical and Suez Canal Company shares did not sell well overseas. Britain, United States, Austria and Russia did not buy a significant number of shares. All French shares were quickly sold in France. A contemporary British sceptic claimed:

*One thing is sure our local merchant community doesn't pay practical attention at all to this grand work and it is legitimate to doubt that the canal's receipts could ever be sufficient to recover its maintenance fee. It will never become a large ship's accessible way in any case.*

The British government had opposed the project from the outset to its completion. The canal opened on 17 November 1869.

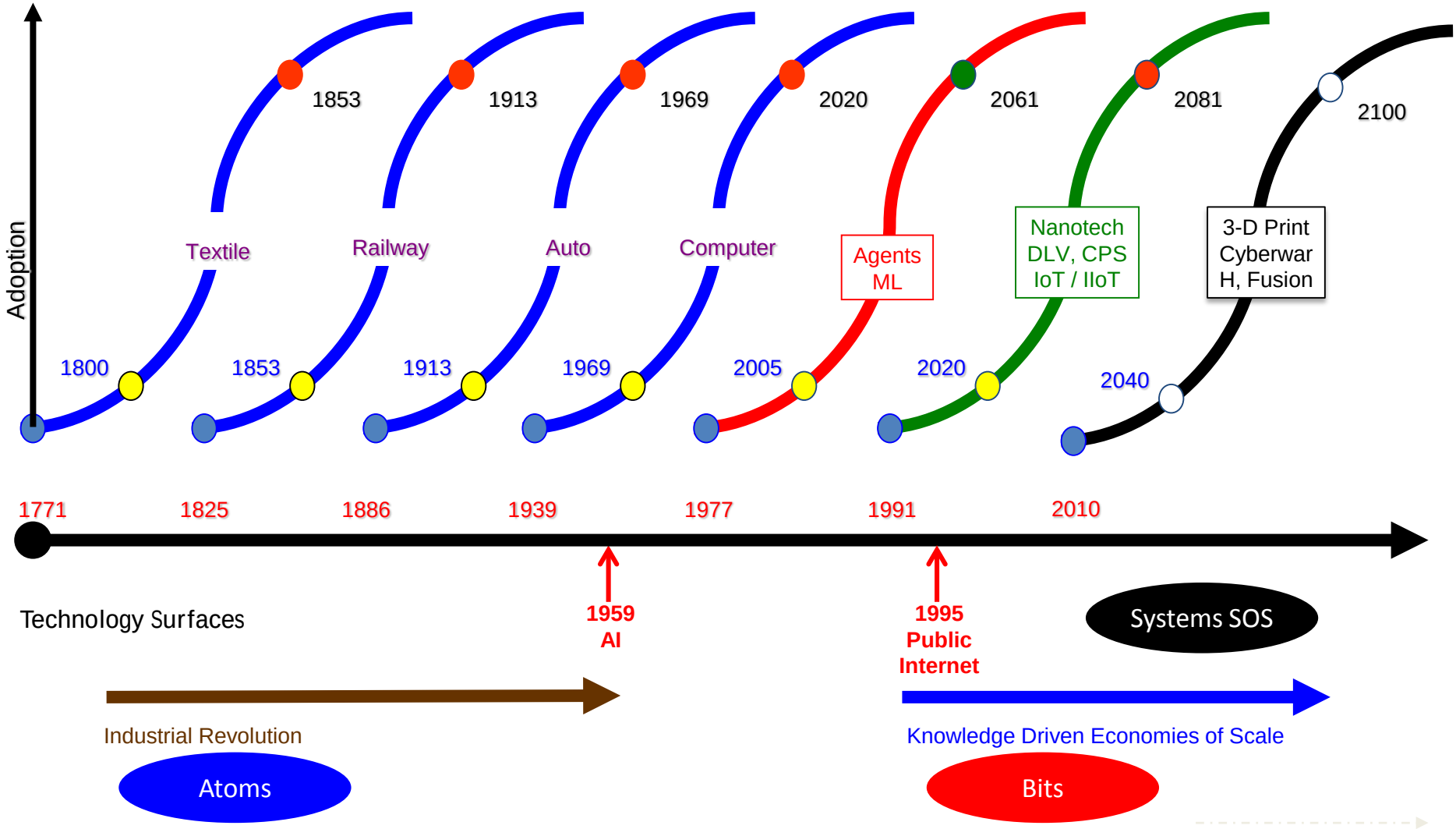
The first ship through the canal was the British P&O liner *Delta*. Although *L'Aigle* was officially the first vessel through the canal, HMS *Newport*, captained by George Nares, passed through it first. On the night before the canal was due to open, Captain Nares navigated his vessel, in darkness and without lights, through the mass of waiting ships until it was in front of *L'Aigle*. When dawn broke the French were horrified to find that the Royal Navy was first in line and that it would be impossible to pass them. Nares received both an official reprimand and an unofficial vote of thanks from the British Admiralty for his actions in promoting British interests and demonstrating such superb seamanship.

After the opening the Suez Canal Company was in financial difficulties. Less than 500 ships passed during the first few years. External debts forced Said Pasha's successor, Isma'il Pasha, to sell his country's share in the canal for £4 million (about £86 million in 2013) to the United Kingdom in 1875 but French shareholders still held the majority. Prime Minister Benjamin Disraeli was accused by William Ewart Gladstone of undermining Britain's constitutional system, because he had not obtained consent from Parliament when purchasing the shares with funding from the Rothschilds.

In 2012, nearly 20,000 ships used The Suez Canal. On an average, 50 ships navigate the canal daily, carrying more than 300 million tons of goods per year. On August 5, 2014, President Sisi of Egypt announced the building of a new Suez Canal project to add 45-mile parallel lane to allow more ships to use this freight transportation option (www.theguardian.com/world/2014/aug/05/egypt-build-new-suez-canal).

# The Wealth of Nations ● Nature of the Firm (Transaction Cost Economics)

*Economic history and data related to Textile, Railway, Automobiles and Computers taken from work by Norman Poire*




It takes about 28-30 years for an idea to be socialized before it is accepted and adopted.
If 1999 was the birth year for IoT concept, then we expect exponential growth by 2030.

- Apple Developers Conference, Santa Clara Convention Center (March 2014)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