How's IoT different from Internet and How it may be the same?

A Technologist's View

Aaron Thean

Professor, Electrical & computer Engineering,

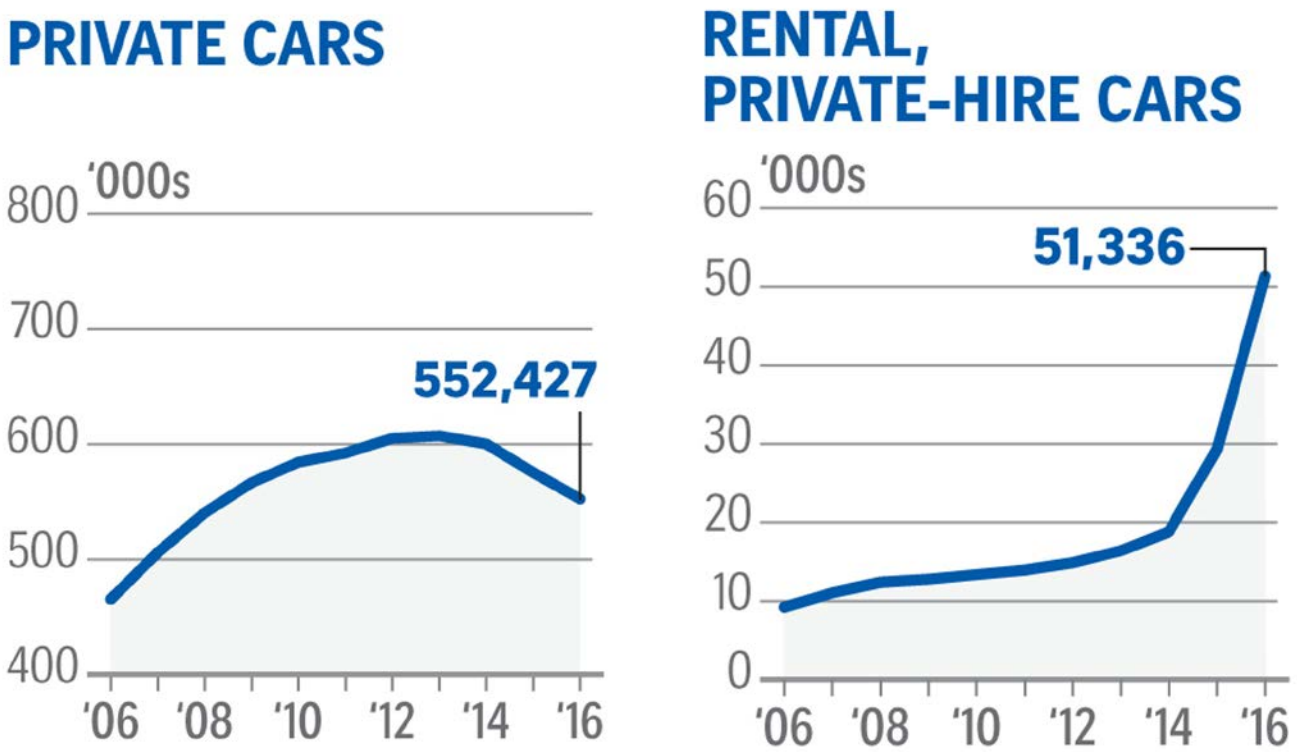
Director, Office of Deputy President Research & Technology,

National University of Singapore.

THE STRAITS TIMES

Private car numbers fall to eight-year low

Published Jan 21, 2017



Do you own a car?

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IOT: **My Singapore Experience**

"Precision" Transportation

On Demand Transport : Where & When **Services**

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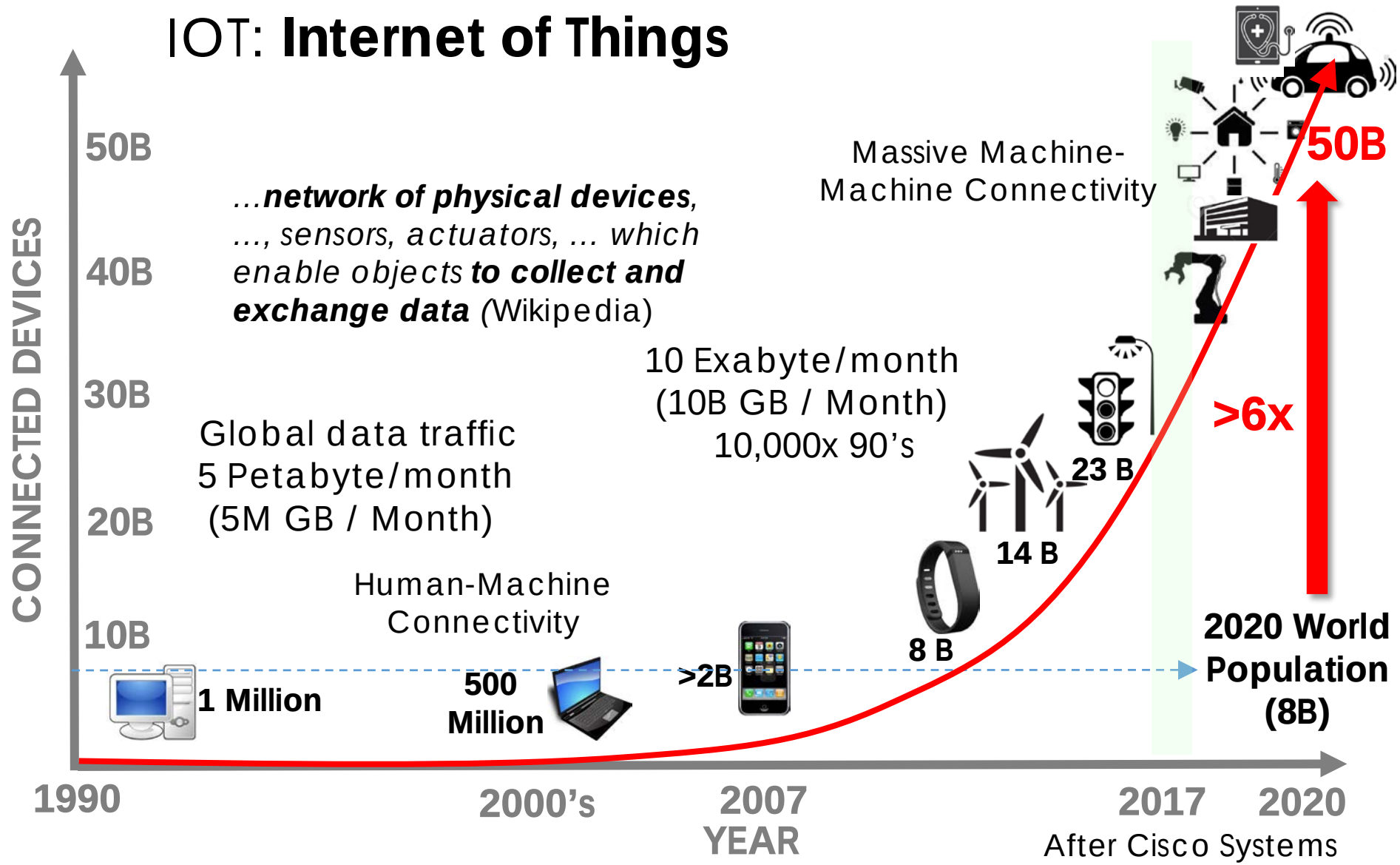
IOT: **Internet of Things**



- Towards massive machine-to-machine connectivity

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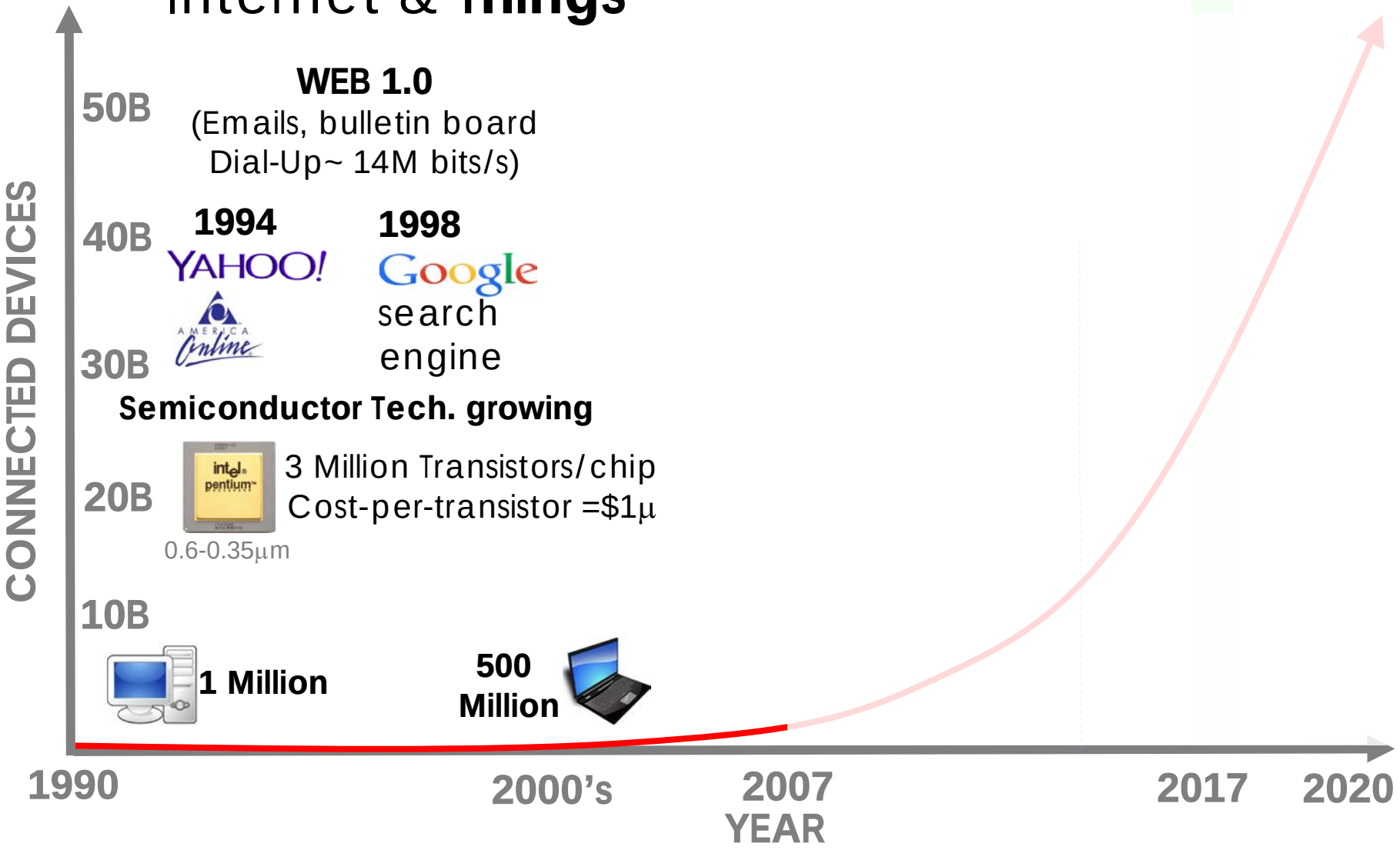
Internet & **Things**



- 90's Technology: Started with connectivity of hosts (Servers)

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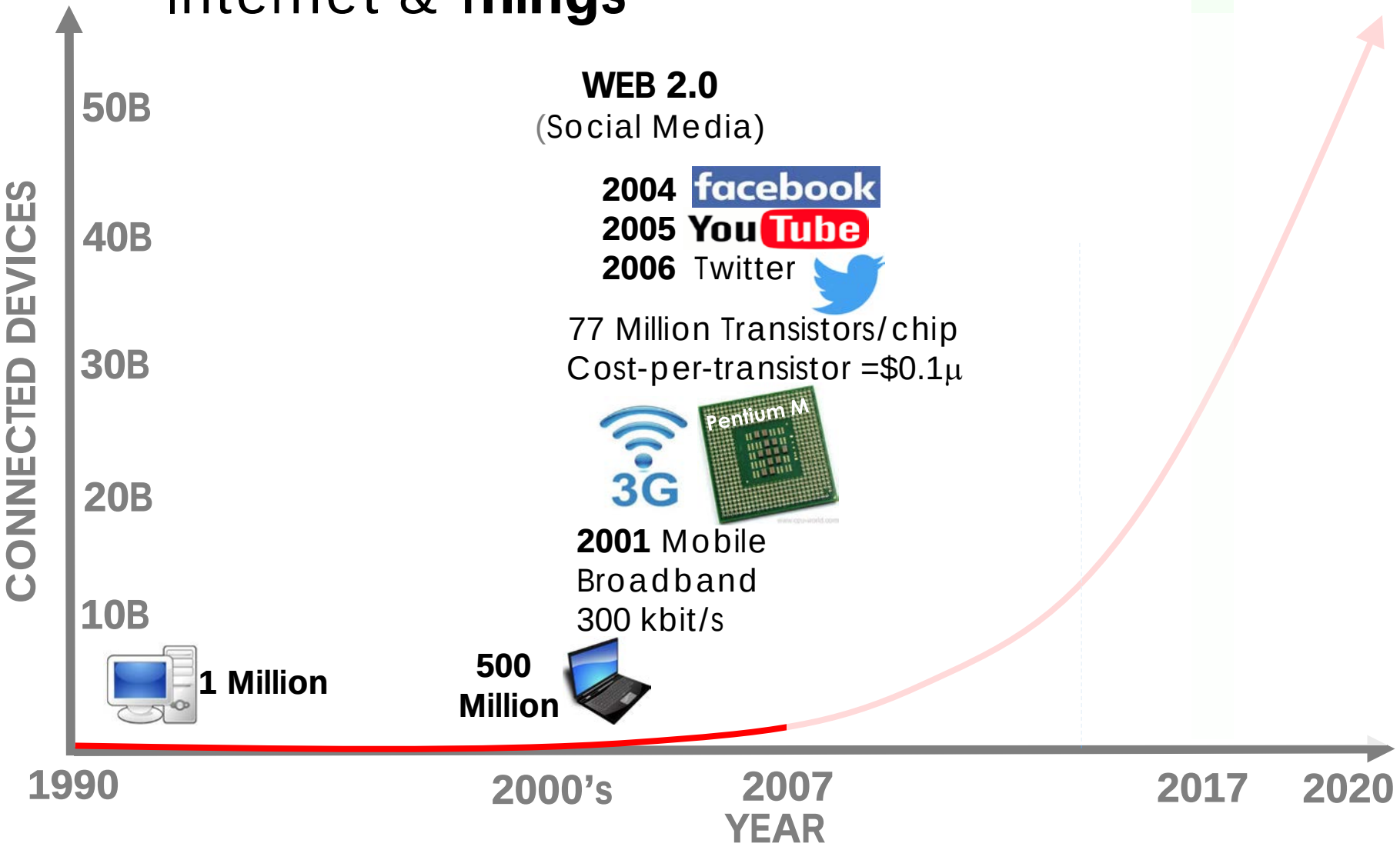
Internet & **Things**



- 2000's Technology: Heading towards the inflection point

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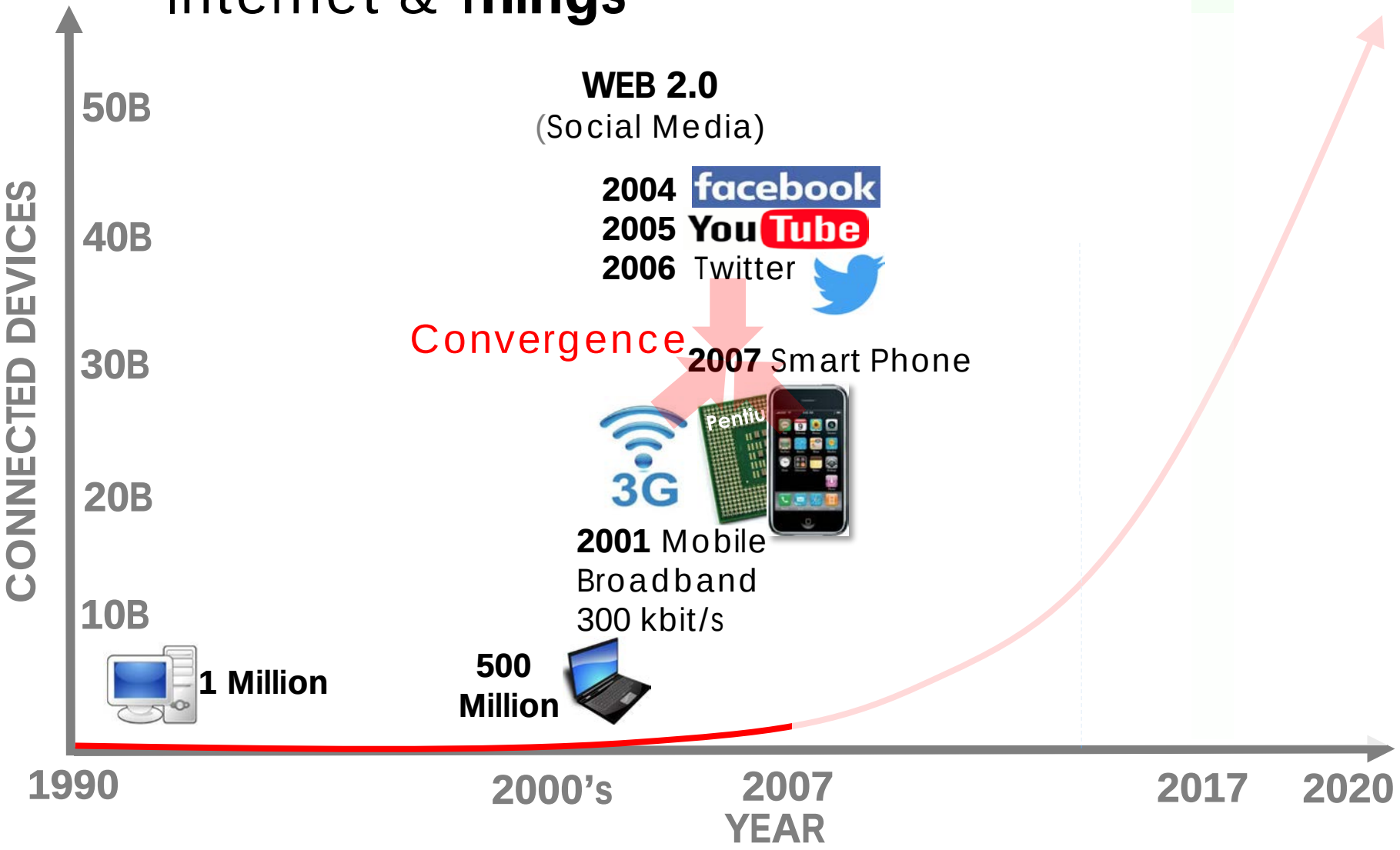
Internet & **Things**



- Convergence of Wireless tech, Computing, & Media with the advent of the Smart Phones

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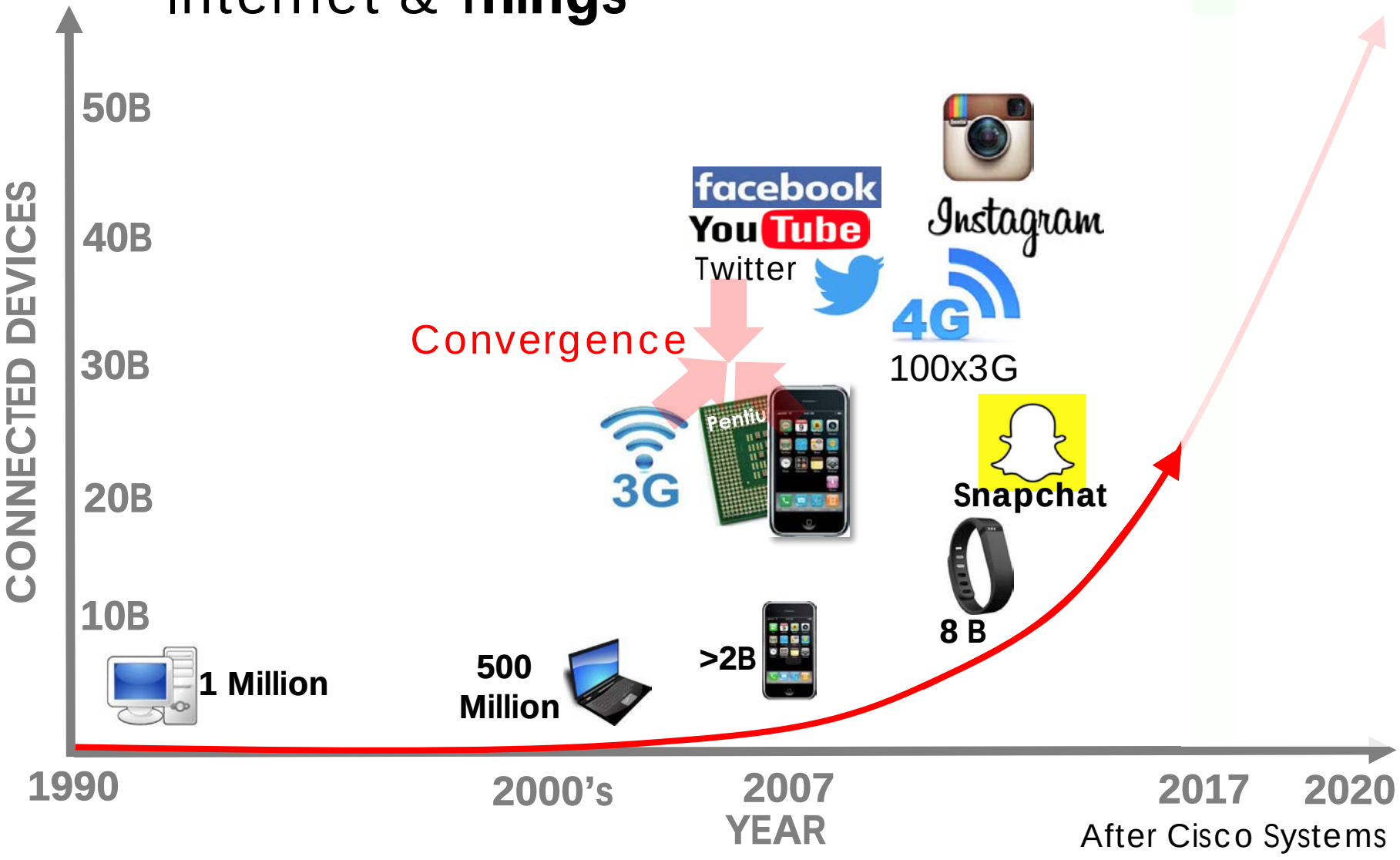
Internet & **Things**



- Mobile Apps drove the utilization of personal computing

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Internet & **Cyber-Physical Systems** (My Kid, Today)

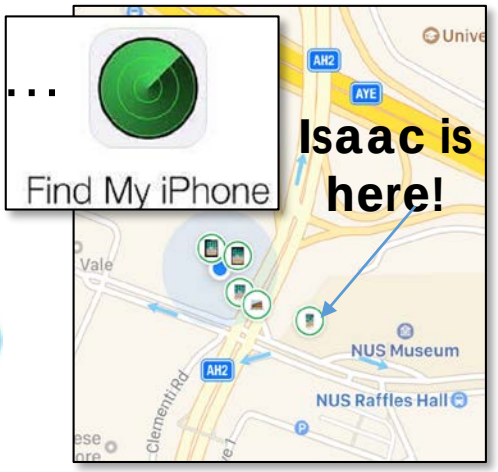
"Alexa, turn on the lights on?"

Connect with friends in EU & USA

Cloud

Online Games, Videos, Homework

To find him...



School Projects

"**Wirelessly-Integrated** Everywhere & Anytime"

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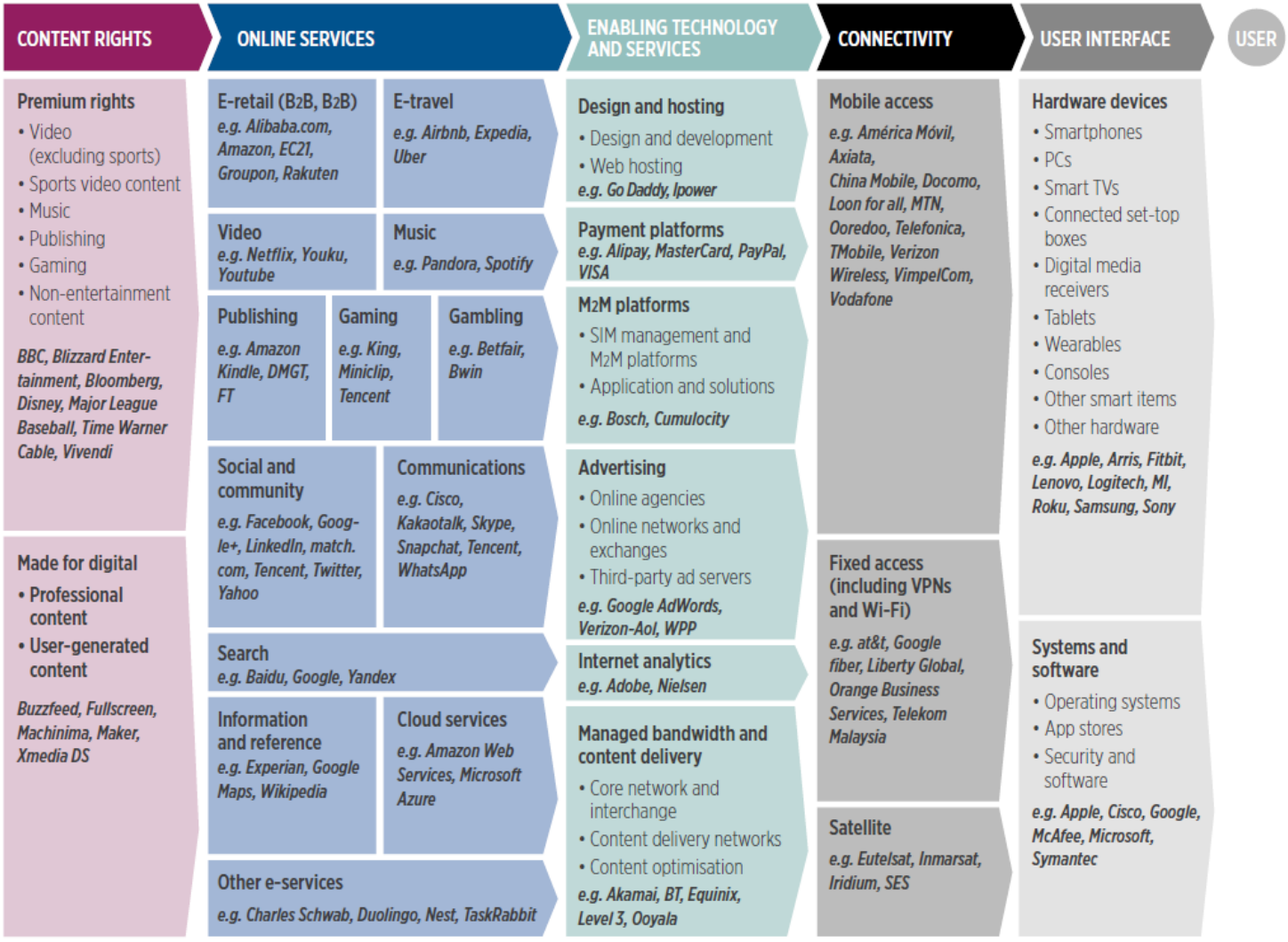
Internet & **Value Chain**



Note: M2M is machine to machine, and VPN is virtual private network.

Source: A.T. Kearney analysis

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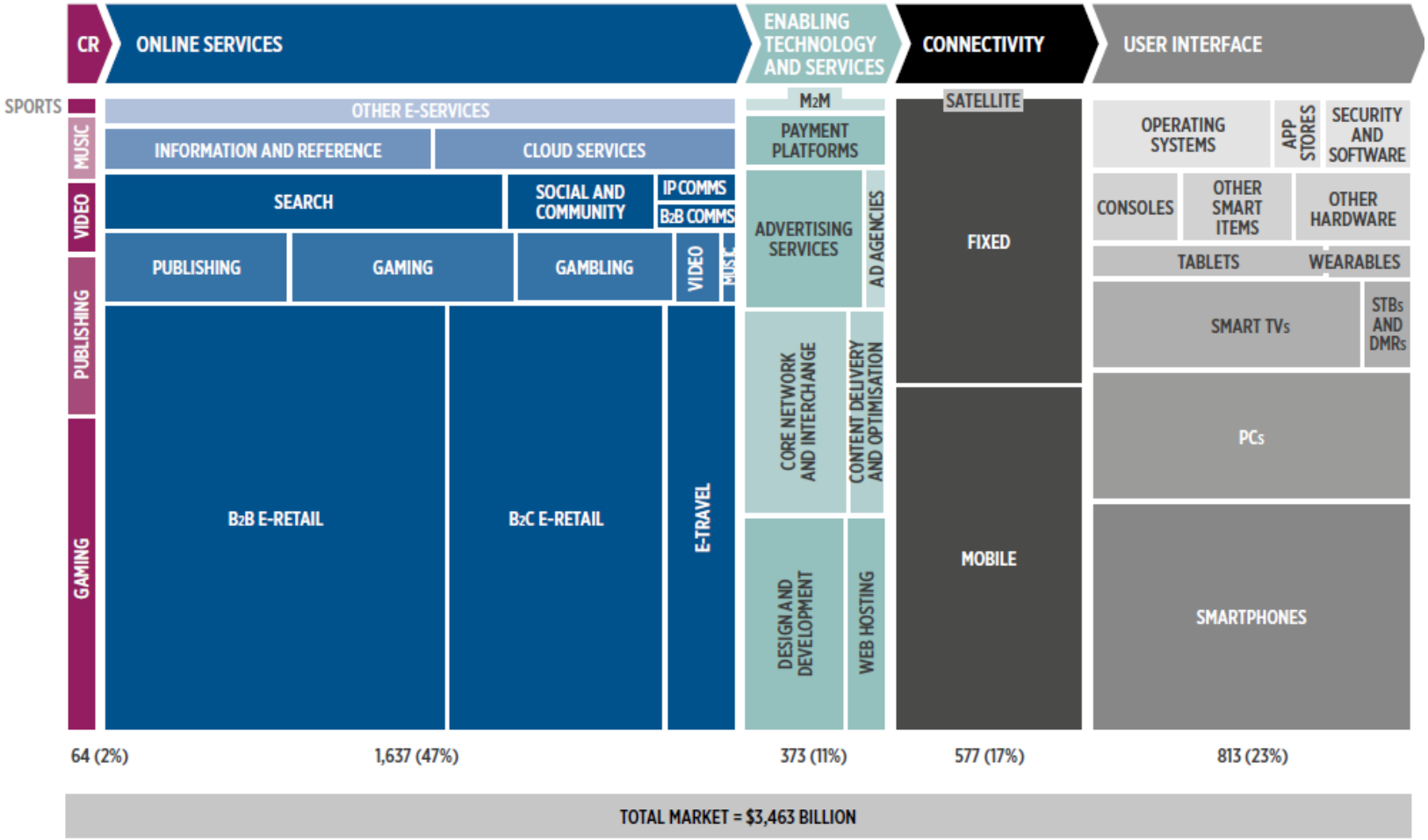
Internet & **Value Chain**

Market size by segment and category

$ billion, % of total market, 2015



GSMA: The Internet Value Chain A study on the economics of the internet May 2016, Financial statements, investor presentations, broker reports; A.T. Kearney analysis

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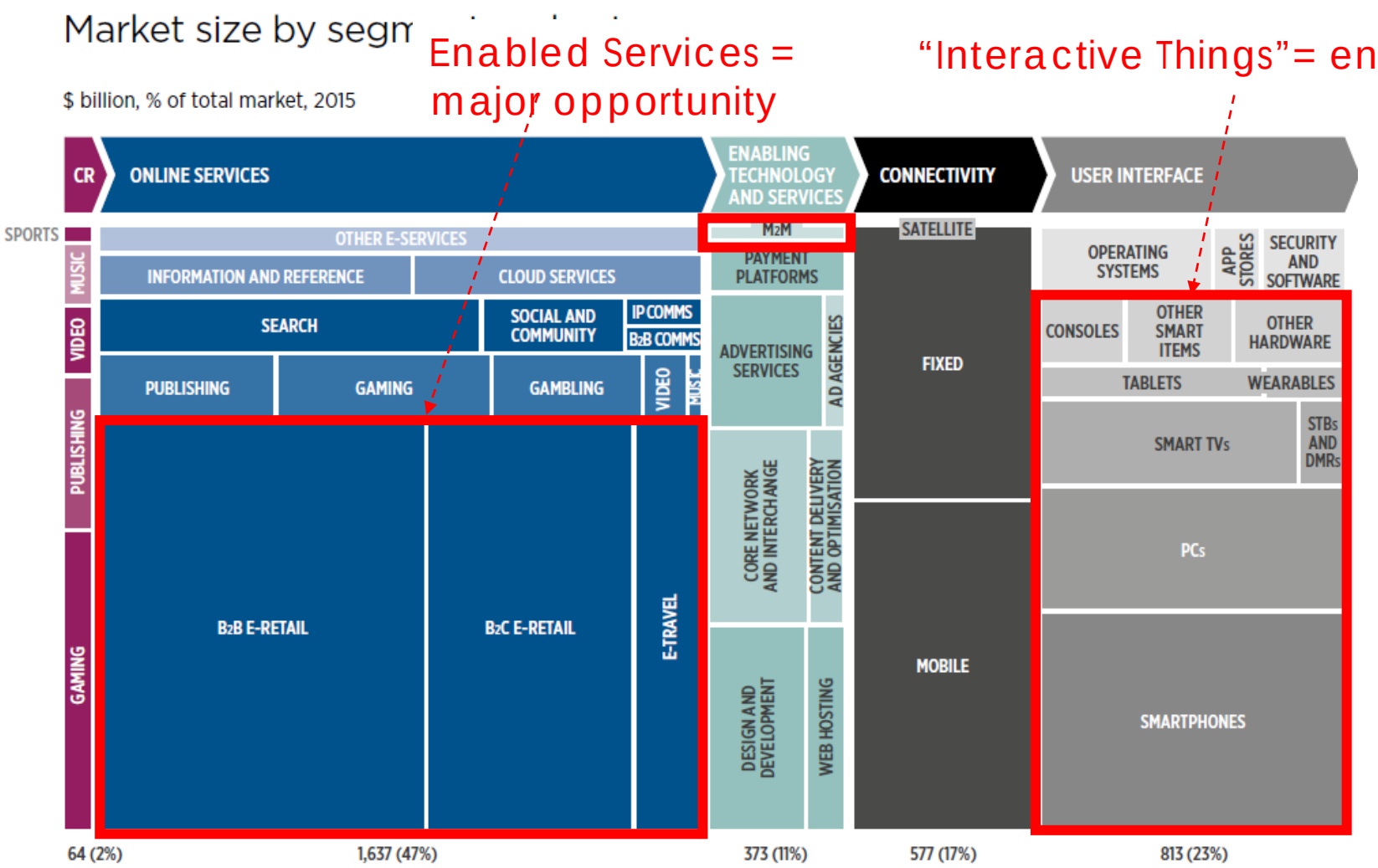
Internet & **Value Chain**



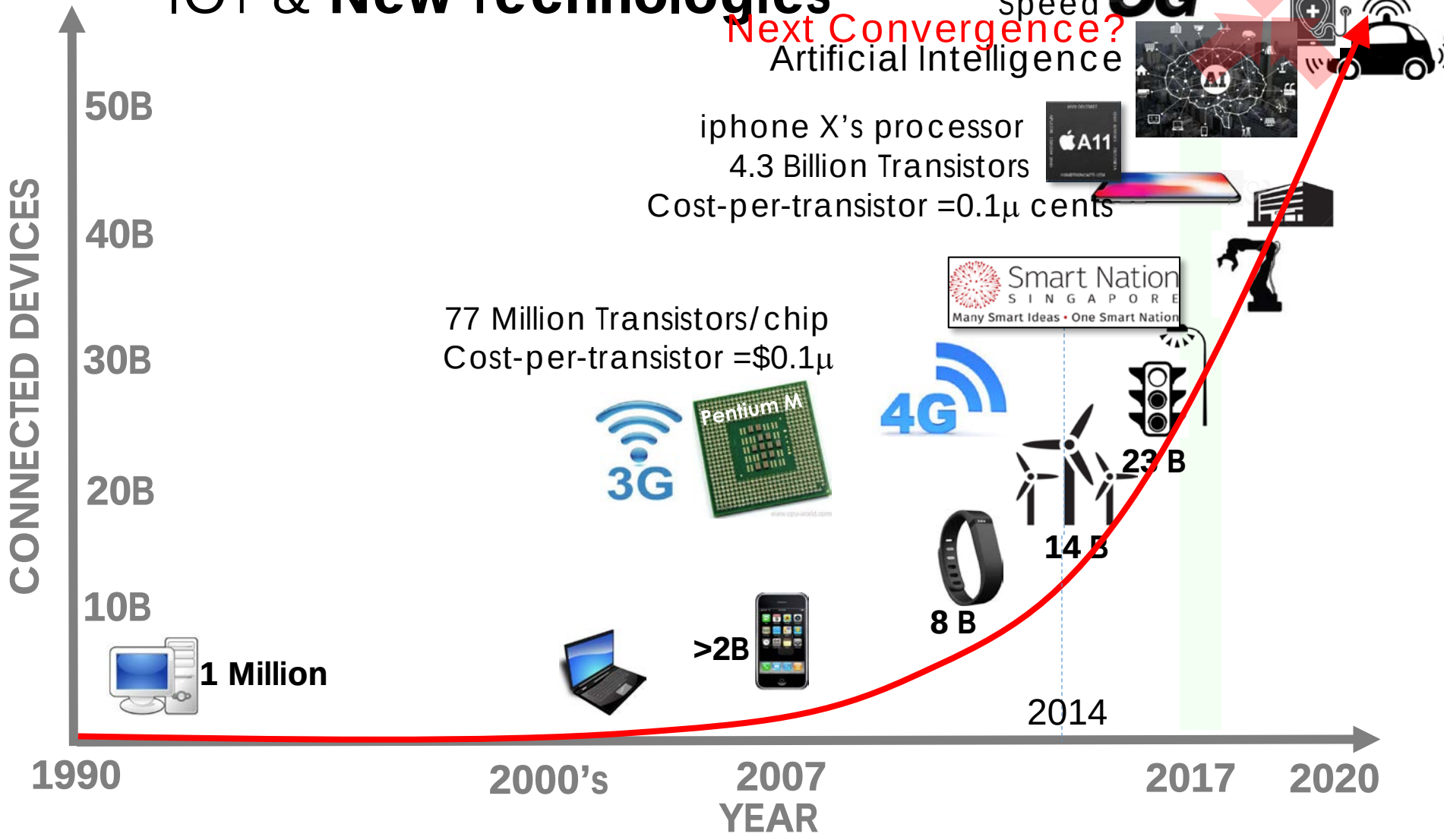
- How will this map over to IoT?

Who will make the money?

Internet enabled or Enabling Internet

Rank	Company	Country	Industry	Cash (USD Millions)	Total Assets (USD Millions)
1	MICROSOFT	US	Technology	$113,239	$193,468
2	APPLE	US	Technology	$67,155	$321,686
3	ORACLE	US	Technology	$66,078	$134,991
4	CISCO SYSTEMS	US	Technology	$65,756	$121,652
5	TOYOTA MOTOR	Japan	Automotive	$48,680	$421,092
6	GENERAL ELECTRIC	US	Industrial	$48,129	$365,183
7	JOHNSON & JOHNSON	US	Consumer goods	$41,907	$141,208
8	SAMSUNG ELECTRONICS	South Korea	Consumer electronics	$29,602	$217,086
9	TOTAL	France	Oil and gas	$29,145	$230,978
10	AMAZON	US	Retail	$25,981	$83,402
11	GENERAL MOTORS	US	Automotive	$24,801	$221,690
12	BP	UK	Oil and gas	$23,528	$263,316
13	COCA-COLA	US	Beverages	$22,516	$87,270
14	DAIMLER	Germany	Automotive	$21,745	$256,134
15	HON HAI PRECISION INDUSTRY	Taiwan	Consumer electronics	$20,041	$80,257
16	TAIWAN SEMICONDUCTOR	Taiwan	Technology	$19,572	$58,410
17	HONDA MOTOR	Japan	Automotive	$18,795	$169,193
18	ABBOTT LABORATORIES	US	Pharma	$18,775	$52,666
19	QUALCOMM	US	Telecoms	$18,648	$52,359
20	VODAFONE	UK	Telecoms	$18,623	$192,620
21	SONY	Japan	Consumer electronics	$17,953	$157,613
22	PFIZER	US	Pharma	$17,850	$171,615
23	INTEL	US	Technology	$17,099	$113,327

IOT & **New Technologies**



- New Technology & Mobile Computing Capability emerging

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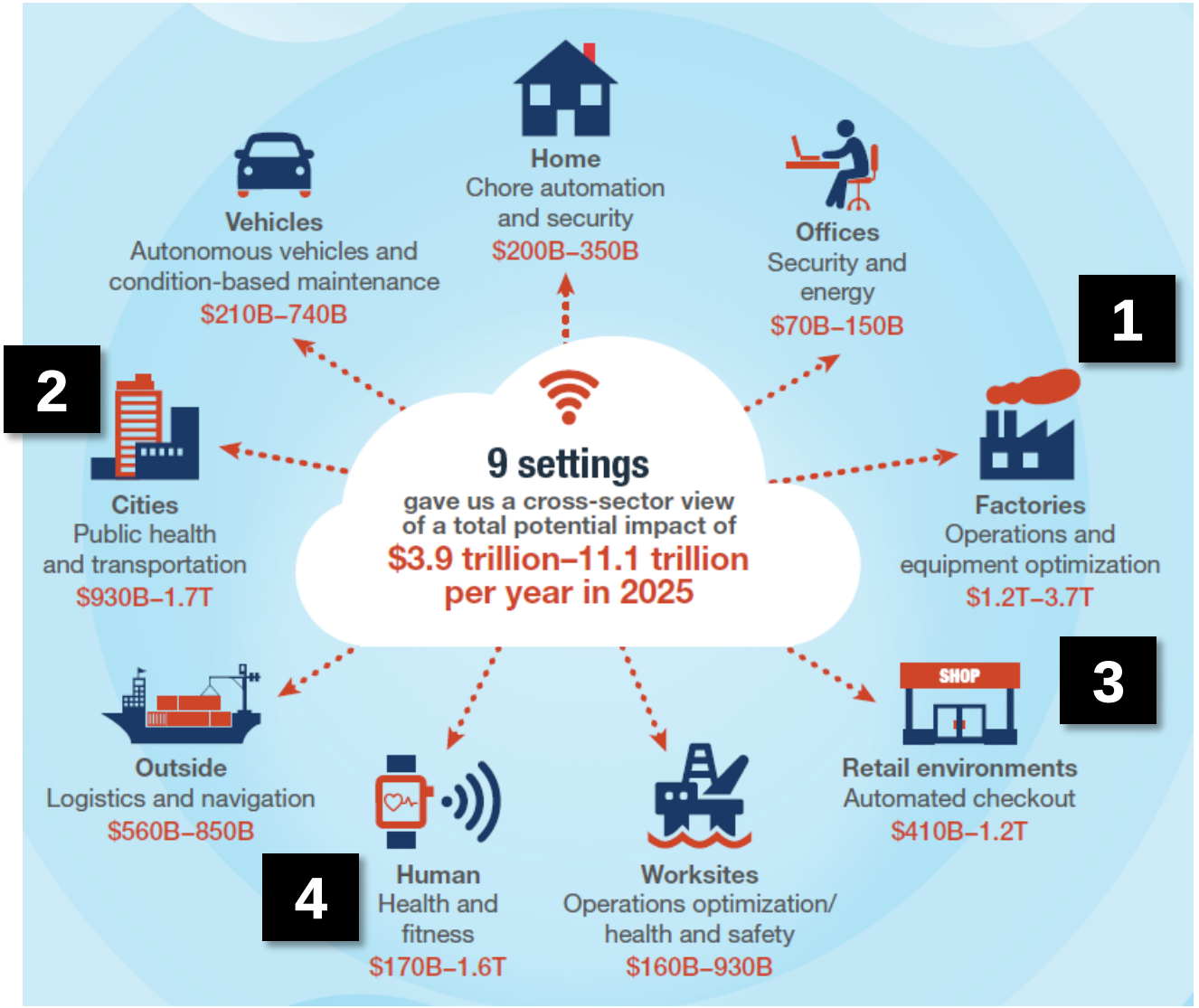
IOT & **Anticipated Opportunities**



McKinsey&Company Jun 2015

IOT & **Smart City & Energy Grid**

Smart meters relay energy usage and pricing information between consumers and electricity providers.

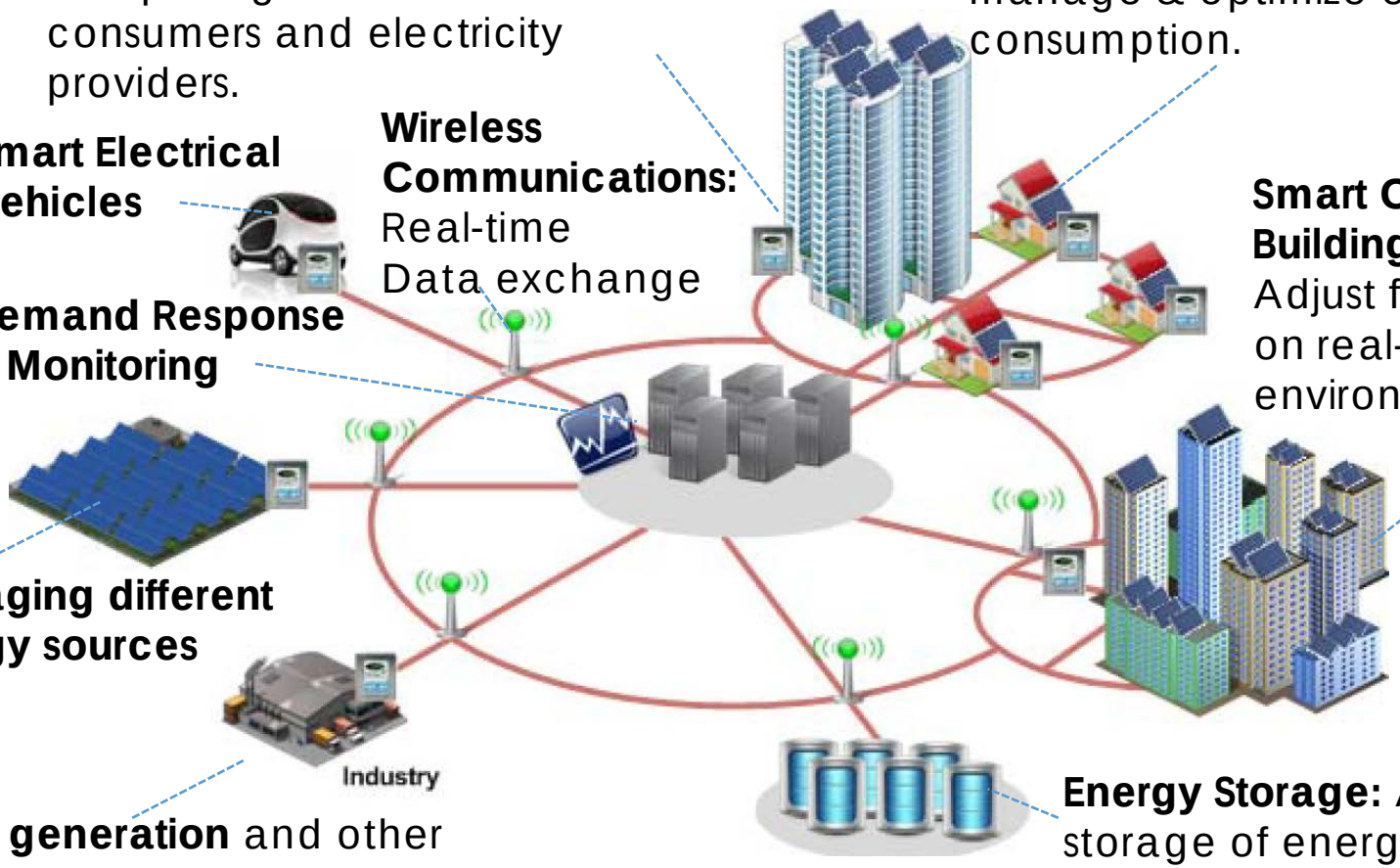
Smart homes Automation to manage & optimize energy consumption.

Smart Electrical Vehicles

Wireless Communications: Real-time Data exchange

Demand Response & Monitoring

Smart Offices & Buildings Adjust facilities based on real-time usage & environment



Managing different energy sources

Power generation and other electricity providers can better manage their production with real-time data

Energy Storage: Adapative storage of energy during (during off-peaks)

IOT & **Smart Health**

New wireless wearable devices & sensors

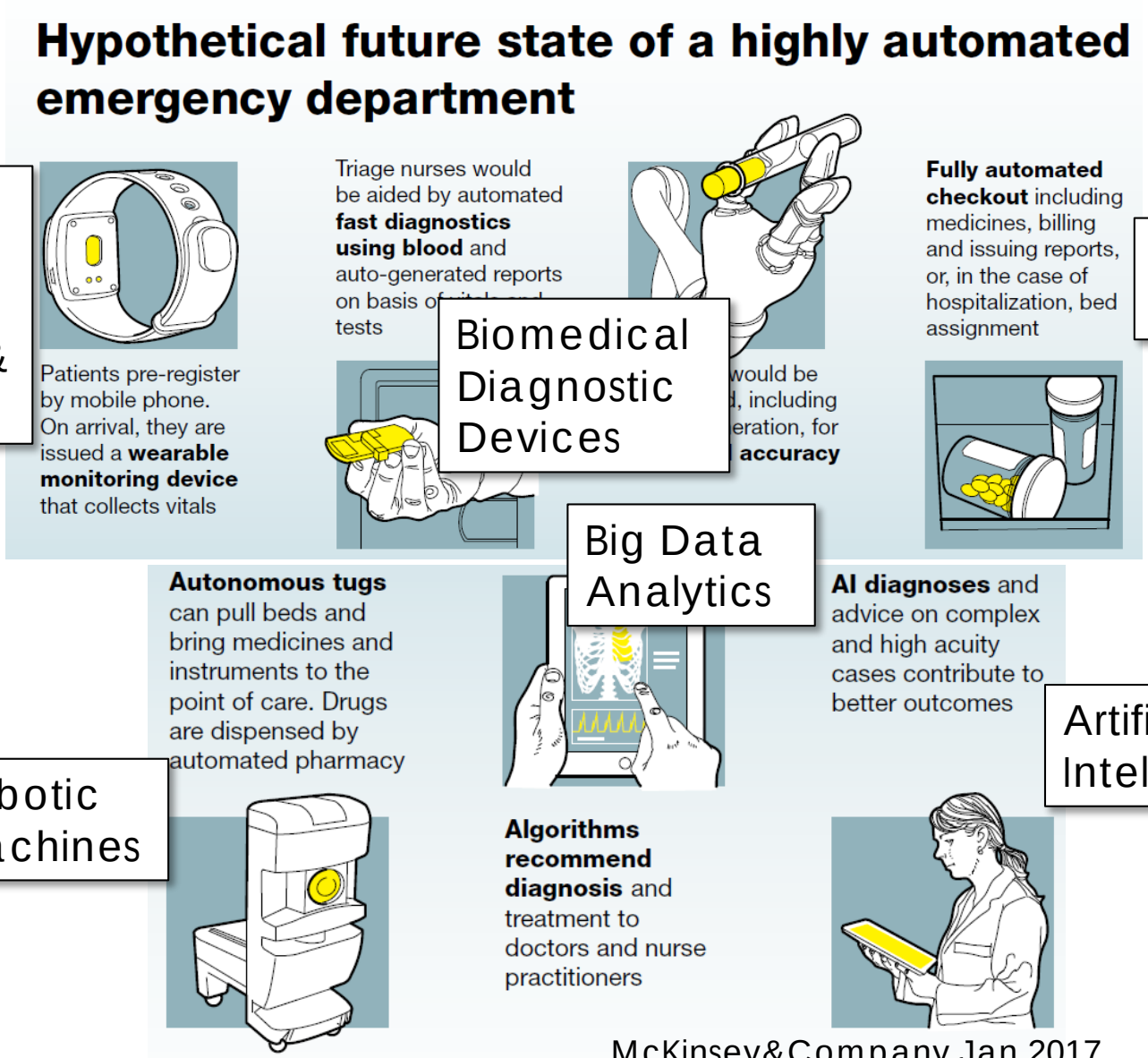
Networked Services

Biomedical Diagnostic Devices

Big Data Analytics

Artificial Intelligence

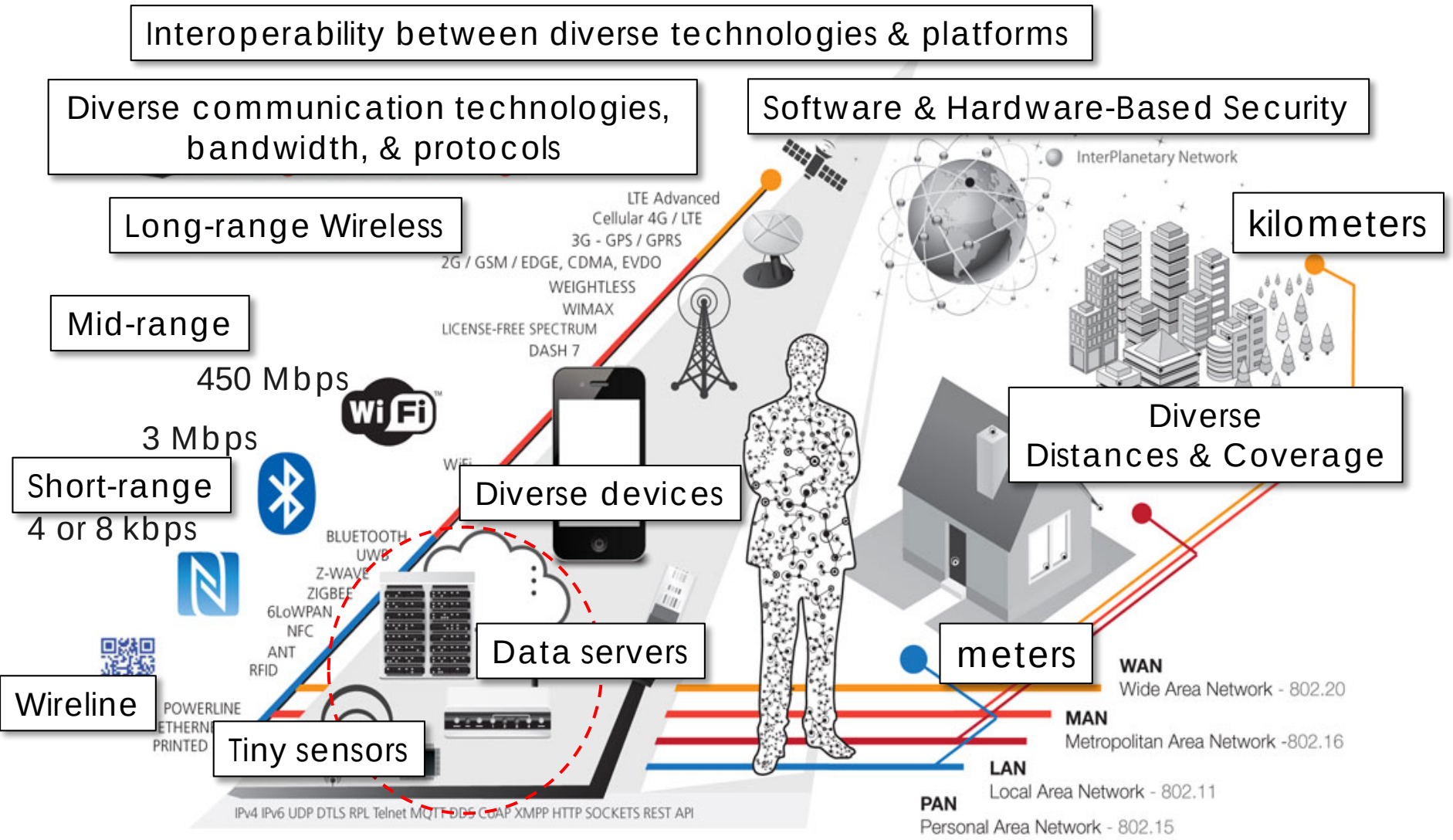
Robotic Machines



McKinsey&Company Jan 2017

FUTURE THAT WORKS: AUTOMATION, EMPLOYMENT, AND PRODUCTIVITY

IOT: Diverse **Technology Challenges**



- Opportunities for Software & Hardware Innovations

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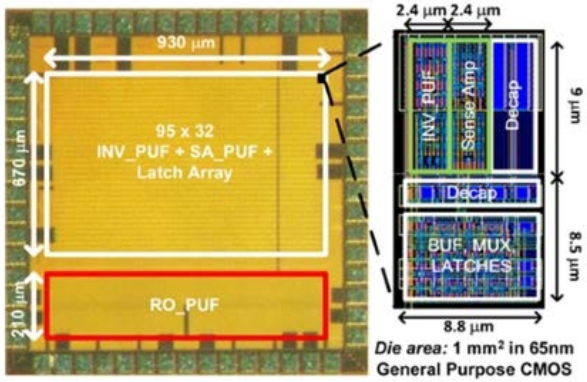
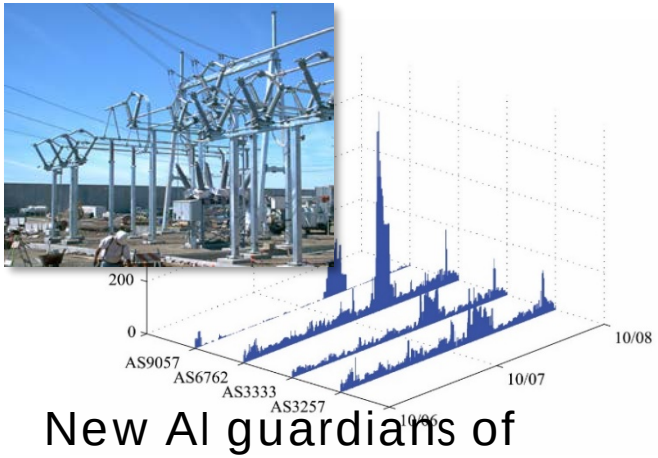
IOT: **New Technology Examples**

Biplab Sikdar



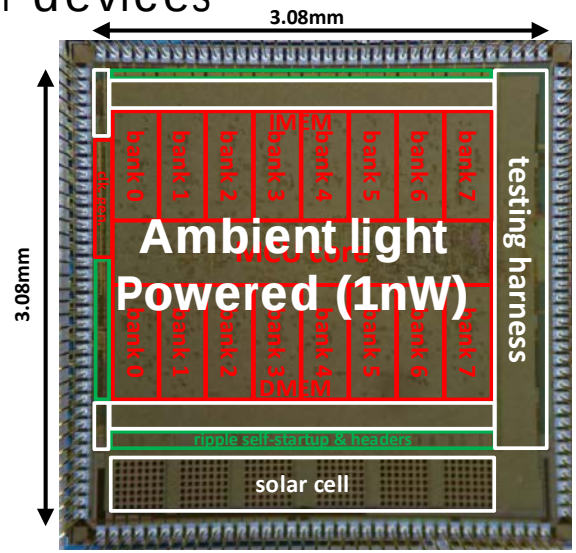
Millimeter-sized security chip
Built-in "Silicon Fingerprints" for IoT devices

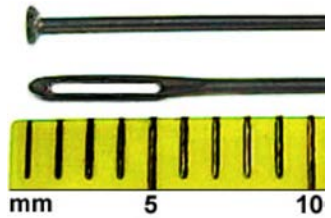


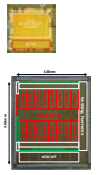
New AI guardians of Power grids & Transportation Networks

Massimo Alioto

Green IC







Size of Pinhead
To scale

Battery-less microcontroller that operates with power consumed by just 1000 human cells

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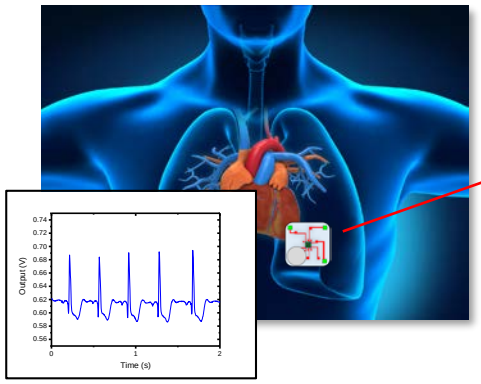
IOT: **New Technology Examples**

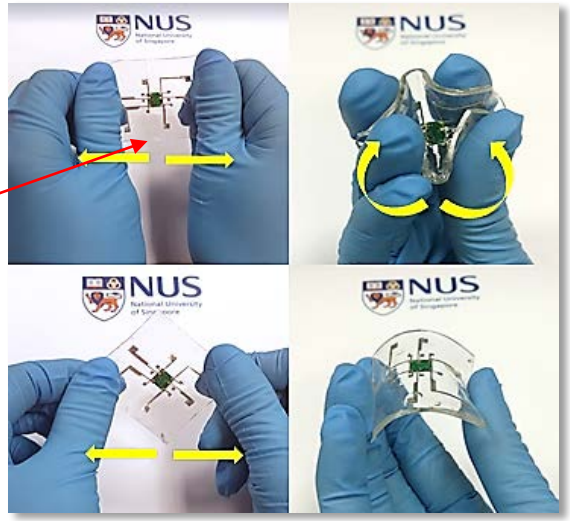
Heng Chun Huat
&
Aaron Thean

HiFES: Hybrid Integrated Flexible Electronics for Next-Gen. Wearable Technologies

Wearable ECG



Conformal & Robust



Hard-Soft Hybrid Materials:
Micro Chip + Liquid Metal Alloy + Rubber

- Many cool technologies to come – Exciting for a technologist!

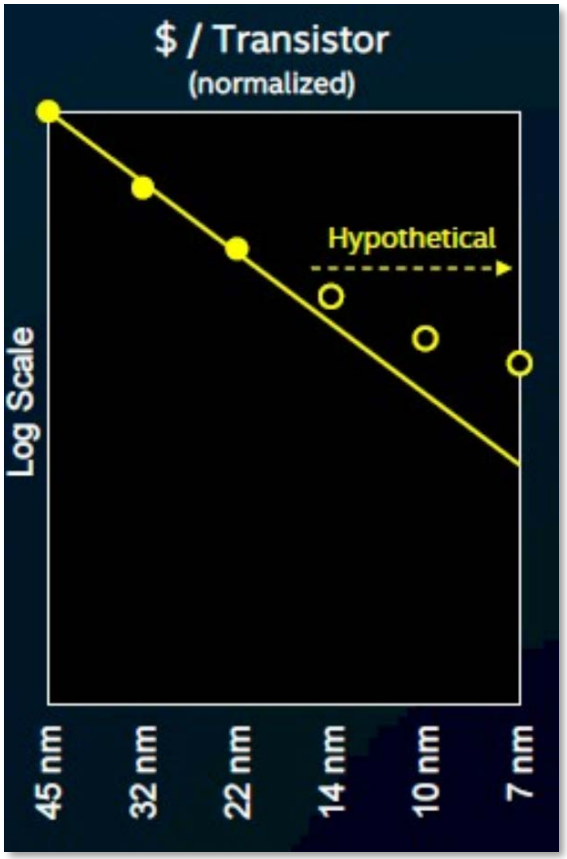
IOT: **New Technology Necessary But Commoditized**

	Connection Cost/Month
Digital Signage	$5-$10
Smart Meters	$0.75-$1.50
Zig-Bee, Z-Wave-Bluetooth, WiFi Etc.	<$1 – few cents

Dilip Sarangan, Frost & Sullivan, Jun 28 2016 for Nearshore Americas

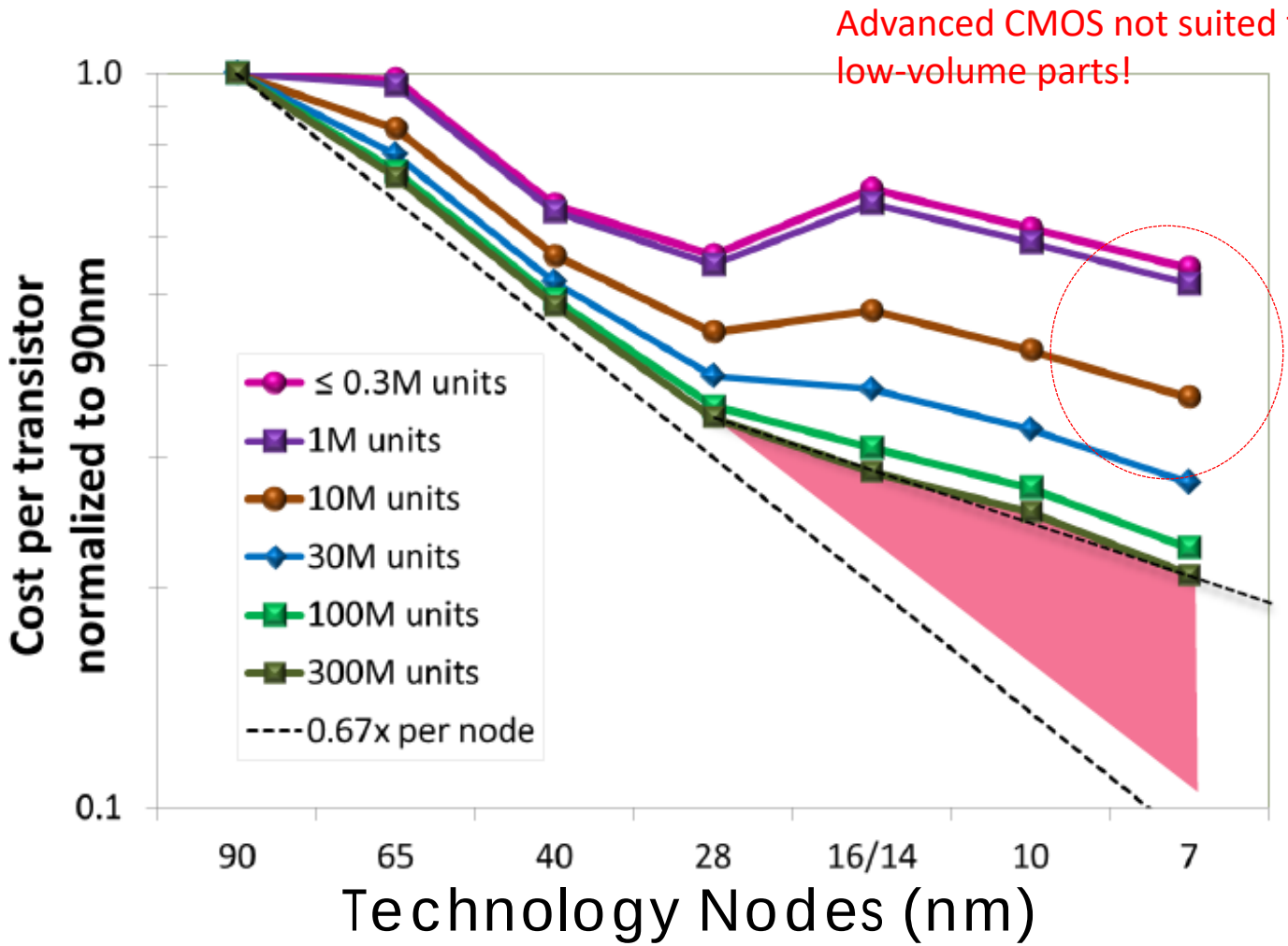
- Data Communication & Information processing technology are commodities?

Moore's Law & Semiconductor



Intel

Not all Semiconductor are Equal…Especially for IOT



Greg Yeric, ARM, IEDM 2015

- Advanced Tech not suitable for High-Mix Low Volume IoT?

How about IoT Vs IIOT & Industry 4.0?

Advanced Semiconductor Manufacturing

$9.5 Billion foundry: 300mm wafer plant production capacity of over 100,000 wafers per month, & 8000 employees

E.g. TSMC's Fab 15 (Taichung, Taiwan) will be TSMC's 3rd Gigafab
Building area = 430,000 square meters
Clean room area ~ 14 soccer fields
(TSMC Press Release 2010/07/16)

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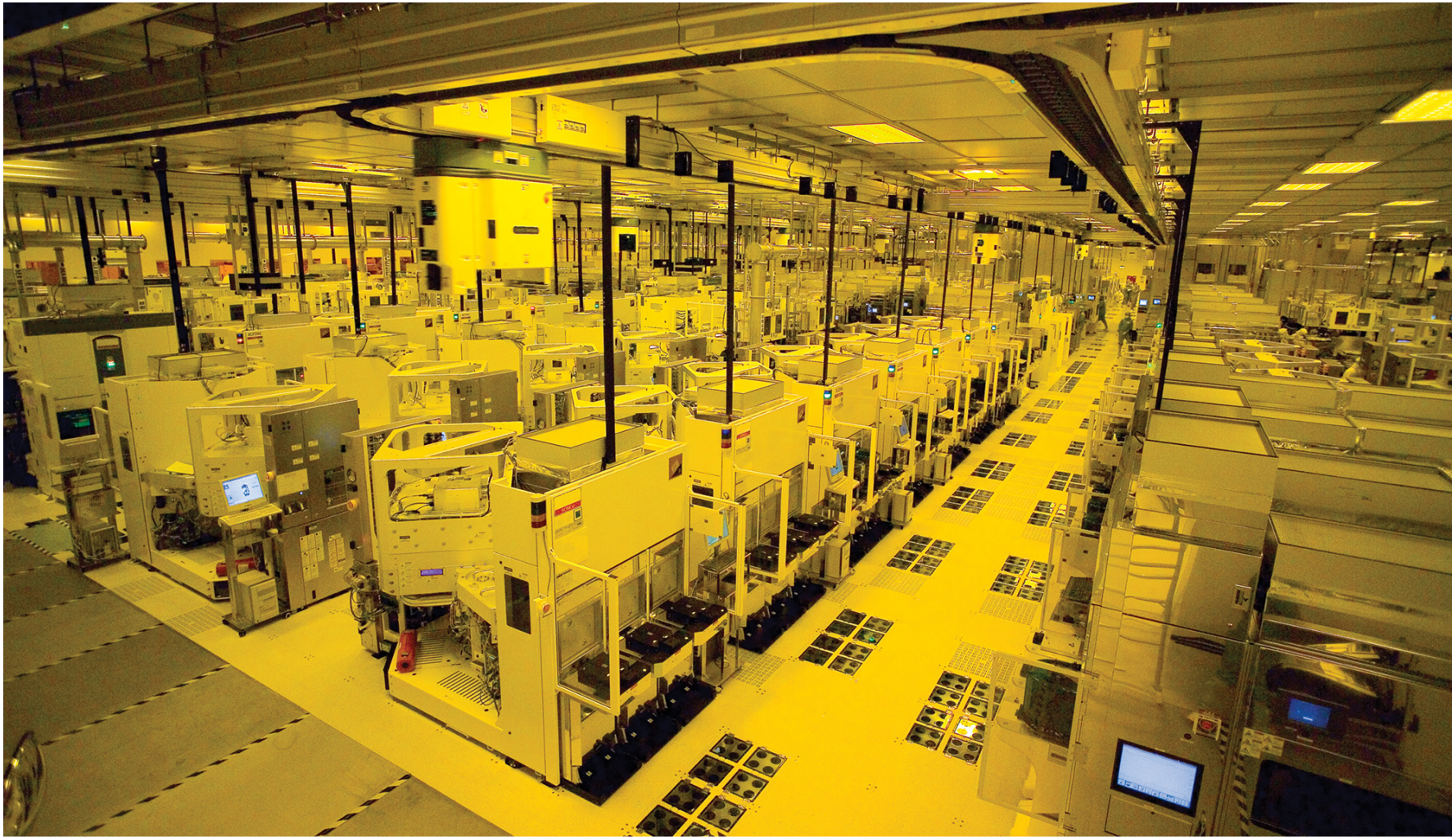
Example of Clean Room



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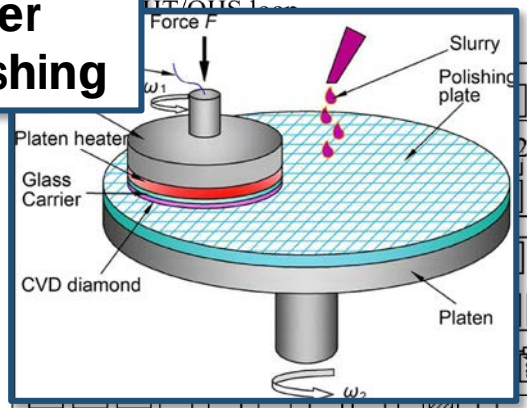
Example of Cleanroom Equipment Layout

Wafer Polishing



Wafer Transport

Film Deposition

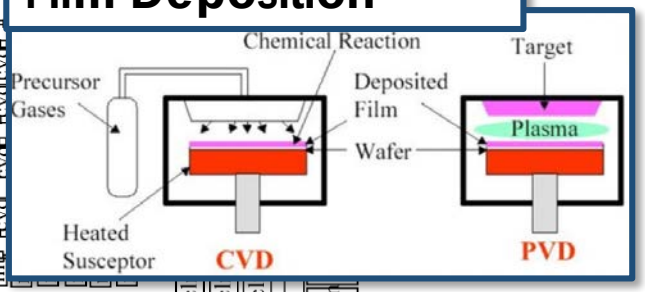
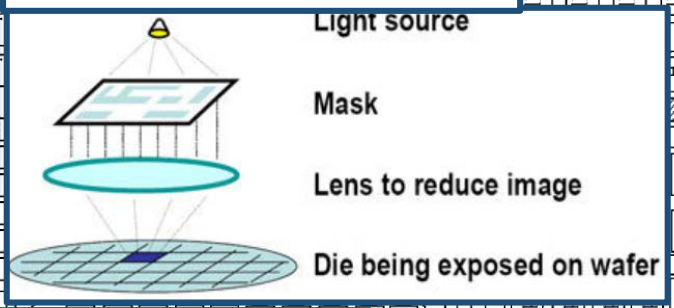
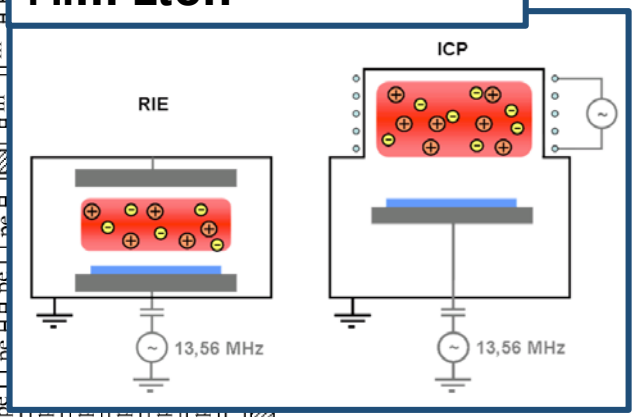


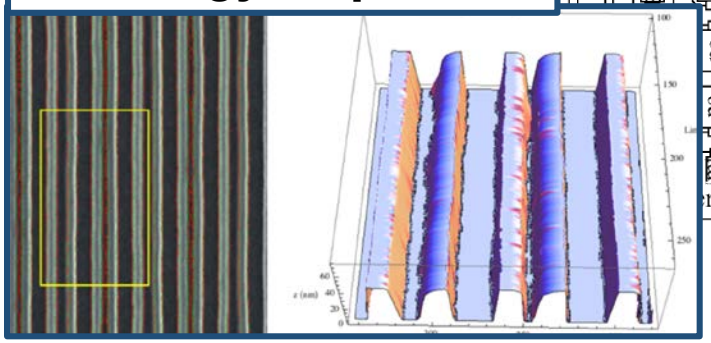
Photo Lithography



Film Etch



Metrology/Inspection



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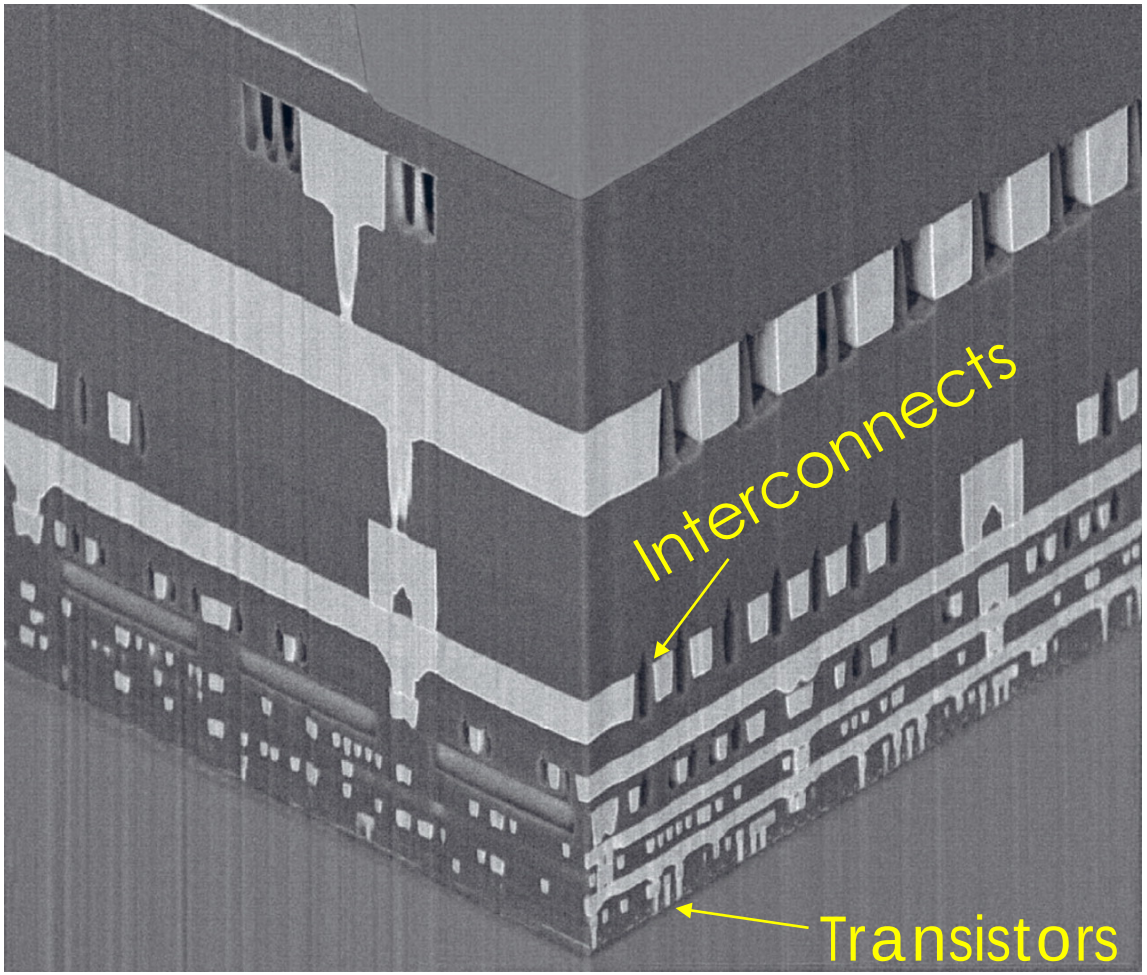
CMOS Microprocessor Chip



Layer-by-layer Planar Processing

Deposition→Patterning →Etch→Fill→Planarize

= 1000's process steps + 3-5 Metrology steps per layer

After: Ultra-precision engineering in lithographic exposure equipment for the semiconductor industry
Robert-H. Munnig Schmidt
Published 16 July 2012.DOI: 10.1098/rsta.2011.0054 Original from IBM Research

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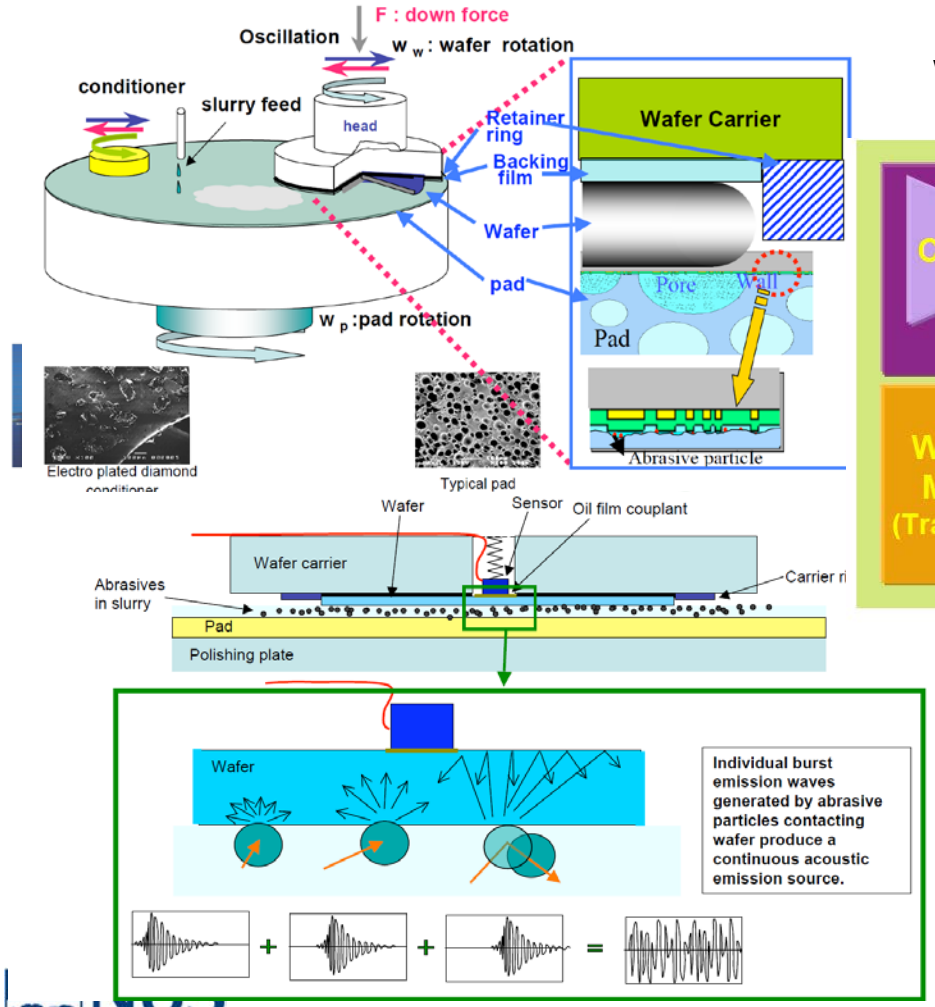
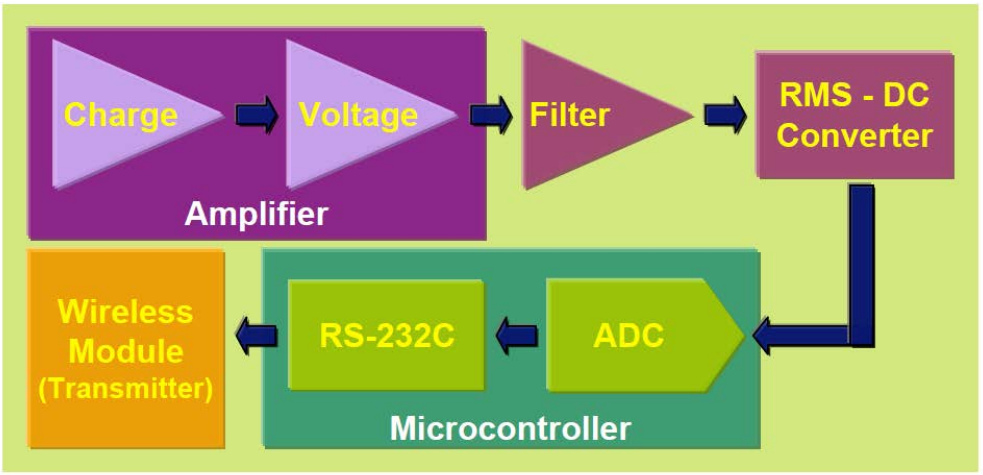
Advanced Equipment-level Sensors & Control

Example: Chemo-mechanical Polishing



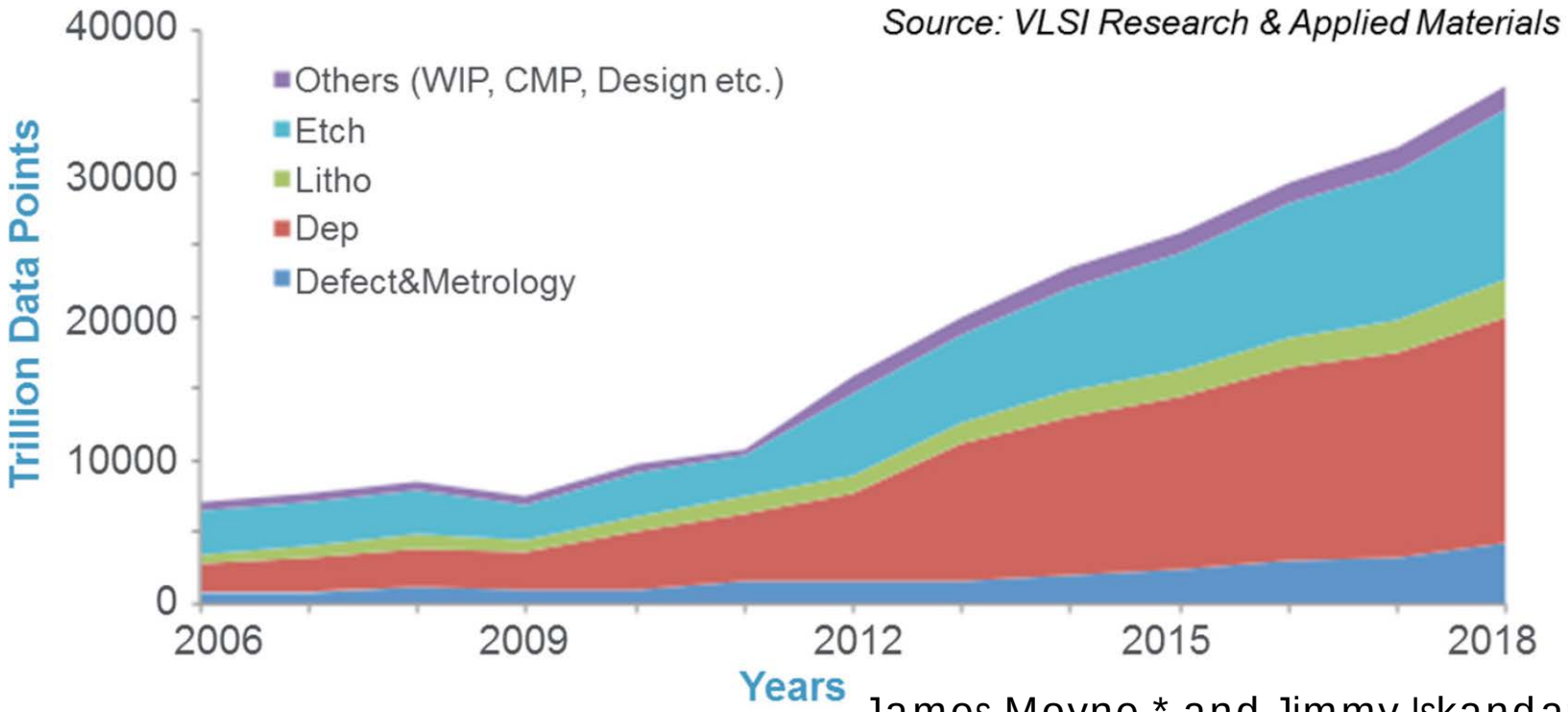
Wireless/Wired Sensor Data Transfer



Source: David Dornfeld
University of California at Berkeley
Planarisation Technology Workshop
Combining Multiscale Modelling and In-Process Monitoring to Optimise CMP
UCD Advanced Manufacturing Science Research Centre. 17 August 2007

National University of Singapore

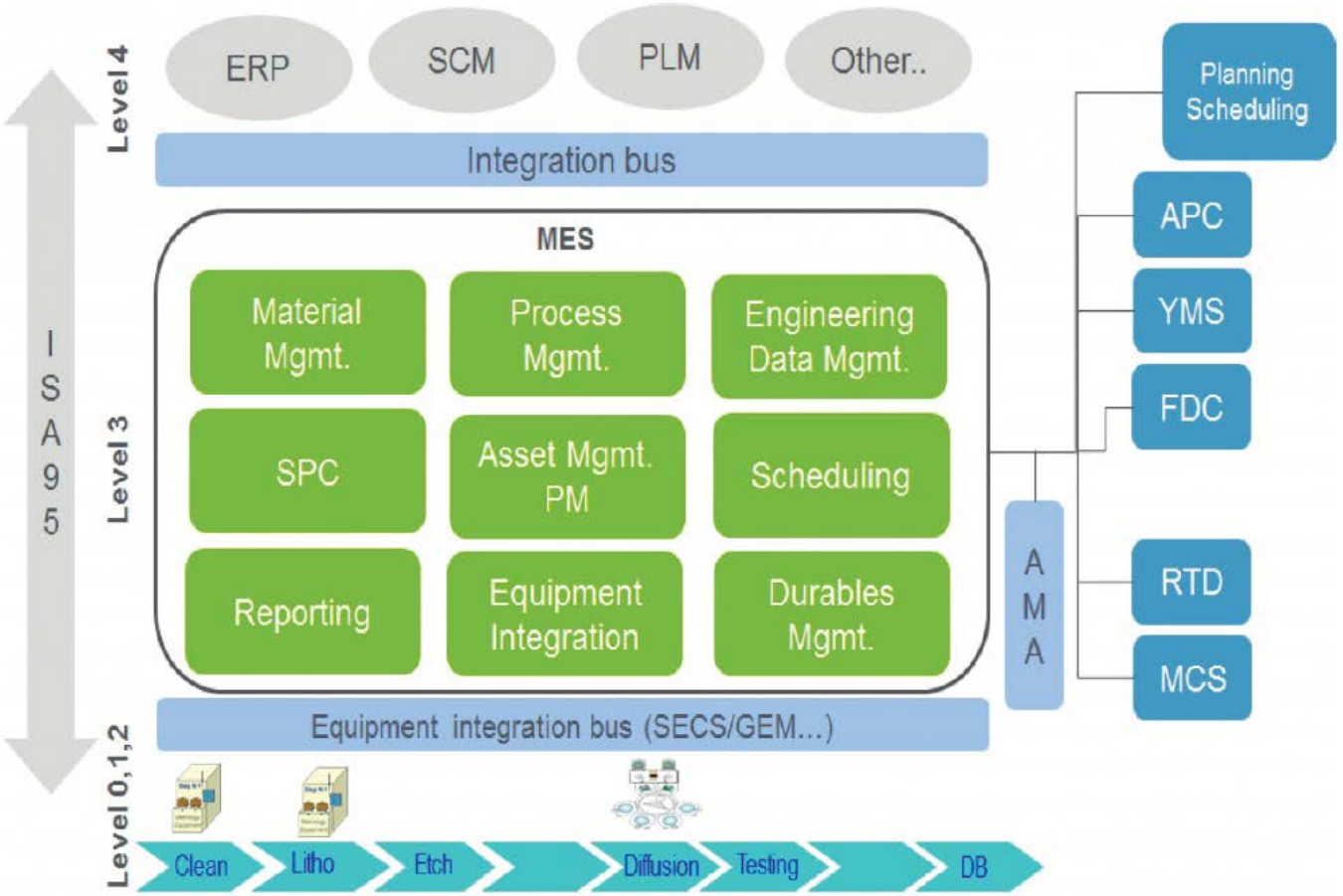
“Big data explosion in semiconductor manufacturing”



James Moyne * and Jimmy Iskandar, Processes **2017**, 5, 39, pp 1-20,

- Technology more complex → Manufacturing more complex → More data

Enterprise-Control System Integration for Fab



Source: Applied Materials

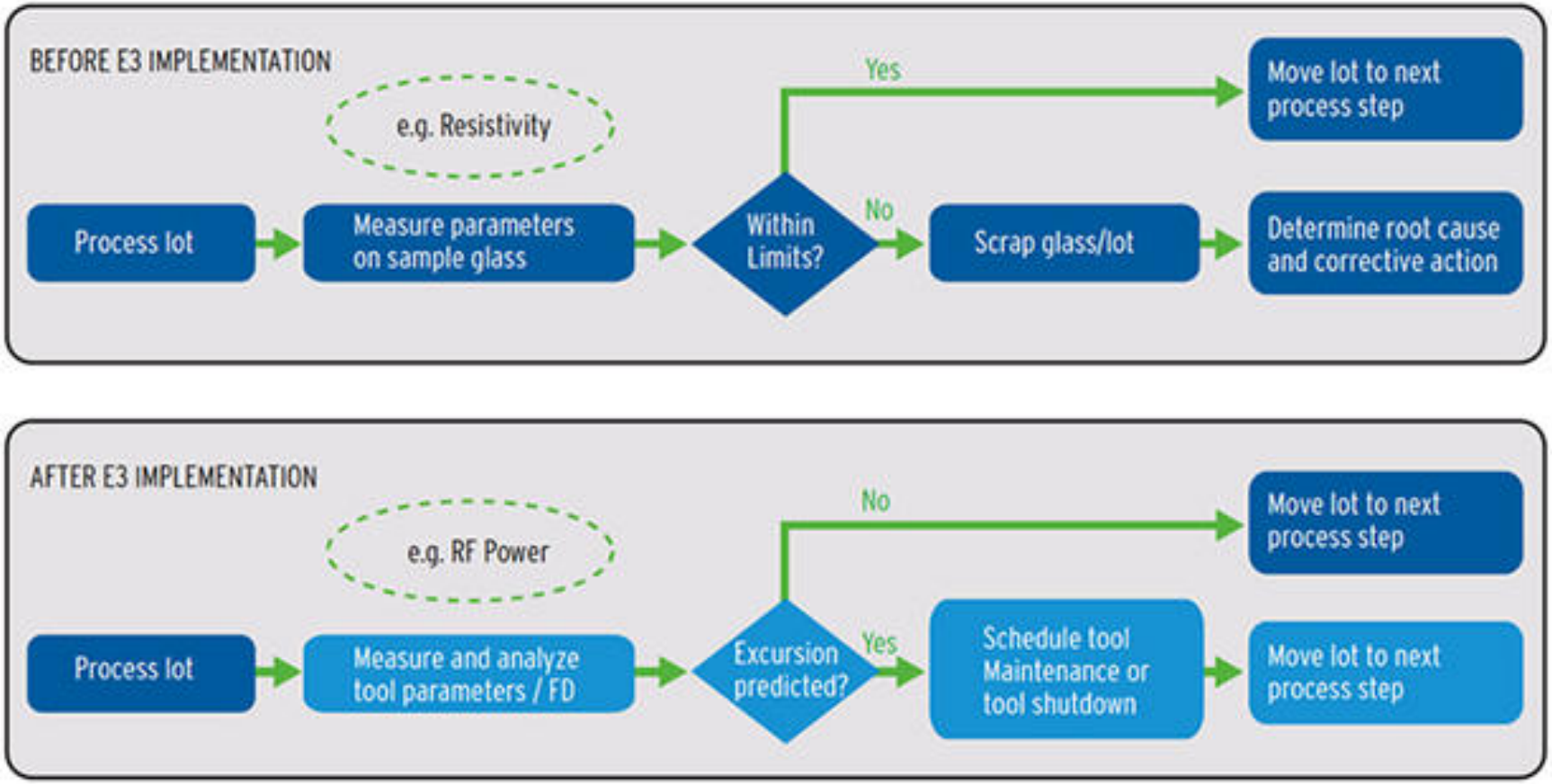
APPLIED MATERIALS®
make possible

APPLIED SMARTFACTORY® FAULT DETECTION AND CLASSIFICATION

Fault detection and classification (FDC) transforms sensor data into summary statistics and models that can be analyzed against user defined limits to identify process excursions. For process and equipment engineers, maximizing equipment effectiveness, reducing yield excursions, improving product cycle time and enhancing the overall output of the factory are key success metrics. SmartFactory FDC is built on Applied's equipment control technology, the E3 platform, which promotes information sharing.

Source: Applied Materials

NUS National University of Singapore



Source: Applied Materials

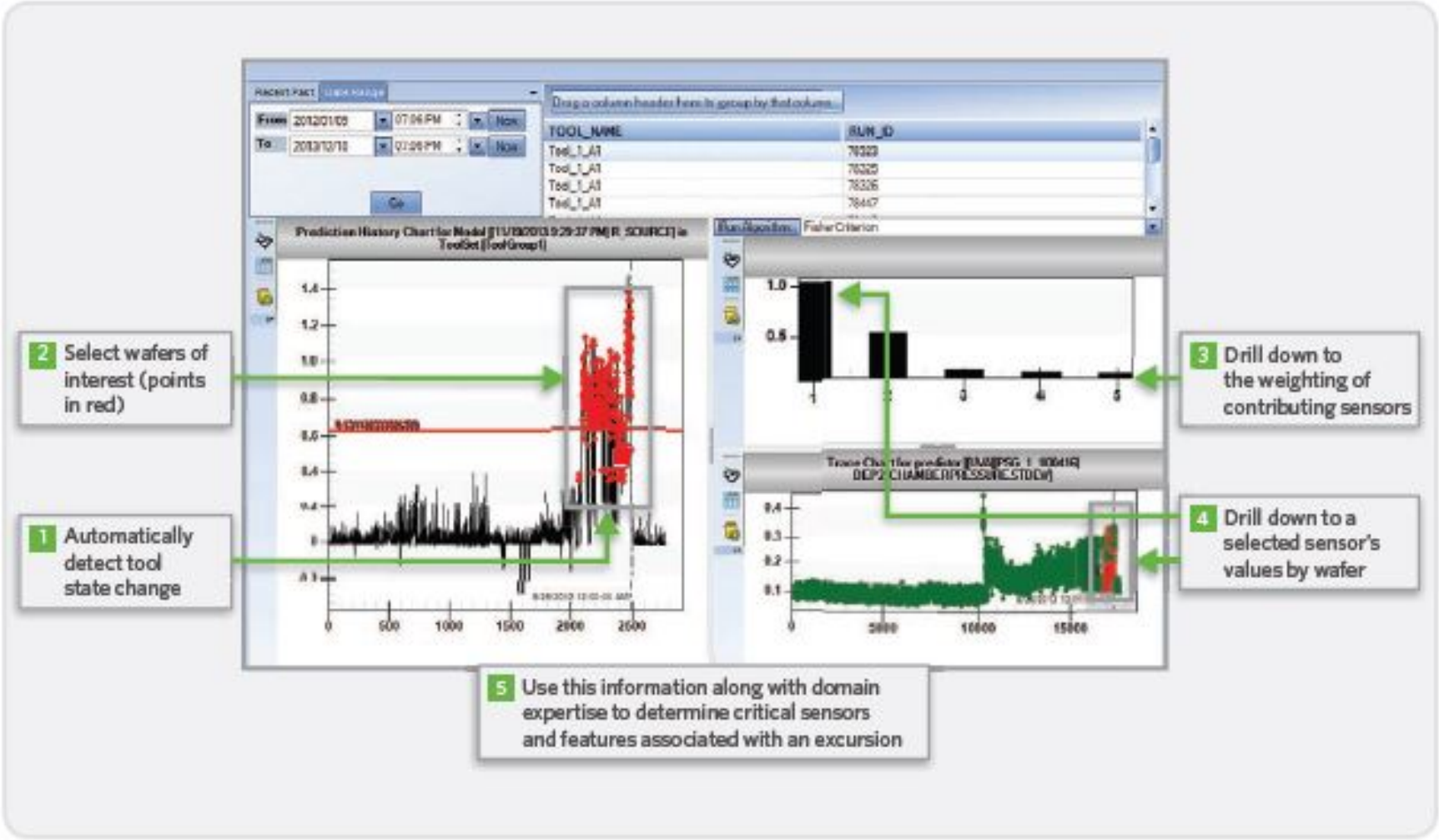


Illustration of ability to determine critical sensors associated with a particular excursion, leveraging techniques originally developed for predictive technologies (virtual metrology and predictive maintenance).

Source: Applied Materials

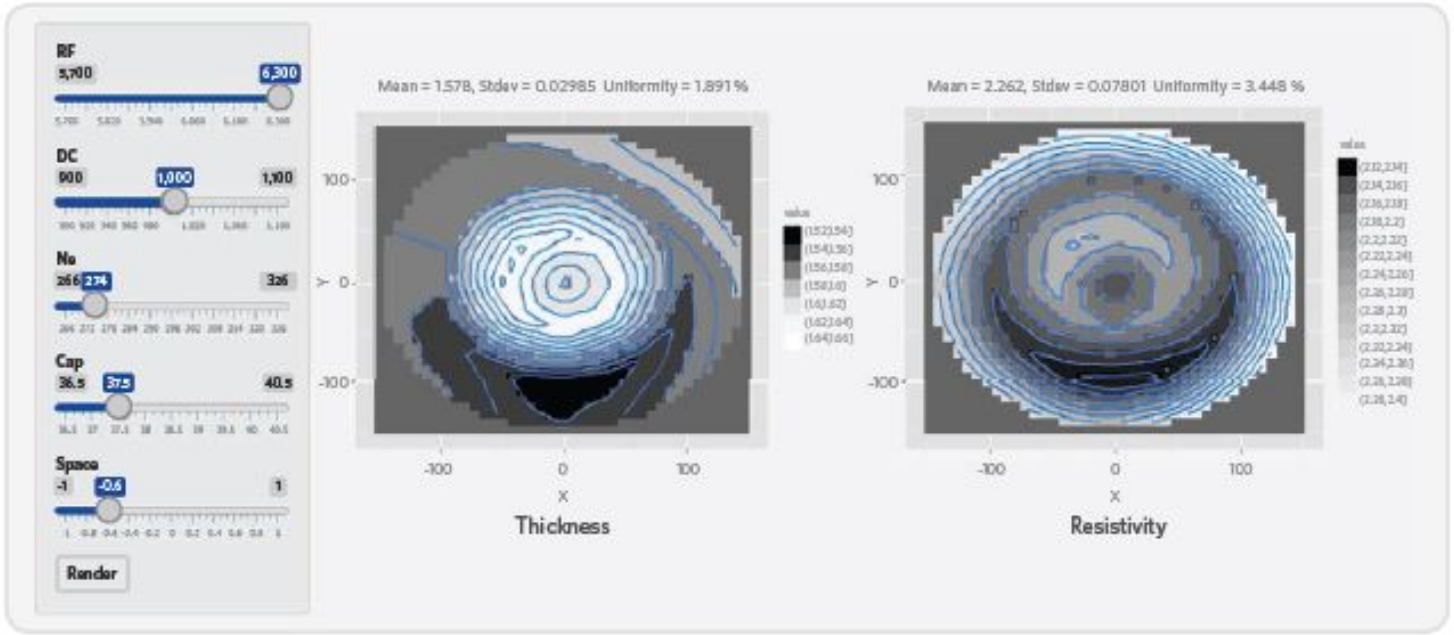
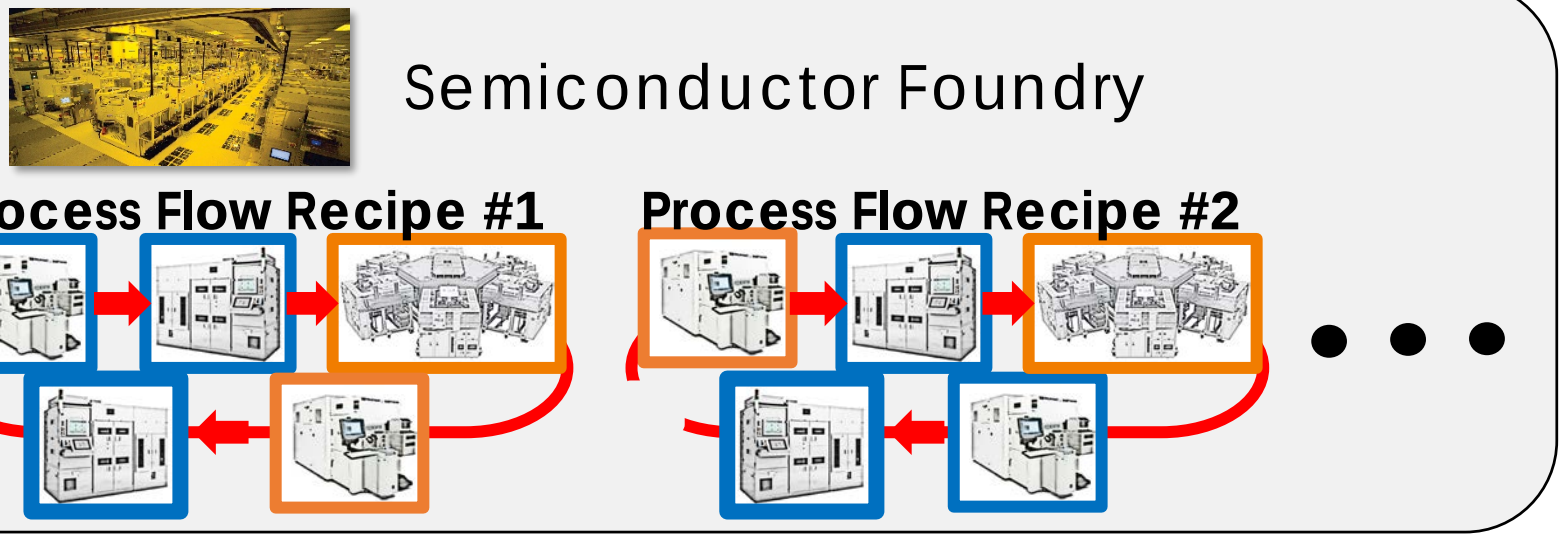


Illustration of topography prediction using FD information, and the ability to adjust key parameters to simulate their impact on topography and determine the optimal settings for a desired topography.

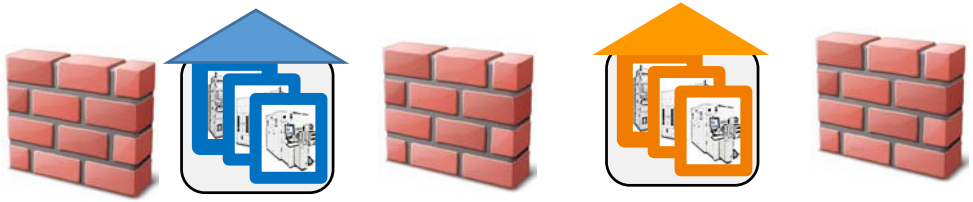
Source: Applied Materials

Issue with IIOT Customer-Supplier Data Sharing

Chip Customers

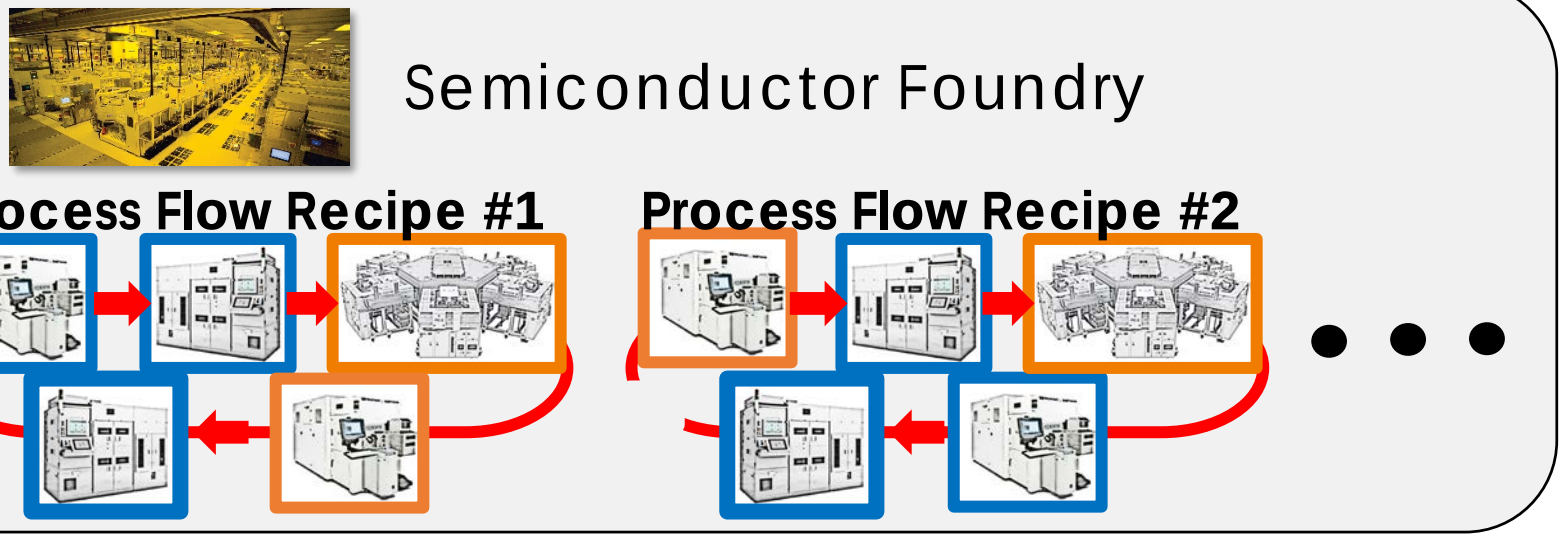


Equipment Manufacturers



Issue with IIOT Customer-Supplier Data Sharing

Chip Customers



- Process flow utilizing different equipment & recipes for different customers
- Process flow = Useful Contextual info
- Process flow info is firewalled between customers
- Foundry can implement Smart IIOT Manufacturing to optimize factory/business

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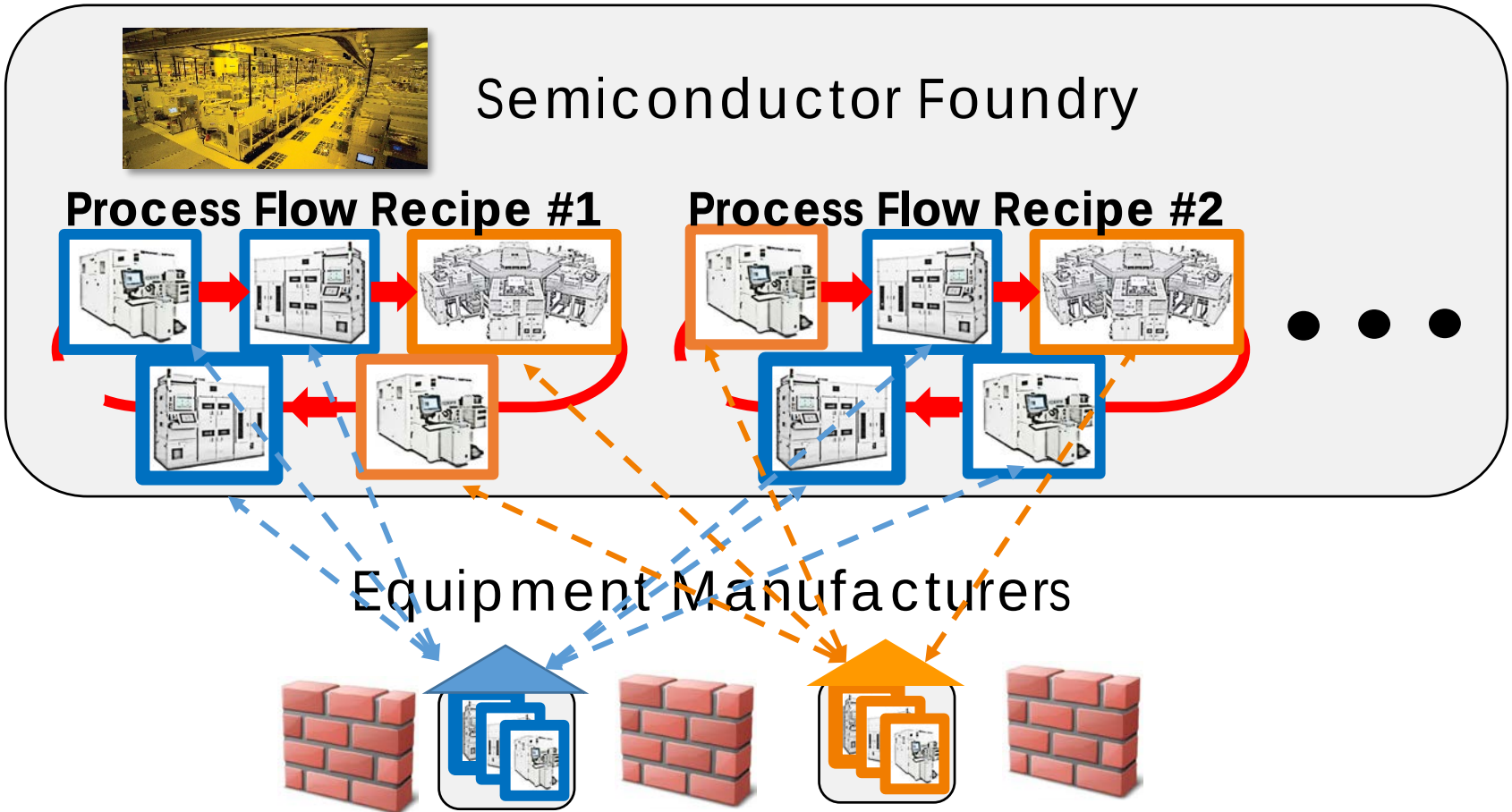
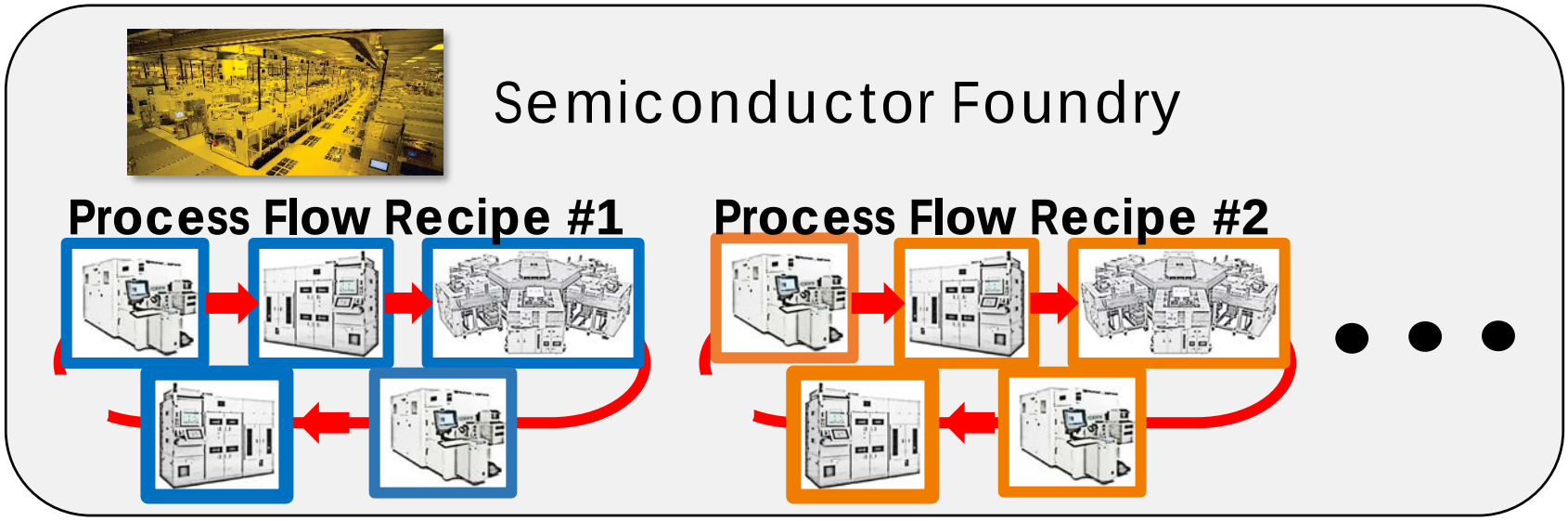
Issue with IIOT Customer-Supplier Data Sharing

- Equipment data to Equipment suppliers lack contextual info –Process flow is proprietary for Chip customers
- Foundry cannot share equipment data between competiting suppliers



Issue with IIOT Customer-Supplier Data Sharing

- Possible Solution:
  - -Data-analytics Service + Integrated Tool Suites
  - -Partnerships (Supplier-Supplier-Foundry) for data sharing



Equipment Manufacturers

Messages

- **Internet**: Key businesses are Services & Smart Mobile Devices

- **Internet of Things**: Devices & Communication will be commoditized (especially edge devices), Hardware+Data analytic bundled services seem valuable but business model not well defined yet.

- **Industrial Internet of Things & Industry 4.0**: Hardware+Data analytic bundled services valuable. Data-analytic enabled Smart Manufacturing business model is well defined. Challenge is data-sharing.

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Thank You!