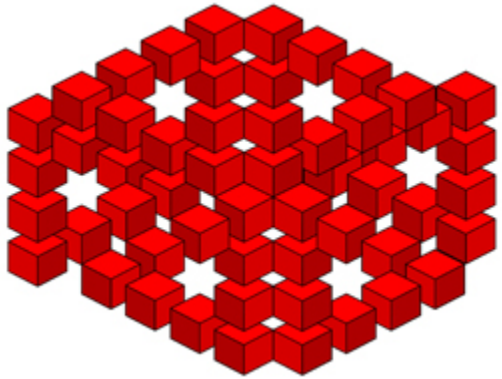
From Imagination and Invention to Innovation

Translational Engineering



Dr Shoumen Palit Austin Datta

MIT Auto-ID Labs and ICRI, Research Affiliate, Department of Mechanical Engineering, Massachusetts Institute of Technology ▪ shoumen@mit.edu

Senior Scientist, MDPnP Lab Medical Device Interoperability, Massachusetts General Hospital, Harvard Medical School ▪ sdatta8@mgh.harvard.edu

Translate ideas to deliver value

Use R&D as profit solvers

Industry KPI - efficiency, waste reduction, market share

Monetization – Convergence

SCM Data Collaboration (http://bit.ly/SCM-DATA-SHARING)

Economic History of GPT (http://bit.ly/PAUL-DAVID-GPT)

Information Asymmetry (Akerlof, Spence, Stiglitz)

The Nature of the Firm (Ronald Coase)

Role of Technology (Robert Solow)

(The Actual) Metcalfe's Law

Trust in Social Networks

Systems Science

Graph Theory

Platforms

Analysis

Data

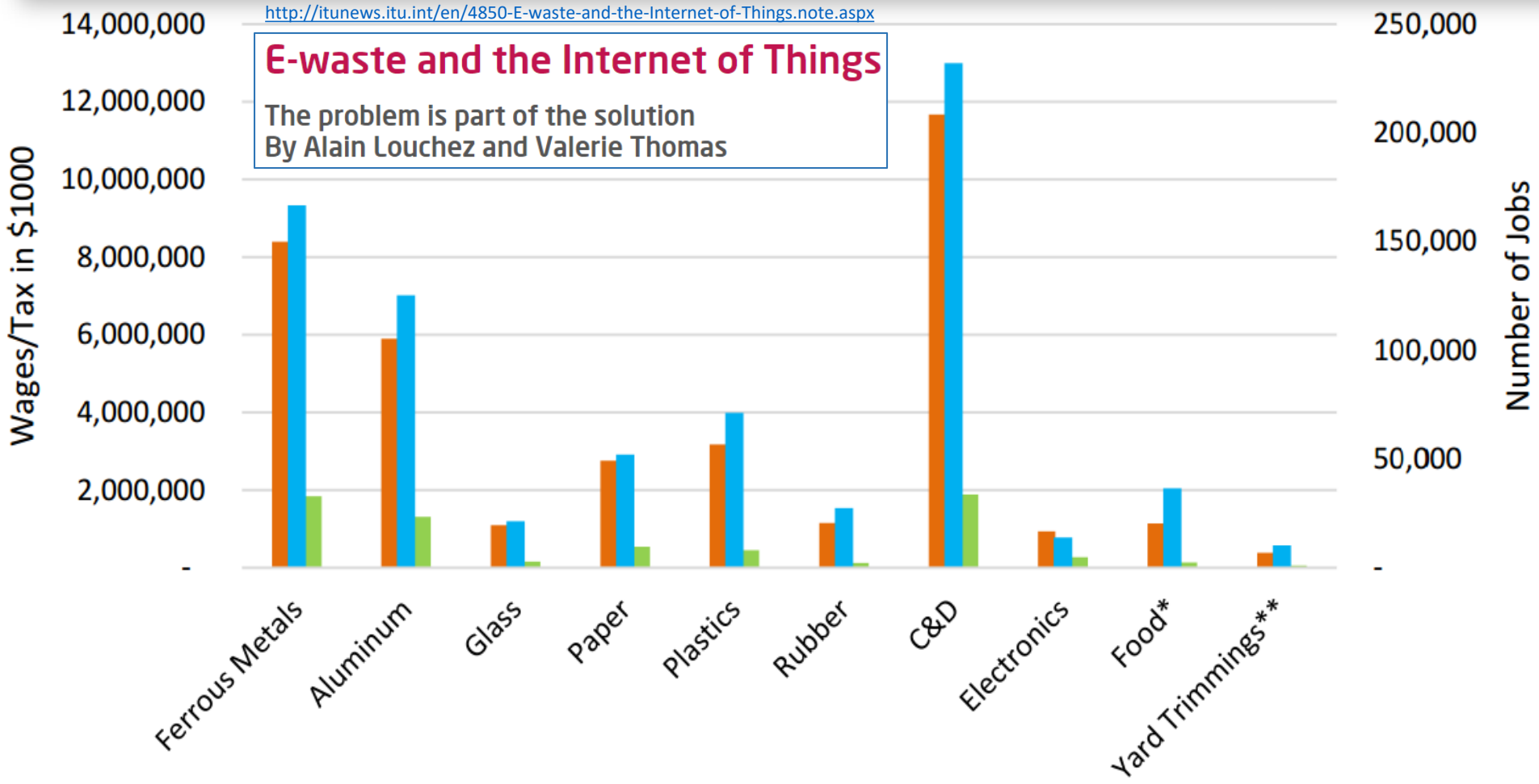
Efficiency Driver - Connected Infrastructure - Industrial Internet

Industry	Segment	Type of Savings	Estimated Value Over 15 Years (Billion nominal US dollars)
Aviation	Commercial	1% Fuel Savings	$30B
Power	Gas-fired Generation	1% Fuel Savings	$66B
Healthcare	System-wide	1% Reduction in System Inefficiency	$63B
Rail	Freight	1% Reduction in System Inefficiency	$27B
Oil & Gas	Exploration & Development	1% Reduction in Capital Expenditures	$90B

Dr Peter Closson Evans (GE Global Strategy and Analytics, 2013)

Potential ROI for GE from micro-savings approach . Estimated savings approaching $300 billion over 15 years.

The explosion (and prevention) of waste due to Industrial IoT



*Food category includes animal feed, meal, meat, fats, oils and tallow, as well as community food service

**Yard Trimmings category includes biodiesel, biogas, compost, mulch and wood chips

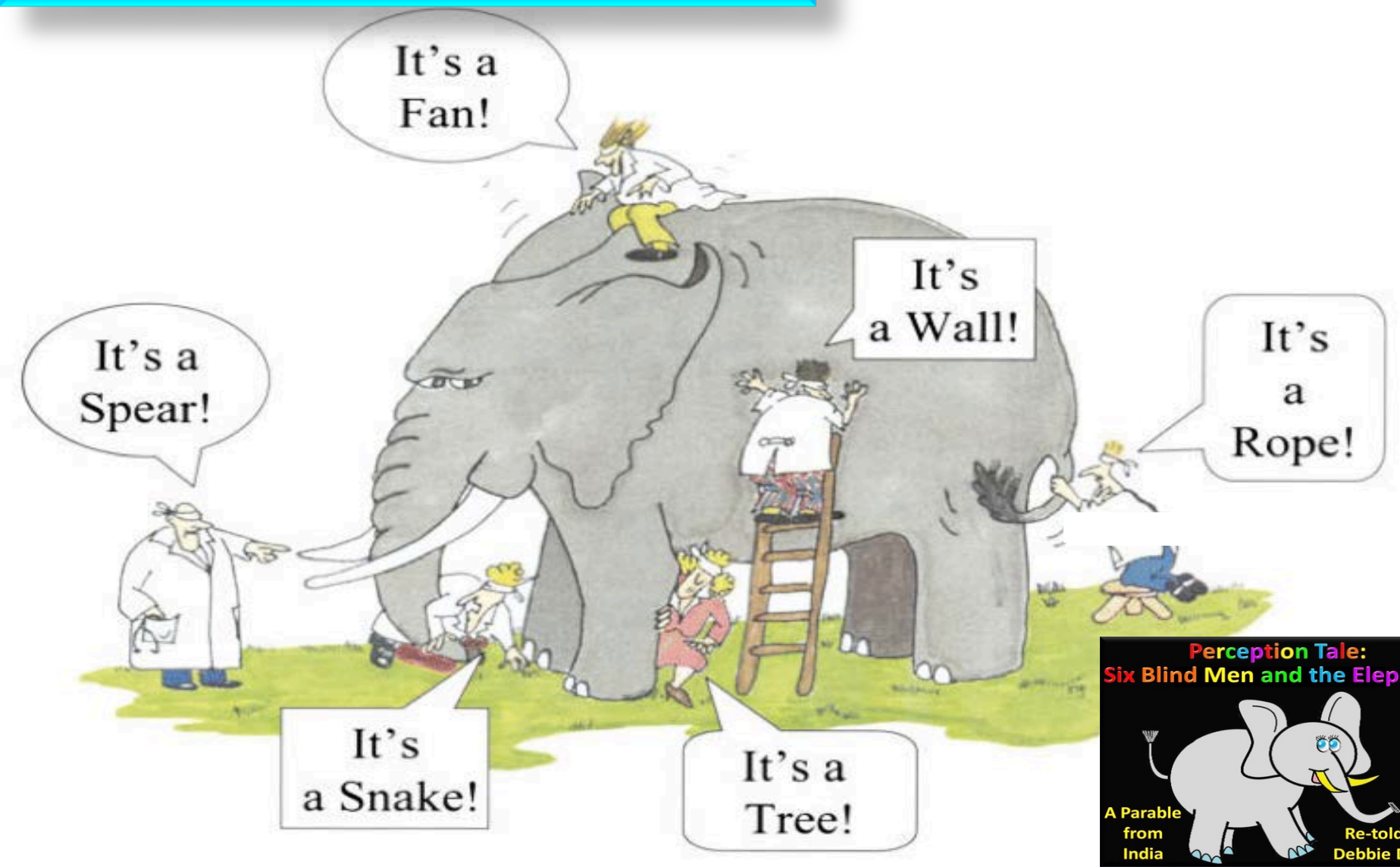
https://www.epa.gov/sites/production/files/2016-11/documents/final_2016_rei_report.pdf

Imperative to frame, define and ask the correct questions

Answers are dependent on questions

DYNAMIC BY DESIGN
RISK POOLING COMPONENTS
MODULAR SYSTEMS ARCHITECTURE
INTEROPERABLE VARIANT CONFIGURATION

Children's story based on an Indian folk tale dating back at least 2000 years. Offers insight into what happens if the systems view of a problem is ignored. Six men who are very knowledgeable are blind. They encounter an elephant and each gives his analysis of the 'system' based on the particular part of the elephant (system) they happen to touch. Each is partly right since they have made contact with one major subsystem. However, they are wrong because in their blindness they failed to comprehend the system as a whole. Often in CPS the limited perspectives (embedded systems, communication, physical Plant) of individual domains may lead to failure for as a whole (integration).



The new normal – SERVICES – not products

Internet of Things
isn't about things

IoT is a design metaphor

applicable to any domain

Design, Architecture, Modularity, Standards and Interoperability between Standards

Outcome

Digital Objects Management

Digital Operations Management

Digital Supply Chain Management

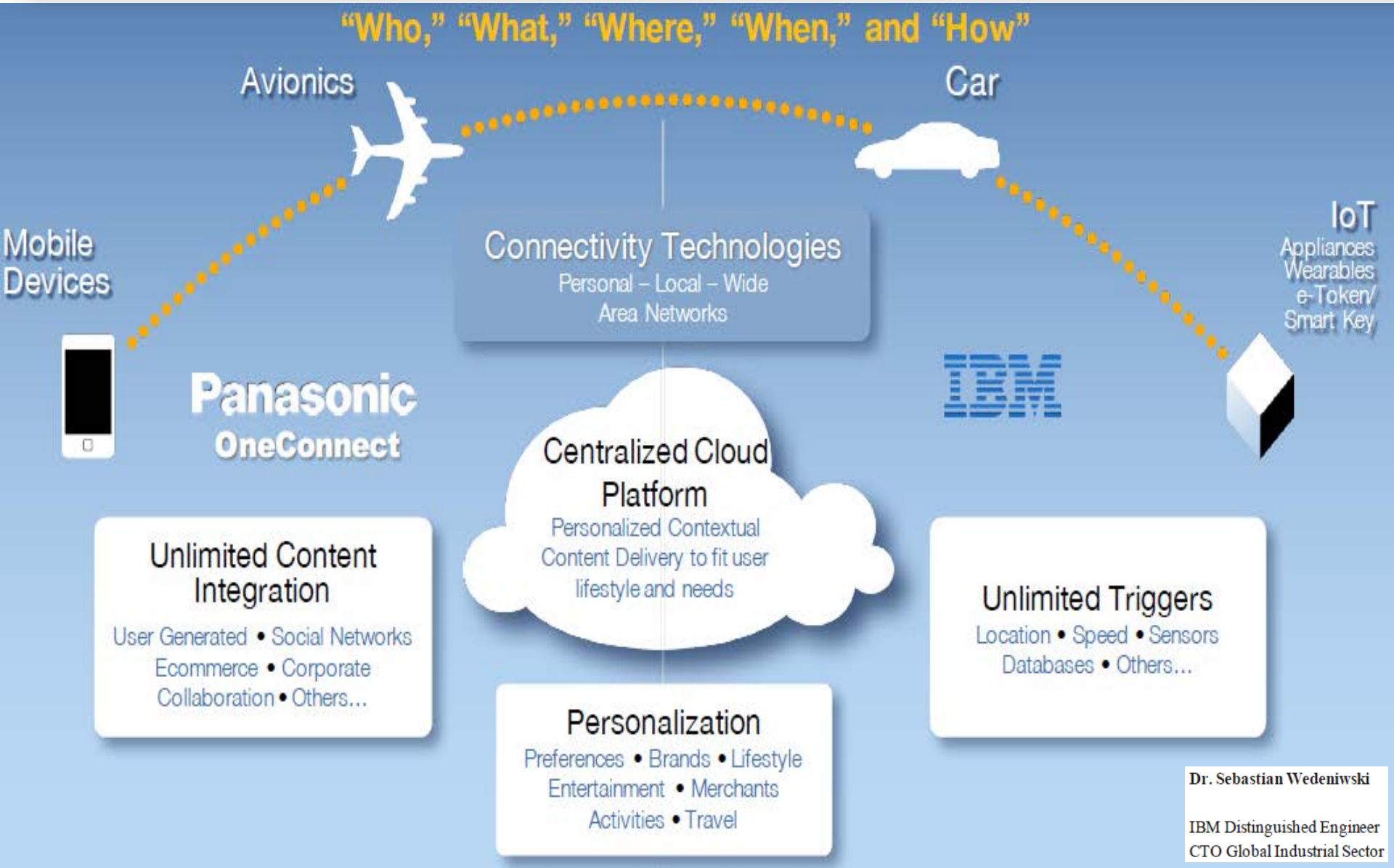
Digital Service Lifecycle Management

Digital Customer Relationship Management

Digital Certification for Security, Privacy, Authentication

UI Designed by Old Uncle while intoxicated – The dead weight of old technology

IoT Design Metaphor - Contextual Content Connects on Interoperable Platforms



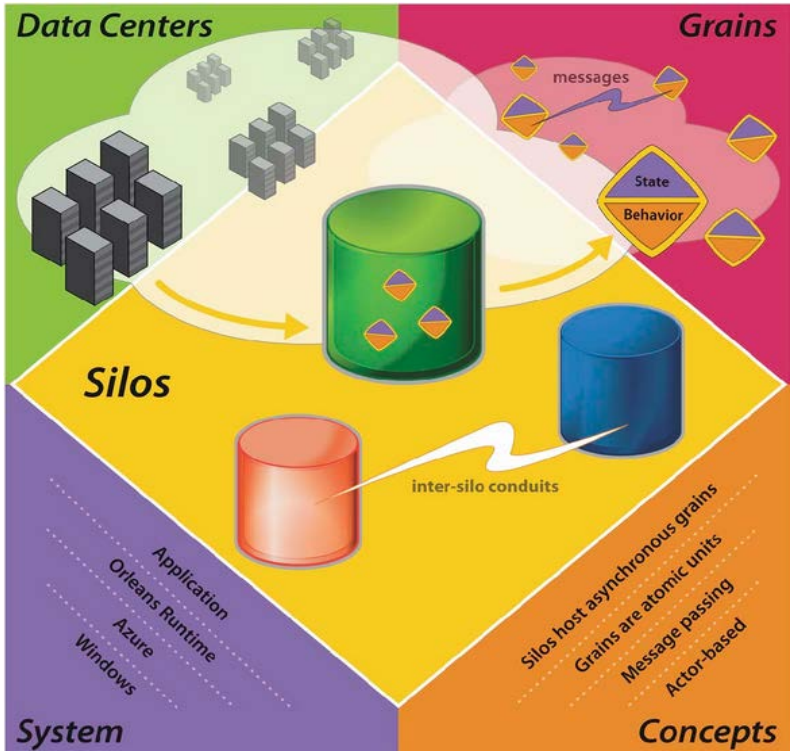
Dr. Sebastian Wedeniwski

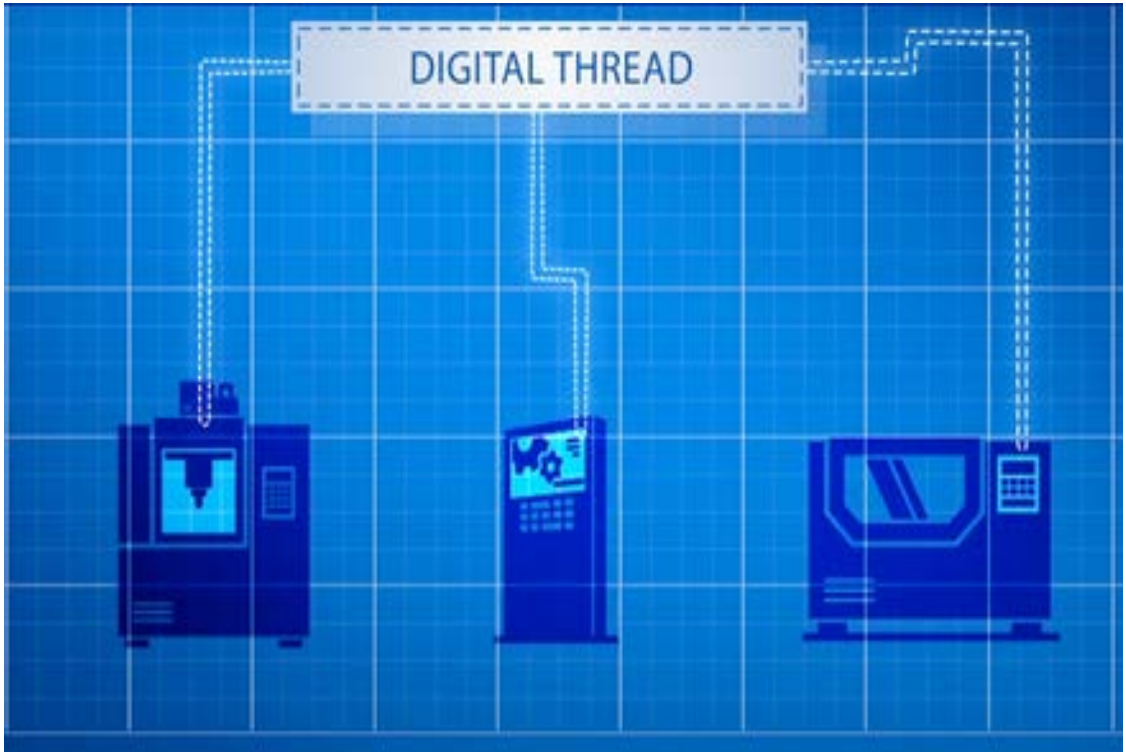
IBM Distinguished Engineer
CTO Global Industrial Sector

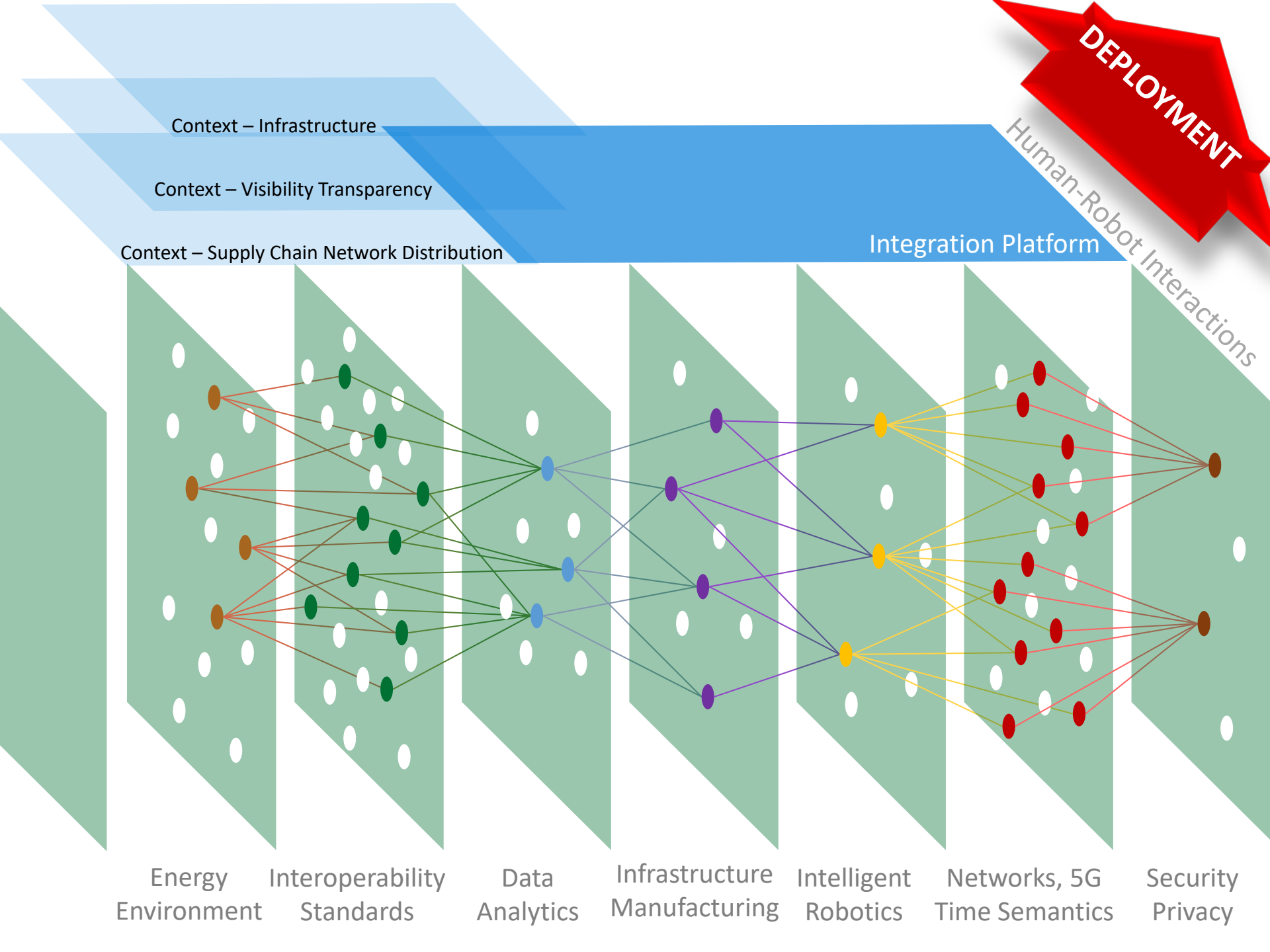
Evolution of Platform Architectures

Plug and Play Modularity

Drag and drop to connect / disconnect / re-connect the digital thread






DEPLOYMENT
Human-Robot Interactions
Context – Infrastructure
Context – Visibility Transparency
Context – Supply Chain Network Distribution
Integration Platform
Energy
Environment
Interoperability
Standards
Data
Analytics
Infrastructure
Manufacturing
Intelligent
Robotics
Networks, 5G
Time Semantics
Security
Privacy

Decoupling Static EBM to Modular ABM

Cost MTBF Speed

1 $y_t = \beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \ldots + \beta_K x_{Kt} + \varepsilon_t$

2 $y_t = \beta_0 + \beta_1 x_{1t} + \quad + \ldots + \beta_K x_{Kt} + \varepsilon_t$

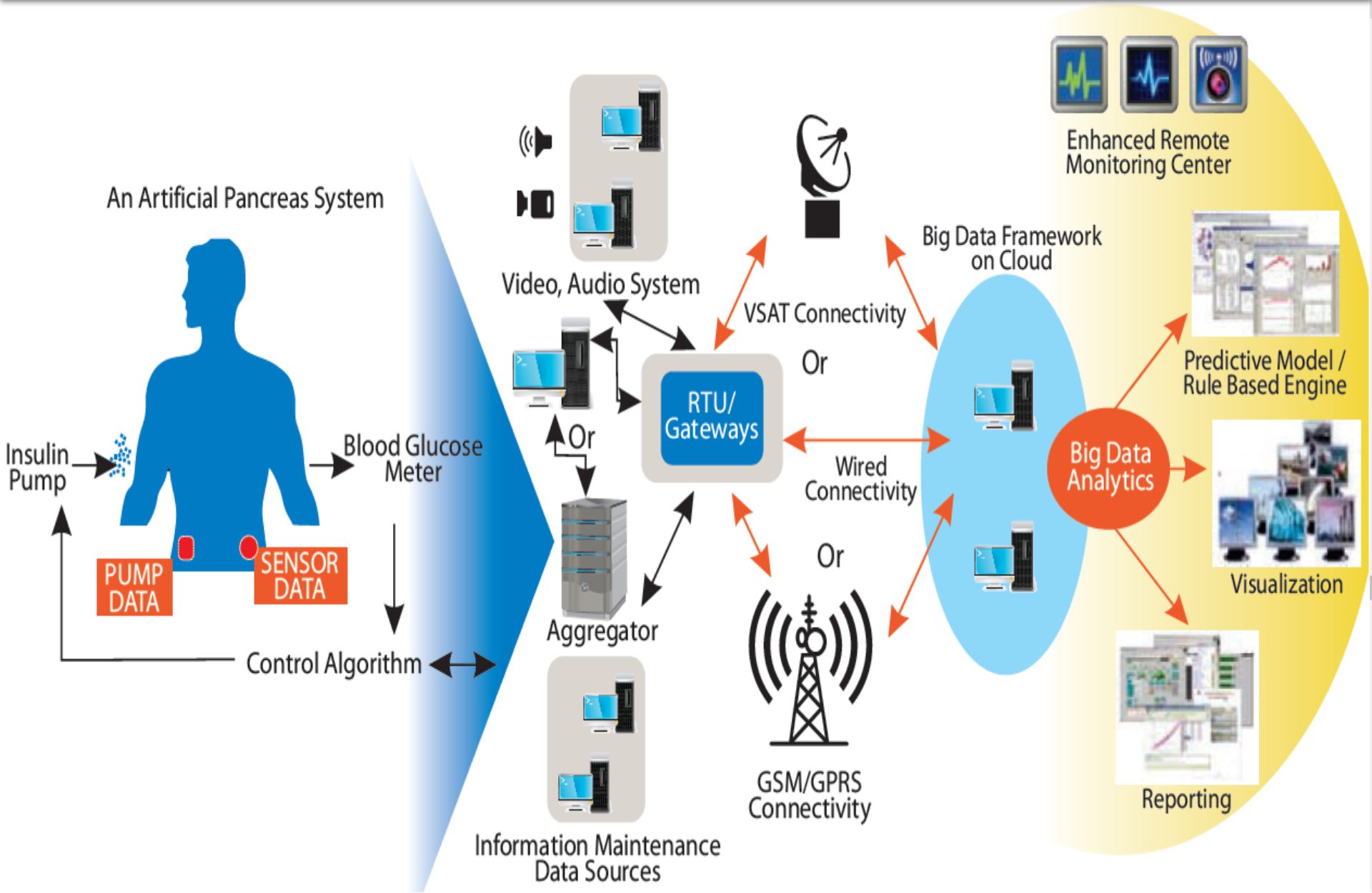
3 $y_t = \beta_0 + \beta_1 x_{1t} + a_2 z_{2t} + \ldots + \beta_K x_{Kt} + \varepsilon_t$

CONTEXT RELEVANT VARIABLE AGENT
Intelligent decision support systems

Maintaining UpTime - Plug & Play Architecture mapped to MTBF linked to Supply Chain Systems


Internet of Energy
Turbine Digital Twin

IoS Diabetes Management ● Artificial Pancreas Device Systems



www.tcs.com/SiteCollectionDocuments/White%20Papers/Personalized-Artificial-Pancreas-Device-Systems_1014-1.pdf

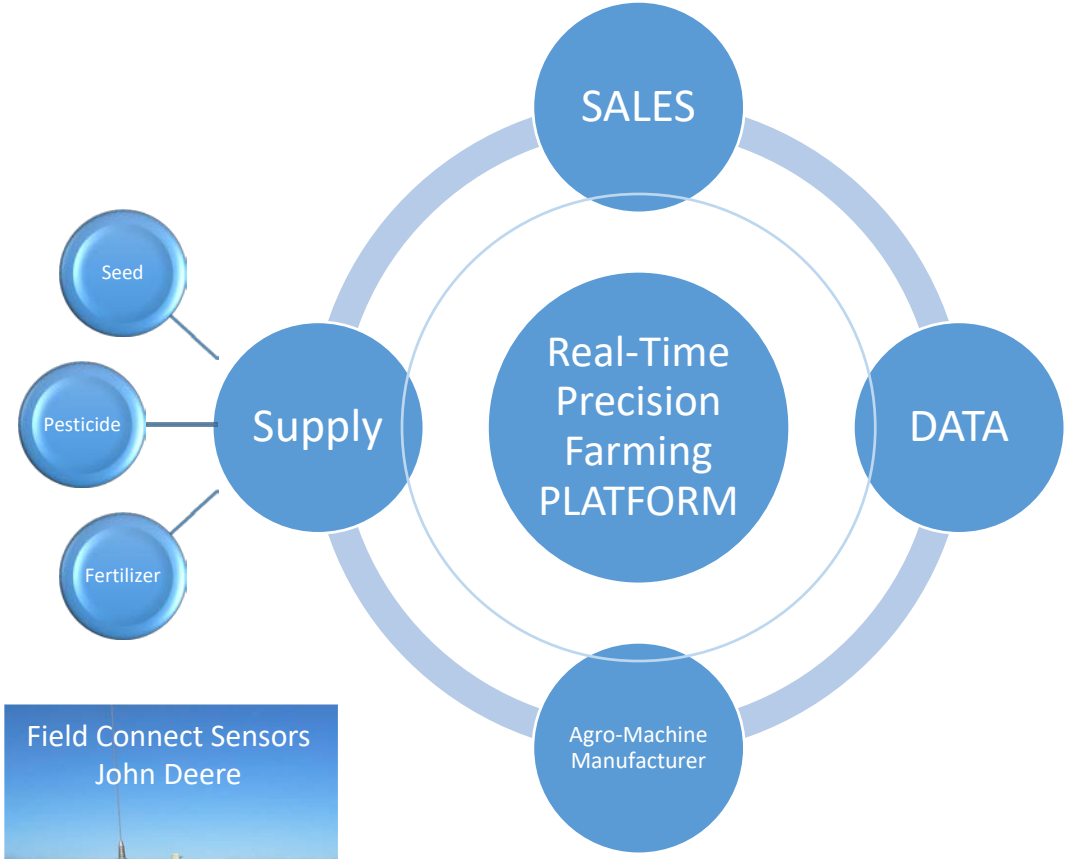
Precision Farming – Converging IoS Ecosystems – Fertilizer, Salinity, Water

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

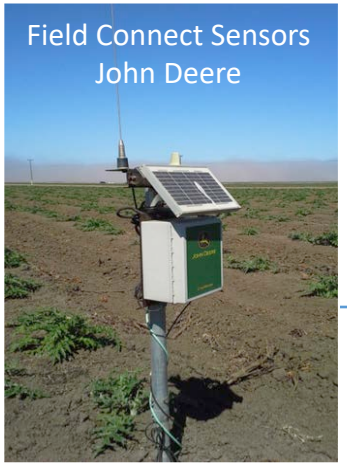
Retail Supply Chain – Sourcing / Distribution / Warehouse / Transportation
Track & Trace – Commodity Traders – Risk Management – Regulators (FDA)



-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

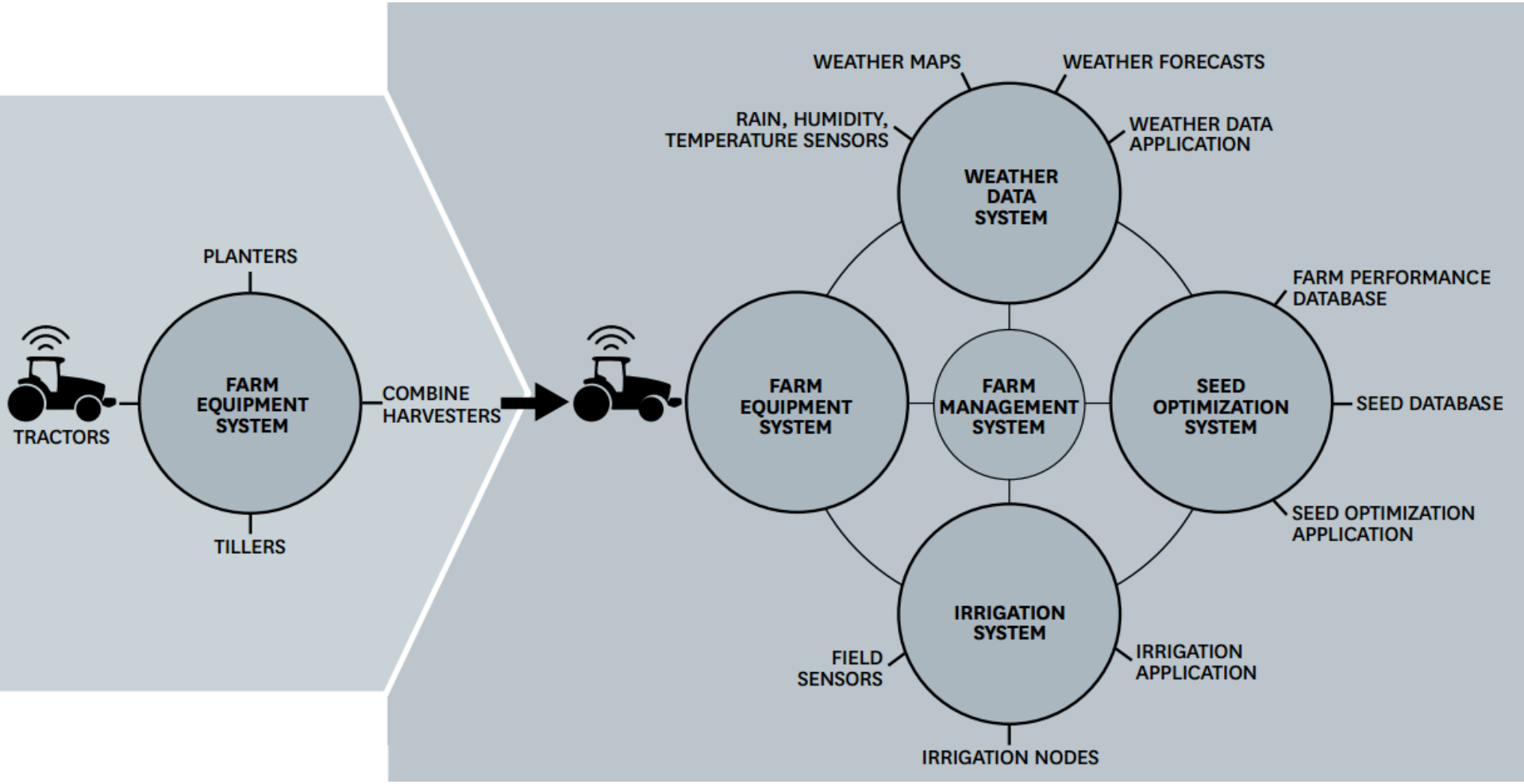
Leverage data to run long and short term simulations to plan for "what if" to optimize profit
- Weather patterns
- Demand uncertainty
- Export and import
- Tariff, cost, excise
- Regulatory policy



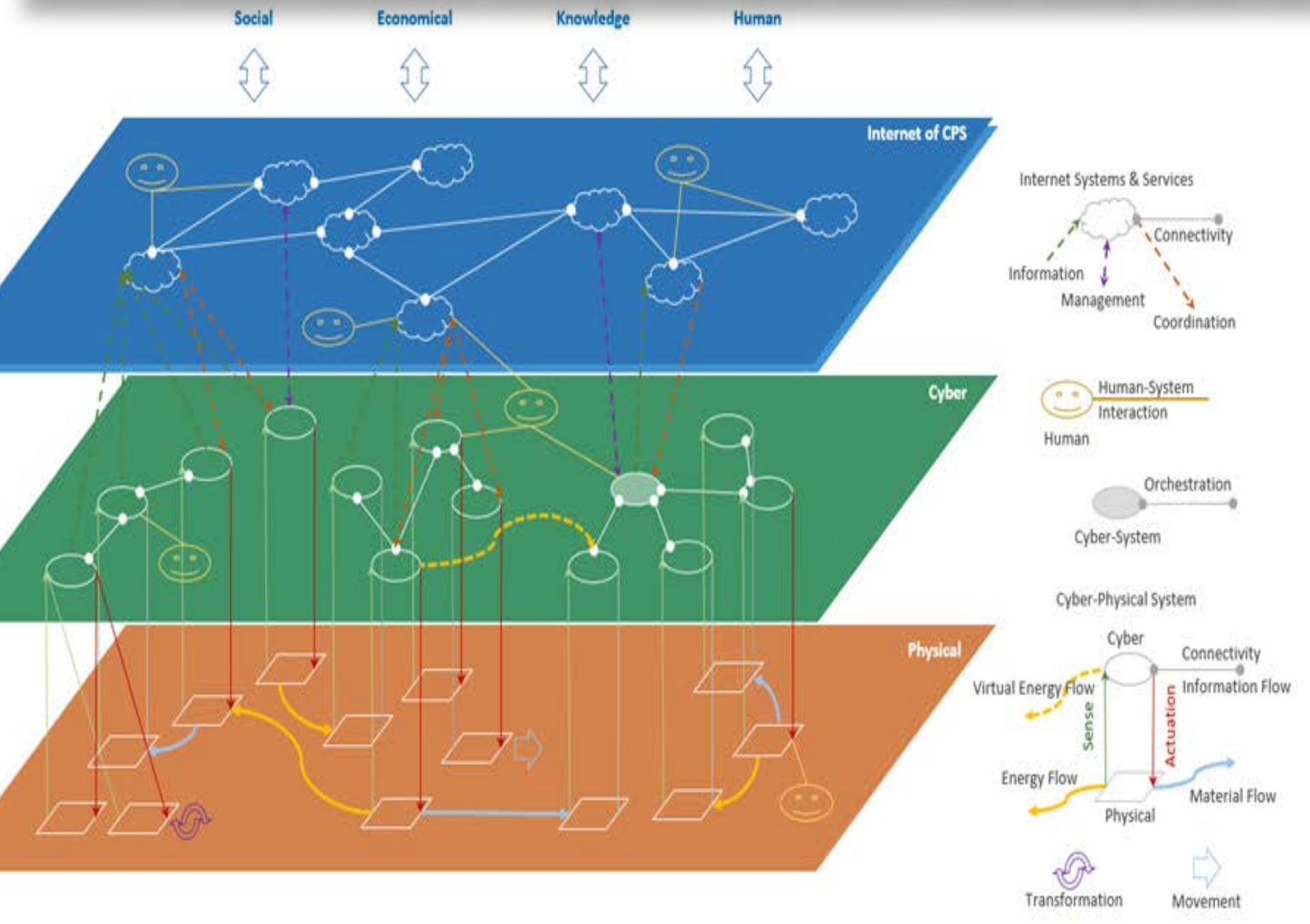
- Optimize MRO to improve asset uptime
- Mobile data collection and dissemination
  - soil sample / nutrient analysis (GCMS)
  - moisture monitors / field connect data
  - temperature / dielectric constant
  - color and chemistry of crops
  - growth rate / fertilizer distribution
  - weather micro-impact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

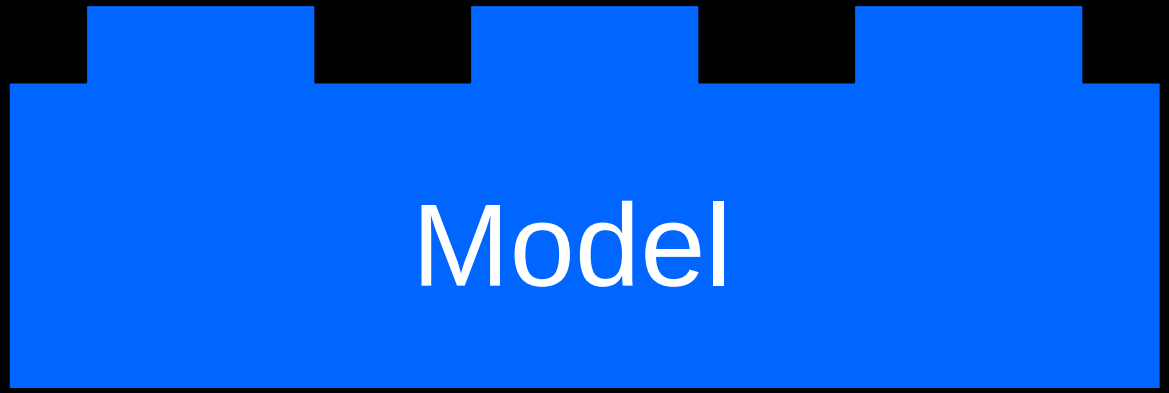
NASA Soil Moisture Active Passive (SMAP)

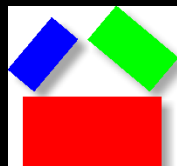
Classical Agricultural System of Systems



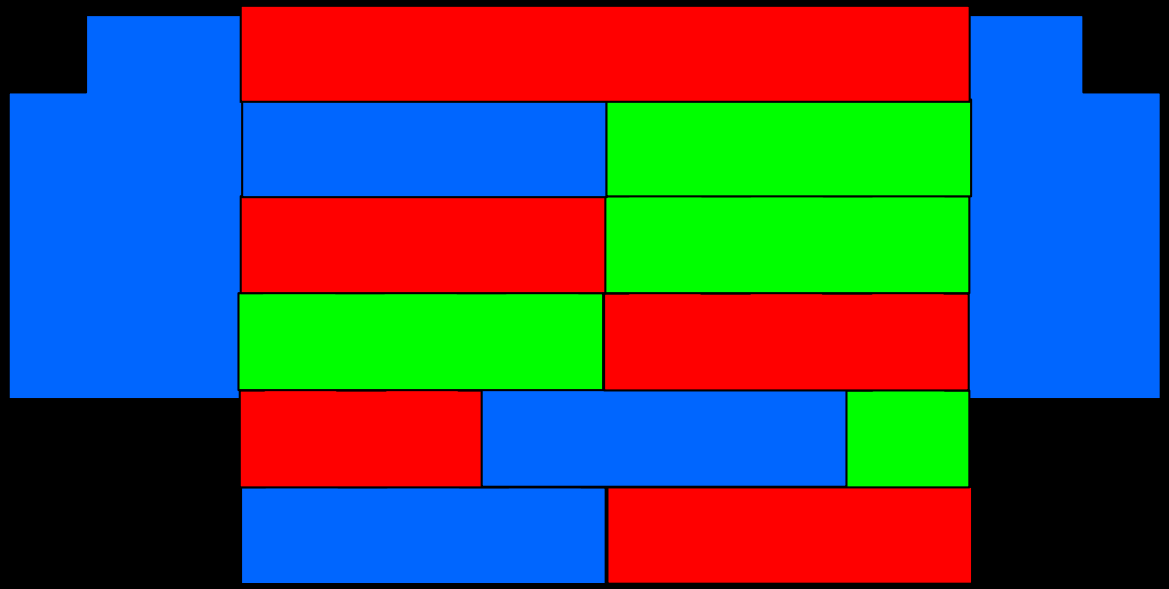
http://bit.ly/HBR-IoT-PDF


Social
Economical
Knowledge
Human
Internet of CPS
Cyber
Physical
Internet Systems & Services
Connectivity
Information
Management
Coordination
Human-System
Interaction
Human
Orchestration
Cyber-System
Cyber-Physical System
Cyber
Connectivity
Virtual Energy Flow
Information Flow
Sense
Actuation
Energy Flow
Material Flow
Physical
Transformation
Movement

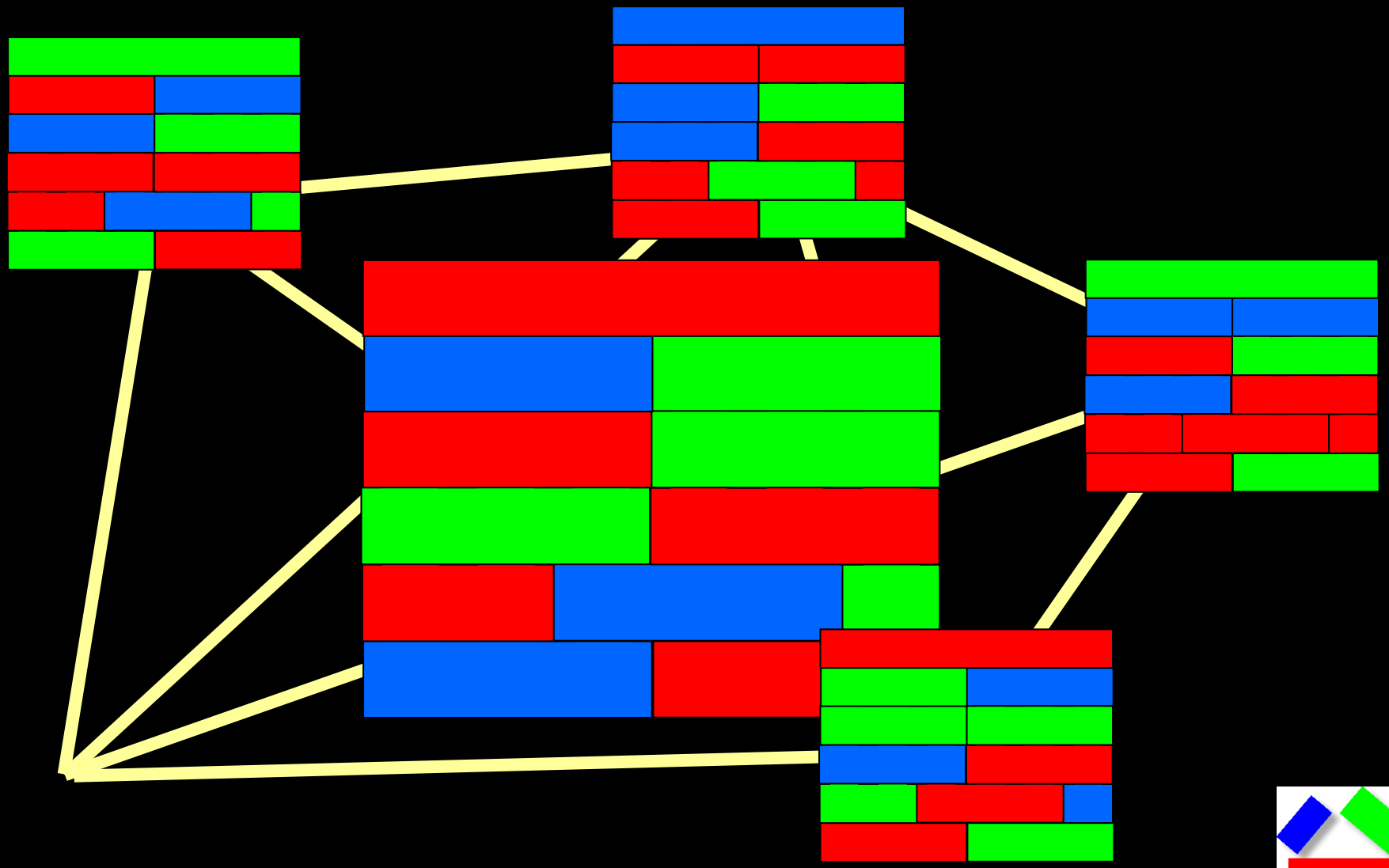

Model



Software Defined Architecture - Modularity, Integration, Interoperability



Modular Architecture – Networks, System of Systems, Global Integration



POTENTIAL FOUNDATIONAL STEPS for ENTERPRISE EVOLUTION

OUTCOME

Translational Engineering

IT IS NOT A ROADMAP. IT IS A COMPASS. IT IS A CONTINUUM.

You can't build an elephant using the mouse as a model

Necessitates industry partnerships and innovation to create products and services which can harvest R&D efforts and lead to economic growth ie profitability.

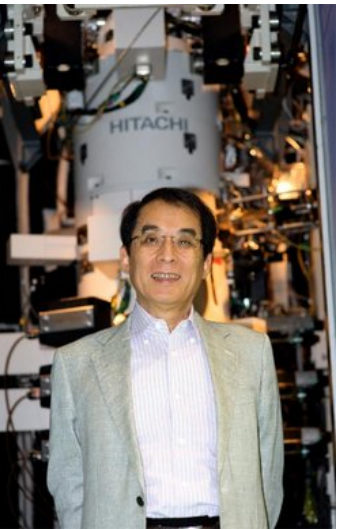
Data ...


More data points ...

Data shows emerging pattern ...

Young's Double Slit Experiment with Electrons

Dr. Akira Tonomura, Hitachi Research Laboratories, 1-280, Higashi-Koigakubo, Kokubunji-shi, Tokyo 185-8601, Japan



http://blogs.scientificamerican.com/guest-blog/what-does-the-new-double-slit-experiment-actually-show/

Sunlight

S_0

S_1

S_2

d

D

P

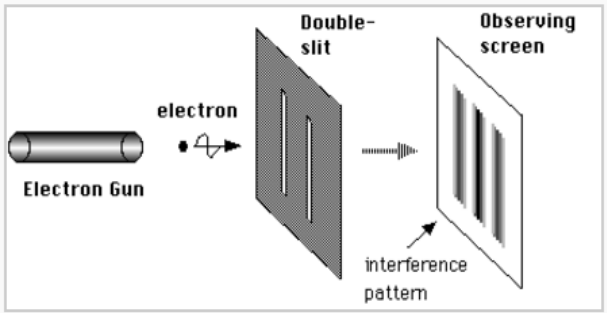
Bright

Dark

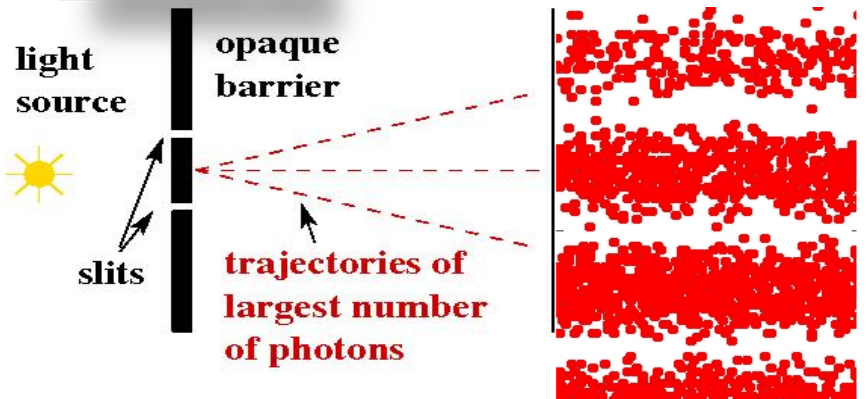
B_2 D_2 B_1 D_1 O D_1 B_1 D_2 B_2

Screen with single slit

Screen with double slit



Photons or particles of matter (like an electron) produce a wave pattern



Transform ideas into reality

OUTCOME

The Practice of the Outcome Economy

Customers don't want a circulation pump …

… they want a cozy and warm home.

J	O	B	S
Job-to-be-Done Context-specific **problem** facing a customer	**Objectives or Outcomes** Functional, emotional, social **metrics**	**Barriers** Factors inhibiting getting job done (**pains / gains**)	**Solutions** Products, services, compensating behaviors

M.W. Johnson: Seizing the white space, 2010

The Principles of the Outcome Economy

The Practice of the Outcome Economy

"People don't want to buy a quarter-inch drill… …they want a quarter-inch hole!"
- Theodore Levitt

Solution
What?

Job
Why?

And they want this hole without

- getting hurt
- falling from a ladder
- having to clean up
- drill a crooked hole
- …

J	O	B	S
Job-to-be-Done Context-specific **problem** facing a customer	**Objectives or Outcomes** Functional, emotional, social **metrics**	**Barriers** Factors inhibiting getting job done (**pains / gains**)	**Solutions** Products, services, compensating behaviors

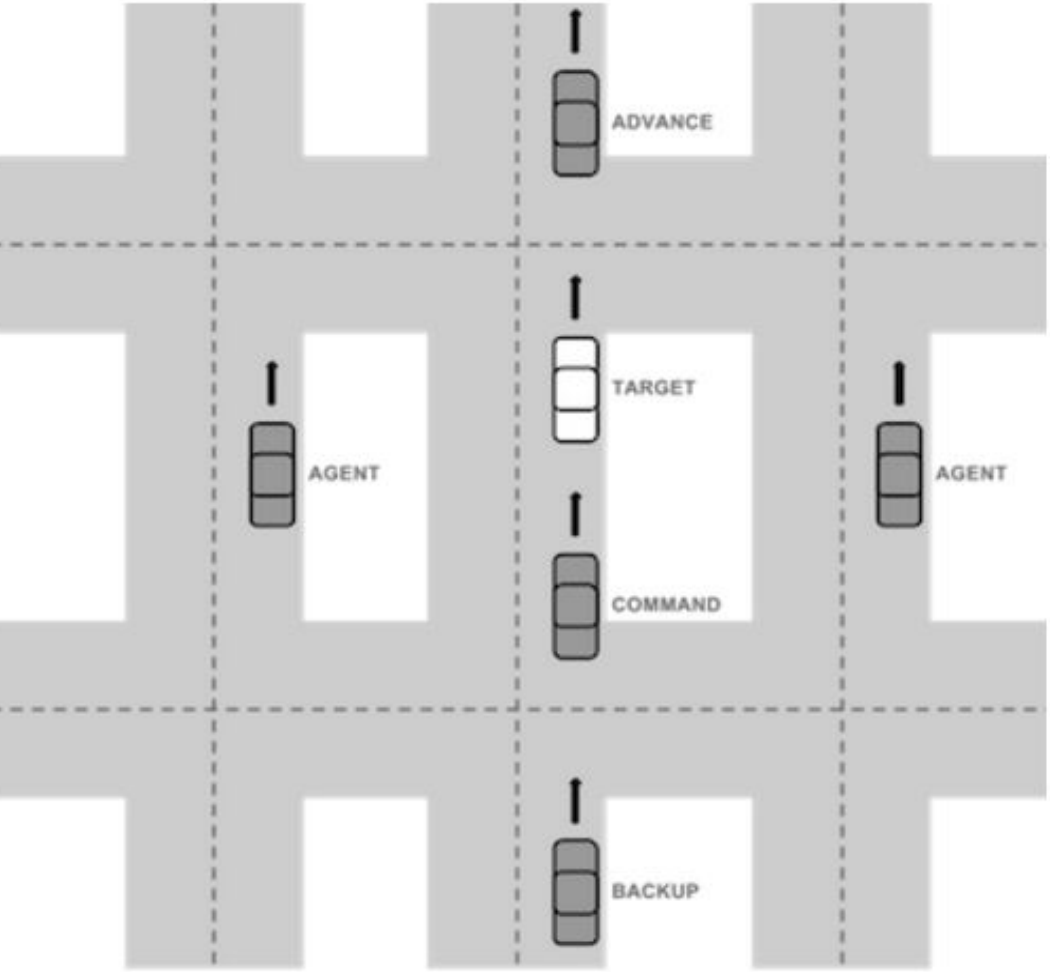
The Principles of the Outcome Economy

Cost of FBI surveillance of 325,000 individuals for 4 weeks in the USA

(Agent Cost Per Hour × Number of Agents) + (Vehicle Operating × Number of Vehicles)
= ($50/hour × 5) + ($5/hour × 5)
= $275/hour

$60 BILLION

$$\frac{\text{FBI Agent Salary + Benefits}}{\text{Working Hours in a Year}} = \frac{\$98{,}467 + 32{,}495}{2600} = \$50/\text{hour}$$



THE YALE LAW JOURNAL

PRINT ARCHIVE FORUM SUBMISSIONS MASTHEAD ABOUT CONTACT

VOLUME 123 2013-2014

FORUM

Tiny Constables and the Cost of Surveillance: Making Cents Out of *United States v. Jones*

09 JAN 2014

Kevin S. Bankston and Ashkan Soltani

INTRODUCTION

As Judge Richard Posner once said, "Technological progress poses a threat to privacy by enabling an extent of surveillance that in earlier times would have been prohibitively expensive," thereby "giving the police access to surveillance techniques that are ever less expensive and ever more effective."[1] Among these "'fantastic advances'"[2] in surveillance technology is the Global Positioning System (GPS), which provides law enforcement with an inexpensive means to track the precise geographic locations of criminal suspects. The Supreme Court recently addressed this technology in *United States v. Jones*, which considered whether the police's attachment of a GPS device to a suspect's car, and the use of that device to monitor the car's movements along public roads for twenty-eight days, constituted a search under the Fourth Amendment.[3]

Cost of FBI surveillance of 325,000 individuals for 4 weeks in the USA

International mobile subscriber identity – IMSI
IMSI-catcher is a eavesdropping device to intercept mobile phone traffic and track mobile phone users.

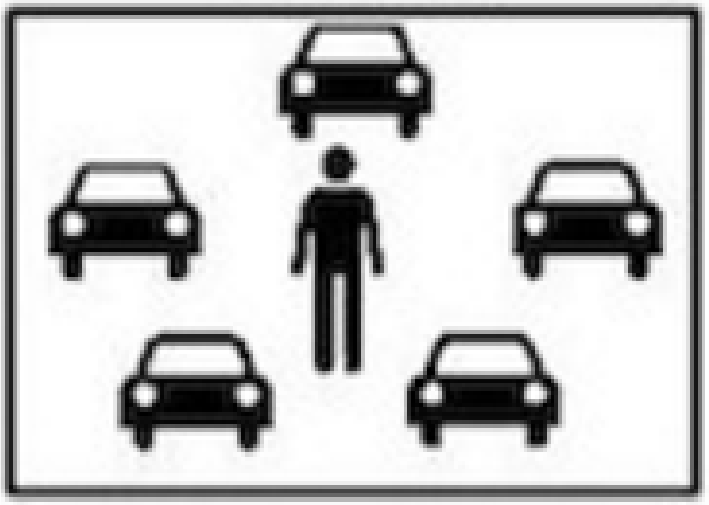
$23 BILLION

$$\frac{\text{Device Install \& Remove Time} \times \text{Agent Cost Per Hour}}{\text{Range of Hours of Investigation}} + (\text{Agent Cost Per Hour} \times 2 \text{ Agents}) + \text{Vehicle Operating Cost Per Hour}$$

$$= \frac{4 \text{ hours} \times \$50}{(24 \text{ to } 627 \text{ hours})} + (\$50 \times 2) + \$5$$

$$= \$105 \text{ to } \$113 \text{ per hour}$$

$275/hr



$113.33/hr

Cost of FBI surveillance of 325,000 individuals for 4 weeks in the USA

$2 BILLION

Cost of FBI surveillance of 325,000 individuals for 4 weeks in the USA

Fees for obtaining cell location data $= \frac{\$0.04 \text{ to } \$5.21}{\text{hour}}$

$8 MILLION

Breakdown by Cell Carrier:

AT&T: $100 set up fee + $25/day
- For 1 day of surveillance: $125/24 hours = $5.21/hour
- For 1 month of surveillance:

$$\$100 \text{ set up} + (\$25/\text{day} \times 28 \text{ days}) = \frac{\$800}{28 \text{ days} \times 24 \text{ hours}} = \frac{\$800}{672 \text{ hours}} = \$1.19/\text{hour}$$

T-Mobile: $100/day = $4.17 /hour

Sprint: $30/month
- For 1 day of surveillance: $30/24 hours = $1.25/hour
- For 1 month of surveillance: $30/672 hours = $0.04/hour

$275/hr

$113.33/hr

$10/hr

$0.04/hr

Surveillance Undergoes Digital Transformation

	1 day		1 week		28 days	
Method	Estimated cost	Cost per hour	Estimated cost	Cost per hour	Estimated cost	Cost per hour
Foot Pursuit	$1,200.00	$50.00	$8,400.00	$50.00	$33,600.00	$50.00
Car Pursuit	$2,520.00	$105.00	$17,640.00	$105.00	$70,560.00	$105.00
Covert Foot Pursuit	$6,000.00	$250.00	$42,000.00	$250.00	$168,000.00	$250.00
Covert Car Pursuit	$6,600.00	$275.00	$46,200.00	$275.00	$184,800.00	$275.00
Beeper	$2,720.00	$113.33	$17,840.00	$106.19	$70,760.00	$105.30
IMSI Catcher or "Stingray"	$2,520.00	$105.00	$17,640.00	$105.00	$70,560.00	$105.00
GPS	$240.00	$10.00	$240.00	$1.43	$240.00	$0.36
Cell Phone (AT&T)	$125.00	$5.21	$275.00	$1.64	$800.00	$1.19
Cell Phone (T-Mobile)	$100.00	$4.17	$700.00	$4.17	$2,800.00	$4.17
Cell Phone (Sprint)	$30.00	$1.25	$30.00	$0.18	$30.00	$0.04

$60 billion

100X

$8 million

Kevin S. Bankston & Ashkan Soltani, Tiny Constables and the Cost of Surveillance: Making Cents Out of United States v. Jones, 123 YALE L.J. ONLINE 335 (2014), http://yalelawjournal.org/forum/tiny-constables-and-the-cost-of-surveillance-making-cents-out-of-united-states-v-jones

Digital Surveillance { You Talk We Listen – NSA }

Kevin S. Bankston & Ashkan Soltani, Tiny Constables and the Cost of Surveillance: Making Cents Out of United States v. Jones, 123 YALE L.J. ONLINE 335 (2014), http://yalelawjournal.org/forum/tiny-constables-and-the-cost-of-surveillance-making-cents-out-of-united-states-v-jones

$60 billion

Covert Car Pursuit

$60 BILLION - for 325,000 targets over 4 weeks

$275.00

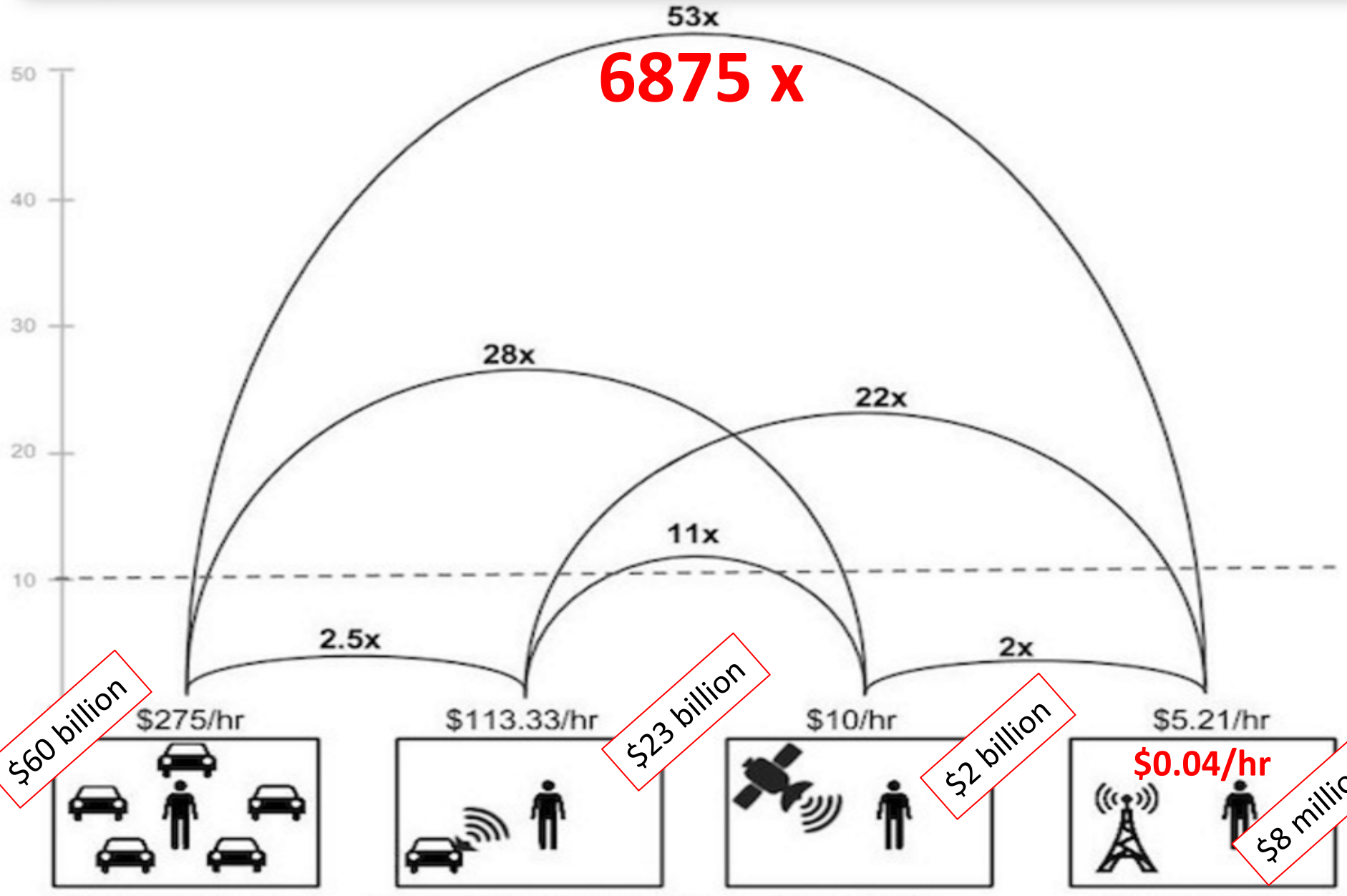
$8 million

Cell Phone

$8 MILLION - for 325,000 targets over 4 weeks

$0.04

Digital Transformation – Reduce Transaction Cost



Transaction Cost

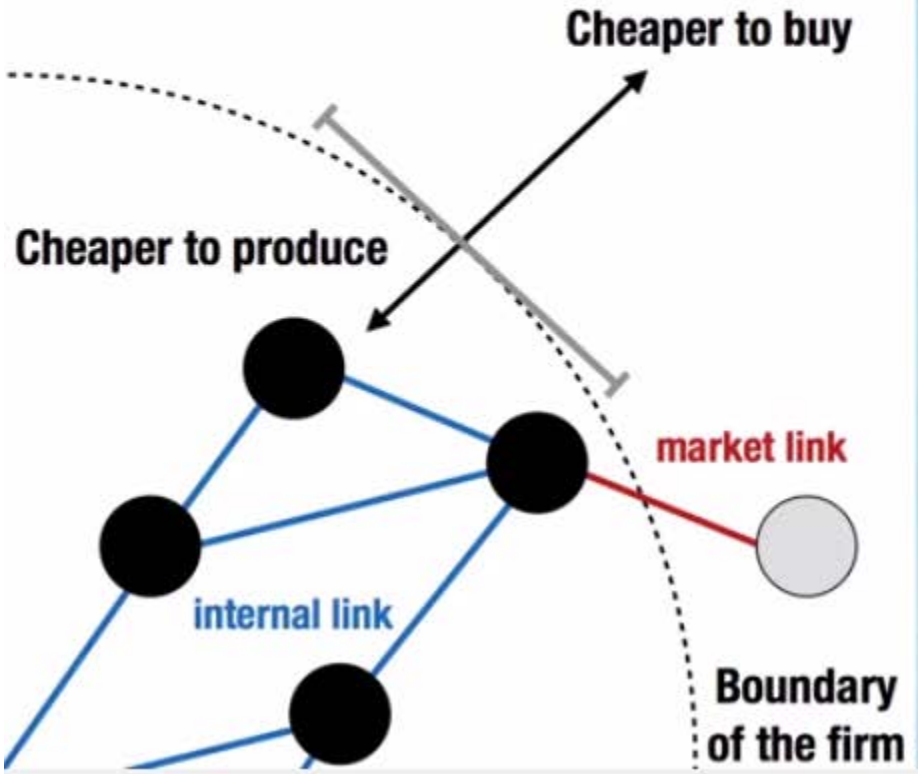
everywhere, every enterprise, every action

The Nature of the Firm – Transaction Cost

Written in 1937, when Coase was only 26, this paper tackles the question of why people choose to organize themselves in business firms rather than each contracting out for themselves.

Ronald Coase

(1910-2013 - Nobel Prize 1991)



OUTCOME

Ronald Coase, an LSE student from 1929–1932. http://bit.ly/COASE-5-PAPERS

THE FIRM
THE MARKET
AND THE LAW
R.H.Coase

1931

"IF YOU TORTURE THE DATA LONG ENOUGH, IT WILL CONFESS."
-RONALD COASE

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1991
Ronald H. Coase

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Ronald H. Coase - Facts

Ronald H. Coase

Born: 29 December 1910, Willesden, United Kingdom

Died: 2 September 2013, Chicago, IL, USA

Affiliation at the time of the award: University of Chicago, Chicago, IL, USA

Prize motivation: "for his discovery and clarification of the significance of transaction costs and property rights for the institutional structure and functioning of the economy"

The Nature of the Firm

By R. H. Coase

Economic theory has suffered in the past from a failure to state clearly its assumptions. Economists in building up a theory have often omitted to examine the foundations on which it was erected. This examination is, however, essential not only to prevent the misunderstanding and needless controversy which arise from a lack of knowledge of the assumptions on which a theory is based, but also because of the extreme importance for economics of good judgment in choosing between rival sets of assumptions. For instance, it is suggested that the use of the word "firm" in economics may be different from the use of the term by the "plain man."[1] Since there is apparently a trend in economic theory towards starting analysis with the individual firm and not with the industry,[2] it is all the more necessary not only that a clear definition of the word "firm" should be given but that its difference from a firm in the "real world," if it exists, should be made clear. Mrs. Robinson has said that "the two questions to be asked of a set of assumptions in economics are: Are they tractable? and: Do they correspond with the real world?"[3] Though, as Mrs. Robinson points out, "more often one set will be manageable and the other realistic," yet there may well be branches of theory where assumptions may be both manageable and realistic. It is hoped to show in the following paper that a definition of a firm may be obtained which is not only realistic in that it corresponds to what is meant by a firm in the real world, but is tractable by two of the most powerful instruments of economic analysis developed by Marshall, the idea of the margin and that of substitution, together giving the idea of substitution at

[1] Joan Robinson, *Economics is a Serious Subject*, p. 12.
[2] See N. Kaldor, "The Equilibrium of the Firm," *Economic Journal*, March, 1934.
[3] Op. cit., p. 6.

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2009

Elinor Ostrom, Oliver E. Williamson

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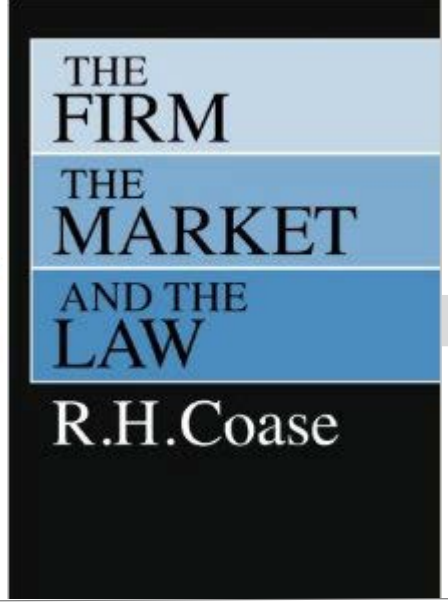
4

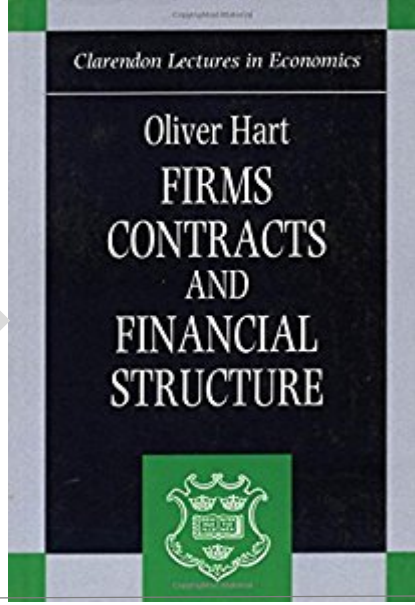
Prize Lecture

Transaction Cost Economics: The Natural Progression

Oliver E. Williamson delivered his Prize Lecture on 8 December 2009 at Aula Magna, Stockholm University. He was introduced by Professor Bertil Holmlund, Chairman of the Economic Sciences Prize

In my youth it was said that what was too silly to be said may be sung.
In modern economics it may be be put into mathematics.
(***Ronald Coase***)





The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2016
Oliver Hart, Bengt Holmström

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The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2016
Oliver Hart, Bengt Holmström

Share this: 38

Bengt Holmström

Bengt Holmström

Born: 18 April 1949, Helsinki, Finland

Affiliation at the time of the award: Massachusetts Institute of Technology (MIT), Cambridge, MA, USA

Prize motivation: "for their contributions to contract theory"

Oliver Hart

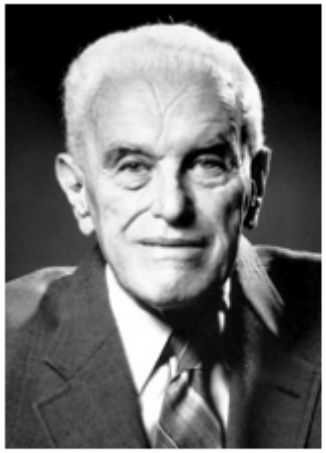
Oliver Hart

Born: 9 October 1948, London, United Kingdom

Affiliation at the time of the award: Harvard University, Cambridge, MA, USA

Prize motivation: "for their contributions to contract theory"

GAME THEORY



John C. Harsanyi
Prize share: 1/3

John F. Nash Jr.
Prize share: 1/3

Reinhard Selten
Prize share: 1/3

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1994 was awarded jointly to John C. Harsanyi, John F. Nash Jr. and Reinhard Selten *"for their pioneering analysis of equilibria in the theory of non-cooperative games"*.

GAME THEORY

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2005
Robert J. Aumann, Thomas C. Schelling

Share this: 11

Thomas C. Schelling - Facts

Photo: T. Zadig

Thomas C. Schelling

Born: 14 April 1921, Oakland, CA, USA

Died: 13 December 2016, Bethesda, MD, USA

Affiliation at the time of the award: University of Maryland, Department of Economics and School of Public Policy, College Park, MD, USA

Prize motivation: "for having enhanced our understanding of conflict and cooperation through game-theory analysis"

Field: game theory

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2005
Robert J. Aumann, Thomas C. Schelling

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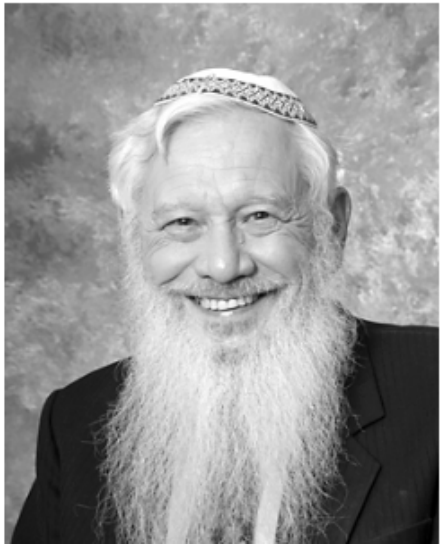
Robert J. Aumann - Facts



Robert J. Aumann

Born: 8 June 1930, Frankfurt-on-the-Main, Germany

Affiliation at the time of the award: University of Jerusalem, Center for RationalityHebrew, Jerusalem, Israel

Prize motivation: "for having enhanced our understanding of conflict and cooperation through game-theory analysis"

Field: game theory

GAME THEORY

Objective

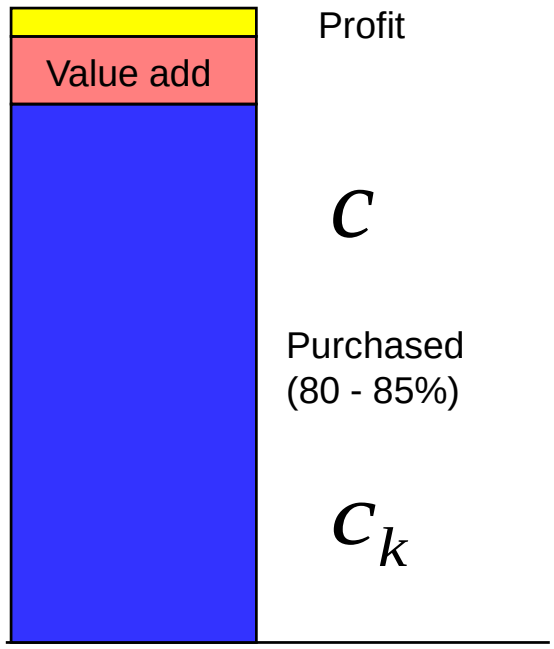
Reduce Information Asymmetry

Achieve credible information sharing

Eliminating sources of inefficiency

Telecom Supply Chain Case

Telecom Supply Chain Case



Depends on the contract

Profit

c

Purchased
(80 - 85%)

c_k

Private forecast info: ξ

FLEXTRONICS

ERICSSON

AT&T

S

M

Operator

r: Price charged
by m to operator

Gartner

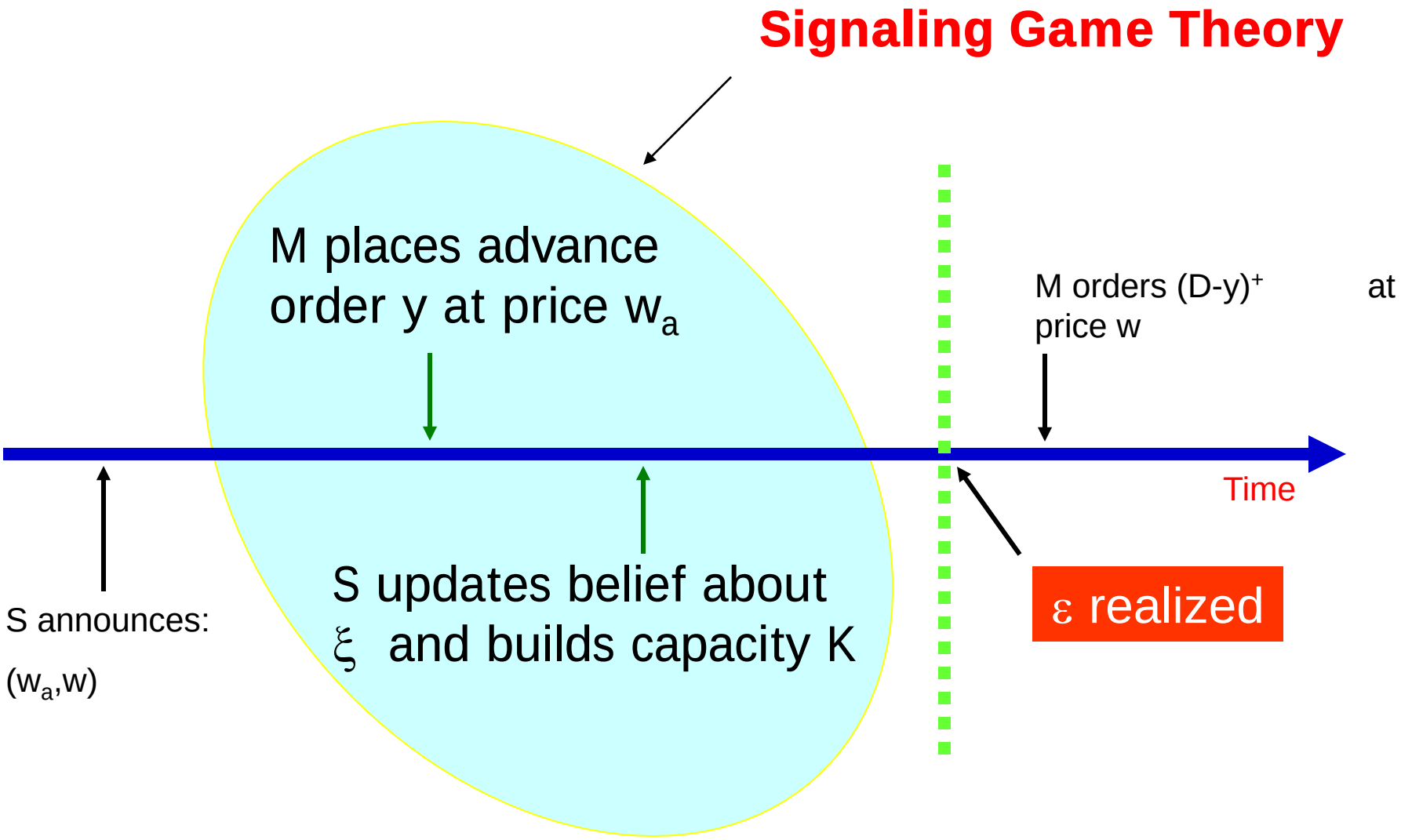
Forecast

$\mu + \varepsilon$

Market uncertainty

Source: Özalp Özer and Wei Wei

Advance Purchase Contract: Sequence of Events



Capacity Planning Problem

- Short product lifecycle (clockspeed)
- Demand is uncertain prior to capacity decision

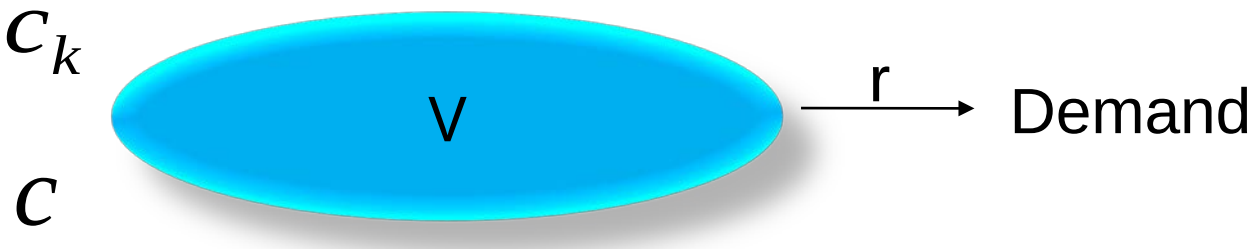
$$D = \mu + \xi + \varepsilon$$

Market uncertainty $\varepsilon \sim G(\cdot)$

Manufacturer's private forecast update

Supplier's prior belief $\xi \in [\underline{\xi}, \overline{\xi}]$ $\xi \sim F(\cdot),$

Centralized System



Optimization Problem

$$\max_{K \geq 0} E\left[(r-c)\min\left(K, \mu + \xi + \underbrace{\varepsilon}_{random} \right) \right] - c_k K$$

Optimal Capacity

$$K^{cs} = G^{-1}\left(\frac{r-c-c_k}{r-c} \right) + \mu + \xi$$

Decentralized System Wholesale Contract with Symmetric Information

- Manufacturer's profit:

$$(r-w)E\left[\min\left(K, \mu+\xi+\underset{random}{\varepsilon}\right)\right]$$

- Supplier's optimization problem:

$$\max_{K\geq 0}(w-c)E\left[\min\left(K, \mu+\xi+\underset{random}{\varepsilon}\right)\right]-c_k K$$

- Optimal capacity: $K^{ws} < K^{cs}$

$$K^{ws}=\mu+\xi+G^{-1}\left(\frac{w-c-c_k}{w-c}\right)$$

Decentralized System Wholesale Contract with Asymmetric Information

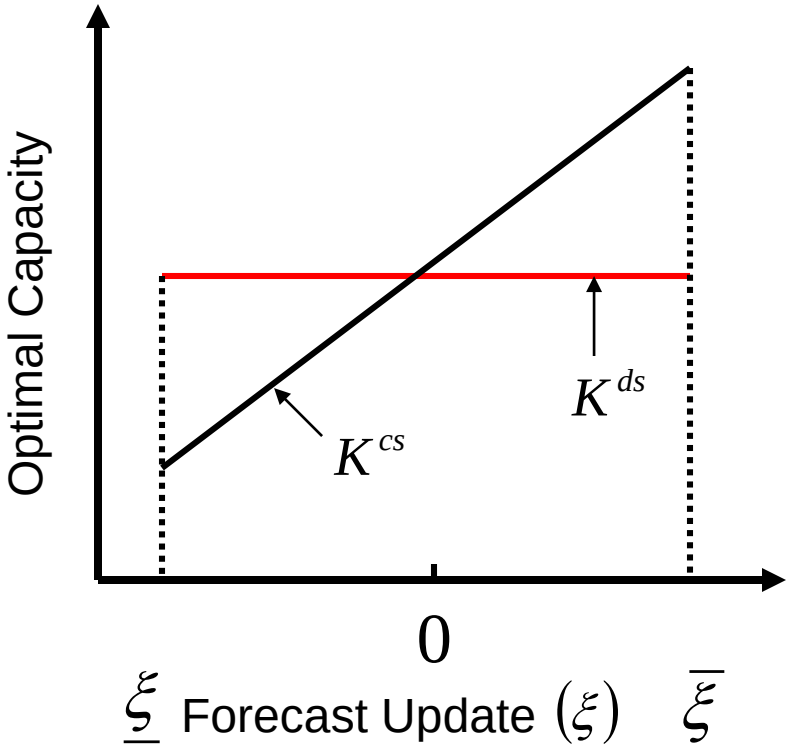
- Supplier's Optimization Problem:

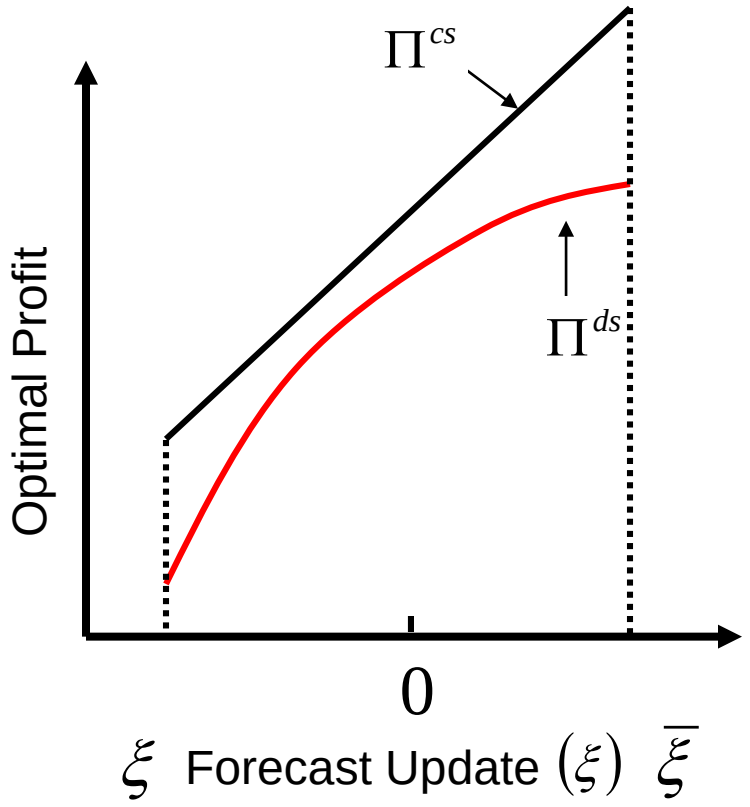
$$\max_{K\geq 0} E\left[(w-c)\min\left(K, \mu + \underbrace{\xi + \varepsilon}_{random}\right)\right] - c_k K$$

- Optimal Capacity (in reality):

$$K^{ds} = (F \circ G)^{-1}\left(\frac{w-c-c_k}{w-c}\right) + \mu$$

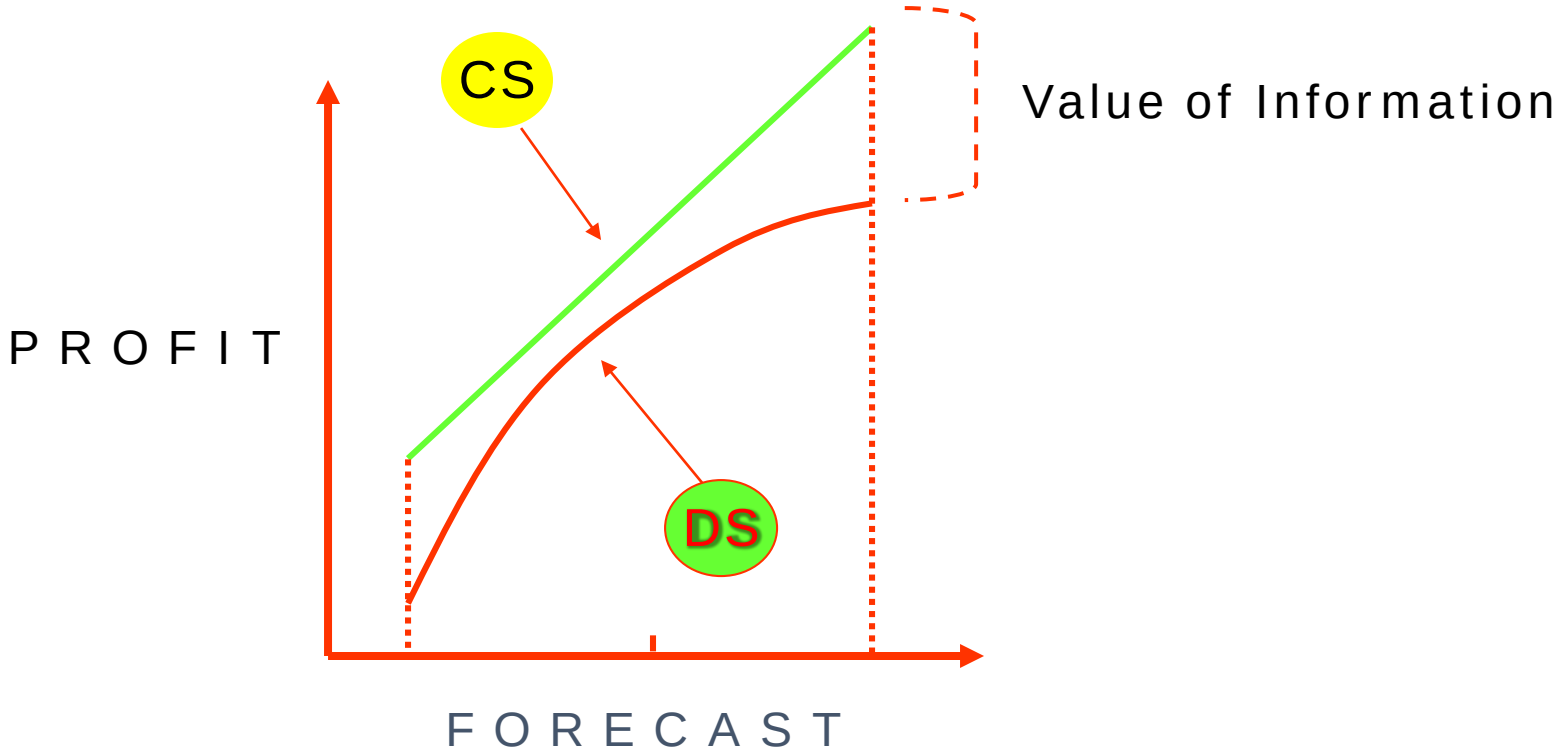
Wholesale Price Contract





Dr Shoumen Datta, MIT
<shoumen@mit.edu>

Value of Information



INFORMATION

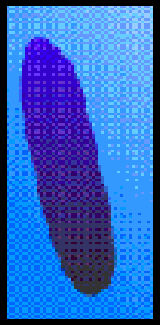
ACQUISITION
TRANSACTION COST

INFORMATION

DATA

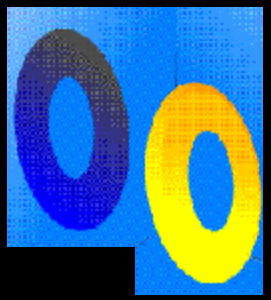
What is this ?

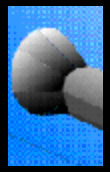
What is this ?



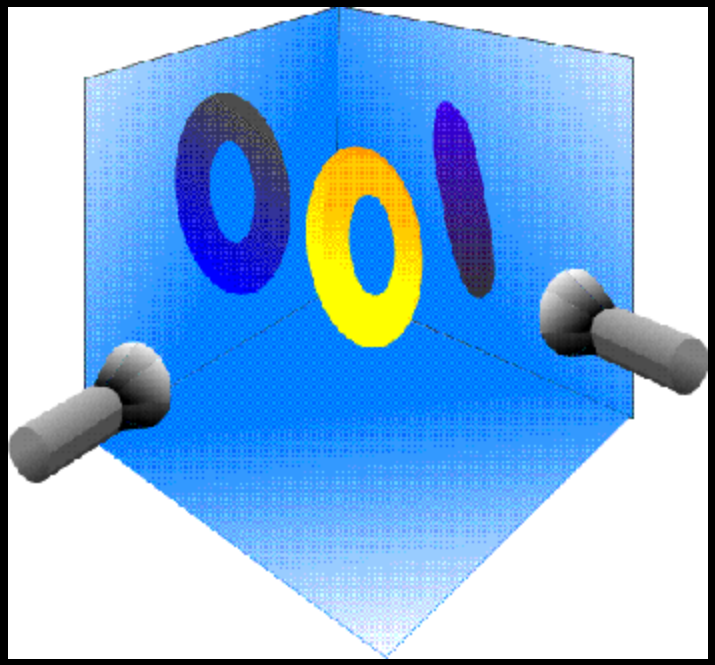
What is this ?

What is this ?



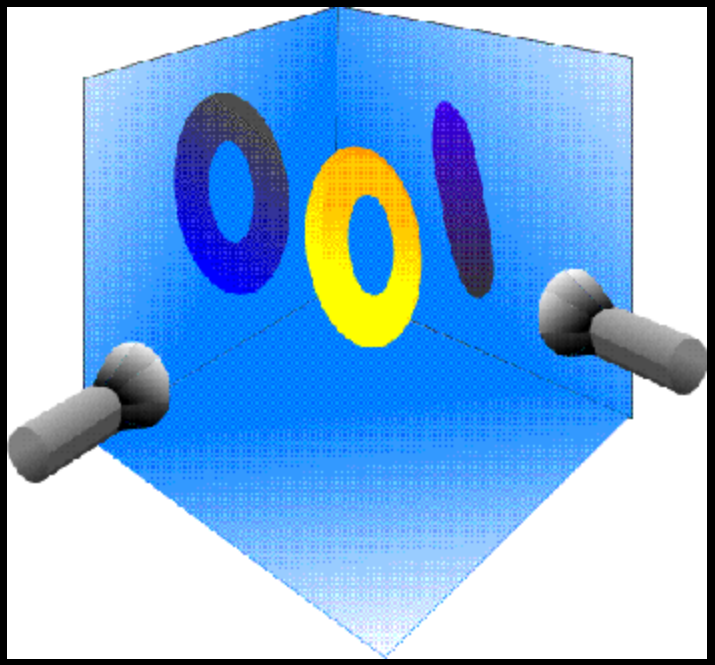


What is this ?



http://obelia.jde.aca.mmu.ac.uk/multivar/pca_graf.htm

Principal Component Analysis

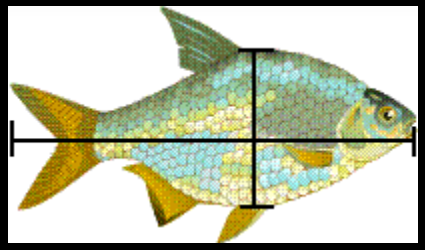


Doughnut never changed shape but dependent projections are different.

What is this ?

Eagle (3D) projected on 2D can be recognized as an eagle because the image retains enough information.

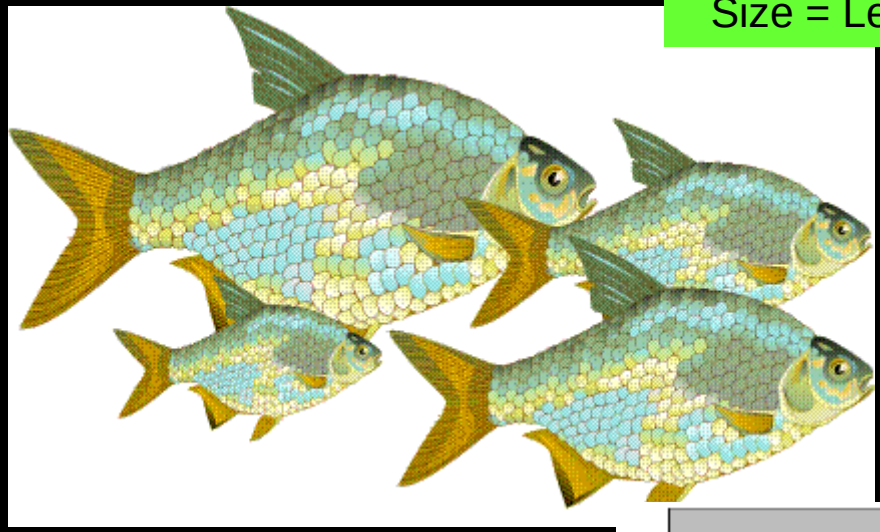
Data v Information: Systems Introduce Artifacts & Inaccuracies

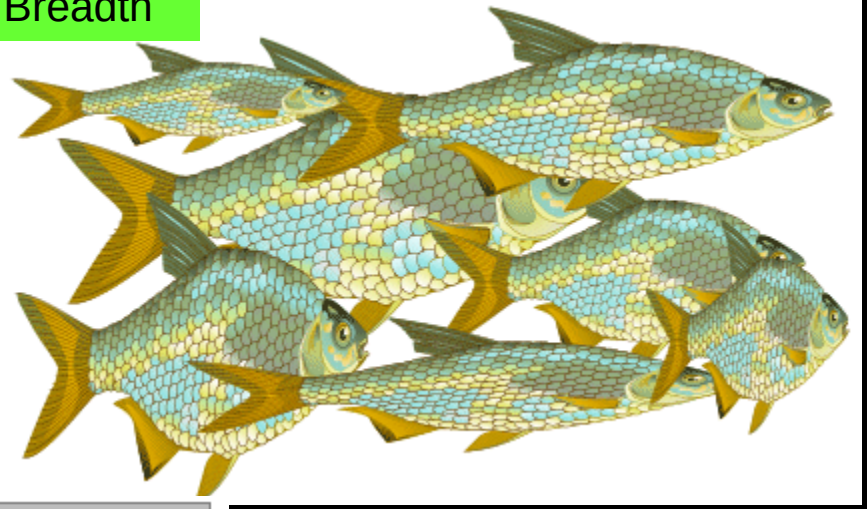


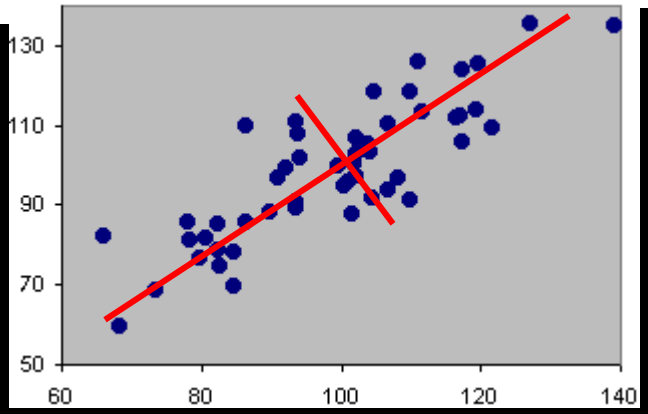
Retain 87.5% of the information

Retain 62.5% of the information

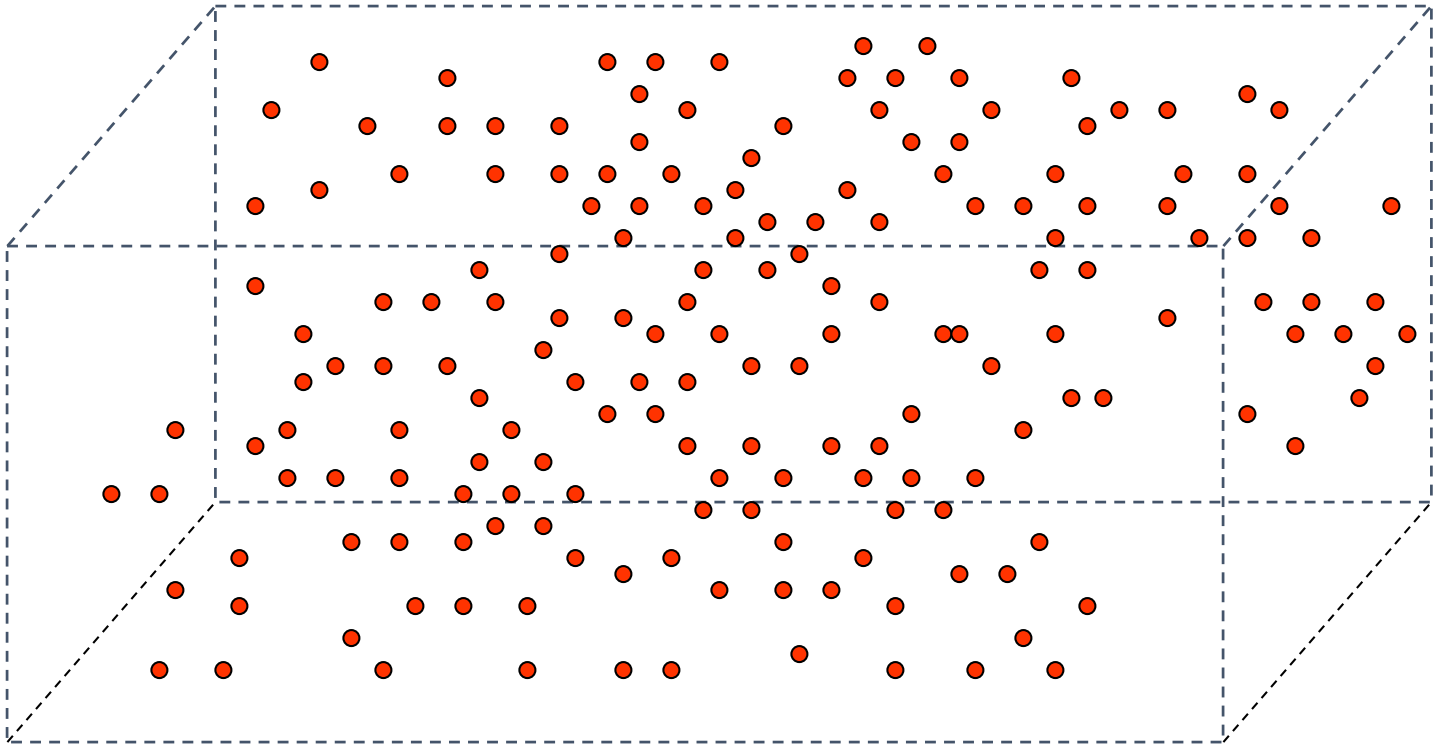
Size = Length + Breadth







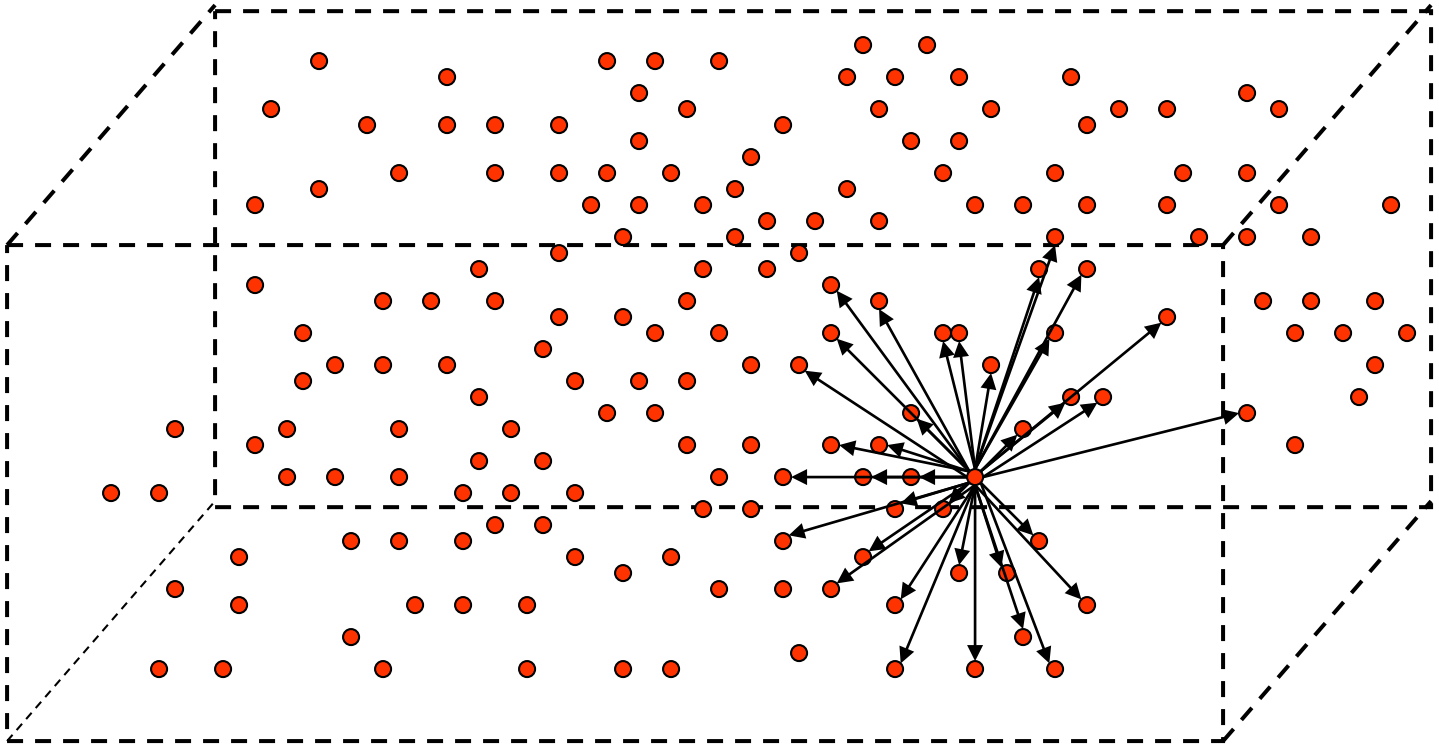
Clustering – Classification by Reduction



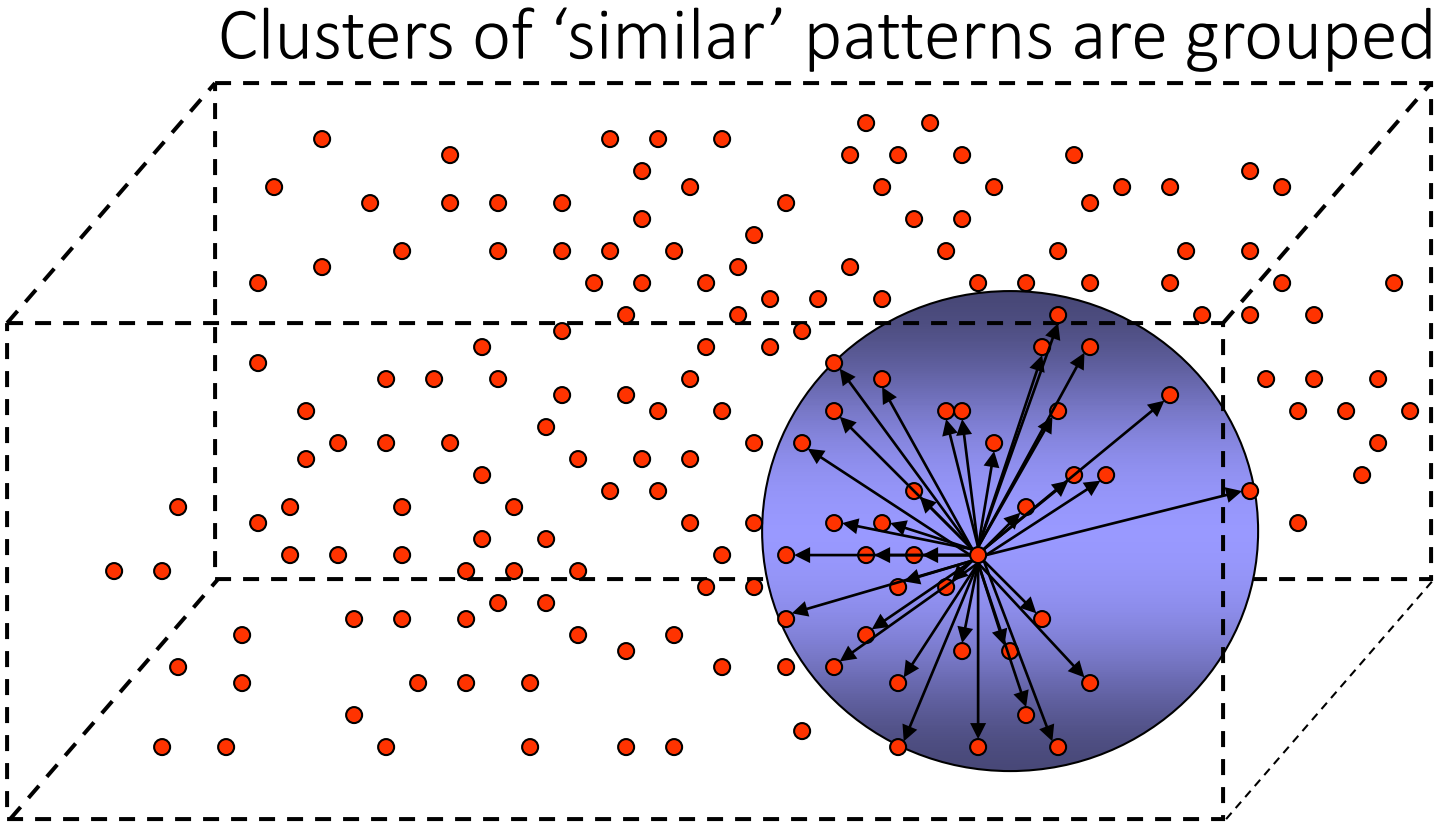
Patterns plotted in ‘n’ dimensional space.
Each point (pattern) represent multiple
(n) pieces of information (dimensions).

Clusters

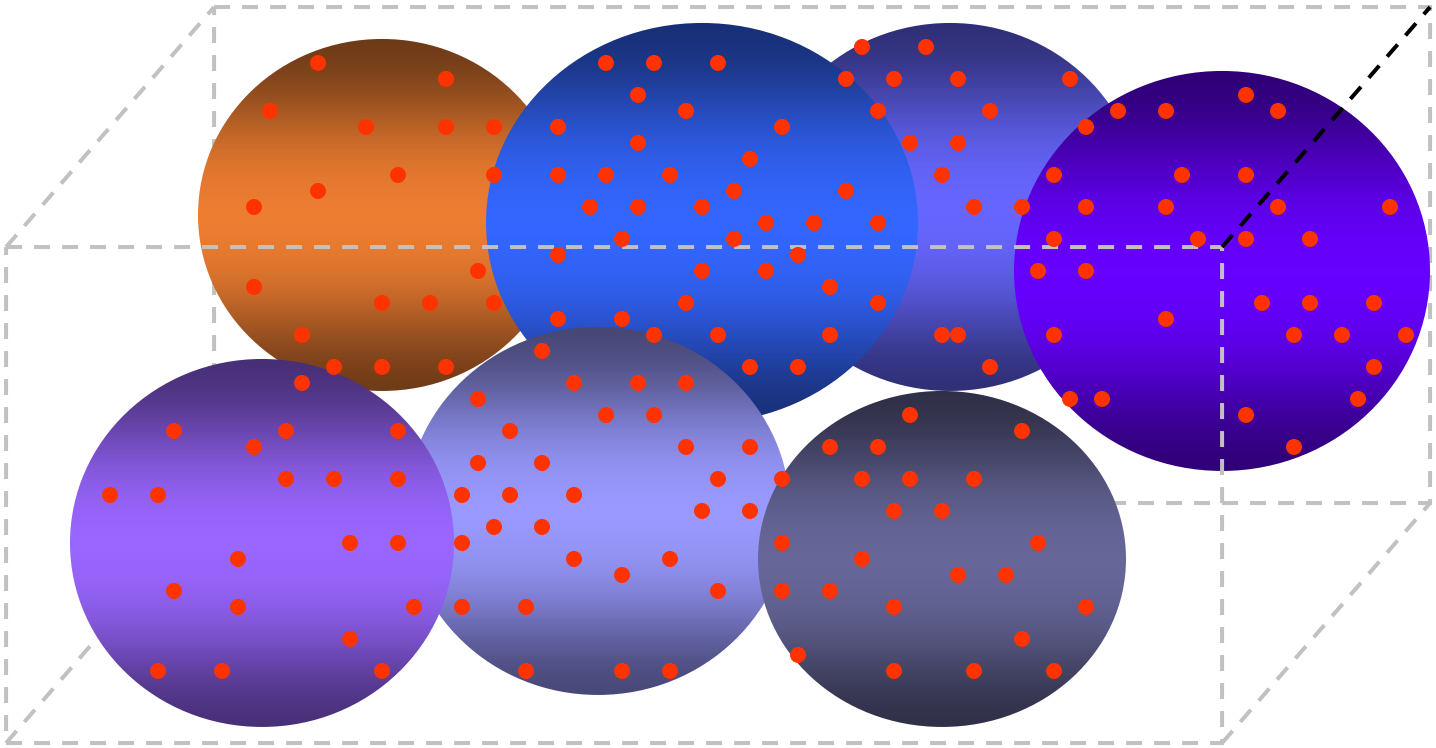
Distances are calculated to determine similarity.



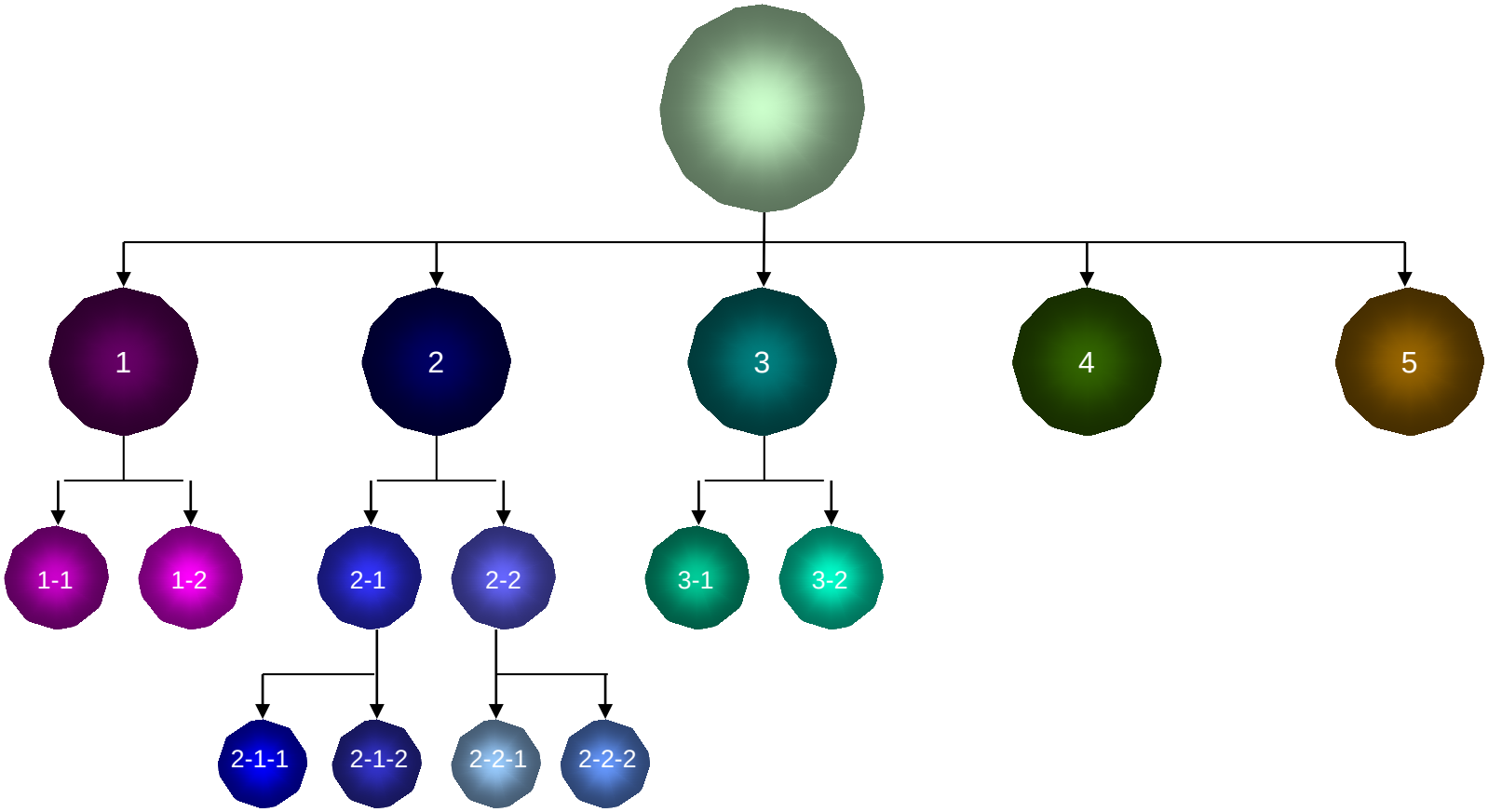
Clustering



Patterns contained within family of clusters



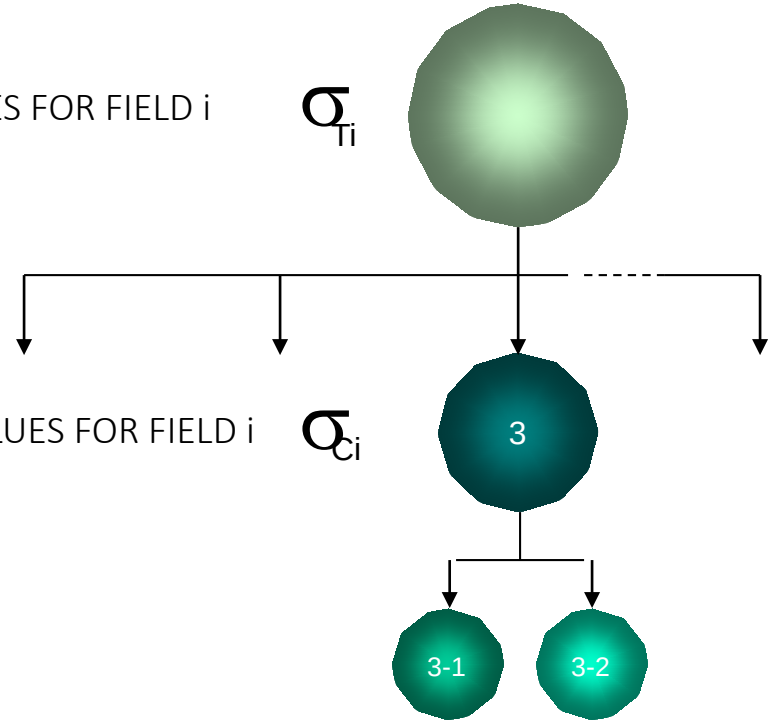
Hierarchical Clustering - Granularity of Clustering



Characterizing Clusters

TOTAL POPULATION OF VALUES FOR FIELD i σ_{Ti}

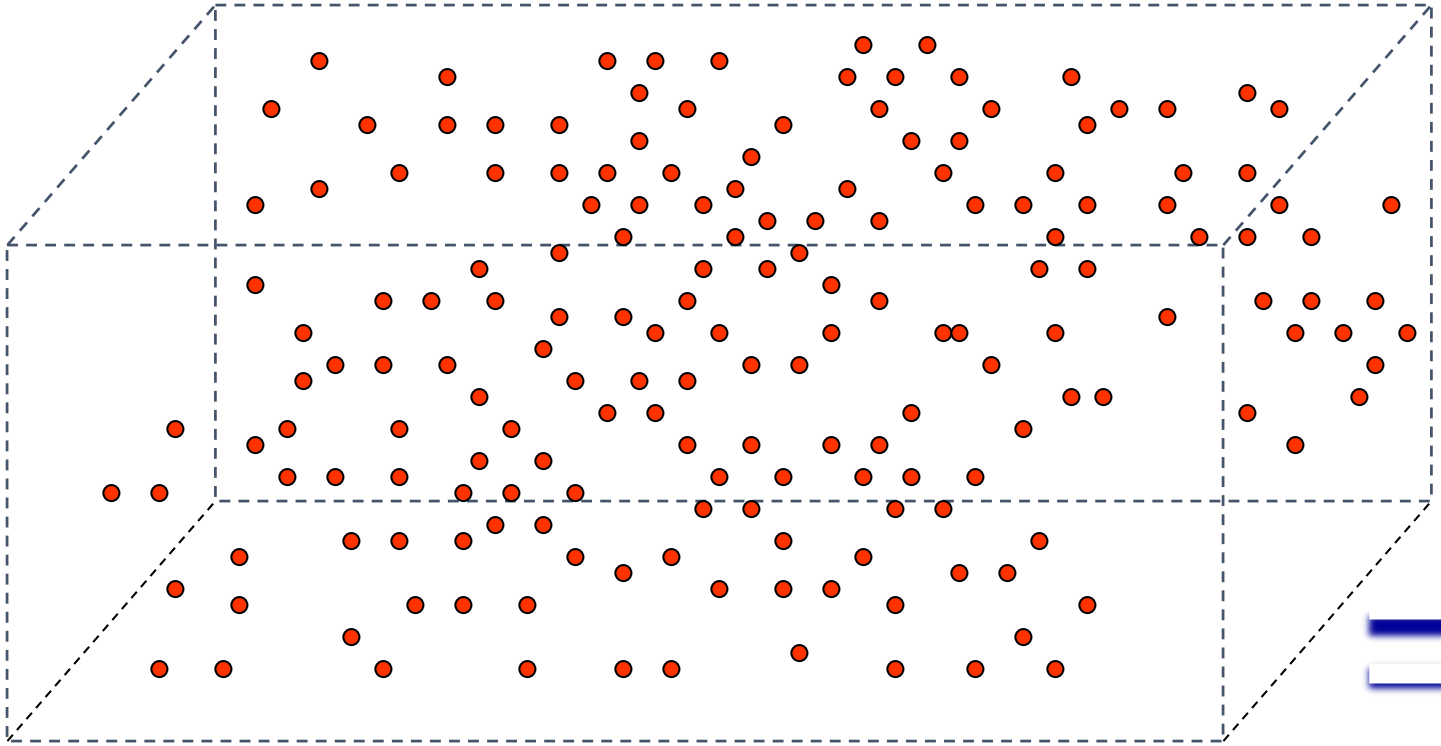
CLUSTER POPULATION OF VALUES FOR FIELD i σ_{Ci}



Standard Deviation Ratio: Identifies how much a field in a particular cluster varies in comparison to all clusters. The standard deviation ratio for field i is calculated by dividing σ_{Ci} by σ_{Ti}

If the standard deviation ratio for a field is small, the field may partly characterize this cluster.

Reductionist Approach – What you did to data



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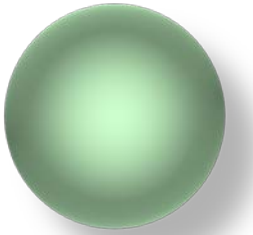
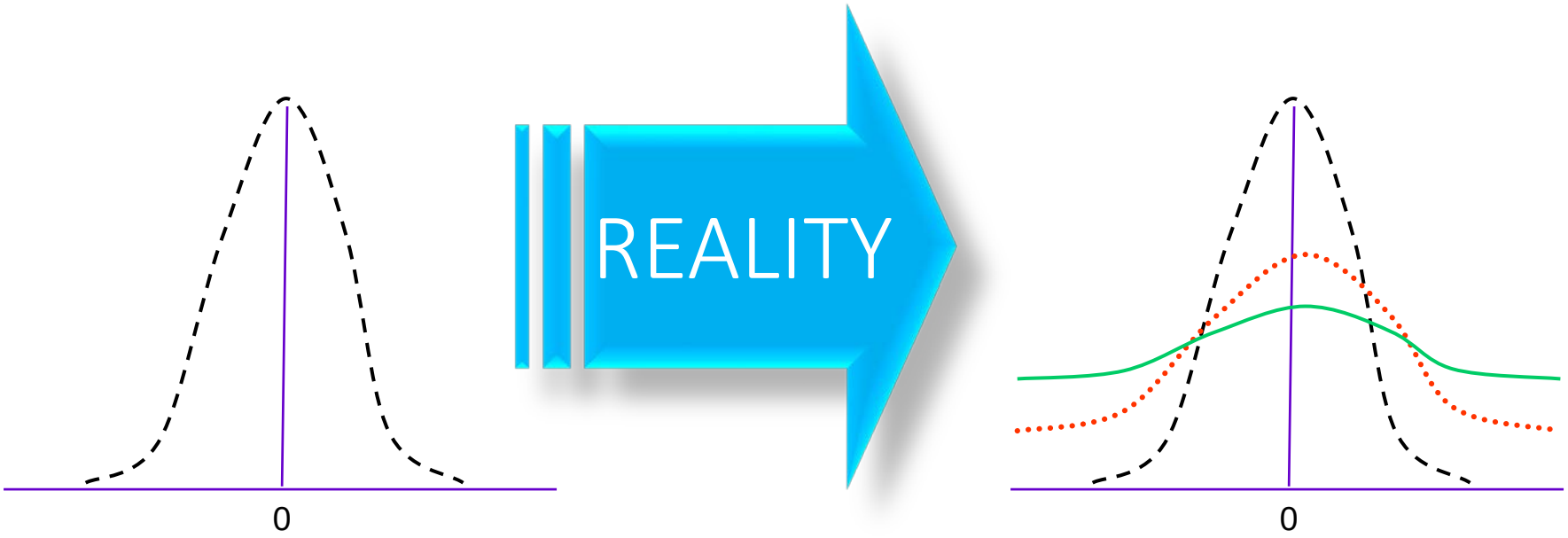


TOTAL POPULATION
OF VALUES FOR FIELD i


REALITY
0
0

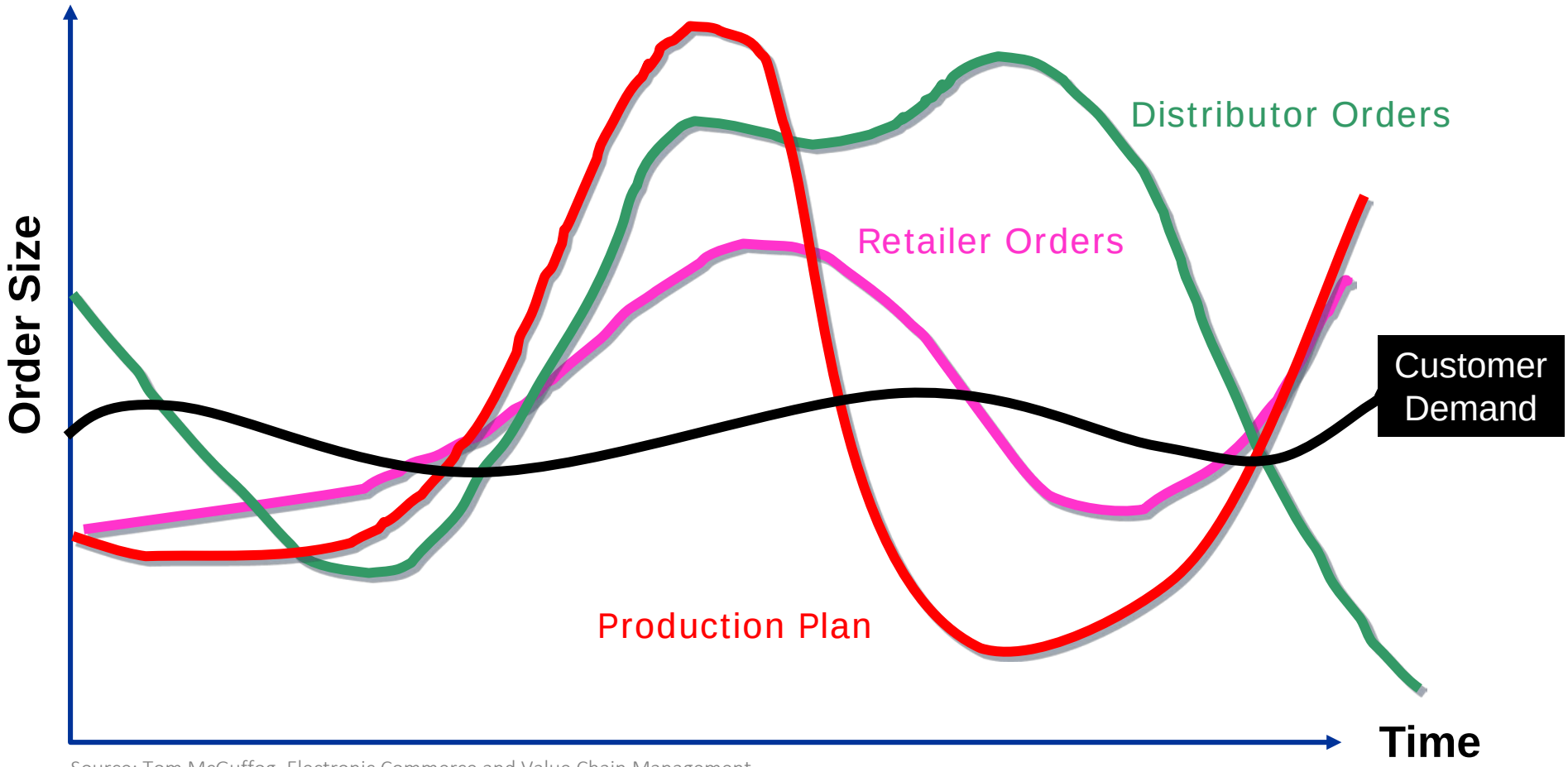
Information Inequality (Arrow) Information Asymmetry

The Forrester Effect

Nobel Prize in Economics 1972 ● Kenneth Arrow, John Hicks
Nobel Prize in Economics 2001 ● Stiglitz, Spence & Ackerloff

The Bullwhip Effect

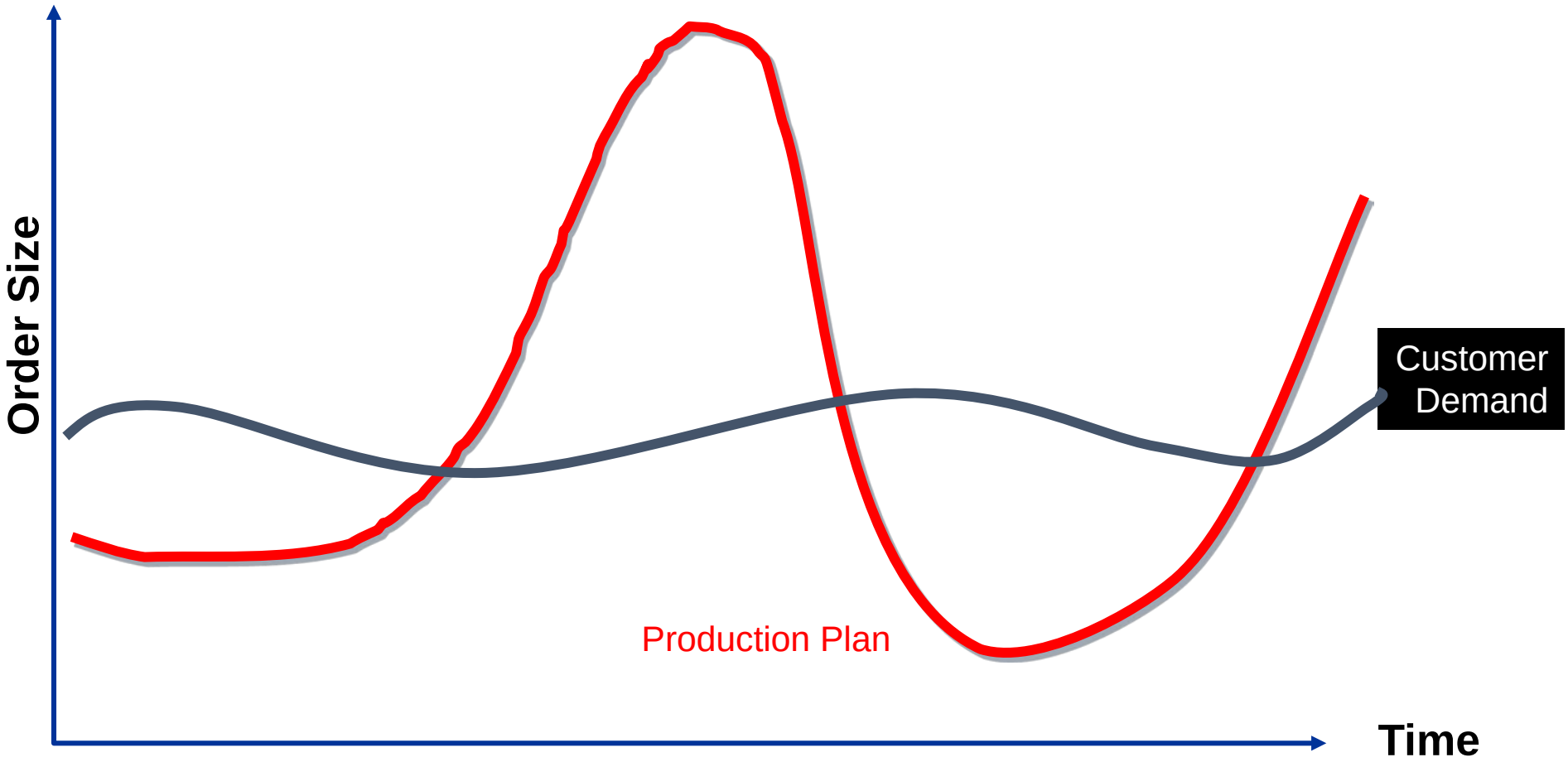
Information Asymmetry between Demand and Supply



Source: Tom McGuffog, Electronic Commerce and Value Chain Management

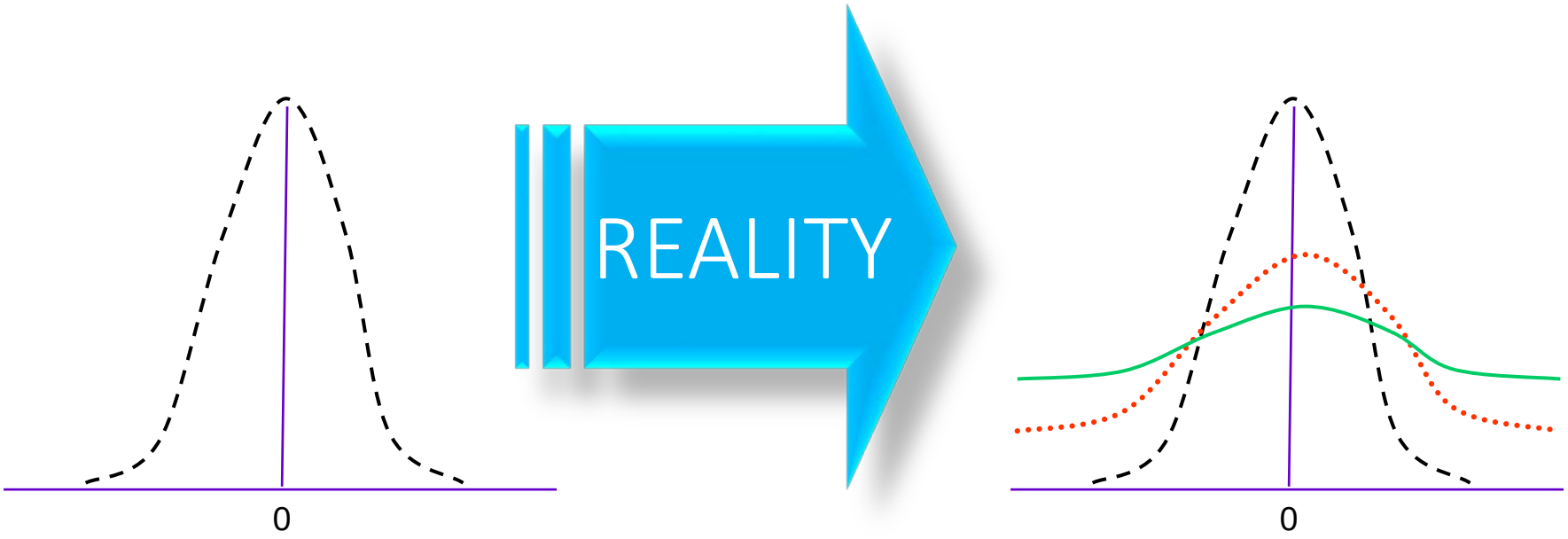
Uncertainty

Nobel Prize in Economics 2002 ●Daniel Kahneman & Vernon Smith



Cannot Ignore Errors

Nobel Prize in Economics 2003 ● Clive Granger and Robert Engle



About High Volume Big Data before "Big Data" → Datta & Granger (2003 – 2005)

$$y_t = \beta_0 + \sum_{j=1}^{N_y} \varphi_j y_{t-j} + \sum_{k=1}^{K} \sum_{i=1}^{N_{x_{kt}}} \alpha_{ki} x_{kt-i} + \varepsilon_t$$

$$\sigma_t^2 = \theta_0 + \theta_1 \varepsilon^2_{t-1} + \theta_2 \varepsilon^2_{t-2} + \ldots + \theta_q \varepsilon^2_{t-q}$$

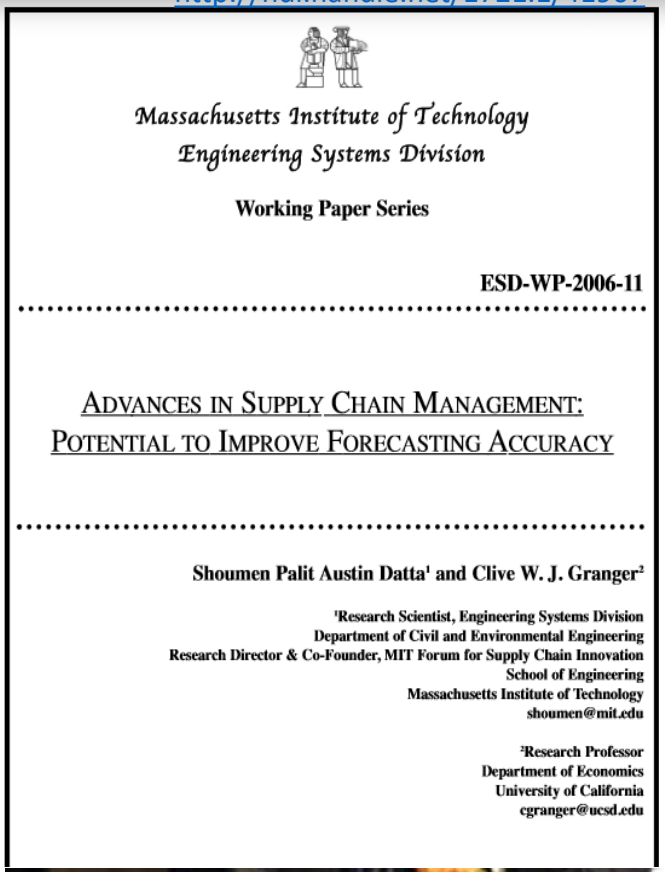
Variance of the random error term DEPENDS NOT ONLY on previous lagged errors (t-1, t-2, …., t-q) but also on LAGGED VALES OF THE VARIANCE (t-1, t-2, …, t-p)

$$y_t = \beta_0 + \sum_{j=1}^{N_y} \varphi_j y_{t-j} + \sum_{k=1}^{K} \sum_{i=1}^{N_{x_{kt}}} \alpha_{ki} x_{kt-i} + \varepsilon_t$$

$$\sigma_t^2 = \theta_0 + \sum_{i=1}^{q} \theta_i \varepsilon^2_{t-i} + \sum_{j=1}^{p} \tau_j \sigma^2_{t-j}$$

Generalized Auto Regressive Conditional Heteroskedasticity

http://hdl.handle.net/1721.1/41907



Massachusetts Institute of Technology
Engineering Systems Division

Working Paper Series

ESD-WP-2006-11

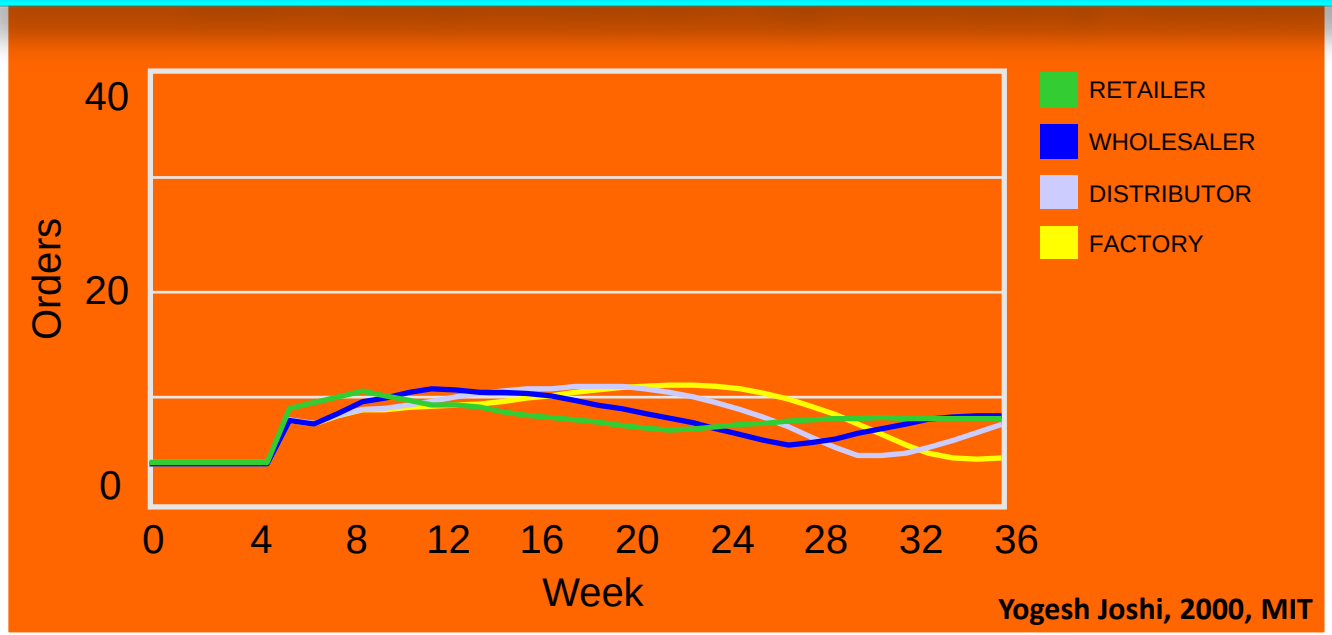
ADVANCES IN SUPPLY CHAIN MANAGEMENT:
POTENTIAL TO IMPROVE FORECASTING ACCURACY

Shoumen Palit Austin Datta[1] and Clive W. J. Granger[2]

[1]Research Scientist, Engineering Systems Division
Department of Civil and Environmental Engineering
Research Director & Co-Founder, MIT Forum for Supply Chain Innovation
School of Engineering
Massachusetts Institute of Technology
shoumen@mit.edu

[2]Research Professor
Department of Economics
University of California
cgranger@ucsd.edu

Can real-time data reduce transaction costs? Can information symmetry reduce volatility?



Transaction Cost Economics

- Nobel Prize in Economics 1991 - Ronald Coase
- Nobel Prize in Economics 2009 - Oliver Williamson

Macroeconomics in Business Cycles

- Nobel Prize in Economics 2004 - Finn Kydland & Edward Prescott

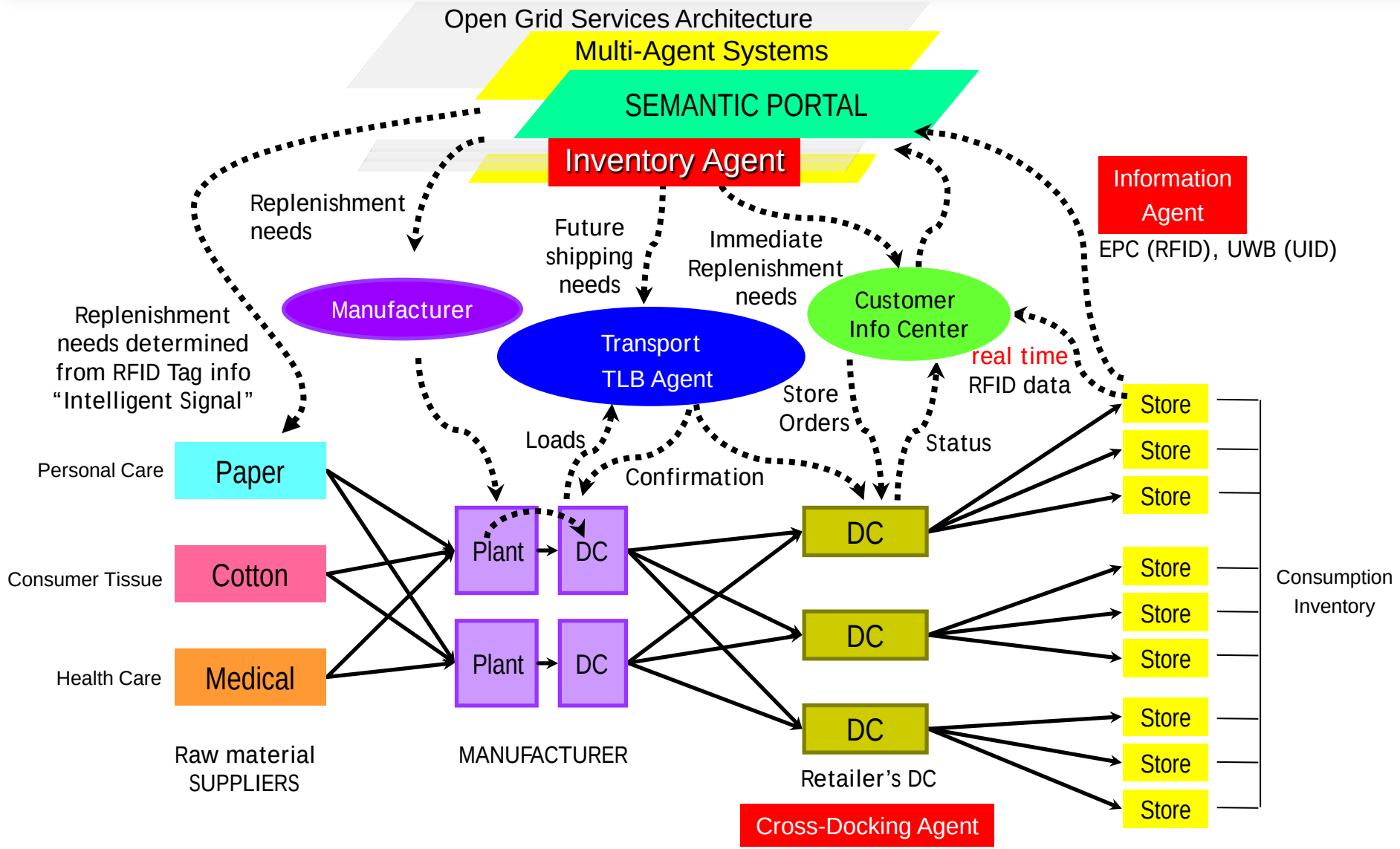
Game Theory Strategies in Cooperation

- Nobel Prize in Economics 2005 - Robert Aumann & Thomas Schelling

Contract Theory

- Nobel Prize in Economic 2016 – Bengt Holmstrom and Oliver Hart

Real-time data, transparency and transaction costs
Network information asymmetry induces volatility



Markets are about Outcomes

If business is synonymous with profitability, it follows that success in the context of business outcomes, usually, are driven by the ability to profit.

What drives profitability?

Transaction cost

Outcomes which cannot deliver a higher margin of profit by increasing the transaction cost differential are not serving business and industry.

FIVE FOUNDATIONAL STEPS for ENTERPRISE EVOLUTION

Markets want outcomes and solutions, not numbers

PLATFORM CONVERGENCE

Platform and interoperability reduces transaction cost

Leading causes of death in the USA

1. 597,689 Heart Disease
2. 574,743 Cancer
3. 138,080 Chronic lower respiratory diseases
4. 129,476 Stroke
5. 120,859 Accidents
6. 83,494 Alzheimer's disease
7. 69,071 Diabetes
8. 56,979 Influenza &Pneumonia
9. 47,112 Kidney diseases
10. 41,149 Suicide

www.cdc.gov/nchs/fastats/deaths.htm

● 2010 ● OIG HHS bad hospital care deaths about 180,000 patients in Medicare alone in a year

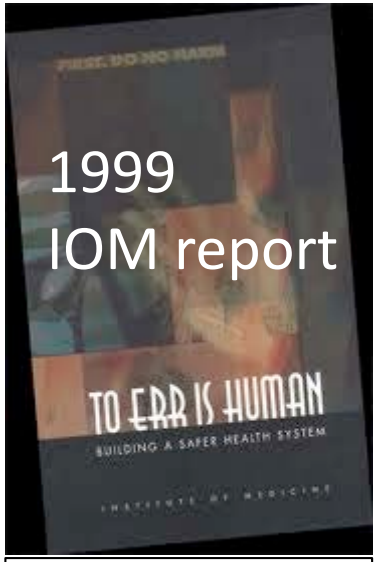
Patient Safety 2013
Exploring Quality of Care in the U.S.

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

A New, Evidence-based Estimate of Patient Harms Associated with Hospital Care

John T. James, PhD

Dr Julian Goldman



98,000
deaths due to error

210,000 – 440,000 deaths

400,000 deaths due to medical mistakes – shared with the US Senate

Deaths by medical mistakes hit records

Tejal Gandhi, MD, president of the National Patient Safety Foundation and associate professor of medicine, Harvard Medical School, spoke at the hearing.

The way IT is designed remains part of the problem

WASHINGTON | July 18, 2014

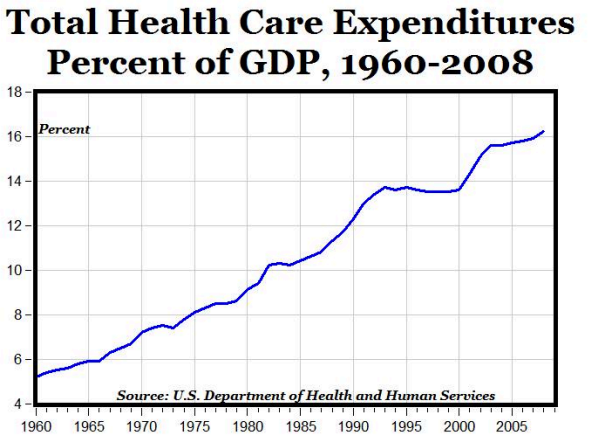
It's a chilling reality – one often overlooked in annual mortality statistics: Preventable medical errors persist as the No. 3 killer in the U.S. – third only to heart disease and cancer – claiming the lives of some 400,000 people each year. At a Senate hearing Thursday, patient safety officials put their best ideas forward on how to solve the crisis, with IT often at the center of discussions.

Hearing members, who spoke before the Subcommittee on Primary Health and Aging, not only underscored the devastating loss of human life – more than 1,000 people each day – but also called attention to the fact that these medical errors cost the nation a colossal $1 trillion each year.

"The tragedy that we're talking about here (is) deaths taking place that should not be taking place," said subcommittee Chair Sen. Bernie Sanders, I-Vt., in his opening remarks.

Third Leading cause of death in the USA ?

1. 597,689 Heart Disease
2. 574,743 Cancer
3. ***Deaths Due to Medical Errors (180,000 - 210,000 - 440,000)***
4. 138,080 Chronic lower respiratory diseases
5. 129,476 Stroke
6. 120,859 Accidents
7. 83,494 Alzheimer's disease
8. 69,071 Diabetes
9. 56,979 Influenza &Pneumonia
10. 47,112 Kidney diseases
11. 41,149 Suicide



Equivalent to at least one 747 airplane crash every day

Nurses blame interoperability woes for medical errors

$30B could be saved each year from better device coordination

March 16, 2015

Each year, a staggering 400,000 people are estimated to have died due to medical errors. What's more, each day there's also 10,000 serious complications resulting from medical mistakes. Part of the blame, nurses are saying, can be attributed to the lack of interoperability among medical devices.

MD PnP™

Getting Connected for Patient Safety™

Change Expectations > Change Technology > Change Healthcare

The Medical Device "Plug-and-Play" (MD PnP) Interoperability Program is promoting innovation in patient safety and clinical care by leading the adoption of patient-centric integration of medical devices and IT systems in clinical environments.

www.mdpnp.org

HOME | ABOUT PROGRAM | PROJECTS | NEWS | EVENTS | PUBLICATIONS & TALKS | OUR LAB | Sitemap

Medical Device "Plug-and-Play" Interoperability Program working on "safe interoperability™" to improve patient safety

MD PnP MedTech Hackathon Open Medical Device and Data Integration Platforms to Support the Management of Ebola

Post-Surgical Morphine Infusion System – Unintegrated Devices

Infusion Pump

Capnometer

PATIENT
Simulator
Ventilator

Intelligent Monitor

Vital Signs Monitor

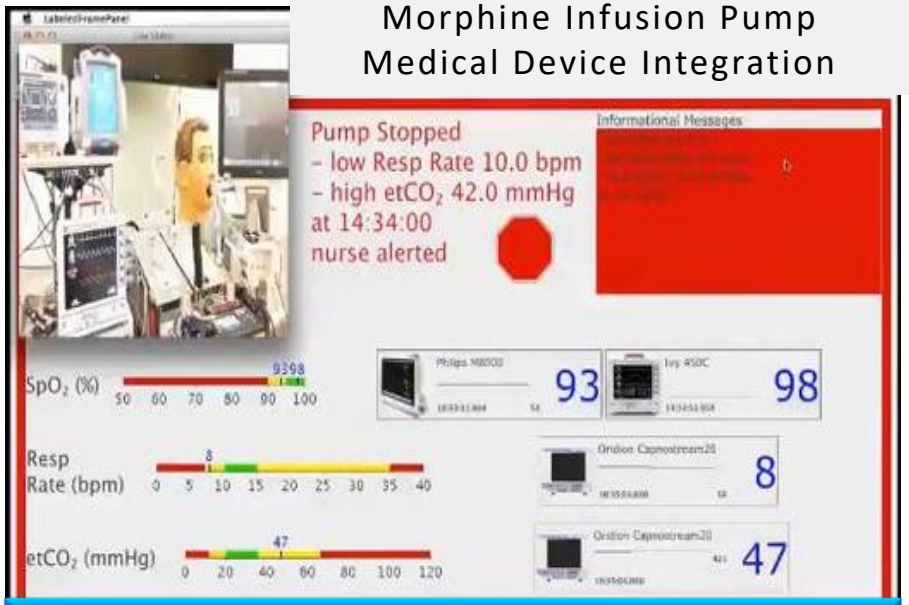
Simulator connected to vital signs monitor

Fluke ProSim 8 connected to intelligent monitor

- O_2 Saturation
- Respiratory Rate
- end-tidal CO_2

Connected Data
Collective Analysis
Automated Response

Morphine Infusion Pump
Medical Device Integration



Patient Controlled Analgesia Safety Application

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

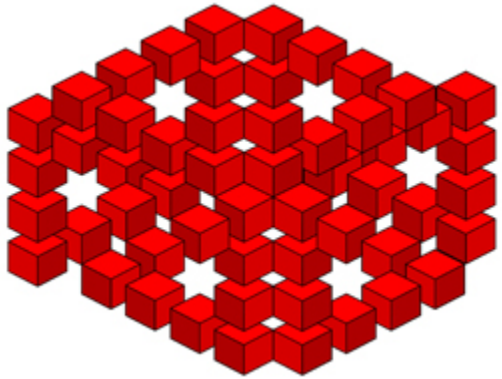
Sensor-less Vital Signs?

http://bit.ly/DK-RF

https://people.csail.mit.edu/fadel/papers/wivi-paper.pdf

http://bit.ly/IOT-MIT

See PDF marked "**HEALTHCARE**"



Dr Shoumen Palit Austin Datta

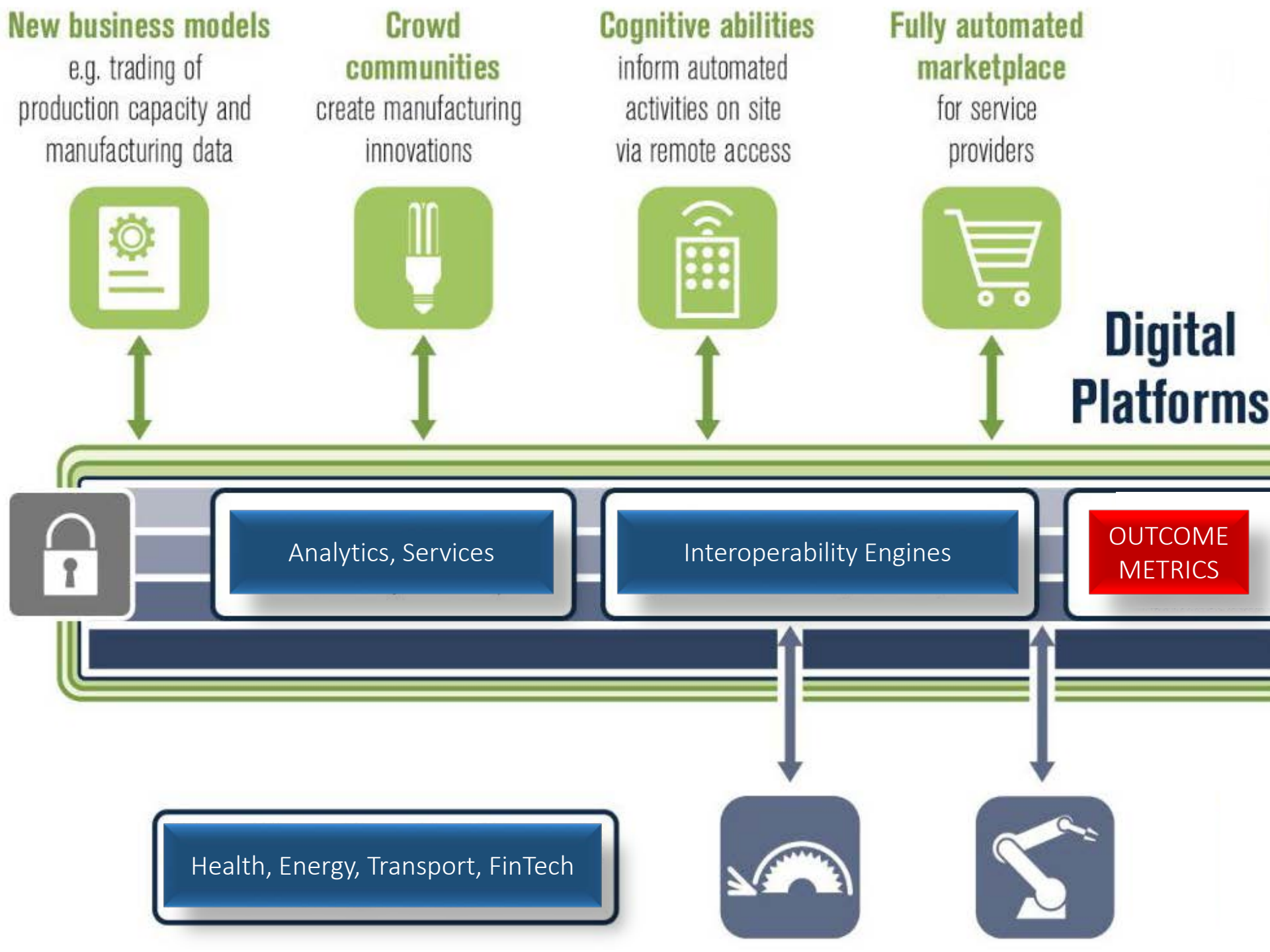
MIT Auto-ID Labs and Research Affiliate, Department of Mechanical Engineering, Massachusetts Institute of Technology ● shoumen@mit.edu

Senior Scientist, MD PnP Lab, Medical Device Interoperability, Massachusetts General Hospital, Harvard Medical School ● www.mdpnp.org

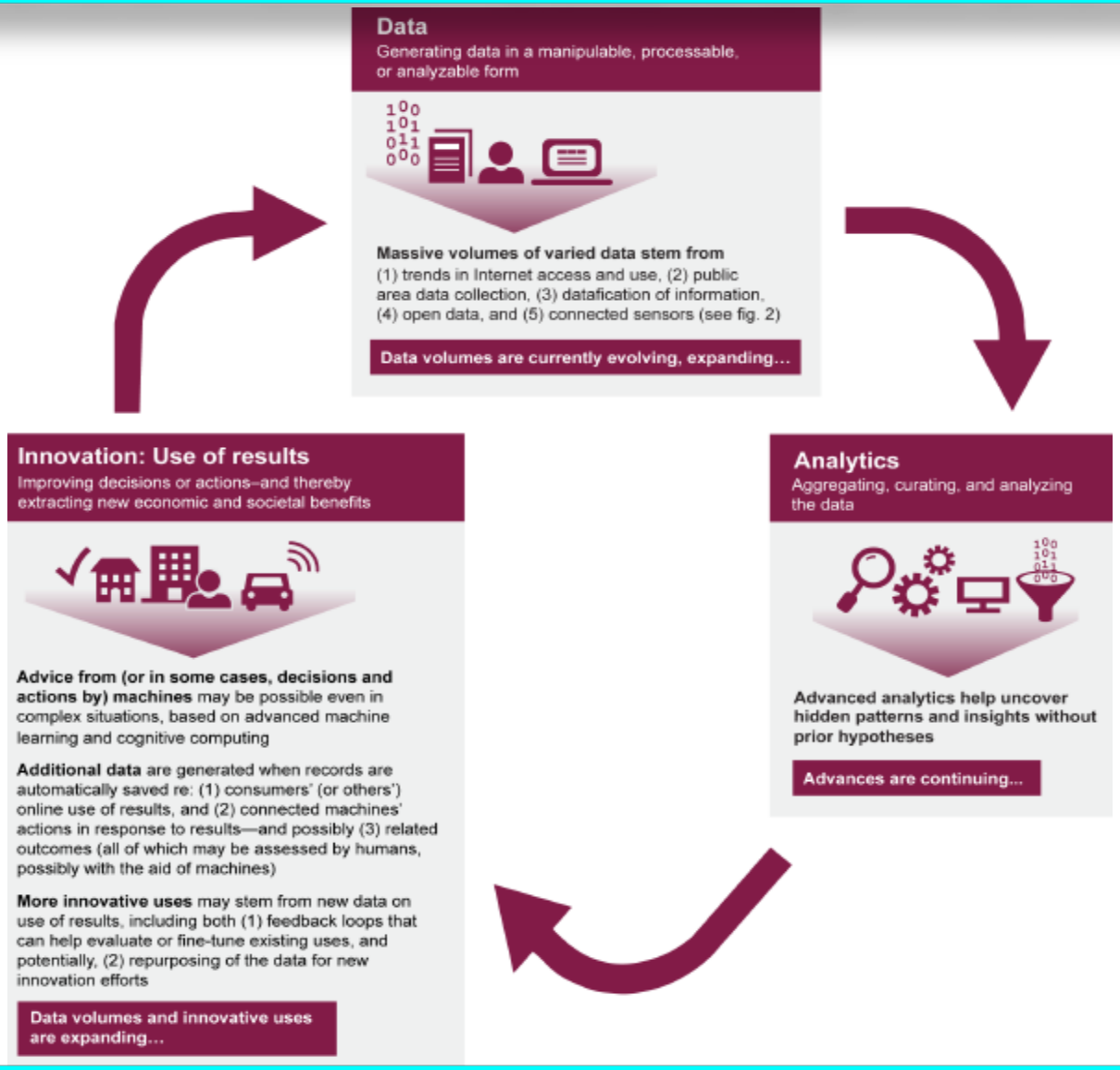
Markets want outcomes and solutions, not numbers

CONVERGENCE ON A PLATFORM

Platform interoperability - reduces death due to errors


New business models
e.g. trading of production capacity and manufacturing data
Crowd communities
create manufacturing innovations
Cognitive abilities
inform automated activities on site via remote access
Fully automated marketplace
for service providers
Digital Platforms
Analytics, Services
Interoperability Engines
OUTCOME METRICS
Health, Energy, Transport, FinTech

Digital Transformation – Data, Analytics and Innovation



Data, Analytics, Innovation - Reduce Transaction Cost?

Published October 1, 2000. Distribution restricted to Sponsors until January 1, 2001.

WHITE PAPER

The Networked Physical World

Proposals for Engineering the Next Generation of Computing, Commerce & Automatic-Identification

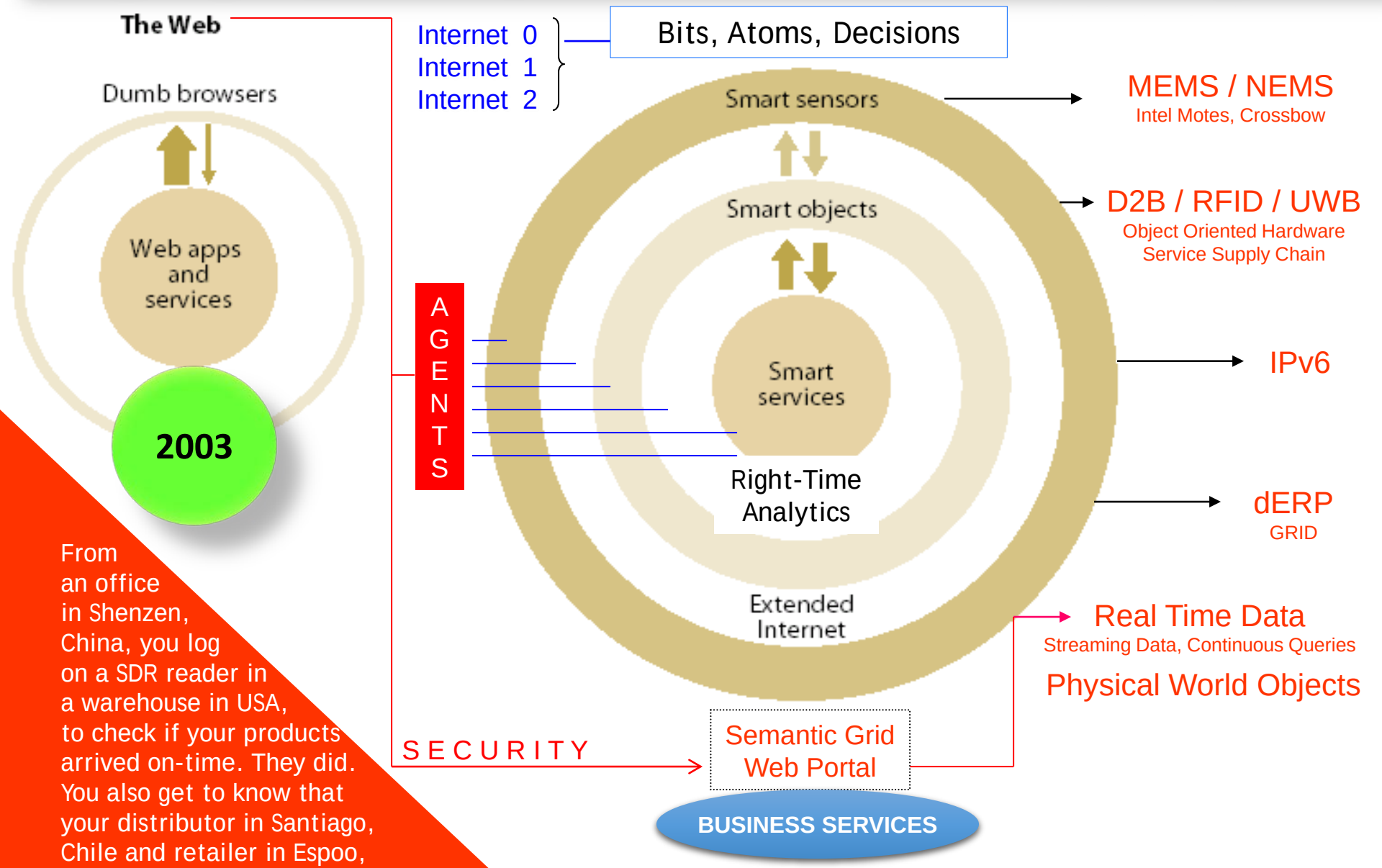
Sanjay Sarma, David L. Brock & Kevin Ashton

MIT AUTO-ID CENTER MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 77 MASSACHUSETTS AVENUE, BUILDING 3-449G, CAMBRIDGE, MA 02139-4307

ABSTRACT

The Auto-ID Center at the Massachusetts Institute of Technology is a new industry sponsored lab charged with researching and developing automated identification technologies and applications. The Center is creating the infrastructure, recommending the standards, and identifying the automated identification applications for a networked physical world. All technologies and intellectual property developed at the Auto-ID Center are freely distributed. This white paper outlines the Auto-ID Center's key conclusions and research progress after its first year of research.

Integrating Ubiquitous Analytics in Real-Time with Data, Information, Application



From an office in Shenzen, China, you log on a SDR reader in a warehouse in USA, to check if your products arrived on-time. They did. You also get to know that your distributor in Santiago, Chile and retailer in Espoo, Finland also checked the delivery status, moments before you logged on.

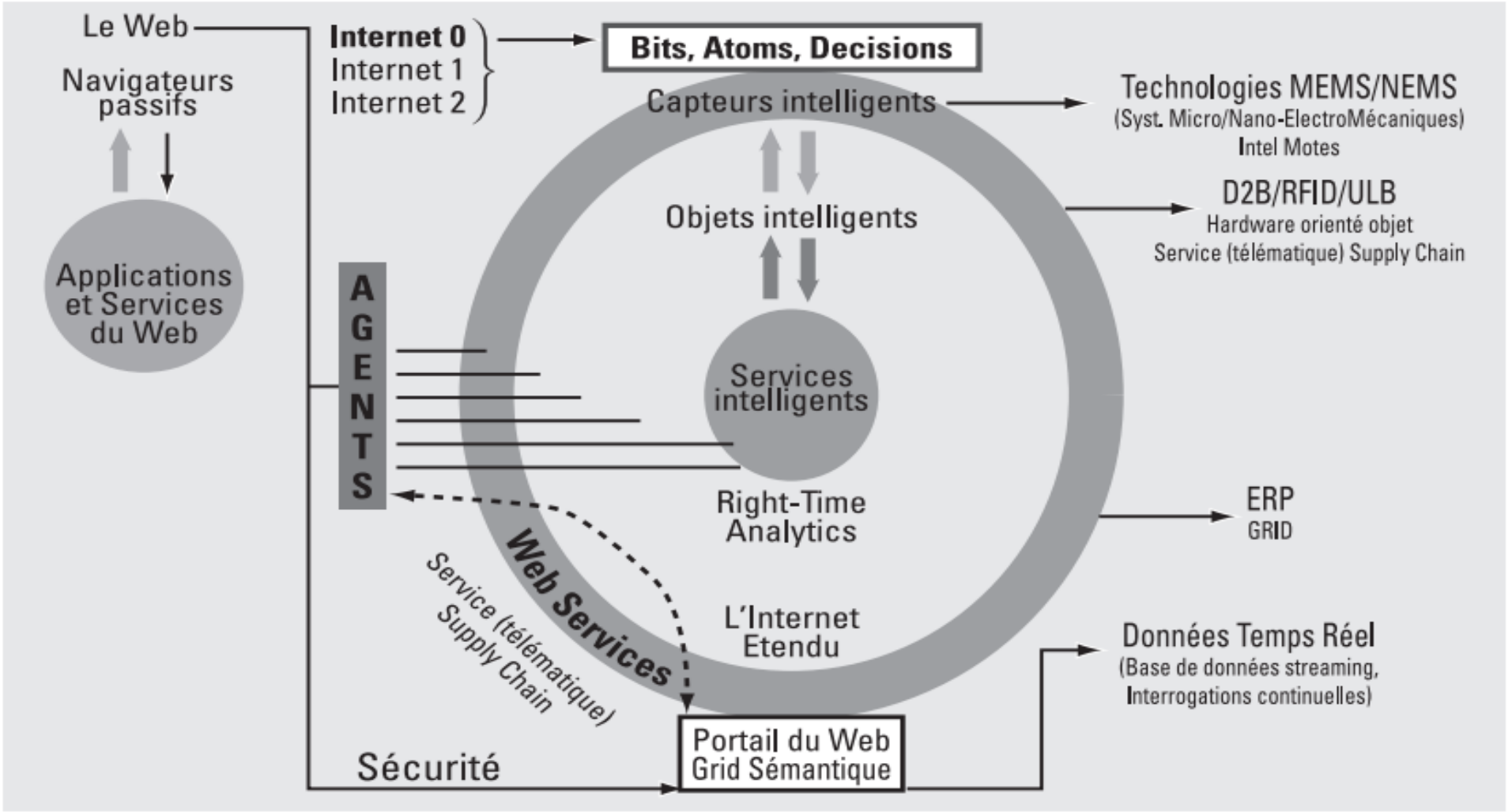
SDR Data Interrogators as Ubiquitous Internet Appliances in IoT (2003)

2004

ADAPTER, OPTIMISER, PRÉVOIR
La convergence des concepts, des outils, des technologies et des normes peut-elle accélérer l'innovation ?

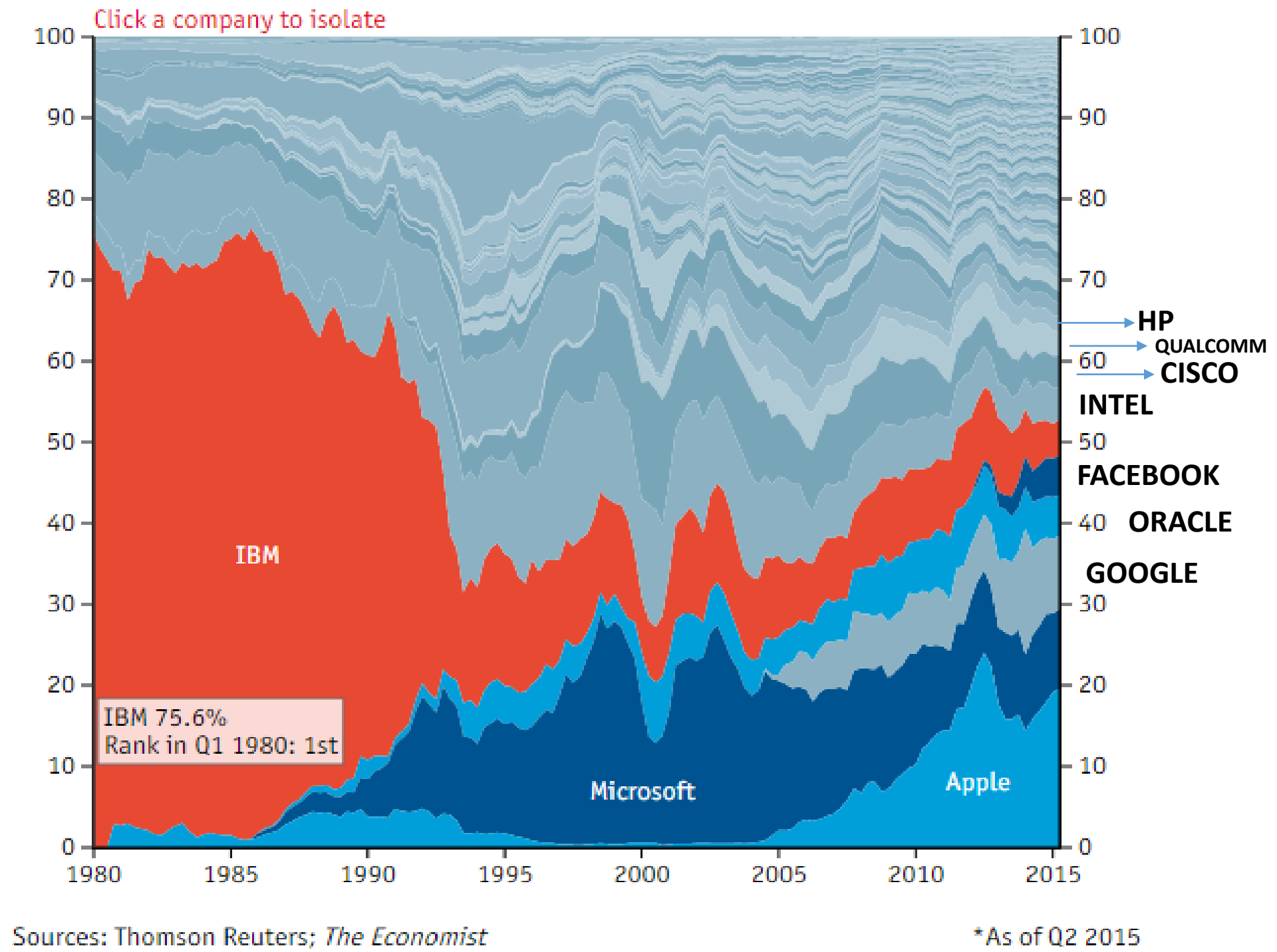
Dr Shoumen DATTA
Chercheur, Département Ingénierie des Systèmes, Forum pour l'Innovation dans la chaîne logistique
Directeur général de l'Ecole d'Ingénierie, Massachusetts Institute of Technology

Figure 3 : Pour l'émergence de systèmes décisionnels adaptifs, il est nécessaire de mettre en communication bits, atomes et décisions.



Depuis un bureau à Shinzen en Chine, vous vous connectez à un lecteur SDR situé dans un entrepôt aux Etats-Unis de manière à vérifier si vos produits sont arrivés en temps voulu. Ce fut le cas. Vous allez aussi apprendre que votre distributeur à Santiago du Chili et votre détaillant à Espoo en Finlande ont eux aussi vérifié où en était la livraison quelques instants avant vous

Digital Transformation



Sources: Thomson Reuters; *The Economist*

*As of Q2 2015

> $ 2.1 Trillion

< $0.4 Trillion

Autonomy and Algorithms are inextricably linked with

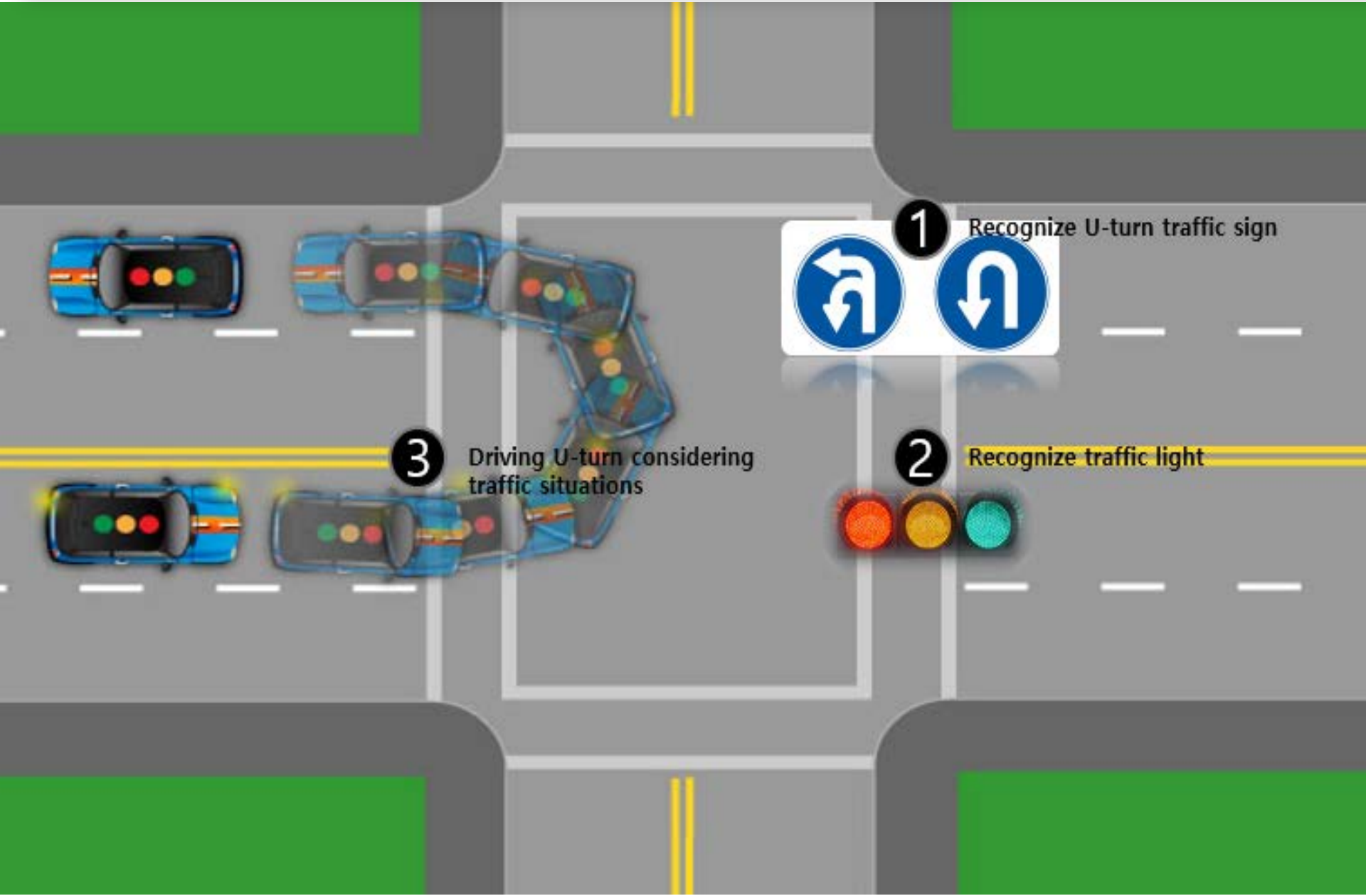
Data Economy

Transportation - Automobiles and Aviation

Smart Cities (Sensor Networks)

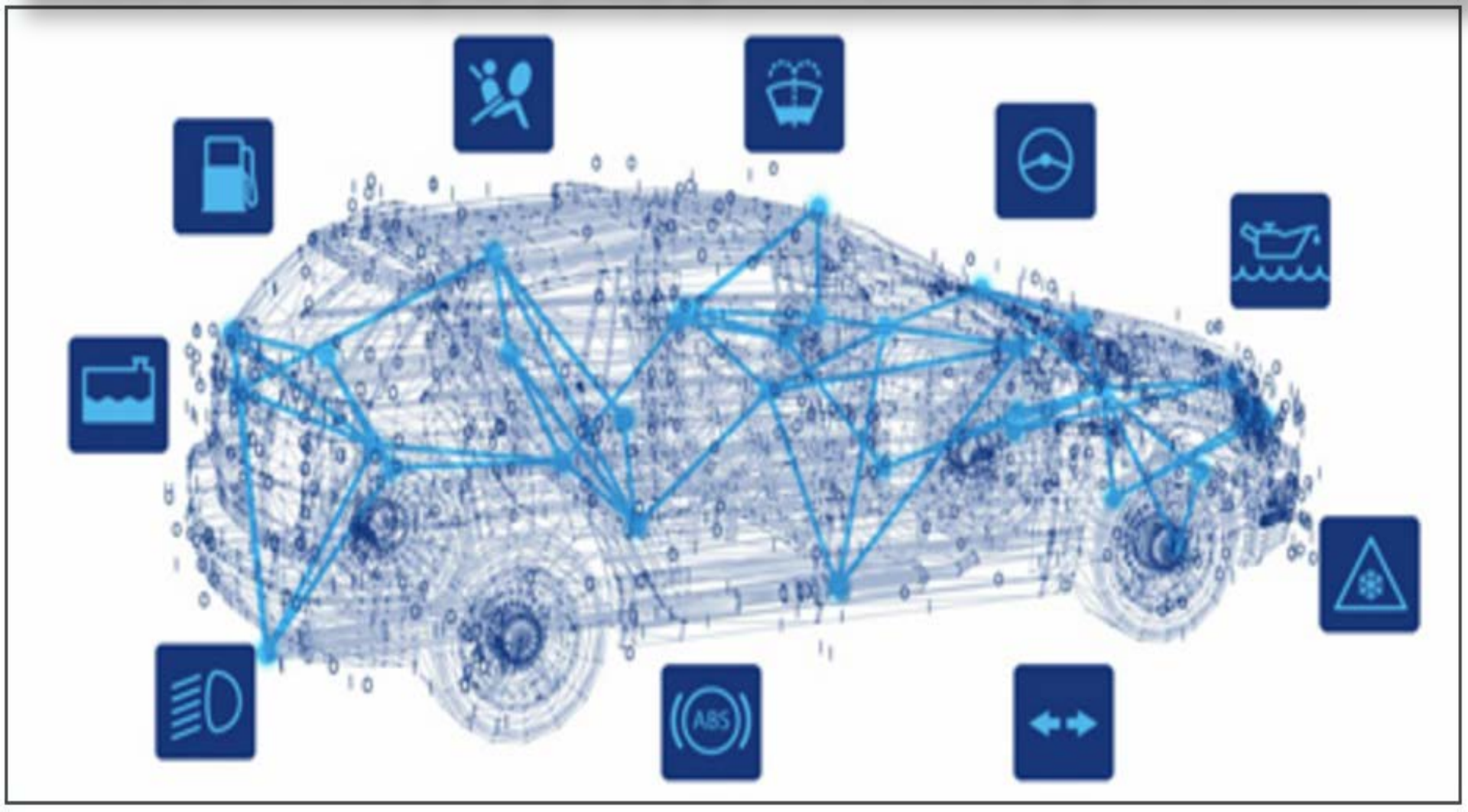
Automobile Manufacturers in Quest of Silicon Valley

An autonomous vehicle is making an U turn - how much - data, latency, bandwidth, computation



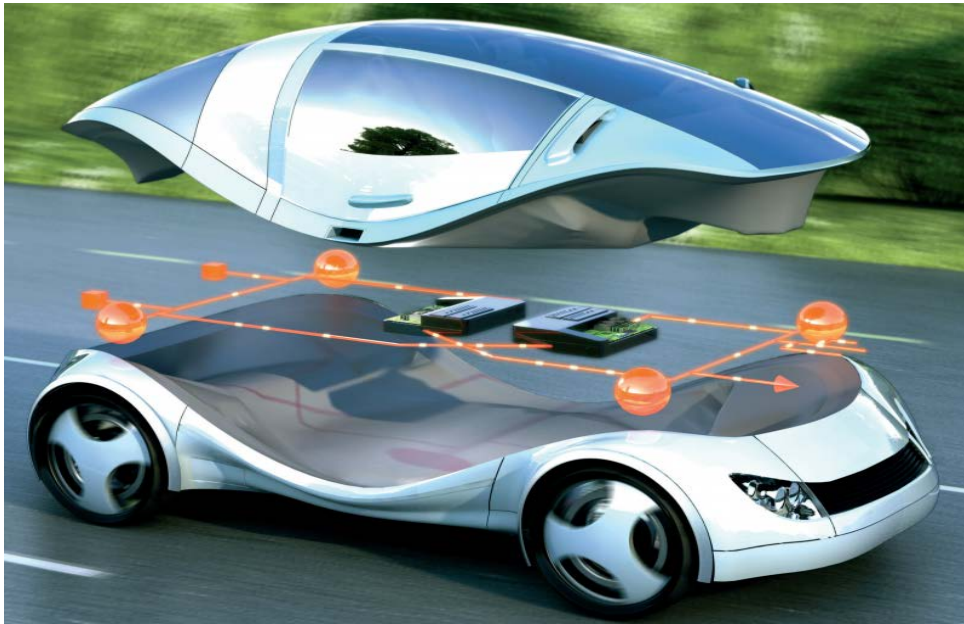
Automobile Maintenance

130 Terabyte (TB) per vehicle per annum



Data Economy – Crunch the numbers

- 250+ million cars in US & EU (100+ million in China)
- Assume only 1/10 in US is a connected vehicle
- 130TB/car/year x 25 million cars = 3.25 x 10^{12} GB
- Cost of data storage



https://aws.amazon.com/s3/pricing/

	Standard Storage	Standard - Infrequent Access Storage †	Glacier Storage
First 1 TB / month	$0.0300 per GB	$0.0125 per GB	$0.007 per GB
Next 49 TB / month	$0.0295 per GB	$0.0125 per GB	$0.007 per GB
Next 450 TB / month	$0.0290 per GB	$0.0125 per GB	$0.007 per GB
Next 500 TB / month	$0.0285 per GB	$0.0125 per GB	$0.007 per GB
Next 4000 TB / month	$0.0280 per GB	$0.0125 per GB	$0.007 per GB
Over 5000 TB / month	$0.0275 per GB	$0.0125 per GB	$0.007 per GB

Data Storage Cost - 1 in 10 connected cars

- 250 million cars in US and EU (100 million in China)
- Assume only 1/10 in US is a connected vehicle
- 130TB/car/year x 25 million cars = 3.25×10^{12} GB
- Cost of data storage = \$0.0125 x 3.25×10^{12} GB
- Cost = US \$40.625 x 10^{9} (using infrequent user rate)

\$40 Billion / year

87000 flights per day in US ● 1TB data per flight

Why data and information innovation requires radically new thinking if we want to connect e.g. transportation

- **Cost of annual data storage, using current tools:**
  - **CARS - almost $1 trillion**
  - **PLANES - more than $1 billion**

This is cost of data storage, alone. You haven't yet retrieved data, analyzed data and connected the analytics to the consumer.

Is data storage necessary?

Store decisions, not data?

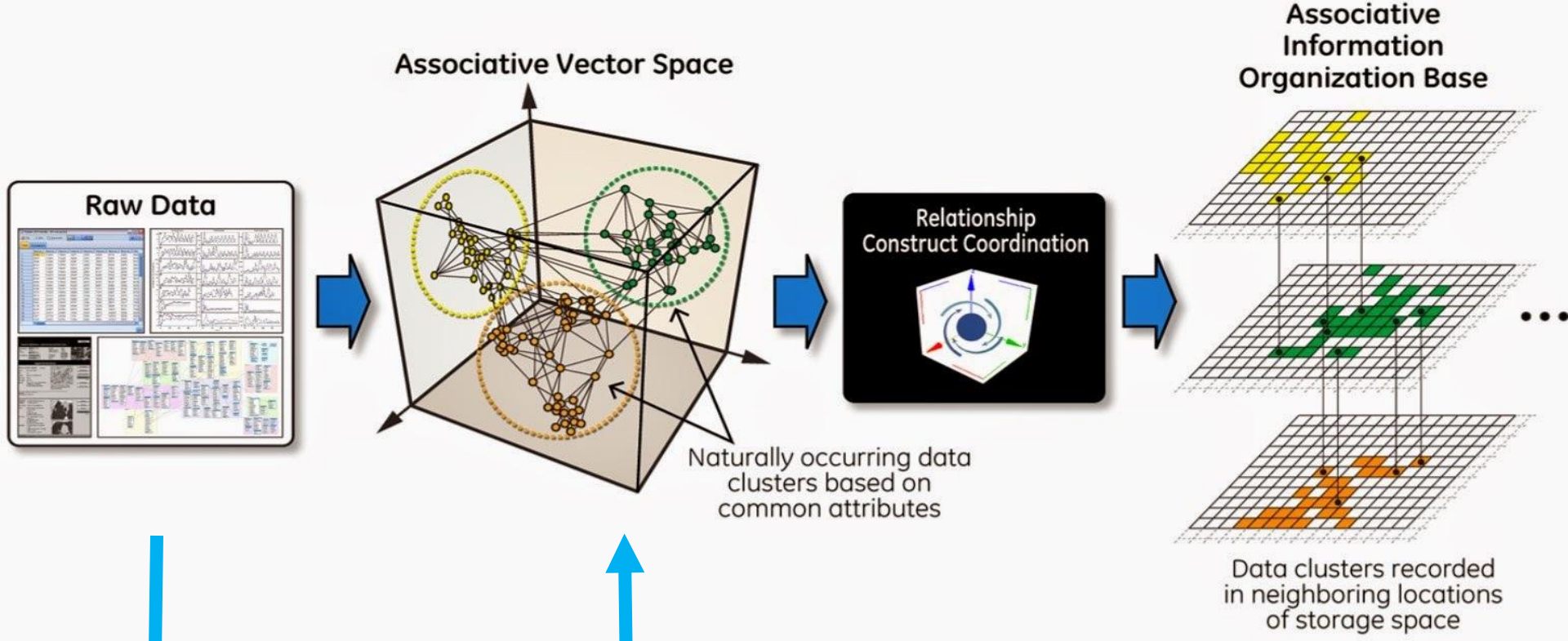
Think Transformation

5 MB hard drive being shipped out of IBM (1956)

2 TB hard drive slightly larger than a credit card (2015)

Emerging Frontier

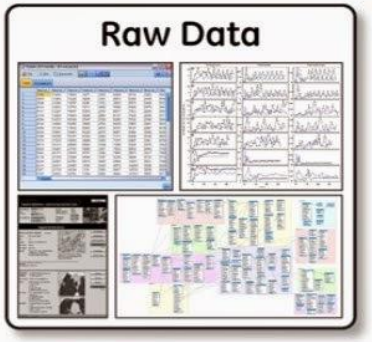
Data Curation – sorting out what we need

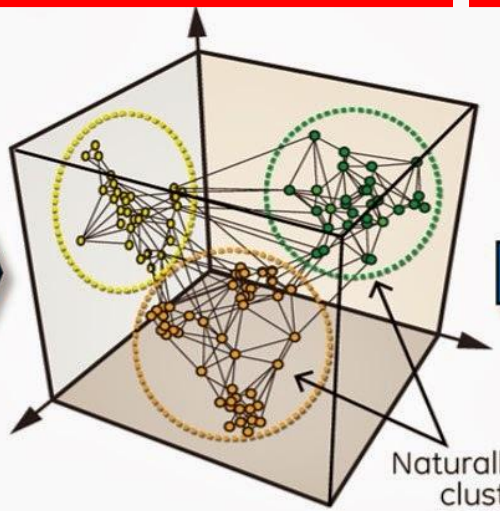

Raw Data
Associative Vector Space
Naturally occurring data clusters based on common attributes
Relationship Construct Coordination
Associative Information Organization Base
Data clusters recorded in neighboring locations of storage space

CURATE

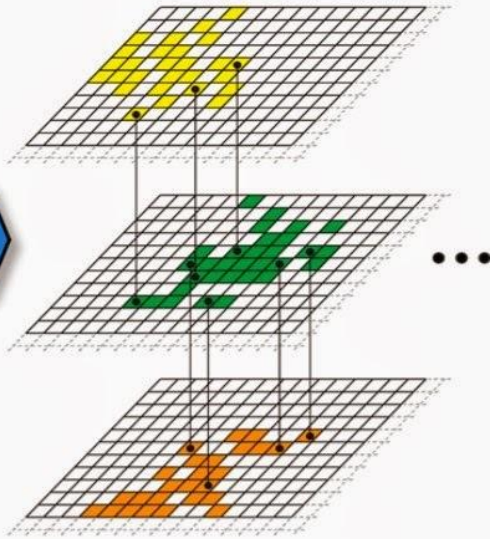
Perception Layer
Sensors, Actuators, Beacons

Associative Information Organization Base

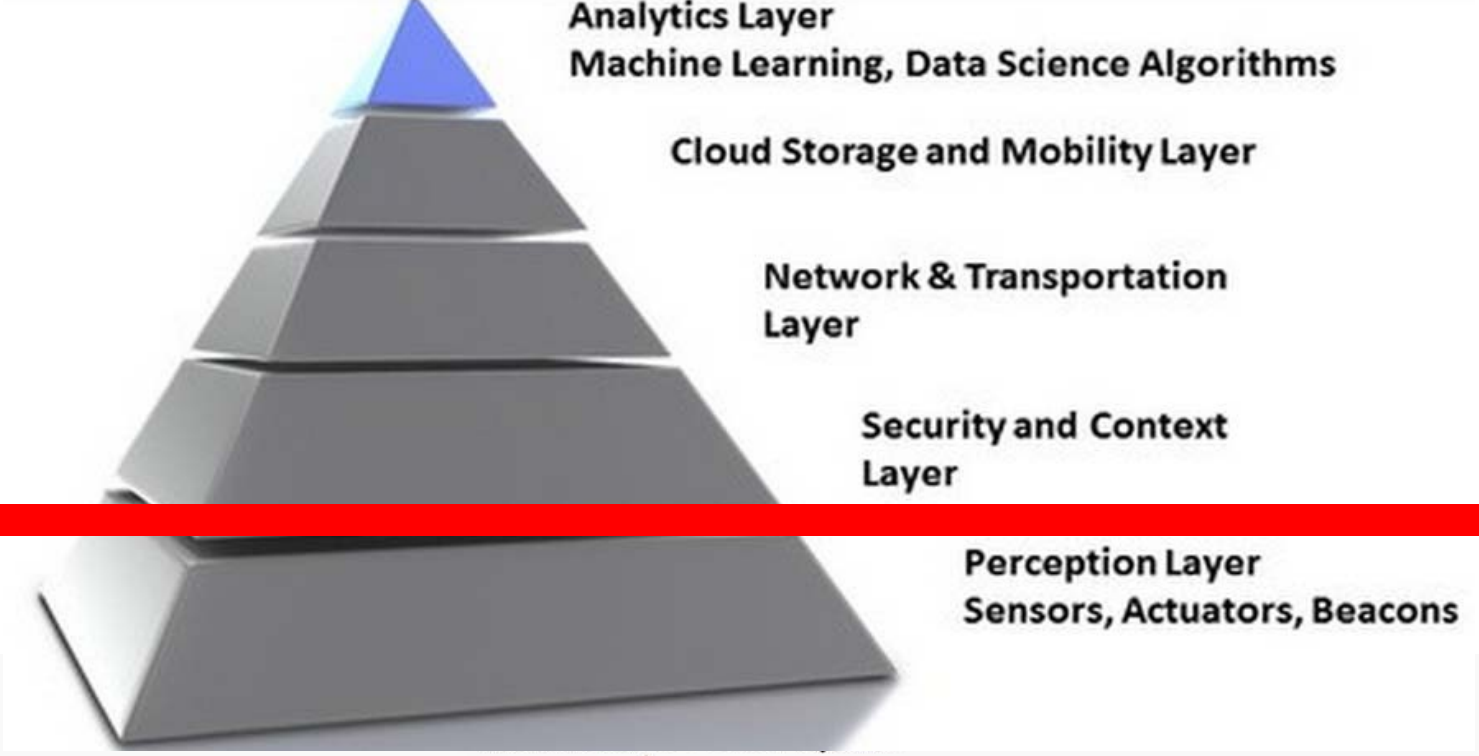


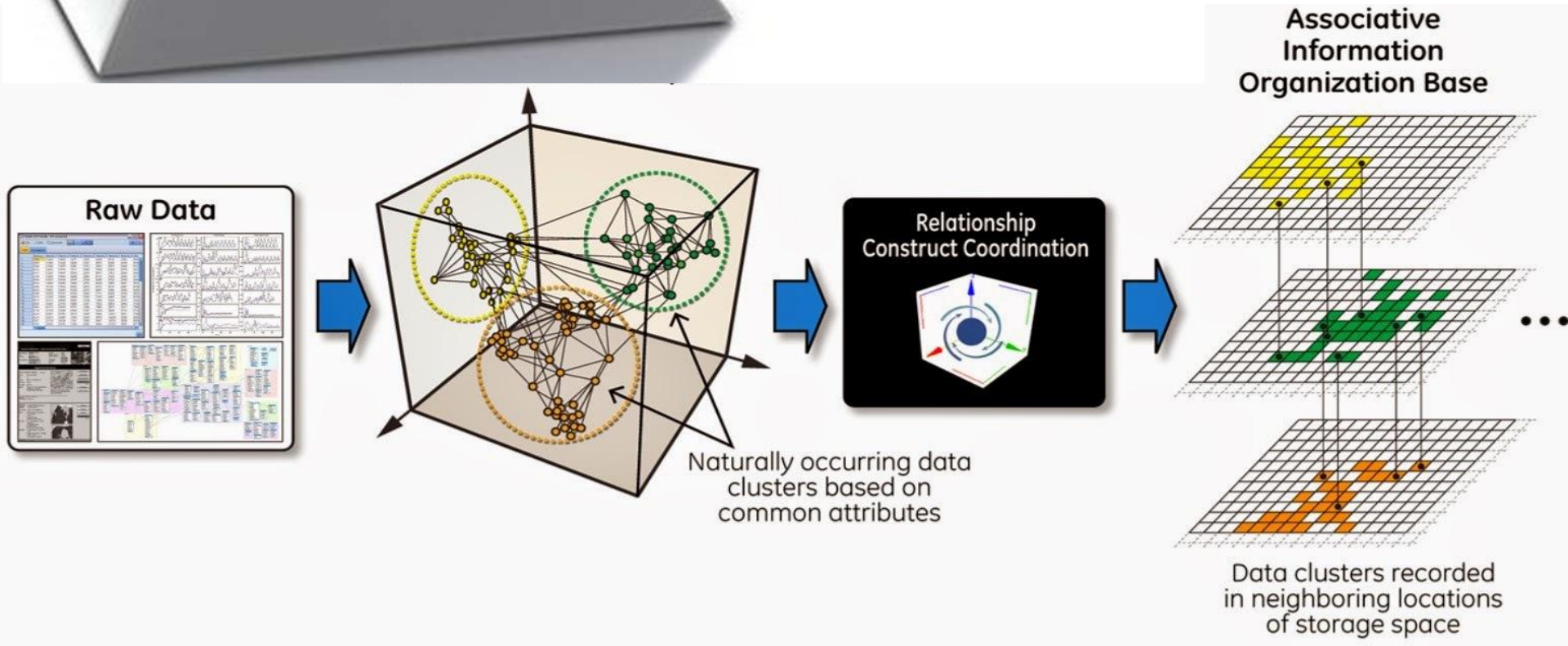


Naturally occurring data clusters based on common attributes

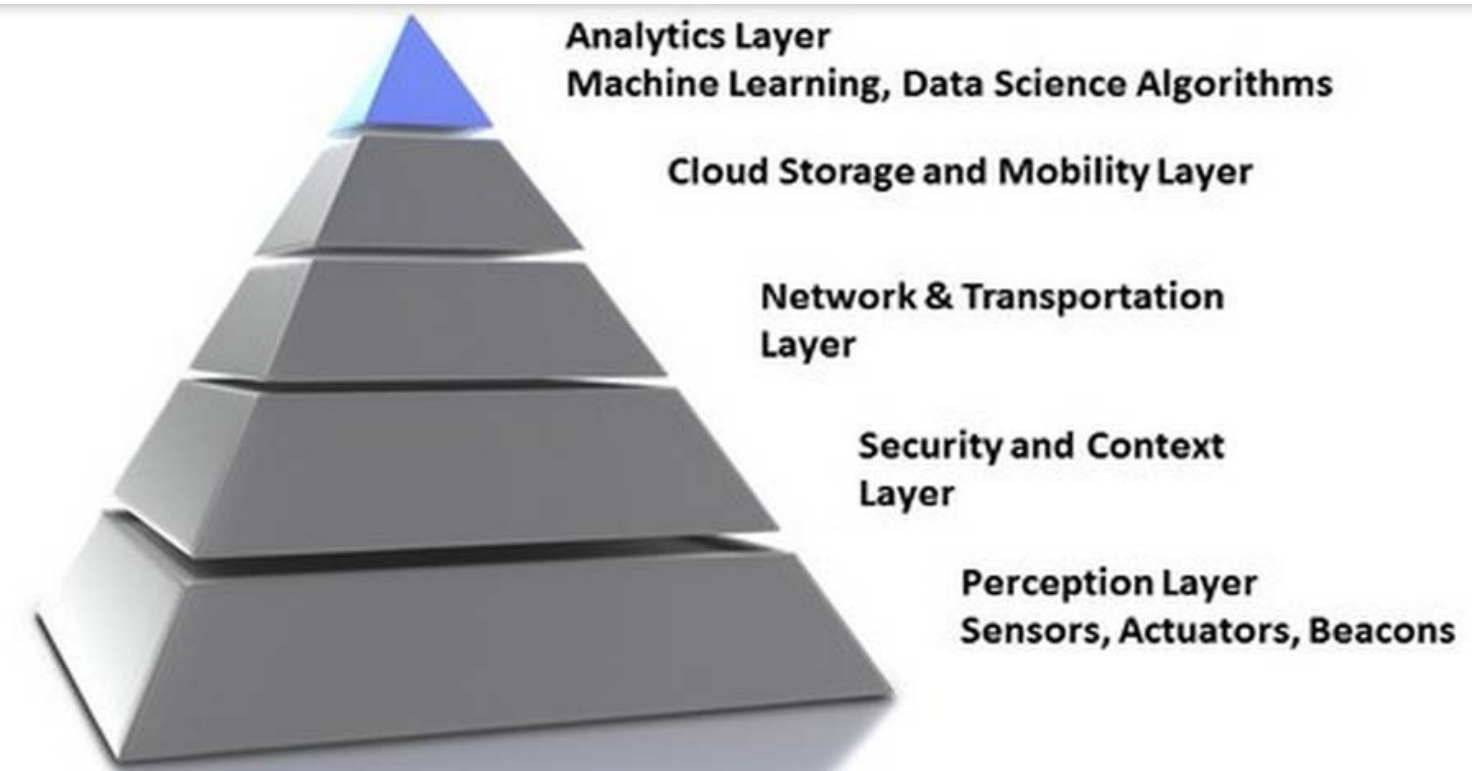


Data clusters recorded in neighboring locations of storage space


Analytics Layer
Machine Learning, Data Science Algorithms
Cloud Storage and Mobility Layer
Network & Transportation Layer
Security and Context Layer
Perception Layer
Sensors, Actuators, Beacons


Raw Data
Relationship Construct Coordination
Associative Information Organization Base
Naturally occurring data clusters based on common attributes
Data clusters recorded in neighboring locations of storage space

MONEY


Analytics Layer
Machine Learning, Data Science Algorithms
Cloud Storage and Mobility Layer
Network & Transportation Layer
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Perception Layer
Sensors, Actuators, Beacons

Challenges in Data Curation

- Noise obscures signal
- Data acquired is a blend of noise with signal
- Signal volatility introduces noise which is often proportional to signal

→ How do we correct/reduce the error due to this “noisy channel” factor?

→ Can novel algorithms reduce/deconstruct data to subtract “noise” and reconstruct the signal?

→ What about the application of the principles of (Shannon, Kalman-Bucy) error correcting algorithms?

☑ https://en.wikipedia.org/wiki/Kalman_filter
☑ http://news.mit.edu/2010/explained-shannon-0115
☑ http://www.cs.cmu.edu/~guyb/realworld/errorcorrecting.html
☑ http://www.cs.cmu.edu/~aarti/Class/10704/lec16-shannonnoisythrm.pdf

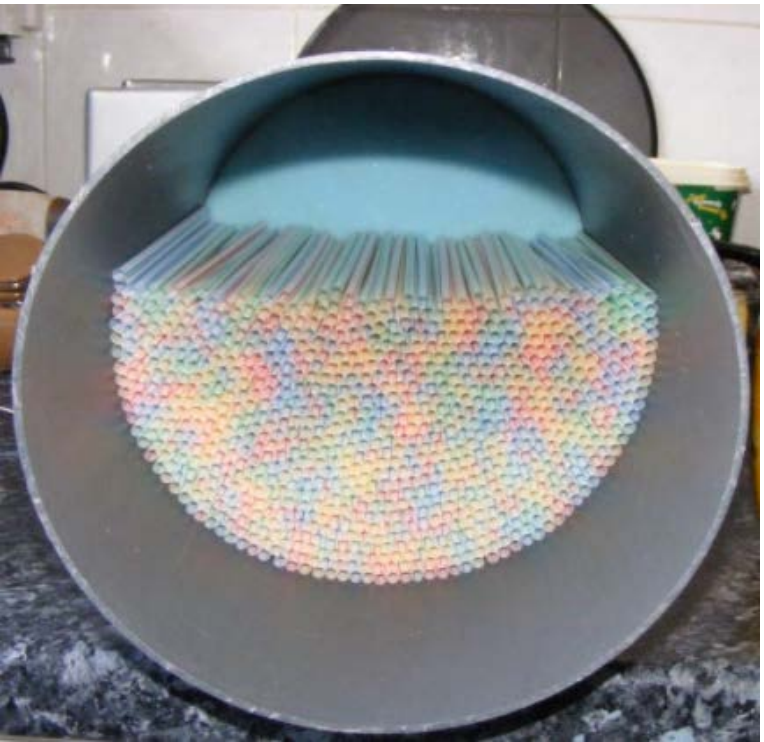
Data Curation Concepts from Laminar Flow

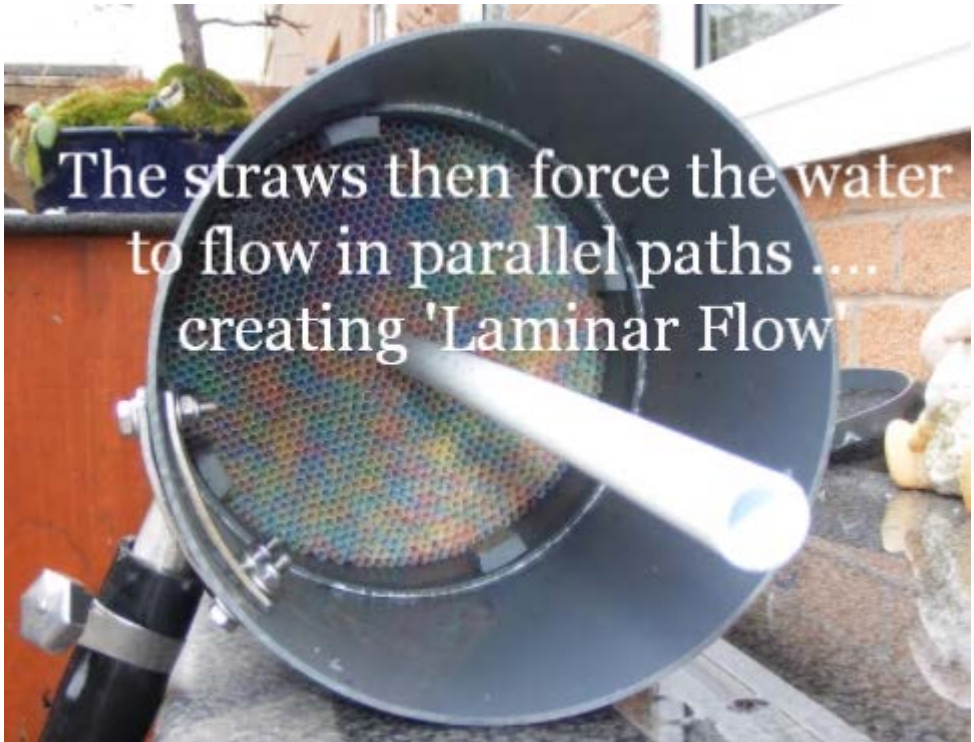
Smart City data is not an unique issue in this context. This is applicable across all data domains.

This a data curation problem. We are observing related signal/noise issues in big data analytics.

Are there any concepts related to data curation which may be triggered by laminar flow?

http://bit.ly/LAMINAR-FLOW-DATA-CURATION-CONCEPT





Data

CONTEXT

Project Oxygen

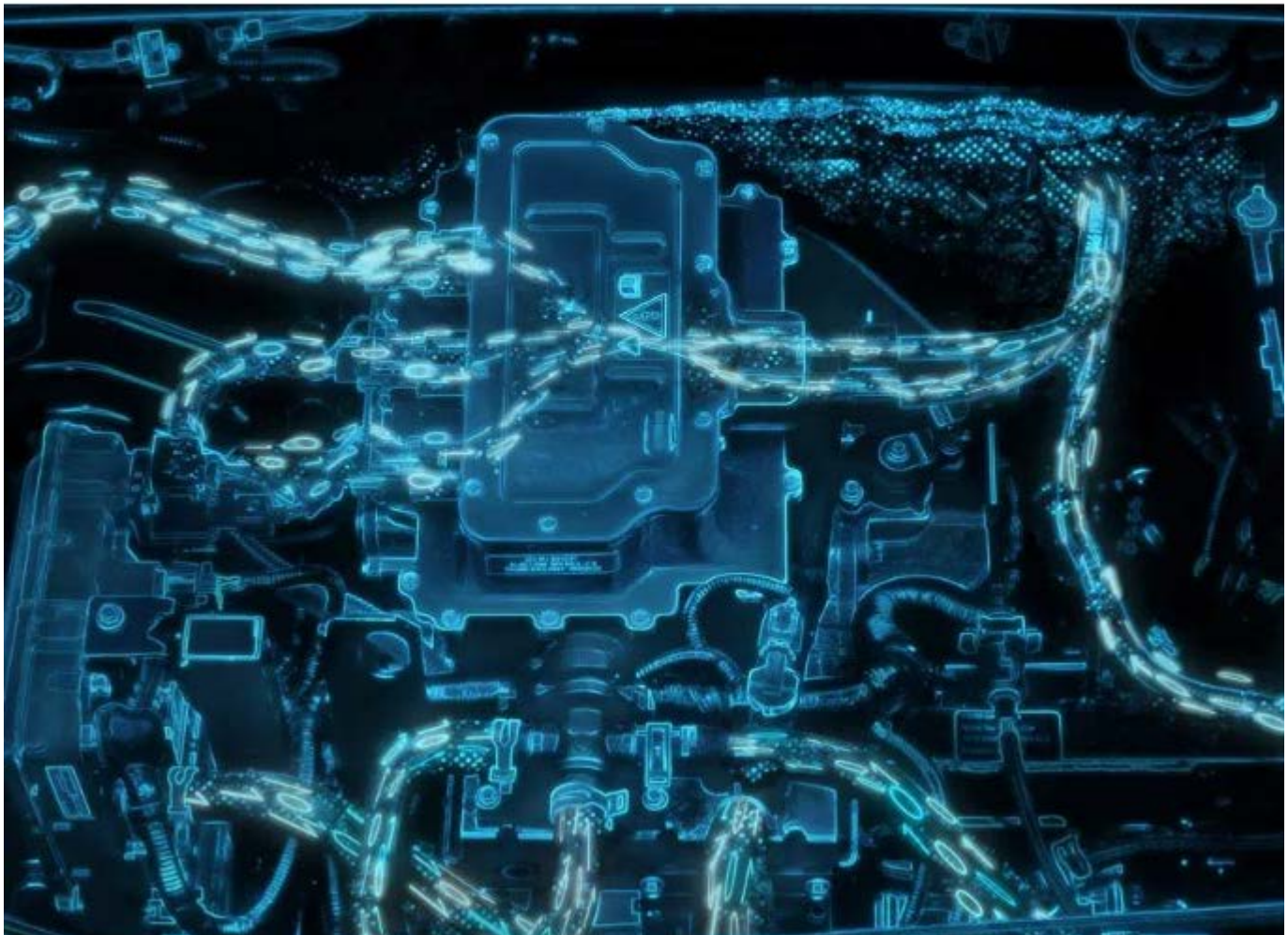
Data Connectivity

Transport

Equal to about a dozen HD movies and exceeds storage capacity of most smartphones

https://qz.com/344466/connected-cars-will-send-25-gigabytes-of-data-to-the-cloud-every-hour/

Connected cars will send 25 gigabytes of data to the cloud every hour



Cost of 3G (2013) vs 3G/4G (2016) US Data Plans

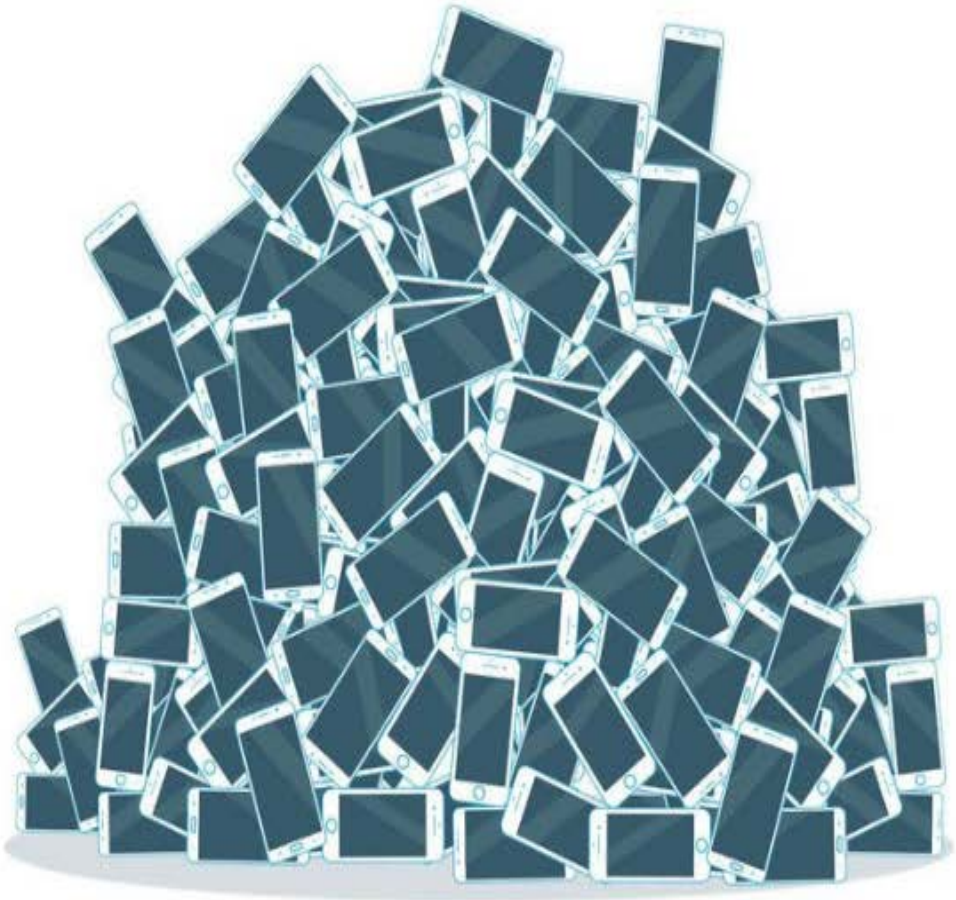
Bandwidth (Gb)	AT&T	Verizon	Sprint	T-mobile
.5				$20
1				
2				
2.5				$30
3			$34.99	
4	$30	$30		
4.5				$40
6	$40	$40	$49.99	
6.5				$50
8		$50		
8.5				$60
10	$60	$60		
10.5				$70
12		$70	$79.99	
14		$80		
15	$90			
16		$90		
18		$100		Not Available
20	$110	$110		
30	$185	$185		
40	$260	$260		
50	$335	$335		

Affordability	B+	C	A+
1GB - 1.5GB			
2GB - 3GB	$40		$20
4GB - 5GB	$50	$50	
6GB - 7GB	$60	$70	$35
8GB	$70		
10GB	$80	$90	$50
12GB	$90		

http://www.toptenreviews.com/services/internet/best-mobile-broadband-providers/

Autonomous car data

In 2020, the average autonomous car may process 4,000 gigabytes of data per day, while the average internet user will process 1.5 gigabytes.

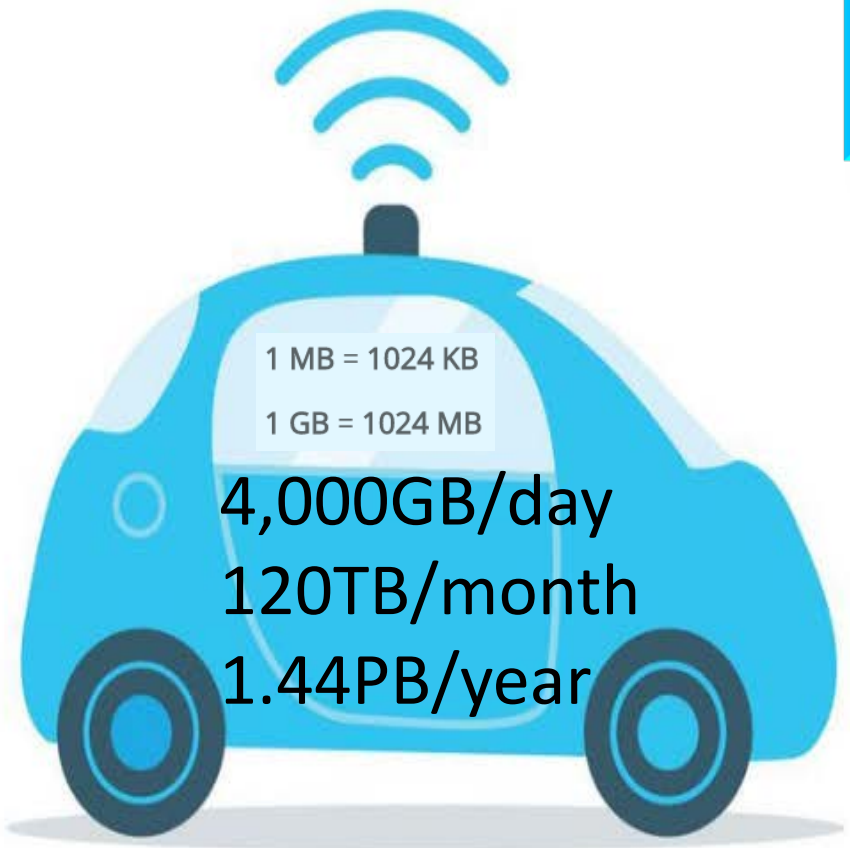


1 autonomous car = 2,666 internet users

Autonomous car data $12.41 million per car per year

In 2020, the average autonomous car may process 4,000 gigabytes of data per day, while the average internet user will process 1.5 gigabytes.

2016 US Data Plans 10 GB data (per month) = $85 or 2% of GNI per person

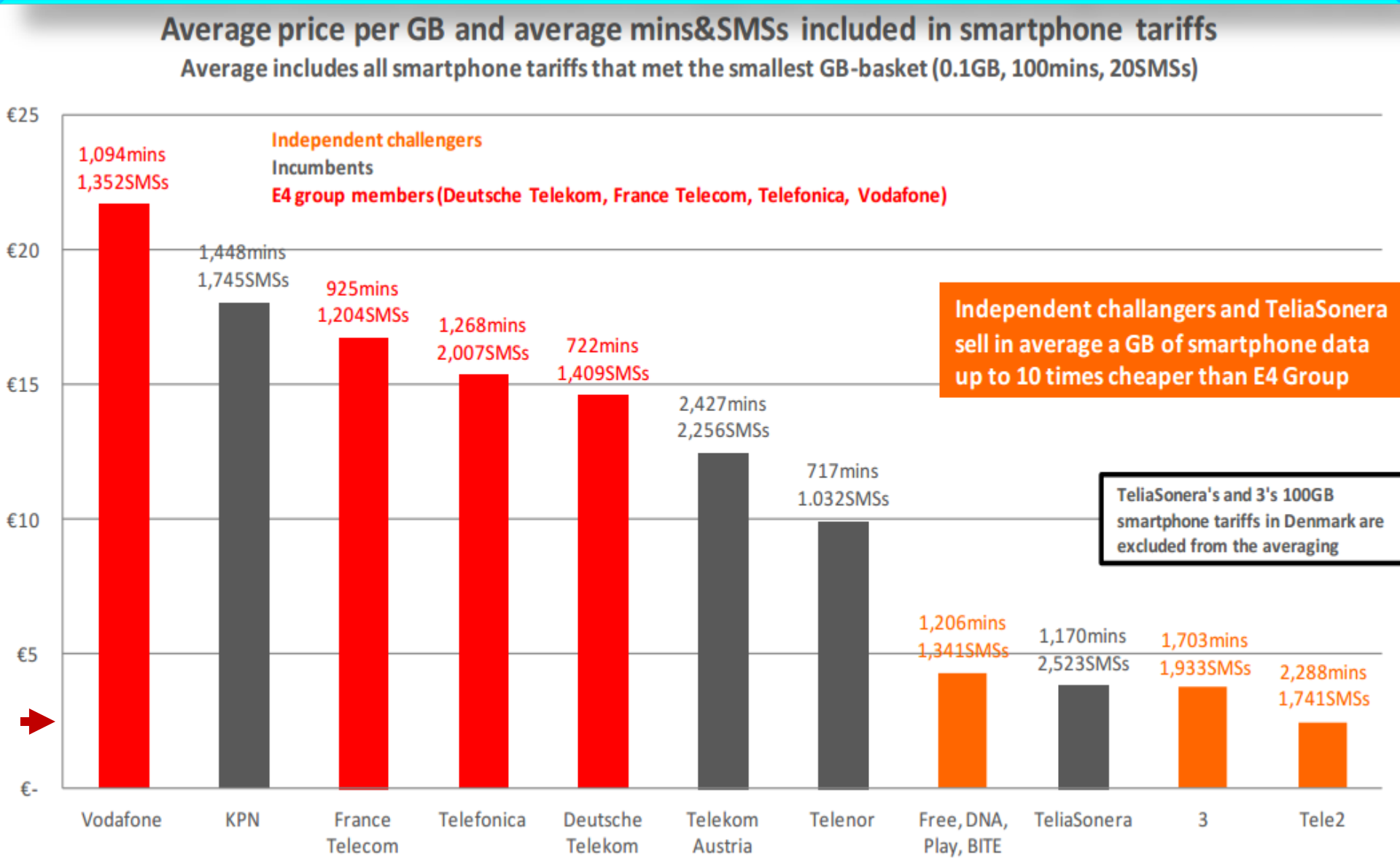


US

➡ African fixed broadband prices are, on average, 64% of GNI per capita

www.oafrica.com/broadband/african-internet-and-broadband-facts-from-measuring-the-information-society-2013-report/

Lowest cost of Mobile Broadband in EU approx. US$26.30/GB (highest US$231.4/GB)

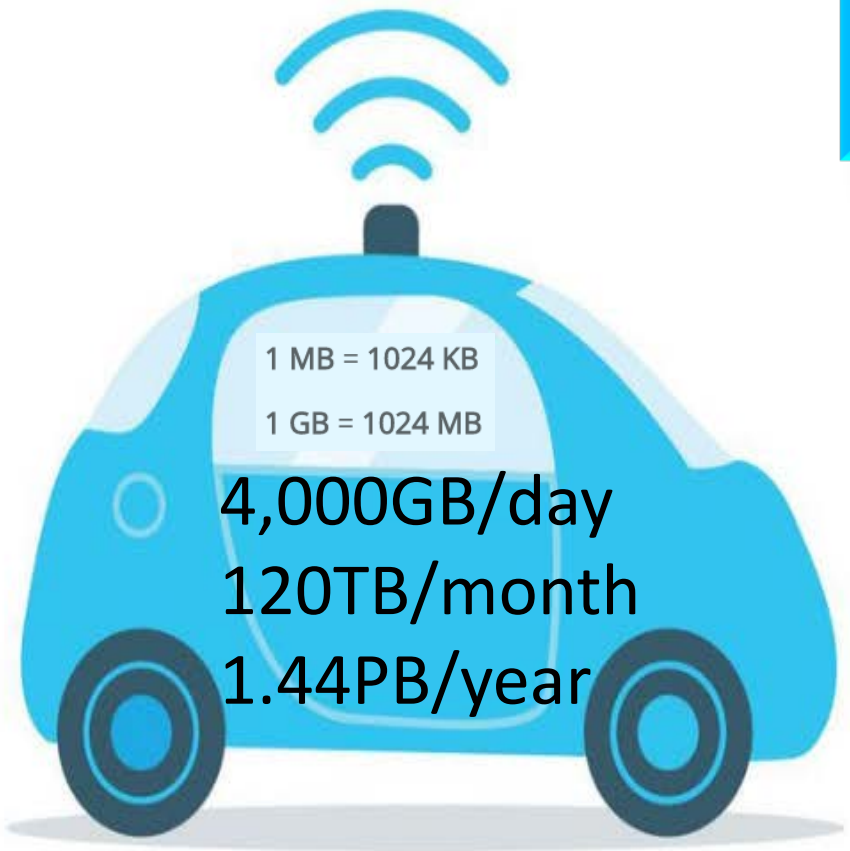


https://ec.europa.eu/digital-single-market/en/news/mobile-broadband-prices-europe-2016
http://www.rewheel.fi/downloads/Rewheel_EU27_mobile_data_cost_competitiveness_report_May_2013_FINAL.pdf

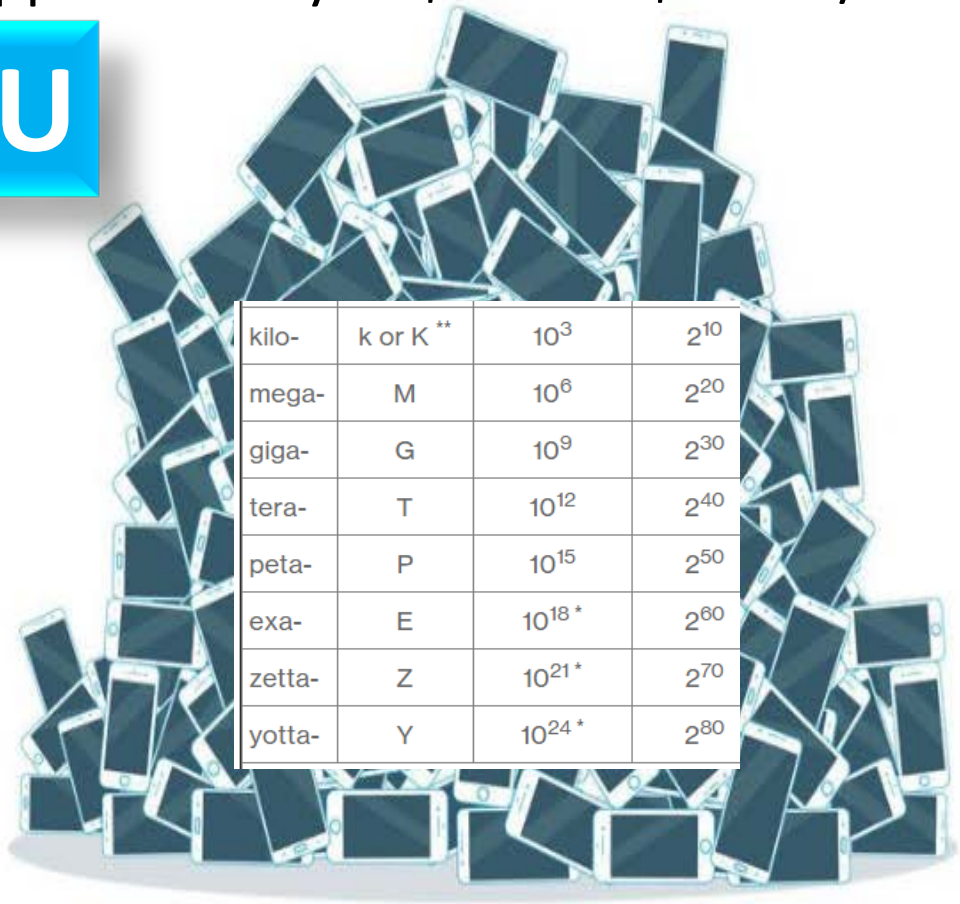
Autonomous car data $38.40 million per car per year

In 2020, the average autonomous car may process 4,000 gigabytes of data per day, while the average internet user will process 1.5 gigabytes.

Lowest cost of 0.1GB data in EU27 approximately US$2.63 or $26.30 / GB

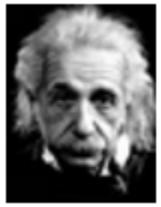


EU



kilo-	k or K **	10^3	2^{10}
mega-	M	10^6	2^{20}
giga-	G	10^9	2^{30}
tera-	T	10^{12}	2^{40}
peta-	P	10^{15}	2^{50}
exa-	E	10^{18} *	2^{60}
zetta-	Z	10^{21} *	2^{70}
yotta-	Y	10^{24} *	2^{80}

1 autonomous car = 2,666 internet users



"We can not solve our problems with the same level of thinking that created them"

Autonomous Vehicles

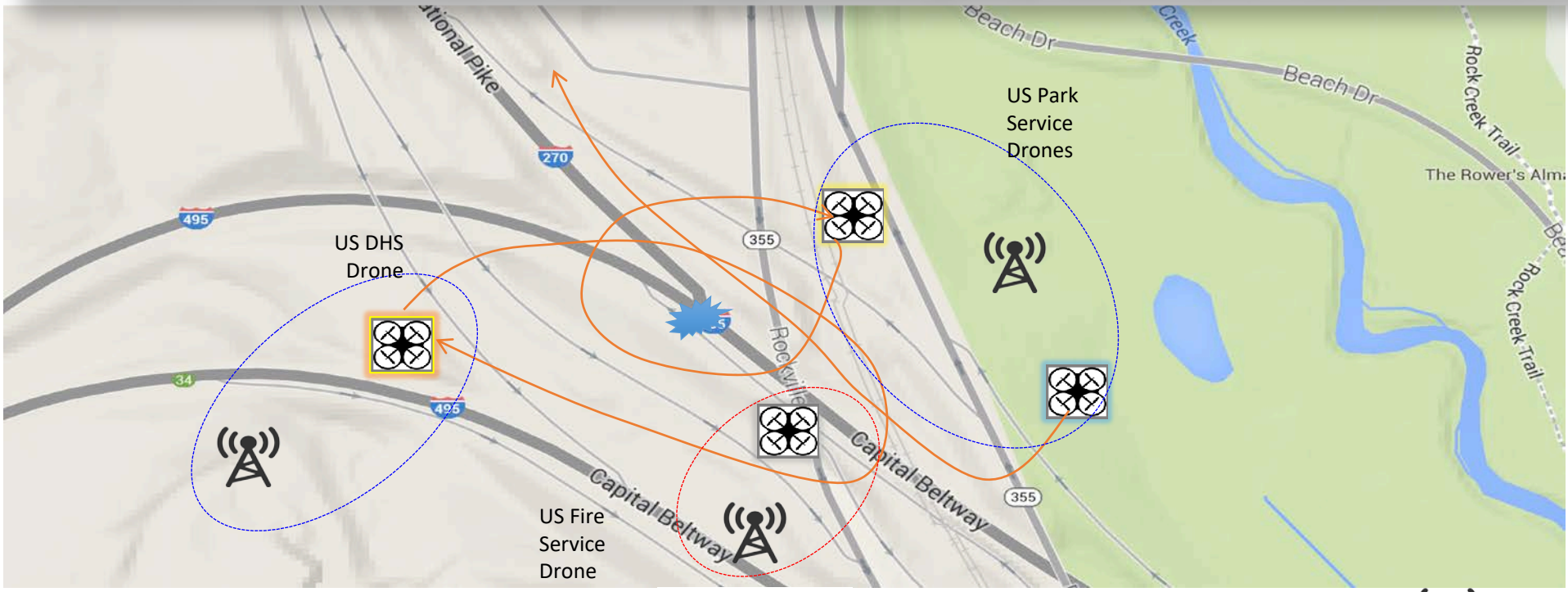
NEW tools, NEW technologies, NEW economic models, NEW transaction cost structures, NEW digital businesses, NEW engineering design, NEW computational paradigms

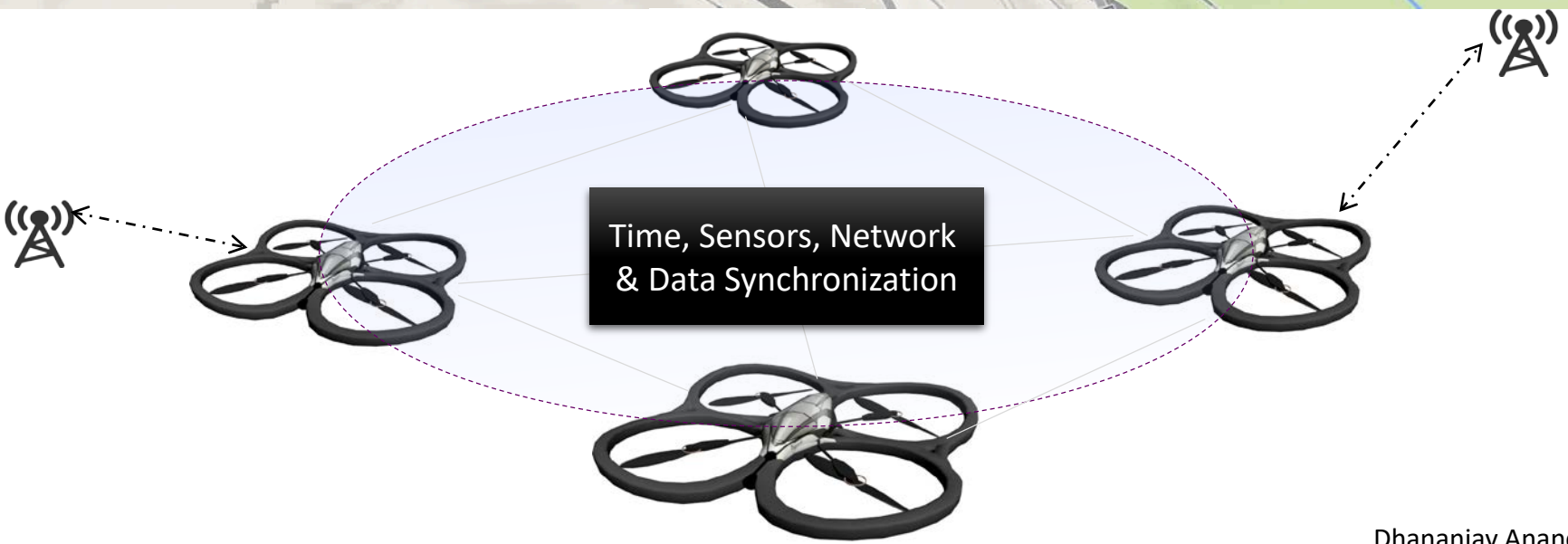
The NEW normal – SERVICES – not products

Adoption (of autonomous cars) is unrelated to cost of product (car) but determined by the cost of essential services (zero latency, mobile computation, connectivity, cybersecurity, energy recharge)

Transportation Coordination - Emergency “Crash to Care” Response

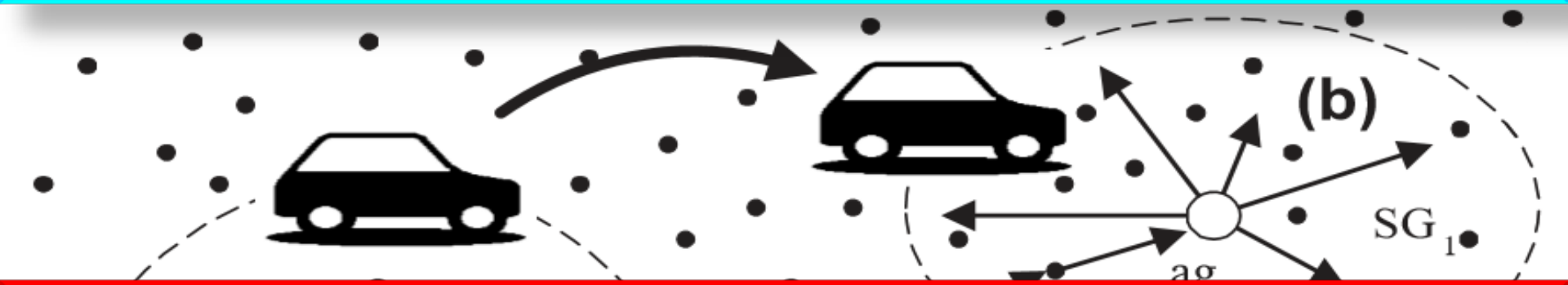
Transportation of real-time data key to emergency search and rescue drones





Dhananjay Anand, NIST

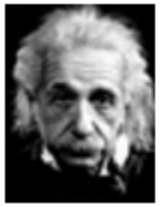
WSN In-Network Processing



EDGE INTELLIGENCE

Eyeriss: An Energy-Efficient Reconfigurable Accelerator for Deep Convolutional Neural Networks

EYERISS

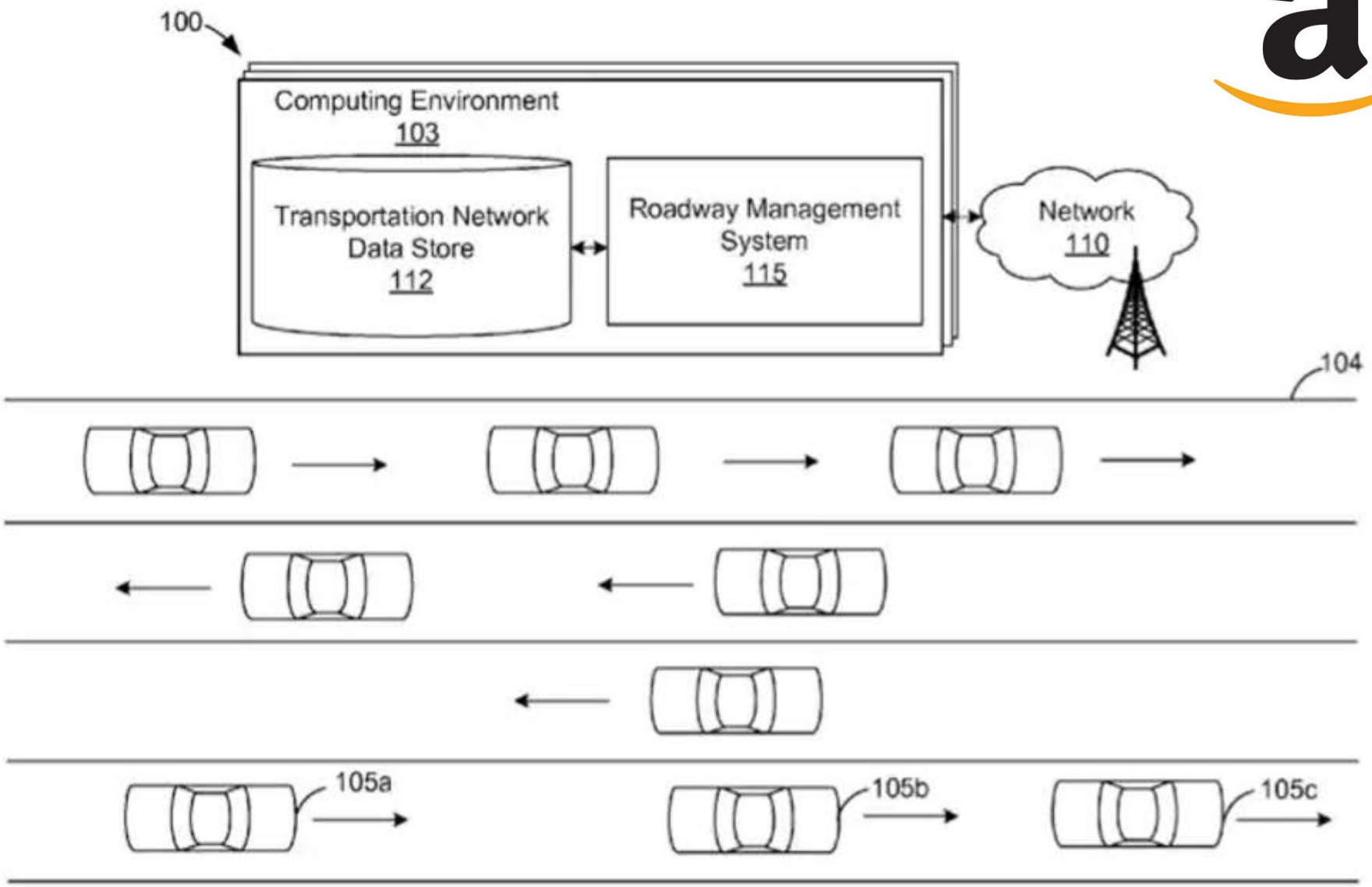


"We can not solve our problems with the same level of thinking that created them"

No large innovation has come from within a system. Tesla didn't come out of the automotive industry. SpaceX didn't come out of Boeing or Lockheed and by the way GM spent millions of dollars trying to do an electric car before Tesla. More money, more resources, more knowledge, too much knowledge. Wal-Mart didn't innovate retail. Amazon did. NBC and CBS didn't innovate media. Facebook, Twitter and YouTube did. Genentech didn't come out of Pharma. It came from a guy who was an associate at Kleiner – Bob Swanson *(in partnership with Herbert Boyer of UCSF).*

http://medcitynews.com/2017/01/vinod-khosla-healthcare-startups-hate/

Reversible lanes pose problem for autonomous cars and trucks, but Amazon has worked out a possible solution

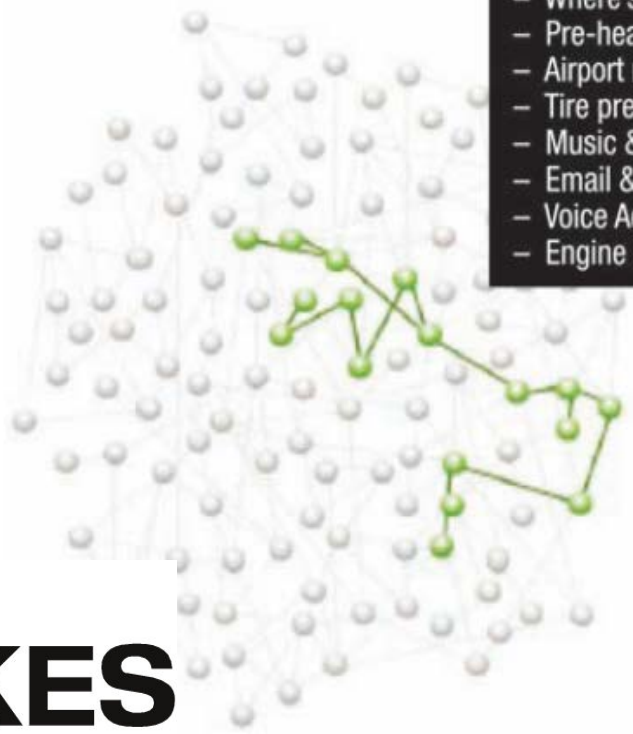


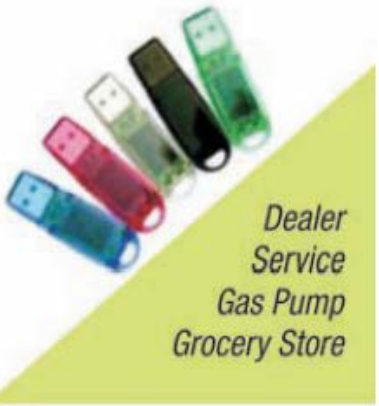
Amazon's self-driving patent proposes a centralised roadway management system that communicates with self-driving cars to help coordinate vehicle movement at a large scale. Photograph: USPTO

2005 – Swap form factor for “atoms” (connect bits, cars, engines, toilets)

12 years later, swappable car batteries are in discussion, but form factor for energy is still large.

On 17th November 2005, during a conversation in my office at MIT, I was requested to write a short article, on future trends in e-business, to be included in a publication to accompany the successful completion of the Tekes supported e-logistics program (ELO) in 2006. It was suggested that I send the completed article in about six weeks to allow for translation in Finnish.





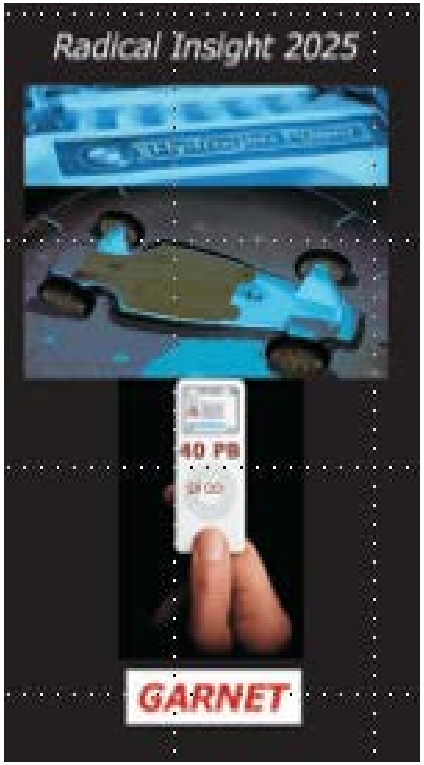
TEKES

2006 Paradigm Shift in Interoperability? https://dspace.mit.edu/handle/1721.1/56251

Swap "atoms" form factor

19. Wigner E. and Huntington H.B. On the possibility of a metallic modification of hydrogen. *J. Chem. Phys.*, 1935, v.3, 764–770.

12 years ago, the idea was of "portability" of atoms [eg: running your car on (metallic) hydrogen]



S. Datta, published (by TEKES in 2006)
https://dspace.mit.edu/handle/1721.1/56251

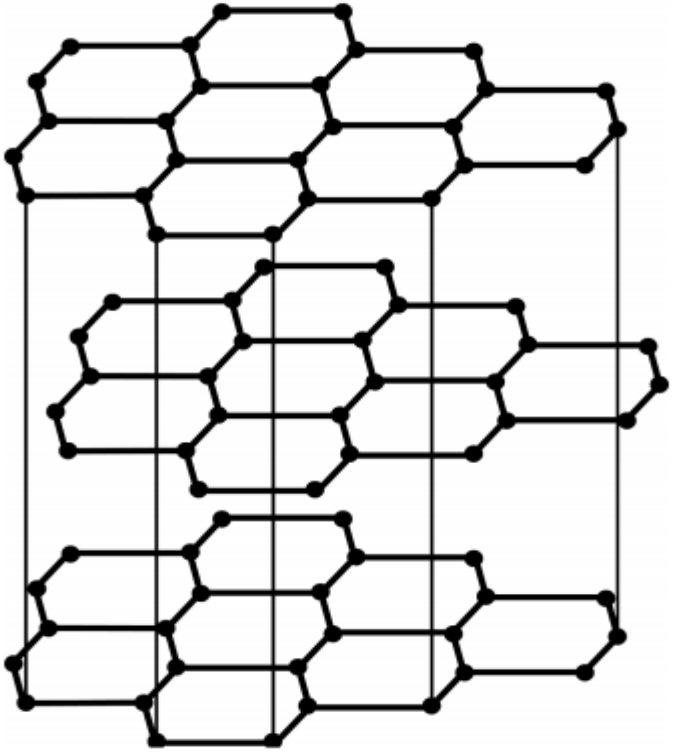


Fig. 1: Schematic representation of the layered lattice of graphite. Wigner and Huntington [19] would propose that most energetically favorable form of metallic hydrogen would assume this crystal structure. http://www.ptep-online.com/index_files/2011/PP-26-07.PDF

J. D. Bernal who first put forward the view that all substances go over under very high pressure into metallic or valence lattices" [19].

The rationale of "portability" of atoms was based on the theory of metastable metallic hydrogen

Harvard scientists announce they've created metallic hydrogen, which has been just a theory

January 26, 2017 |

19. Wigner E. and Huntington H.B. On the possibility of a metallic modification of hydrogen. *J. Chem. Phys.*, 1935, v.3, 764–770.

http://news.harvard.edu/gazette/story/2017/01/a-breakthrough-in-high-pressure-physics/

Swap “atoms” form factor – a different way of thinking about inventory at hand

12 years ago, the idea was of “portability” of atoms [eg: running your car on (metallic) hydrogen]

Drive any vehicle – car, ship, plane, rocket
Use metallic hydrogen in a USB drive form

Swap it anywhere to replenish

Think SCM - near-zero inventory of fuel, the weight of fuel, inventory carrying cost and energy used to carry inventory

https://dspace.mit.edu/handle/1721.1/56251

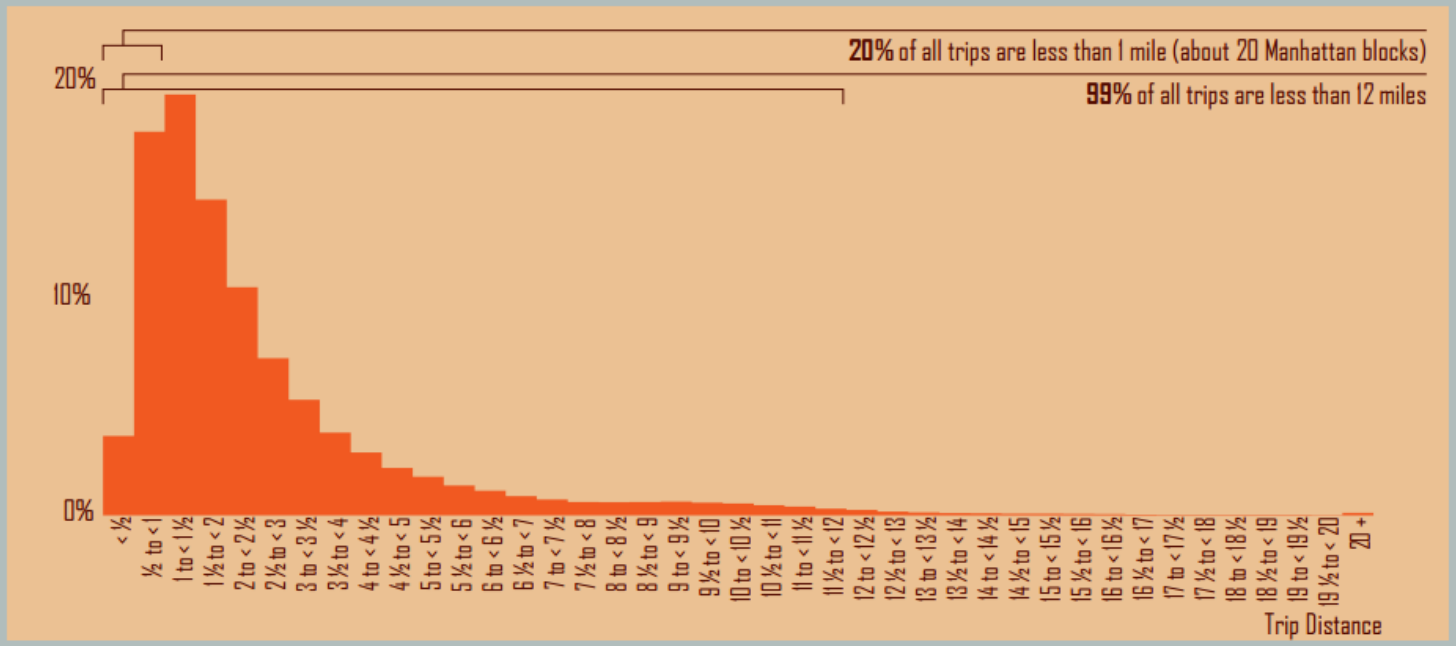
Swap “atoms” form factor – a different way of thinking about a typical taxi ride

http://www.nyc.gov/html/tlc/downloads/pdf/2014_taxicab_fact_book.pdf

Yellow taxis provide an average of

485,000
trips/day

The average trip distance is **2.6** miles



http://map.mathshell.org/download.php?fileid=1706

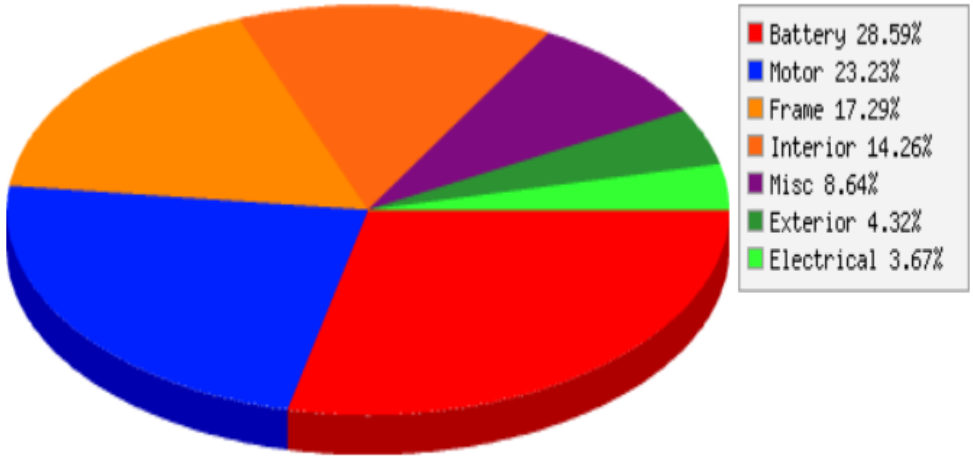
12 gallons

72 lb @ 6 lb/gal

Smaller cars generally have gas tanks that hold **12 gallons** worth of gas, while larger cars can hold 15 or **16 gallons**. For the purpose of this story, let's say gas costs $3.85 a gallon. A car with a **12**-gallon tank costs $46.20 to fill up while a larger car with a 15-gallon tank costs $57.75. Jul 5, 2013

How much energy (inventory) and weight of energy (gas or battery) is a vehicle carrying for an average 2.6 mile trip?

TESLA MODEL S WEIGHT – 4,600+ LB



Battery Pack **1323 lb**

- 1323 lb (1)

Aluminum Space Frame

- ~ 800 lb

Motor / Drivetrain

- ~ 350 lb – electric motor + inverter
- ~ 175 lb – differential
- ~ 250 lb – wheels + tires
- ~ 120 lb – brakes calipers, discs, lines
- ~ 80 lb – air suspension

Interior

- ~ 200 lb – front powered seats + rears
- ~ 190 lb – windshield, windows, hatch
- ~ 150 lb – pano glass and assembly
- ~ 80 lb – carpet, padding, mats
- ~ 40 lb – dash, trim, panels

Exterior

- ~200 lb – doors, frunk, hatch, body

Misc

www.teslarati.com/tesla-model-s-weight/

Swap “atoms” form factor – a different way of thinking about a typical taxi ride

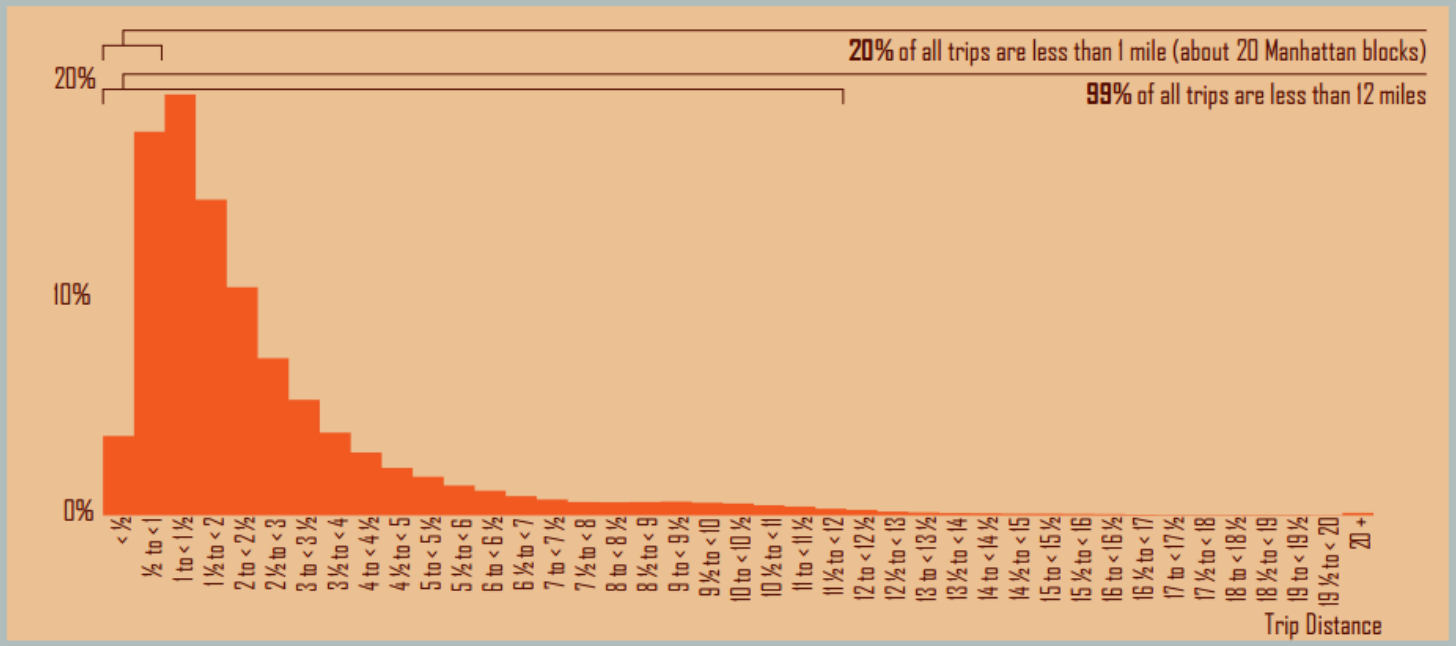
http://www.nyc.gov/html/tlc/downloads/pdf/2014_taxicab_fact_book.pdf

Yellow taxis provide an average of

485,000 trips/day

1300 lb battery for a 2.6 mile trip?

The average trip distance is **2.6** miles



http://map.mathshell.org/download.php?fileid=1706

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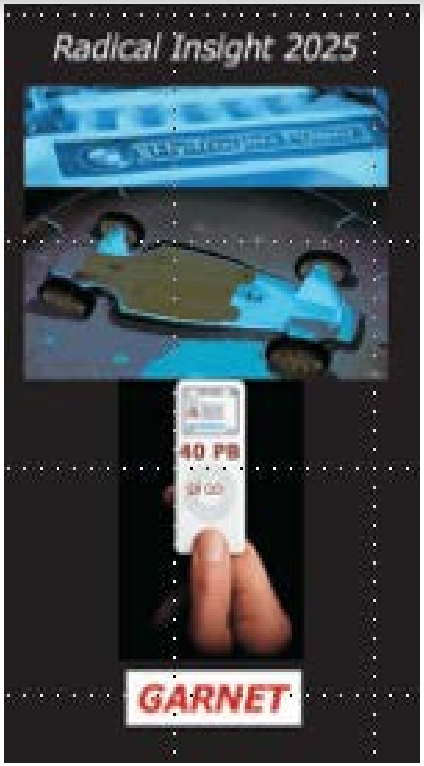
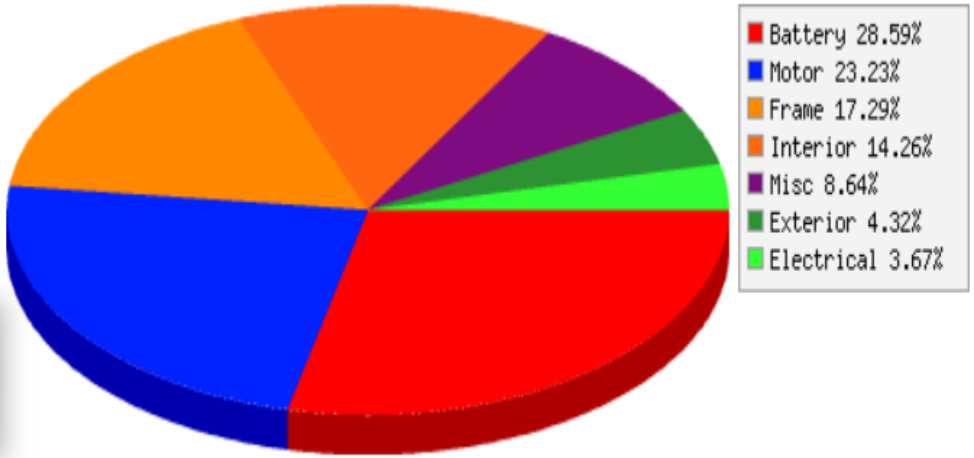
Change the equation!



10 gram Hydro-Stick
(Shoumen Datta, 2017)

TESLA MODEL S WEIGHT – 4,600+ LB



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- ~200 lb – doors, frunk, hatch, body

Misc

www.teslarati.com/tesla-model-s-weight/

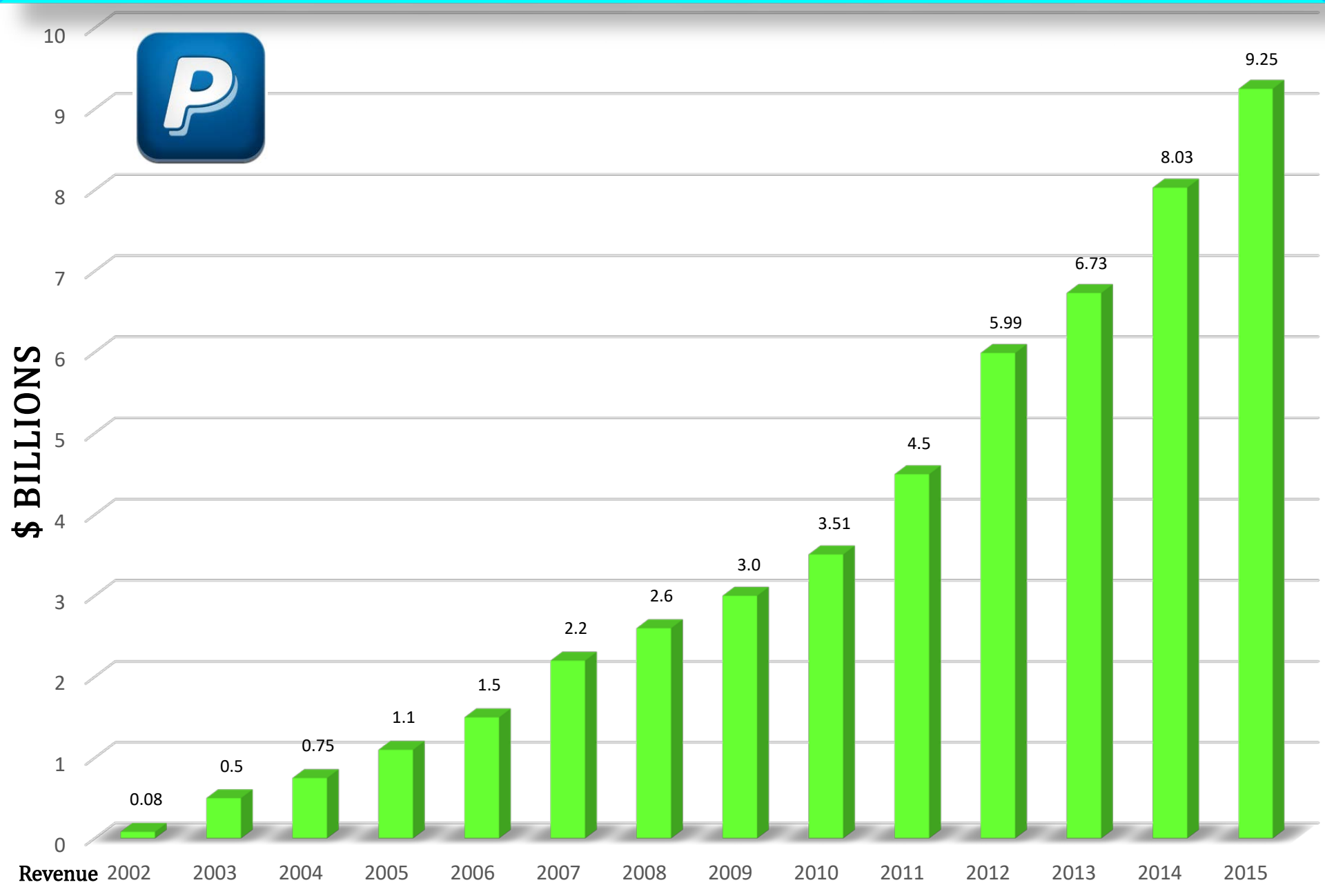
Swap “atoms” form factor – Hydro-Stick of metallic Hydrogen is not a panacea

The form factor of energy and its source for transportation may undergo many radical metamorphoses because one solution may not suit all the different type of needs. Tesla’s approach may be overdue for an overhaul.

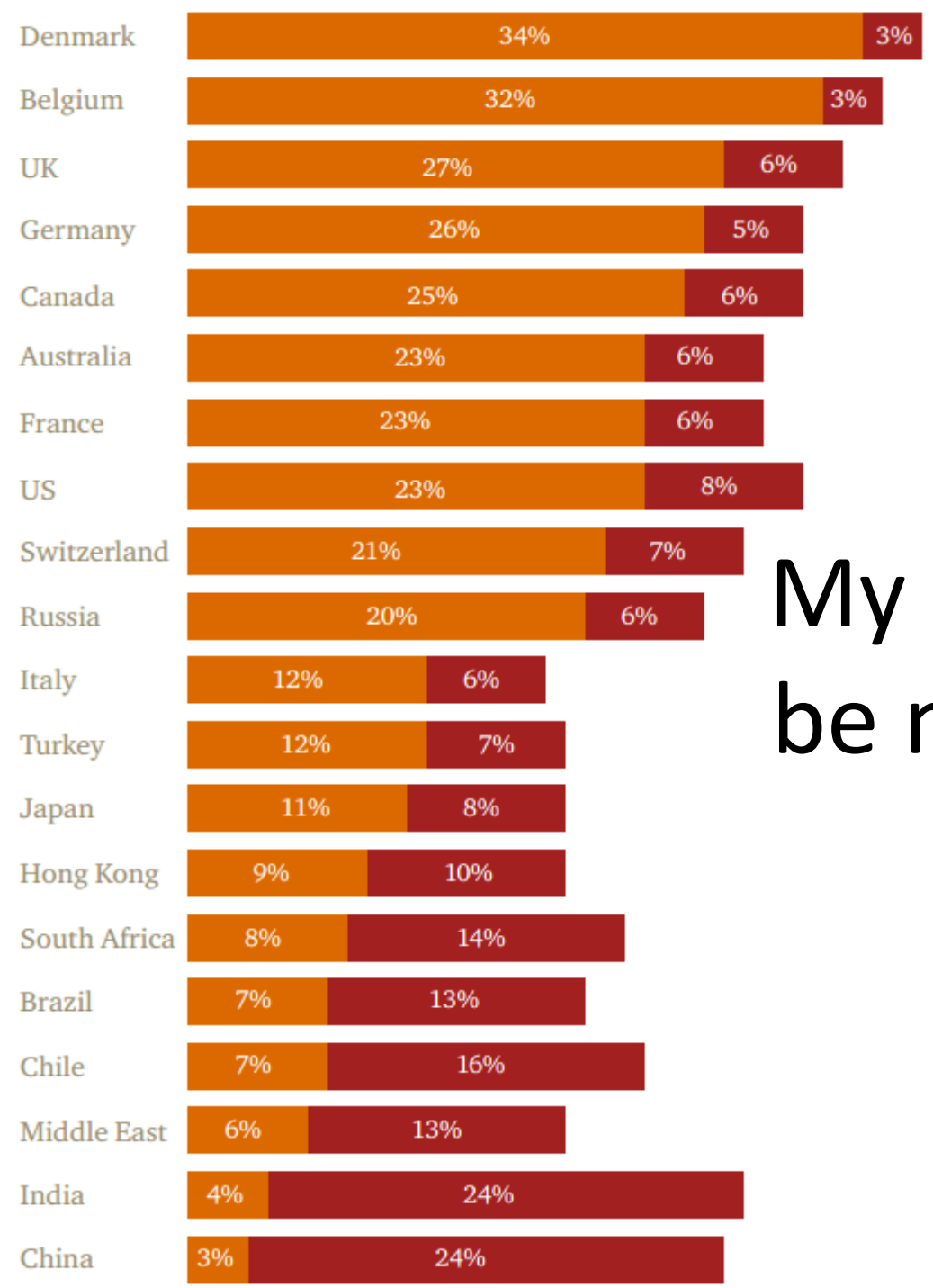
New ideas. New solutions. New engineering.

TRANSLATIONAL ENGINEERING

Transaction Cost Economics – The Micro-Revenue Revolution



Digitalization Morphs Behavior?



My mobile phone will be my purchasing tool

Strongly disagree | Strongly agree

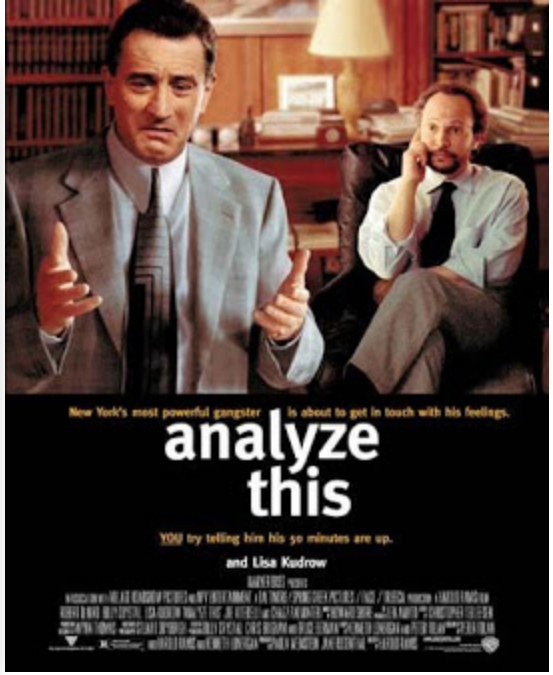
http://bit.do/PURCHASING-TOOL

Median Age
DE / JP – 46
Belgium – 43
DK / FR – 42
CAN / UK – 41
US / CN – 37
India – 27
Niger – 15

MICRO-REVENUE

from each distributed point of contact

US $50



MILLION

PAY-PER-ANALYTICS ➲ Depending on QoS outcome?

Who will you pay? Who will bill? Who guarantees QoS?

Samsung, UCSF Partner to Accelerate New Innovations in Preventive Health Technology

Pair Will Work to Validate Promising New Sensors and Analytics for Next-Generation Digital Health Solutions

WHO WILL
RECEIVE HOW MUCH
OF THE PAYMENTS ?

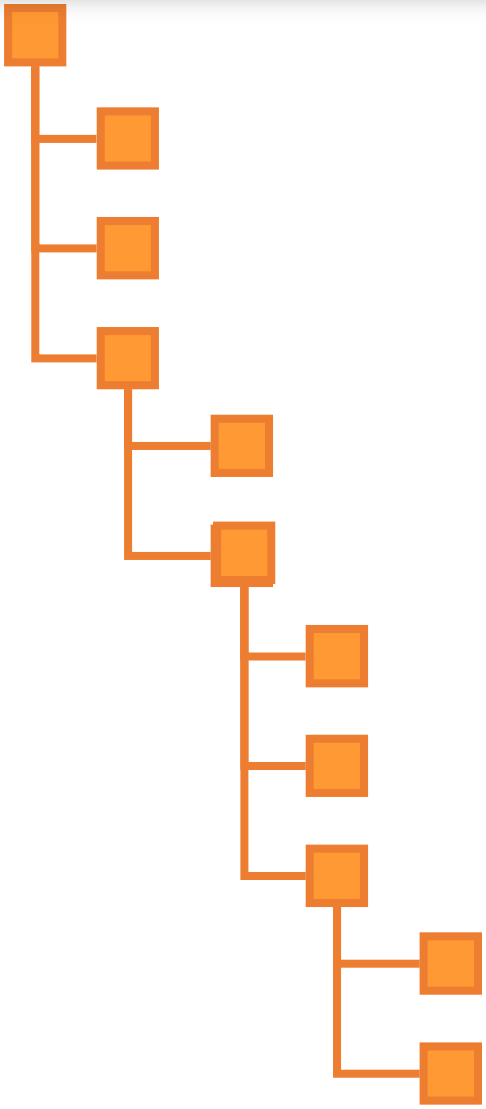
HOW DO YOU
KNOW SERVICE
WAS DELIVERED ?

PAY-PER-ANALYTICS model in a SERVICE ECOSYSTEM ?

CUSTOMER
PAYS ONLY FOR QUALITY
OF SERVICE DELIVERED

WHO INTEGRATES
THE END-2-END
SERVICE PLATFORM?

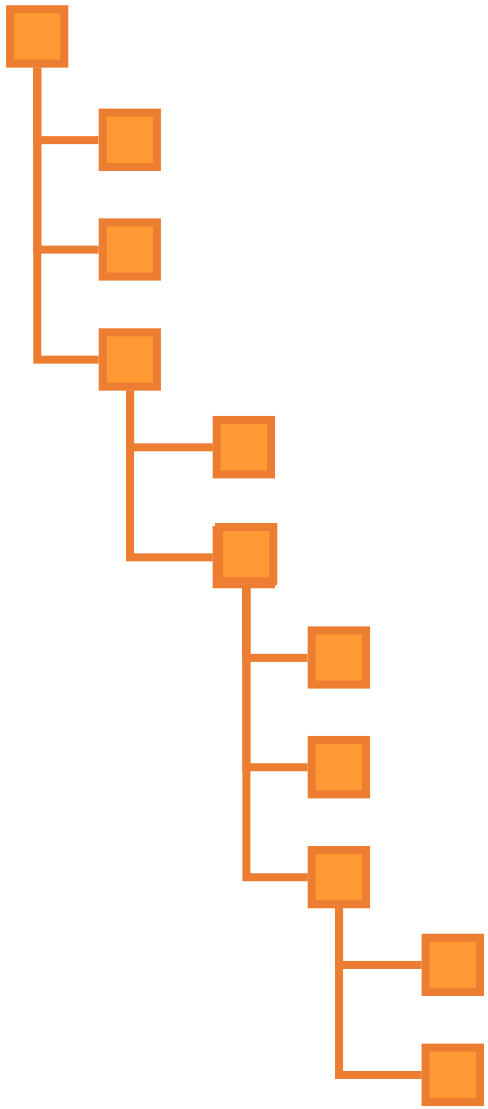
PAY-PER-INSTANCE from PoC in SERVICE ECOSYSTEMS



Sets, Subsets, Identification, Relation, Data – Unique Digital Ledger Entry

WHO WILL
RECEIVE HOW MUCH
OF THE PAYMENTS ?

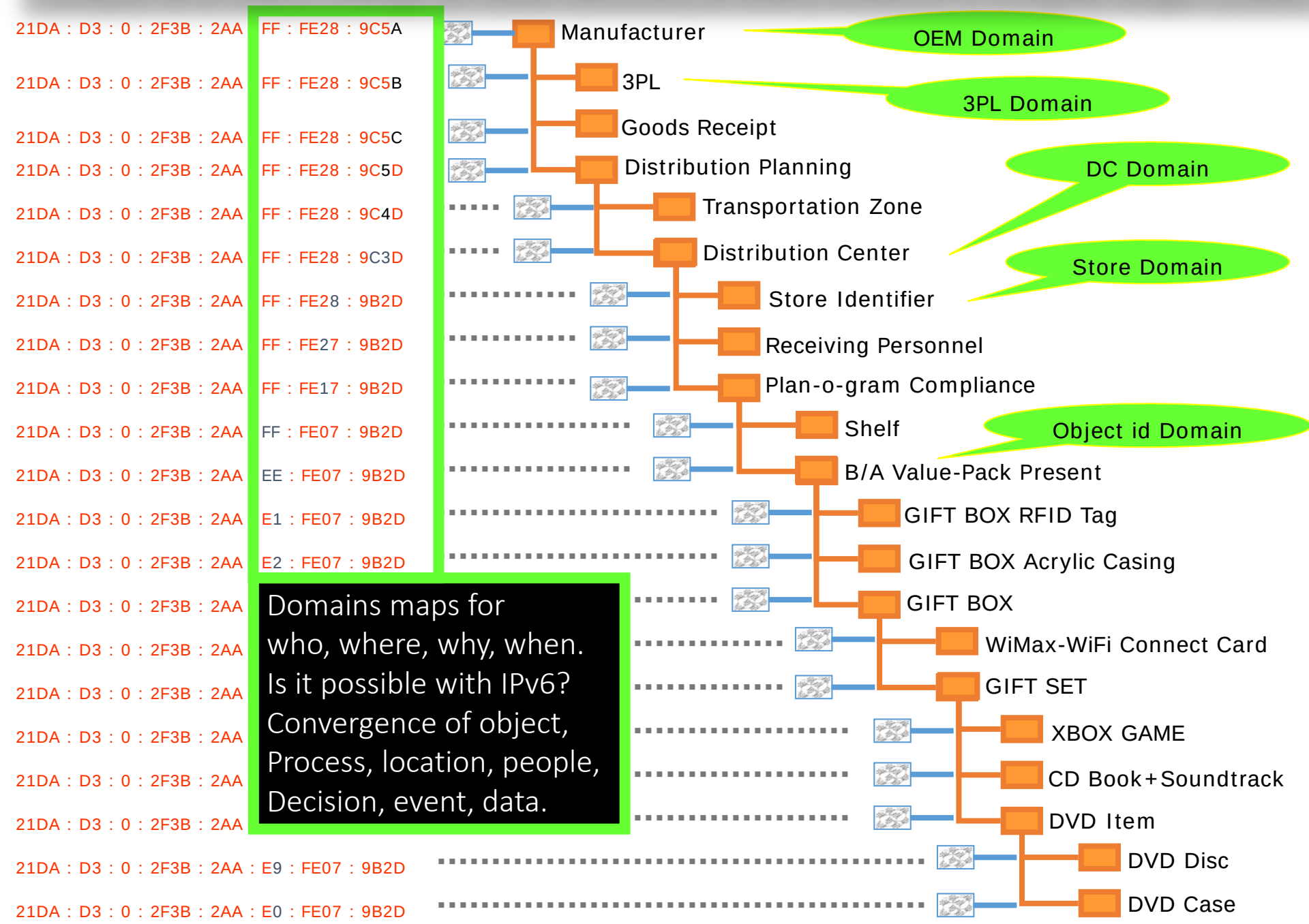
HOW DO YOU
KNOW SERVICE
WAS DELIVERED ?



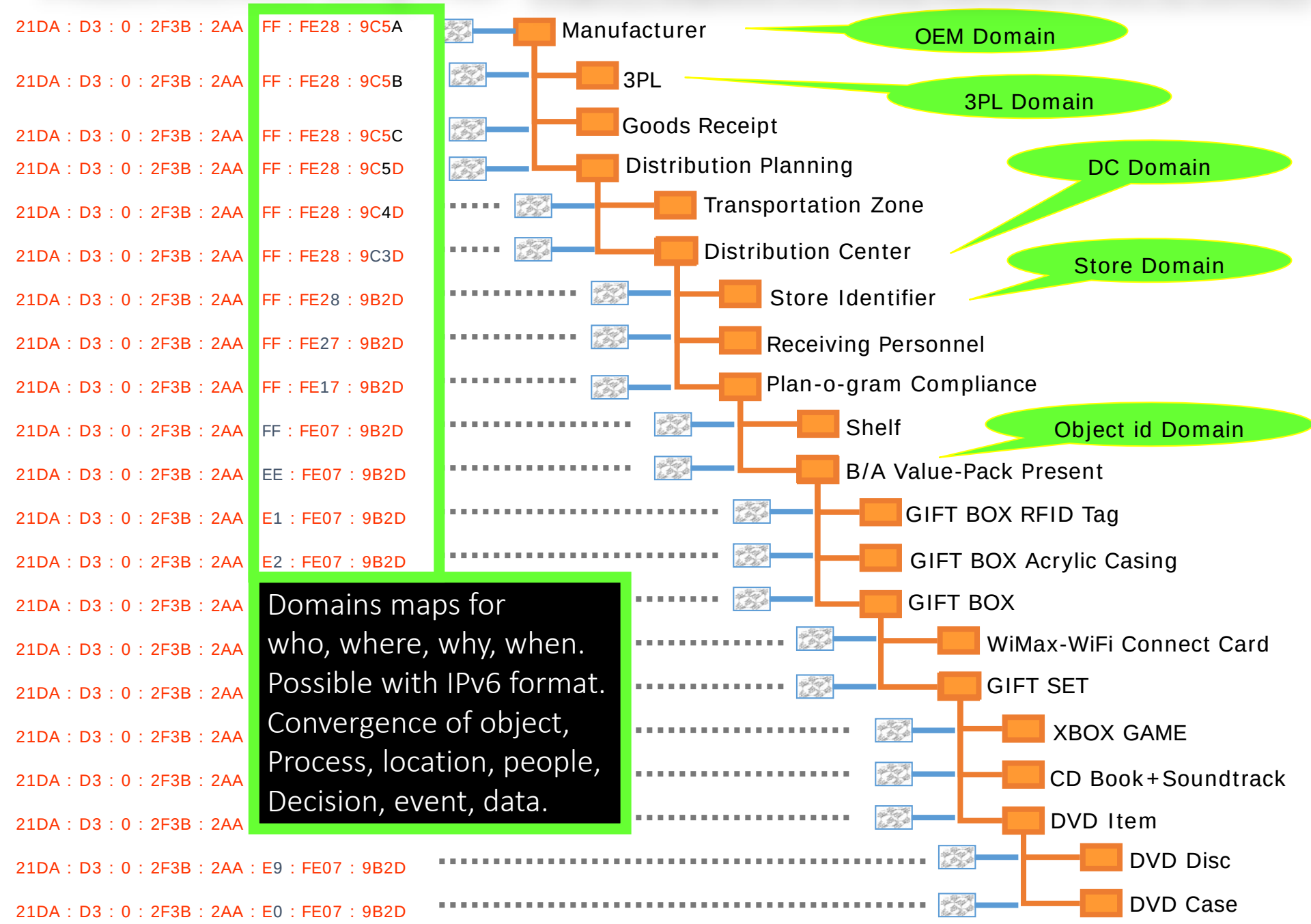
CUSTOMER
PAYS ONLY FOR QUALITY
OF SERVICE DELIVERED

WHO INTEGRATES
THE END-2-END
SERVICE PLATFORM?

Unique id of every change (in state function) at every instance in a digital ledger (2006)



PreBLOCKCHAIN using IPv6? https://dspace.mit.edu/handle/1721.1/104429



Digital Ledger

PRELUDE TO BLOCKCHAIN

Healthcare worries in FinTech
3,550 crypto-coins and other non-currency applications of distributed digital ledgers don't talk to each other!

Why the prelude to distributed digital ledger focus on the IPv6 format?

Standards-Interoperability

WWW "internet" grew from 13 million users in 1994 to 4 billion in 2016, due to set of common standards for displaying and sharing information. It didn't "just happen" – individuals and entities came together (IETF, W3C) to bridge and help foster standards.

Windhover Principles, CBDC, Chain, R3CEV, InterLedger, HyperLedger are efforts (?) in progress for Fintech. http://bit.ly/MIT-WINDHOVER

Symbol	Name	Mined Coins	Difficulty	Price	Volume	Marketcap	Logarithmic
BTC	Bitcoin	16,019,637	286766000000	1.00 BTC	106,409.52 BTC	12,618,638,920.00 USD	
LTC	Litecoin	48,702,029	67726.9	0.01 BTC	71,352.66 BTC	194,114,486.40 USD	
TRUMP	Trump	1,000,000,000	0	0.07 mBTC	1.43 BTC	58,919,960.00 USD	
XEM	NEM	8,999,999,999	0	4.53 µBTC	88.21 BTC	32,114,529.00 USD	
DOGE	DogeCoin	97,102,803,758	23847.7	0.27 µBTC	85.14 BTC	20,651,761.06 USD	
SHIFT	Shift	1,000,000,000	0	0.02 mBTC	1.01 BTC	17,250,630.00 USD	
NXT	Nxt	1,000,000,000	0	0.01 mBTC	38.74 BTC	5,978,643.00 USD	
PPC	Peercoin	21,421,191	13.053	0.30 mBTC	41.75 BTC	5,062,043.77 USD	
VIRAL	Viral	1,000,000,000	0	3.85 µBTC	0.51 BTC	3,032,645.00 USD	
AUR	Auroracoin	14,206,697	248.975	0.15 mBTC	1.03 BTC	1,678,706.86 USD	
QRK	Quarkcoin	248,250,110	677.182	4.50 µBTC	0.56 BTC	879,963.30 USD	
IFC	InfiniteCoin	90,596,277,249	0	0.01 µBTC	0.51 BTC	713,627.06 USD	
EAC	EarthCoin	9,346,468,332	237.106	0.09 µBTC	4.13 BTC	662,599.06 USD	
FTC	Feathercoin	97,440,952	189.802	0.01 mBTC	1.49 BTC	593,310.61 USD	
CLAM	CLAMS	624,000	0	0.89 mBTC	24.83 BTC	436,380.29 USD	
ZET	ZetaCoin	160,594,207	29126.7	3.13 µBTC	0.17 BTC	395,945.28 USD	
DVC	Devcoin	7,519,170,050	14338200000	0.06 µBTC	0.75 BTC	355,370.86 USD	
NVC	Novacoin	774,262	324.544	0.53 mBTC	2.17 BTC	323,239.78 USD	
WDC	WorldCoin	53,342,916	11.3756	0.01 mBTC	1.61 BTC	305,892.27 USD	
TIPS	Fedoracoin	127,010,319,285	277.966	0.00 µBTC	2.52 BTC	267,773.10 USD	
MEC	MegaCoin	18,353,750	10.557	0.02 mBTC	12.22 BTC	260,664.11 USD	
VTC	VertCoin	10,413,700	283.47	0.03 mBTC	3.07 BTC	230,418.79 USD	
ROYAL	Royal	1,000,000,000	0	0.20 µBTC	0.12 BTC	157,540.00 USD	
BQC	BBQCoin	35,687,158	3.544	0.01 mBTC	0.17 BTC	156,857.85 USD	
DGC	Digitalcoin	14,808,023	3.9736	0.01 mBTC	0.55 BTC	133,439.53 USD	
DMD	Diamond	369,496	0.939	0.30 mBTC	0.94 BTC	88,043.59 USD	
DRACO	DTToken	88,888,888	0	1.05 µBTC	0.23 BTC	73,518.64 USD	
NOBL	NobleCoin	752,475,000	5.972	0.11 µBTC	0.63 BTC	65,199.66 USD	
DIME	Dimecoin	206,602,469,376	0	0.00 µBTC	0.11 BTC	54,680.72 USD	
MZC	Mazacoin	307,130,100	2142480	0.22 µBTC	0.13 BTC	53,223.79 USD	
NET	Netcoin	209,704,698	13.783	0.16 µBTC	0.15 BTC	26,429.54 USD	
WAVES	OCEANWAVE	1,000	0	0.32 mBTC	53.69 BTC	249.70 USD	

www.cryptocoincharts.info/coins/info

US NIST CyberPhysical Systems Reference Architecture

www.nist.gov/programs-projects/reference-architecture-cyber-physical-systems

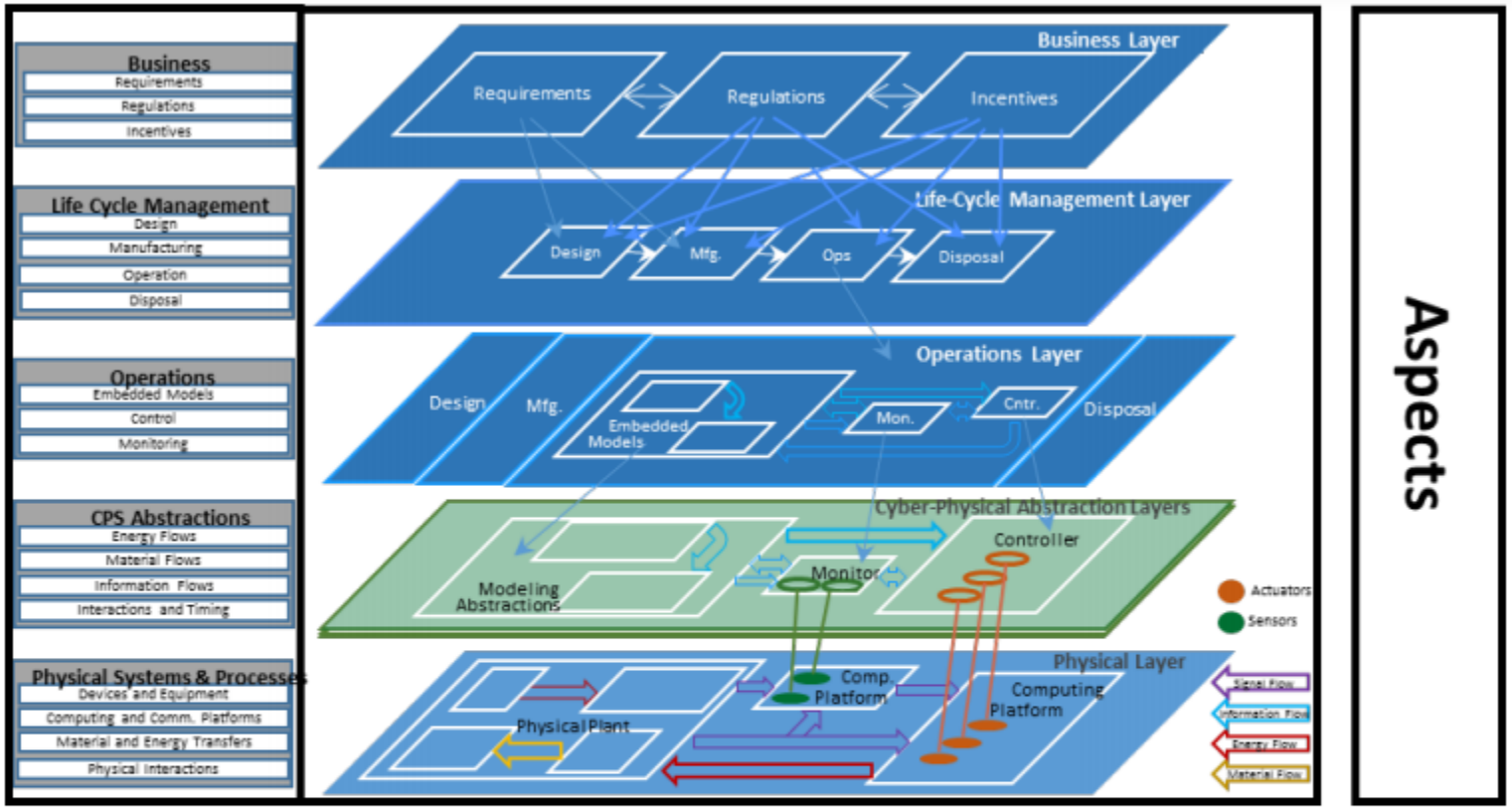


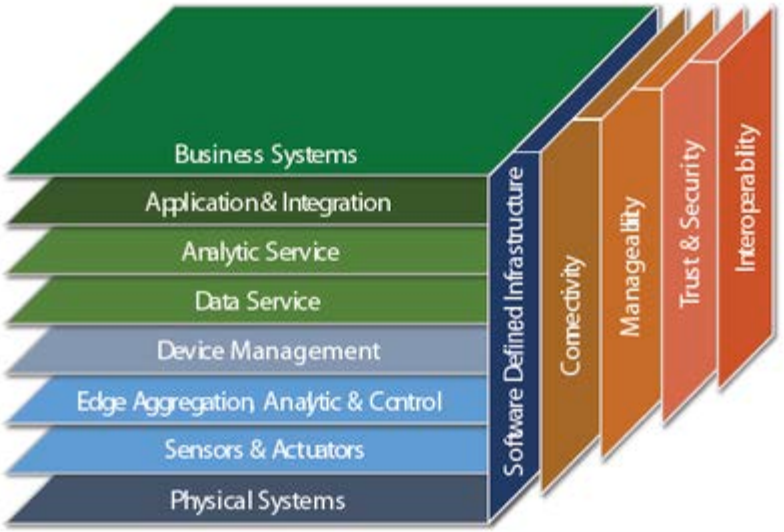
Figure 11: Realization Facet

Figure 11 captures key conceptual layers of the realization facet. Each layer is associated with concepts, components, and notional architectures that can be instantiated into layer- and domain-specific CPS architectures.

CPS PWG Draft Framework for Cyber-Physical Systems, Release 0.8

https://s3.amazonaws.com/nist-sgcps/cpspwg/pwgglobal/CPS_PWG_Draft_Framework_for_Cyber-Physical_Systems_Release_0_8_September_2015.pdf

IIoT Architectural Framework https://www.iiconsortium.org/IIRA-1-7-ajs.pdf



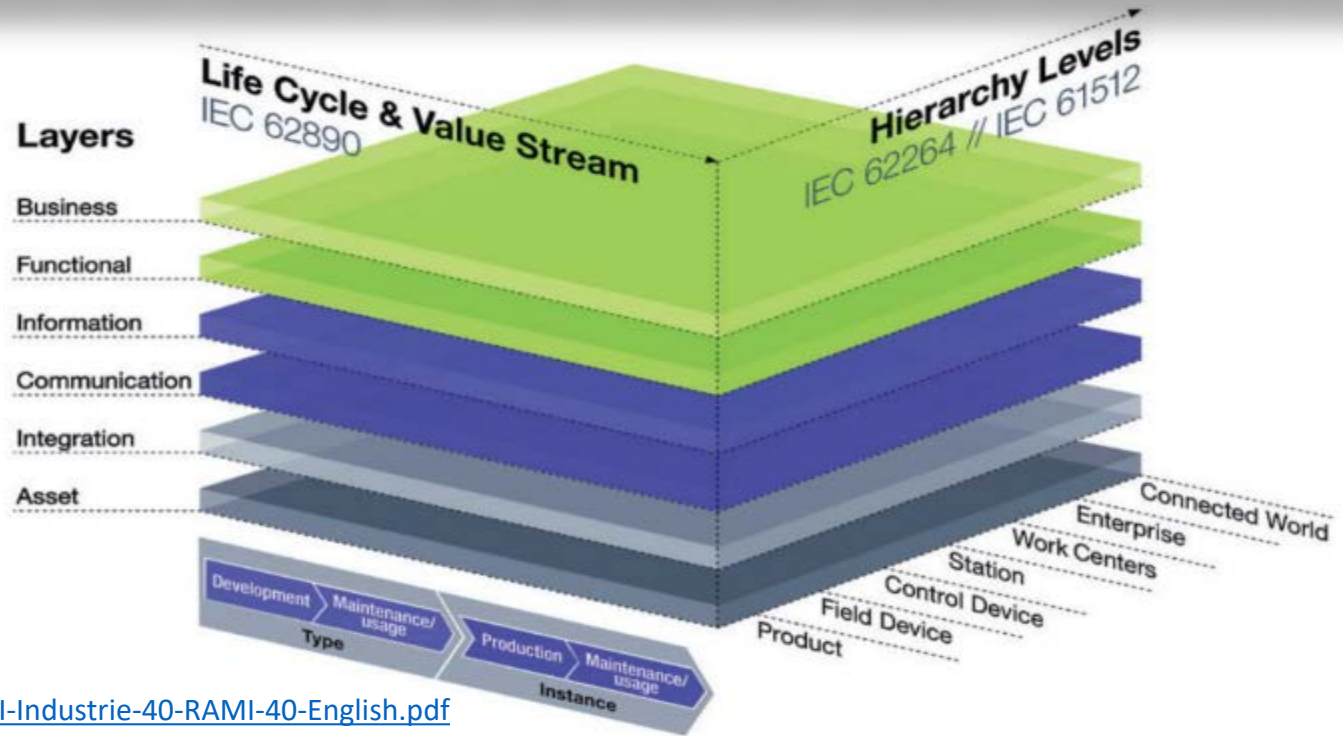
CPS, IIoT, IoT

Global Standards

Reference Architectures

Elusive Quest for Interoperability

IIoT Reference Architecture from Industrial Internet Consortium (L) and Industrie 4.0 (R)



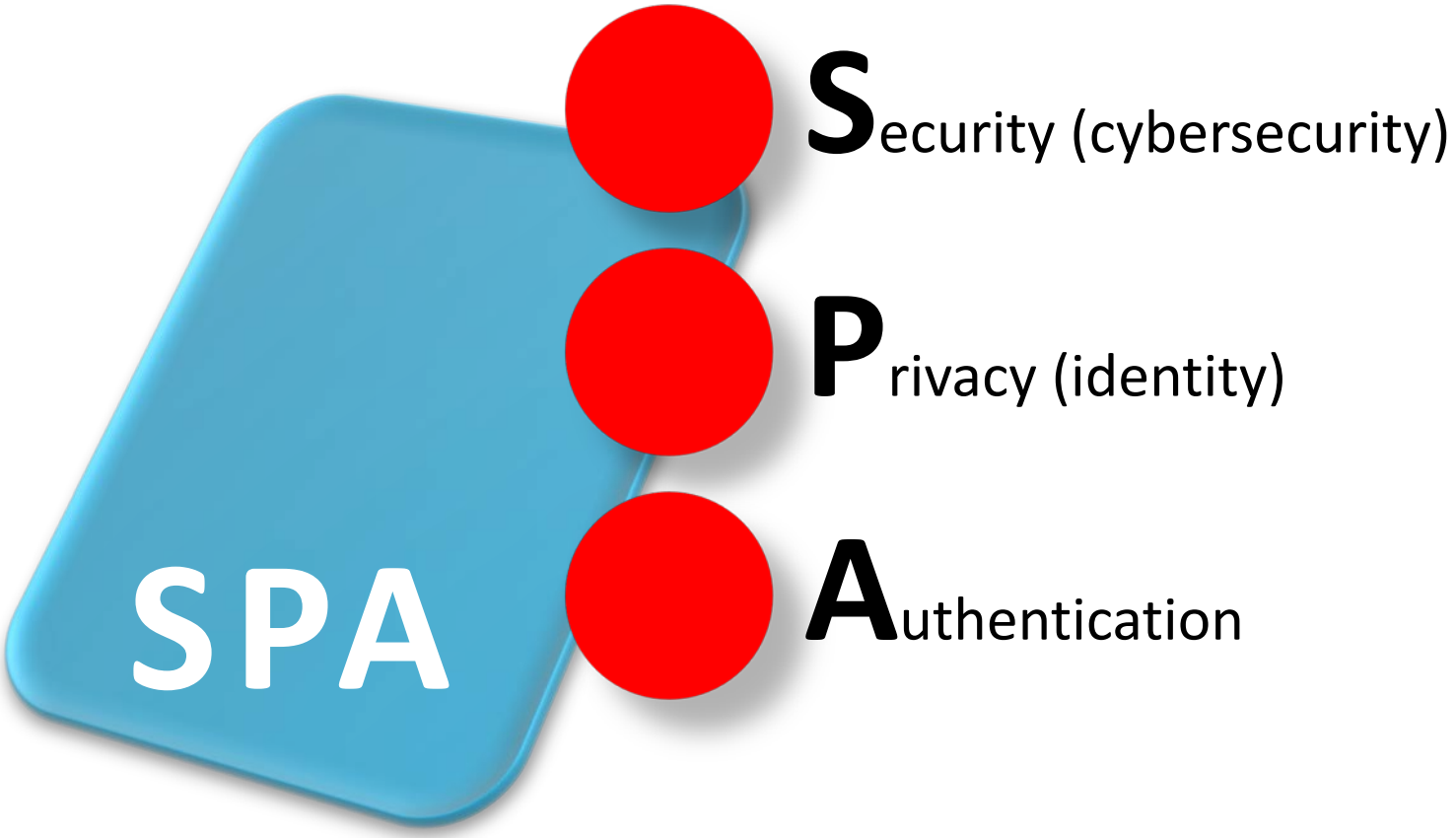
www.zvei.org/Downloads/Automation/ZVEI-Industrie-40-RAMI-40-English.pdf

The IT / OT Divide

CYBERSECURITY

How to turn Problems to Profitable Solutions

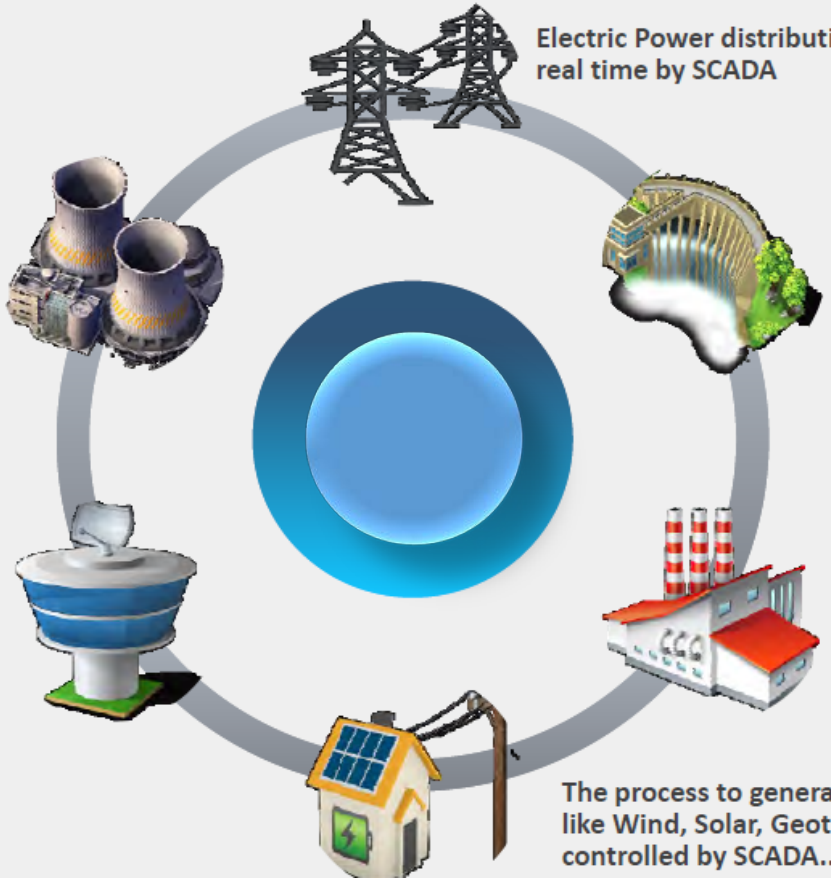
What is slowing down the pace of progress in diffusion and adoption of IoT and IIoT ?



Please remind yourself about these two quotes – great opportunities are often brilliantly disguised as impossible situations and catastrophies or problems are immense opportunities in work clothes.

Cybersecurity was not conceived during the development of Industrial Control Systems

Supervisory Control and Data Acquisition Systems and Programmable Logic Controllers



Electric Power distribution. Substation are controlled in real time by SCADA

Some areas inside a nuclear plant are controlled by SCADA , such as: turbine, centrifuge...

Water Supply network. In water distribution stations SCADA allow the optimum functioning of the pumping systems, obtaining efficient energy usage, optimum administration of the drinkable water.

Railway, air control.. Are controlled by SCADA

In any factory, from car till pens, most part of the factory, like cells, factory-floor, robots.. Are controlled by SCADA.

The process to generate alternative Energy, like Wind, Solar, Geothermal, Biomass, are controlled by SCADA..

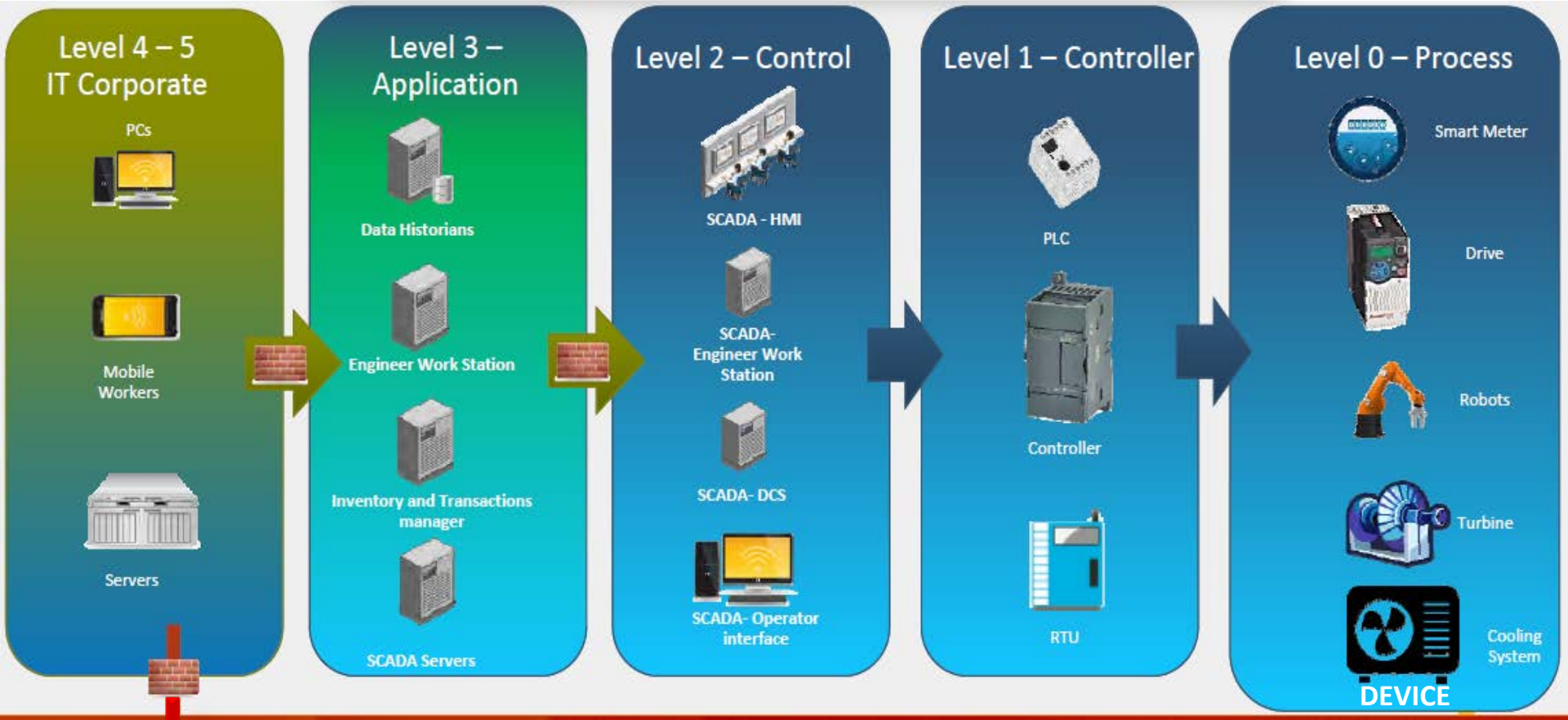
Distributed Control Systems – IT vs OT Chasm

IT		OT
"Open" Easy to install	*Openness*	**"Closed"** Not open to new software after the device leaves the factory
"3" (Mostly UDP, TCP, IP)	*Protocols*	**Thousands of Protocols** (Hundreds in each vertical)
"Updated" (Windows 7, 8, 10, 2008, RH 6, 7)	*Operating Systems (OS)*	**Legacy** (Windows NT, 2003, XP)
3-5 years (Typical Enterprise)	*Lifetime*	**10-20 years**
Mostly **same** Hardware, OS supply chain	*Fragmentation*	Very large number of Hardware, OS implementations
Limited relevance	*Latency*	**Highly critical**
"No Critical" Systems can be updated with more HW	*Performance*	**"Critical"** No impact on performance, legacy HW with small resources

Distributed Control Systems

IT

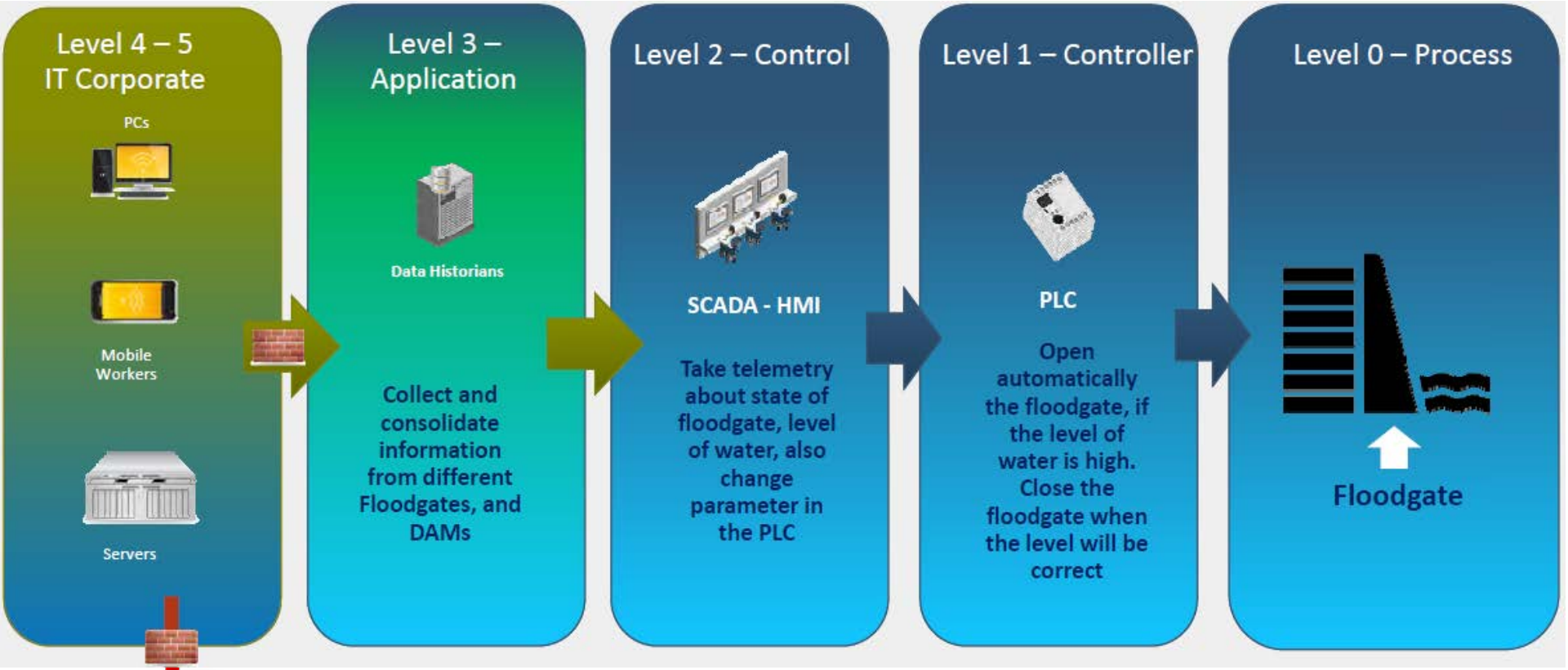
OT



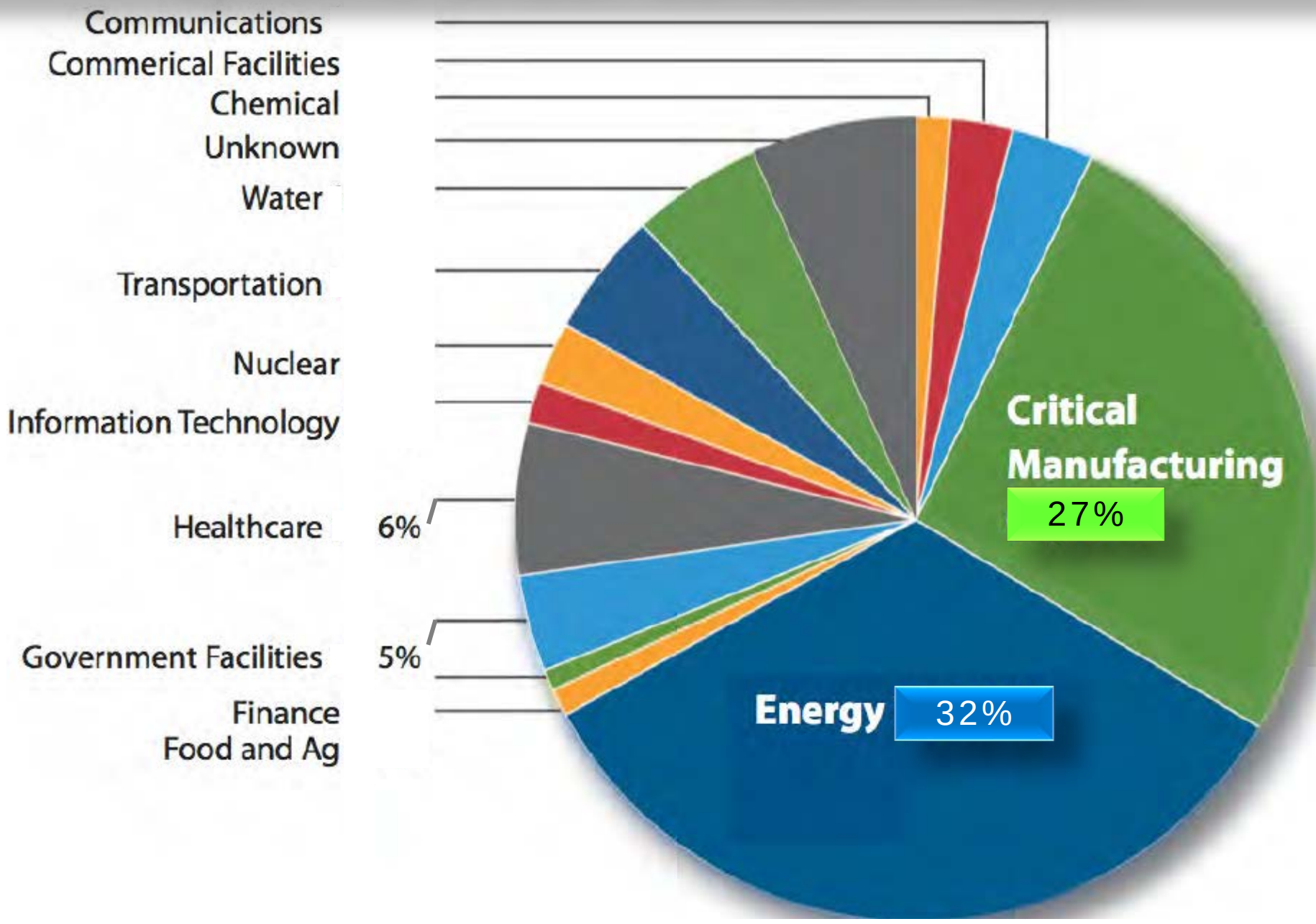
Distributed Control Systems

IT

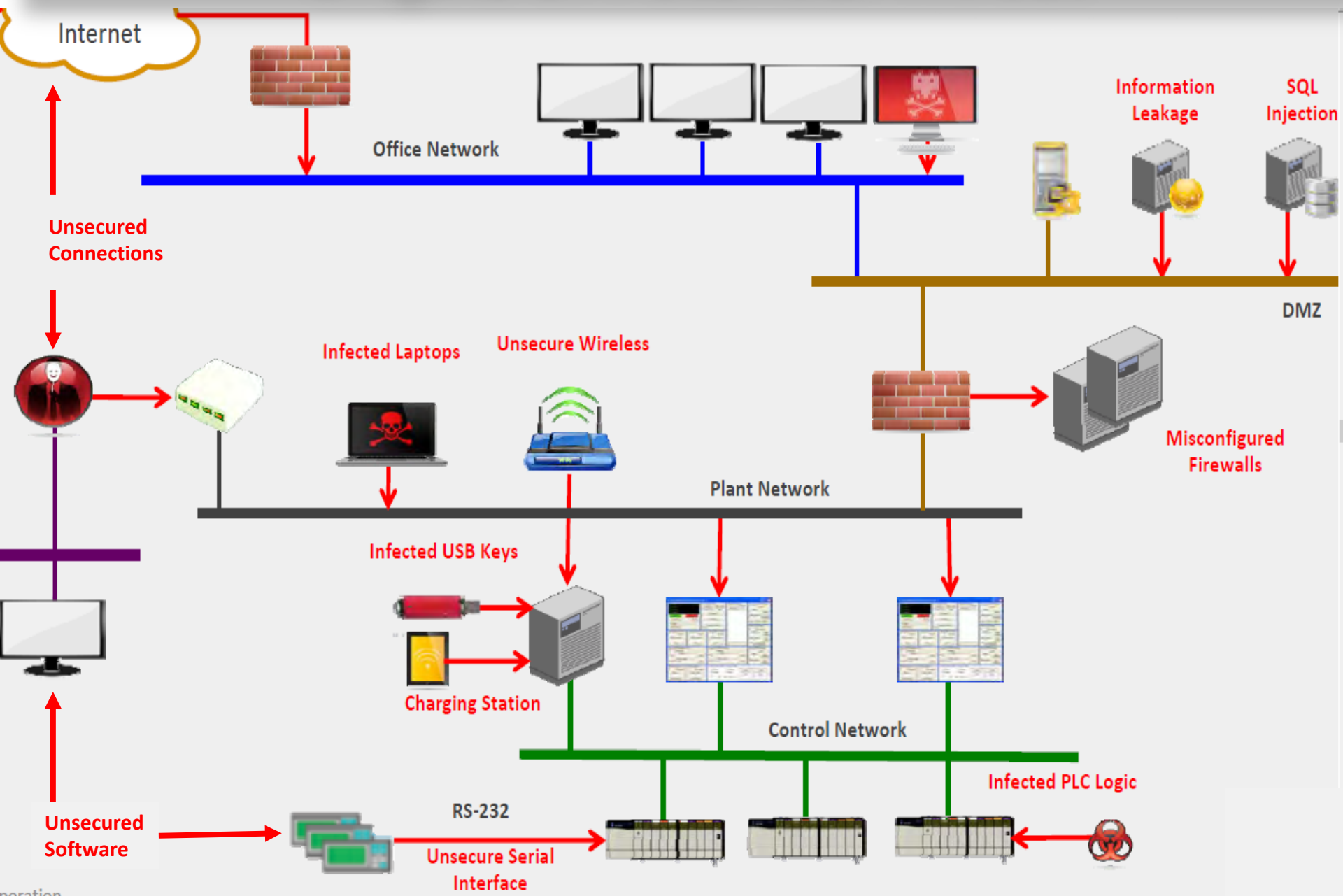
OT



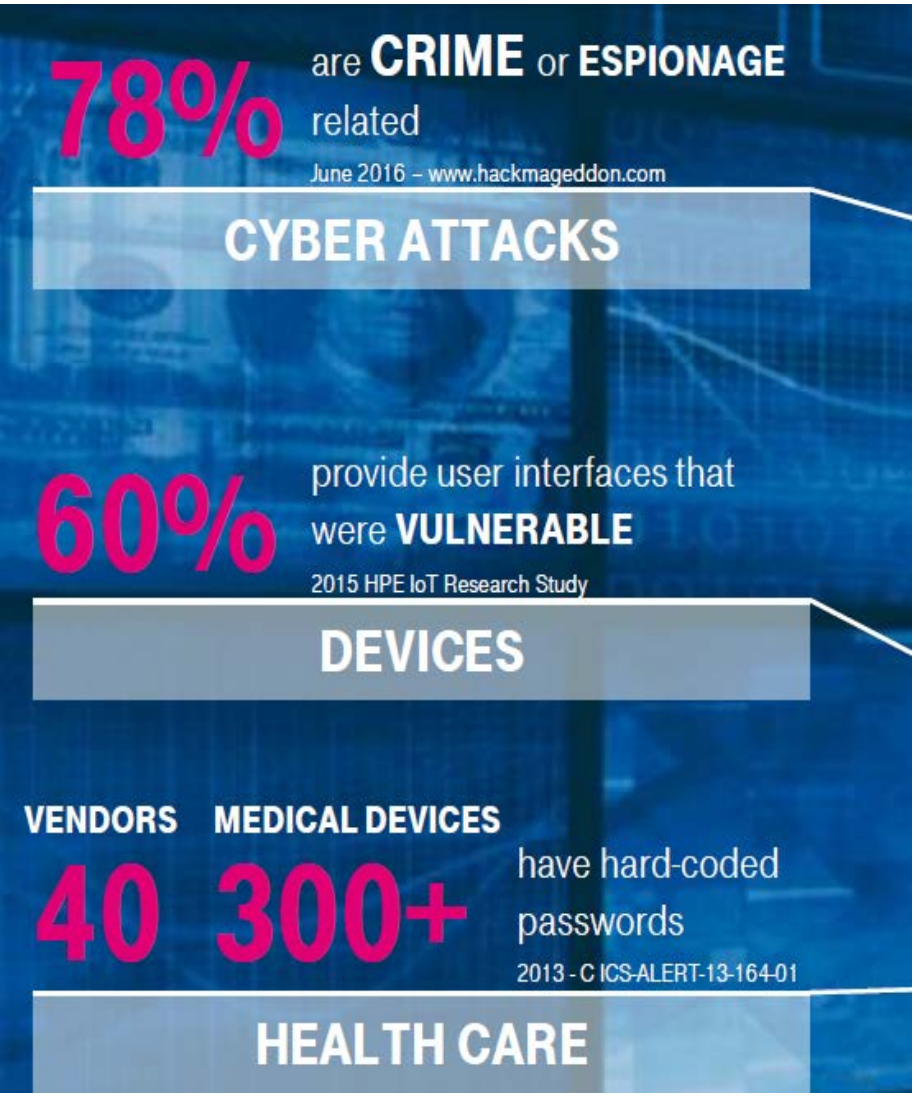
Systems Under Constant Attack

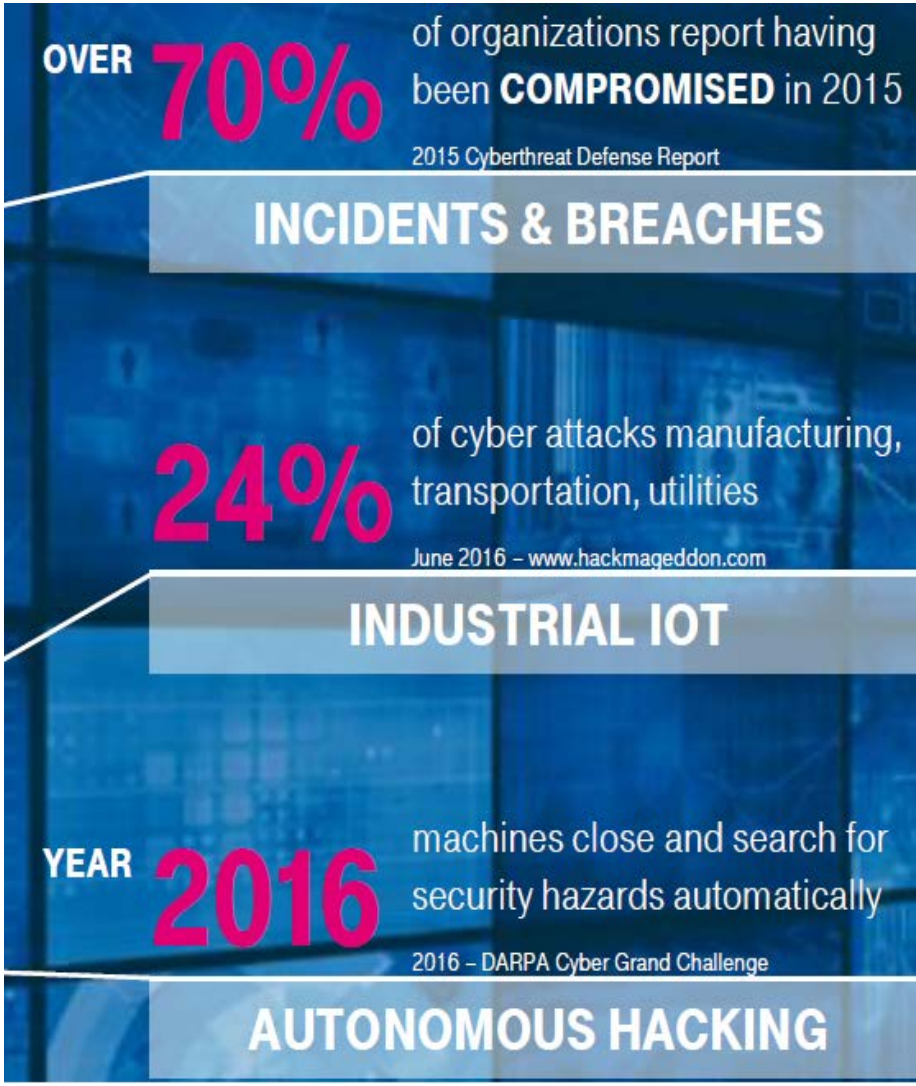


Origins of Potential Threat

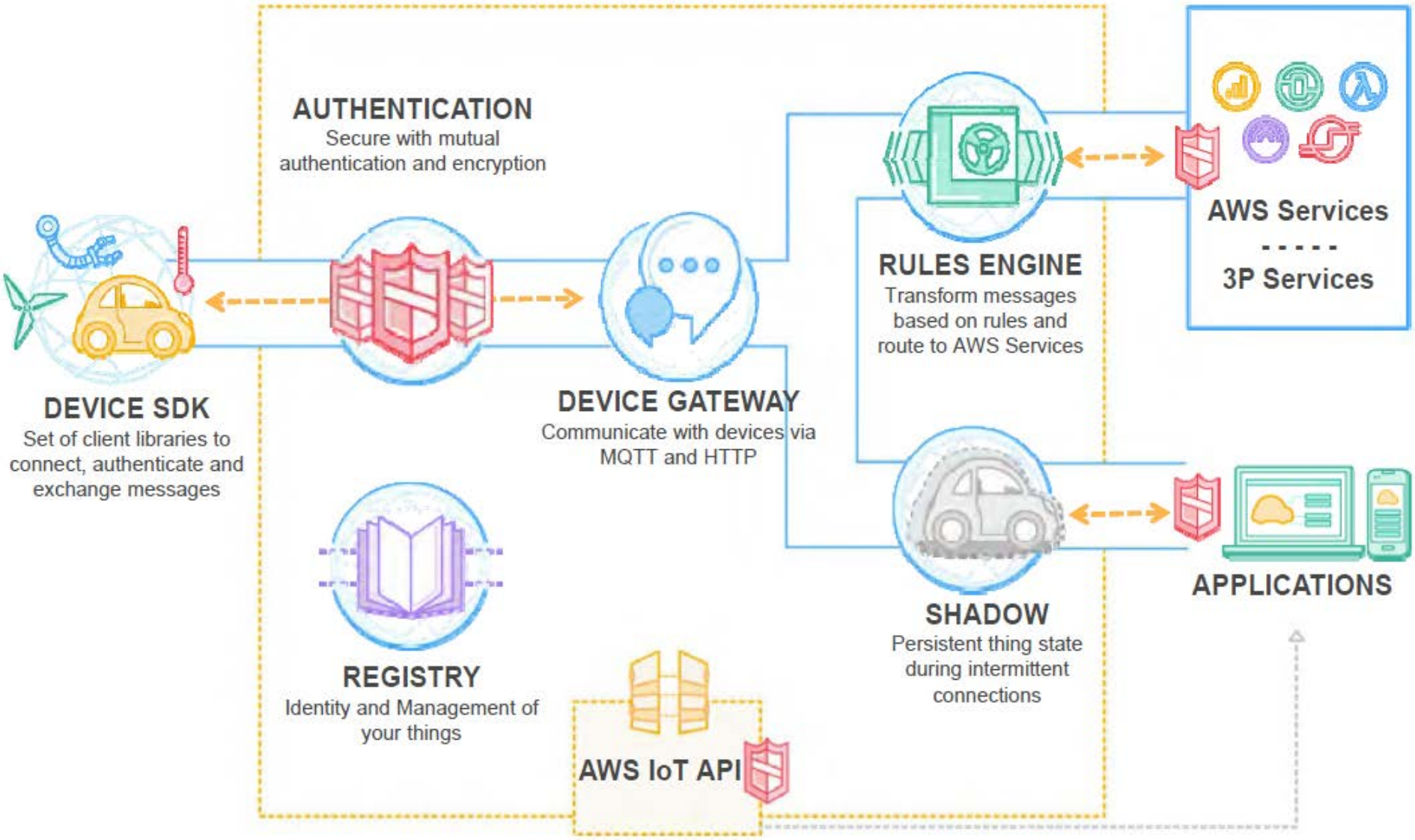


Risk for Systems and Vulnerable Targets

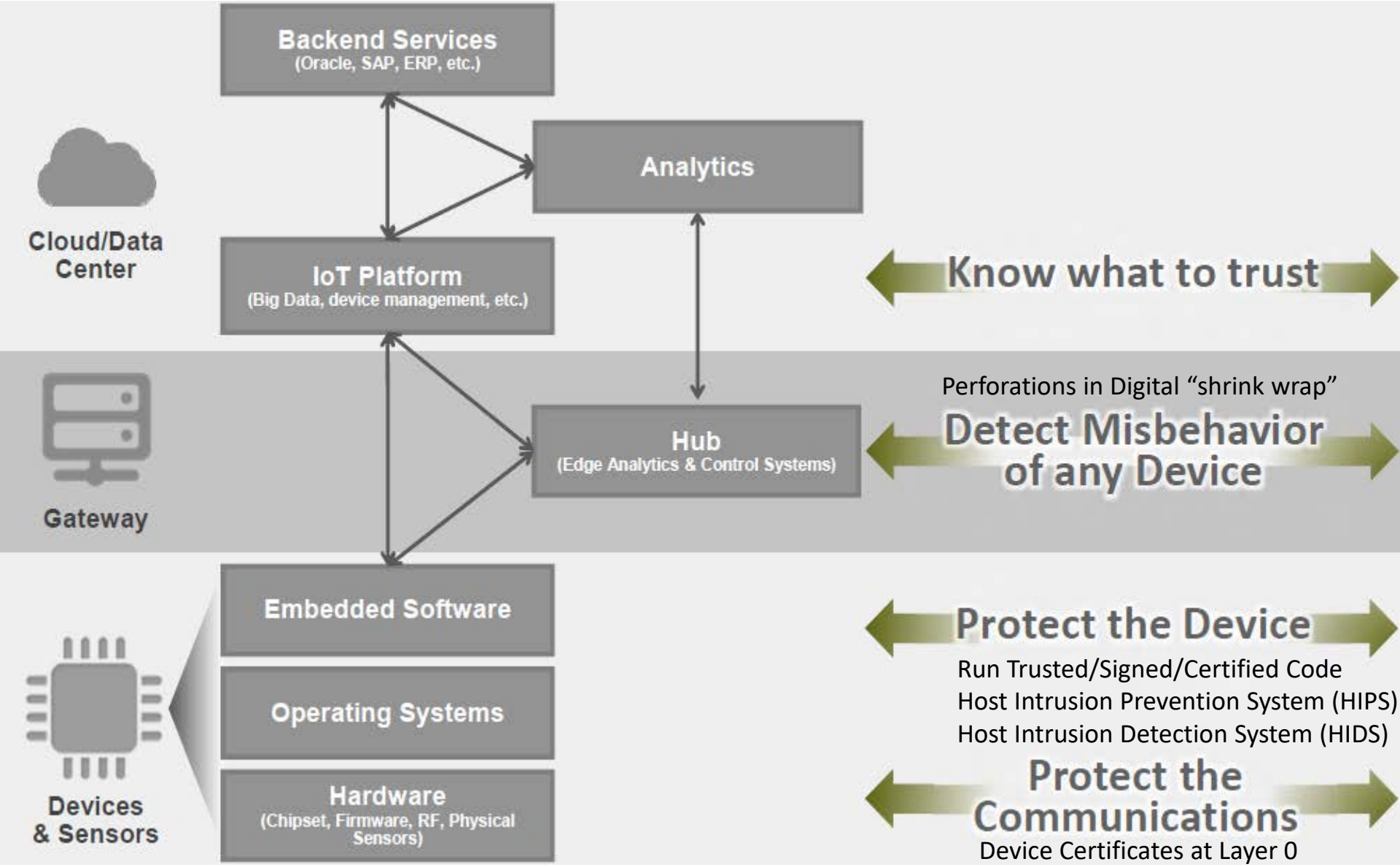




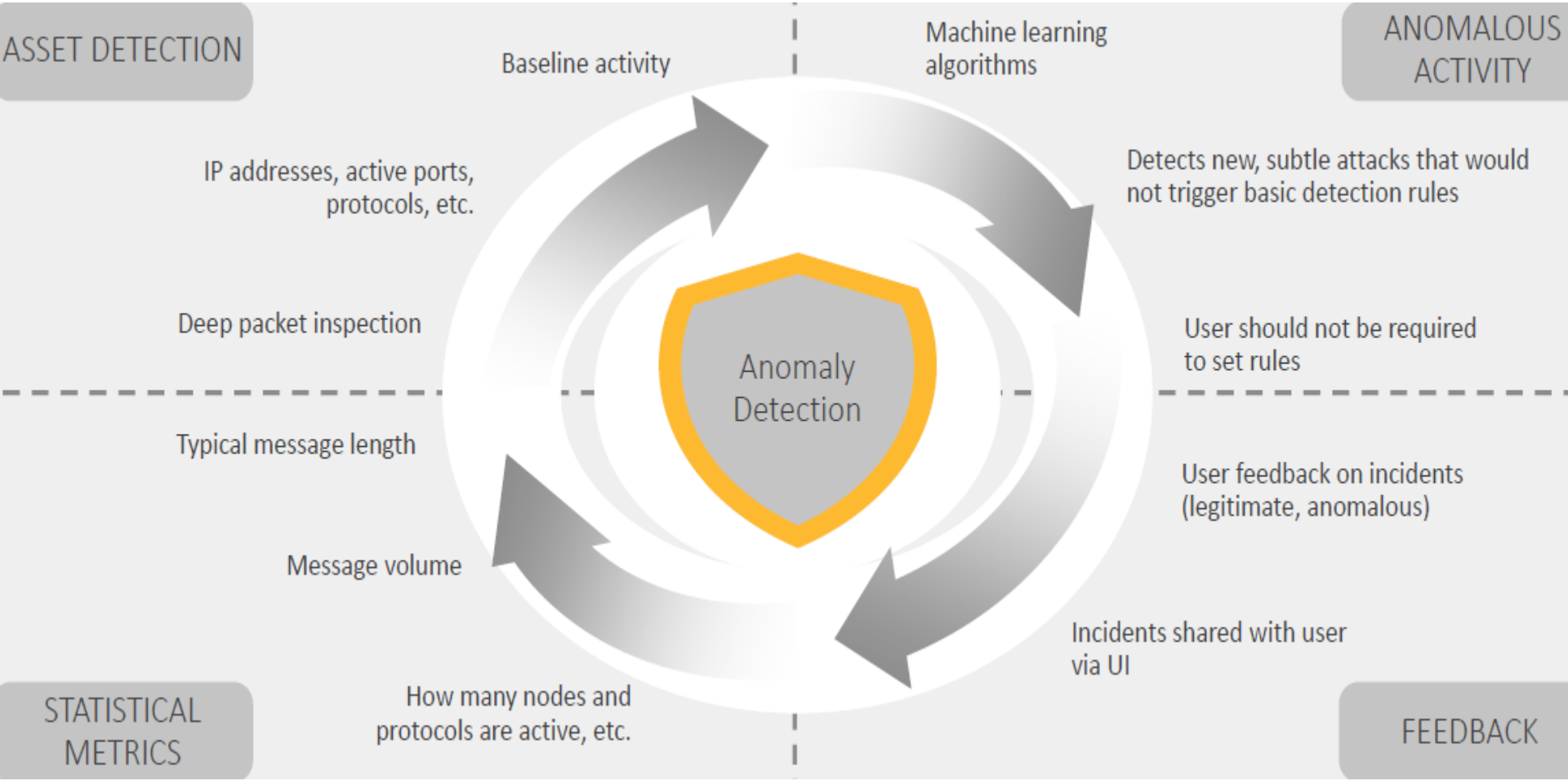
Identification, Identity and Security Steps



Mitigating Threats and Attack



Understanding Networks to Prevent Attack



Every human, every object, every piece of data needs personal security agent(s)

CYBERSECURITY

https://dspace.mit.edu/handle/1721.1/107988

https://blogs.fda.gov/fdavoice/index.php/2017/06/fostering-medical-innovation-a-plan-for-digital-health-devices/

www.nist.gov/sites/default/files/documents/2017/01/30/draft-cybersecurity-framework-v1.1.pdf

www.healthit.gov/sites/default/files/Draft_White_Paper_PGHD_Policy_Framework.pdf

US warns of unusual cybersecurity flaw in heart devices

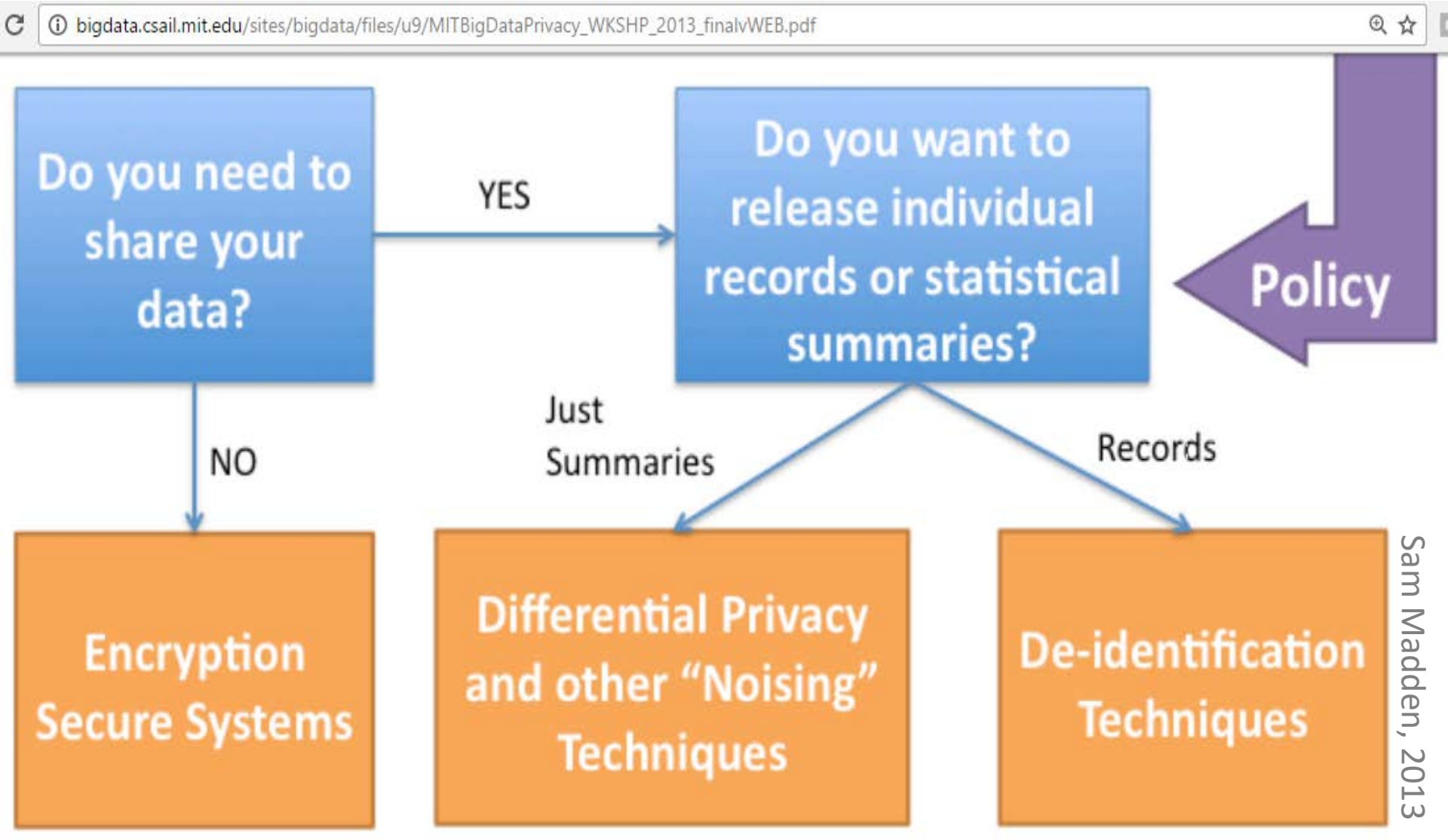
Homeland Security Department is warning the public about an unusual cybersecurity flaw for one manufacturer's implantable heart devices that could allow hackers to remotely take control of a person's defibrillator or pacemaker. The U.S. says security patches will be rolled out automatically over several months to patients with affected St. Jude Medical device transmitters at home, as long as they are plugged into the network. The transmitters send device data back to medical professionals. Abbott Laboratories' St. Jude says it's not aware of any deaths or injuries related to the vulnerability, nor is it aware of any specific device or system that's been targeted. (Glen Stubbe/Star Tribune via AP, File)

The company's Merlin@home Transmitter electronically sends details on the device's performance to a website where the patient's physician can review the information. But that device can also be hacked.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5052027/

Personal Security Agents / Unique Digital ID

Security and privacy are linked, in many instances, for individuals and for personal data (eg health)




IN CASE OF
CYBERATTACK
BREAK GLASS
AND PULL CABLES

R&D Investment in Science and Engineering

Immense Market Growth & Business Opportunities

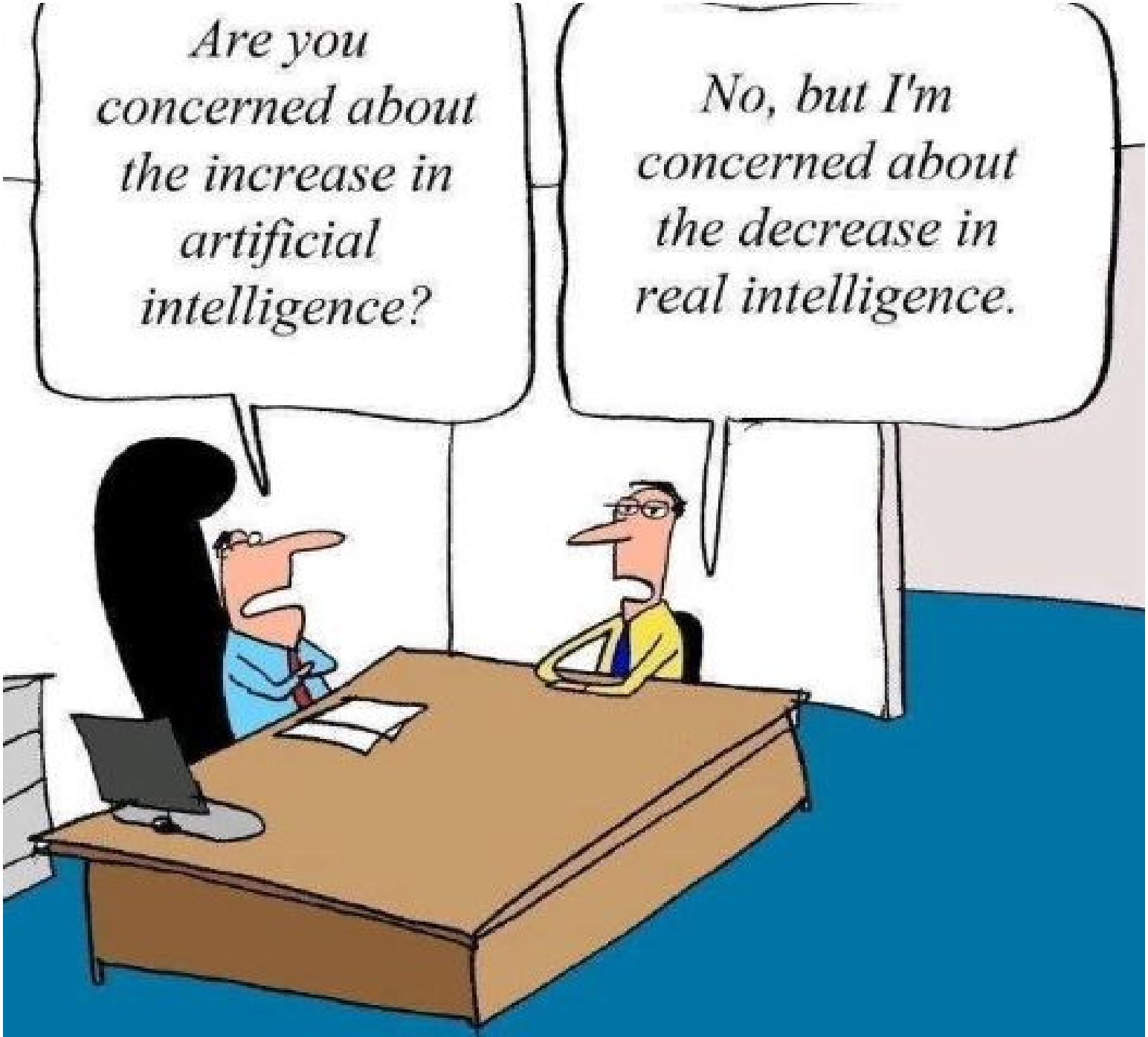
FOOD, ENERGY, WATER, HEALTHCARE, TELCO, TRANSPORT, FINTECH

http://bit.ly/IOT-MIT

http://bit.ly/Amorphous-Certainties

https://www.whitehouse.gov/sites/default/files/microsites/ostp/ostp_exit_memo_final.pdf

The biggest threat to innovation is internal politics and an **organizational culture**, which doesn't accept failure and/or doesn't accept ideas from outside, and/or cannot change.

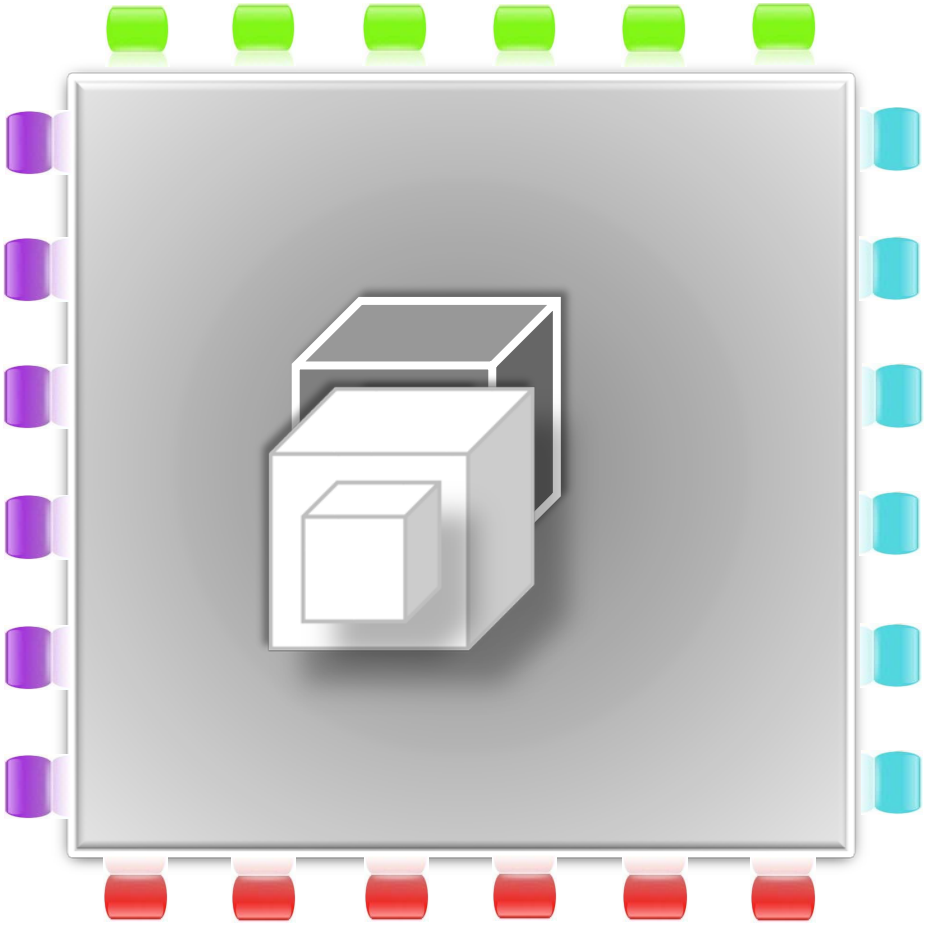

Are you concerned about the increase in artificial intelligence?
No, but I'm concerned about the decrease in real intelligence.

Ready to Get Started?

Differentiate, decompose, solve, synthesize, repeat

A Guide To Asking Granular Questions

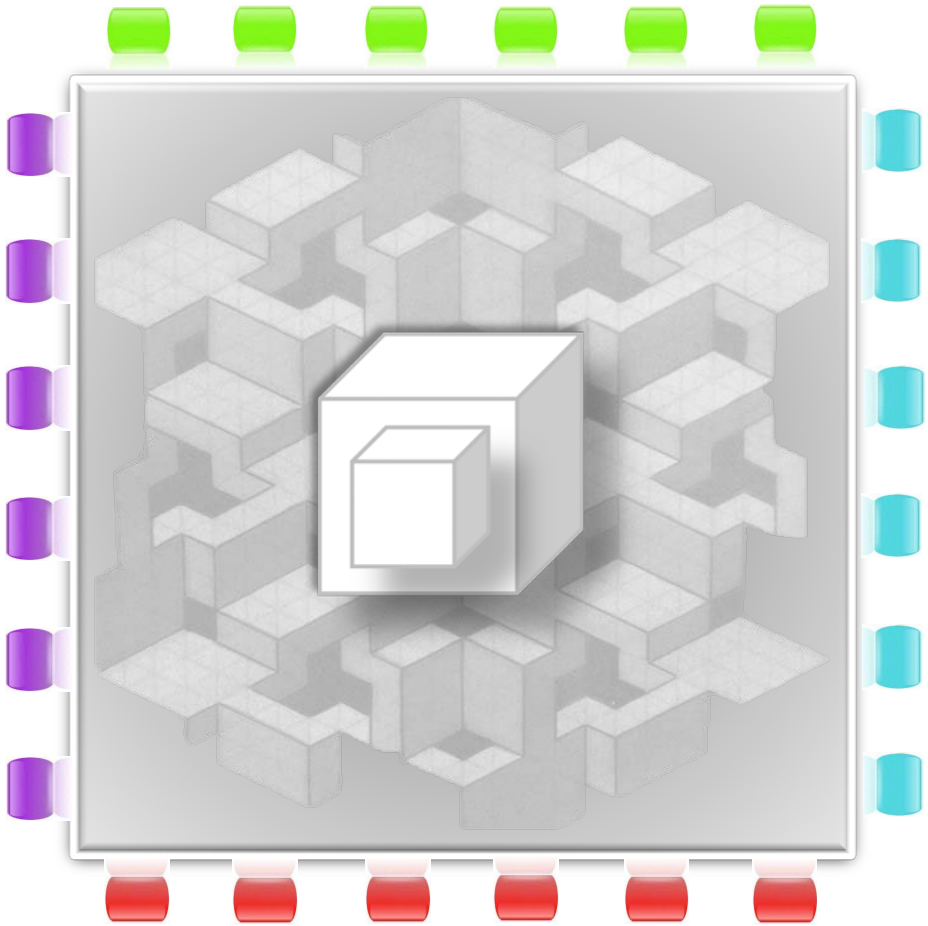
https://dspace.mit.edu/handle/1721.1/106496



Differentiate, Unpack, Decompose, Solve, Synthesize, Evaluate, Repack, Reproduce, Deploy

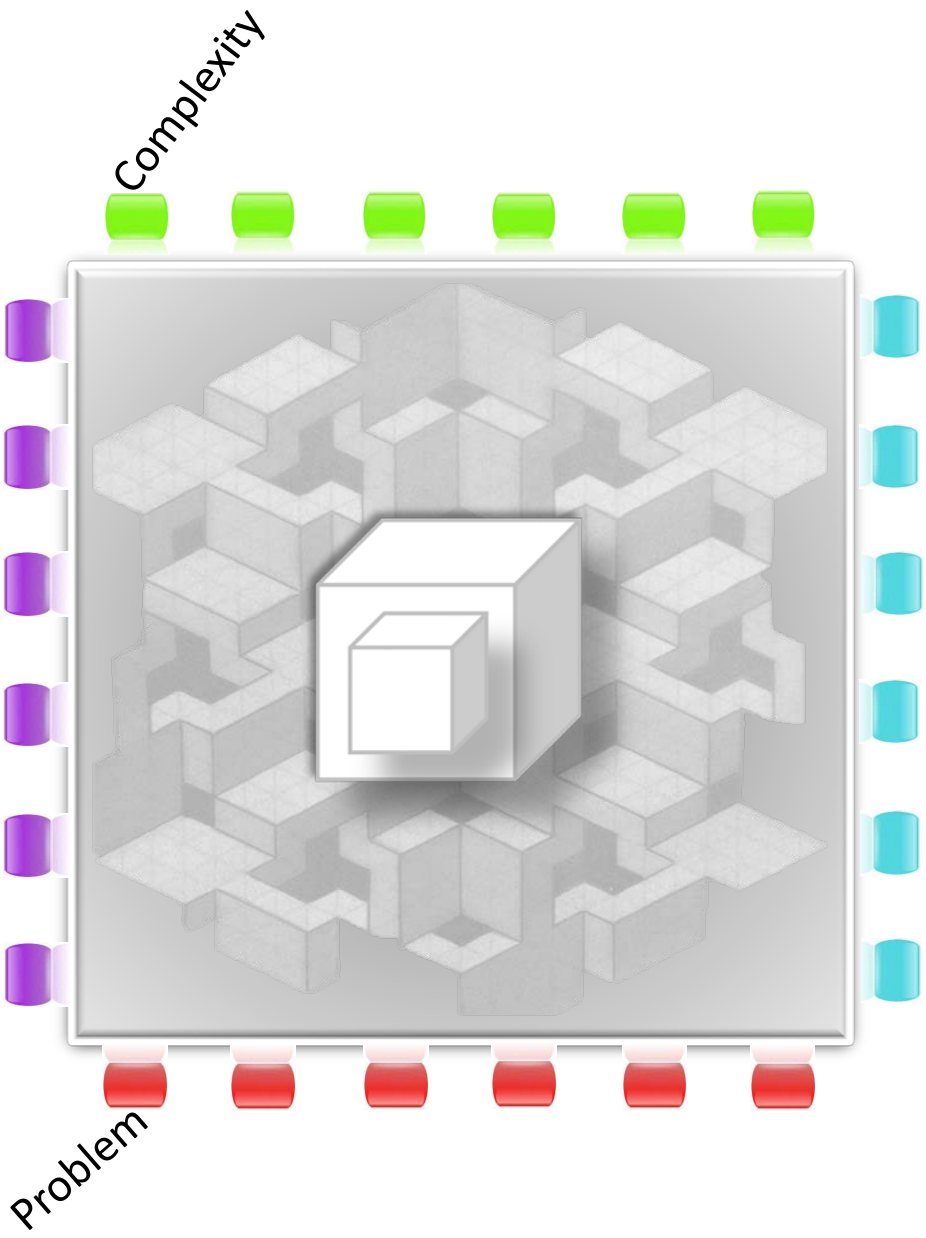
The following series of steps are a compass. The outcome may catapult you to places least expected. This is a fraction of what needs to happen, over and again, in order to determine how to transform vision and research, into reality and applications to improve quality of life, community and increase profitability.

The most difficult part is to differentiate and isolate the problem.

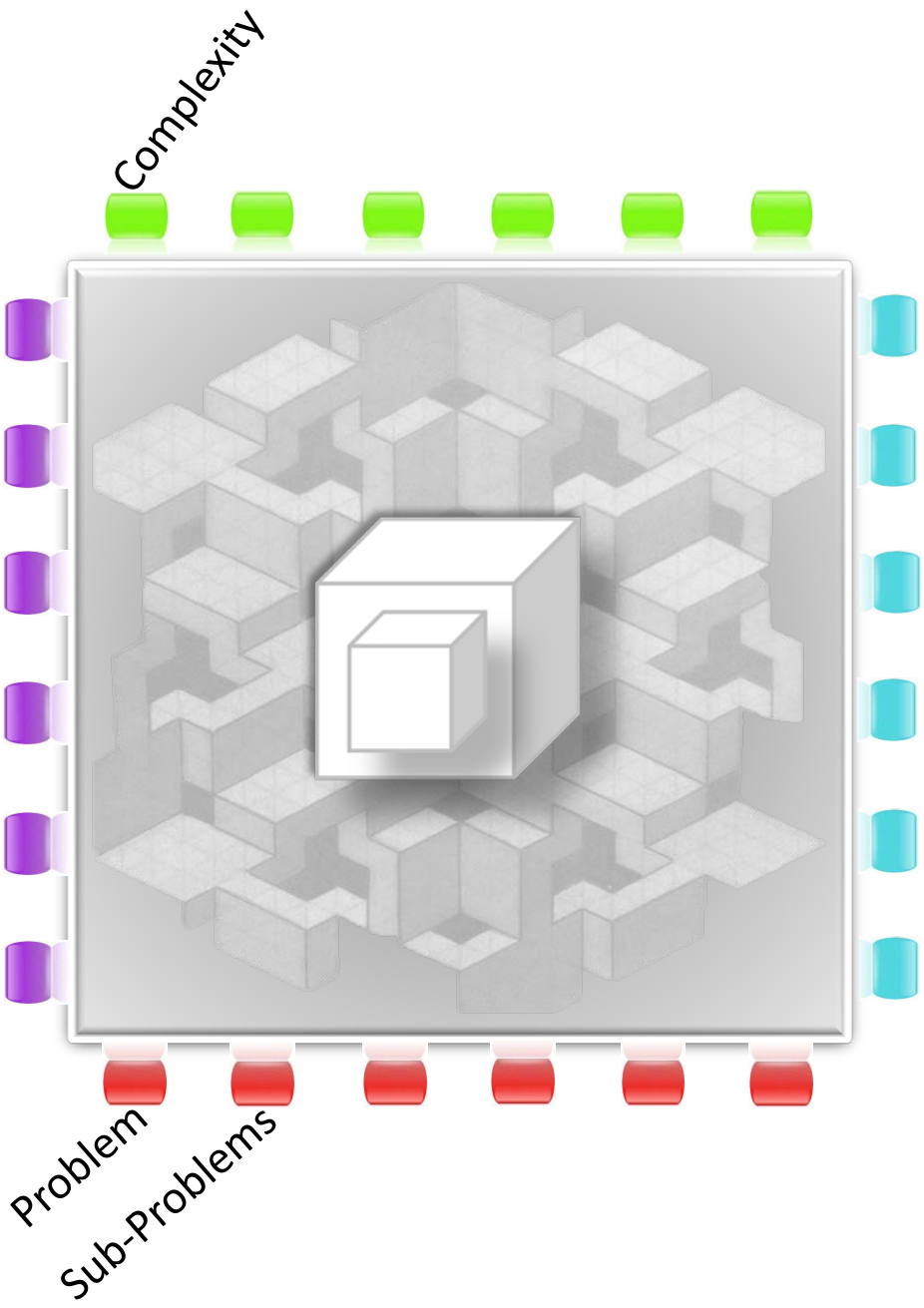


Problem

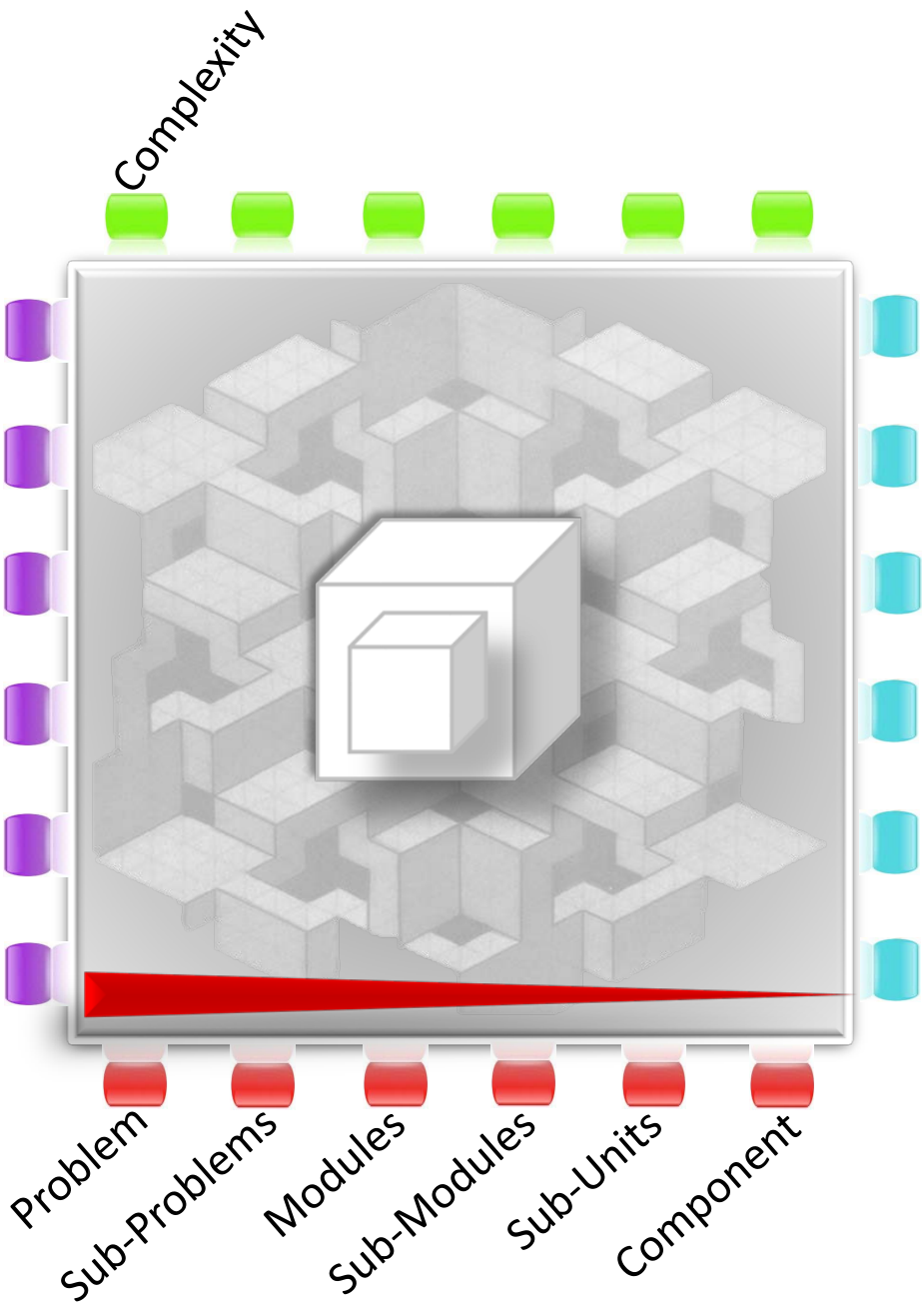
Can you understand and define the problem at its level of complexity?


Complexity
Problem

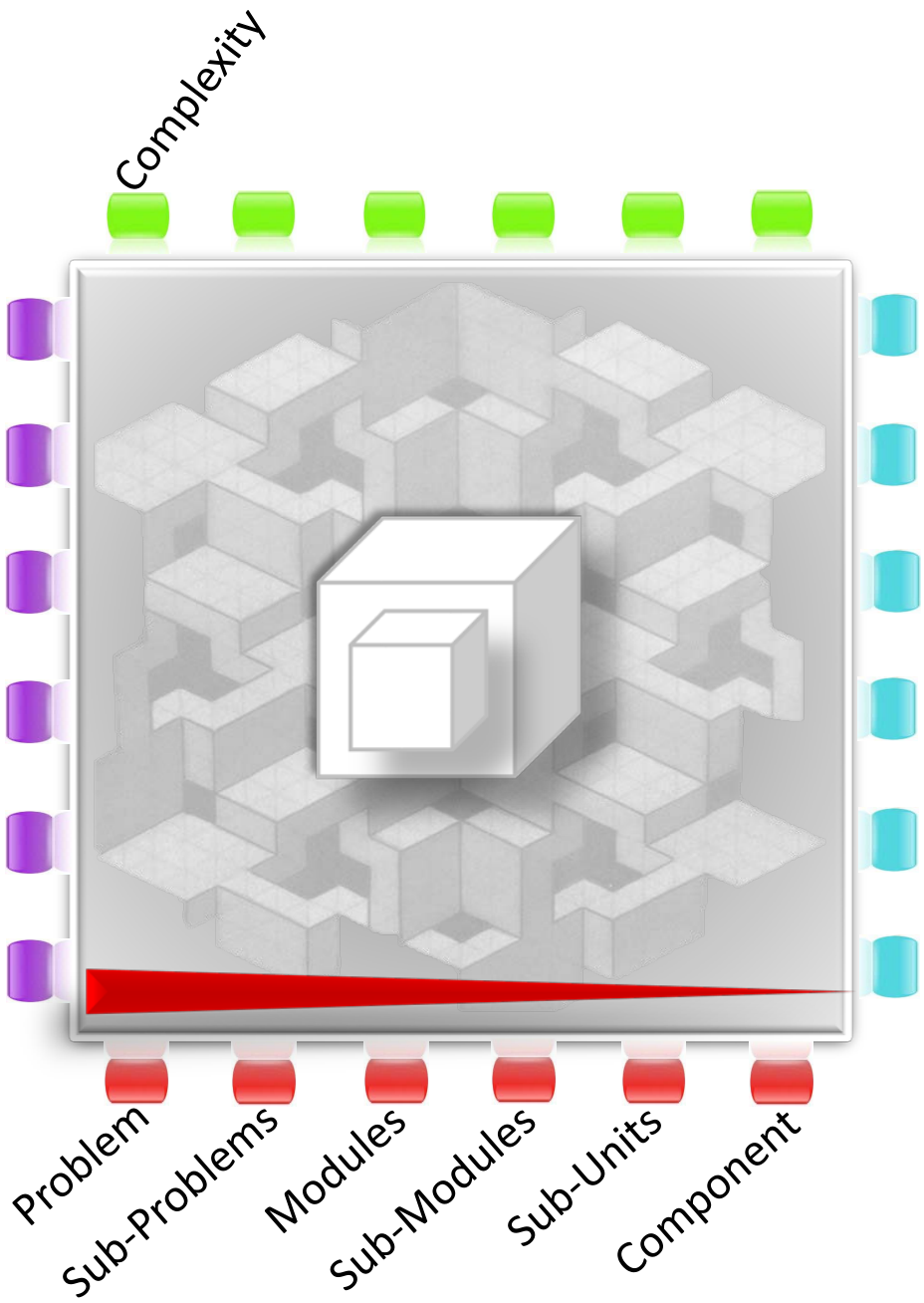
If you can, then it should be less difficult to unpack the problem.


Complexity
Problem
Sub-Problems

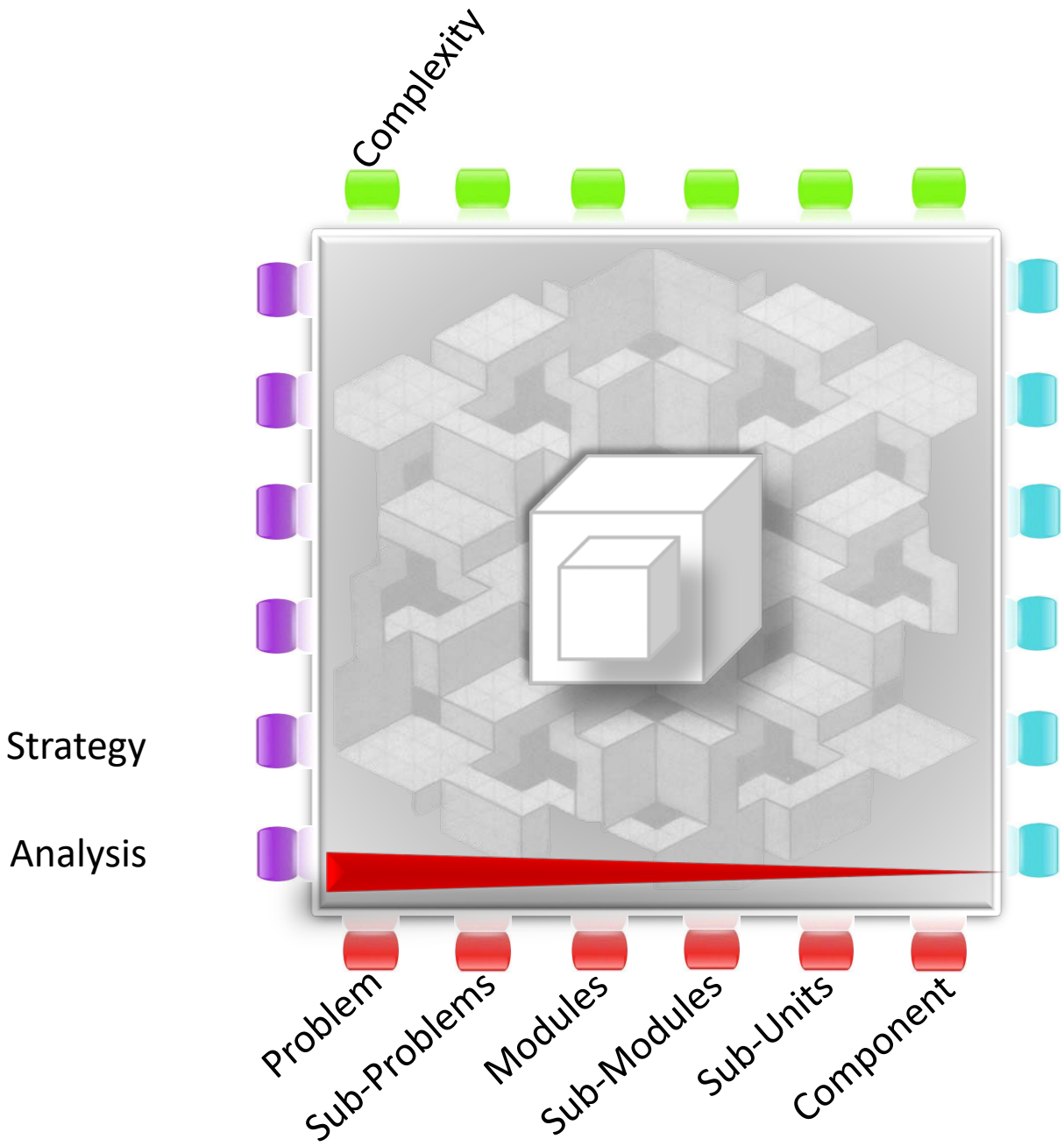
Start the cascade to unpack the problem to its basic component level.


Complexity
Problem
Sub-Problems
Modules
Sub-Modules
Sub-Units
Component

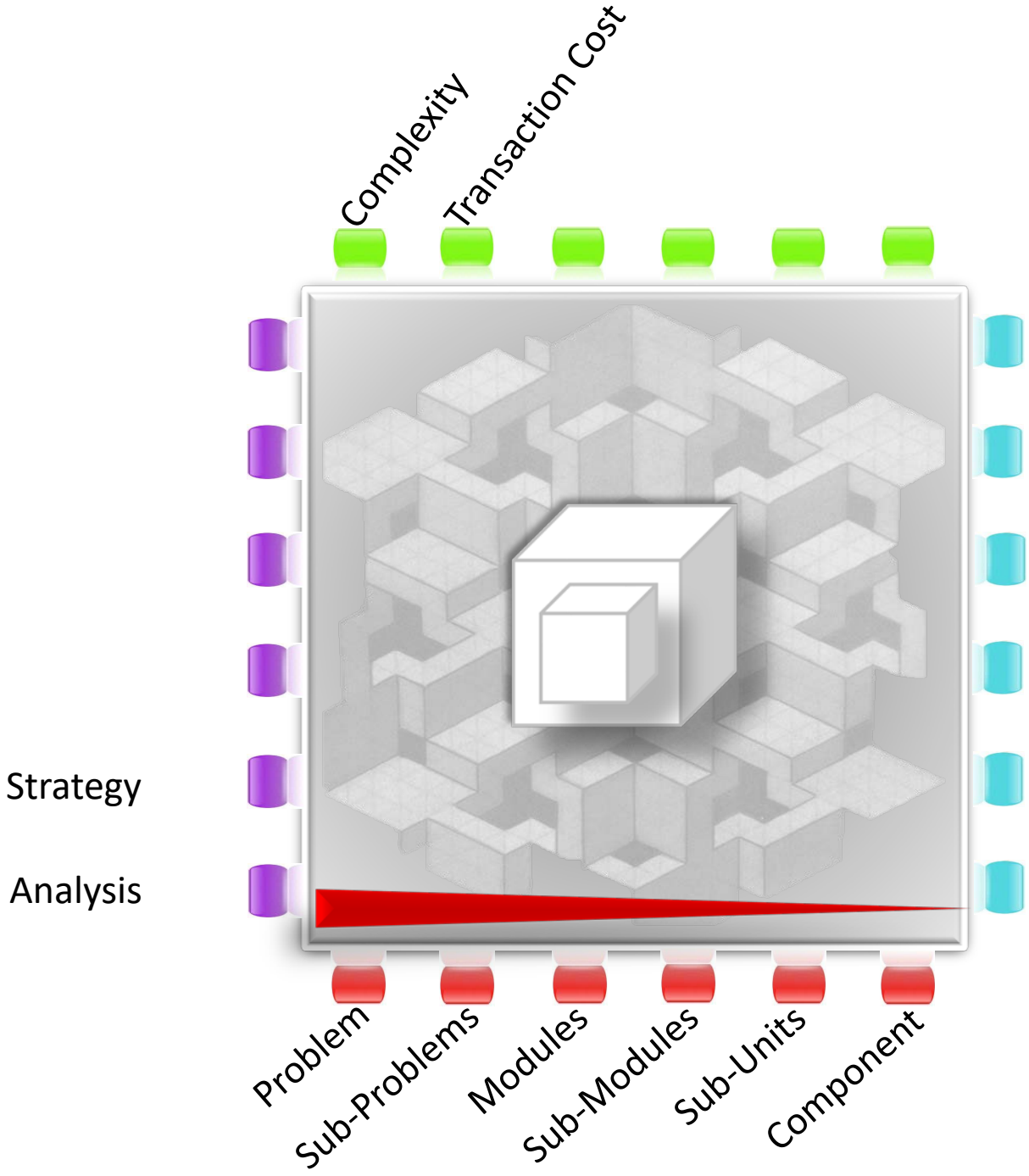
Now we are ready for analysis of the problem as a whole (complexity) and/or dissected into various stages and the parts (each component).


Complexity
Analysis
Problem
Sub-Problems
Modules
Sub-Modules
Sub-Units
Component

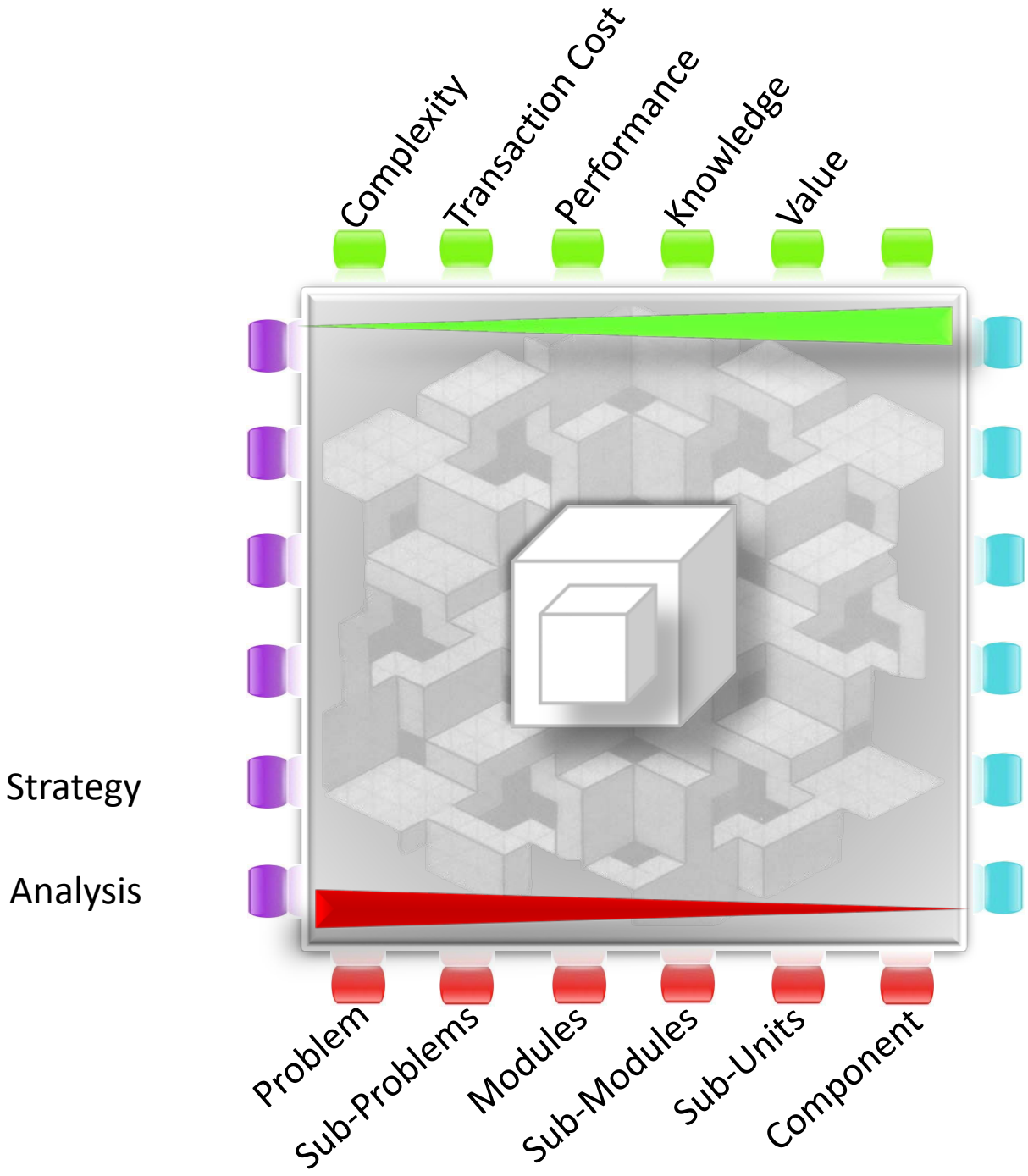
Analysis may provide clues to strategy to address the problem and parts


Complexity
Strategy
Analysis
Problem
Sub-Problems
Modules
Sub-Modules
Sub-Units
Component

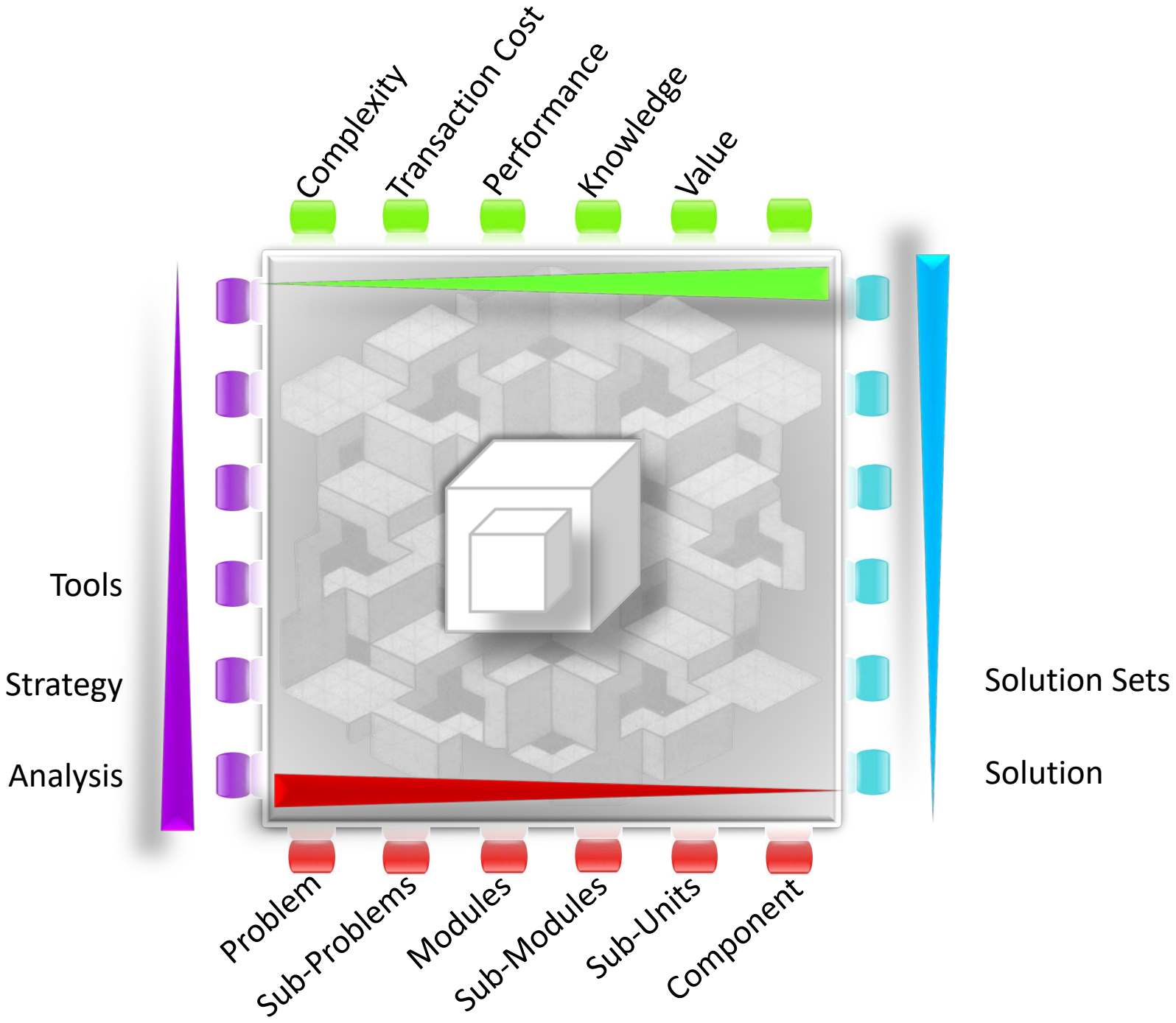
Probably the most difficult segment of the exercise is transaction cost analysis. It is key to grasp the economic context of the change. If cost, value (later), and profitability (target), are not aligned then the economic tripod (the purpose of the business) may be in a quagmire.


Complexity
Transaction Cost
Strategy
Analysis
Problem
Sub-Problems
Modules
Sub-Modules
Sub-Units
Component

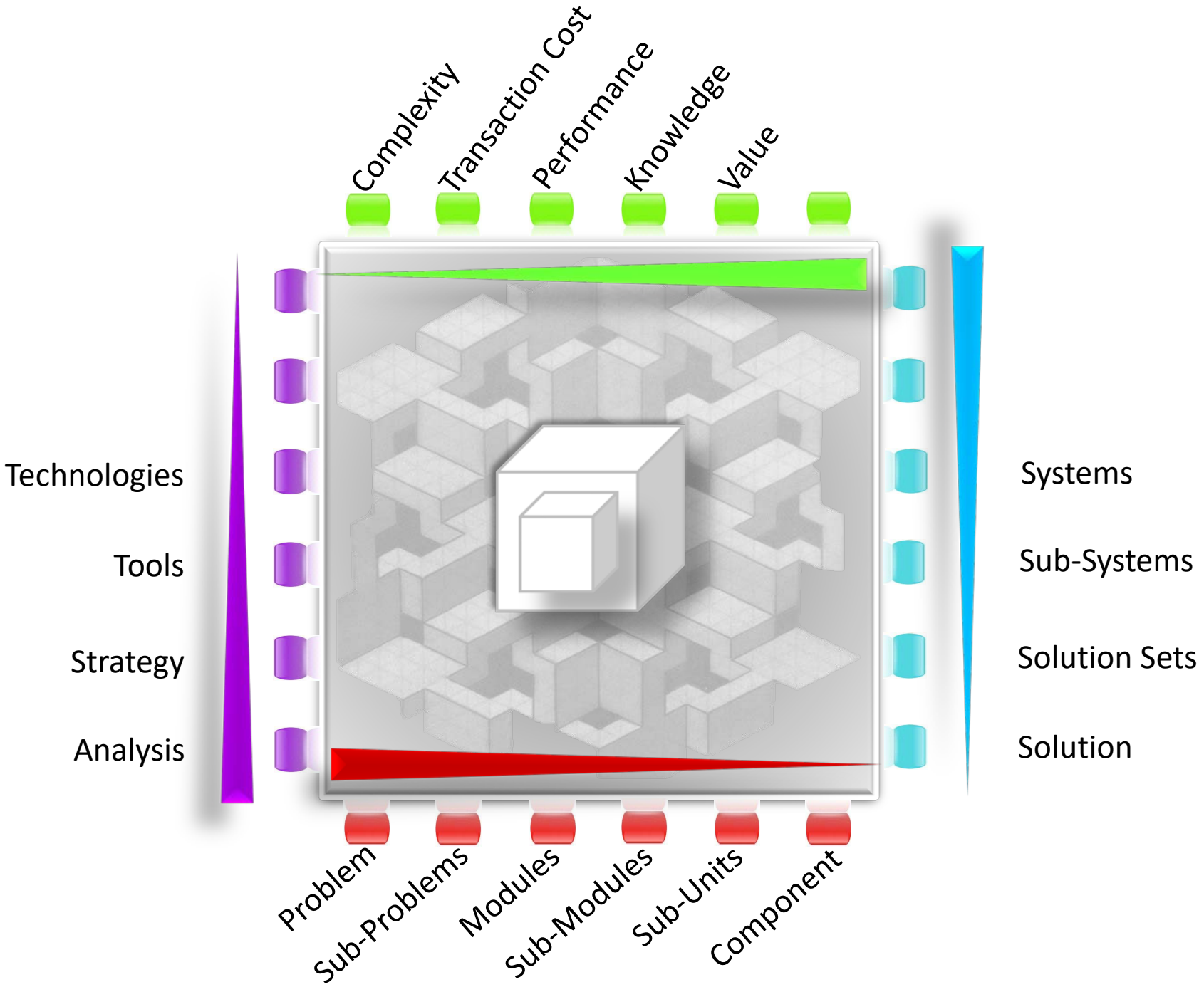
Transaction cost analysis is critical but its influence, impact, and linkage must be taken into account, in the context of performance, potential for useful knowledge expansion within the business and cost versus value.


Complexity
Transaction Cost
Performance
Knowledge
Value
Strategy
Analysis
Problem
Sub-Problems
Modules
Sub-Modules
Sub-Units
Component

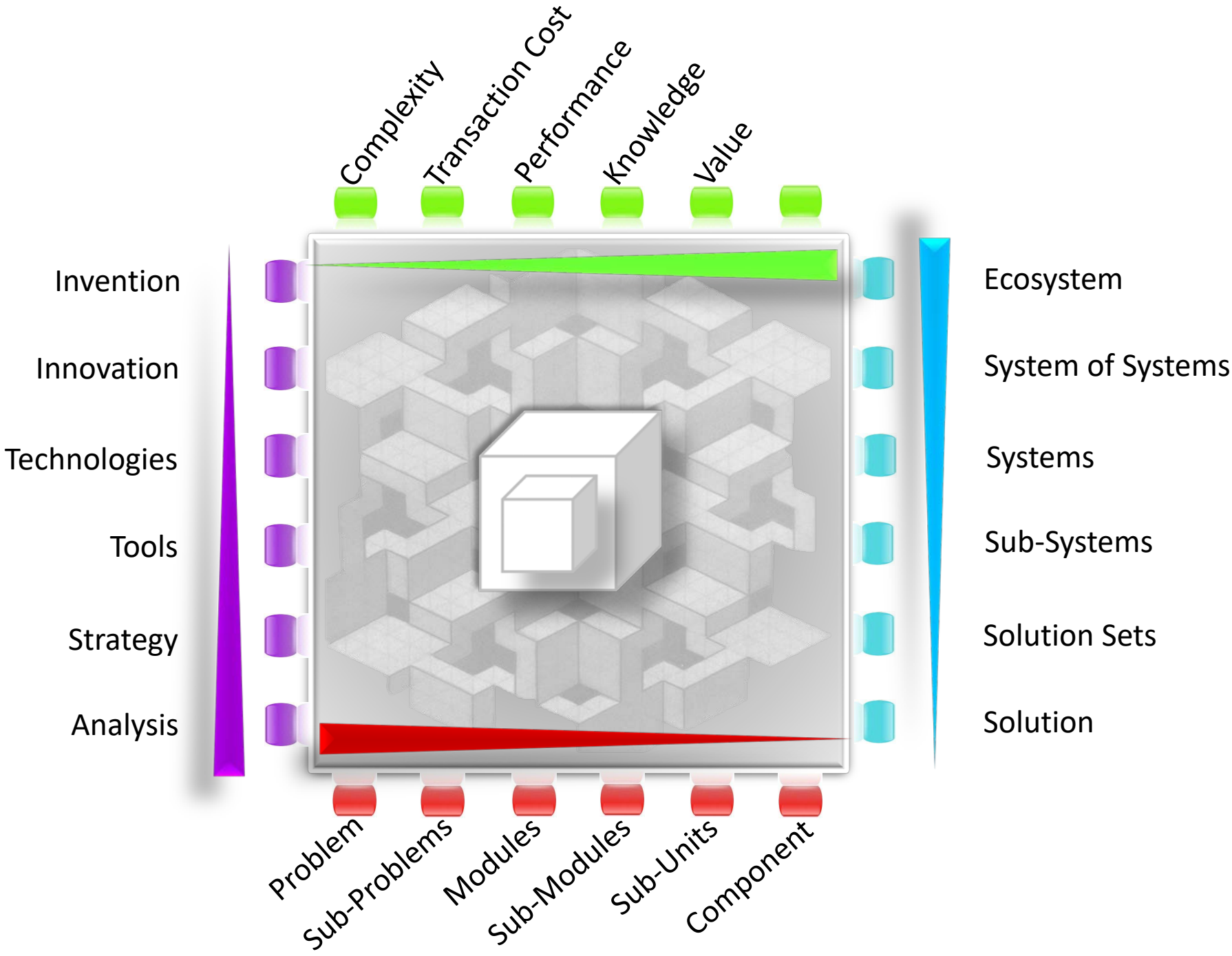
Tools available to create solutions and solutions sets will continue to inform the cost vs value discussion.


Complexity
Transaction Cost
Performance
Knowledge
Value
Tools
Strategy
Analysis
Solution Sets
Solution
Problem
Sub-Problems
Modules
Sub-Modules
Sub-Units
Component

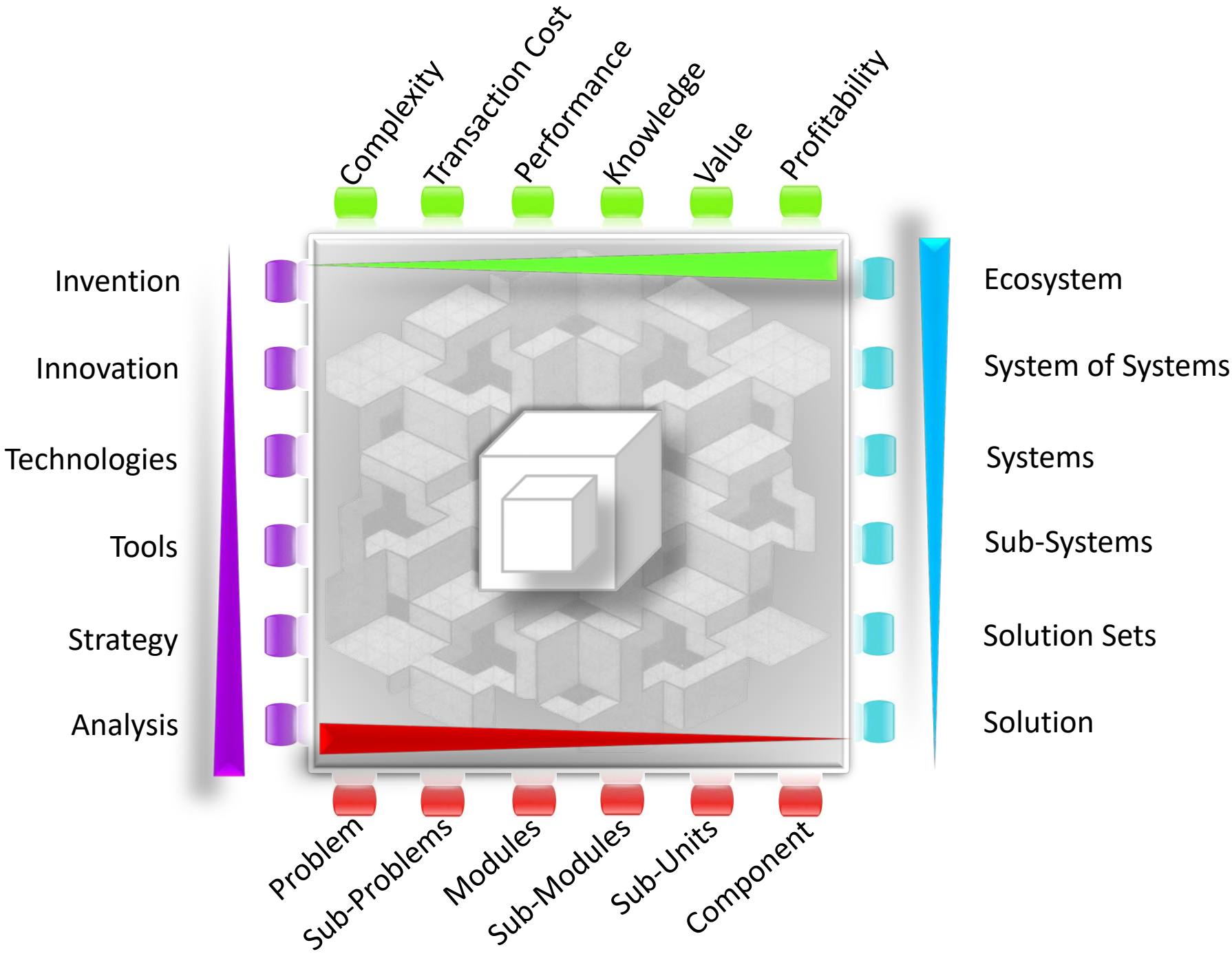
Are there technologies available (external to the business) which can augment or catalyze better solutions and improve systemic solutions?


Complexity
Transaction Cost
Performance
Knowledge
Value
Technologies
Tools
Strategy
Analysis
Systems
Sub-Systems
Solution Sets
Solution
Problem
Sub-Problems
Modules
Sub-Modules
Sub-Units
Component

Can industry-academic partnerships help channel innovation, and even invention, to bolster solutions not only across business systems but also within the ecosystem where the business may operate, globally?

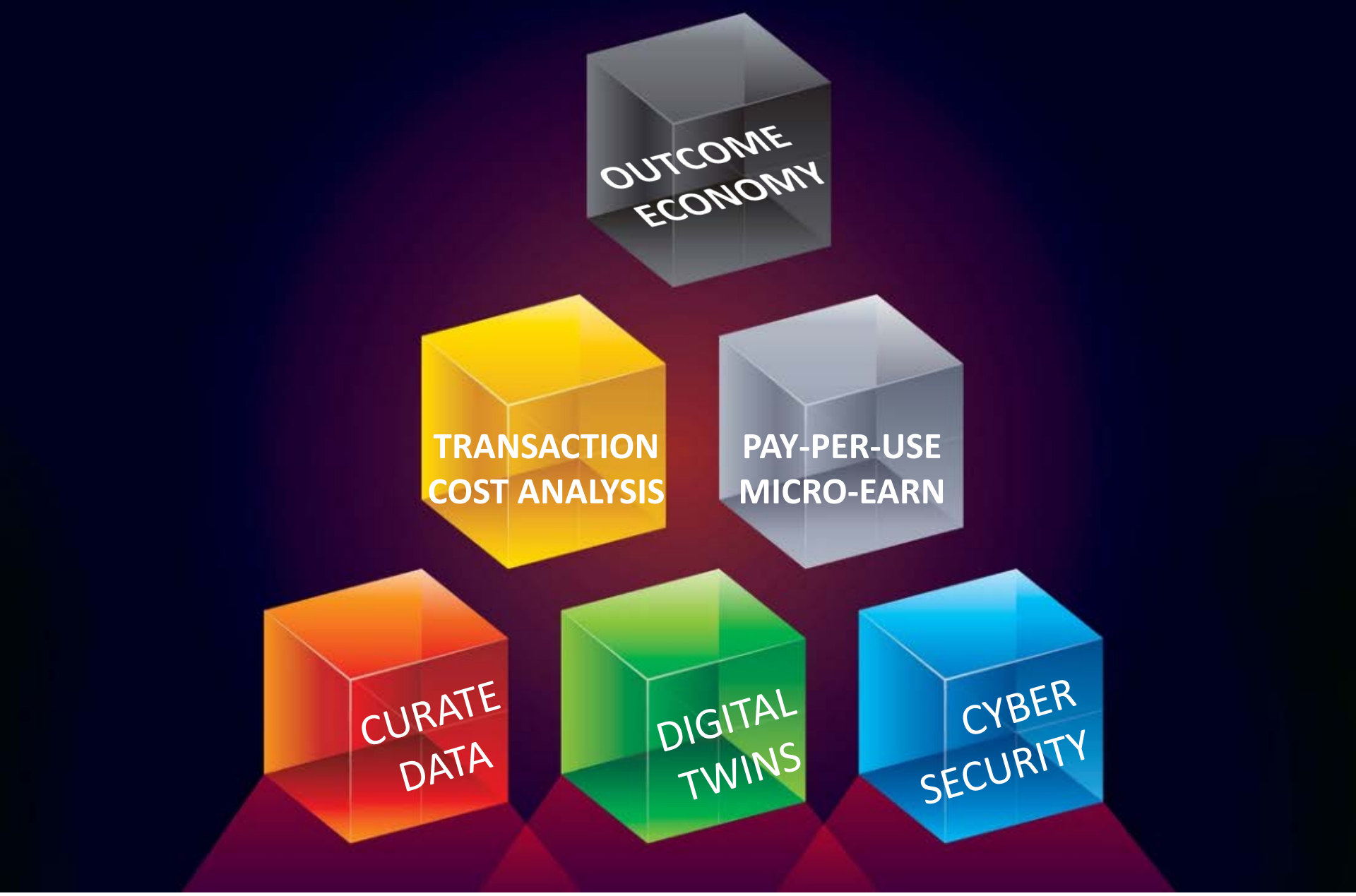

Complexity
Transaction Cost
Performance
Knowledge
Value
Invention
Innovation
Technologies
Tools
Strategy
Analysis
Ecosystem
System of Systems
Systems
Sub-Systems
Solution Sets
Solution
Problem
Sub-Problems
Modules
Sub-Modules
Sub-Units
Component

The ultimate outcome of this exercise is to get a handle on the potential to improve profitability.


Complexity
Transaction Cost
Performance
Knowledge
Value
Profitability
Invention
Innovation
Technologies
Tools
Strategy
Analysis
Ecosystem
System of Systems
Systems
Sub-Systems
Solution Sets
Solution
Problem
Sub-Problems
Modules
Sub-Modules
Sub-Units
Component

Temporary Conclusion

Translational engineering is a transformation of vision into reality. It is usually multi-dimensional, and works only through cross-pollination of trans-disciplinary domains. Solving problems is one modus operandi. Often, strategic analyses may indicate the need for change in business models or operations or market penetration. All outcomes must target ethical profitability, but the sense of profit, may be also relevant to the impact on community. It may count, yet cannot be counted, in the context of cost, or economic value added or dividends. The balance, prudence, and wisdom, is quintessential, for responsible leadership.



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