Industry 4.0 and Society 5.0

Society 5.0

Chart 4: The 17 SDG Goals Source: UN Public Relations Center

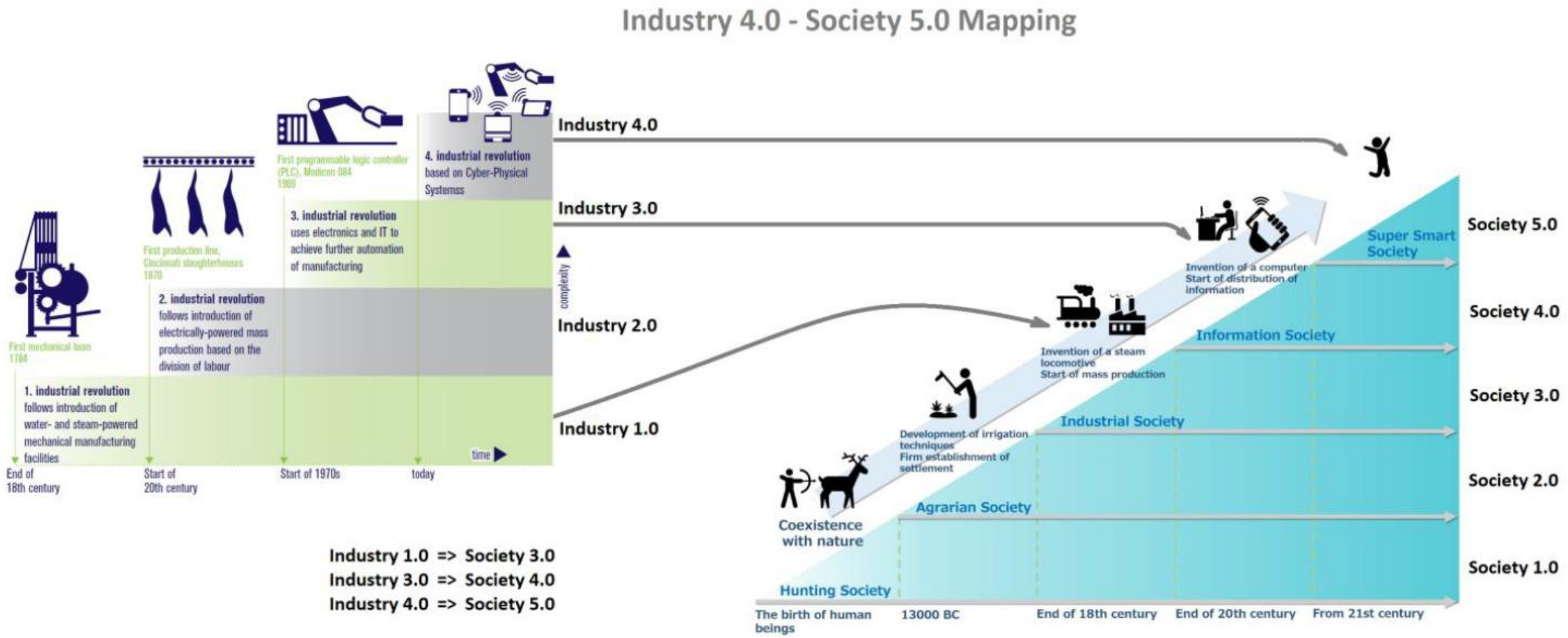
NSF CIVIC Initiative

Society 5.0 – Industry 4.0

2018

2013

Industry 4.0 – Society 5.0



Industry 4.0 – Society 5.0 (II)

CHAPTER I

Development of Human Society

To date, humankind has lived in four types of society: Hunting, Agrarian,Industrial, and Information. Digital transformation heralds a fifth stage.

The rapid spread of the Internet and smartphones since the 1990s has produced abundant data that circulate around the world creating new value all the time. Having inhabited such an Information Society in recent years, humankind is now at an important turning point for civilization. The premises on which society is based are about to change dramatically as people come to terms with the emergence of environmental burden and social disparity caused by traditional economic systems on the one hand and rapid digital transformation on the other.

Opinions on how to categorize societies vary, but the 5th Science and Technology Basic Plan[5] identified the societies in which humankind lived in the past as the Hunting Society (Society 1.0), Agrarian Society (Society 2.0), Industrial Society (Society 3.0) and Information Society (Society 4.0), and termed a new society to follow them "Society 5.0."

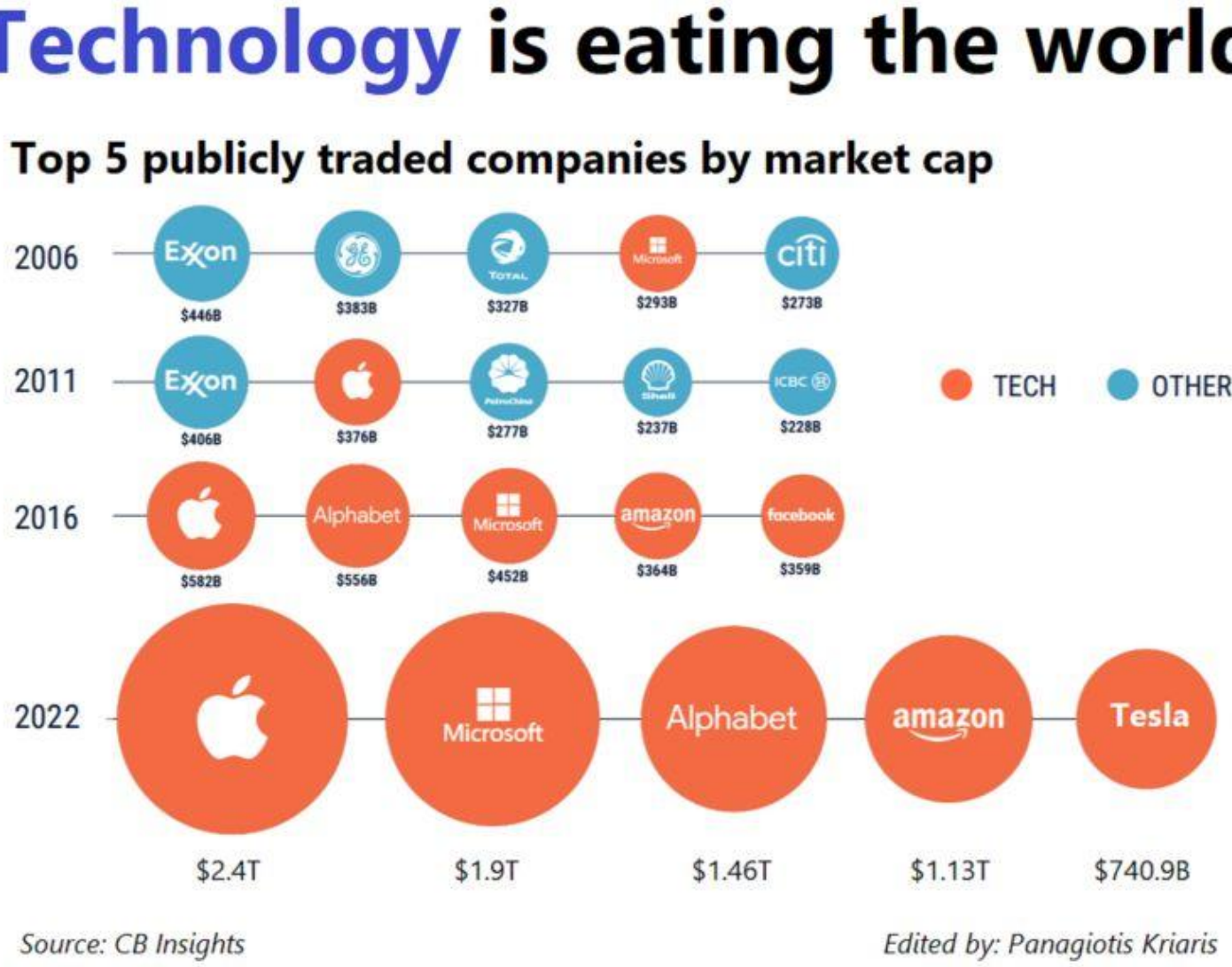
A series of past revolutions including the agricultural and industrial revolutions have brought about not only technological advances and greater convenience, but also structural changes to society. It is difficult to accurately foresee what kind of society the ongoing "Society 5.0" revolution will create. Rather than attempting to predict the future, it is important for us to be key players in the revolution, to indicate direction, and to work with a diverse range of people to create the future.

The history of human society has been characterized by liberation from restrictions and acquisition of freedom through enhanced capabilities stemming from new tools and techniques. Moving from the Hunting Society to the Agrarian Society, humans gained and enhanced the ability to produce food, which freed them from hunger. In the Industrial Society they increased production capabilities and mobility by harnessing motive power. In the Information Society digitalization enhanced the capacity of telecommunications and information processing, which drastically increased freedom to access information and communication of all kind, and freely exploring various opportunities for internet-based services. In the following chapters, we will first summarize how the premises on which society is based will be changed by digital transformation. Based on this summary, we will then describe a new society to be created and consider the kinds of capabilities to be acquired and enhanced, restrictions to be eased and freedoms to be gained, and values to pursue in this new society.

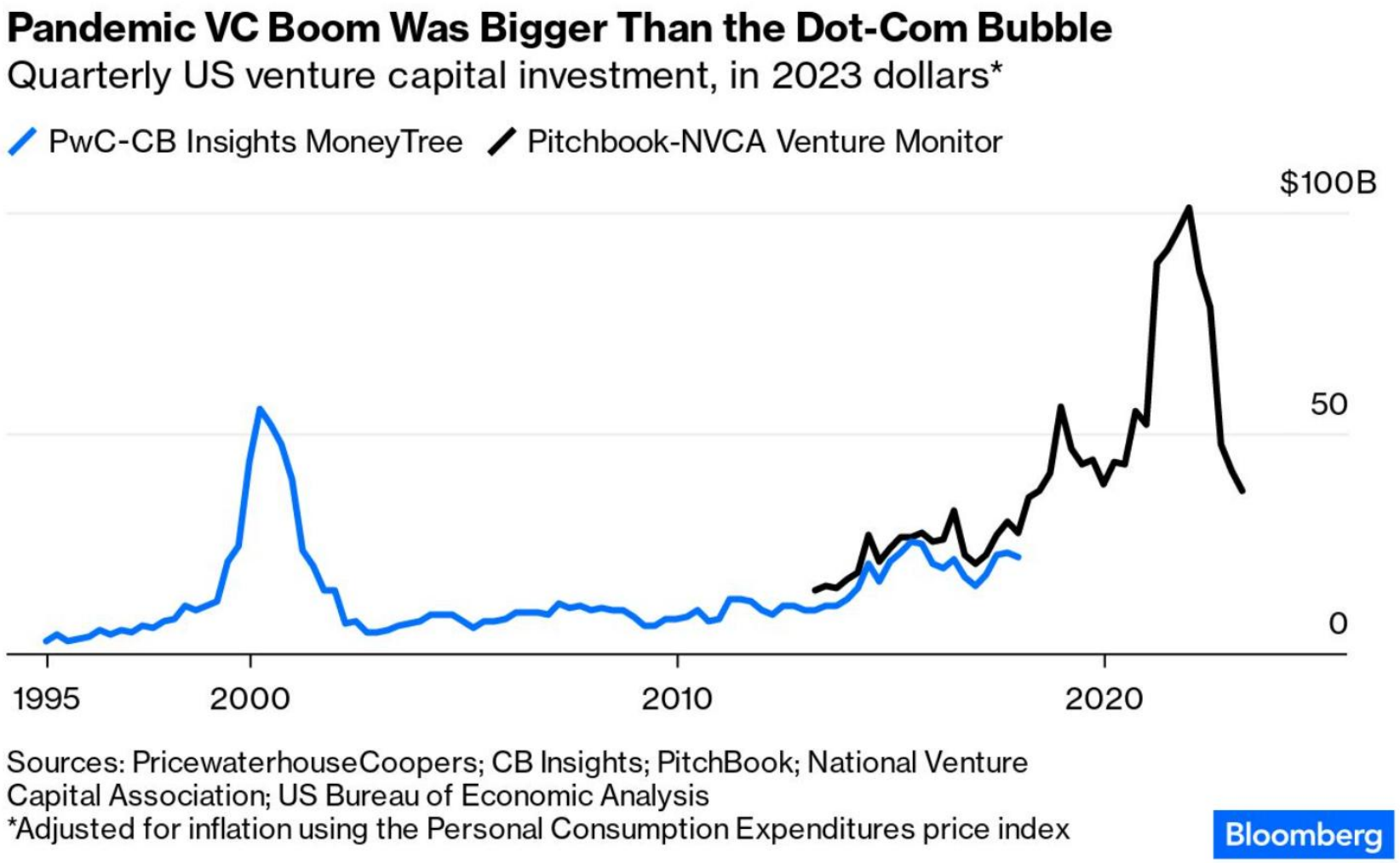
5 Government of Japan, The 5th Science and Technology Basic Plan (January 22, 2016) http://www8.cao.go.jp/cstp/kihonkeikaku/5honbun.pdf

Chart 1: Development of Human Society

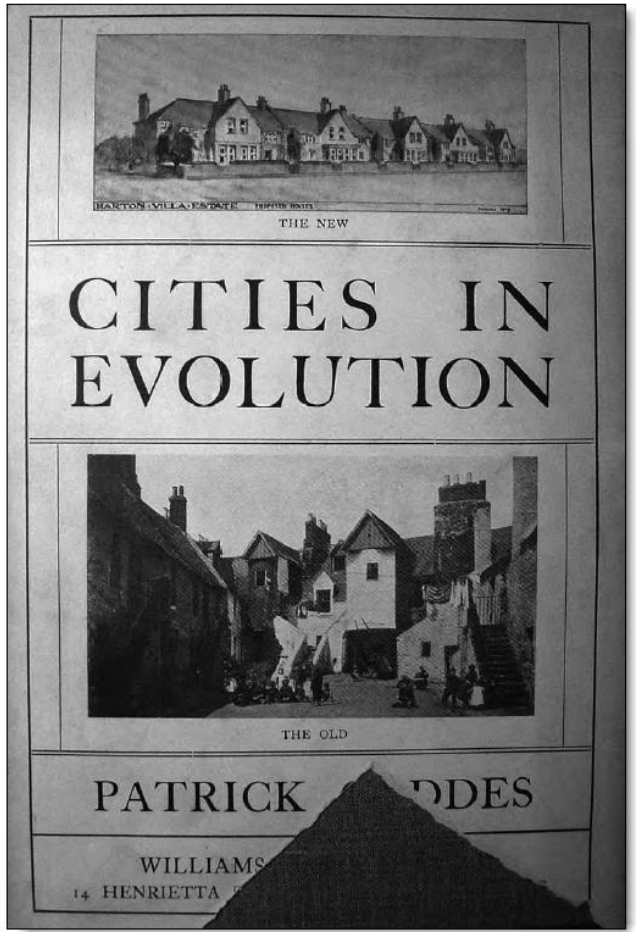
Digital Transformation and New Order



Dot-com Bubble

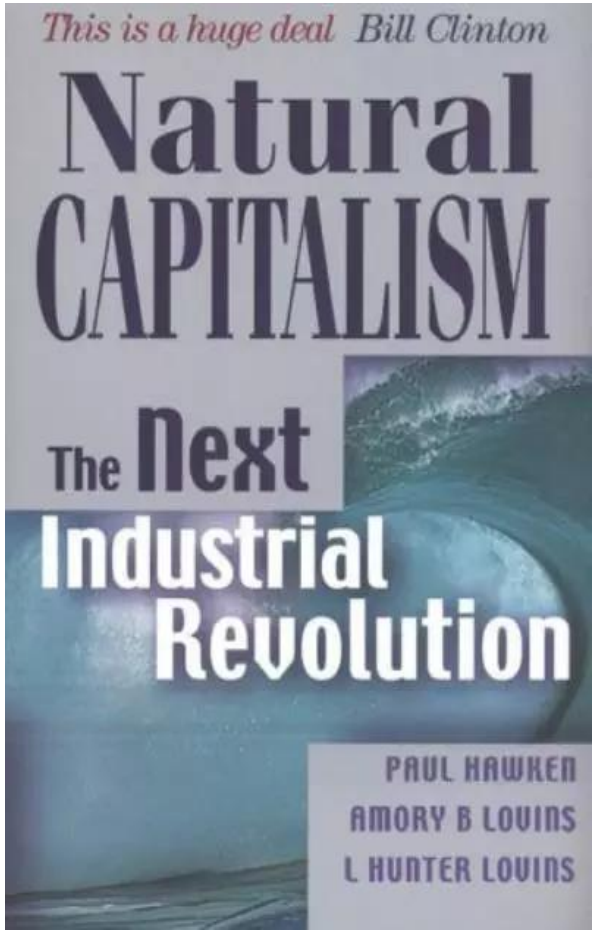


A New Industrial Revolution

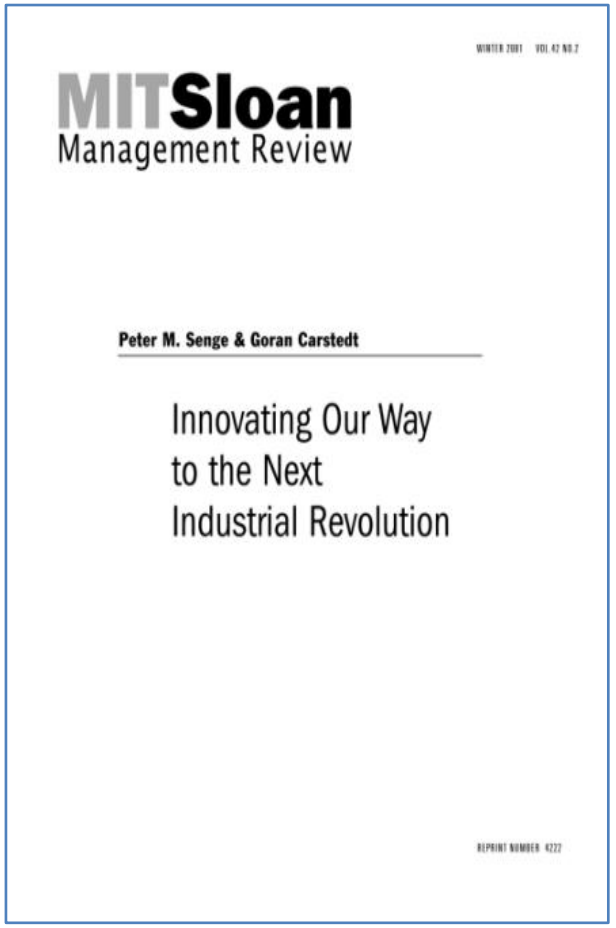


(Patrick Geddes)

1915

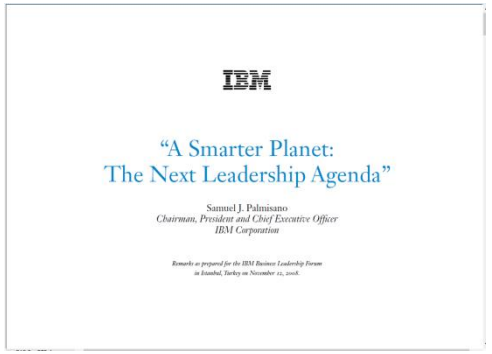


1998

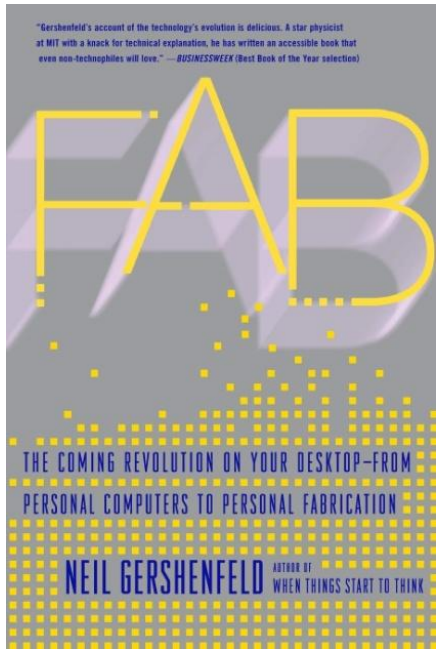


2001

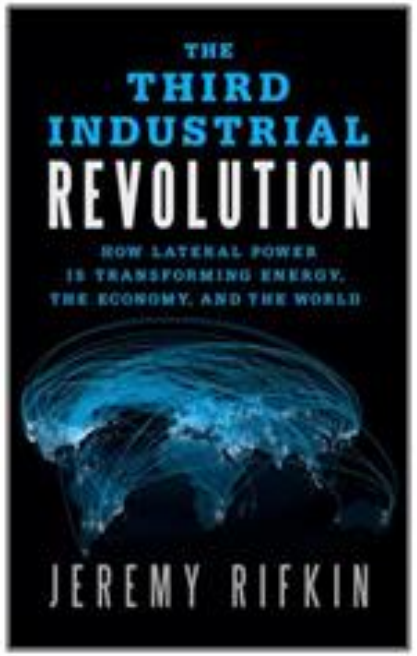
A New Industrial Revolution (II)



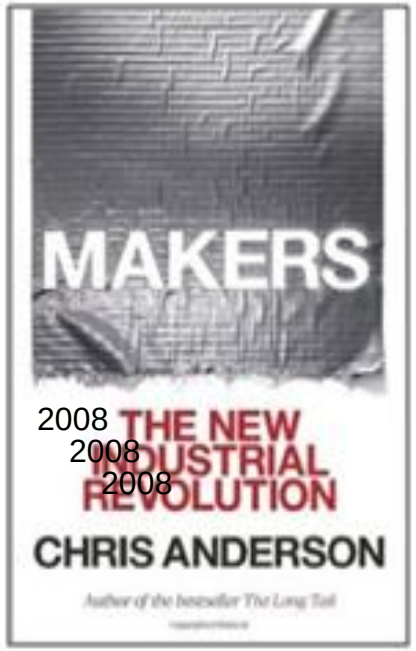
2008



2004



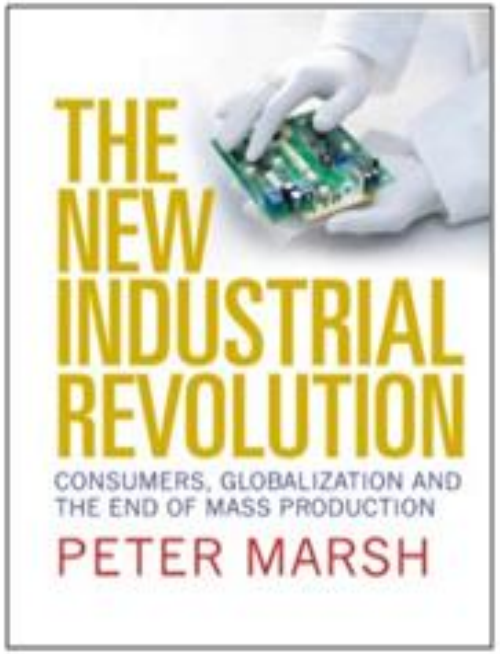
2011



2008
2008
2008

2012

2016

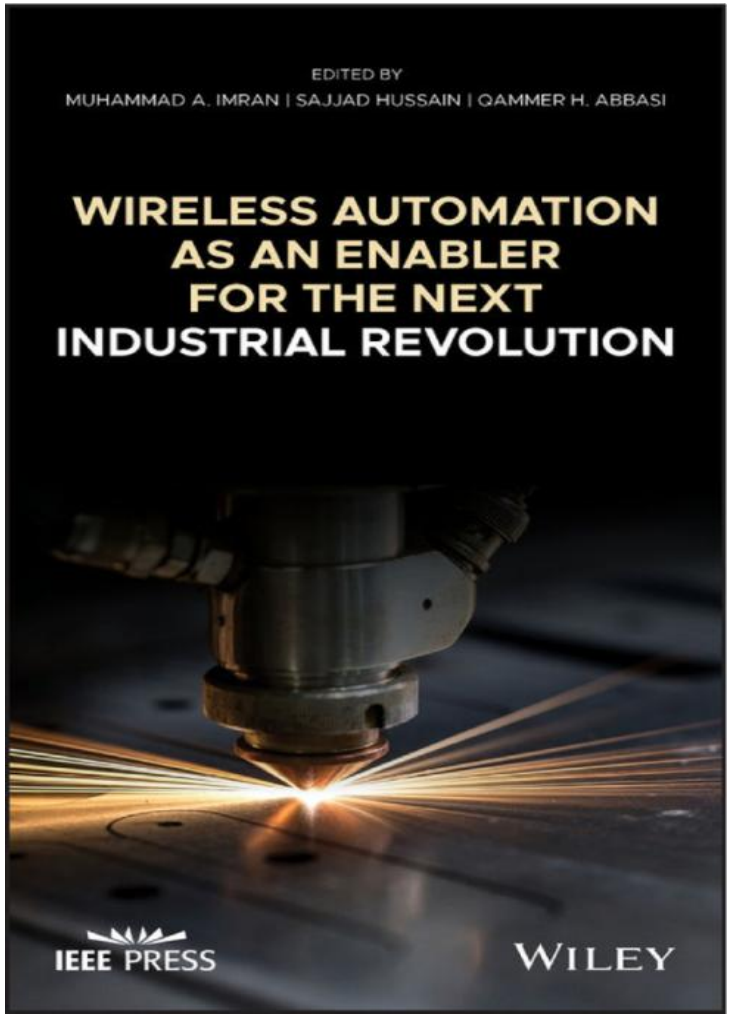


2012

A New Industrial Revolution (III)

(Rifkin)

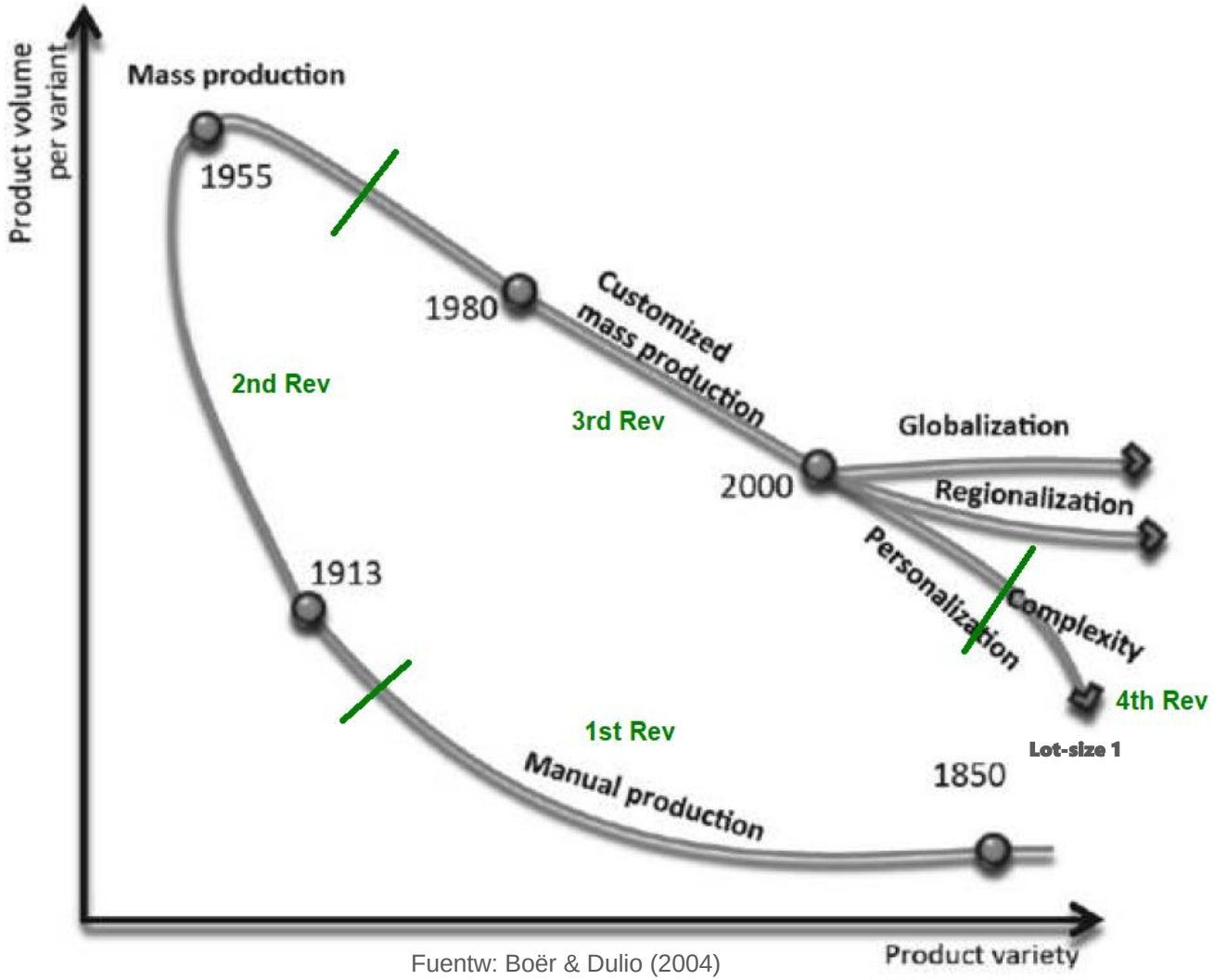
2020



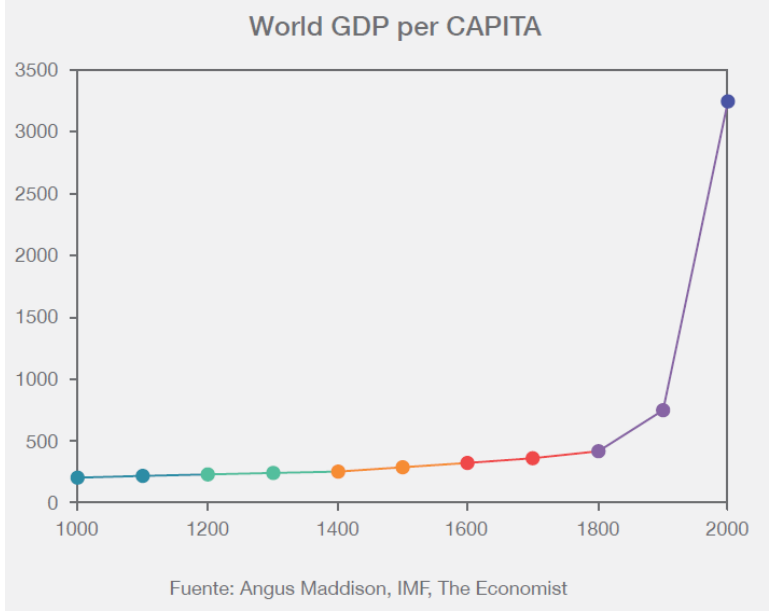
2020

2013

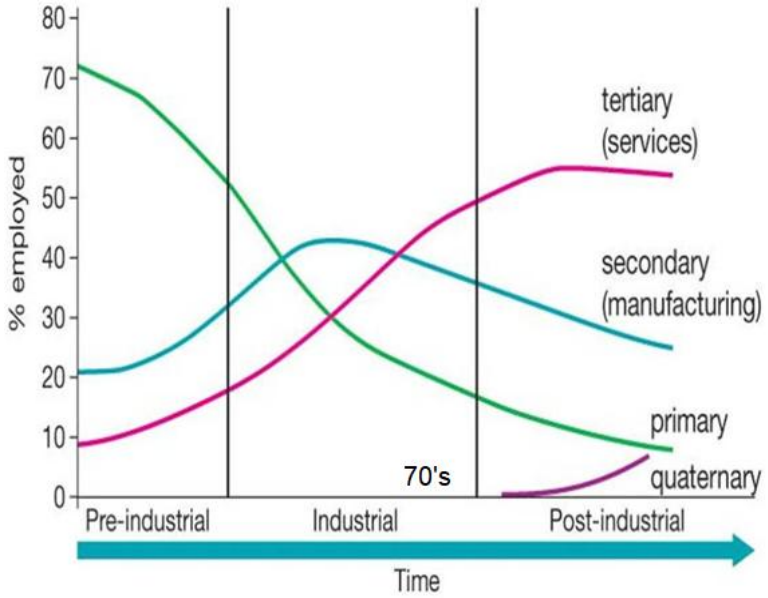
Causes



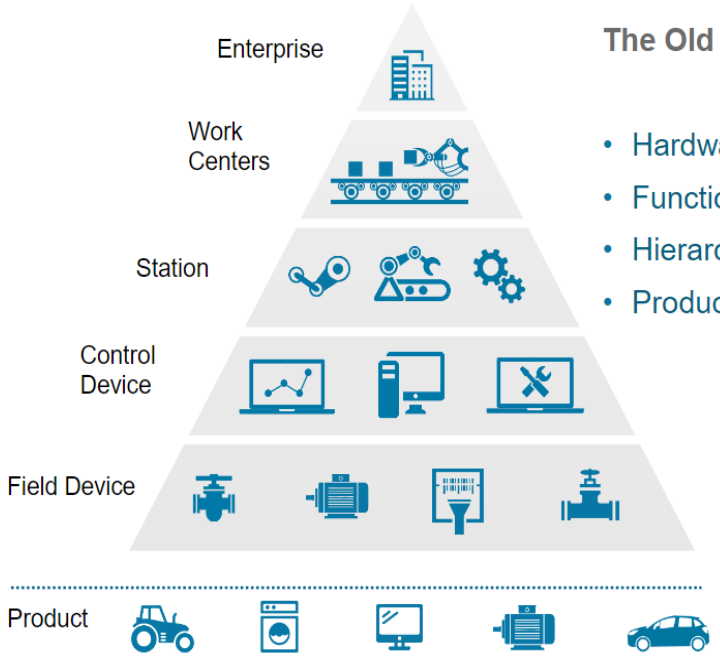
Fuentw: Boër & Dulio (2004)



Fuente: Angus Maddison, IMF, The Economist



Flexibility and Digitalization

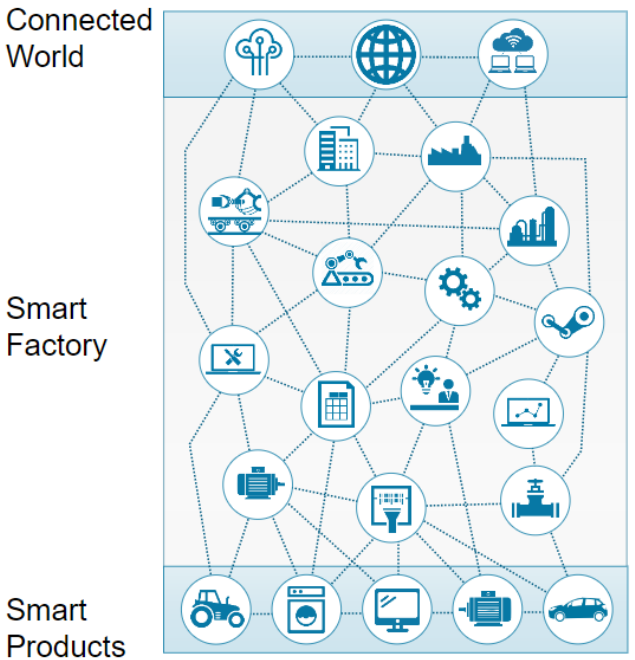


The Old World: Industrie 3.0

- Hardware-based structure
- Functions are bound to hardware
- Hierarchy-based communication
- Product is isolated

The New World: Industrie 4.0

- Flexible systems and machines
- Functions are distributed throughout the network
- Participants interact across hierarchy levels
- Communication among all participants
- Product is part of the network



Digitalitzation

April 2016

DIN SPEC 91345 DIN

ICS 03.100.01; 25.040.01; 35.240.50

Reference Architecture Model Industrie 4.0 (RAMI4.0)
English translation of DIN SPEC 91345:2016-04

Referenzarchitekturmodell Industrie 4.0 (RAMI4.0)
Englische Übersetzung von DIN SPEC 91345:2016-04
Modèle de référence de l'architecture de l'industrie 4.0 (RAMI4.0)
Traduction anglaise de DIN SPEC 91345:2016-04

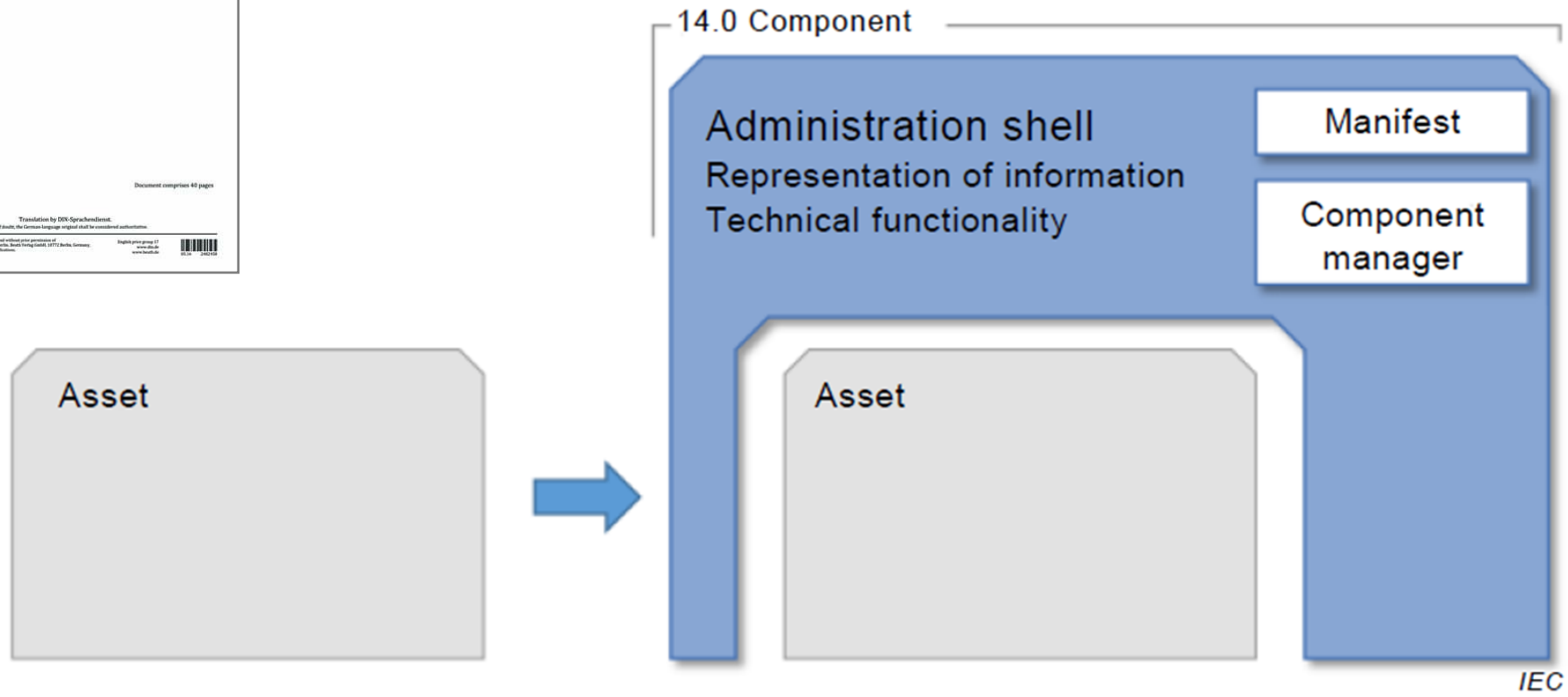
There are various procedures for developing a DIN SPEC.
This document has been developed in accordance with the PAS procedure.

Document comprises 40 pages

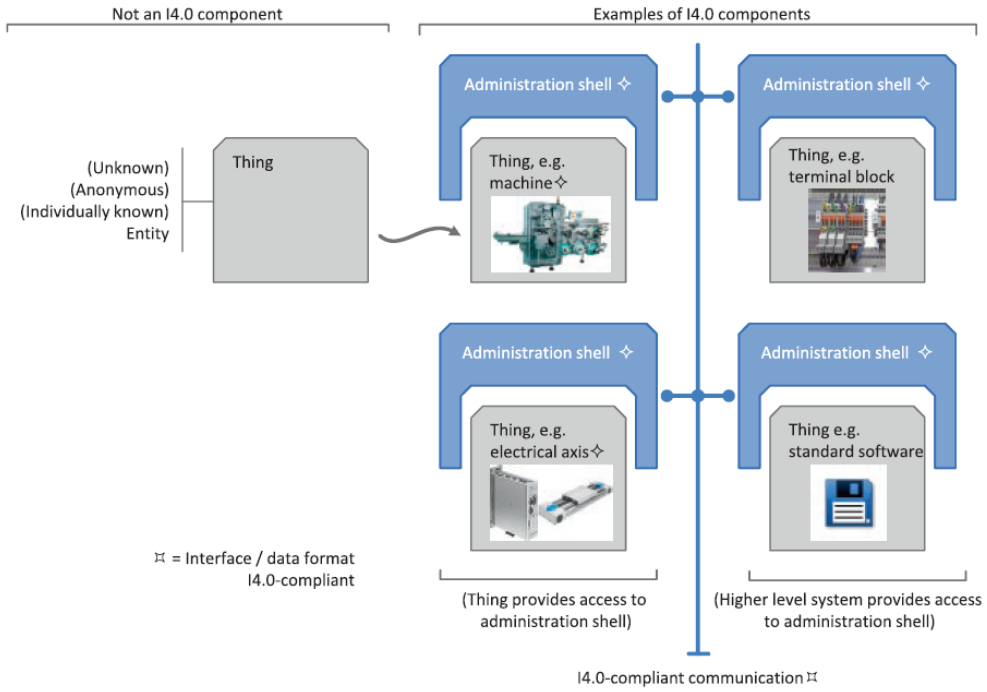
Translation by DIN-Sprachendienst.
In case of doubt, the German-language original shall be considered authoritative.

English price group 17
www.din.de
www.beuth.de

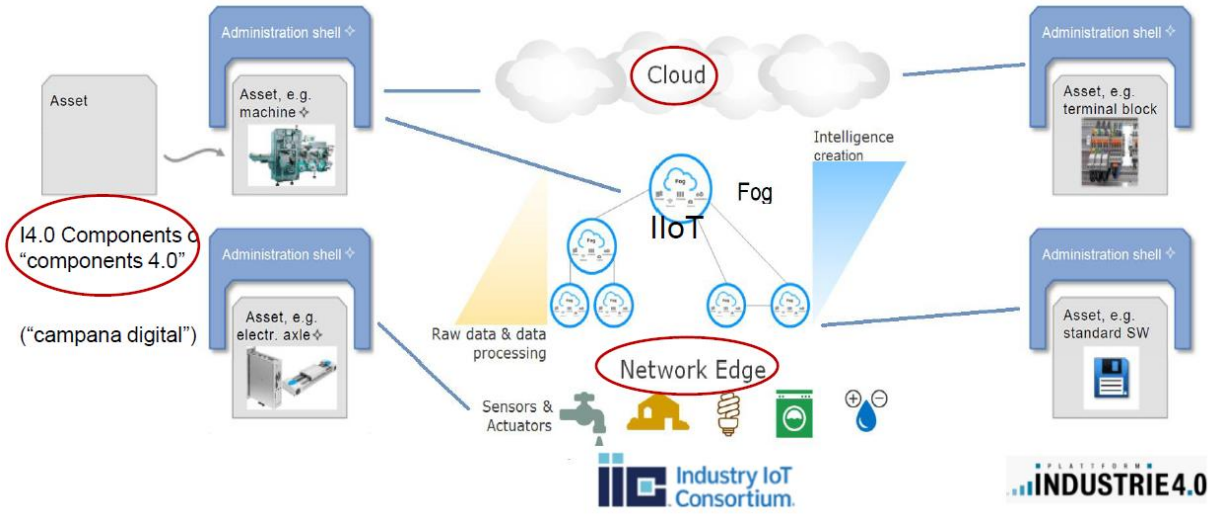
DIN SPEC 91345 - RAMI 4.0: Reference Architecture Model Industry 4.0
(IEC PAS 63088)



IT/OT Convergence, Reference Architectures



RAMI 4.0



IIRA

(Ciberseguretat)

Safety: Protegir a les persones dels sistemes

Security: Protegir als sistemes de les persones

Cyber-Physical Systems (Helen Gill NSF 2006)
IT/OT Convergence (Rockwell Automation 2007)
https://www.controleng.com/benefits-suggested-with-convergence-of-it-controls

Agents (Wooldridge, Fonseca)

Agent-Based Software Engineering

Michael Wooldridge
Mitsubishi Electric Digital Library Group
18th Floor, Centre Point, 103 New Oxford Street
London WC1A 1EB, United Kingdom
mjw@dlib.com

September 19, 1997

Abstract

The technology of intelligent agents and multi-agent systems seems set to radically alter the way in which complex, distributed, open systems are conceptualized and implemented. The purpose of this paper is to consider the problem of building a multi-agent system as a software engineering enterprise. The article focuses on three issues: (i) how agents might be specified; (ii) how these specifications might be refined or otherwise transformed into efficient implementations; and (iii) how implemented agents and multi-agent systems might subsequently be verified, in order to show that they are correct with respect to their specifications. These issues are discussed with reference to a number of case-studies. The article concludes by setting out some issues and open problems for future research.

Applied Artificial Intelligence, 28:504–531, 2014

ISSN: 0883-9514 print/1087-6545 online
DOI: 10.1080/08839514.2014.905820

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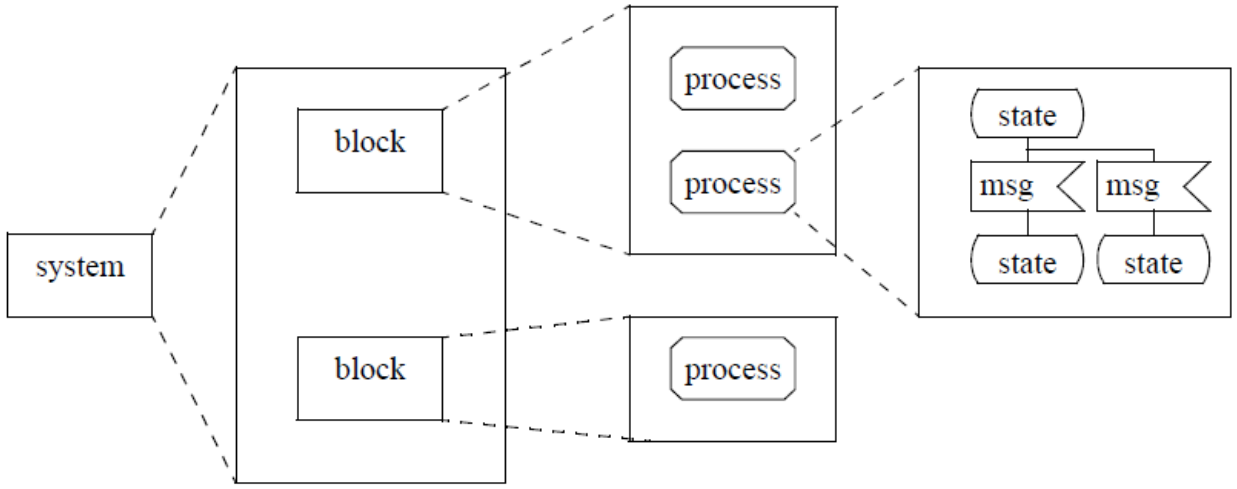
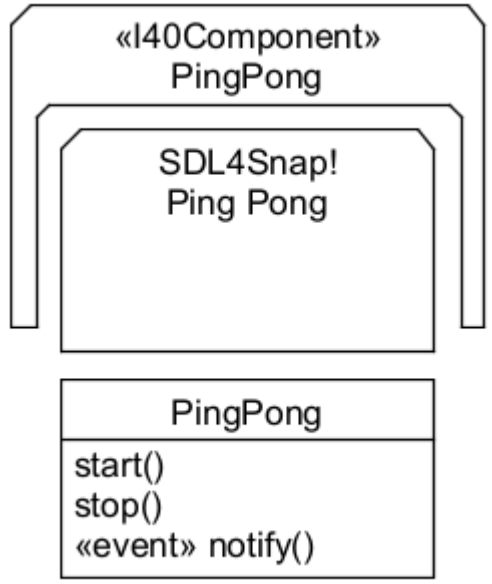
USING SPECIFICATION AND DESCRIPTION LANGUAGE TO FORMALIZE MULTIAGENT SYSTEMS

Pau Fonseca i Casas
Statistics and Operations Research Department, Universitat Politècnica de Catalunya – BarcelonaTech, Barcelona, Spain

□ *Simulation is a multidisciplinary field of study used in different scopes, involving people with different areas of knowledge and backgrounds. Formal languages become important tools in order to build, understand, and maintain the simulation models. The formalization of an intelligent agent is not an easy task because of the complex behavior it owns. In this study, we apply a formal and graphical language, called* Specification and Description Language, *to formalize an intelligent agent. This formalization captures the complete and unambiguous behavior of the agents and simplifies the understanding of the agents' behaviors because of the graphic structure of the language. This formal representation of the model also simplifies joining multiagent system (MAS) models and interaction models through the formalization. In addition, because Specification and Description Language is a standard language, several tools are capable of understanding the model, which leads to an automatic implementation.*

Agents (SDL / UML)





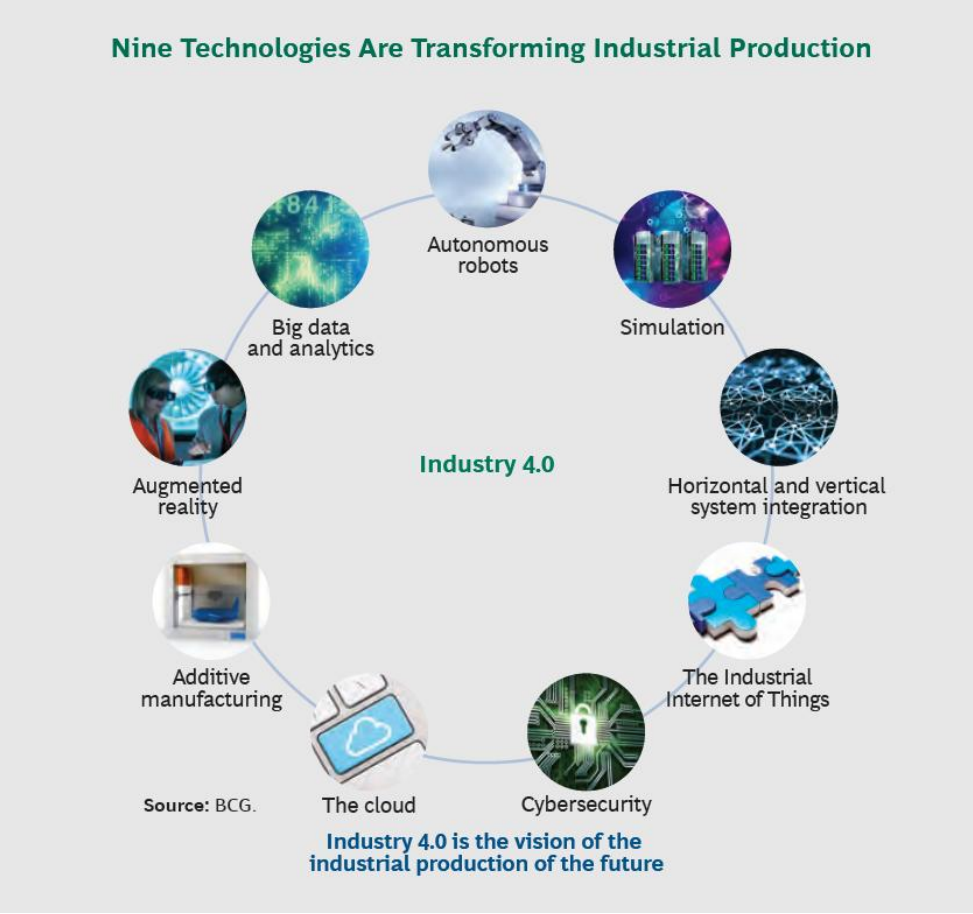
Biblio

According to SDL specification ITU-T Z.100, systems, blocks and processes are agents.

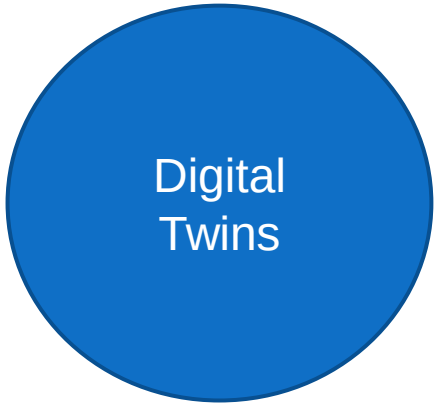
According to ITU-T Z.109 SDL can be defined as an UML Profile

RAMI 4.0 components
Can be defined as
UML components
Stereotypes.

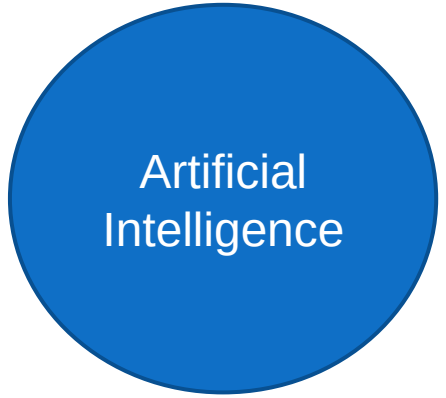
Industry 4.0



Original Boston Consulting Group Model (2015)

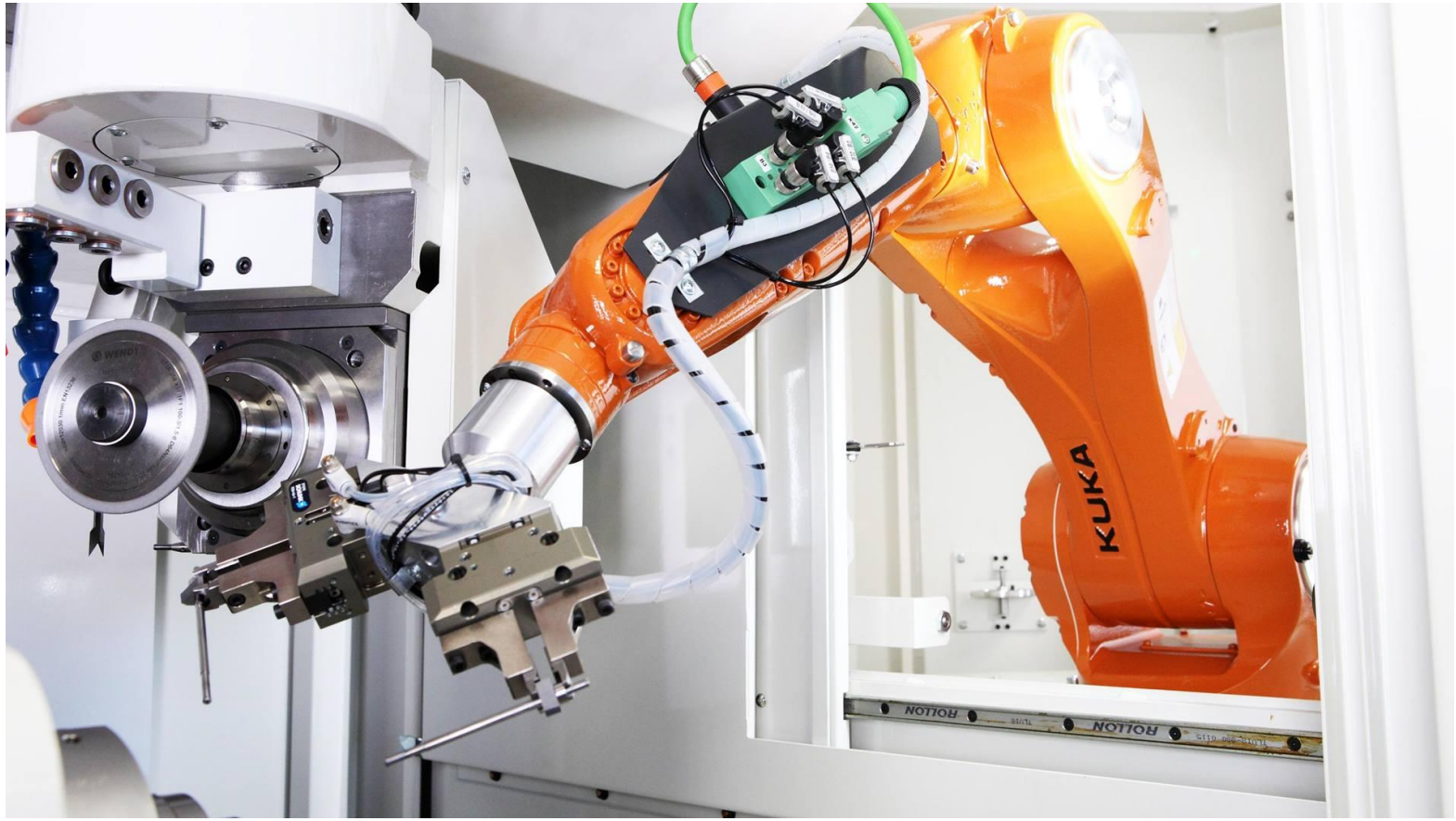


At center

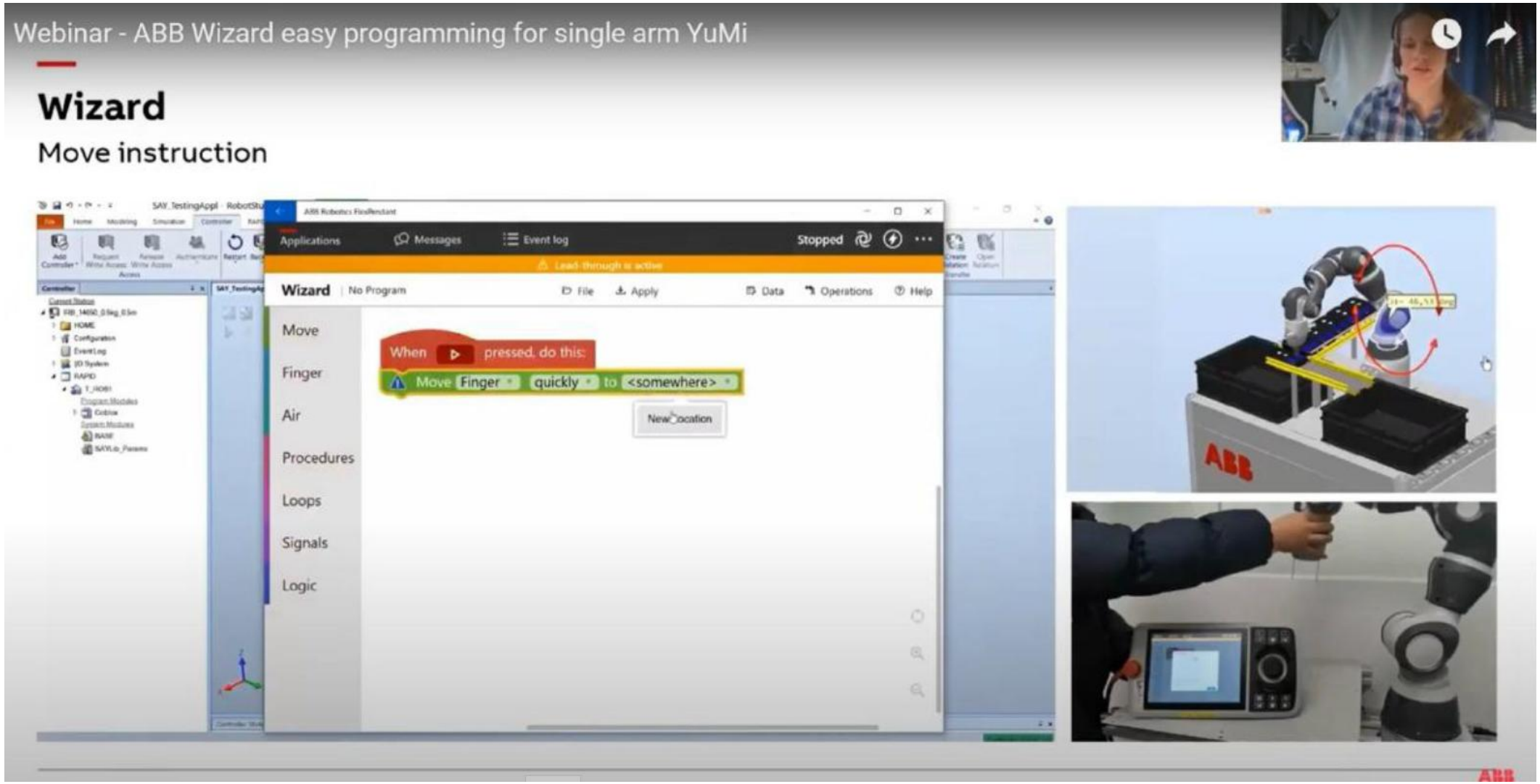


Everywhere

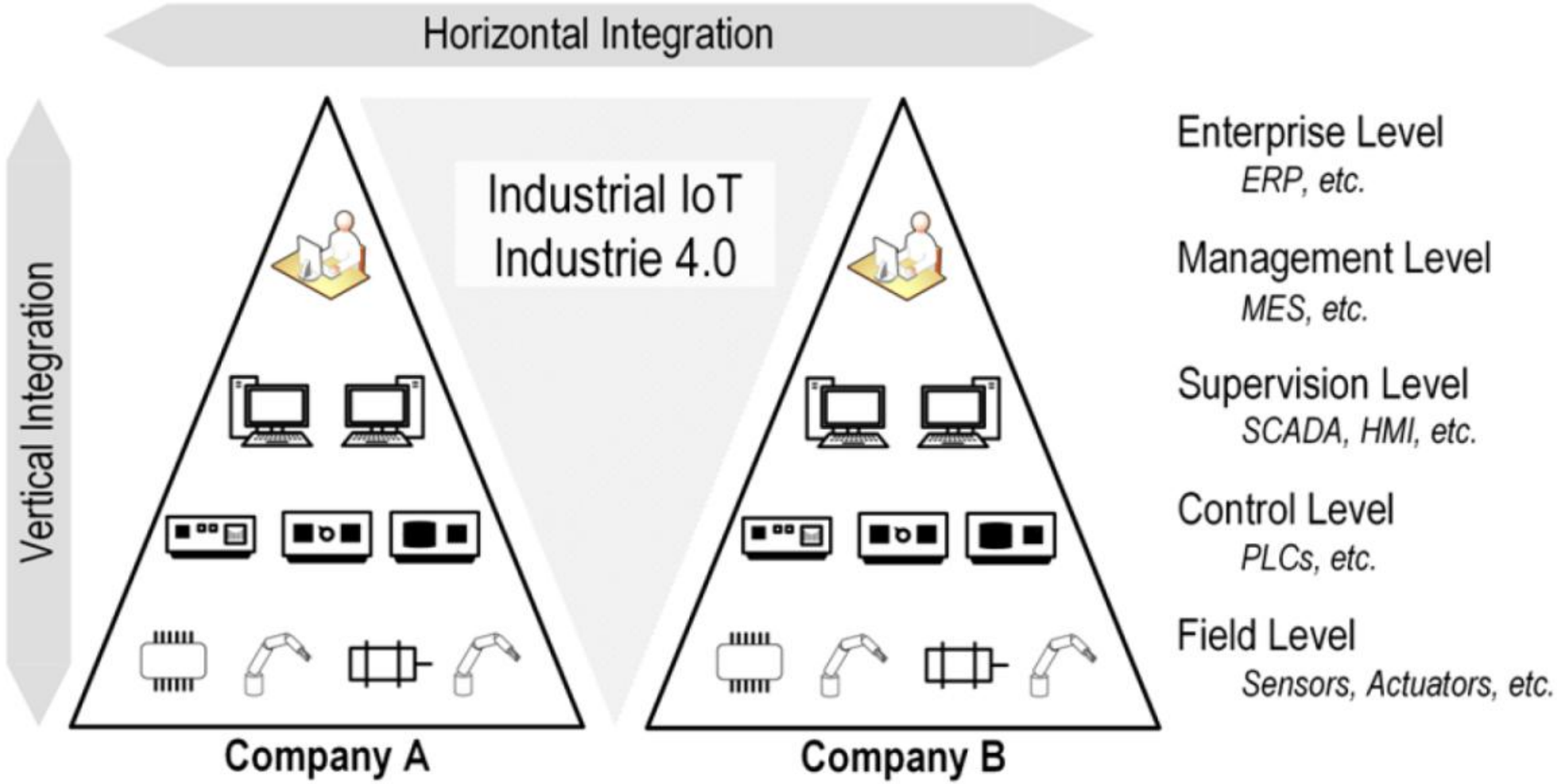
Advanced and Autonomous Robotics



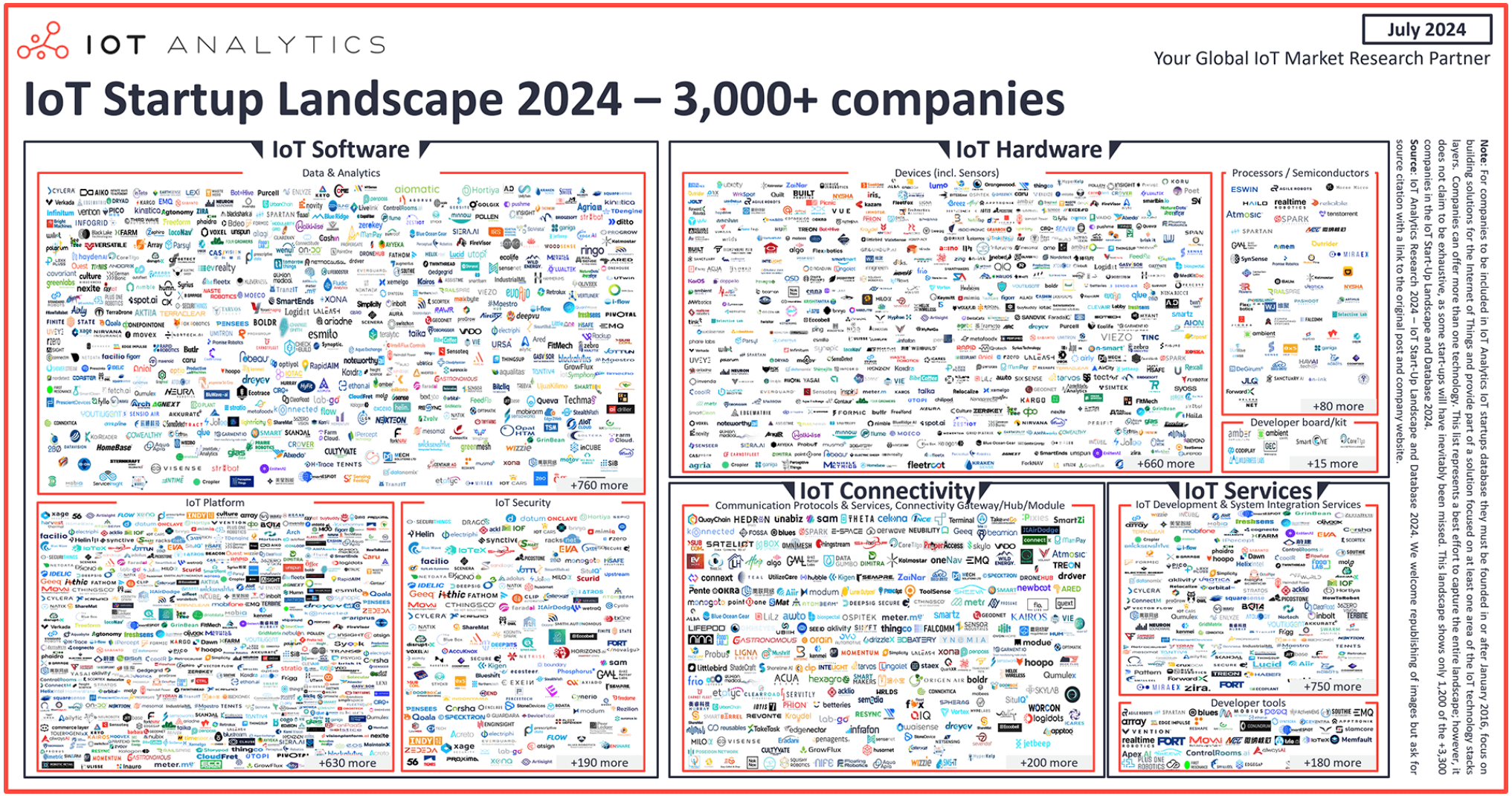
Simulation (A Digital Twin Pillar)



Horitzontal and Vertical Integration



IoT


IOT ANALYTICS
July 2024
Your Global IoT Market Research Partner
IoT Startup Landscape 2024 – 3,000+ companies
IoT Software
Data & Analytics
+760 more
IoT Platform
+630 more
IoT Security
+190 more
IoT Hardware
Devices (incl. Sensors)
+660 more
Processors / Semiconductors
+80 more
Developer board/kit
+15 more
IoT Connectivity
Communication Protocols & Services, Connectivity Gateway/Hub/Module
+200 more
IoT Services
IoT Development & System Integration Services
+750 more
Developer tools
+180 more
Note: For companies to be included in IoT Analytics IoT startups database they must be founded in or after January 2016, focus on building solutions for the Internet of Things and provide part of a solution focused on at least one area of the IoT technology stacks layers. Companies can offer more than one technology. This list represents a best effort to capture the entire landscape; however, it does not claim to be exhaustive, as some start-ups will have inevitably been missed. This landscape shows only 1,200 of the +3,300 companies in the IoT Start-Up Landscape and Database 2024.
Source: IoT Analytics Research 2024 – IoT Start-Up Landscape and Database 2024. We welcome republishing of images but ask for source citation with a link to the original post and company website.

IoT-II

IOT ANALYTICS

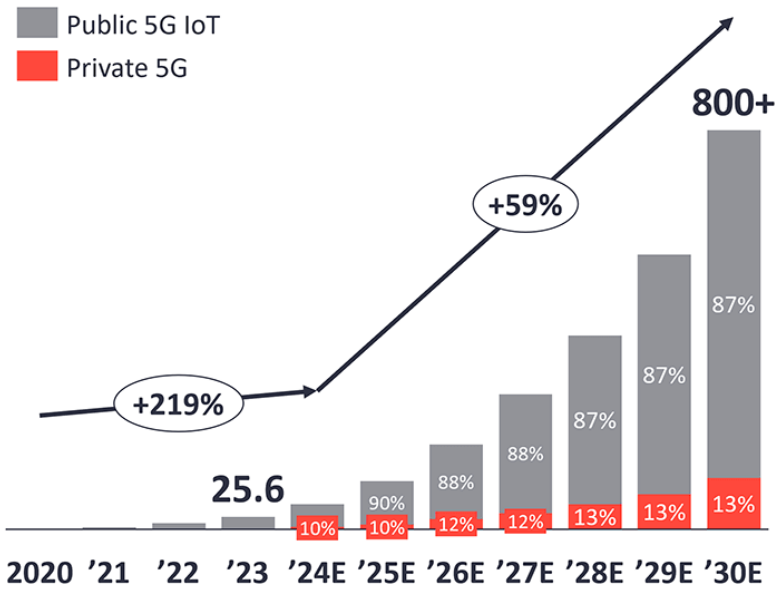
September 2024

Your Global IoT Market Research Partner

Market snapshot: 5G IoT

Market size

Global 5G IoT connections by type of deployment in millions (2018–2030)



Market players

(selection*)

HUAWEI, NOKIA, SAMSUNG, ERICSSON, ZTE, vodafone, 中国电信 CHINA TELECOM, 中国移动 China Mobile, China unicom中国联通, Deutsche Telekom, MEDIATEK, Qualcomm, UNISOC, QUECTEL, Fibocom, Telit Cinterion

Key 5G IoT use cases

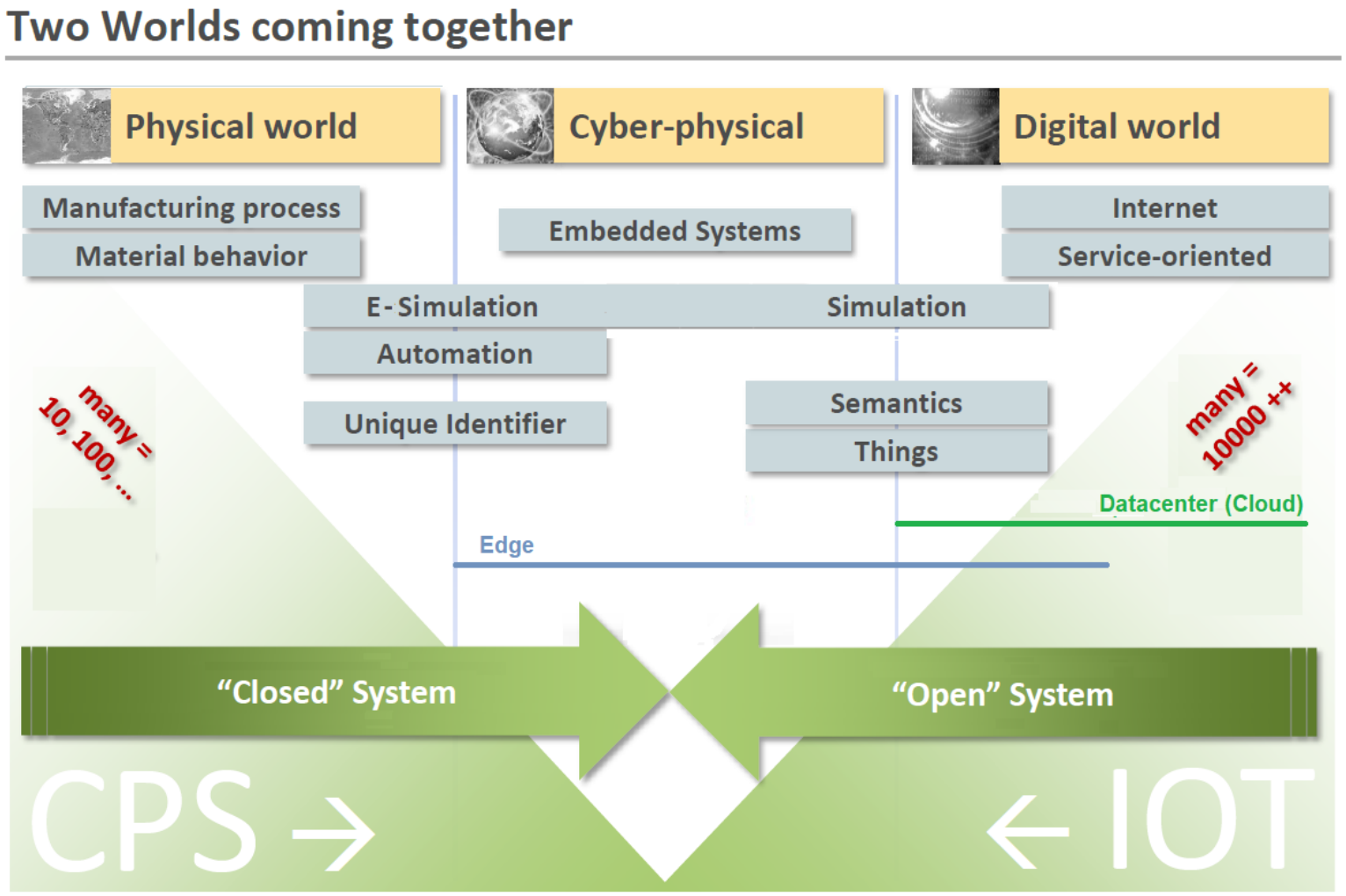
(selection of 5 out of 15 from the full market report)

- Remote control of assets
- Facility or campus connectivity and coverage
- Logistics automation using AGVs and AMRs
- Camera-based facility surveillance
- Facility or asset inspection using AR glasses

* = Just a few selected market players are shown—the list is not exhaustive.

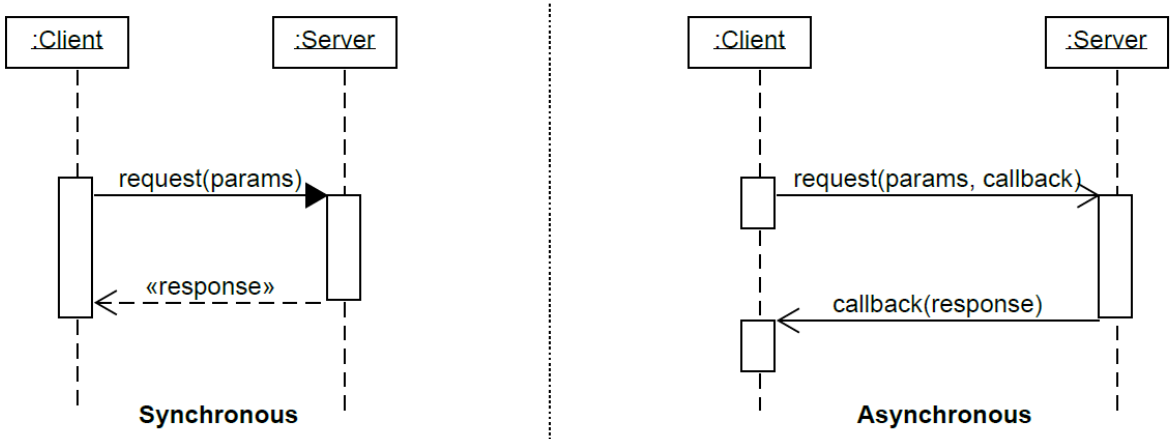
Source: IoT Analytics Research 2024 – 5G IoT & Private 5G Market Report 2024–2030. Conditions for republishing: Source citation with link to original post and company website.

Embedded Systems, IoT

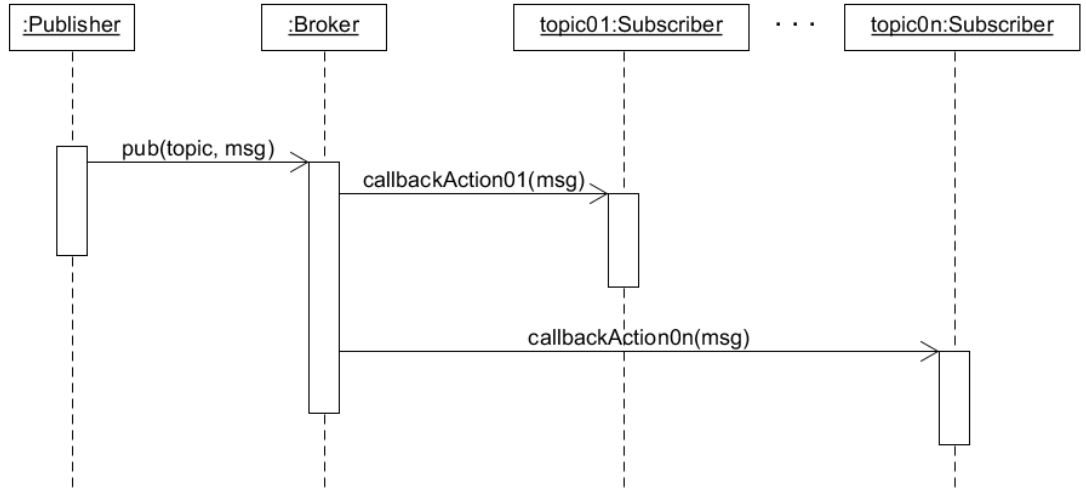


Source: Sabina Jeschke (Univ. Aachen)

IoT and Architectural Considerations



Client-Server



PubSub (asynchronous nature)

Architectures are tecnology agnostic.
Implementations require "tecnology mapping", which basically
is determine protocols or plataforms: MQTT, OPC-UA, HTTP, Kafka

I4.0 Protocols: HTTP, MQTT, OPC-UA

- HTTP (Hypertext Transfer Protocol) RFC 1945 **(orig) – RFC 9112**

  https://www.geeksforgeeks.org/blogs/http-full-form

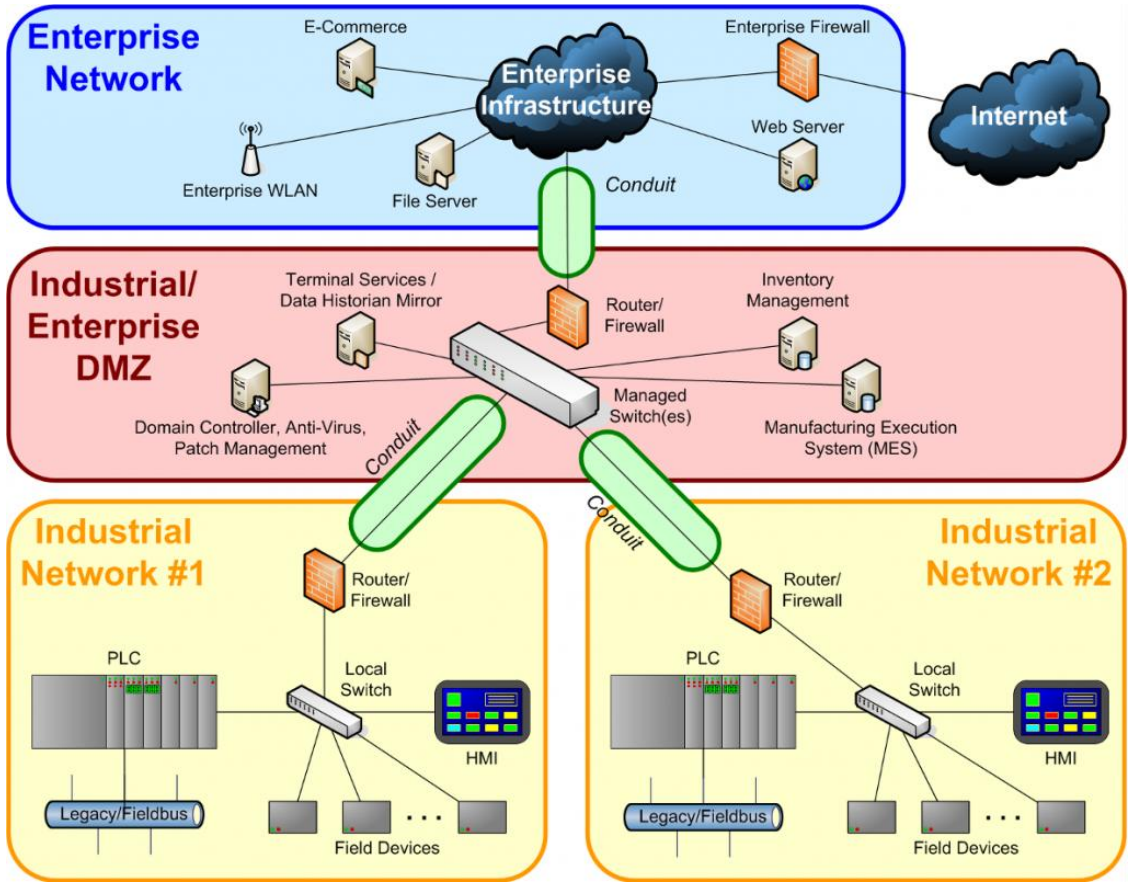
- MQTT (Message Queuing Telemetry Transport) **ISO/IEC 20922 –** OASIS 3.1.1

  https://www.hivemq.com/info/mqtt-essentials

- OPC-UA (Open Platform Communications – Unified Architecture) **IEC 62541 -** Specs

  https://opcfoundation.org/resources/brochures

Cybersecurity

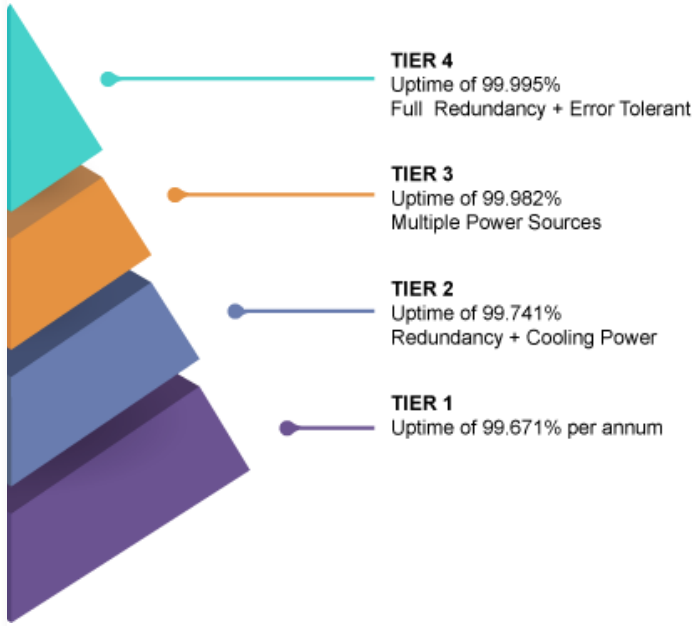


IEC 62443
Zones and Conduits

European Framework: NIS 2 Directive (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2016.194.01.0001.01.ENG&toc=OJ:L:2016:194:TOC)

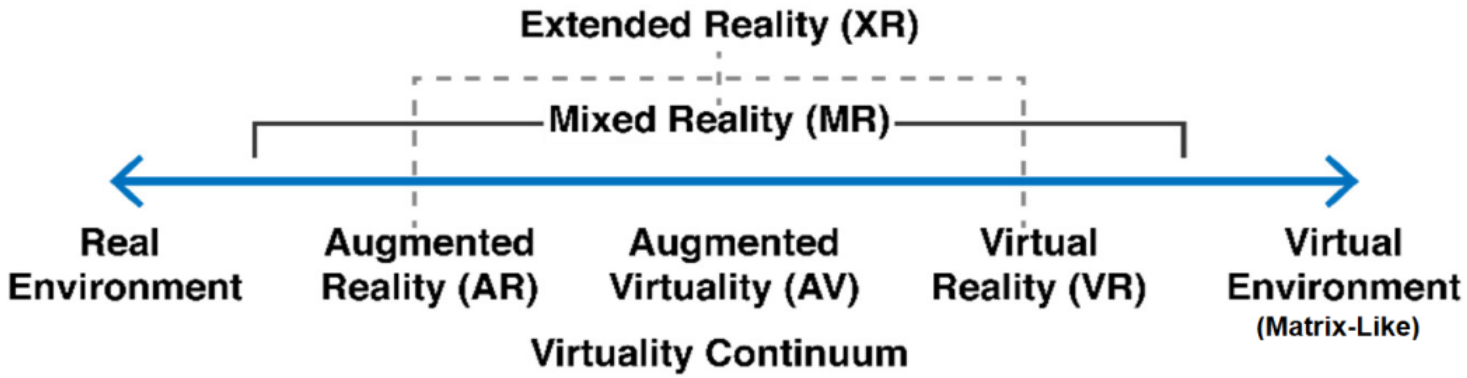
Cloud Computing

Datacenters



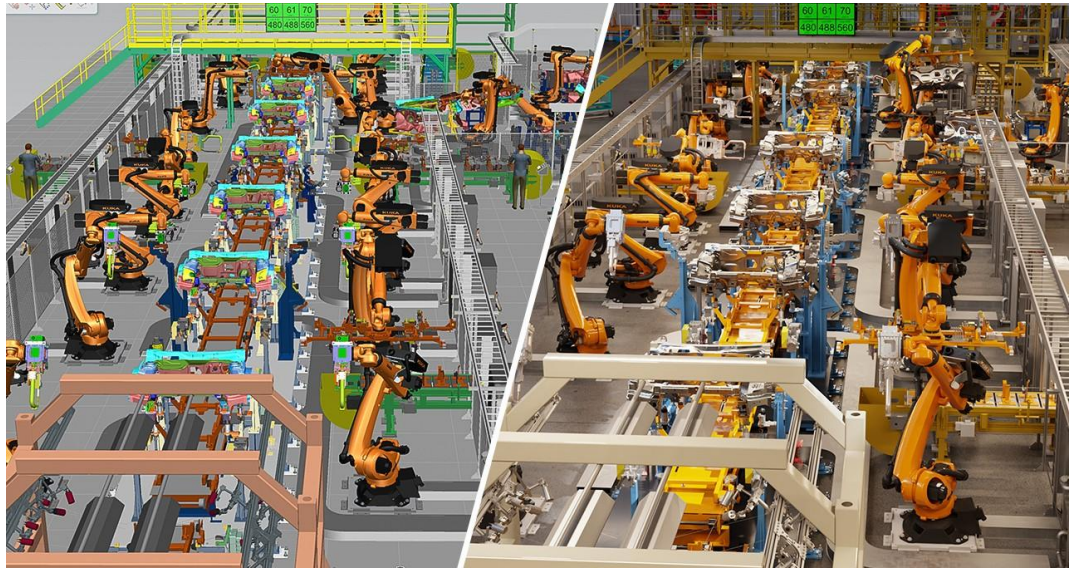
3D Printing

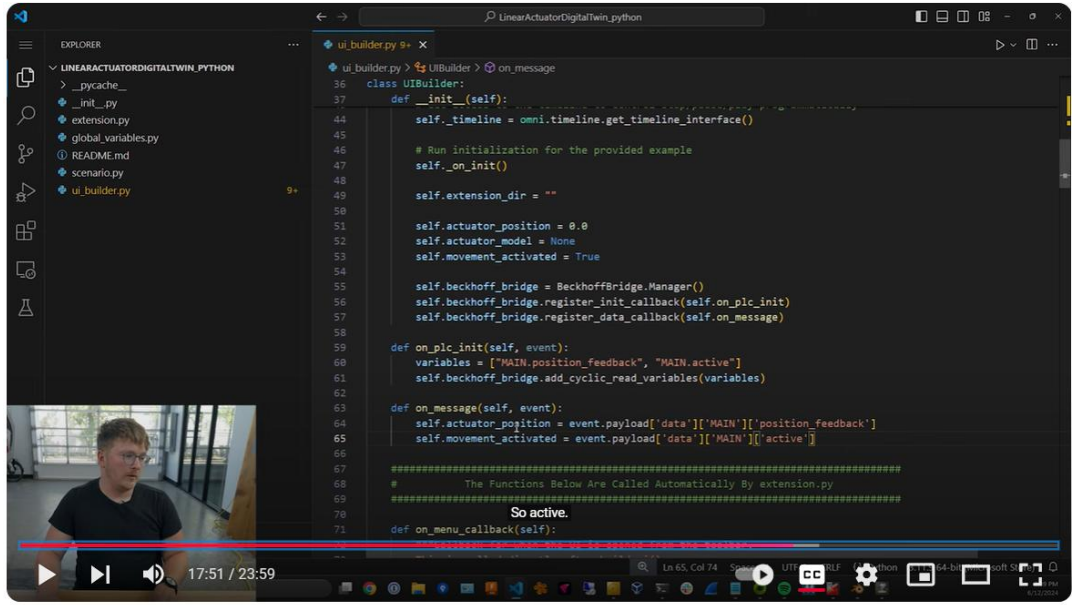
Augmented Reality



Continuum de Milgram

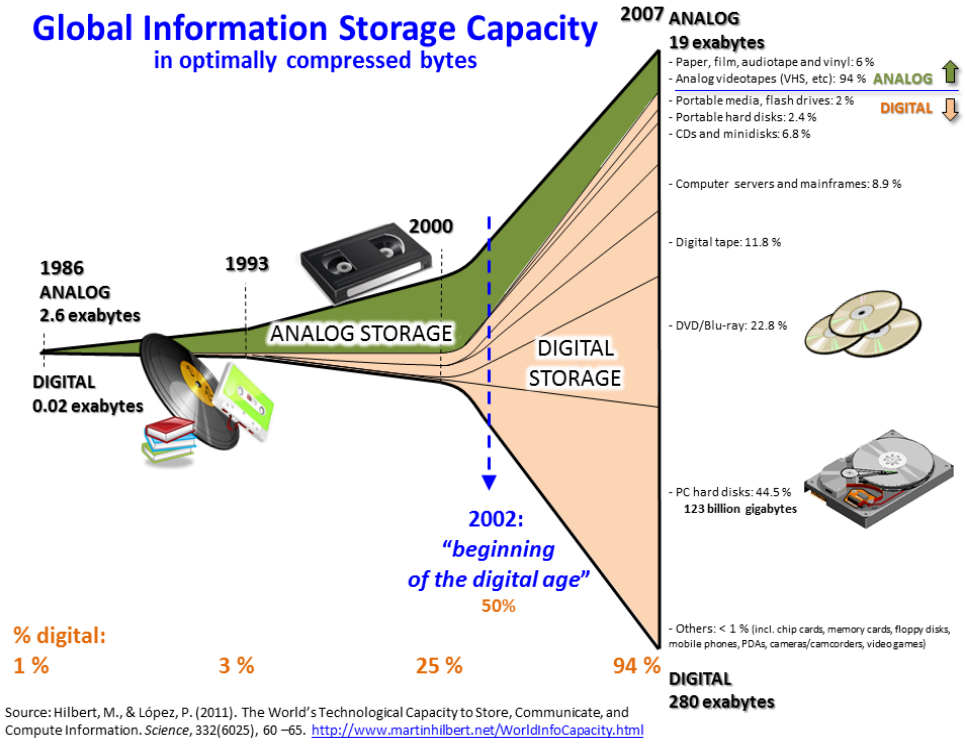
Industrial Metaverse



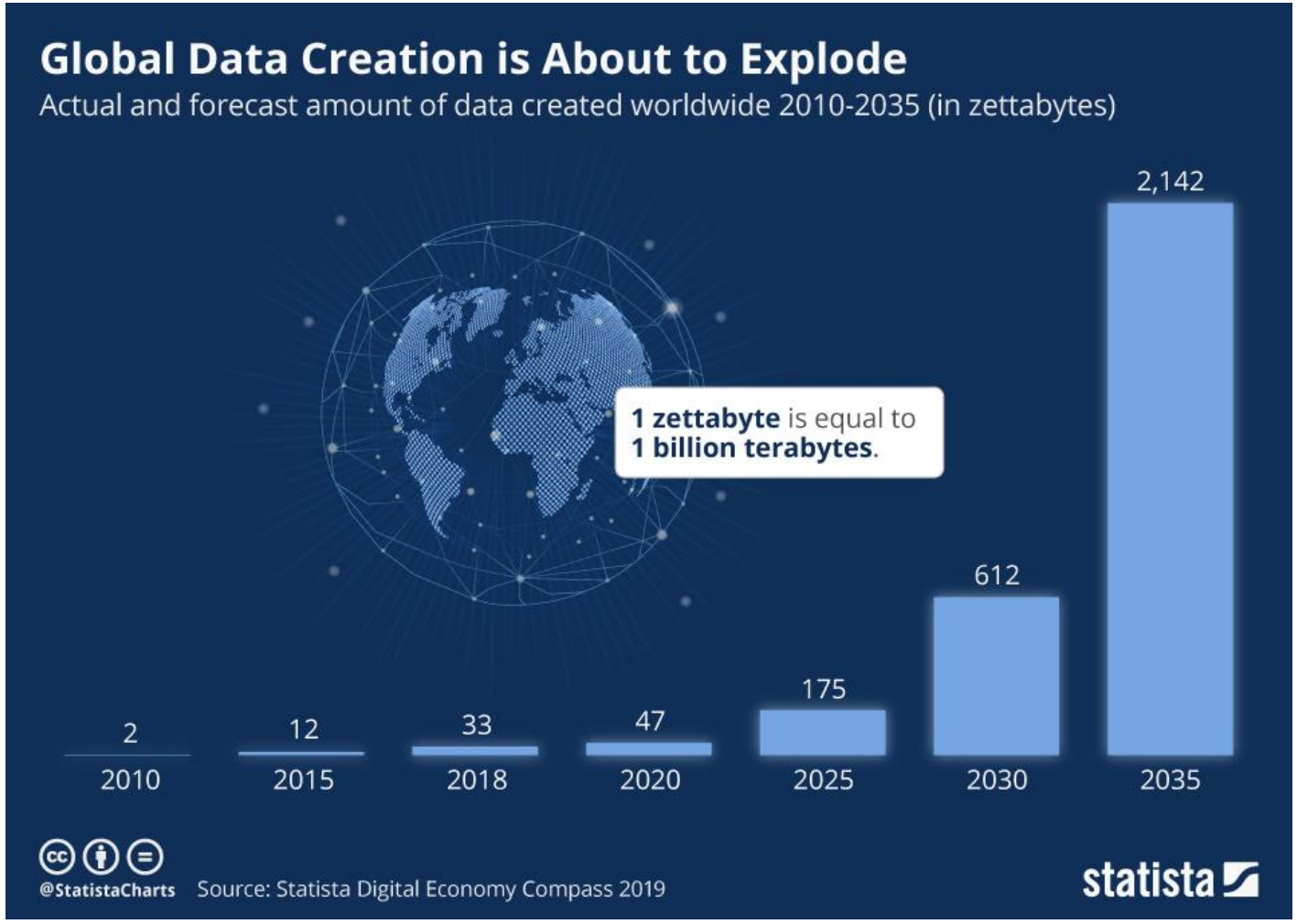


How To Build Digital Twins In Omniverse Tutorial

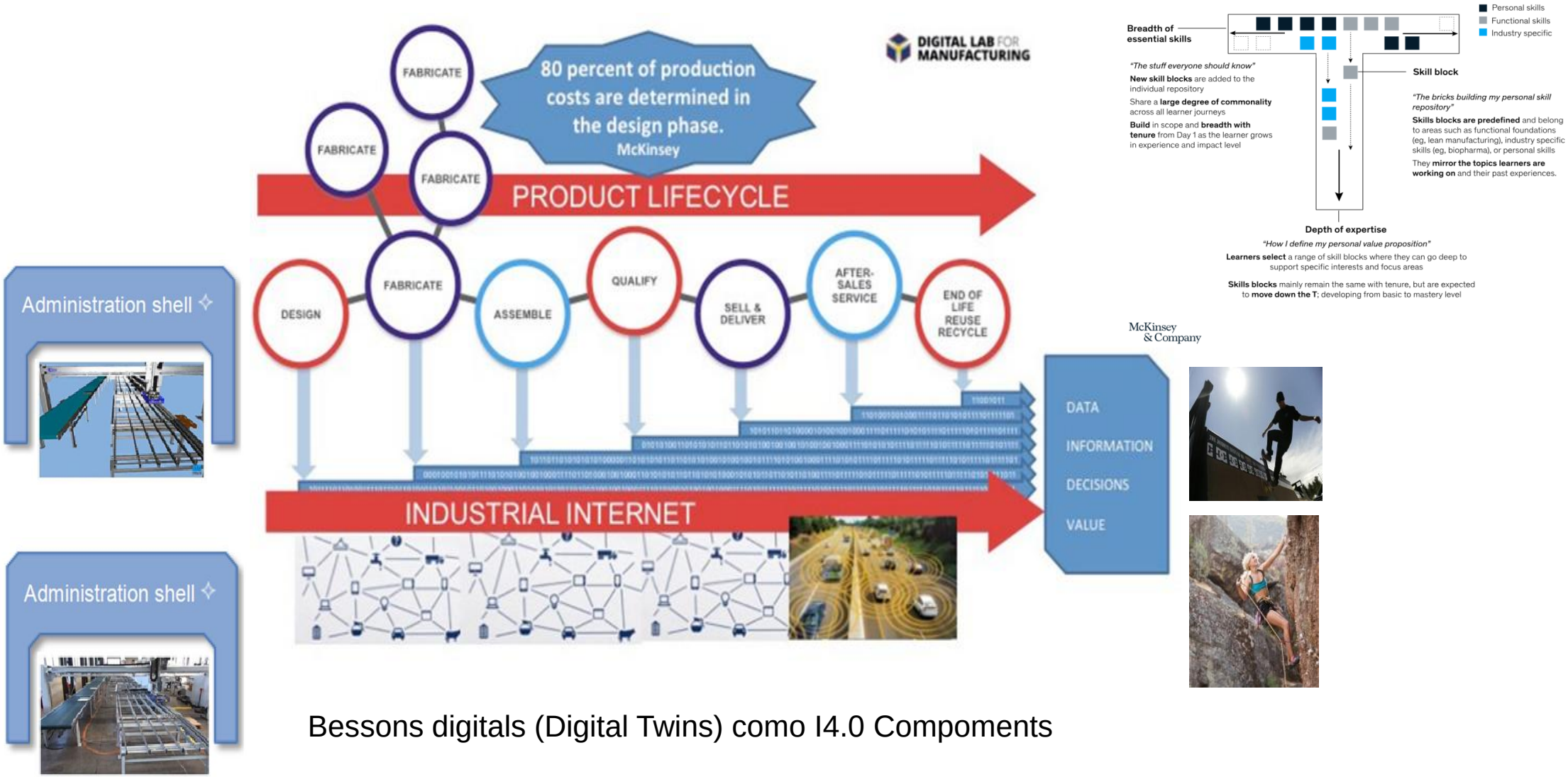
Data Analytics and Big Data



Source: Hilbert, M., & López, P. (2011). The World's Technological Capacity to Store, Communicate, and Compute Information. *Science*, 332(6025), 60 –65. http://www.martinhilbert.net/WorldInfoCapacity.html

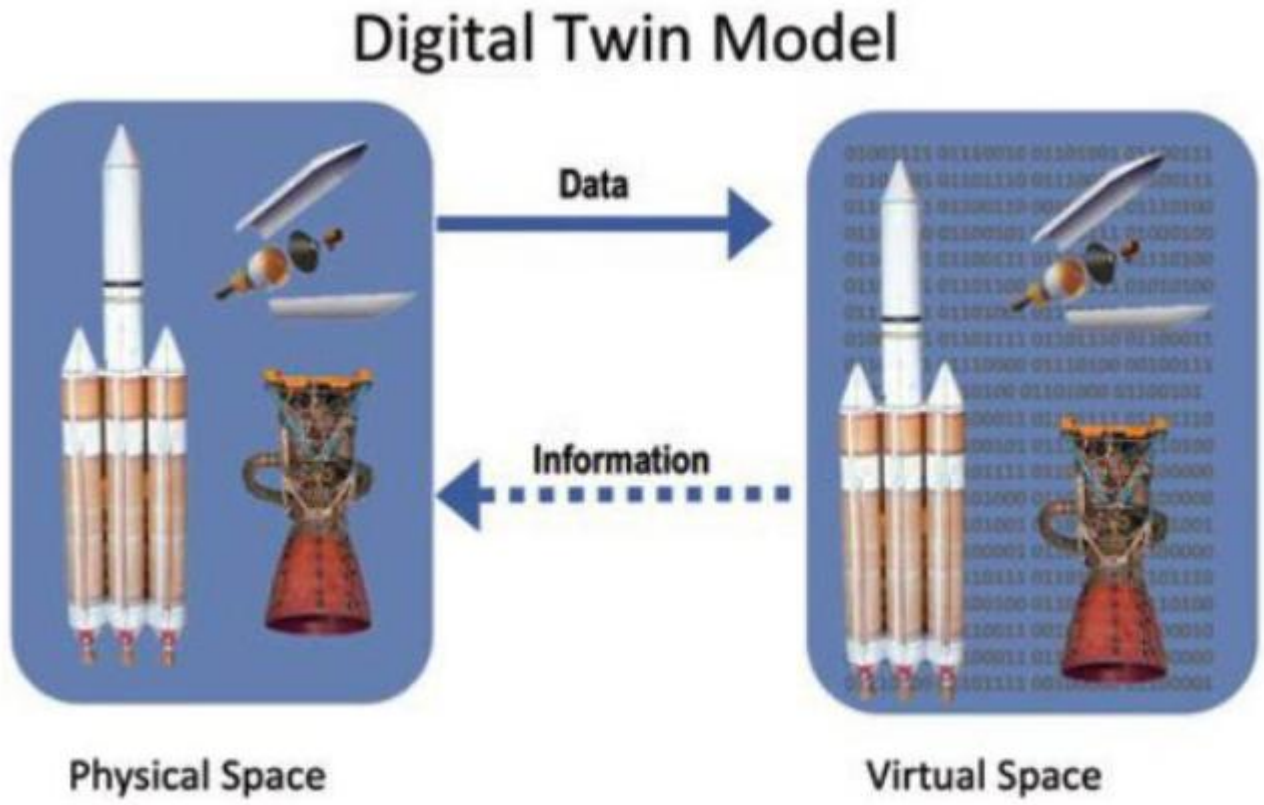


A Visión of Digital Transformation



Bessons digitals (Digital Twins) como I4.0 Compoments

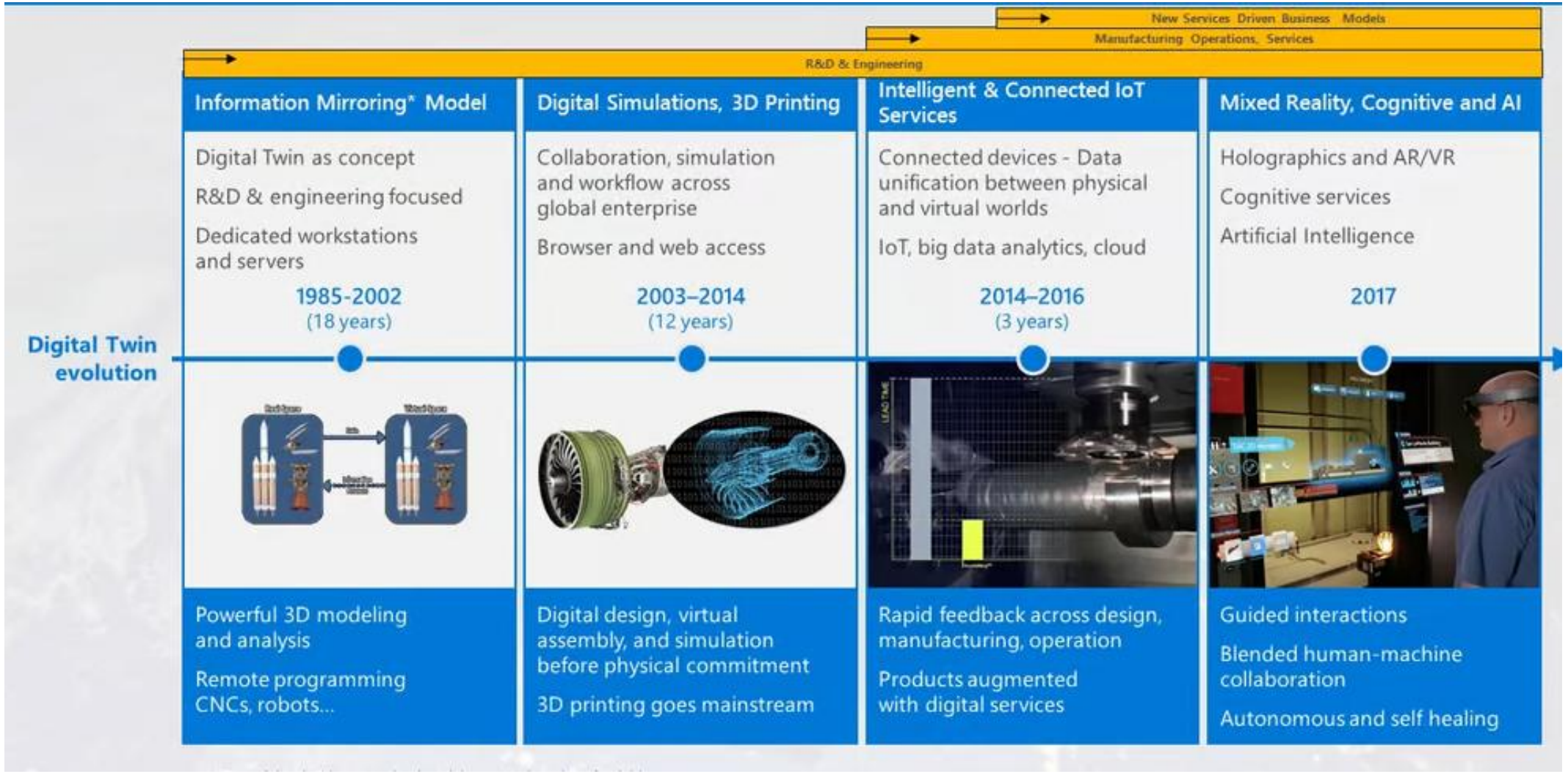
Digital Twins



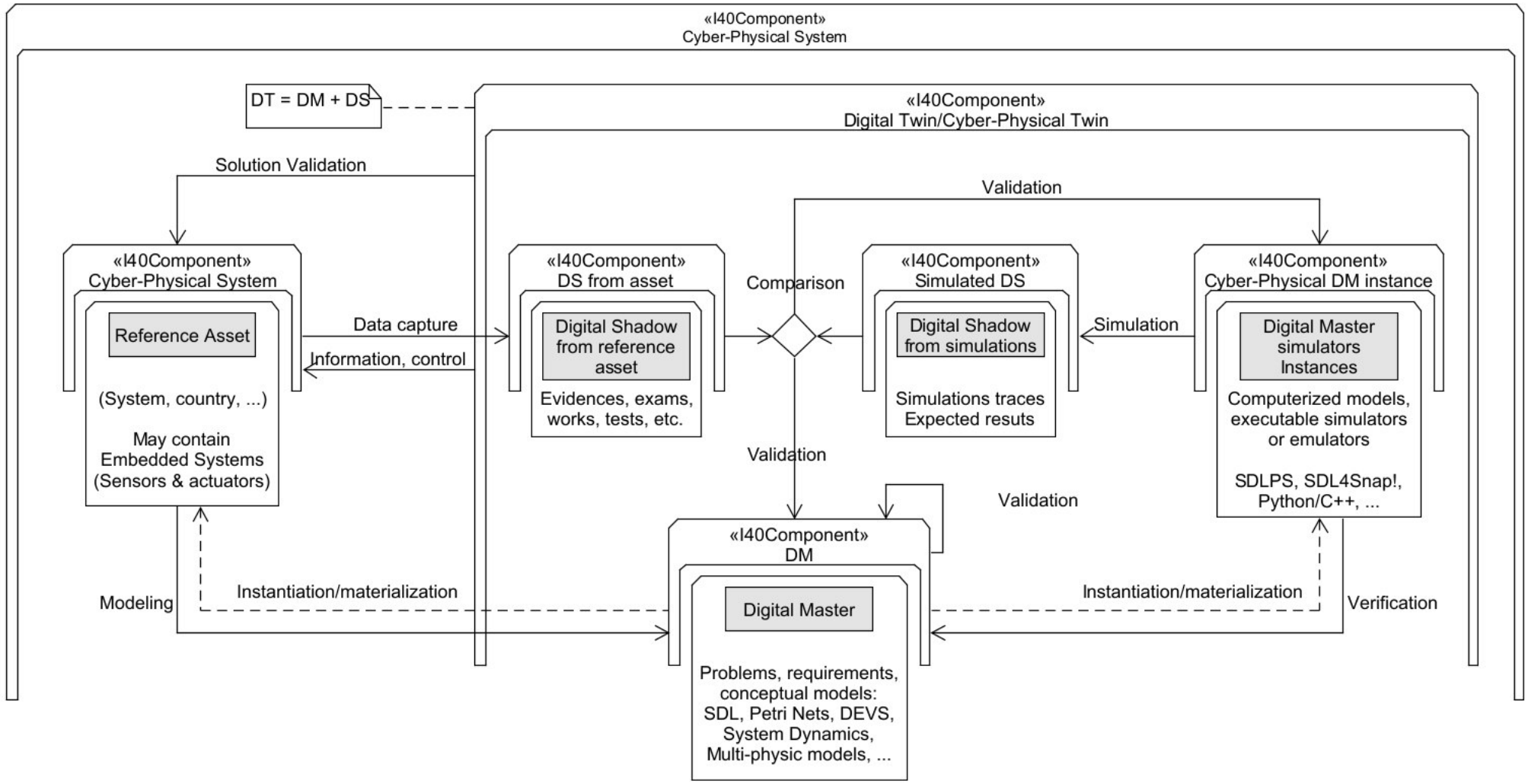
Michael Grieves (2002) – Univ. Michigan

https://www.digitaltwinconsortium.org/initiatives/the-definition-of-a-digital-twin

Digital Twins Evolution



Digital Twins Components



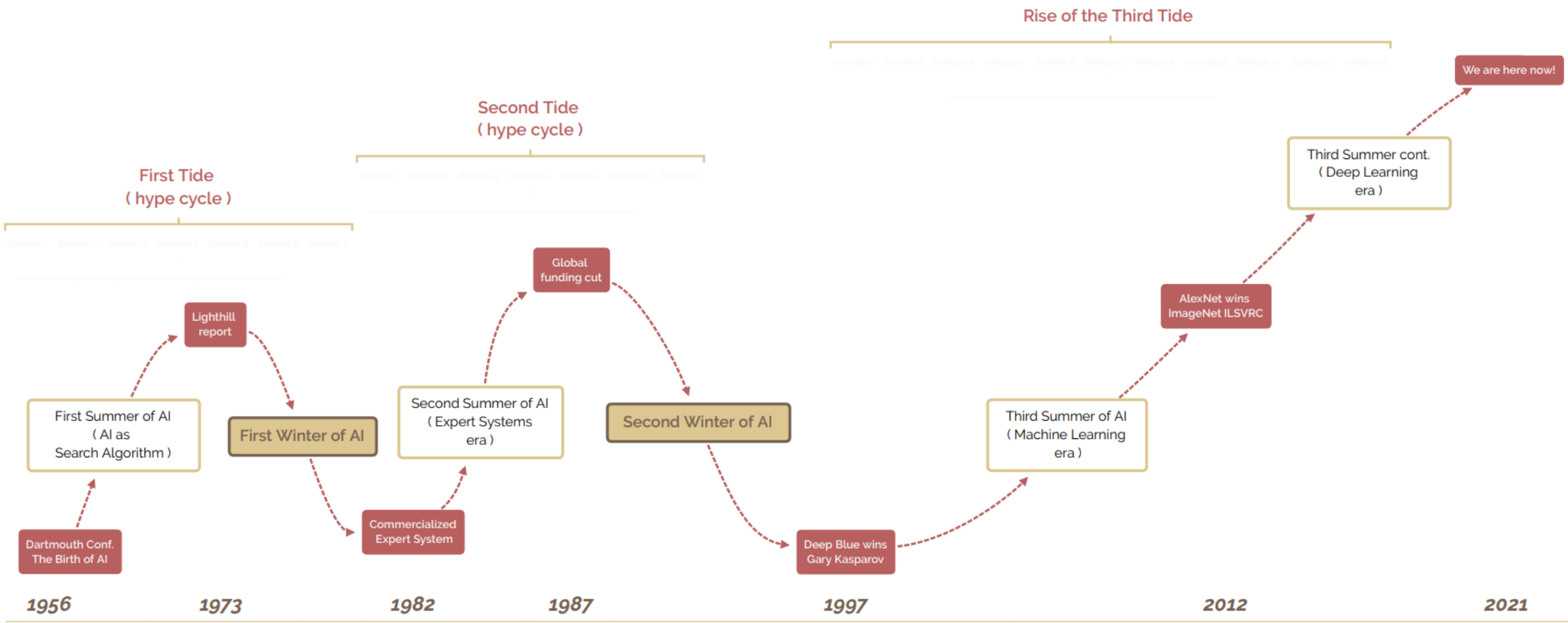
Digital Twins Examples

- https://aps-digital-twin.autodesk.io (Autodesk)
- https://www.aretian.com/aretian-cdt (Aretian - BCN)
  - https://www-elperiodico-com.translate.goog/es/barcelona/20241127/municipios-gran-barcelona-planificaran-crecimiento-urbanistico-economico-con-nuevo-gemelo-digital-metropolitano-112094639?_x_tr_sl=es&_x_tr_tl=en&_x_tr_hl=es&_x_tr_pto=wapp
- https://pand.sdlps.com (InLab)
- https://phet.colorado.edu (PhET)

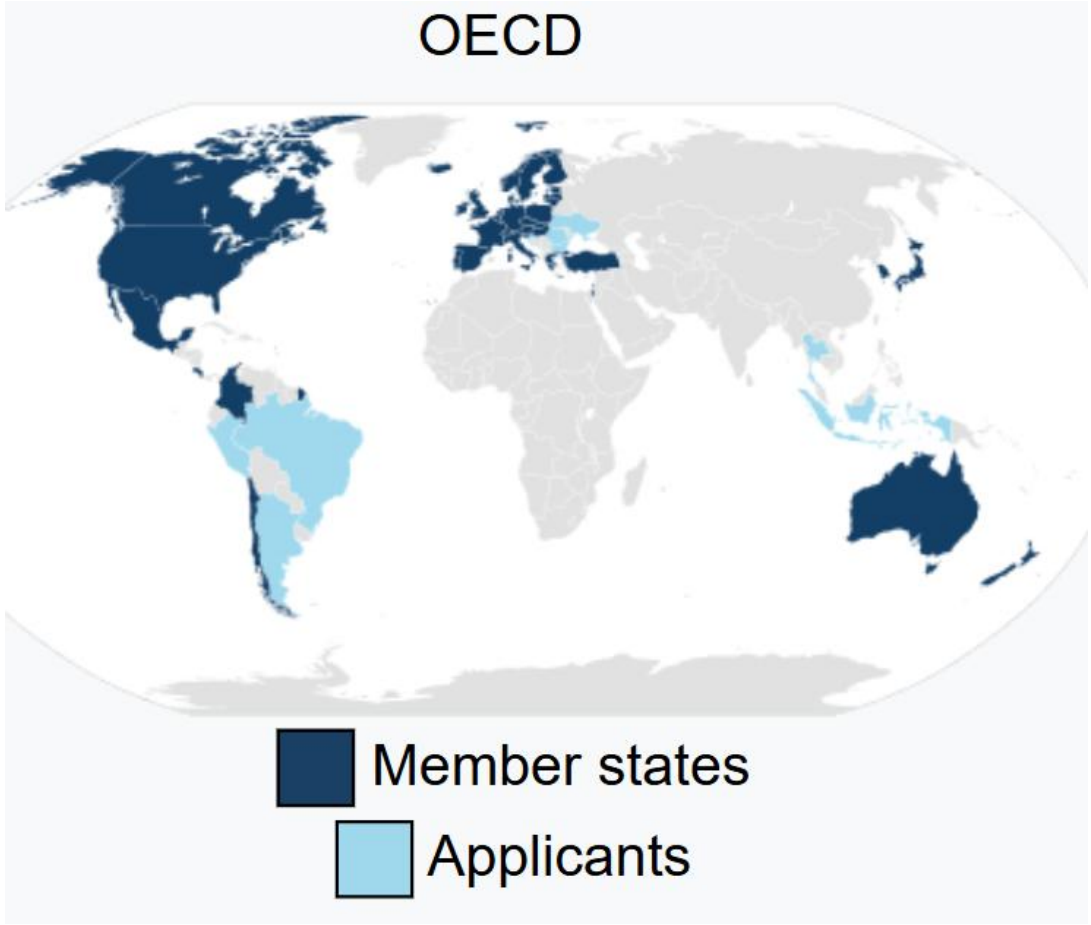
Digital Twins Prototyping

- https://snap.berkeley.edu (Snap*!*)
- https://xavierpi.com/proto (MQTT – Snap*!*)

Artificial Intelligence



Educational System



Organisation for Economic Co-operation and Development

PISA
(Programme for International Student Assessment)

- Reading skills
- Mathematics skills
- Problem solving
- From 2025: Computacional Thinking

a, b, c ... 1, 2, 3 ...

Computacional Thinking

Viewpoint | Jeannette M. Wing

Computational Thinking

It represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use.

Computational thinking builds on the power and limits of computing processes, whether they are executed by a human or by a machine. Computational methods and models give us the courage to solve problems and design systems that no one of us would be capable of tackling alone. Computational thinking confronts the riddle of machine intelligence: What can humans do better than computers? and What can computers do better than humans? Most fundamentally it addresses the question: What is computable? Today, we know only parts of the answers to such questions.

Computational thinking is a fundamental skill for everyone, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability. Just as the printing press facilitated the spread of the three Rs, what is appropriately incestuous about this vision is that computing and computers facilitate the spread of computational thinking.

...

cisely. Stating the difficulty of a problem accounts for the underlying power of the machine—the computing device that will run the solution. We must consider the machine's instruction set, its resource constraints, and its operating environment.

In solving a problem efficiently, we might further ask whether an approximate solution is good enough, whether we can use randomization to our advantage, and whether false positives or false negatives are allowed. Computational thinking is reformulating a seemingly difficult problem into one we know how to solve, perhaps by reduction, embedding, transformation, or simulation.

Computational thinking is thinking recursively. It is parallel processing. It is interpreting code as data and data as code. It is type checking as the generalization of dimensional analysis. It is recognizing both the virtues and the dangers of aliasing, or giving someone or something more than one name. It is recognizing both the cost and power of indirect addressing and procedure call. It is judging a program not just for correctness and efficiency but for aesthetics, and a system's design for simplicity and elegance.

...

Social Pain

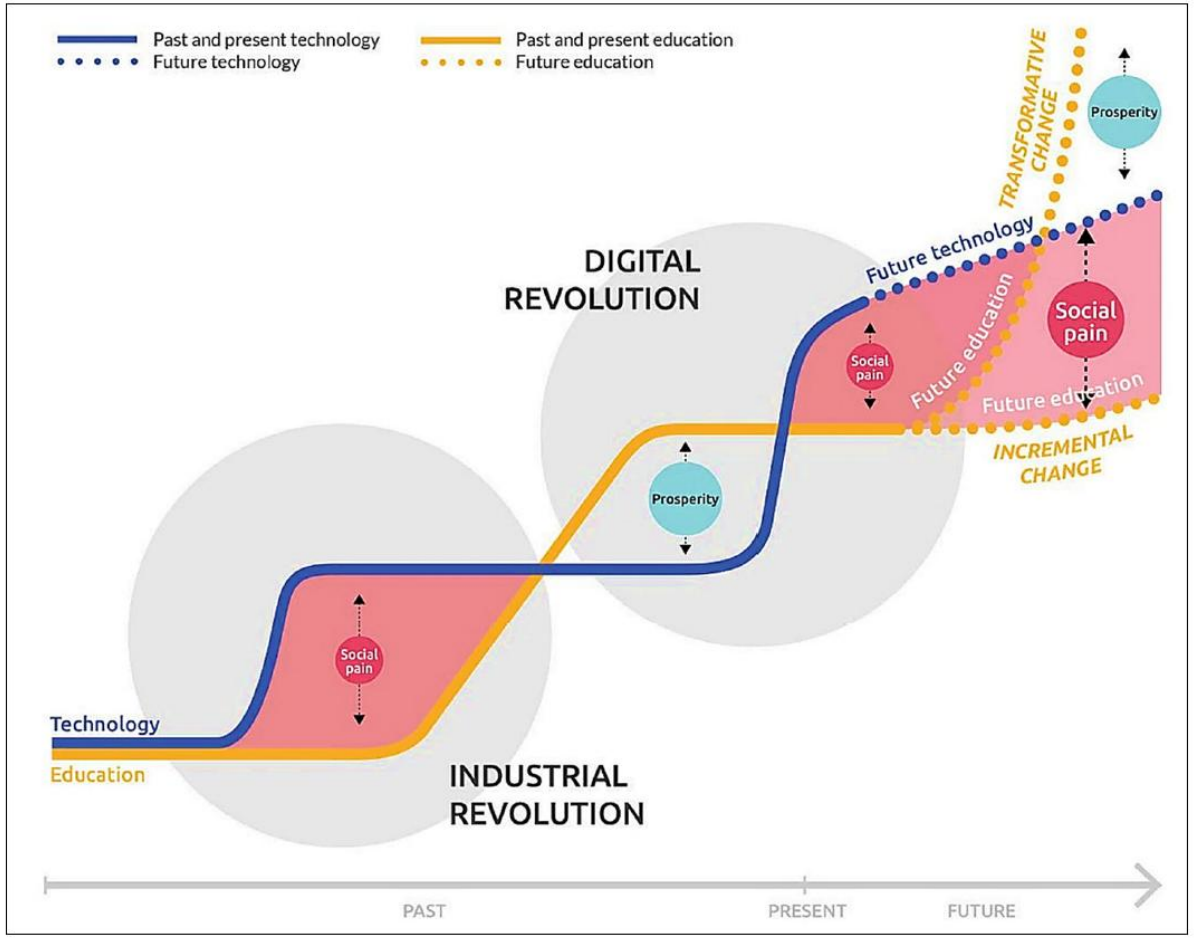
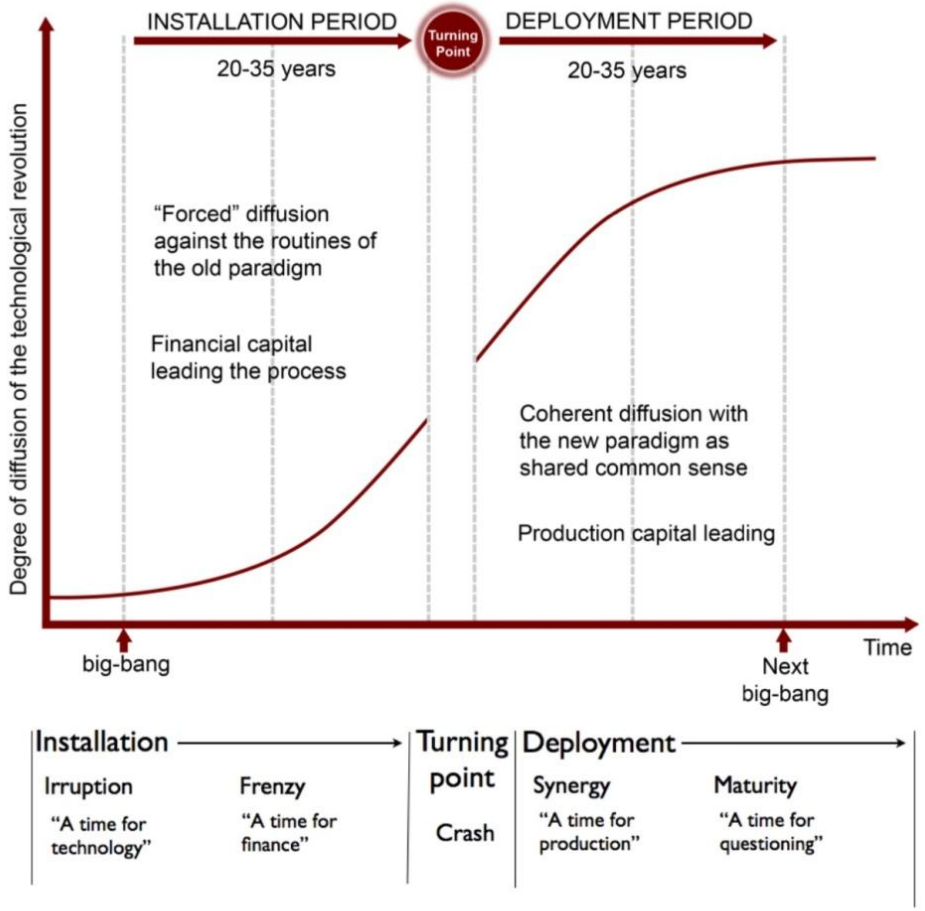


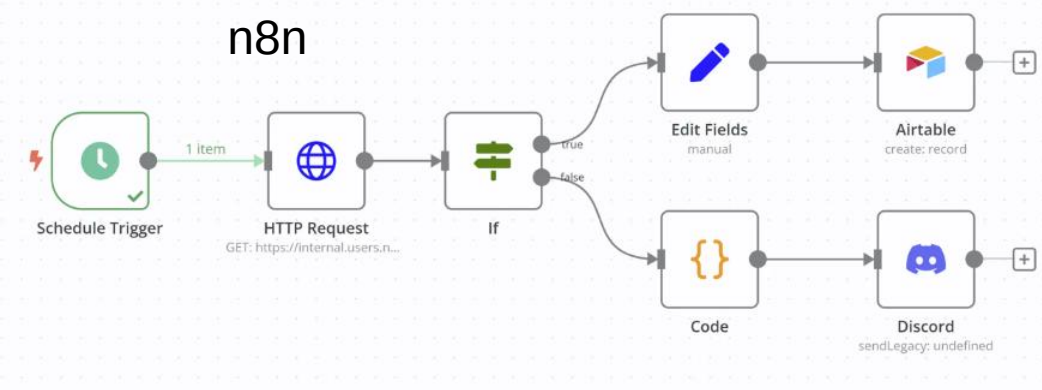
Figure 1. Social pain and prosperity with the industrial and digital revolutions (adapted from OECD [4], which was inspired by Goldin and Katz [8]; license: CC BY-NCSA 3.0 IGO [9]).



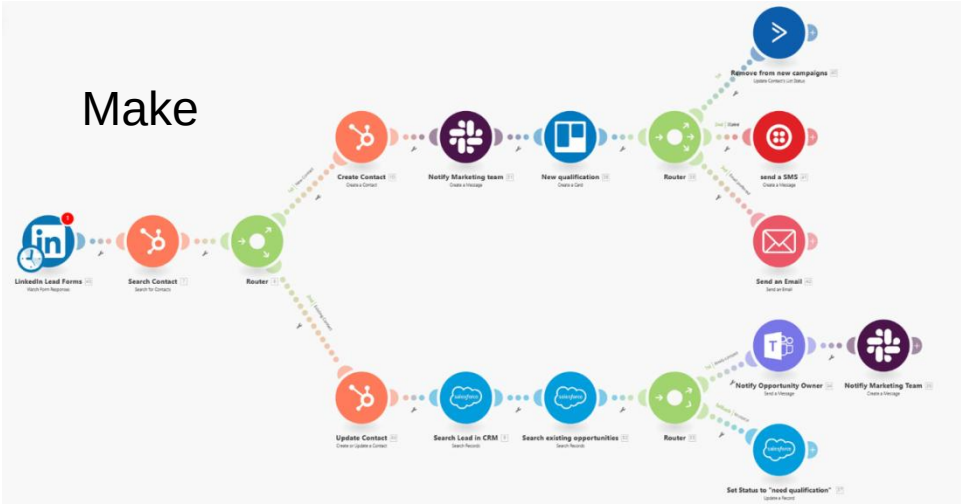
Source, Carlota Perez, 'Technological Revolutions and Financial Capital'

Flow Based Programming

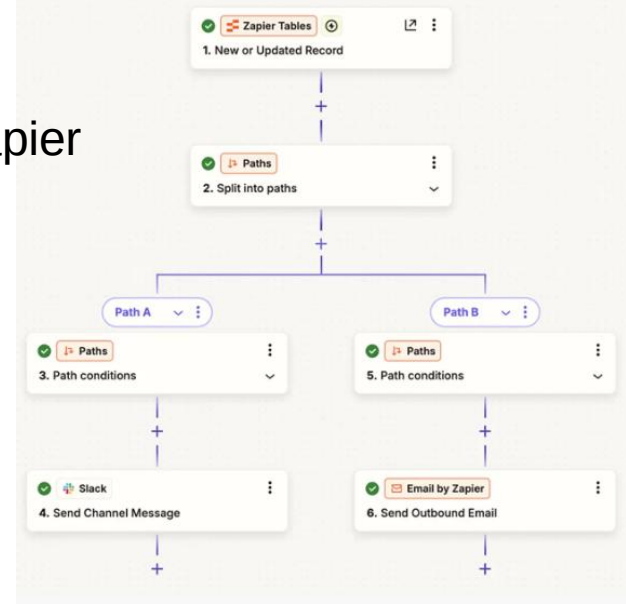
n8n



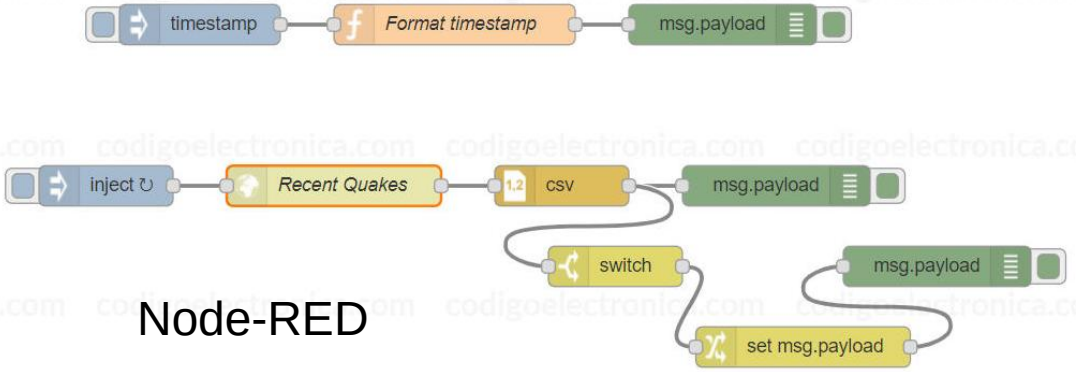
Make



Zapier



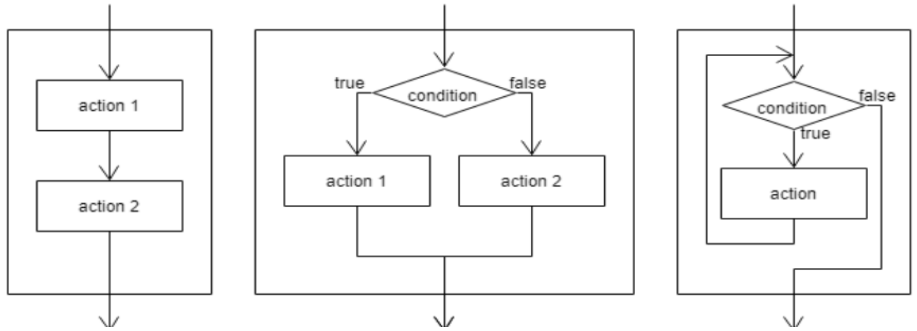
Node-RED



Biblio

Flow Based and Block Based equivalences

Flowchart



Pseudocode

```
...
action 1
action 2
...
```

```
...
if condition then
   action 1
else
   action 2
endif
...
```

```
...
while condition do
   action
endwhile
...
```

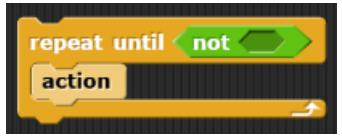
C, JavaScript

```
...
action 1;
action 2;
...
```

```
...
if (condition) {
   action 1;
} else {
   action 2;
}
...
```

```
...
while (condition) {
   action;
}
...
```

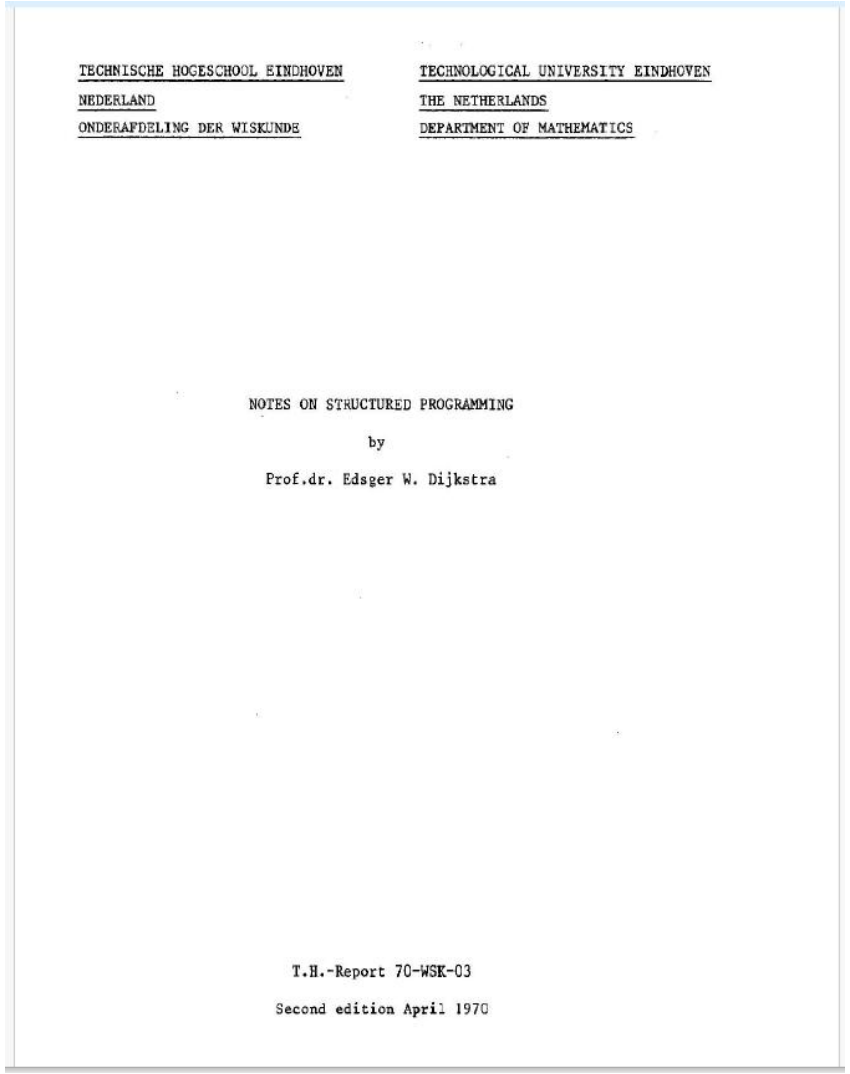
Snap*!*



Sequential

Alternative (if-else)

Repetitive (loop)



TECHNISCHE HOGESCHOOL EINDHOVEN
NEDERLAND
ONDERAFDELING DER WISKUNDE

TECHNOLOGICAL UNIVERSITY EINDHOVEN
THE NETHERLANDS
DEPARTMENT OF MATHEMATICS

NOTES ON STRUCTURED PROGRAMMING

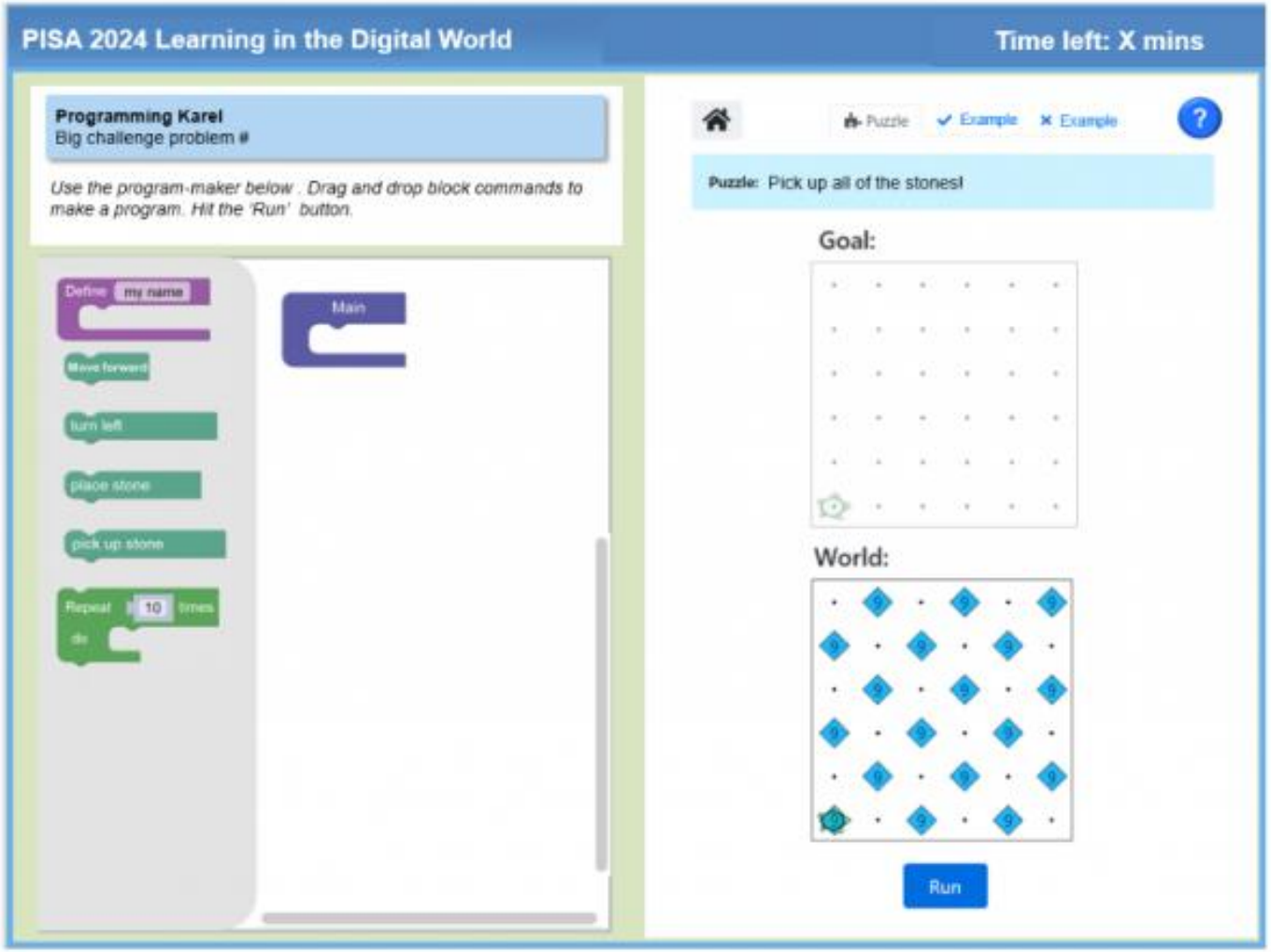
by

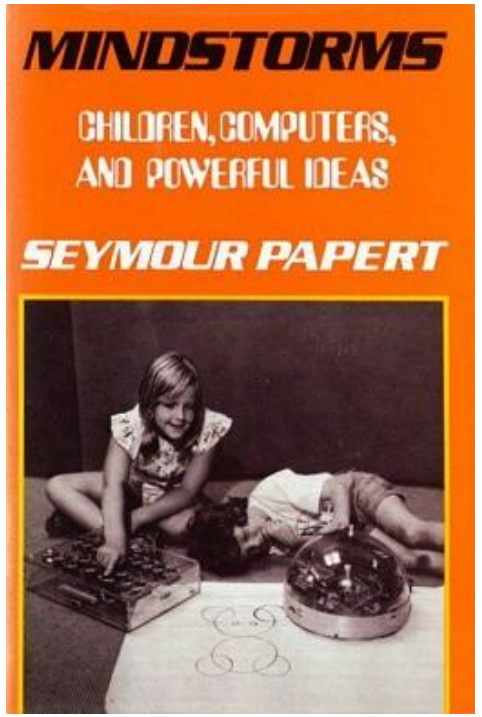
Prof.dr. Edsger W. Dijkstra

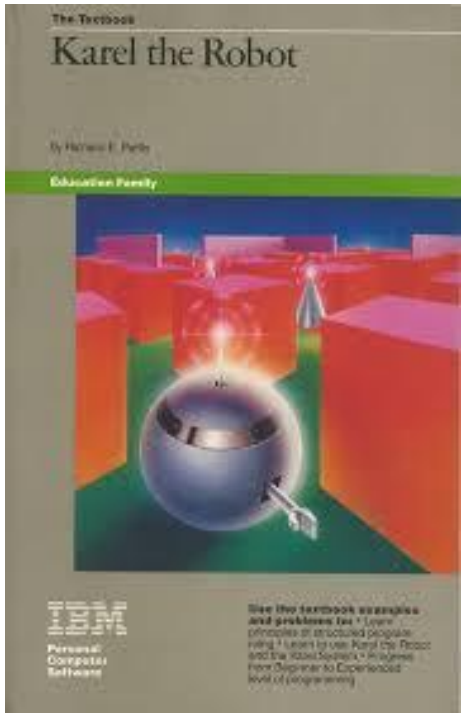
T.H.-Report 70-WSK-03

Second edition April 1970

Computacional Thinking PISA 2025

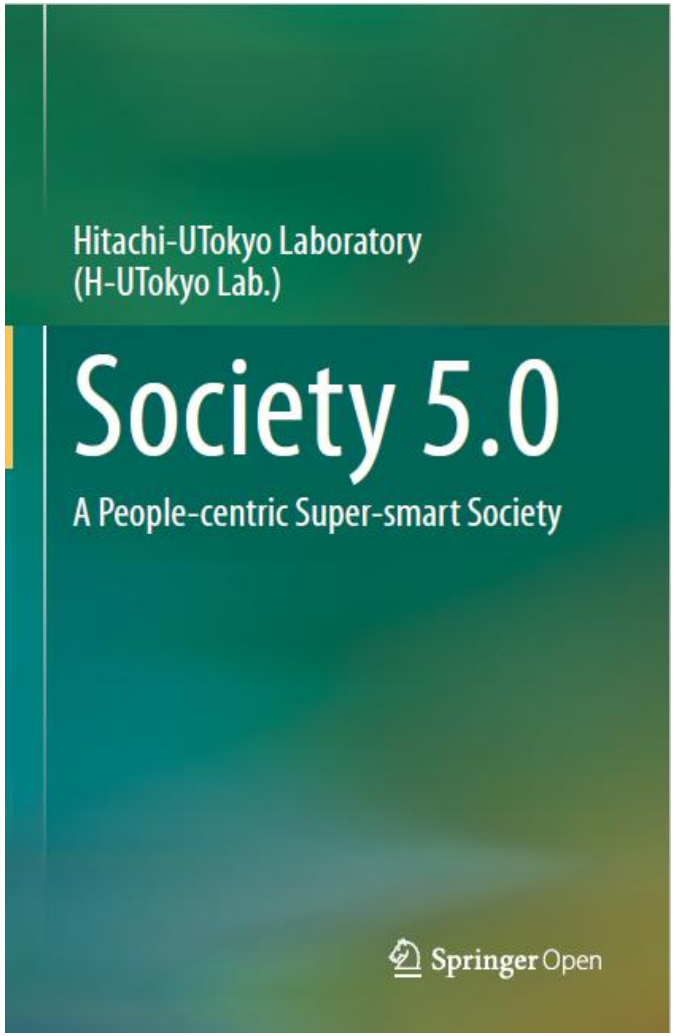






https://codehs.com/editor/hoc/602701/3832/2640

Barcelona Case



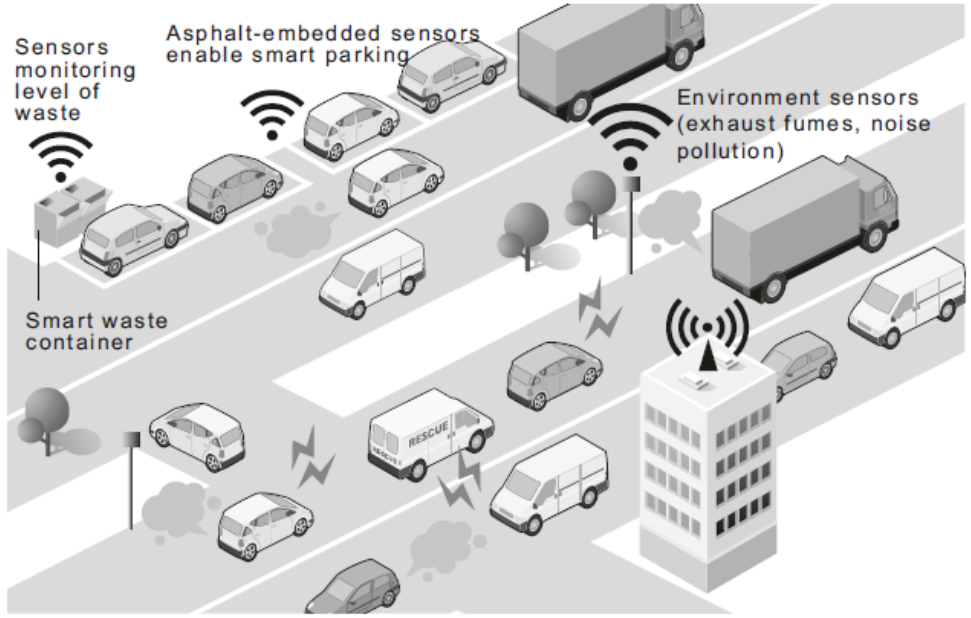
3.5 From Citizen-Led Smart City to Society 5.0

...

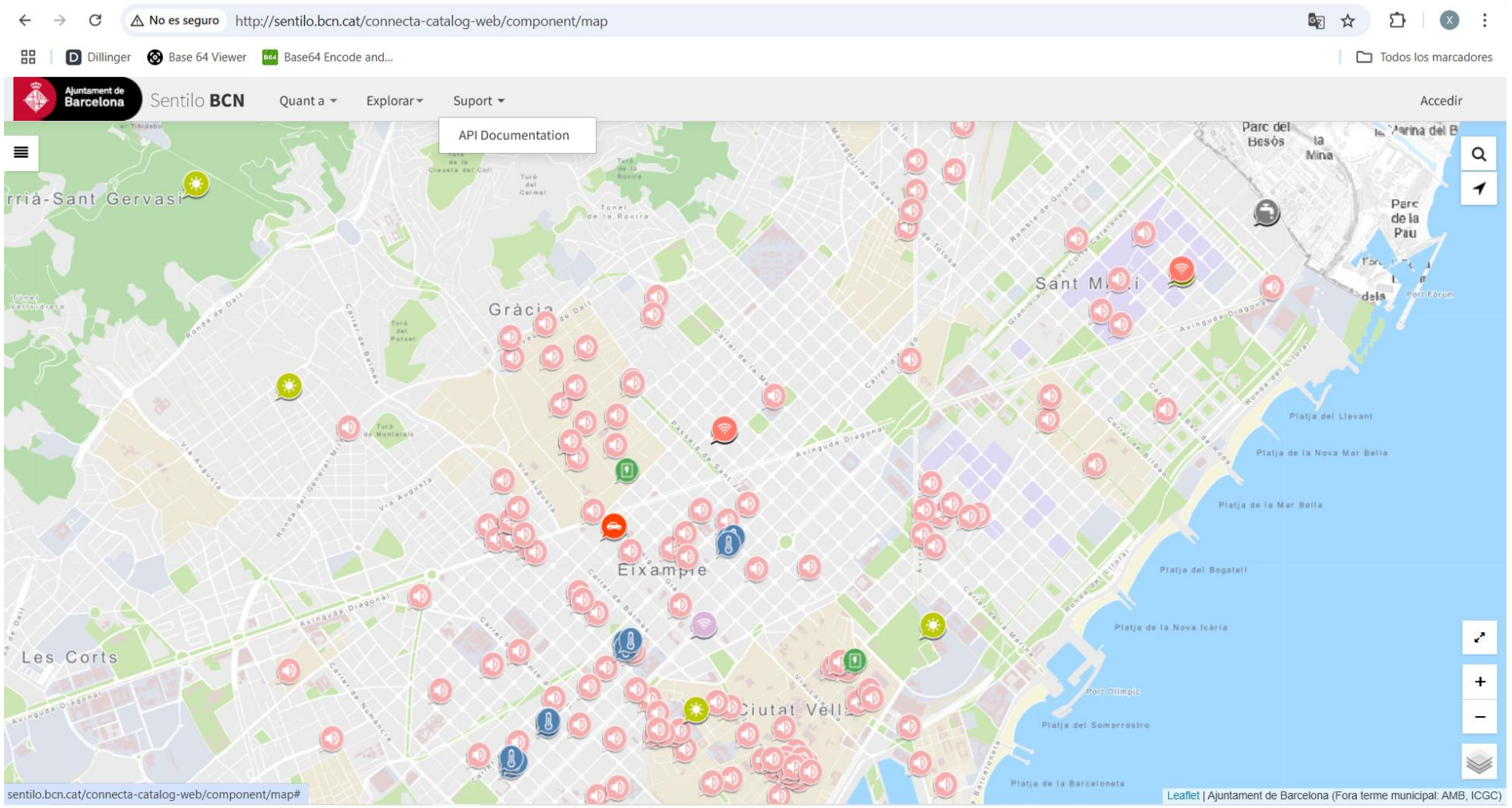
Smart City: Barcelona

...

Other examples of smartification in Barcelona include smart lighting (street-lights that react to the presence of people), smart waste management (roadside waste containers use sensors that monitor when they are full), and smart cycling. An open-source platform called Sentilo connects the sensor data to the city's open data portal (Sentilo 2019). Sentilo has attracted attention for how it makes the data freely accessible globally. Barcelonan initiatives such as this have the potential to be adopted in other cities around the world.



Sentilo



www.sentilo.io http://sentilo.bcn.cat

Industry 5.0

FORSCHUNGSBEIRAT INDUSTRIE 4.0

PLATTFORM INDUSTRIE 4.0

The fourth industrial revolution and „Industry 5.0" – a critical perspective

Joint statement by the Research Council Industrie 4.0 and the Plattform Industrie 4.0 on the use of the term "Industry 5.0"

It is now more than ten years since the term Industrie 4.0 was coined by Henning Kagermann, the former CEO of SAP, Wolfgang Wahlster, the former CEO of the German Research Center for Artificial Intelligence, and Wolf-Dieter Lukas, Head of Department and later State Secretary at the Federal Ministry of Education and Research. In the years since, the initiative that started in Germany has spread around the globe.

Today, Industrie 4.0 is a term that represents a change potentially affecting all areas of society. It refers to the fourth industrial revolution. Like the previous three industrial revolutions, it can be assumed that the current one will bring about far-reaching changes and that it will take a similarly long period of time to fully play out. The typical software shorthand "4.0" refers both to the fourth industrial revolution but also emphasises the special role that software plays in this process. It is a comprehensive concept that included, from the outset, technological aspects, new value creation models, the ability to create new types of products, sustainability, resilience and, in particular, approaches for optimally integrating and supporting humans involved in Industrie 4.0 solutions.

As with every industrial revolution, the fourth industrial revolution also requires measures that build on one other. This means that a technical foundation and international standards must first be created, which then form the basis for the necessary skills and optimal support for workers in production. Active participation by employees is essential here. It would be completely wrong to view Industrie 4.0 through a purely technological lens. And it would be equally misguided to treat the abbreviation "4.0" simply as a version number and replace it with "5.0" on while still the same long but important and correct path.

In fact, this mistake has been more common for some time now: The term "Industry 5.0" has been put forth in the recent past. In addition to some AI-related content, the core of this term is often defined as "human-centricity", i.e. the goal to design labour processes in an optimal manner for workers alongside the best possible support for new production processes. While the content itself is valid, the new term "Industry 5.0" is not needed to describe it because "human-centricity" and societal benefits have been the most important goals of Industrie 4.0 from the outset.

The term "Industry 5.0" is neither necessary nor helpful. It does not contain any new content, and falsely suggests that the fourth industrial revolution is complete and that our attention can be turned to new topics. This unnecessary terminology could lead to uncertainty among companies and well-established international collaborations that are currently working on the implementation of the fourth industrial revolution.

Plattform Industrie 4.0 and the Research Council Industrie 4.0 therefore strongly criticise the frivolous positioning of the unnecessary term "Industry 5.0".

Society 5.0 Research

Internet of Federated Digital Twins: Connecting Twins Beyond Borders for Society 5.0

Tao Yu, *Member, IEEE,* Zongdian Li, *Member, IEEE,* Omar Hashash, *Graduate Student Member, IEEE,* Kei Sakaguchi, *Senior Member, IEEE,* Walid Saad, *Fellow, IEEE,* and Mérouane Debbah, *Fellow, IEEE*

***Abstract*—The concept of digital twin (DT), which enables the creation of a programmable, digital representation of physical systems, is expected to revolutionize future industries and will lie at the heart of the vision of a future smart society, namely, Society 5.0, in which high integration between cyber (digital) and physical spaces is exploited to bring economic and societal advancements. However, the success of such a DT-driven Society 5.0 requires a synergistic convergence of artificial intelligence and networking technologies into an integrated, programmable system that can coordinate DT networks to effectively deliver diverse Society 5.0 services. Prior works remain restricted to either qualitative study, simple analysis or software implementations of a single DT, and thus, they cannot provide the highly synergistic integration of digital and physical spaces as required by Society 5.0. In contrast, this paper envisions a novel concept of an *Internet of Federated Digital Twins (IoFDT)* that holistically integrates heterogeneous and physically separated DTs representing different Society 5.0 services within a single framework and system. For this concept of IoFDT, we first introduce a hierarchical architecture that integrates federated DTs through horizontal and vertical interactions, bridging cyber and physical spaces to unlock new possibilities. Then, we discuss challenges of realizing IoFDT,**

life-cycle, including design, manufacturing, distribution, and recycling [1], [2]. In essence, a fully realized DT is not just a static blueprint or simulation of a physical system, but a dynamic, high-precision, granular replica of a physical system, including its interactions with other physical system. Thus, DTs symbolize a harmonious blend of physical and cyber spaces, which departs from the traditional IoT concept, where interconnectivity is confined among physical objects and data flows mainly in one way from physical to cyber spaces. DTs will be an integral part of future applications ranging from manufacturing to agriculture and enabling the metaverse [3].

DTs will shape the future as a cornerstone of super smart society, dubbed Society 5.0 [4], where the intertwining of cyber and physical spaces drives economic and societal advancement across industries ranging from intelligent transportation to factory automation and robotics. The success of this DT-driven Society 5.0 depends on the seamlessly integration of physical and cyber spaces, ensure precise coordination among DTs and

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Full length article

Building Society 5.0: a foundation for decision-making based on open models and digital twins

Pau Fonseca i Casas [a,*], Xavier Pi i Palomes [b]

[a] Universitat Politècnica de Catalunya – BarcelonaTech, Jordi Girona 31, 08034 Barcelona, Spain
[b] Universitat Oberta de Catalunya (UOC), Barcelona, Spain

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Keywords:
Society 5.0, Digital Twins
LLM, AI
Governance
AI Agents

ABSTRACT

Human societies have undergone significant transformations throughout history, driven by technological advancements and societal needs. The emergence of Industry 4.0 marked a pivotal moment, with the digitalization, integrating automation, data exchange, artificial intelligence, and generating Digital Twins into manufacturing processes. However, as we move forward, the concept of Society 5.0 presents an even more profound shift. Society 5.0 is not an industrial revolution but an application of the industry 4.0 revolution for the decision making at all levels. It emphasizes holistic well-being, sustainability, and inclusivity. It aims to address social, economic, environmental, and technological challenges while fostering economic growth. Therefore, Society 5.0 envisions a harmonious coexistence between humans and technology, leveraging innovations such as artificial intelligence, the Internet of Things (IoT), through data-driven decision-making. At the heart of Society 5.0 lies the concept of Open Models and Digital Twins. These models must be transparent, accessible, and collaborative, allowing citizens to engage directly with assumptions, predictions, and validation processes. Digital Twins with Open Models provide visibility into their inner workings, enabling citizens to understand how decisions are made. Assumptions, data sources, and algorithms become accessible to all. Citizens can actively participate in discussions about model assumptions. By democratizing access to information, we empower individuals to make informed choices that impact their lives, therefore, validation and accountability of these models are key aspects. Digital Twins must undergo rigorous validation processes. Citizens can scrutinize these processes, ensuring accountability and trustworthiness. Society 5.0 represents a radical shift of our society organization founded in the existing Industry 4.0. revolution.

Thank You

Xavier Pi

xpi@enginyers.net