# DFMA® 2017

## 32nd International Forum on Design for Manufacture and Assembly

# *DFI:*
# *Design for Industrial Internet*
# *Design for Internet of Things*

**Bradford L. Goldense**

**June 6, 2017**

Goldense Group, Inc. 1346 South Street Needham, MA 02492 Phone 781-444-5400
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# DFI: Design for Industrial Internet & Design for Internet of Things

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# DFI:
## Design for Industrial Internet
## Design for Internet of Things

***A New Reality***

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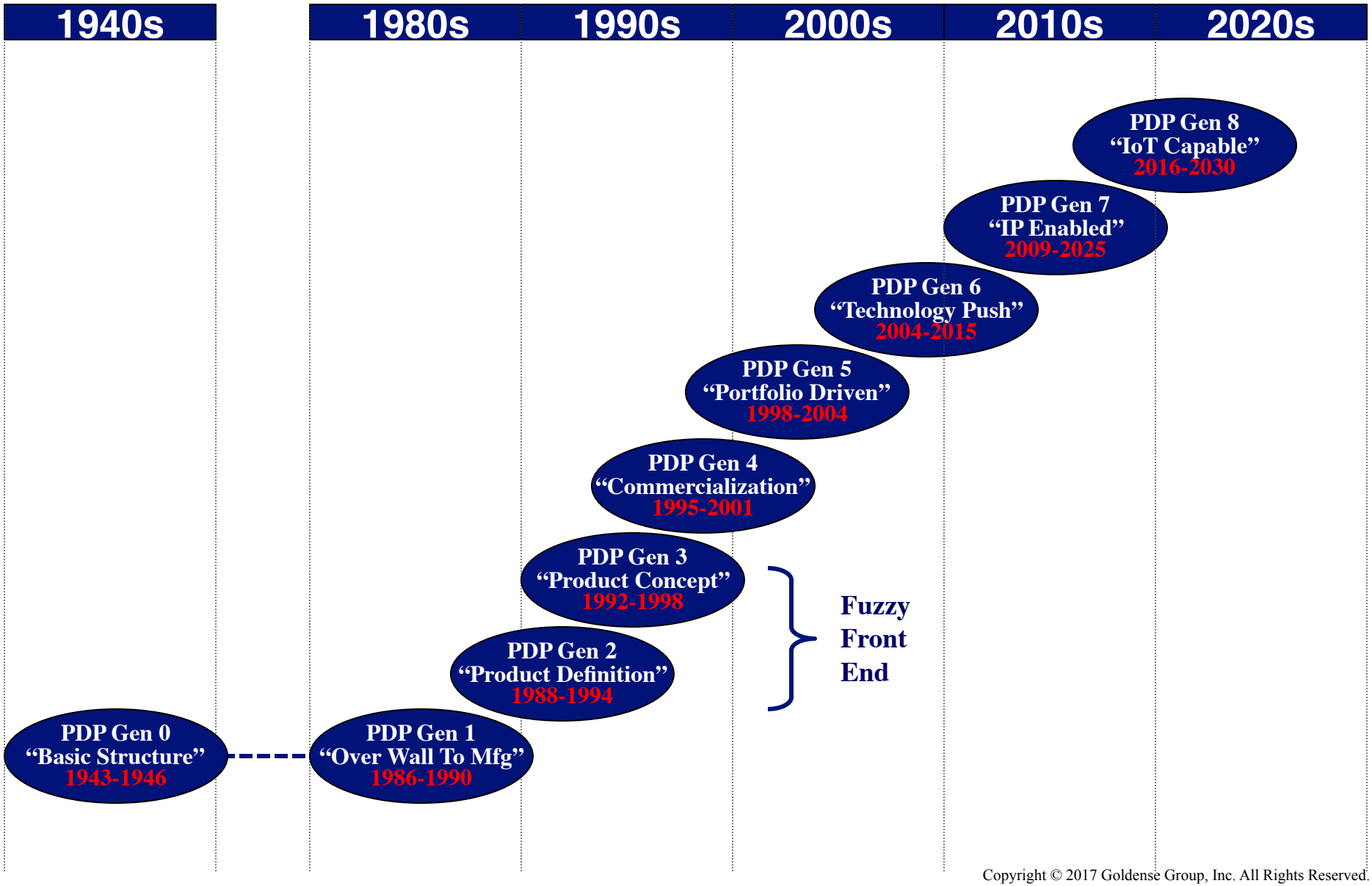
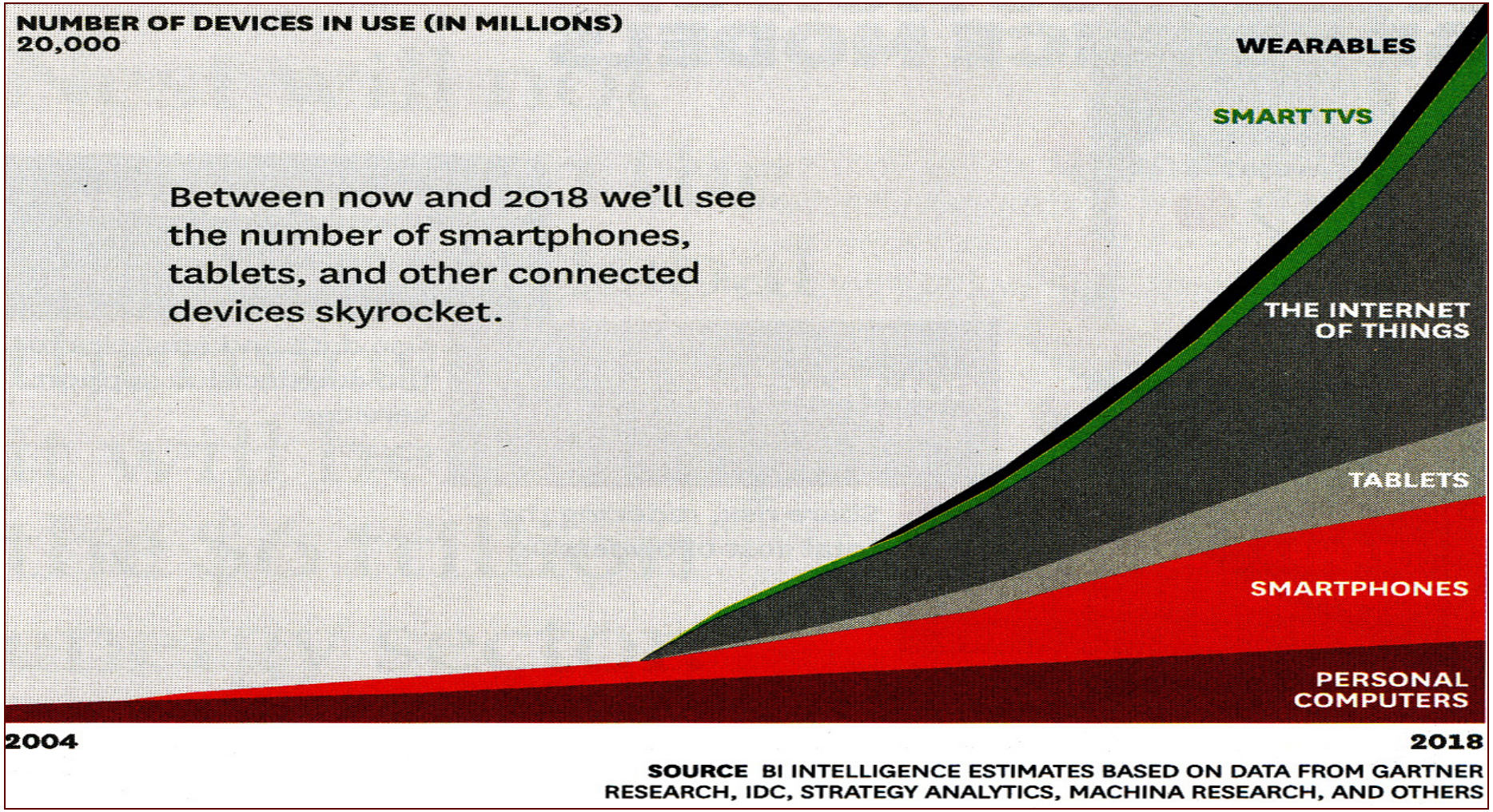
# DFI: Design for Industrial Internet & Design for Internet of Things

## New Reality: The 8th Generation Of Product Development



# DFI: Design for Industrial Internet & Design for Internet of Things

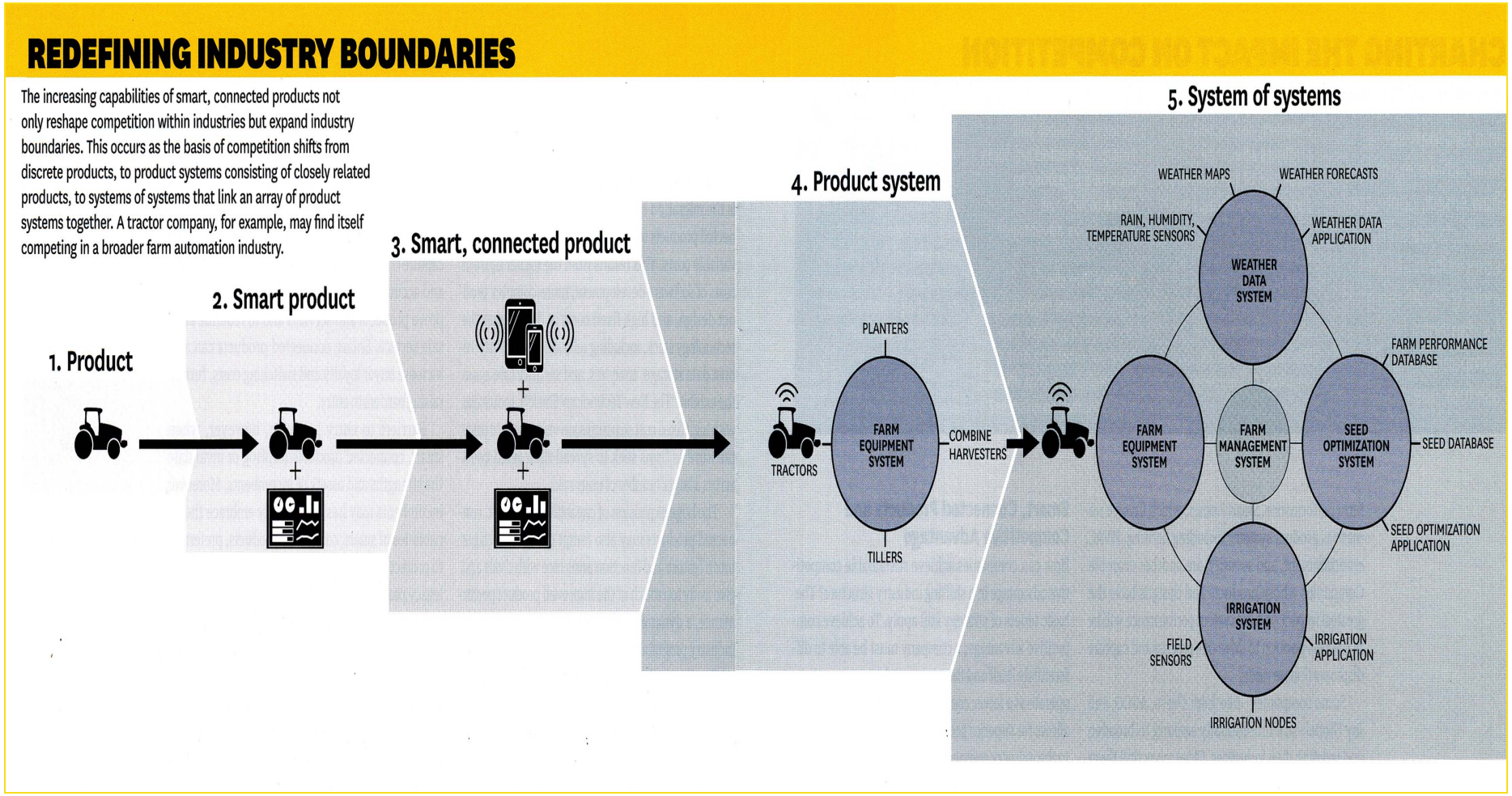
## New Reality: Explosion In Connected Devices




Source: Marco Iansiti and Karim R. Lakhani, "Digital Ubiquity: How Connections, Sensors, and Data Are Revolutionizing Business," *Harvard Business Review*, Harvard Business School Publishing, 60 Harvard Way, Boston, MA, 02163, USA, November 2014, Page 93, Inset: An Explosion In Connected Devices.

# DFI: Design for Industrial Internet & Design for Internet of Things

## New Reality: The Smart Connected Company - Will Compete In Multiple Industries



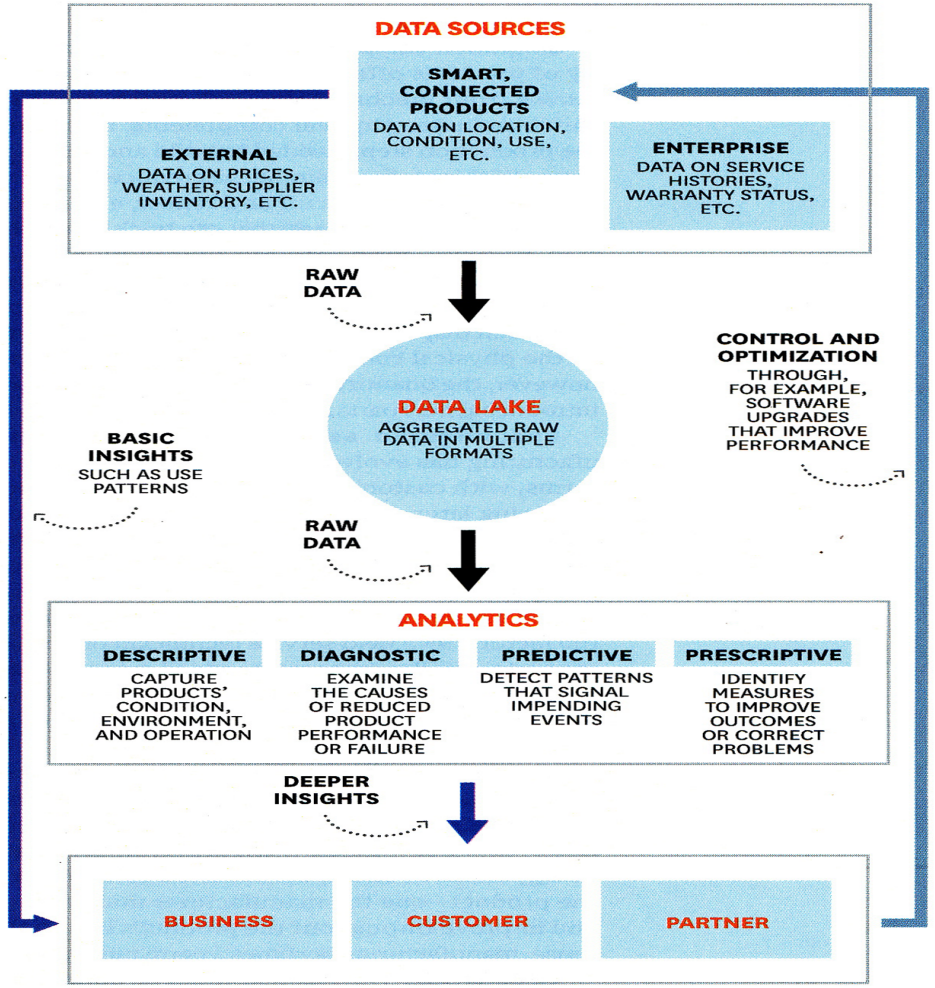

Source: Michael E. Porter and James E. Heppelmann, "How Smart, Connected Products Are Transforming Competition, *Harvard Business Review*, Harvard Business School Publishing, 60 Harvard Way, Boston, MA, 02163, USA, November 2014; Page 74-75, Inset - Redefining Industry Boundaries. [Part 1 of 2 – A Two Part Series]

# DFI: Design for Industrial Internet & Design for Internet of Things

## New Reality: The Smart Connected Company - The "Value Equation" Changes

### CREATING NEW VALUE WITH DATA

Data from smart, connected products is generating insights that help businesses, customers, and partners optimize product performance. Simple analytics, applied by individual products to their own data, reveal basic insights; more-sophisticated analytics, applied to product data that has been pooled into a "lake" with data from external and enterprise sources, unearth deeper insights.




Source: Michael E. Porter and James E. Heppelmann, "How Smart, Connected Products Are Transforming Companies, *Harvard Business Review*, Harvard Business School Publishing, 60 Harvard Way, Boston, MA, 02163, USA, October 2015; Page 103, Inset - Creating New Value With Data. [Part 2 of 2 - A Two Part Series]

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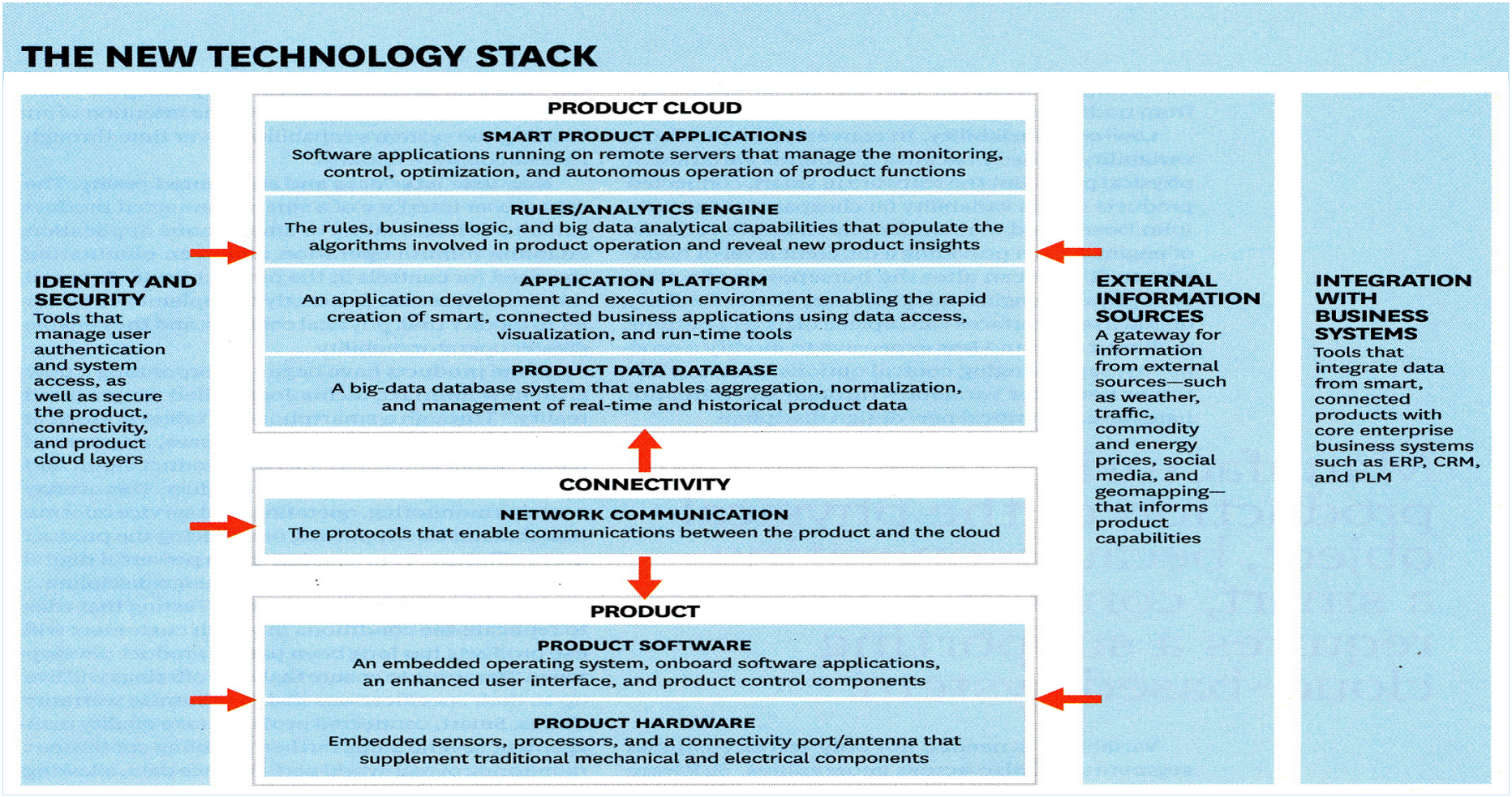
## New Reality: The Smart Connected Company - Product Technology Architecture

SOURCE "HOW SMART, CONNECTED PRODUCTS ARE TRANSFORMING COMPETITION," HBR, NOVEMBER 2014




Source: Michael E. Porter and James E. Heppelmann, "How Smart, Connected Products Are Transforming Companies, *Harvard Business Review*, Harvard Business School Publishing, 60 Harvard Way, Boston, MA, 02163, USA, October 2015; Page 101, Inset - The New Technology Stack. [Part 2 of 2 - A Two Part Series]

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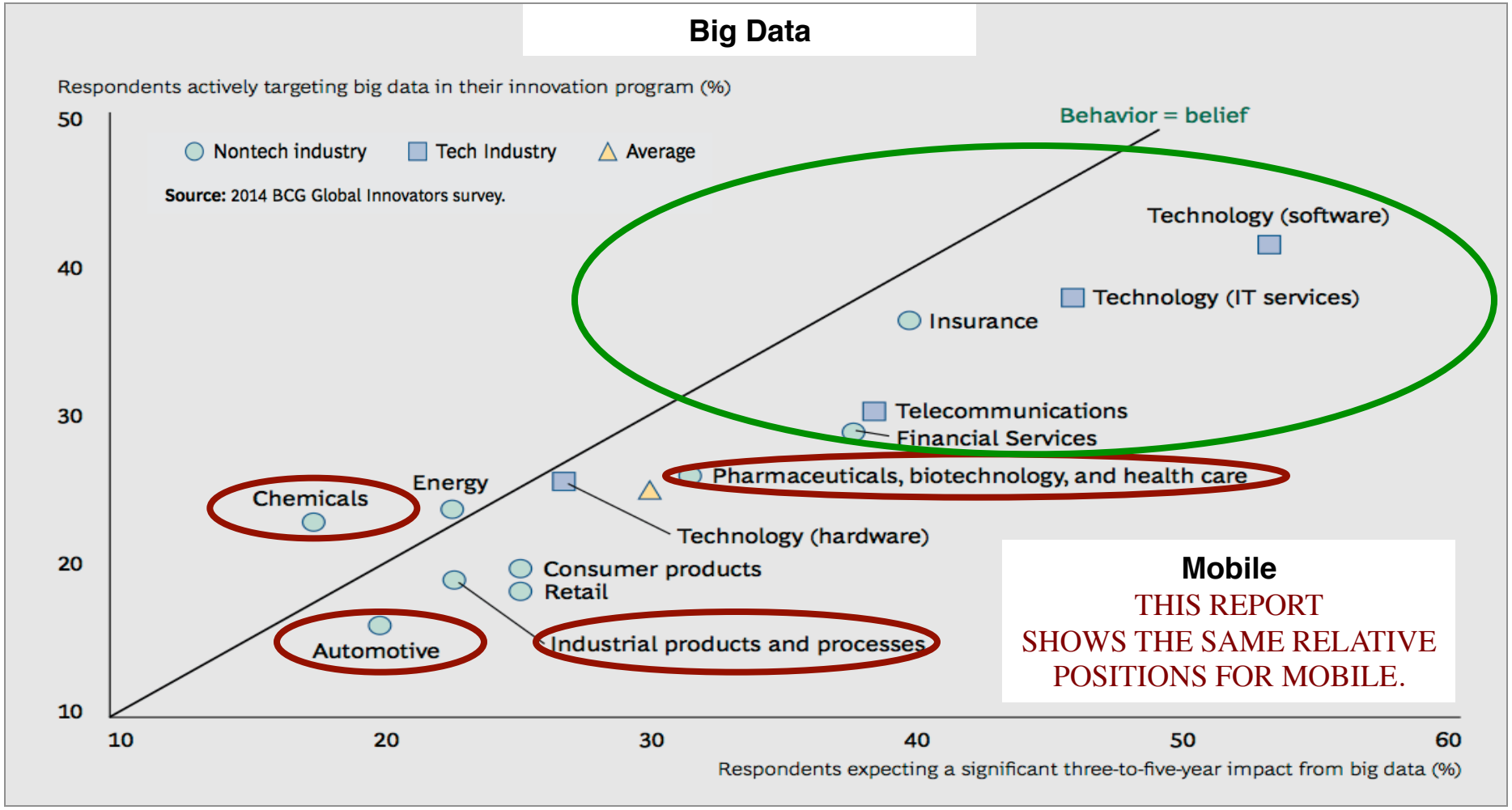
## New Reality: Leader & Laggard Industries Are Already Being Tracked




Source: Kim Wagner, Andrew Taylor, et. al., "The Most Innovative Companies 2014: Breaking Through Is Hard To Do", The Boston Consulting Group, Inc. [BCG], One Beacon Street, Boston, Massachusetts, USA, October 2014, Page 15, Exhibit 7: Underestimating the Importance of – and Underinvesting in – Big Data and Mobile...Big Data.

# DFI:
## Design for Industrial Internet
## Design for Internet of Things

***Explosion of IIoT & IoT***

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# DFI: Design for Industrial Internet & Design for Internet of Things

## Explosion: Design Software - Simulation &Analysis ...AND... EDA

Technavio's market research analyst predicts the global simulation and analysis software market to grow steadily at a CAGR of around 12% during the forecast period. The rising need for products with enhanced quality and innovation is a major driver for this market. The adoption of simulation and analysis software has increased across industries as they compete to achieve "first mover advantage" and strive to become the "prime innovator" in their field.

Source: http://www.technavio.com/report/global-product-lifecycle-management-simulation-and-analysis-software-market

Electronic design automation or EDA comprises software tools that are used for designing electronic systems such as PCBs and ICs. EDA enables electrical engineers (hardware engineers) and computer engineers (software engineers) to design, analyze, and simulate the semiconductor chips. It also encompasses algorithms and methodologies for the design of VLSI circuits. Various EDA tools available in the market today are used to design and develop complicated and large-scale circuits that are then used in products across the industries. EDA tools help semiconductor and electronic products manufacturing companies by reducing product development time and increasing the accuracy of design.

TechNavio's analysts forecast the Global Electronic Design Automation market to grow at a CAGR of 9.93 percent over the period 2013-2018.

Source: http://www.reportsnreports.com/reports/312569-global-electronic-design-automation-eda-market-2014-2018.html

## Explosion: Industrial Automation

Technavio's research analyst predicts the global industrial automation control market to grow steadily at a CAGR of close to 8% during the forecast period. High capital expenditure is the primary growth driver for this market. The rise in capital expenditure in industries such as oil and gas, power, and automotive contributed to the growth of this market. For instance, capital investment by Ford Motors surpassed $7 billion in 2015, and a portion of this investment was used for building new plants, where automation solutions such as DCS, PLC, sensors, and drives were installed.

The growing demand for smart factories is also expected to boost the market over the next four years. The emergence of IoT, integrated with modern industrial automation control systems, is a key emerging trend in this market. As, the integration of IoT reduces CAPEX and OPEX considerably; the leading market vendors will increasingly look to leverage it to expand in this market shortly.

Source: http://www.technavio.com/report/global-automation-industrial-automation-control-market

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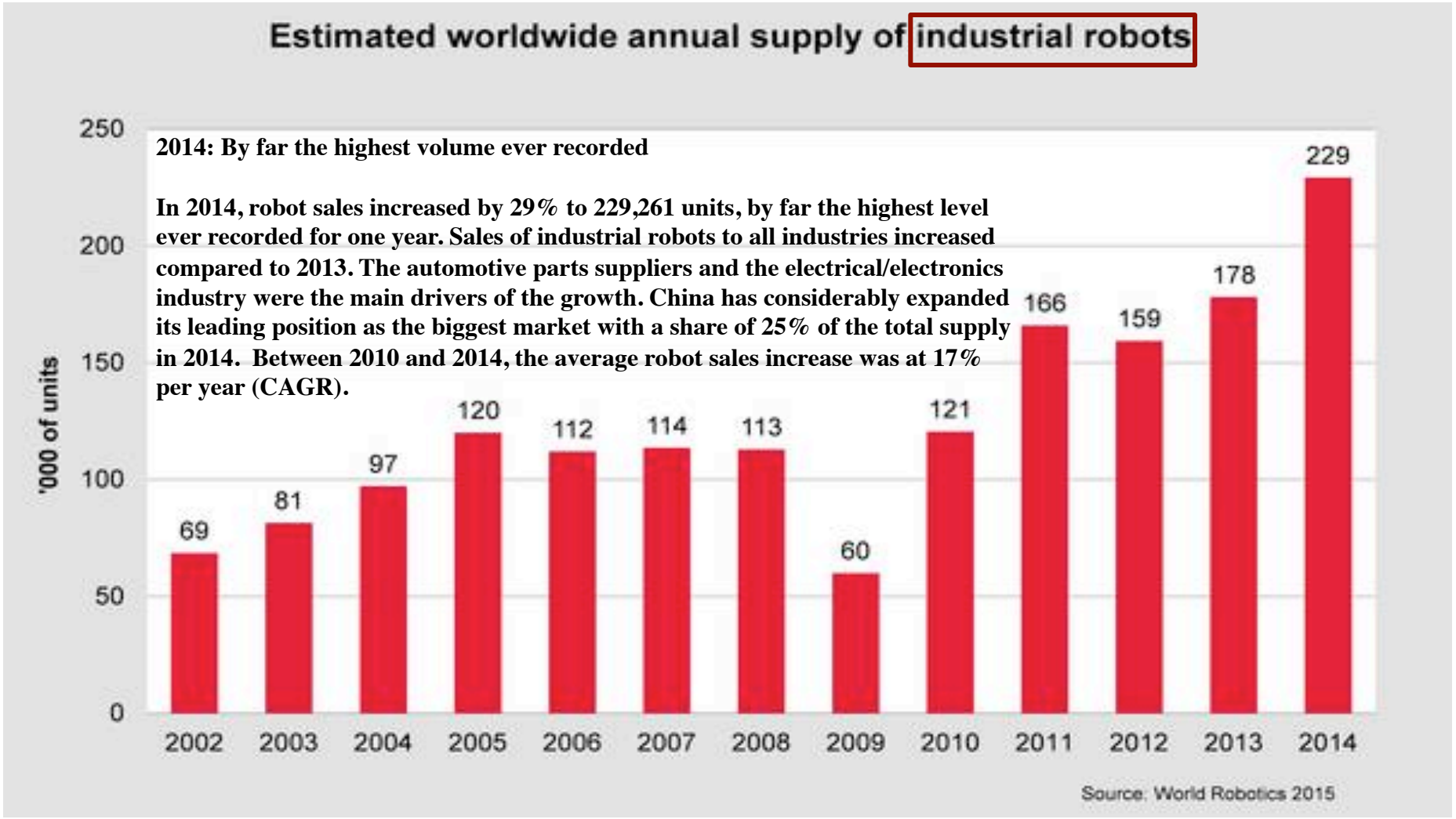
## Explosion: Industrial Robots




Source: http://www.ifr.org/industrial-robots/statistics/

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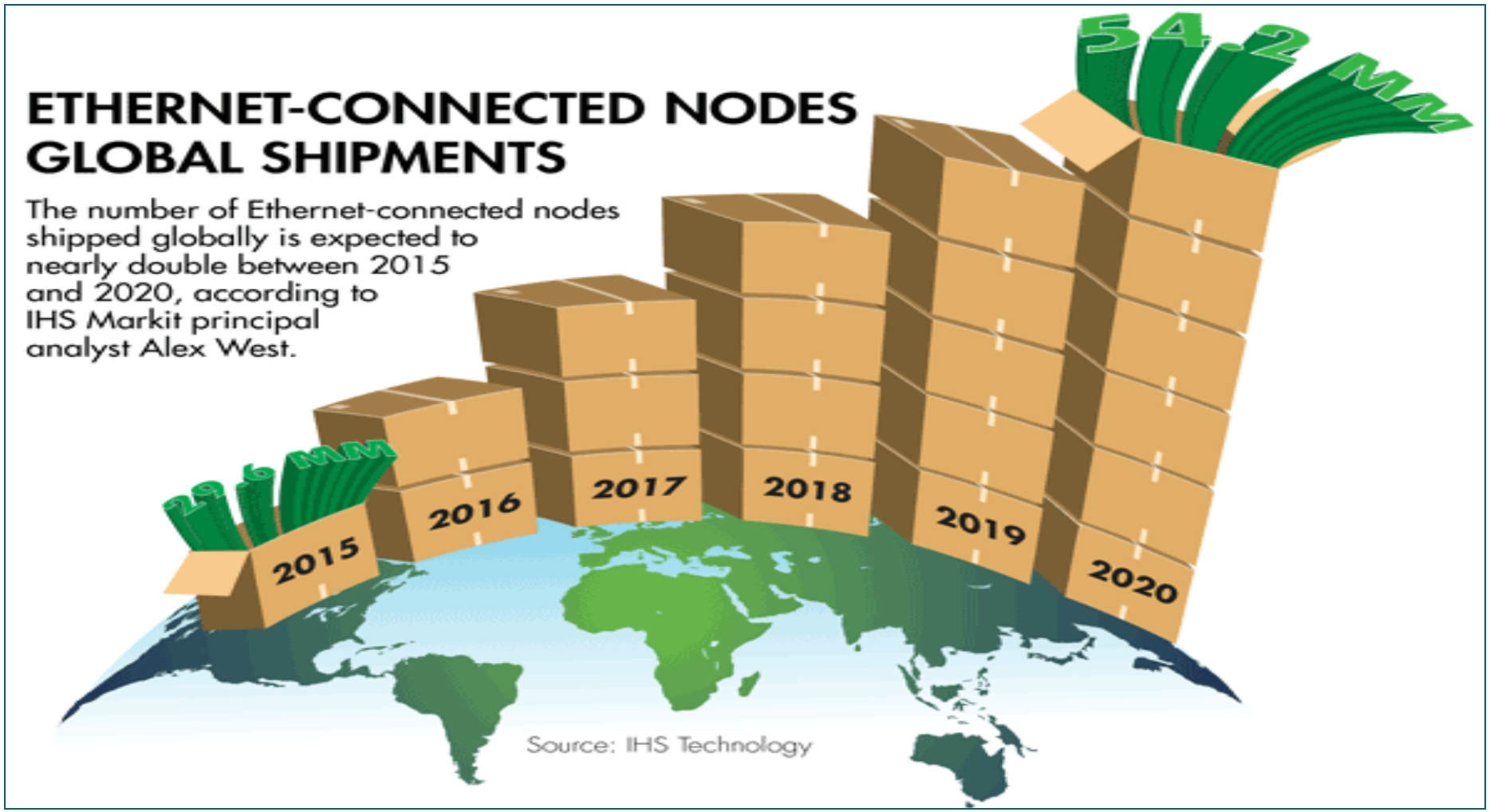
## Explosion: Ethernet Connected Nodes




Source: Victoria Fraza Kickham, "Data Drives The Industrial IoT," Machine Design, Volume 88, Number 12, December 2016. Figure 1: Ethernet-Connected Nodes Global Shipments; Source: IHS Technology.

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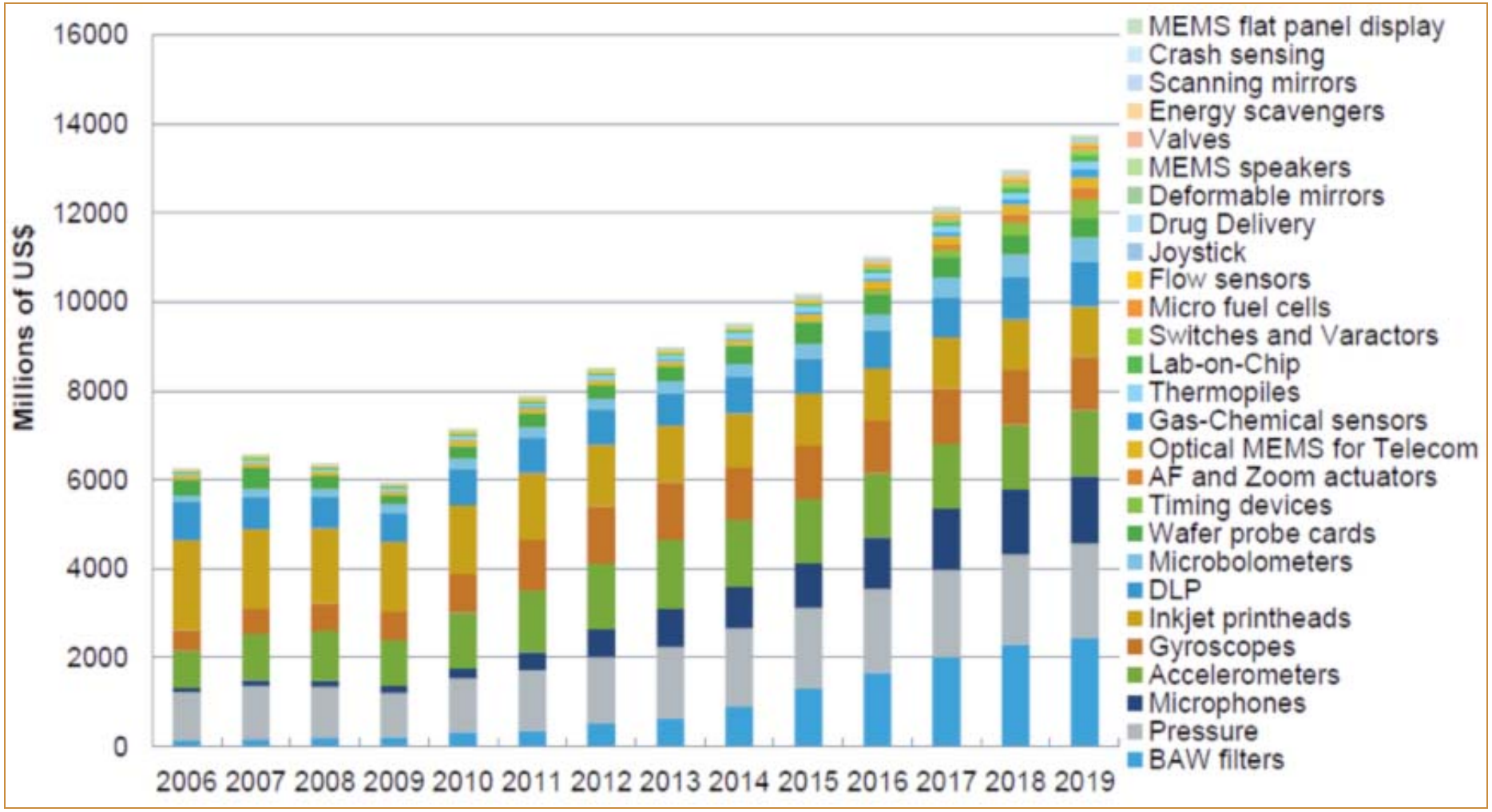
## Explosion: MEMS Devices - Sensors, Displays, Micro Fuel Cells, Gyroscopes, ...




Source: "Total MEMS Market By Device: Forecast 2015-2019," MEMS Market Tracker , IHS, The Capitol Building, Willoughby Road, Oldbury, Brackness RG12 8FZ, United Kingdom, Q3 2015.

## Explosion: Nanotechnology - Global Product Sales USD 4.4 Trillion by 2018

# Nanotechnology Update: Corporations Up Their Spending as Revenues for Nano-enabled Products Increase

February 17, 2014 | State of the Market Report

Governments, corporations, and private investors (venture capitalists) invested $18.5 billion in nanotechnology in 2012, increasing their spending 8% relative to 2010. The U.S. contributed 36% of this amount. Corporations expanded spending by 21% over 201o, while governments and private investors reduced their investments by 5% and 10% respectively. The United States maintained its lead over all other governments, with $2.1 billion of federal and state funding in 2012. U.S. corporations also led global spending on nanotechnology research and development, investing $4 billion in 2012, which was approximately $1 billion more than the next country, Japan. The revenue from nano-enabled products has continued to grow, from $339 billion in 2010 to $731 billion in 2012. This total is a slight decrease in our estimate relative to our last update on nano-enabled product revenues released in 2009. Our expanded forecast for nano-enabled products reveals the global value of nano-enabled products, nano-intermediates, and nanomaterials reaching $4.4 trillion by 2018.

Source: https://portal.luxresearchinc.com/research/report_excerpt/16215

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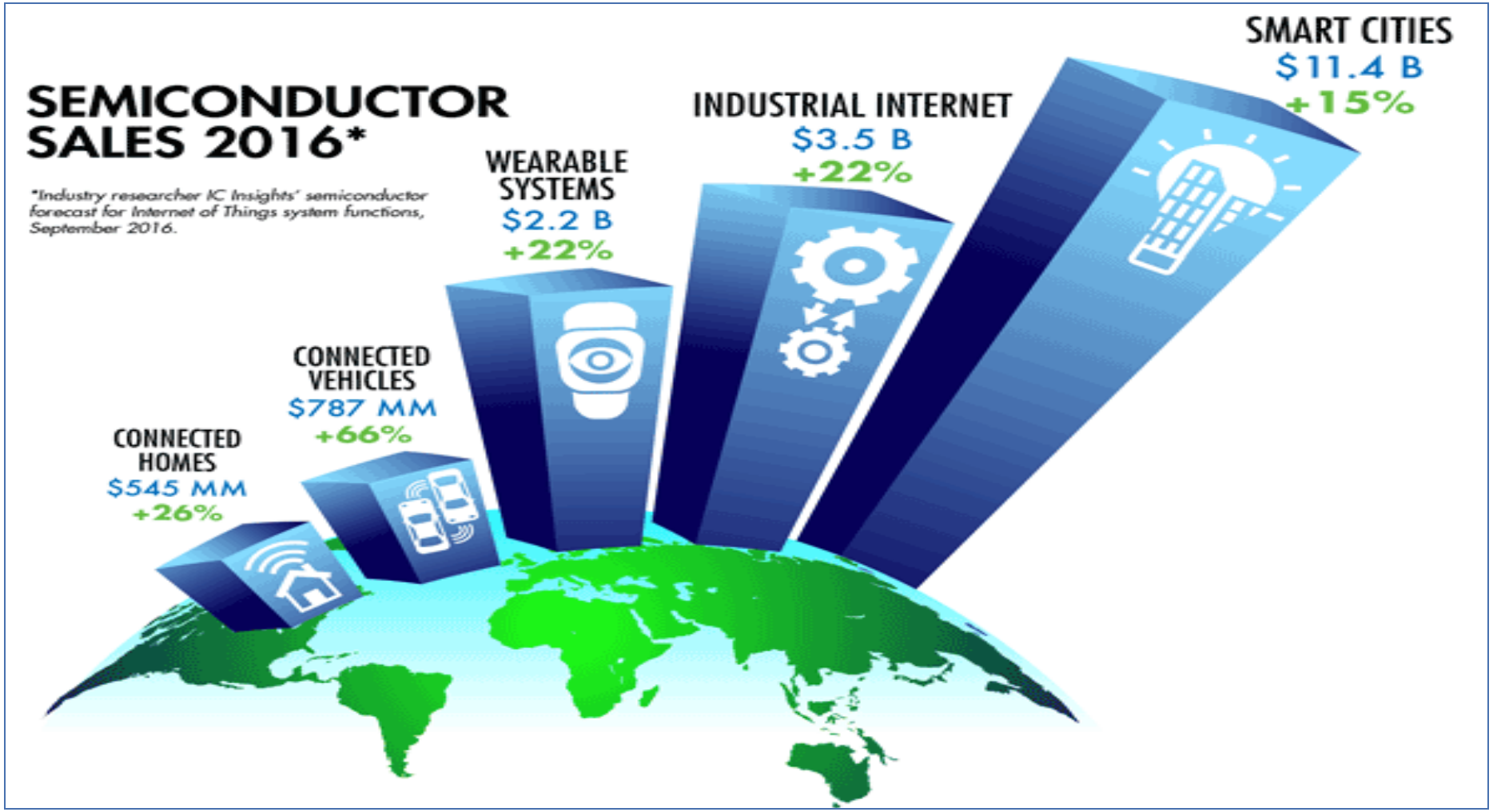
## Explosion: Semiconductor Sales - Major Markets




Source: Victoria Fraza Kickham, "Data Drives The Industrial IoT," Machine Design, Volume 88, Number 12, December 2016. Figure 3: Semiconductor Sales 2016; Source: IC Insights.

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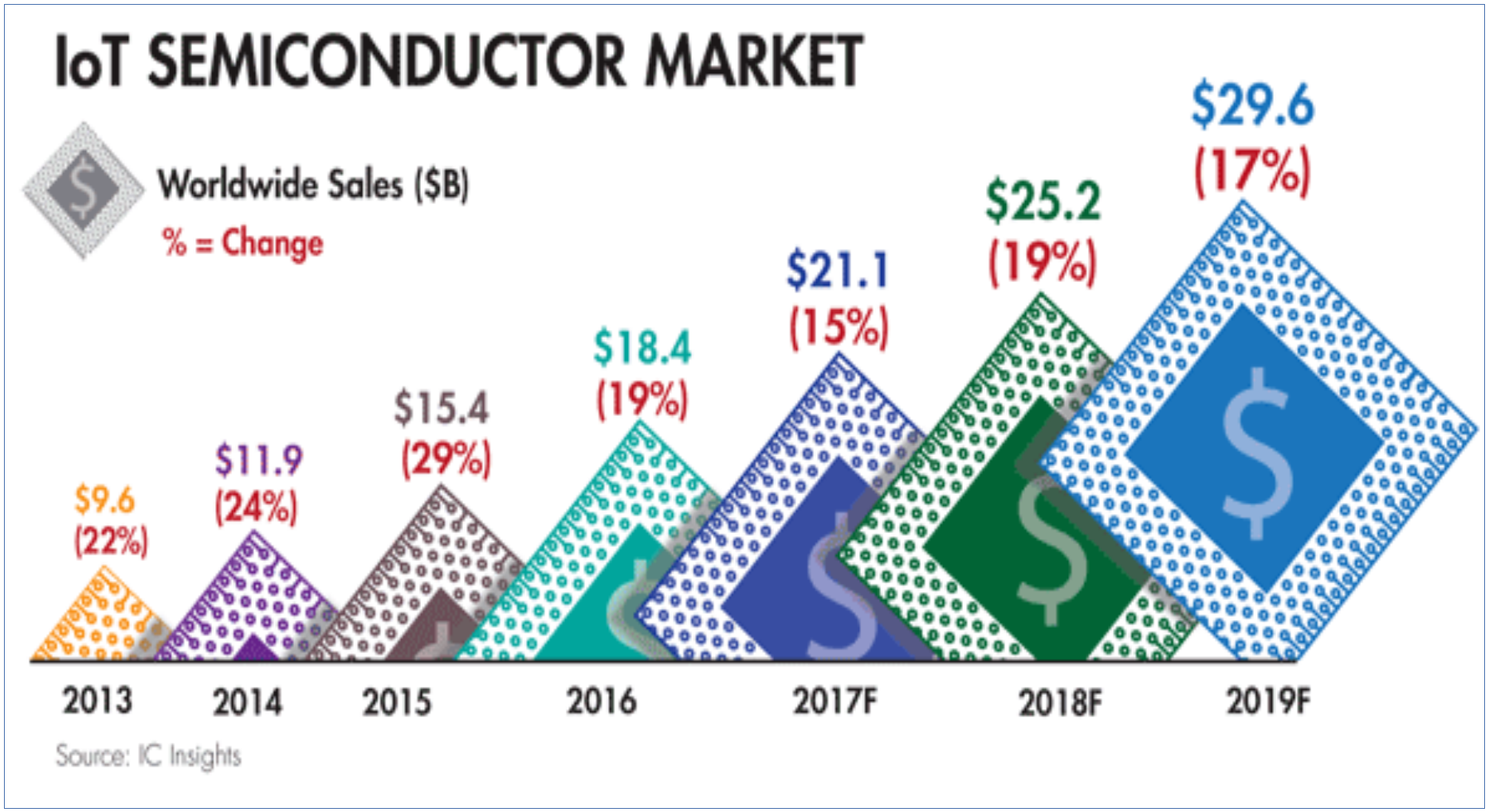
## Explosion: Semiconductors - IoT Infrastructure




Source: Victoria Fraza Kickham, "Data Drives The Industrial IoT," Machine Design, Volume 88, Number 12, December 2016. Figure 4: IoT Semiconductor Market; Source: IC Insights.

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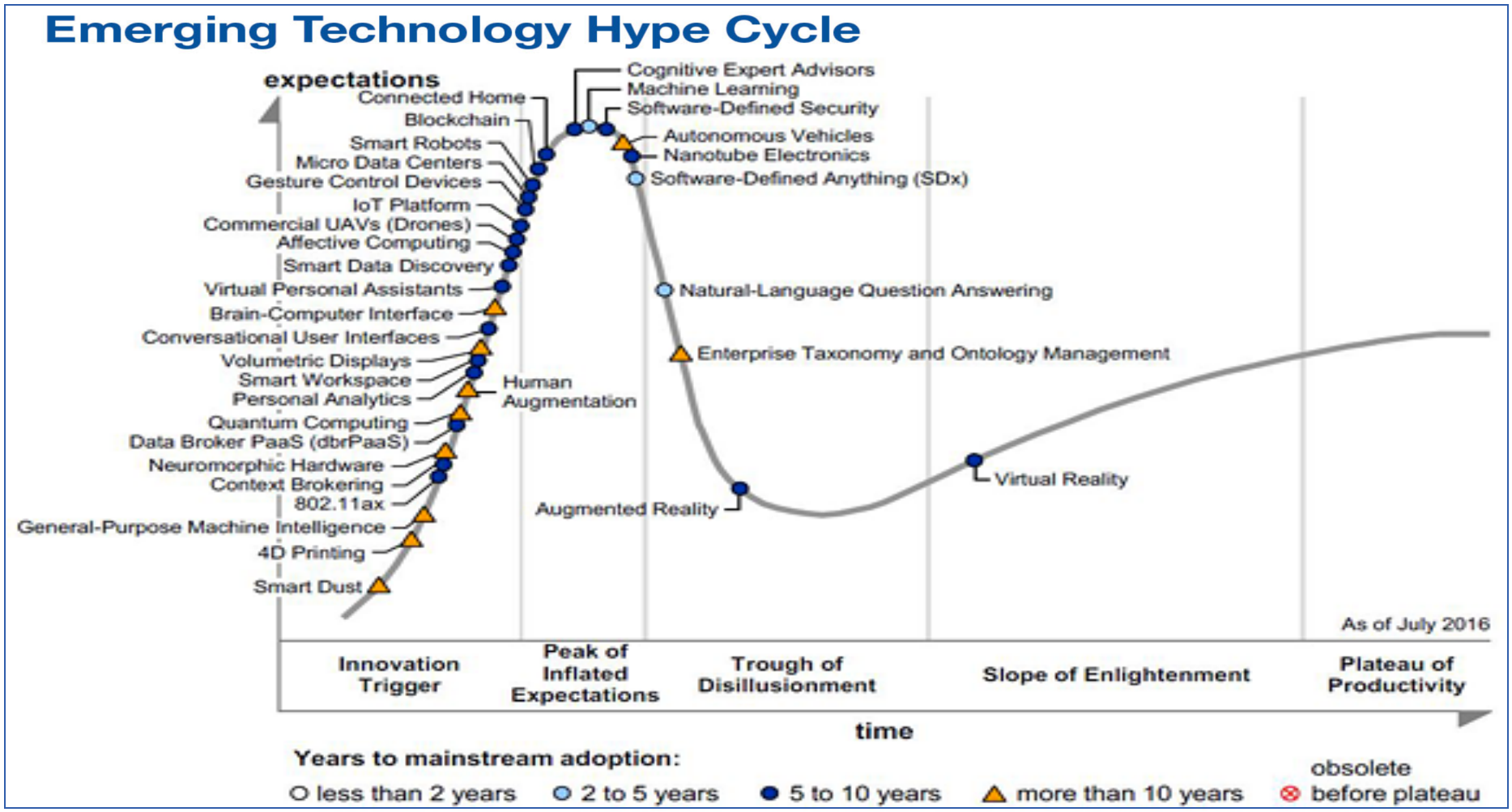
## Explosion: Emerging Technologies - Gartner Hype Cycle 2016




Source: Press Release, "Gartner's 2016 Hype Cycle for Emerging Technologies Identifies Three Key Trends That Organizations Must Track to Gain Competitive Advantage," Gartner, Inc., 56 Top Gallant Road, Stamford, CT, 06902, USA, August 16, 2016, Figure 1: Hype Cycle for Emerging Technologies, 2016.

# DFI: Design for Industrial Internet & Design for Internet of Things

## Explosion: Emerging Technologies - Gartner Hype Cycle 2016 - Three Key Trends

1 **Transparently immersive experiences**: Technology will continue to become more human-centric to the point where it will introduce transparency between people, businesses and things. This relationship will become much more entwined as the evolution of technology becomes more adaptive, contextual and fluid within the workplace, at home, and interacting with businesses and other people.

Critical technologies to be considered include *4D Printing*, *Brain-Computer Interface*, *Human Augmentation*, *Volumetric Displays*, *Affective Computing*, *Connected Home*, *Nanotube Electronics*, *Augmented Reality*, *Virtual Reality* and *Gesture Control Devices*.

2 **The perceptual smart machine age:** Smart machine technologies will be the most disruptive class of technologies over the next 10 years due to radical computational power, near-endless amounts of data, and unprecedented advances in deep neural networks that will allow organizations with smart machine technologies to harness data in order to adapt to new situations and solve problems that no one has encountered previously. Enterprises that are seeking leverage in this theme should consider the following technologies: *Smart Dust, Machine Learning, Virtual Personal Assistants, Cognitive Expert Advisors, Smart Data Discovery, Smart Workspace, Conversational User Interfaces, Smart Robots, Commercial UAVs (Drones), Autonomous Vehicles, Natural-Language Question Answering, Personal Analytics, Enterprise Taxonomy and Ontology Management, Data Broker PaaS (dbrPaaS), and Context Brokering.*

3 **The platform revolution:** Emerging technologies are revolutionizing the concepts of how platforms are defined and used. The shift from technical infrastructure to ecosystem-enabling platforms is laying the foundations for entirely new business models that are forming the bridge between humans and technology. Within these dynamic ecosystems, organizations must proactively understand and redefine their strategy to create platform-based business models, and to exploit internal and external algorithms in order to generate value. Key platform-enabling technologies to track include Neuromorphic Hardware, Quantum Computing, Blockchain, IoT Platform, Software-Defined Security and Software-Defined Anything (SDx).

Source: Press Release, "Gartner's 2016 Hype Cycle for Emerging Technologies Identifies Three Key Trends That Organizations Must Track to Gain Competitive Advantage," Gartner, Inc., 56 Top Gallant Road, Stamford, CT, 06902, USA, August 16, 2016.

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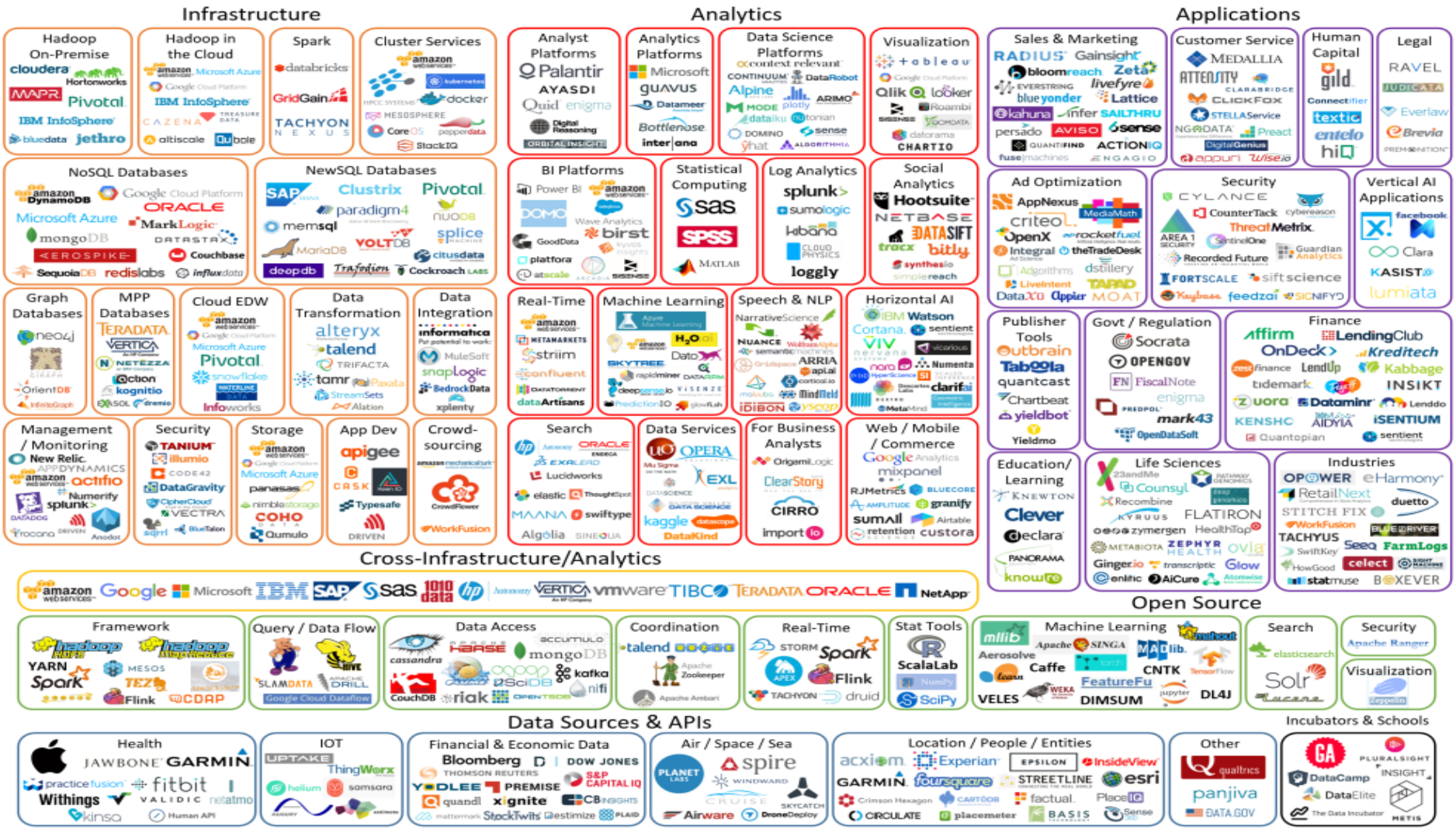
## Explosion: Smart Connected Products Ecosphere - Big Data




Source: Matt Turck, Jim Hao, First-Mark Capita, "Big Data Landscape 2016 (Version 3.0)," March 23, 2016.

# DFI:
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***DFI Strategy***

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# DFI: Design for Industrial Internet & Design for Internet of Things

## Strategy: Degree Of Smart & Connected - 10 Strategic Decisions

### IMPLICATIONS FOR STRATEGY

In a smart, connected world, companies face 10 new strategic decisions. A firm's choices will have a major impact on every activity in its value chain.

**SOURCE** "HOW SMART, CONNECTED PRODUCTS ARE TRANSFORMING COMPETITION," HBR, NOVEMBER 2014

1. **Which set of smart, connected product capabilities and features should the company pursue?**
2. **How much functionality should be embedded in the product and how much in the cloud?**
3. **Should the company pursue an open or closed system?**
4. **Should the company develop the full set of smart, connected product capabilities and infrastructure internally or outsource to vendors and partners?**
5. **What data must the company capture, secure, and analyze to maximize the value of its offering?**
6. **How does the company manage ownership and access rights to its product data?**
7. **Should the company fully or partially disintermediate distribution channels or service networks?**
8. **Should the company change its business model?**
9. **Should the company enter new businesses by monetizing its product data through selling it to outside parties?**
10. **Should the company expand its scope?**

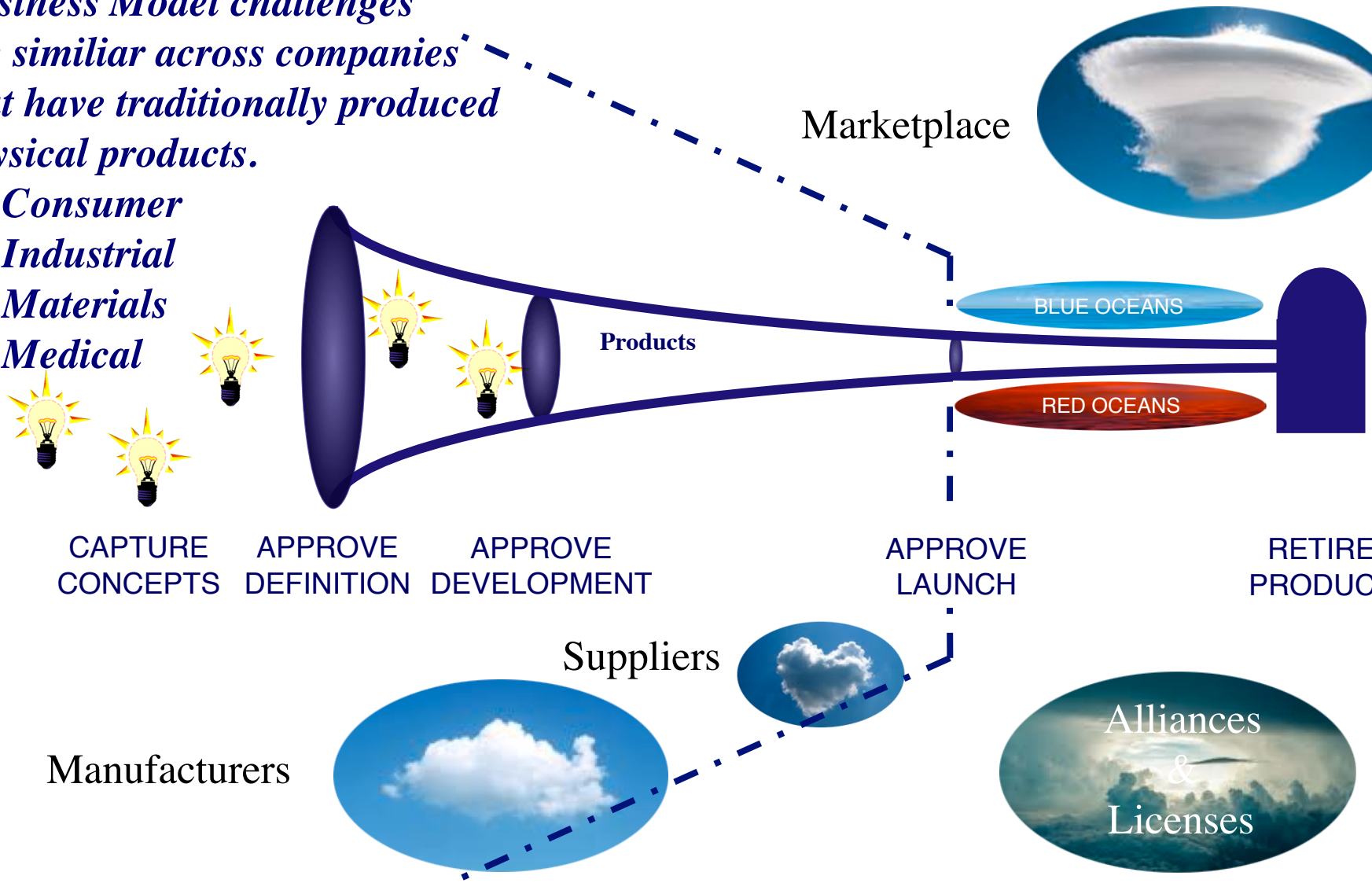
Source: Michael E. Porter and James E. Heppelmann, "How Smart, Connected Products Are Transforming Companies, *Harvard Business Review*, Harvard Business School Publishing, 60 Harvard Way, Boston, MA, 02163, USA, October 2015; Page 99, Inset - Implications For Strategy. [Part 2 of 2 - A Two Part Series]

# DFI: Design for Industrial Internet & Design for Internet of Things

## Strategy: Business Model Similiarity For Companies Designing Physical Products

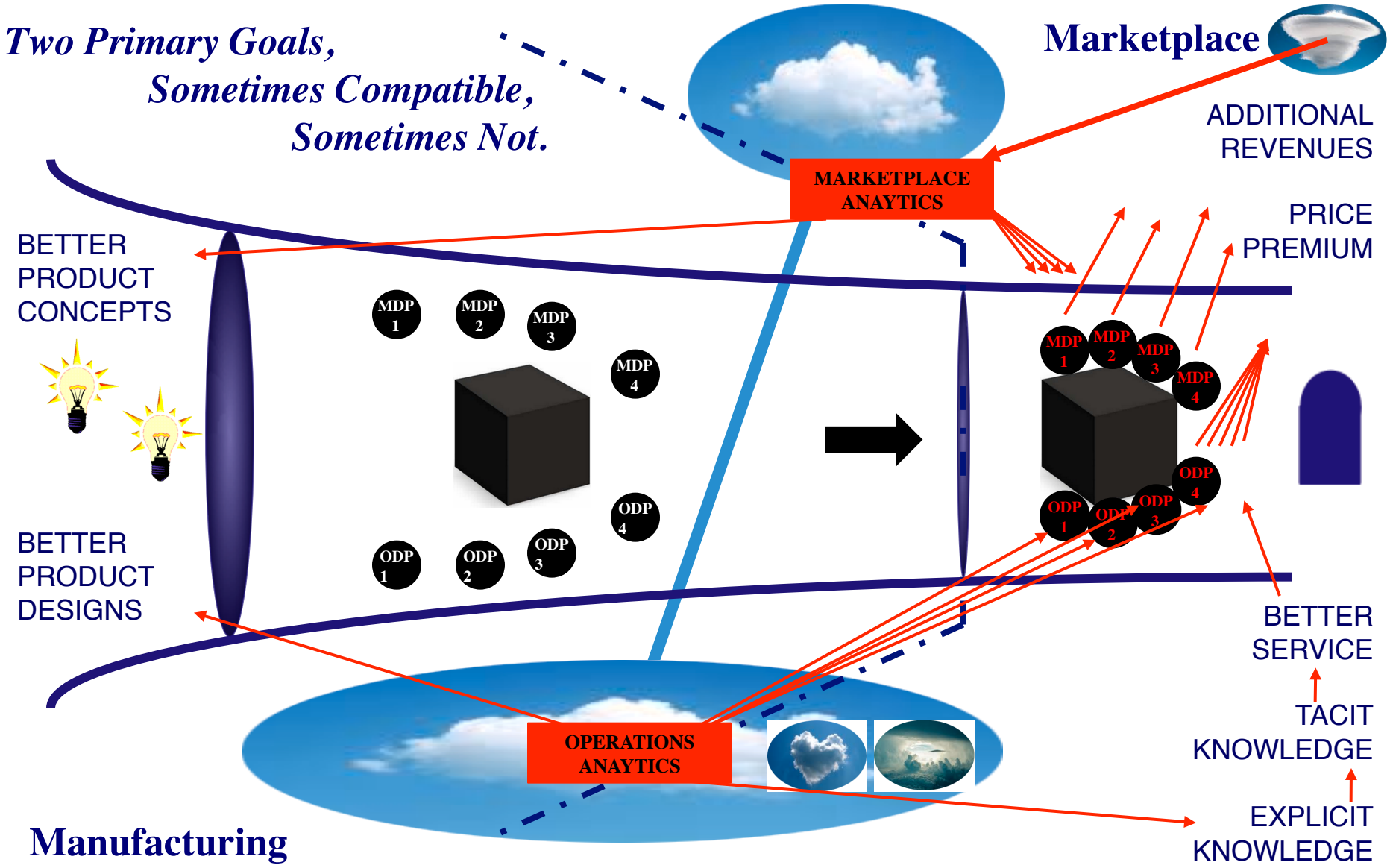
***Business Model challenges are similiar across companies that have traditionally produced physical products.***

- ***Consumer***
- ***Industrial***
- ***Materials***
- ***Medical***



# DFI: Design for Industrial Internet & Design for Internet of Things

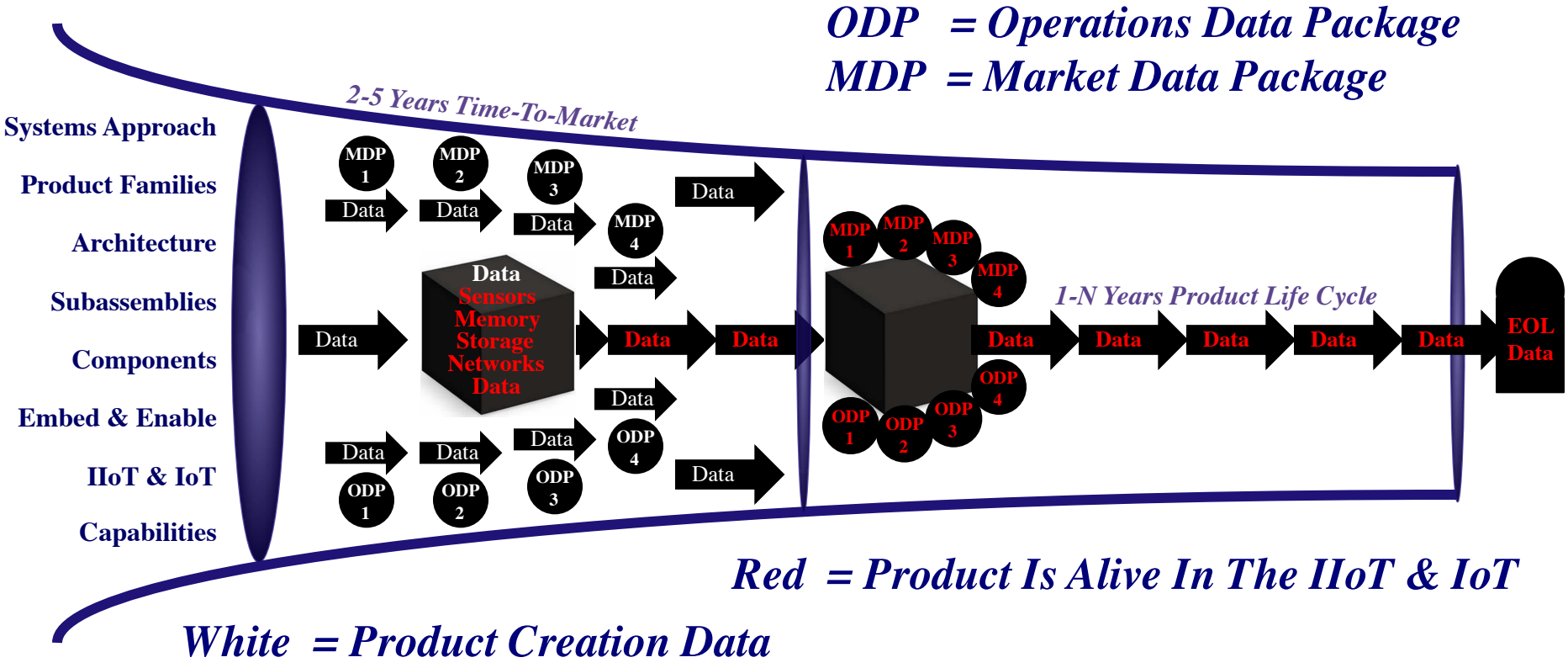
## Strategy: The Black Box Value Model



# DFI: Design for Industrial Internet & Design for Internet of Things

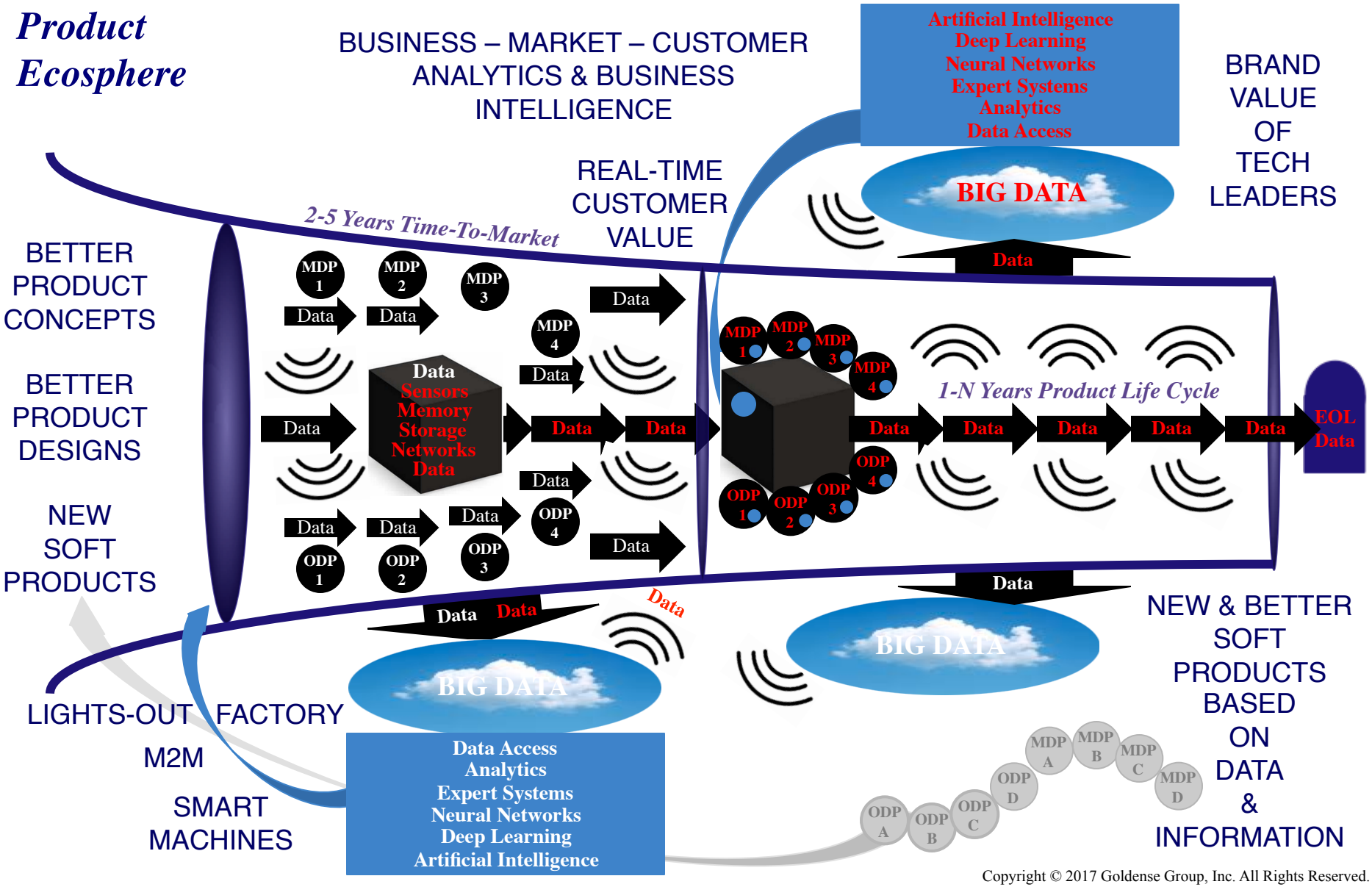
## Strategy: Systems Design & Platform Development

***The Industrial Internet and the Internet of Things are systems.***
***Use a systems approach to enable them.***



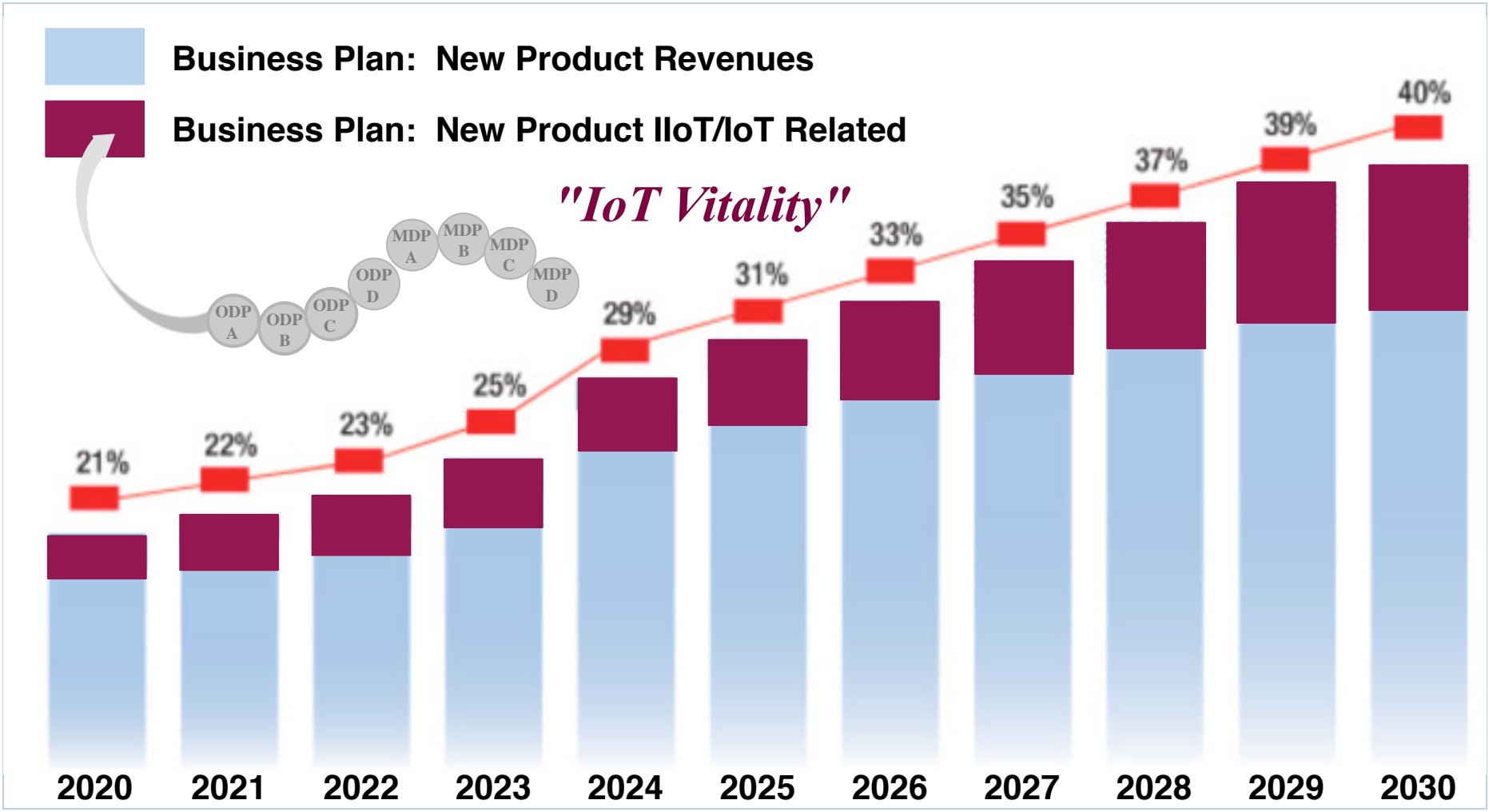
# DFI: Design for Industrial Internet & Design for Internet of Things

## Strategy: Managing ODP & MDP Data & Products



# DFI: Design for Industrial Internet & Design for Internet of Things

## Strategy: Example Corporate Metric = IoT-Related New Product Revenues



# DFI:
## Design for Industrial Internet
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***DFI Practices***

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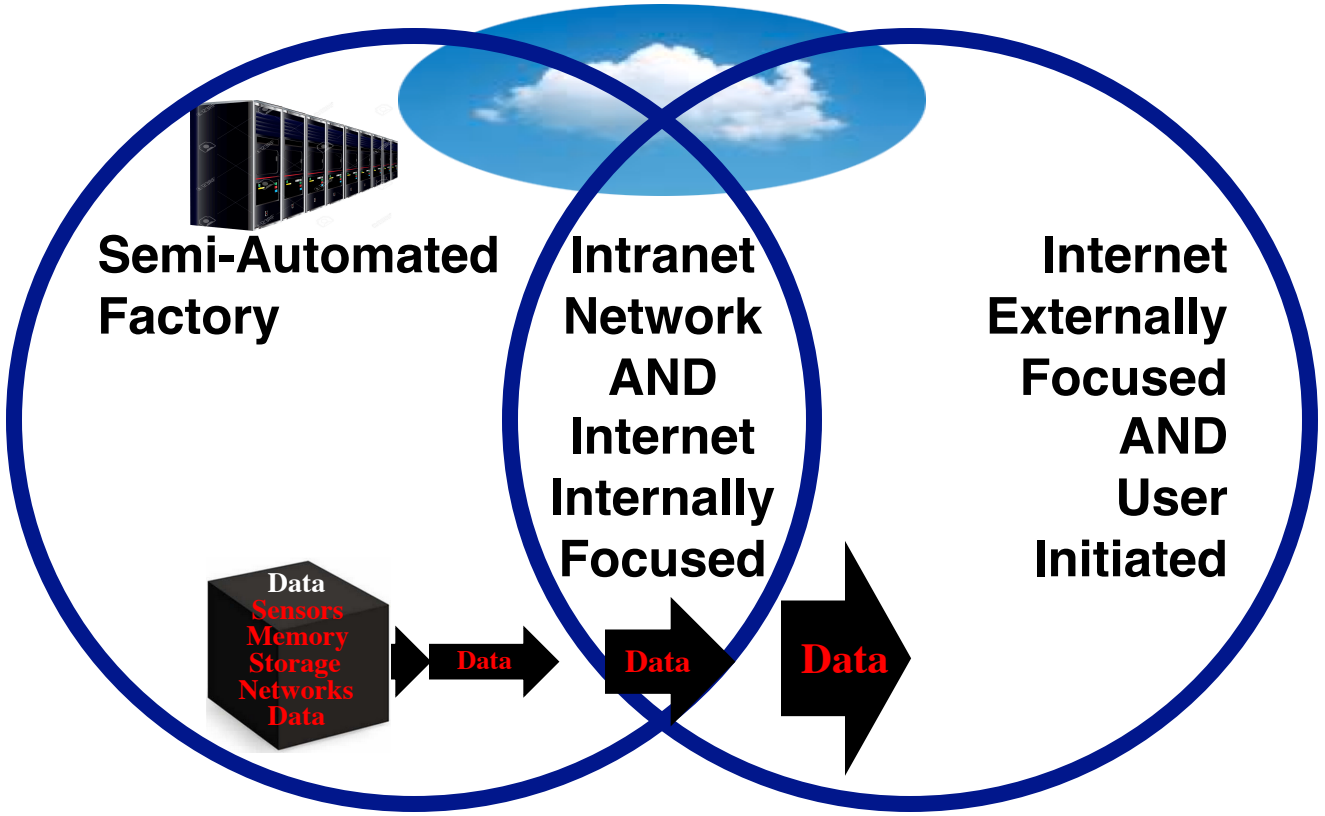
# DFI: Design for Industrial Internet & Design for Internet of Things

## Practices: Product Technology Environment - IIoT & IoT Venn Diagram



# ENGINEERS WILL BE RESPONSIBLE TO SYSTEMATICALLY DESIGN-IN DFI & DFI2 CAPABILITIES

# AT LEAST COST

## New Design Challenges & New Enabling Technologies

**New ways to design electronics into/on/around non-electronic products**
Tapes & Foils
Flexible PCBs
Insets & Carve-Outs
Embedded/Integral

**New Enabling Fasteners**
Actives
Passives

**New Enabling MEMS**
Dozens
Flat Sensors, Zero Thickness

**New Enabling Nanotechnology**

**New Enabling Tribology**
Conductive Coatings
Reflective Coatings
Neutral Coatings
Chemical Coatings

# DFI: Design for Industrial Internet & Design for Internet of Things

## Practices: Emergent Solution Alternatives - Surfaces, Coatings, Sensors

### How can the Danish Technological Institute help you?

- Product-embedded sensors √
- Development of new types of diamond-like thin film, the so-called DLCs
- Development of different oxides ($TiO_2$, $Al_2O_3$, YSZ, CGO)
- Development of new wear-resistant non-stick surfaces
- Test and development of electronically conducting coatings √
- Development of photocatalytic surfaces √
- Development of nanocomposite coatings √
- Development of low temperature coatings for aluminium surfaces
- Cooperation on commercial product development tasks and privately financed contractual research

Source: https://www.dti.dk/specialists/tribological-coatings-and-processes/23608

# DFI: Design for Industrial Internet & Design for Internet of Things

## Practices: Emergent Industry Standards - Autonomous Vehicles Example

| SAE level | Name | Narrative Definition | Execution of Steering and Acceleration/ Deceleration | *Monitoring* of Driving Environment | Fallback Performance of *Dynamic Driving Task* | System Capability *(Driving Modes)* |
|---|---|---|---|---|---|---|
| ***Human driver* monitors the driving environment** | | | | | | |
| 0 | **No Automation** | the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems | Human driver | Human driver | Human driver | n/a |
| 1 | **Driver Assistance** | the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task* | Human driver and system | Human driver | Human driver | Some driving modes |
| 2 | **Partial Automation** | the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task* | **System** | Human driver | Human driver | Some driving modes |
| ***Automated driving system* ("system") monitors the driving environment** | | | | | | |
| 3 | **Conditional Automation** | the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene* | System | **System** | Human driver | Some driving modes |
| 4 | **High Automation** | the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene* | System | System | **System** | Some driving modes |
| 5 | **Full Automation** | the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver* | System | System | System | **All driving modes** |

Source: SAE Standard J3016, "6 Levels of Driving Automation," SAE International, Global Ground Vehicle Standards, January 2014.

# DFI: Design for Industrial Internet & Design for Internet of Things

## Practices: DFI - Design For IIoT & IoT - Framework

### DFA

- Modular Design
- Minimum Part Count
- Standard Parts
- Common Parts
- Multi-Functional Parts
- Self Locating
- Self Fastening
- Handling
  Insertion
  Retrieval
- Symmetry
- Minimize Reorientation
- Facilitate Packaging

+

### Industrial Internet

- IIoT Platform
- Operational/Planned Factory Automation Level [SAE 1-5]
- Value Maximization of Non-Required Data
- Required Positional Transmission & Reception
- End of Life Data Requirements

+

### Internet of Things

- IoT Platform
- Target Customer/User Integration Level [NEW]
- Value Maximization of Non-Required Data
- Optimal Positional Transmission & Reception
- End of Life Data Requirements & Compliance
- End of Life Customer/User Data Retention

+

- Mandatory Legal/Compliance/Regulatory Data
- On-Board Data Retention/Storage
- On-Board Data Processing/Reduction/Analytics
- IP Ownership Partitioning
- Privacy Protection
- TP Data/Analytics Sharing Relationships
- Security Access & Protection
- Optimal Up Time
- Optimal Energy Usage

**= DFI²**

# What other

# "all the time"

# "systematic"

# IIoT & IoT

# design optimization needs

# are in play

# ?

# DFI:
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***DFI Metrics***

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# DFI: Design for Industrial Internet & Design for Internet of Things

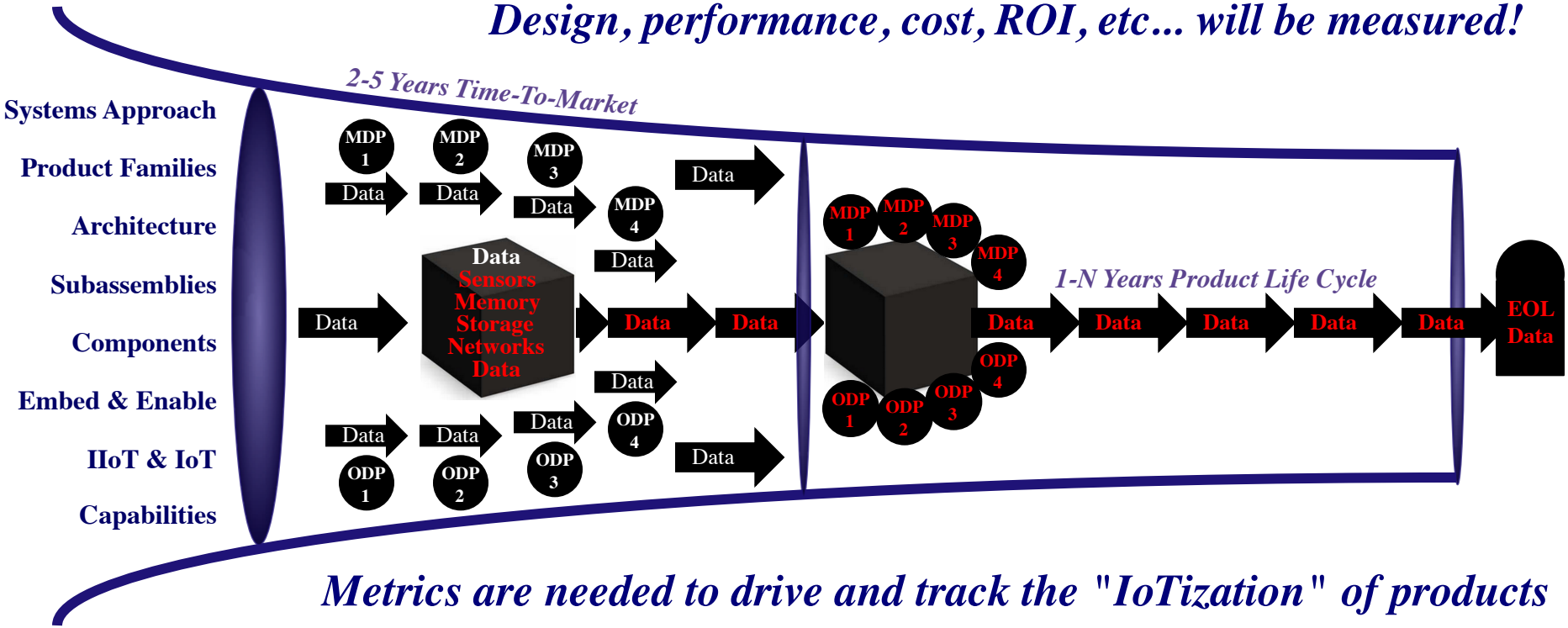
## Metrics: The Smart Connected Connected Product - Throughout The Life Cycle

***Big Data possibilities exist from inception through end-of-life.***

***ODP: Factories will become increasingly automated and connected.***

***MDP: New product and service revenues and profits will be generated.***

***Design, performance, cost, ROI, etc... will be measured!***




***Metrics are needed to drive and track the "IoTization" of products over the next 2-3 decades, until a new normal arrives.***

MDP= Market Data Package
ODP = Operations Data Package

White = Product Creation Data
Red = Product Is Alive In The IIoT & IoT

# DFI: Design for Industrial Internet & Design for Internet of Things

## Metrics: Example Product Metric = Sensor Density Per Product or Area

***Metrics are soon to grace your doorstep.***

"Dr. Janus Bryzek explained that sensors have the potential to change the global economy. He said **sensor usage by mobile devices increased by more than 200% from 2007 to 2012**, and that demand will surge into the trillions over the next decade. "

"Wearables are a hotbed for sensors, with market growth driven by the increasing number of these components in each product sold," said Jérémie Bouchaud, director and senior principal analyst, MEMS & Sensors, at IHS. "The main factor propelling this phenomenon is a transition in market share away from simple products like pedometers and toward more sophisticated multipurpose devices such as smart watches and smart glasses. Instead of using a single sensor like the simpler devices, the more complex products employ numerous components for health and activity monitoring, as well as for their more advanced user interfaces."

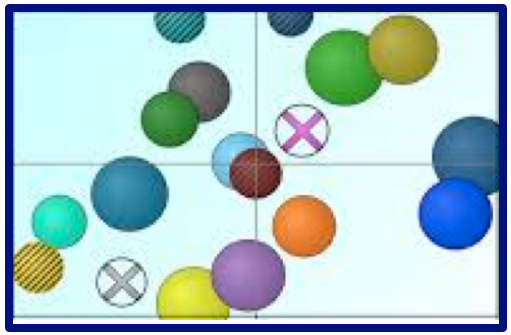
**The average wearable device shipped in 2019 will incorporate 4.1 sensor elements, up from 1.4 in 2013**, according to IHS. The researcher also expects components such as humidity sensors and pulse sensors to move from handsets to wearables, further boosting sensor sales.

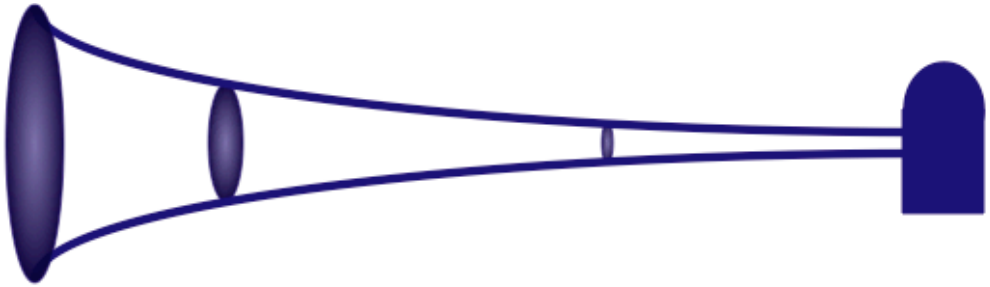
Source: Victoria Fraza Kickham, "Sensors Heat Up Components Market," Machine Design, Volume 87, Number 1, January 2015.

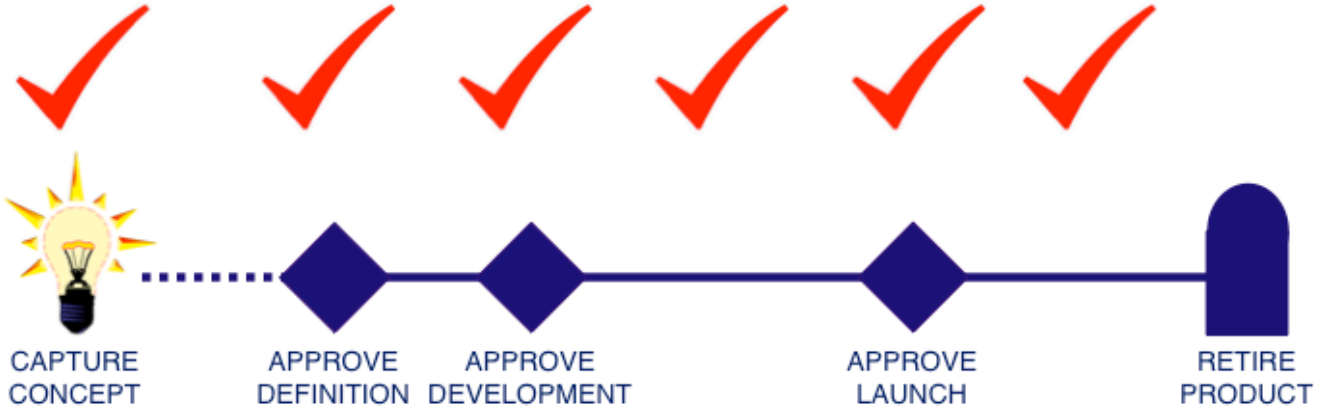
# DFI: Design for Industrial Internet & Design for Internet of Things

## Metrics: The Smart Connected Connected Product - Many Types Are Needed

***Metrics will be of all types:***
***product,***
***project,***
***functional & technical***
***management,***
***improvement projects,***
***and***
***overall***
***corporate performance.***





# DFI: Design for Industrial Internet & Design for Internet of Things

## Metrics: Corporate/Overall - IoT-Related [1 of 2]

### NEW & SUSTAINED PRODUCTS

**% of Vitality from IoT Products** **[Earlier Slide On This]**
**$ Revenue from IoT Products** **[Earlier Slide On This]**
% Patent-Protected IoT Revenue

% New Product Profits from IoT Products
$ New Product Profits from IoT Products

$ Revenue From IoT Licensing

# New IoT Products Released [Pure + Co-Design IoT]
% IoT-Enabled of Total New Products Released

% IoT Products In Development [Pure + Co-Design IoT]

### PRODUCT PORTFOLIOS

$ Revenue Risk Due To Chg'd/Obsoleted IoT Protocols
% Revenue Risk Due To Chg'd/Obsoleted IoT Protocols

$ Revenue Growth From IoT Revenues
% Revenue Growth From IoT Revenues

% Product Revenues IoT-Enabled vs. Company Goal
% Product Profits IoT-Enabled vs. Company Goal

# DFI: Design for Industrial Internet & Design for Internet of Things

## Metrics: Corporate/Overall - IoT-Related [2 of 2]

### TECHNOLOGY & IP PORTFOLIOS

# Active IIoT Nodes
% IIoT Node Plan Achieved

# Active IoT Nodes
% IoT Node Plan Achieved

% Critical IoT Technologies From External Sources
% Critical IoT Technologies Without Source Access

# IoT-Related Gigaflops Under Management
- % Proprietary Data
- % Market/Customer-Shared Data
- % Direct User Access Data

# IoT Patents [Filed, Pending, Awarded, Rej., Abandon]
# IIoT Patents [Filed, Pending, Awarded, Rej., Abandon]

IIoT Process Automation Intelligence Levels

| | |
|---|---|
| % Level 1 Product Lines (PLs) | % Level 4 PLs |
| % Level 2 Product Lines | % Level 5 PLs |
| % Level 3 Product Lines | % Level 6 PLs |

### FINANCIAL INVESTMENT & PERFORMANCE

$ R&D Spending on Internet of Things [New, Sustain]
% R&D Spending on Internet of Things [New, Sustain]

$ Internet of Things Capital
% Internet of Things Capital of Total Capital

% of Portfolio Revenues from IoT Products & Services
% of Portfolio Profits from IoT Products & Services

$ IoT-Related Revenues In Pipeline [1, 2, 3 Yrs]

# DFI: Design for Industrial Internet & Design for Internet of Things

## Metrics: Product & Project Management - IoT-Related

| | |
|---|---|
| **USER** | **Measures of IoT user or customer experiences with the product** |
| **BUSINESS** | **Measures of IIoT & IoT business and financial value of the product.** |
| **MARKET** | **Measures of overall IoT market and marketplace coverage and compatibility.** |
| **FACTORY** | **Measures of overall IIoT factory and operations coverage and compatibility** |

# DFI: Design for Industrial Internet & Design for Internet of Things

## Metrics: IoT - Product & Project Management

| TYPE | METRIC NAME | ACRONYM | DESCRIPTION |
|---|---|---|---|
| USER | User IoT Satisfaction Index | UISI | IIoT/IoT component of Customer Satisfaction Index |
| | % User IoT Satisfaction Level | UISL | User rating of product vs. others in their IoT ecosphere |
| | User IoT Connectivity Index | UICI | Degree to which user controls connectivity options |
| | Product IoT Attractability Index | UIAI | Degree to which user s/b attracted by IoT features |
| BUSINESS | Product IoT Branding Score | PIBS | Degree of brand value derived from IIoT/IoT features |
| | Product IoT Connectability Index | PICI | Degree of post-sale data value accruing to producer |
| | % Product Data Value | PDV | Degree of IoT data/analytics value of product offering |
| | # Product Data Package AddOns | PDPA | Soft information product modules offered w/ product |
| | % Product IoT Price Premium | PIPP | Product price premium enabled by IoT features |
| | % Product IoT Maintenance Premium | PIMP | Maintenance price premium enabled by IoT features |
| MARKET | % Product IoT Compatibility Risk | PICR | Degree of risk that product fits w/ customer ecosphere |
| | % Product IoT Readiness Risk | PIRR | Degree of risk to realize IIoT/IoT product specs |
| | % Product IoT Capability Approval | PICA | Targeted ability level including sensors, s/w, ecosphere |
| | % Product IoT Sensorization Level | PISL | Targeted sensorization level for marketplace activities |
| FACTORY | Factory IIoT Enablement Index | FIEI | Overall capability for lights-out manufacture |
| | % Factory IIoT Communicatibility | FIC | Overall ability to interact with factory processes |
| | % Factory IIoT Transmitability | FIT | Targeted ability to inform factory processes. |
| | % Factory IIoT Receivability | FIR | Targeted ability to react to factory stimuli |
| | % Factory IIoT Sensorization Level | FISL | Targeted sensorization level for automated assembly |
| | % Product Cost for IIoT/IoT | PCI | The % of product cost for IIoT/IoT related features |
| | % Software Cost for IIoT/IoT | SCI | The % of S/W budget for IIoT/IoT related features |

# DFI: Design for Industrial Internet & Design for Internet of Things

## Metrics: Functional & Technical Departments - IoT-Related

### CAPACITY & THROUGHPUT

% IoT Project-Needs Outsourced
% IoT Asset Maintenance Outsourced

% IIoT Project-Needs Outsourced
% IIoT Asset Maintenance Outsourced

% Capacity To Internet of Things Development
% Capacity To Internet of Things Maintenance/Sustain

# IoT Project FTE Requests Unable To Be Met
# IIoT Project FTE Requests Unable To Be Met

### COMPETENCY & CAPABILITY

% IoT Skill Readiness Overall
% IoT Skill Readiness by Skill
% IoT Training Completed
# IoT Certifications
# IoT Internal Blackbelts

% IIoT Skill Readiness Overall
% IIoT Skill Readiness by Skill
% IIoT Training Completed
# IIoT Certifications
# IIoT Internal Blackbelts

% Employees With ≥1 Internet of Things Degrees

### RECRUITMENT & RETENTION

# IoT Hires Planned
% IoT Recruiting Plan Met
# Key IoT Employees Hired # IoT Employees Hired
# Avg Number IoT Credentials per IoT Employee Hired
# Key IoT Open Positions # IoT Open Positions
# Key IoT Employees Lost # IoT Employees Lost
% IoT Employee Attrition

# IIoT Hires Planned
% IIoT Recruiting Plan Met
# Key IIoT Employees Hired # IIoT Employees Hired
# Avg Number IIoT Credentials per IIoT Employee Hired
# Key IIoT Open Positions # IIoT Open Positions
# Key IIoT Employees Lost # IIoT Employees Lost
% IIoT Employee Attrition

### INVESTMENT & RETURN

% R&D Budget IoT-Related Development
% R&D Budget IoT-Related Maintenance

% R&D Budget IoT-Related Development
% R&D Budget IIoT-Related Maintenance

% R&D Budget To Internet of Things

# DFI: Design for Industrial Internet & Design for Internet of Things

## Metrics: Improvement Initiatives & Activities - IoT-Related [Examples of "Might Do"]

### HUMAN ASSETS

% Department Training Program "XYZ" Completed

% Self-Education IoT Website Completed
% Self-Education IIoT Website Completed

% Job Grade Competency Module for IoT Completed
% Job Grade Competency Module for IIoT Completed

% HR Job Descriptions IoT Update Project Completed
% HR Job Descriptions IIoT Update Project Completed

### PHYSICAL ASSETS

% Installation of "New Equipment XYZ" Completed

% Installation of "New Software XYZ" Completed

% Installation of "New Cloud DB XYZ" Completed

### CAPACITY & INFRASTRUCTURE

% Sensor Types Expansion Project Completed

% LAN Types Expansion Project Completed

% WAN Types Expansion Project Completed

% Wireless Protocol Types Expansion Project Completed

% Data Compression-Transmission Project Completed

% Cloud Expansion Project Completed

% Deep Mining Access Project Completed

% Data Utilization & Value Analytics Project Completed

### ENVIRONMENT & CULTURE & CONFIDENCE

% Internet of Things Recognition Awards Completed

% Industrial Internet Recognition Awards Completed

% IoT Supplier Recognition Awards Completed
% IIoT Supplier Recognition Awards Completed

# What other

# "Corporate"

# "Project/Product"

# "Functional/Technical"

# metrics

# are likely

# ?

# DFI:
## Design for Industrial Internet
## Design for Internet of Things

***Summary***

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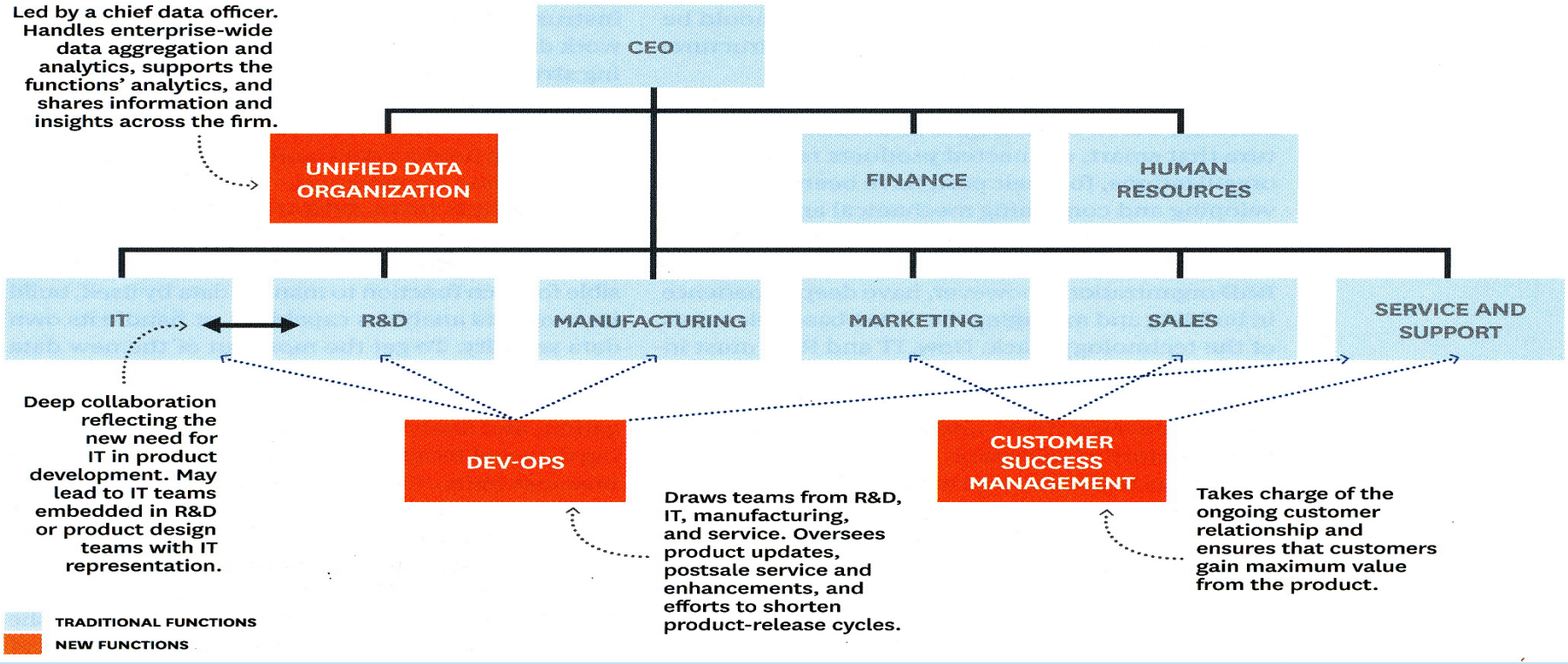
# DFI: Design for Industrial Internet & Design for Internet of Things

## Summary: The Smart Connected Company - Next Generation Organization

### A NEW ORGANIZATIONAL STRUCTURE

Smart, connected products require functions within manufacturing firms to collaborate in new ways. As a result, firms' structures are rapidly evolving. A new functional unit focused on data management is starting to appear. Though rare, units focused on ongoing product development and customer success are also beginning to be recognized.




Source: Michael E. Porter and James E. Heppelmann, "How Smart, Connected Products Are Transforming Companies, *Harvard Business Review*, Harvard Business School Publishing, 60 Harvard Way, Boston, MA, 02163, USA, October 2015; Page 109, Inset – A New Organizational Structure. [Part 2 of 2 - A Two Part Series]

# DFI: Design for Industrial Internet & Design for Internet of Things

## Summary: The Smart Connected Company - Lean Jumps To Another Level

### A NEW ERA OF LEAN

Smart, connected products will help make people, materials, energy, and plant and equipment far more productive, and the repercussions for business processes will be felt throughout the economy.

We will see a whole new era of "lean." Data flowing to and from products will allow product use and activities across the value chain to be streamlined in countless new ways.

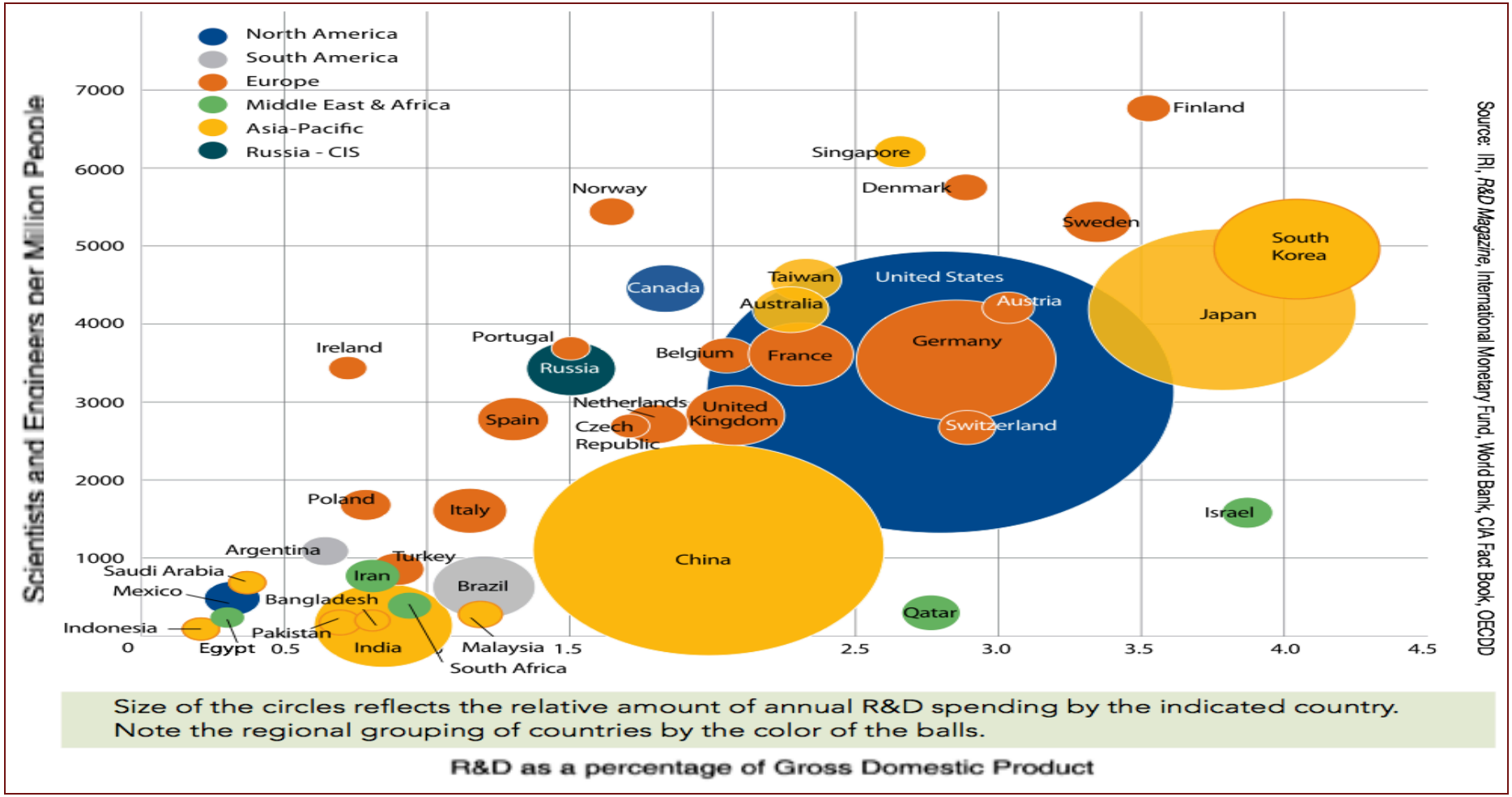
Waste will be cut or eliminated. Sensors in products can identify the need for service before a component fails, reducing downtime. Or they can reveal that maintenance isn't yet necessary. An oil change, for instance, will take place only after oil contamination has hit a certain threshold, rather than according to a schedule. New data analytics will lead to previously unattainable efficiency improvements.

Wasted capacity will be driven out. Because products will report on their location and use, we will be able to make the most of them. Smart, connected elevators, for example, can predict and act on user demand patterns, reducing wait times and electricity use. A building that once might have needed six elevators can provide better service with four. Product-as-a-service models will allow customers to pay only for what they actually need. With data and connectivity, the sharing of assets (think cars or bikes) will become possible or easier than ever before.

Source: Michael E. Porter and James E. Heppelmann, "How Smart, Connected Products Are Transforming Companies, *Harvard Business Review*, Harvard Business School Publishing, 60 Harvard Way, Boston, MA, 02163, USA, October 2015; Page 105, Inset - A New Era of Lean. [Part 2 of 2 - A Two Part Series]

# DFI: Design for Industrial Internet & Design for Internet of Things

## Summary: The World Is Watching - Are You Moving The Needle?




Source: Sponsored by the Industrial Research Institute [IRI] and Advantage Business Media [ABM], "2016 Global R&D Funding Forecast," Supplement To R&D Magazine, Advantage Business Media, 100 Enterprise Drive, Suite 600, Rockaway, NJ 07866, Winter 2016, January 2016; Chart - Page 4.

# DFI: Design for Industrial Internet & Design for Internet of Things

## Summary: What Are You Going To Do About It?

DFI™

DFI2™

DFI²™

# DFI:
## Design for Industrial Internet
## Design for Internet of Things

***Biography: Bradford L. Goldense***

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# DFI: Design for Industrial Internet & Design for Internet of Things

## Biography: Bradford L. Goldense NPDP, CMfgE, CPIM, CCP

Brad Goldense is Founder and CEO of Goldense Group, Inc. [GGI], a thirty year old Needham, Massachusetts consulting and education corporation concentrating in advanced business and technology management practices for product strategy, management, development, and commercialization. Mr. Goldense has consulted to over 200 of the Fortune 1000 and has worked on productivity improvement and automation projects in over 500 manufacturing locations across North America, South America, Europe, Asia, and the Middle East.

Mr. Goldense is a retired member of the graduate engineering school adjunct faculty at the Gordon Institute of Tufts University in Medford, MA, after lecturing and teaching for nineteen years. He holds a BS in Civil Engineering from Brown University and an MBA focused in Cost Accounting and Operations from Cornell University. Brad is a certified New Product Development Professional [NPDP] by the Product Development and Management Association [PDMA], a Certified Manufacturing Engineer [CMfgE] by the Society of Manufacturing Engineers [SME], a Certified Computer Professional [CCP] by the Institute for Certification of Computer Professionals [ICCP], and is Certified in Production and Inventory Management [CPIM] by the American Production and Inventory Control Society [APICS].

Brad is Founder and past President of the Society of Concurrent Product Development [SCPD], the successor organization to the Society of Concurrent Engineering [SOCE] that spawned from IBM in the early 1990s. After fifteen years of volunteering to further the principles of concurrent engineering and product development, Mr. Goldense turned the organization over to a group centered in 3M in 2006. He retired from the board in 2012. A number of periodicals and international organizations spawned from SOCE and SCPD efforts that continue today. Many corporations have adopted concurrent values.

Mr. Goldense is a past member of the Board of Directors of the American Society for Engineering Management [ASEM], a past chapter president of SME's Computer & Automated Systems Association and a past SME regional officer. He was a member of SME's National Technology Council. In that capacity, he wrote much of today's CMfgT and CMfgE examination. Mr. Goldense served for six years on Cornell University's Technology Transfer Committee and the Cornell Johnson Executive Committee.

Brad has appeared on Alexander Haig's World Business Review, and on Public Television, PBS The Business & Technology Network, and CNBC. He has authored or been quoted in some three hundred articles on competitive product development and manufacturing with known industry publications such as Business Week, CFO, Design News, R&D Magazine, Product Design & Development, Purchasing, and others. He currently writes "Goldense On Product Development," the inside back page article for Machine Design, a monthly Penton Publishing magazine.

Prior to founding GGI in 1986, Mr. Goldense held positions at Index Group [the Cambridge-based think tank that spawned "reengineering"], Price Waterhouse Consulting, Texas Instruments, and his family's engineering business. Brad enjoys woodworking, landscaping, reading, boating, and is an avid fresh water fisherman.

# THANK YOU