1.1 Data's Explosion and digitalization: the future we have ahead

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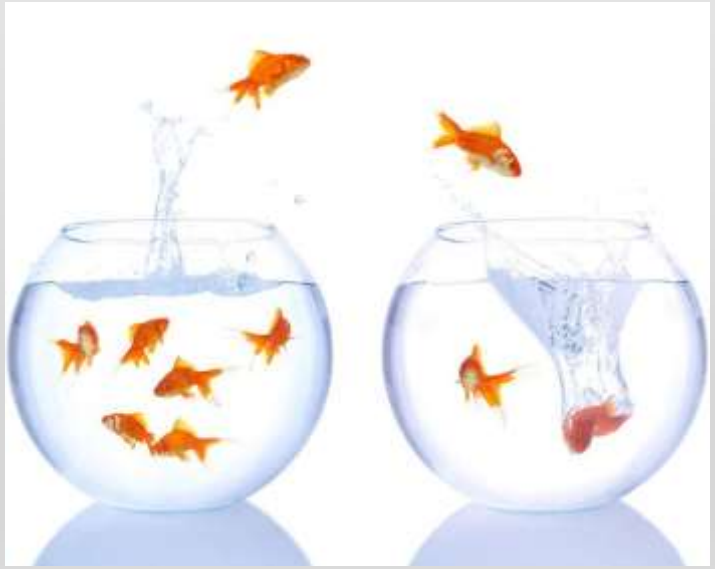
GRICU PhD School 2021

Digitalization Tools for the Chemical and Process Industries

March 11, 2021

Outline of talk

- Digitalization
  - New industry, new manufacturing
  - Technology (r)evolution
  - Theory experiments and simulation
  - HPC and Big Data … towards quantum computing
  - Convergence of technology
  - Digital twins, IoNT and AI
- The future of jobs
  - The job market in 2030
  - Skills and competences required
  - The effect of artificial intelligence
- The role of higher education
  - Science, technology and society
  - Indicators pushing economy



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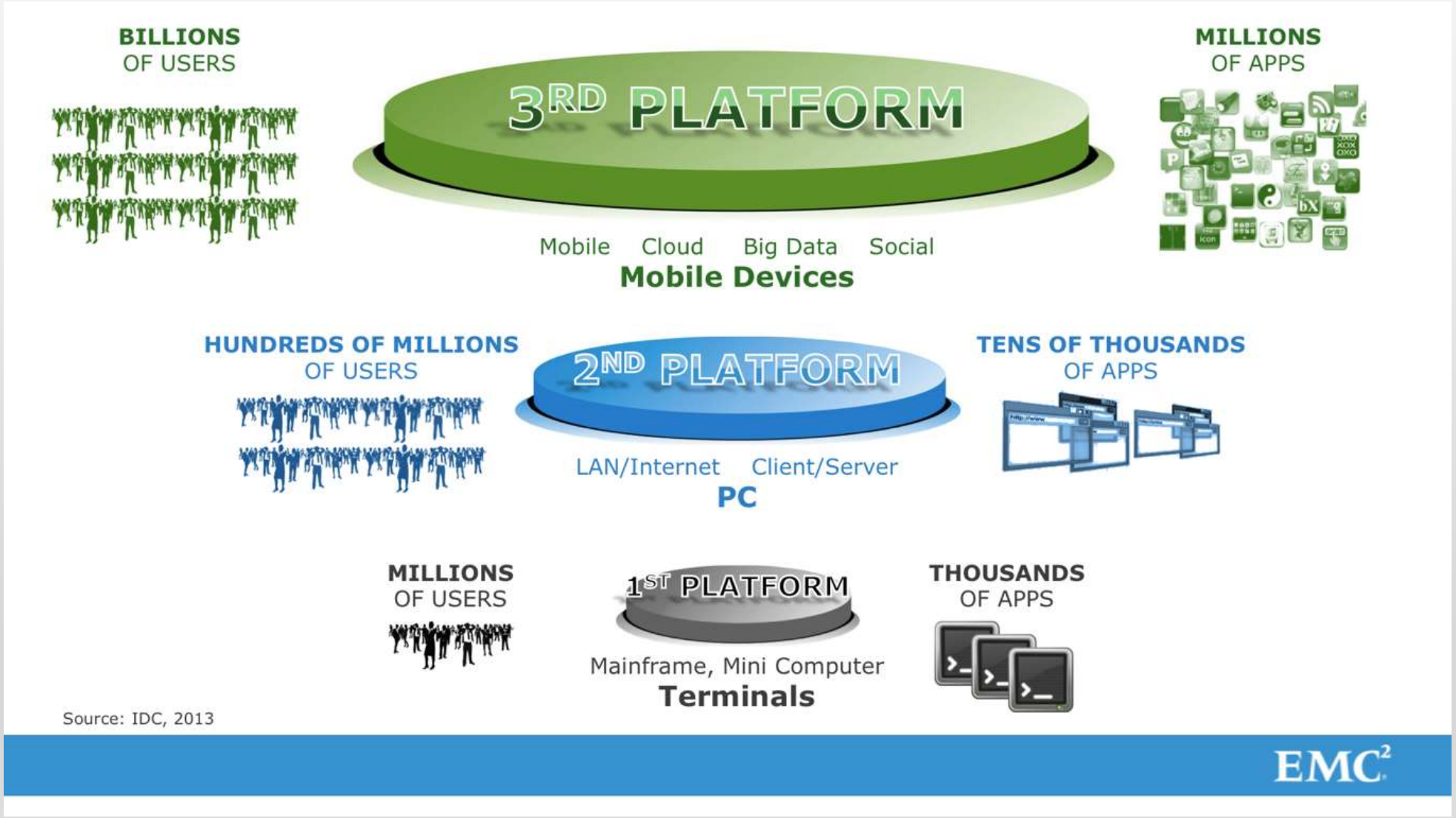
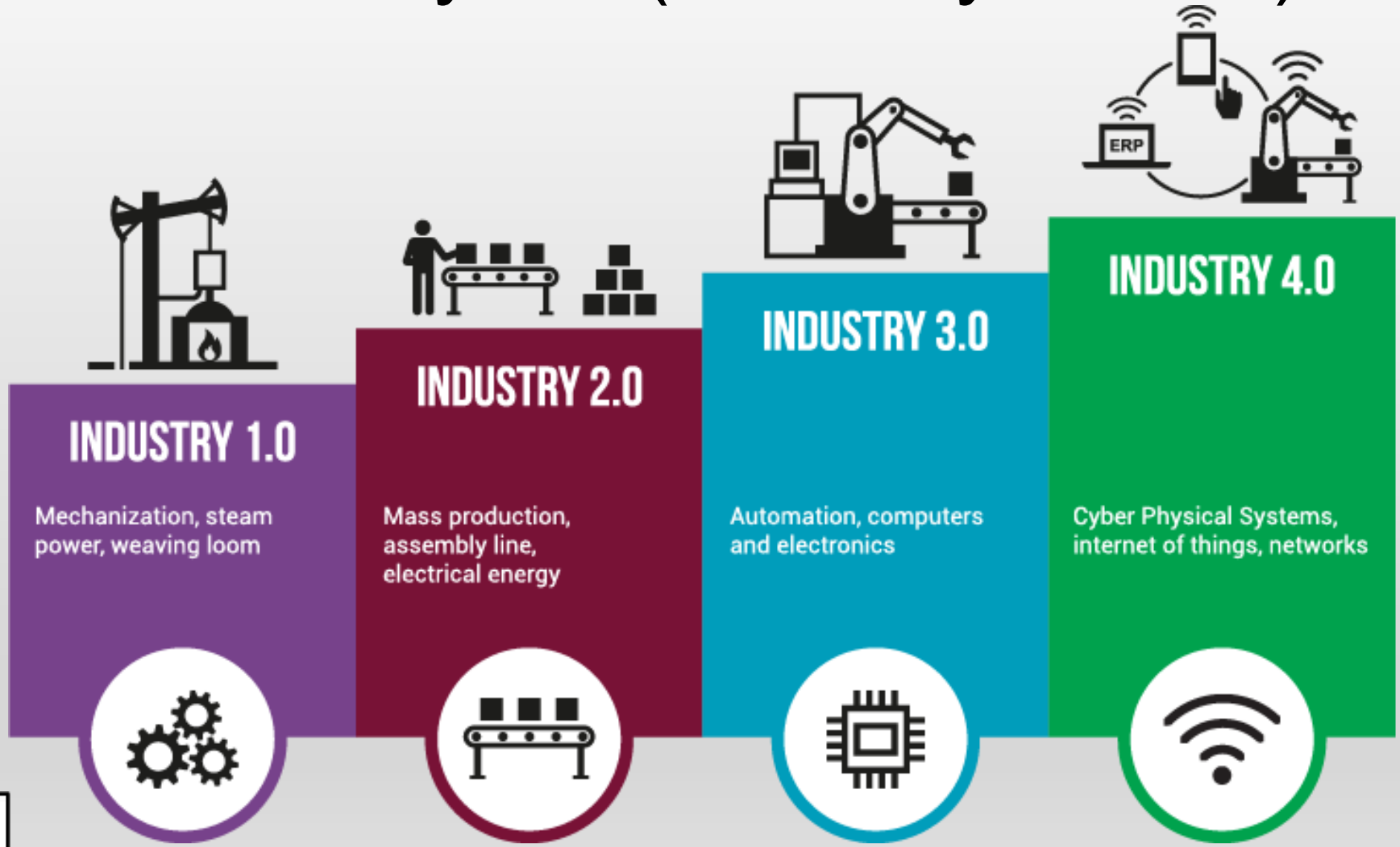
The platform evolution



Towards Industry 4.0 (and beyond …)



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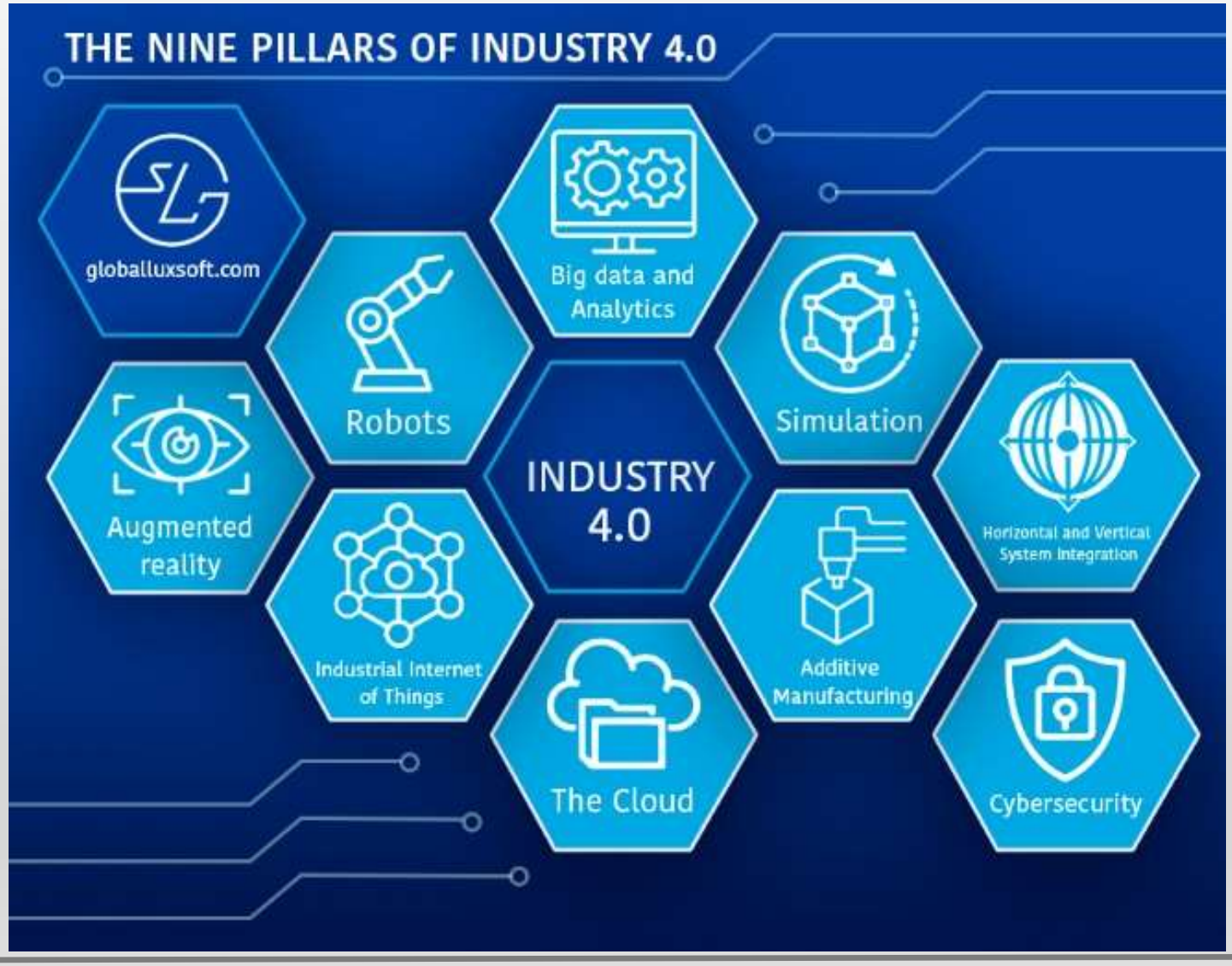
The nine pillars of Industry 4.0



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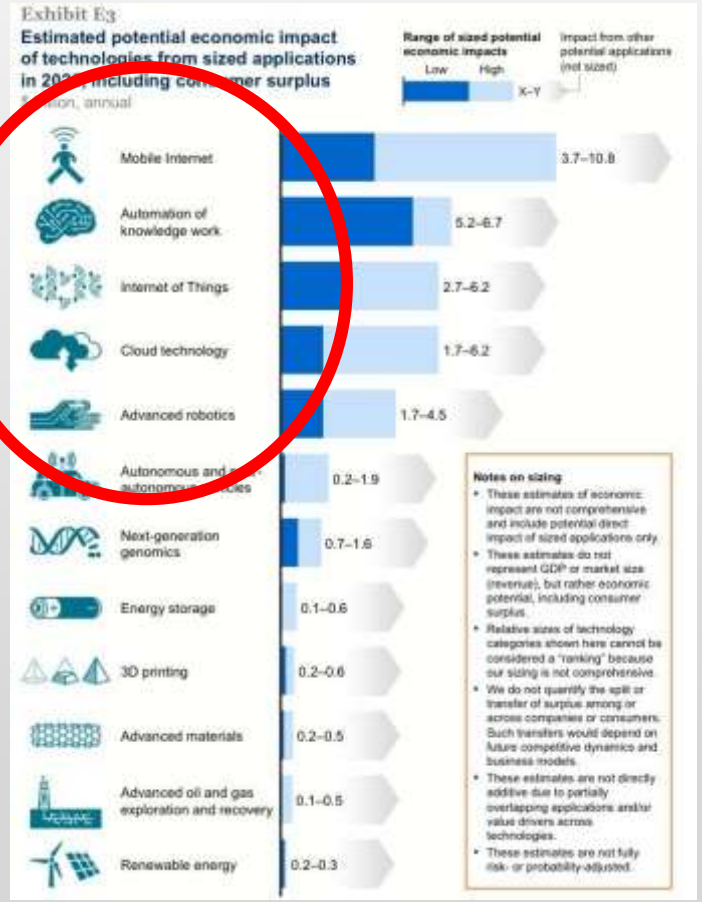
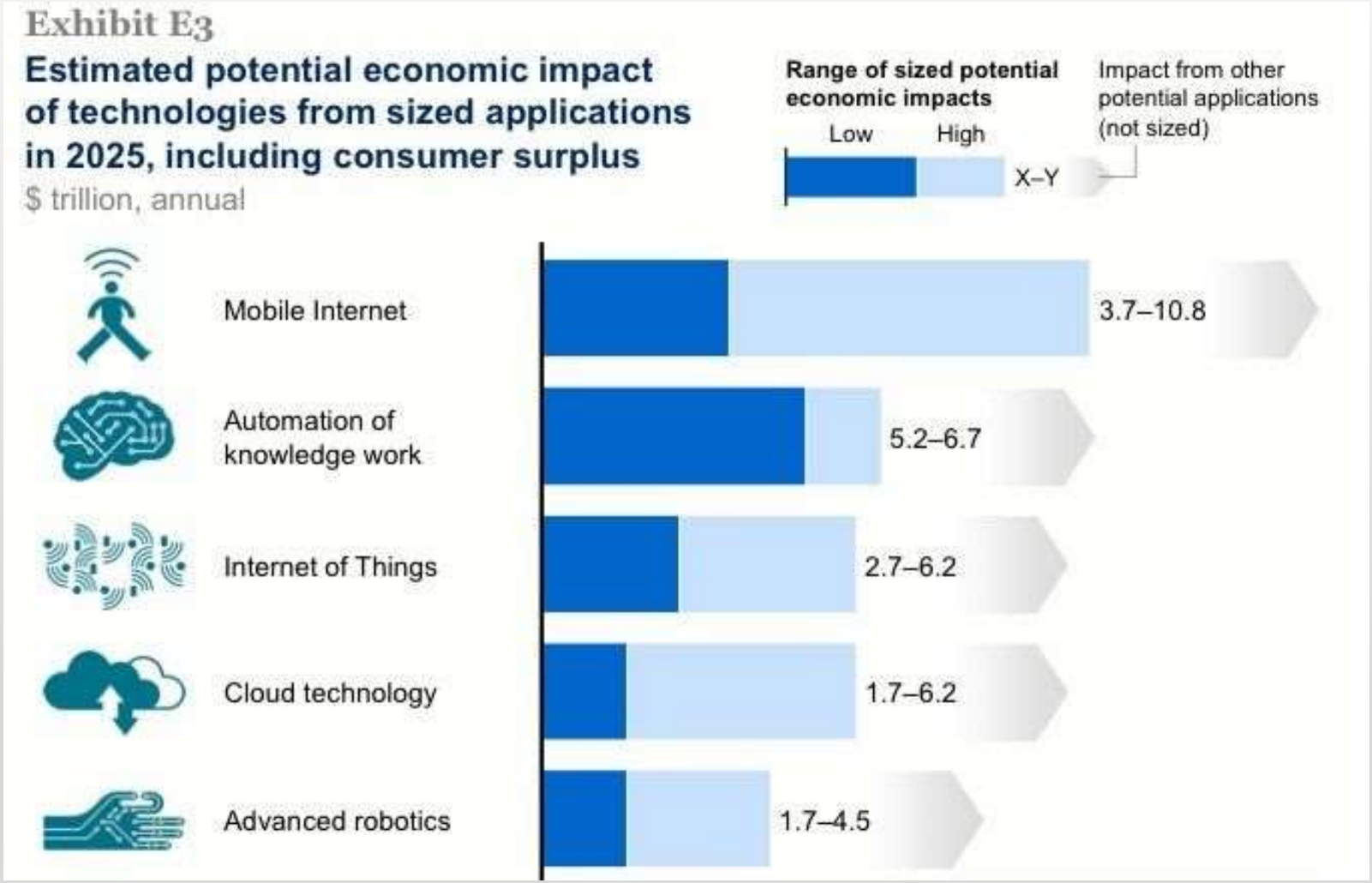
Estimated potential economic impact of technologies in 2025





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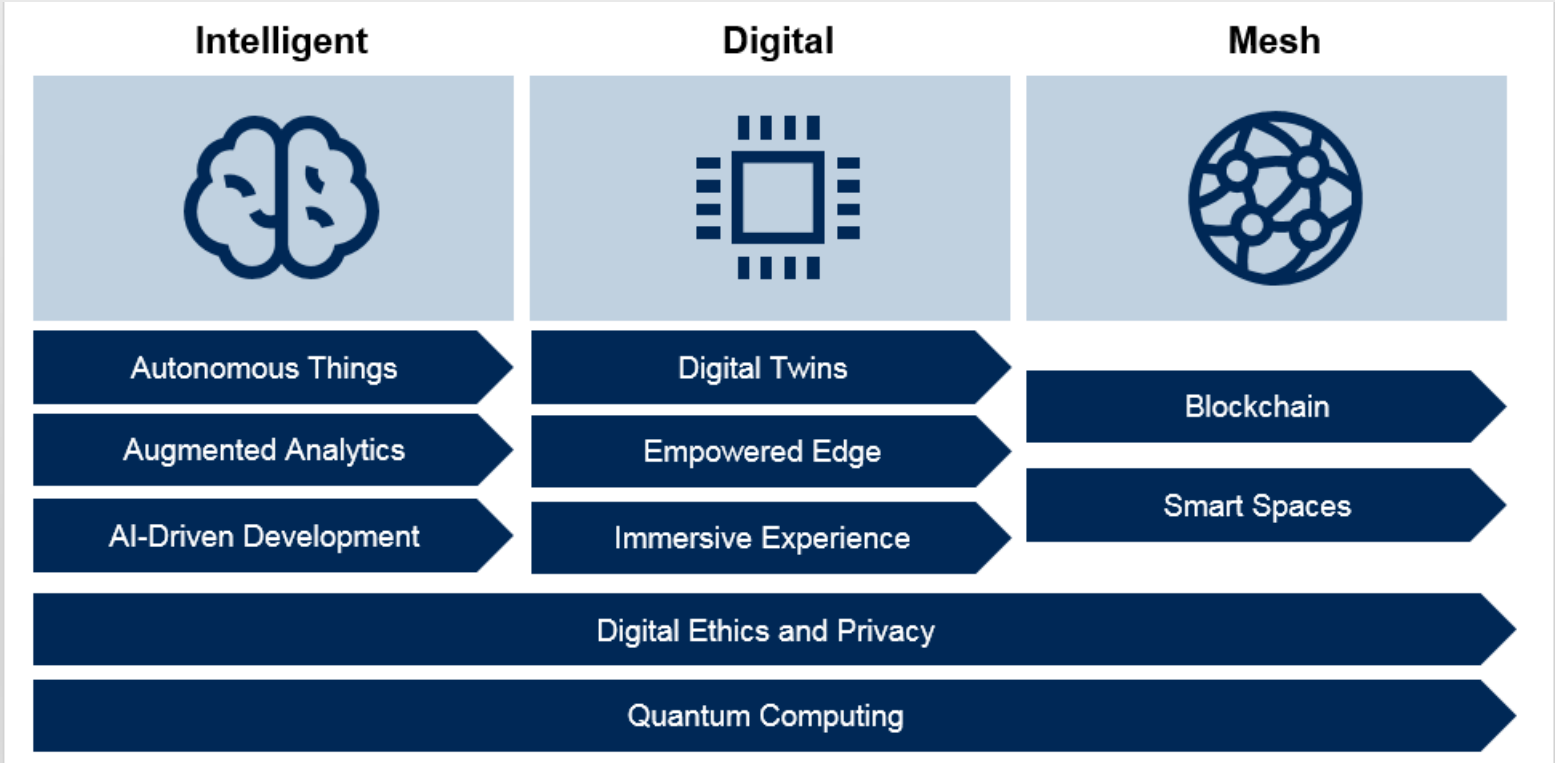
Strategic Technologies

Blockchain, quantum computing, augmented analytics and artificial intelligence will drive disruption and new business models.



Gartner

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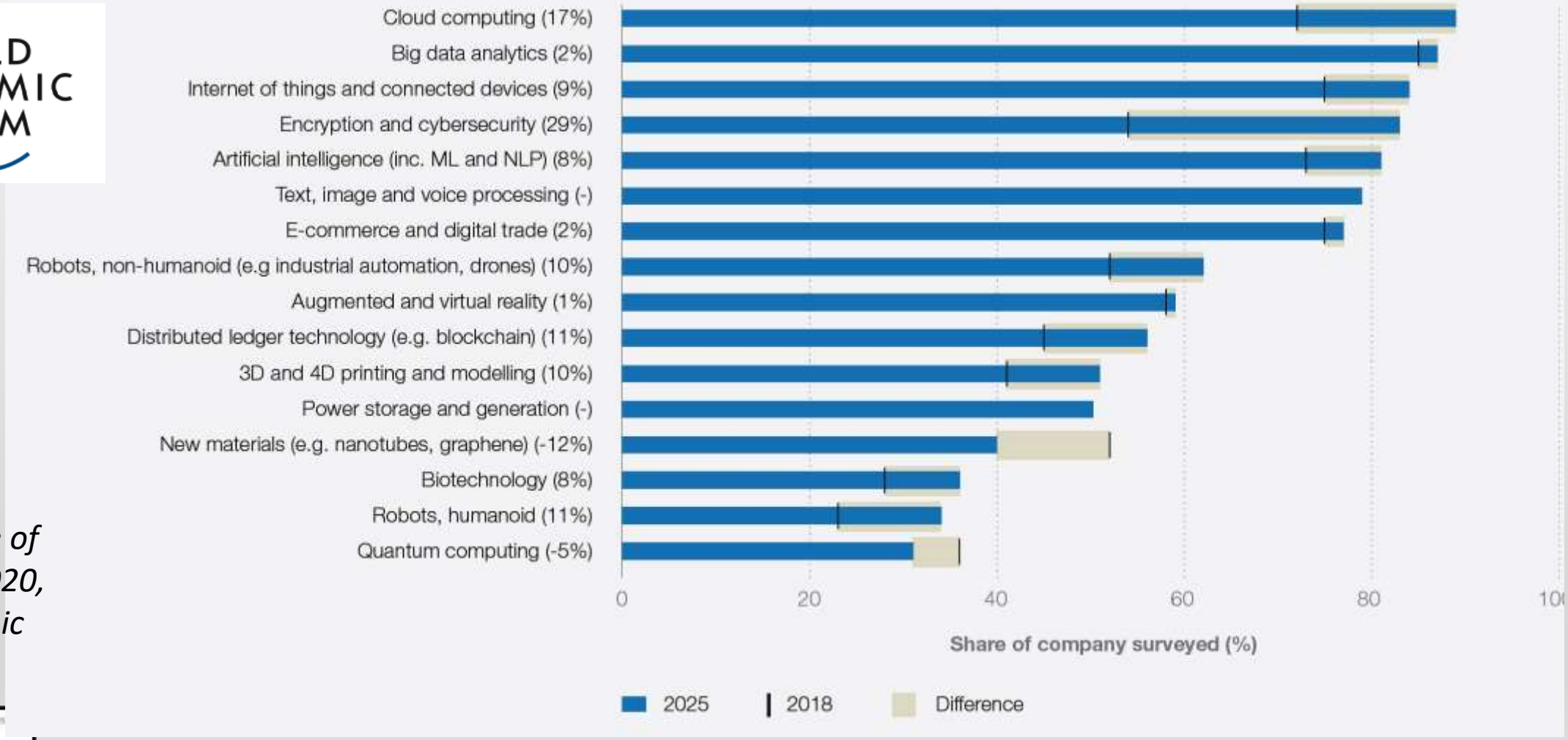
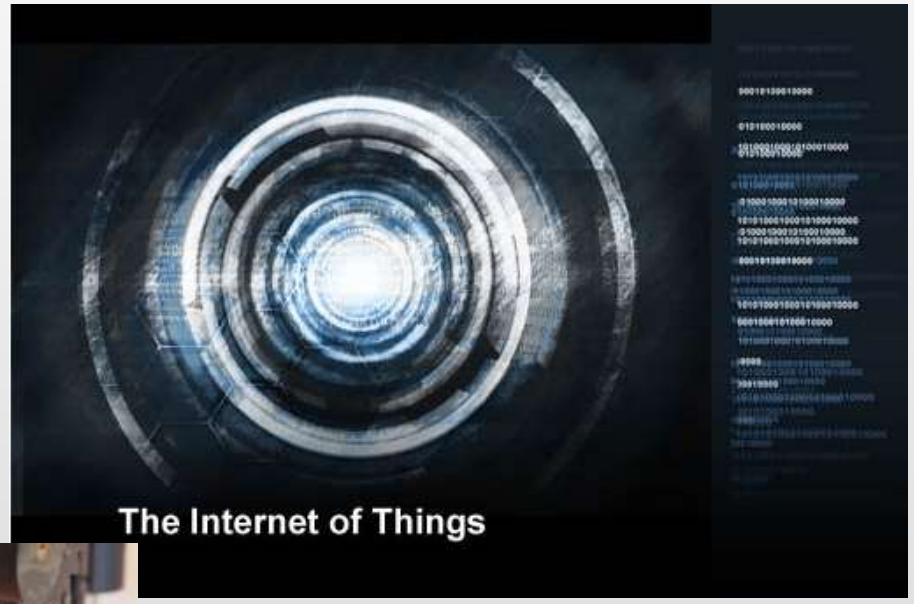
Technologies likely to be adopted by 2025 (by share of companies surveyed)



Source: *Future of Jobs Survey 2020, World Economic Forum.*

Merge of real and virtual world



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Bus senza autista girerà per le strade di Torino: Olli è arrivato dal futuro

CENTRO / 16/01/2020

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Pillars of 21° century scientific method

Theory (since antiquity)

combined with experiment (since Galilei & Newton)

and simulation
(since Metropolis, Teller,
von Neuman, Fermi, ... 1940s)

Excellence in Science requires leadership in all three areas: theory, experiment, and simulations

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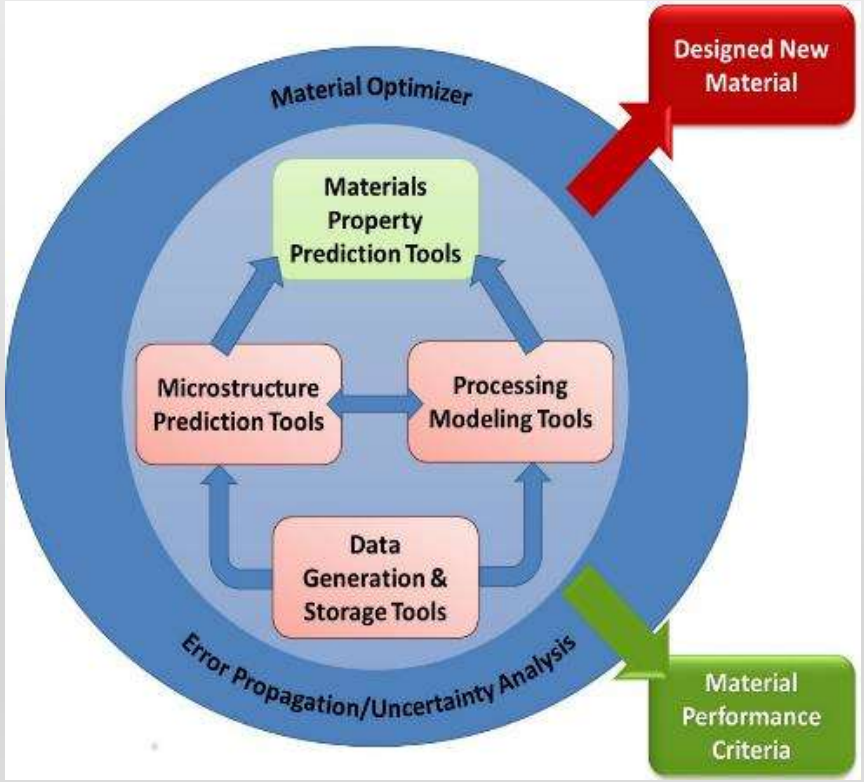
Material Genome Initiative (MGI)

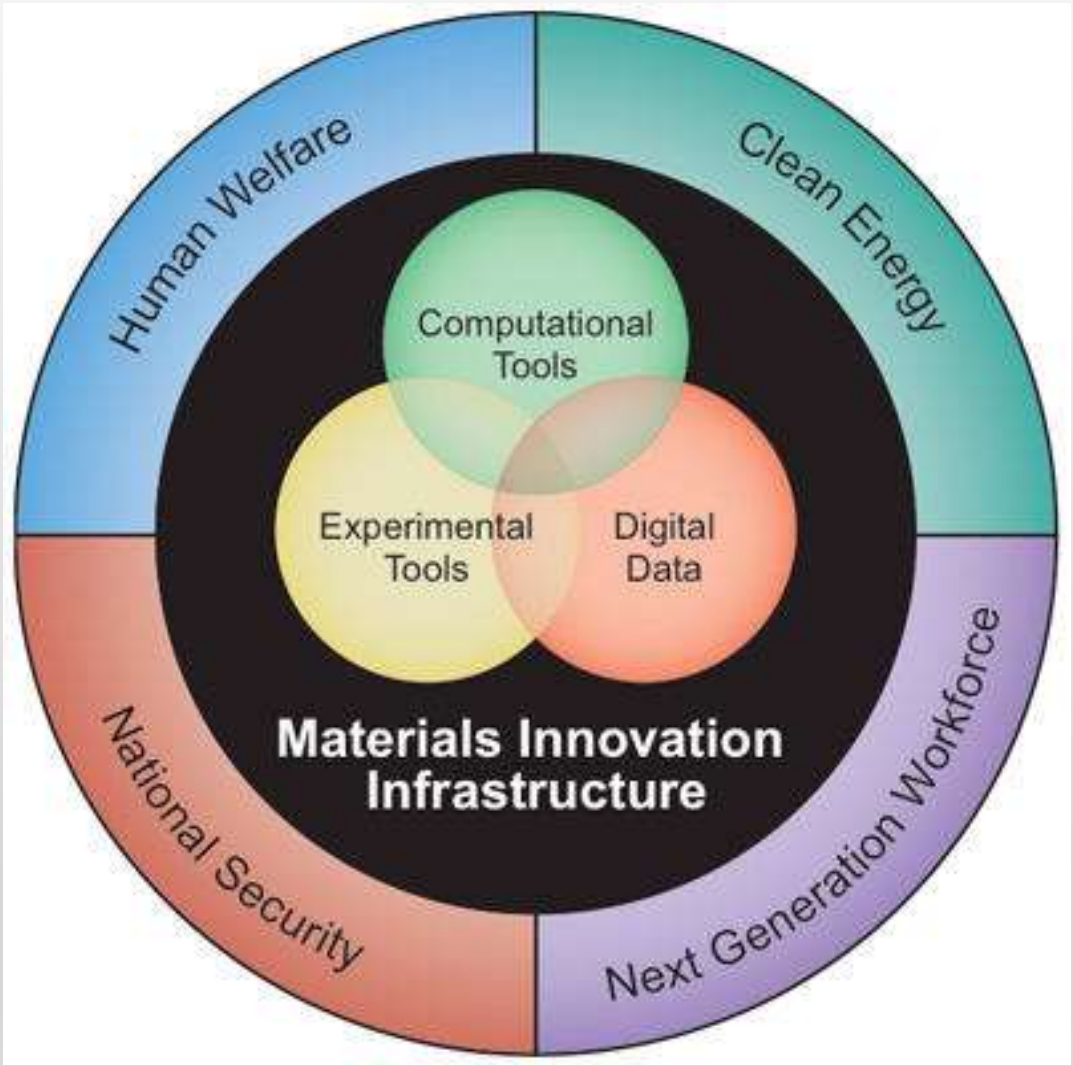
NIST

MATERIALS GENOME INITIATIVE

About MGI

About Material Genome Initiative





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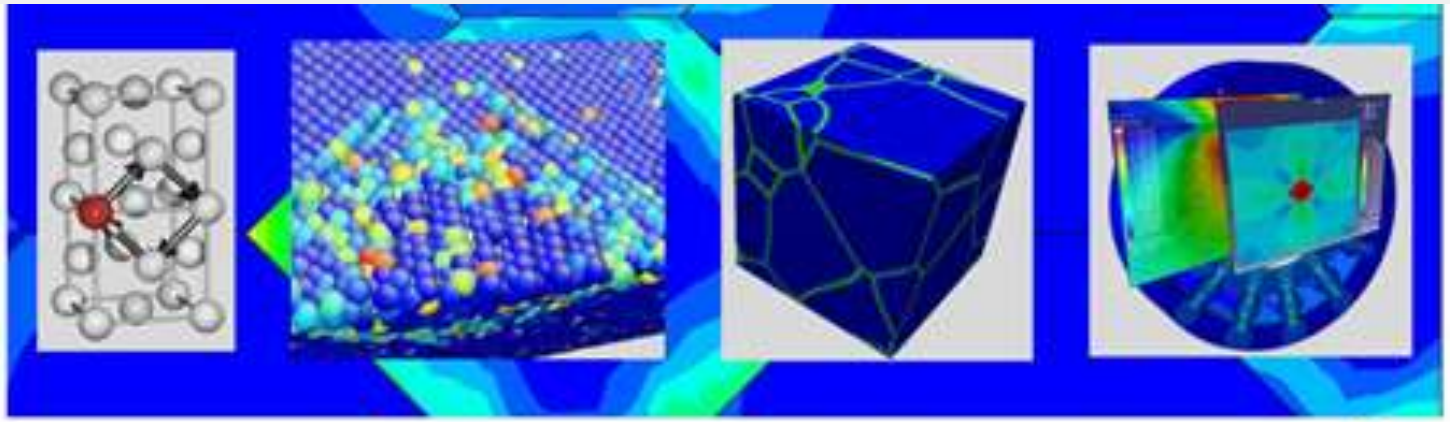
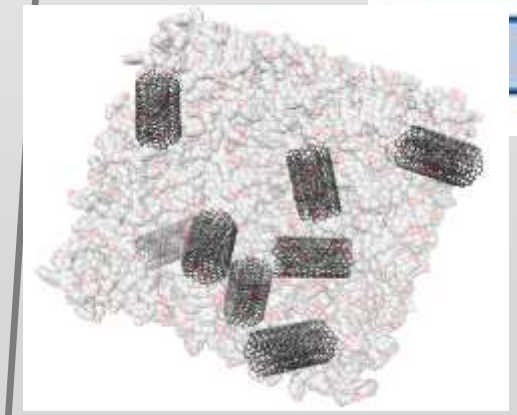
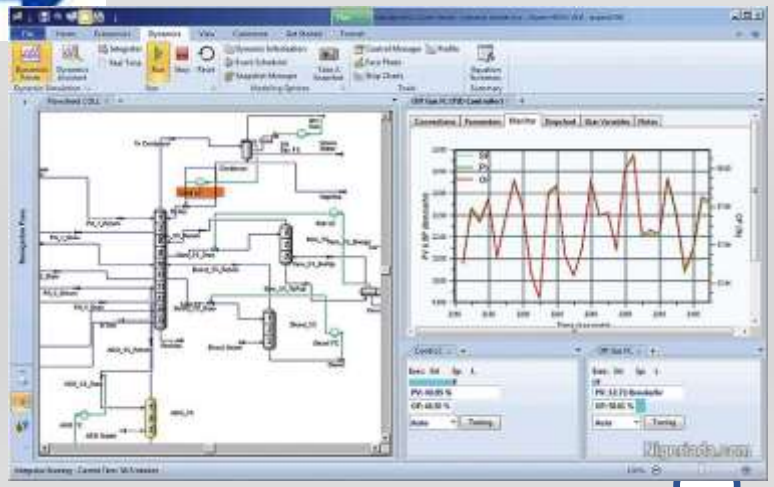
Modelling across the length scales







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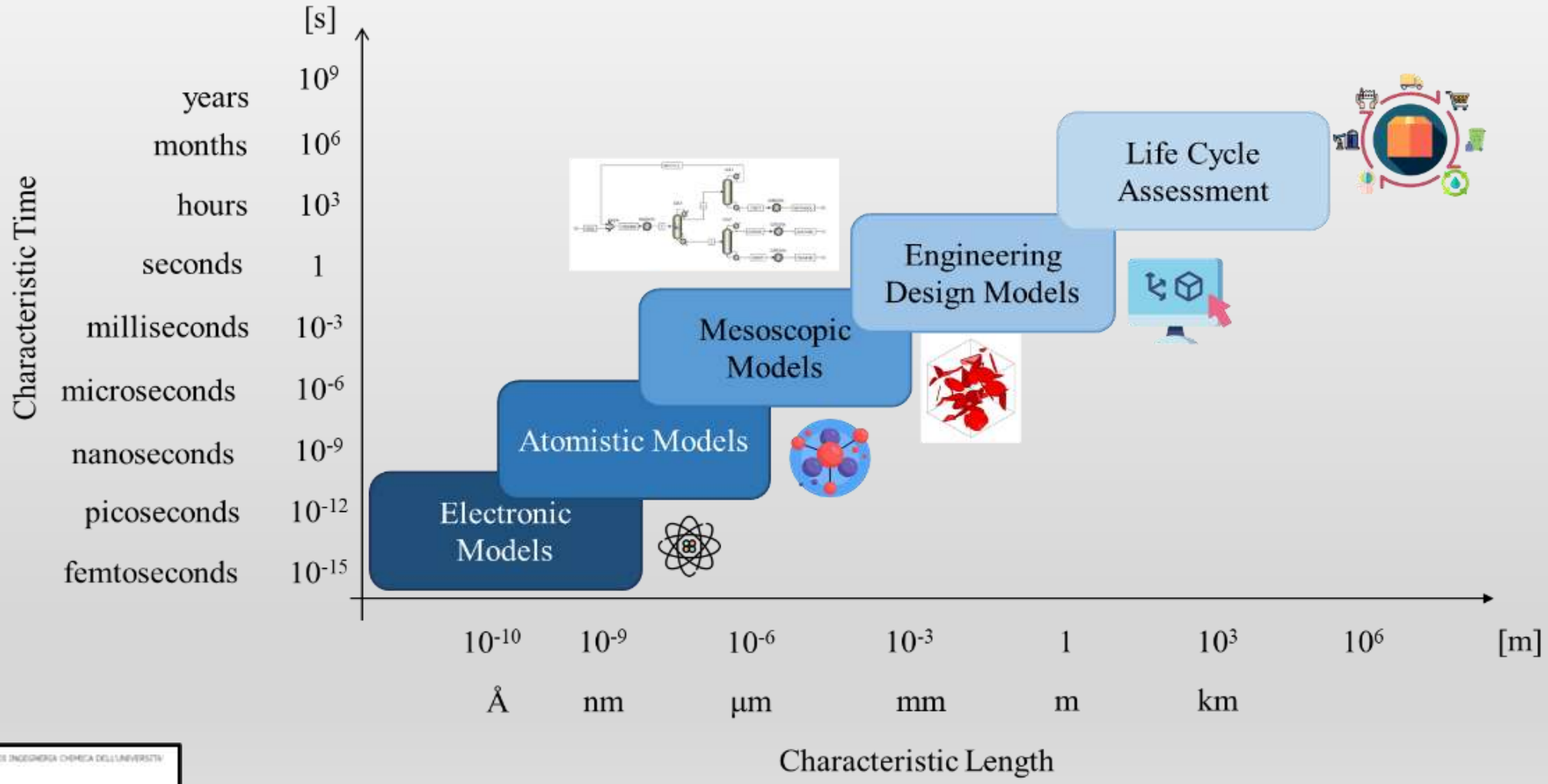
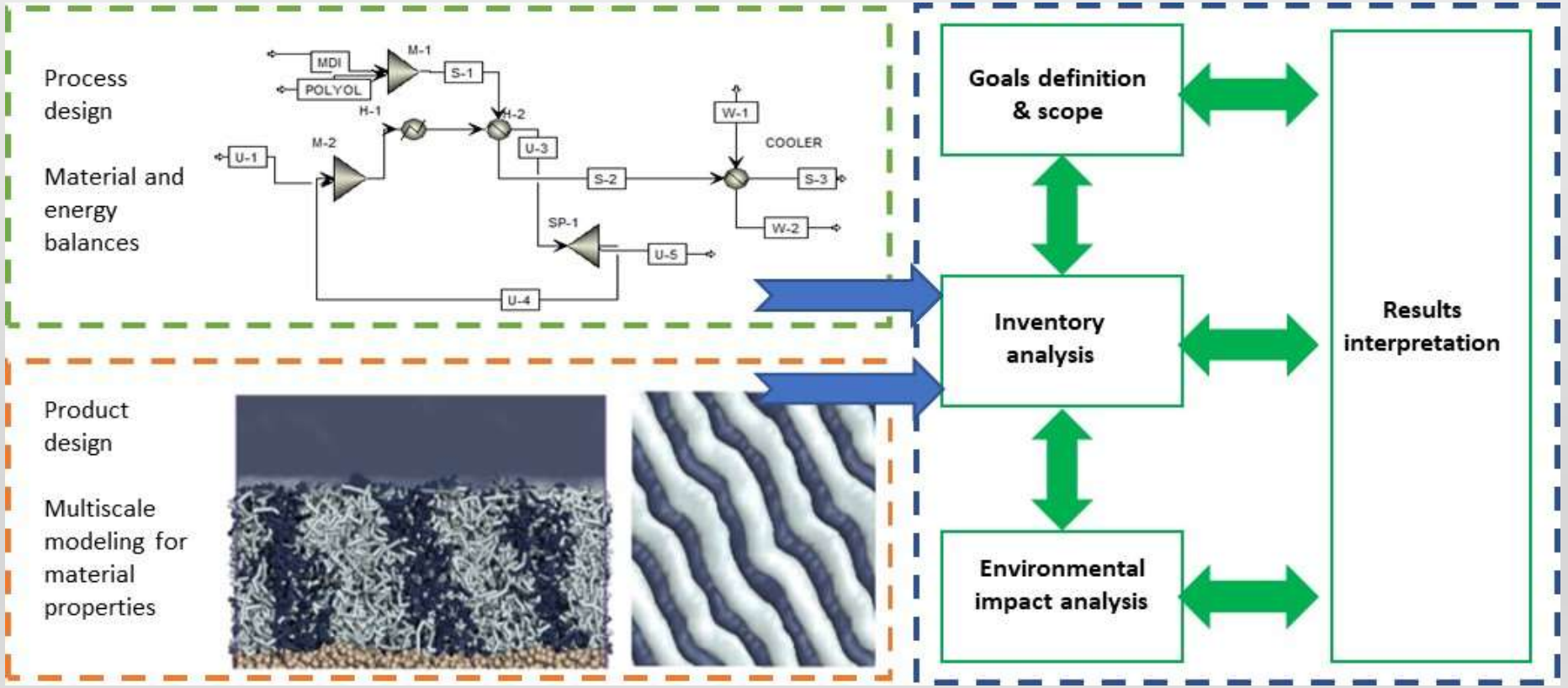
Multiscale Molecular Modeling: the concept



Life Cycle Assessment (LCA)

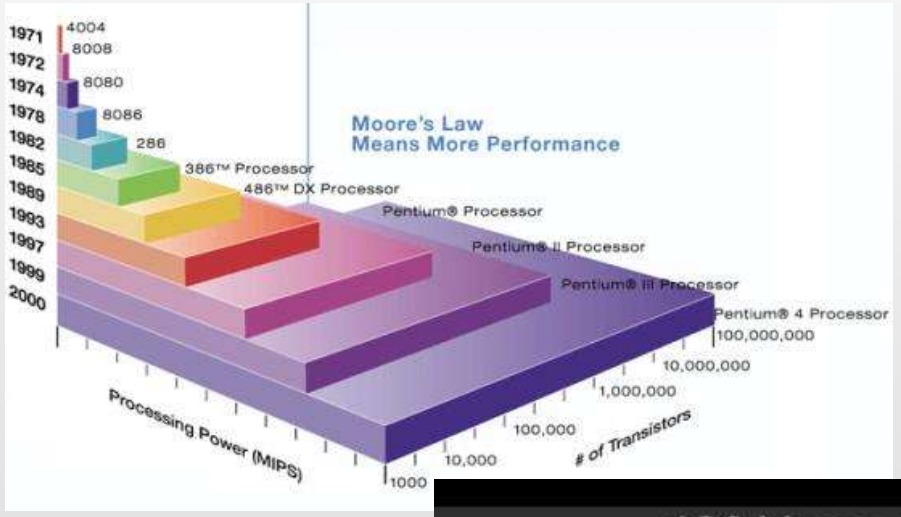
- Integration of process and product design into LCA
  - Allow personalized data for process and product
  - Improve the LCA in the production step



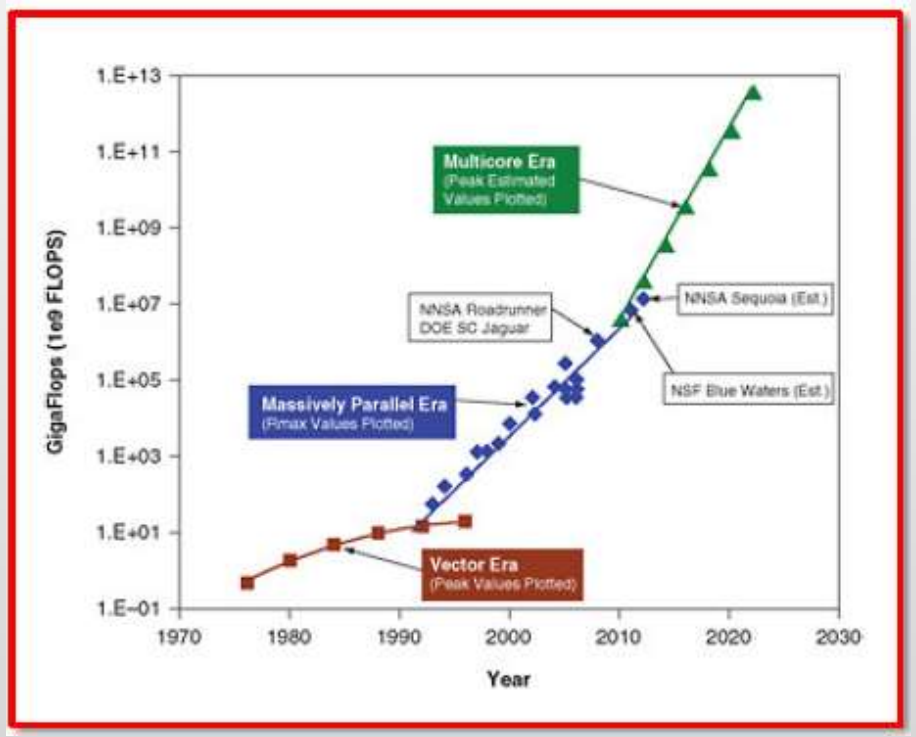
Molecular Simulation vs Theory

- Advances in computational hardware and algorithms
  - Moore's law
    - Gordon Bell Prize: 1Gflop/s in 1988 vs. 27 Tflop/s in 2002
    - More than four order of magnitude increase in 14 years
    - Add 2-3 orders of magnitude from parallelization (cheap today)
    - Costs driven by consumer market

Moore’s law



Number of transistors on a sliver of silicon would double every two years



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Molecular Simulation vs Theory

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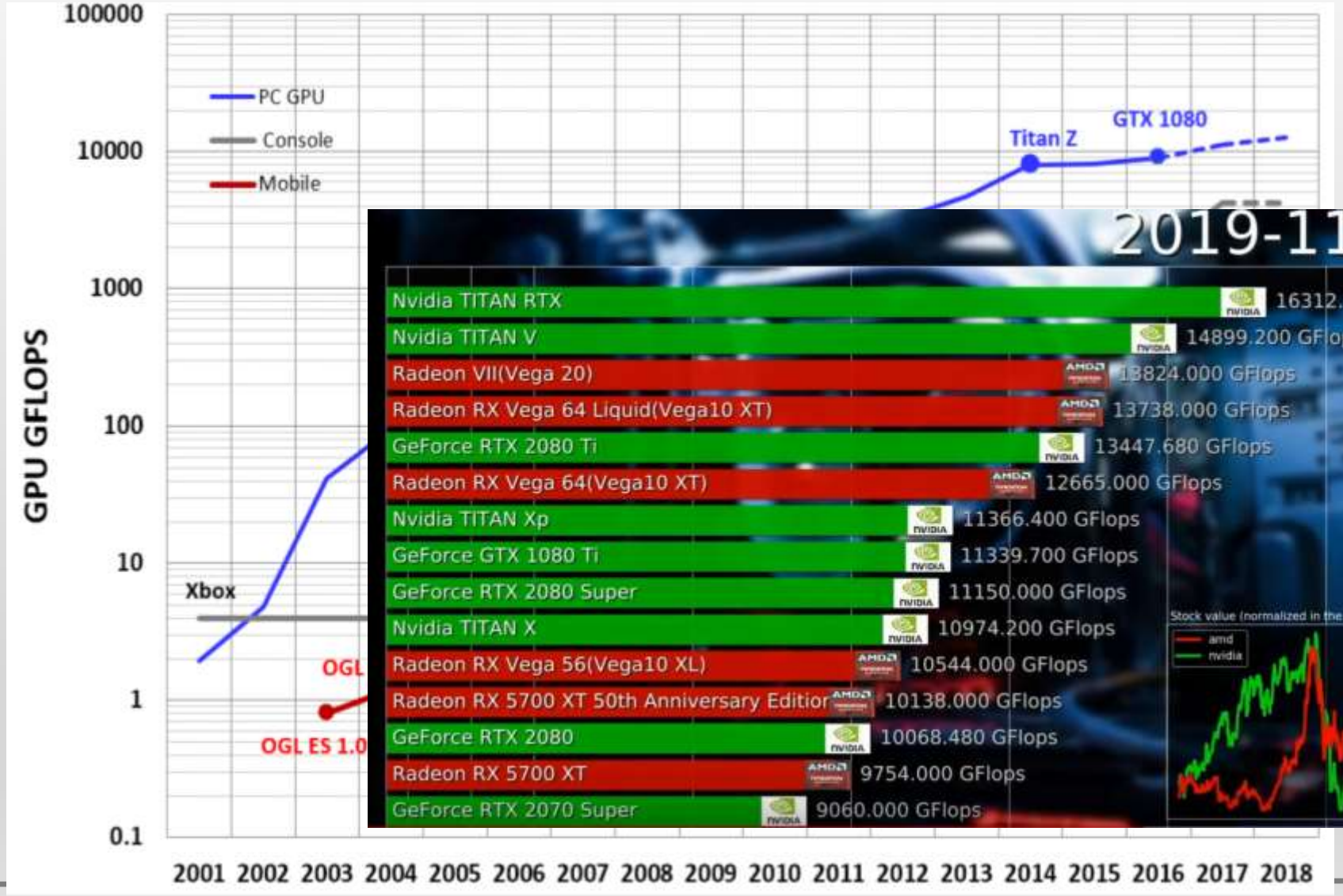
    - Costs driven by consumer market
- Costs for experiment?
  - Labor-intensive, high capital costs
- Costs for theory?
  - Labor-intensive [2]

Do graduate students and/or lab personnel/equipment improve by an order of magnitude every five years?

GPU performances (GFLOPS)



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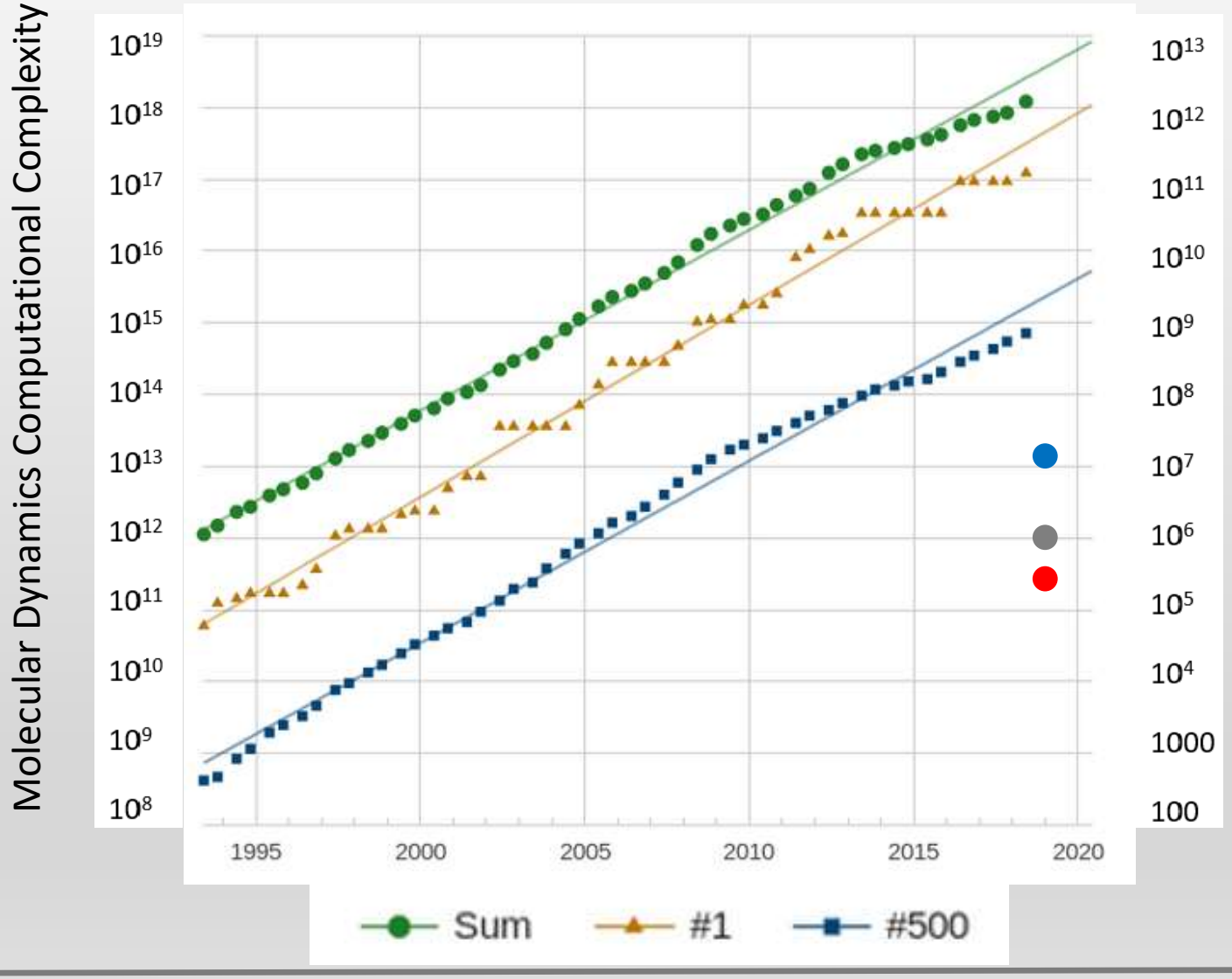
HPC vs GPU performance (GFLOPS)

N. of time steps * n. atoms simulated in one day



For a simple monoatomic fluid is the n. of atoms that can be simulated for 10ns in one day

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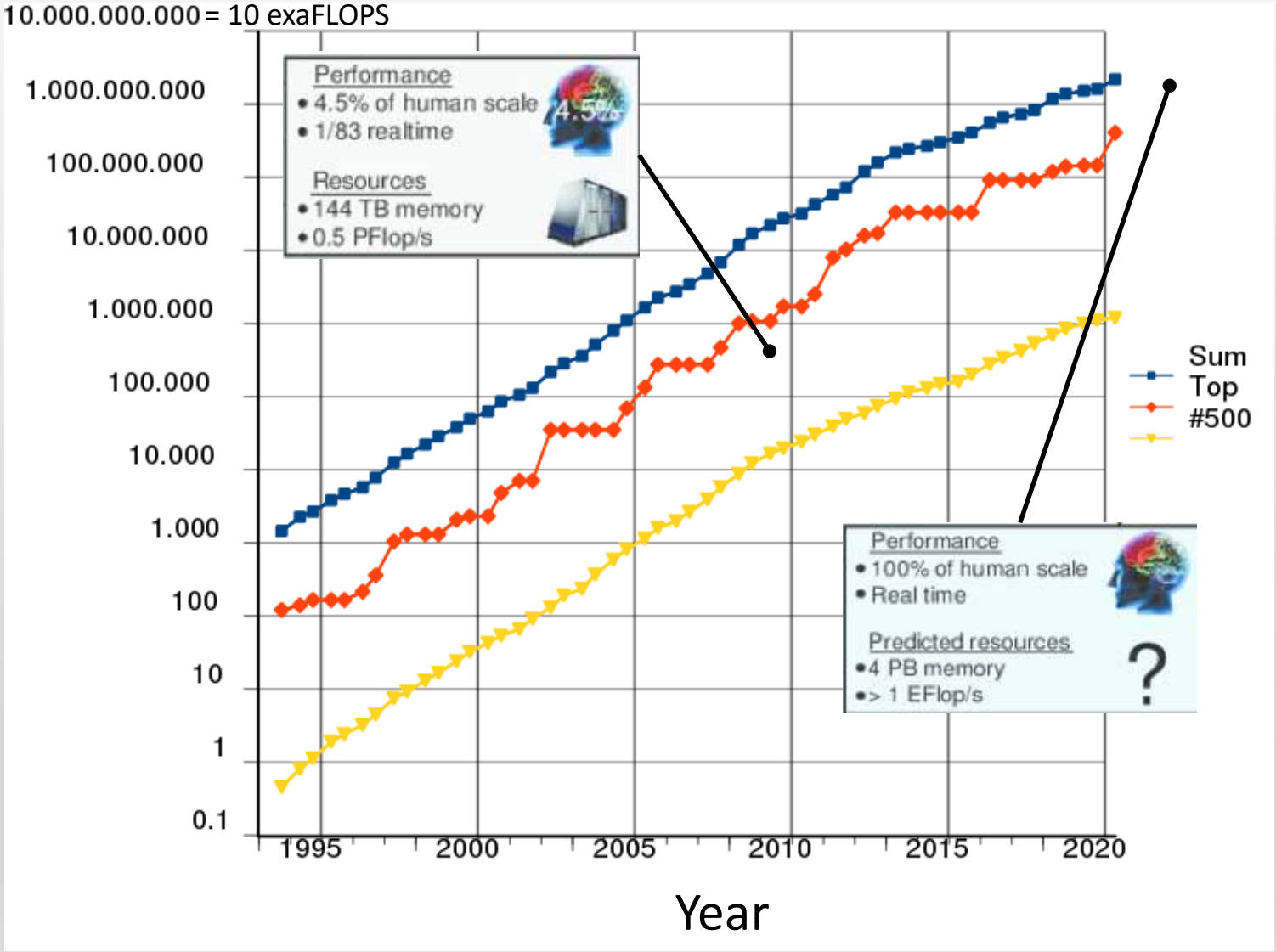
Top 500 HPC evolution in time

Computer power in GFLOPS



The exaScale Power Enigma: why we have to turn to Brain-inspired computers

- Straight forward extrapolation results in a Real time Human brain scale simulation at 1-10 exaFLOPS with 4 PB memory
- A digital computer with this performances might be available in 2022-24 with a power consumption of > 20-30 MW
- The human brain runs on 20 W
- Our brain is a Million times more power efficient

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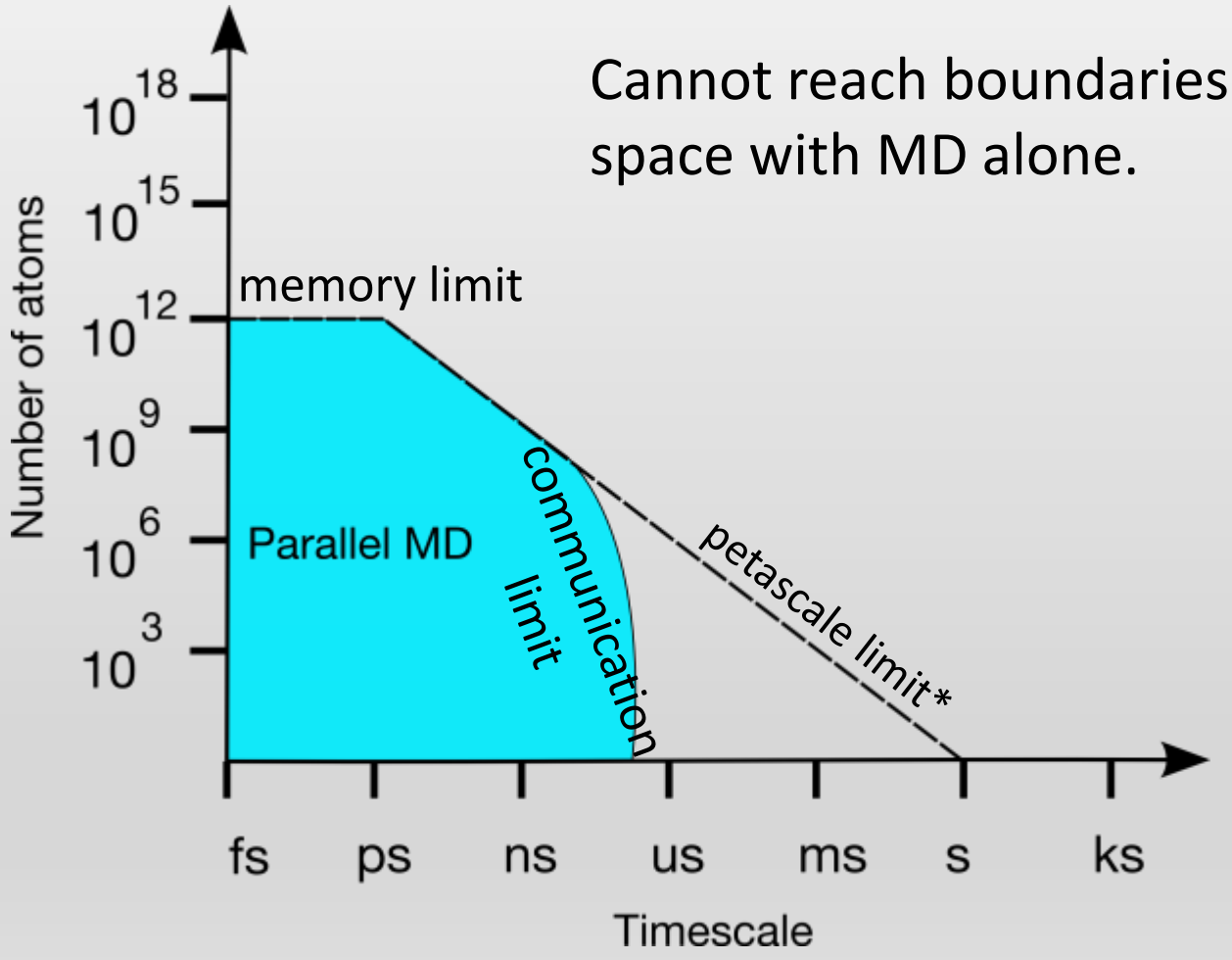
Accessible MD time and length scales

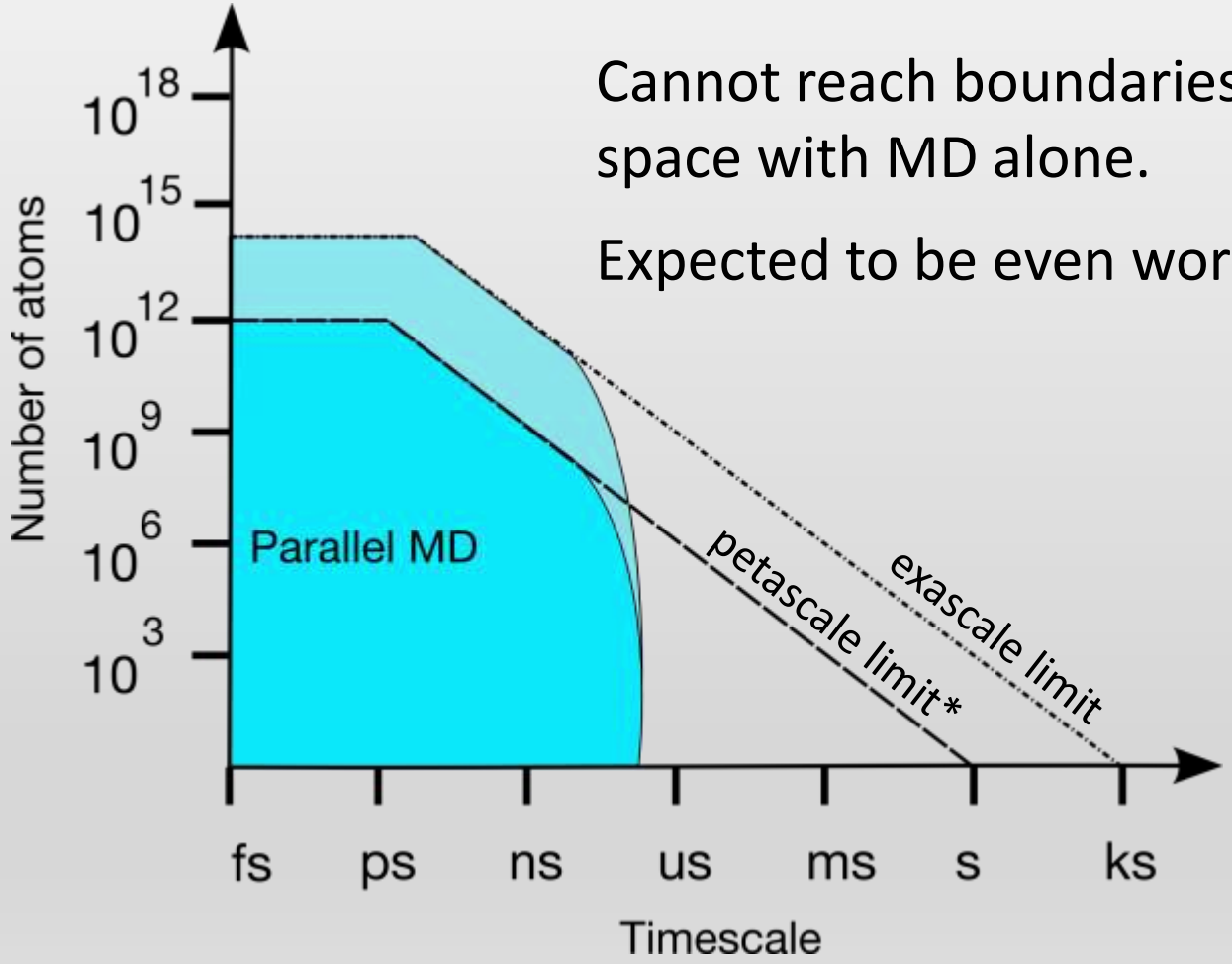
*1 week on Roadrunner – 1 PFLOPS machine, fast EAM potential



Cannot reach boundaries of length-time space with MD alone.

Accessible MD time and length scales

*1 week on Roadrunner – 1 PFLOPS machine, fast EAM potential



Cannot reach boundaries of length-time space with MD alone.

Expected to be even worse at exascale…

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Quantum computing may be the solution?

MENU

nature
International journal of science

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NEWS FEATURE · 02 OCTOBER 2019

Beyond quantum supremacy: the hunt for useful quantum computers

Researchers search for ways to put today's small noisy quantum systems to work.

Science News *from research organizations*

Quantum internet closer to reality

Date: September 26, 2019

Source: U.S. Army Research Laboratory

Summary: New research result brings the quantum internet a step closer. Such an internet could offer the military security, sensing and timekeeping capabilities not possible with traditional networking approaches.

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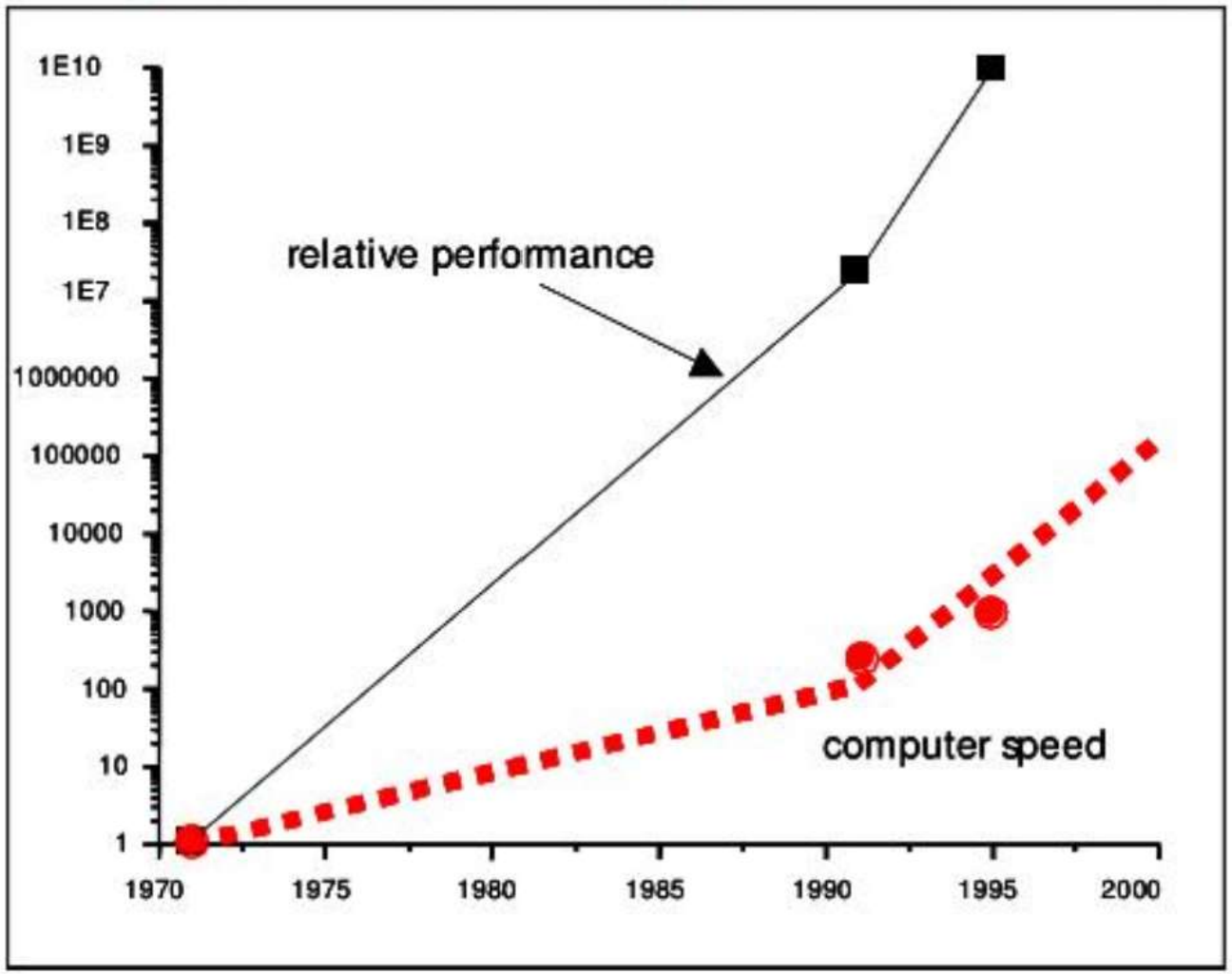
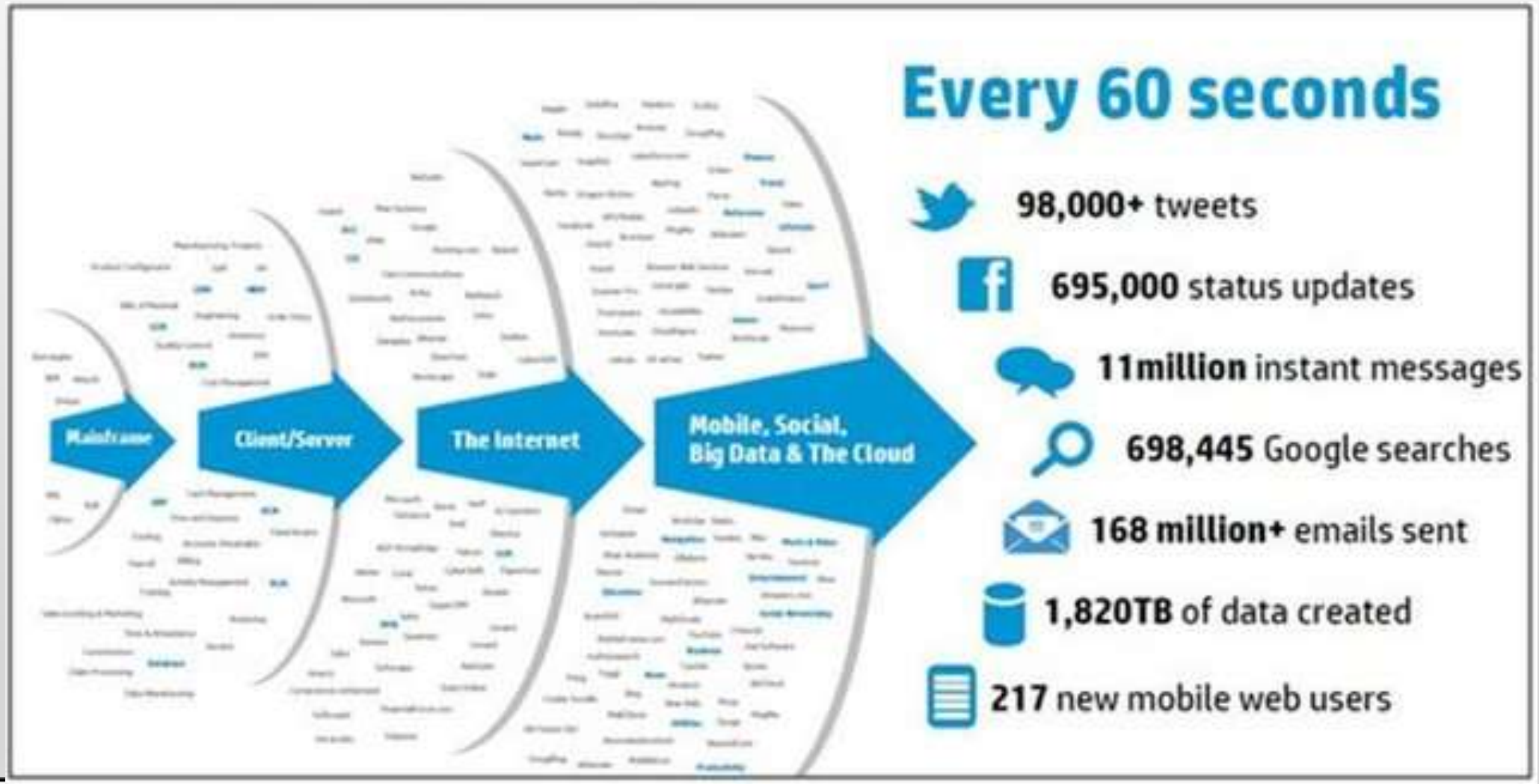
Invest in algorithms … or computer HW?



(source: David Landau, UGA)

Data explosion



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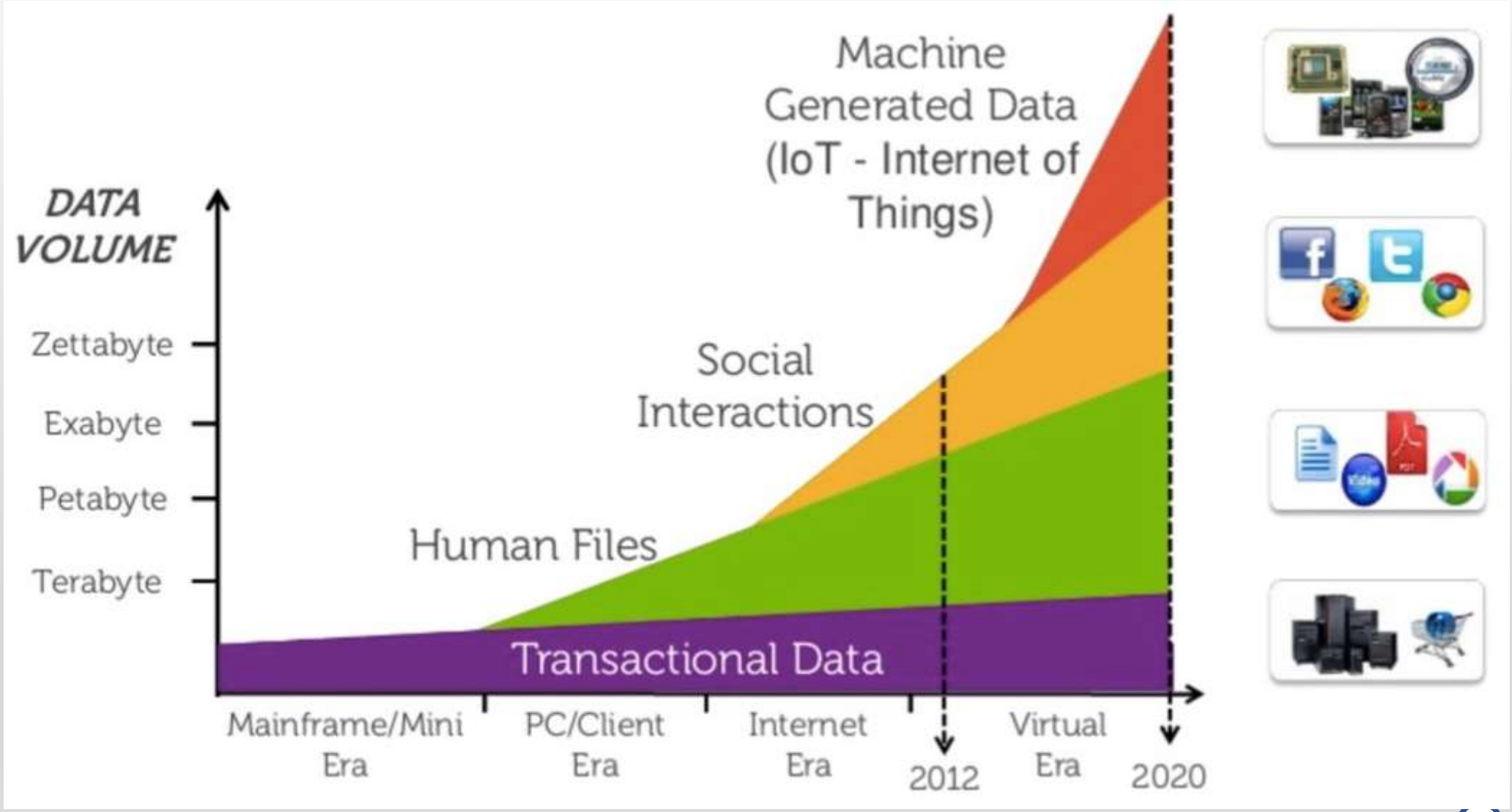
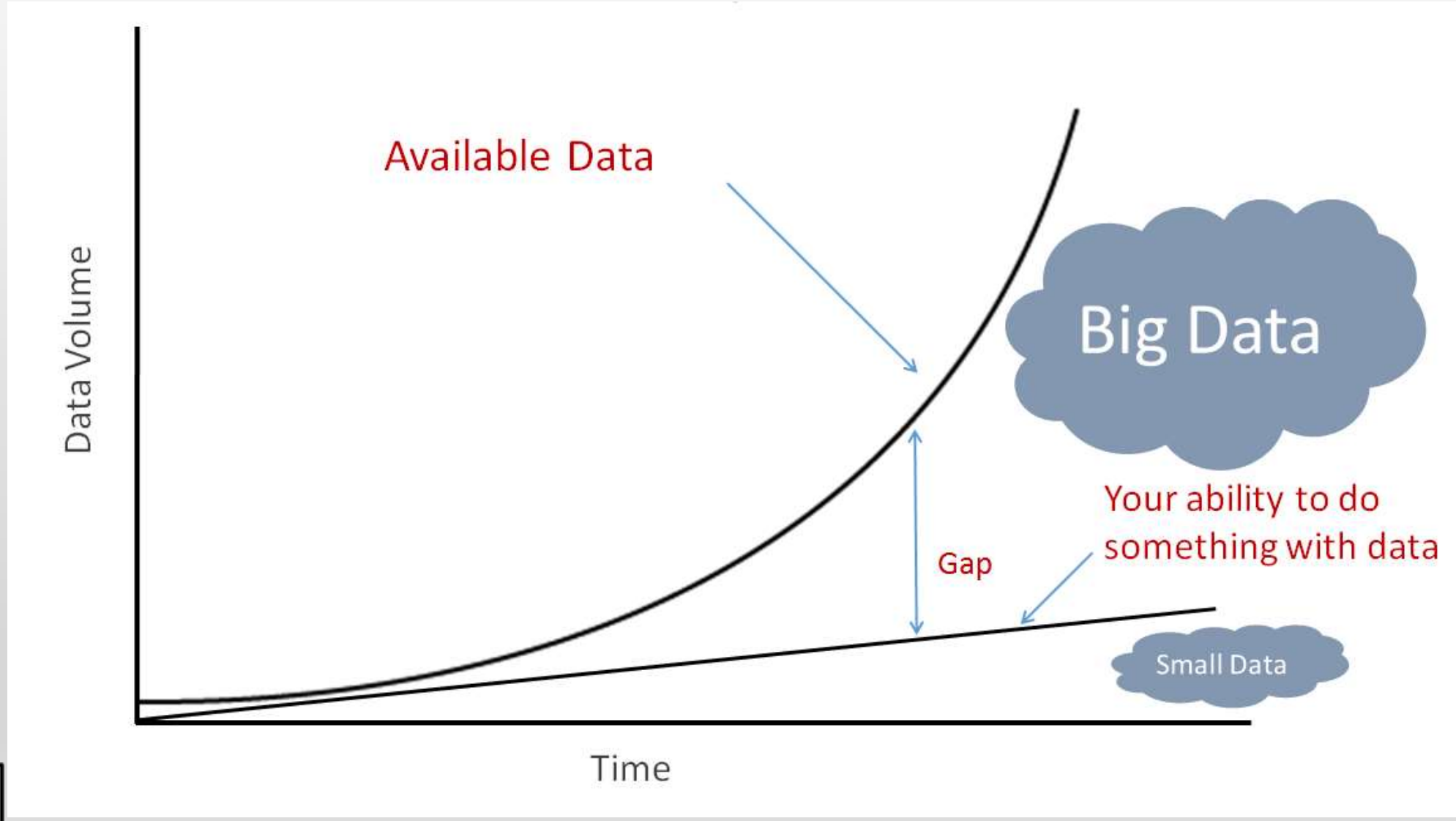
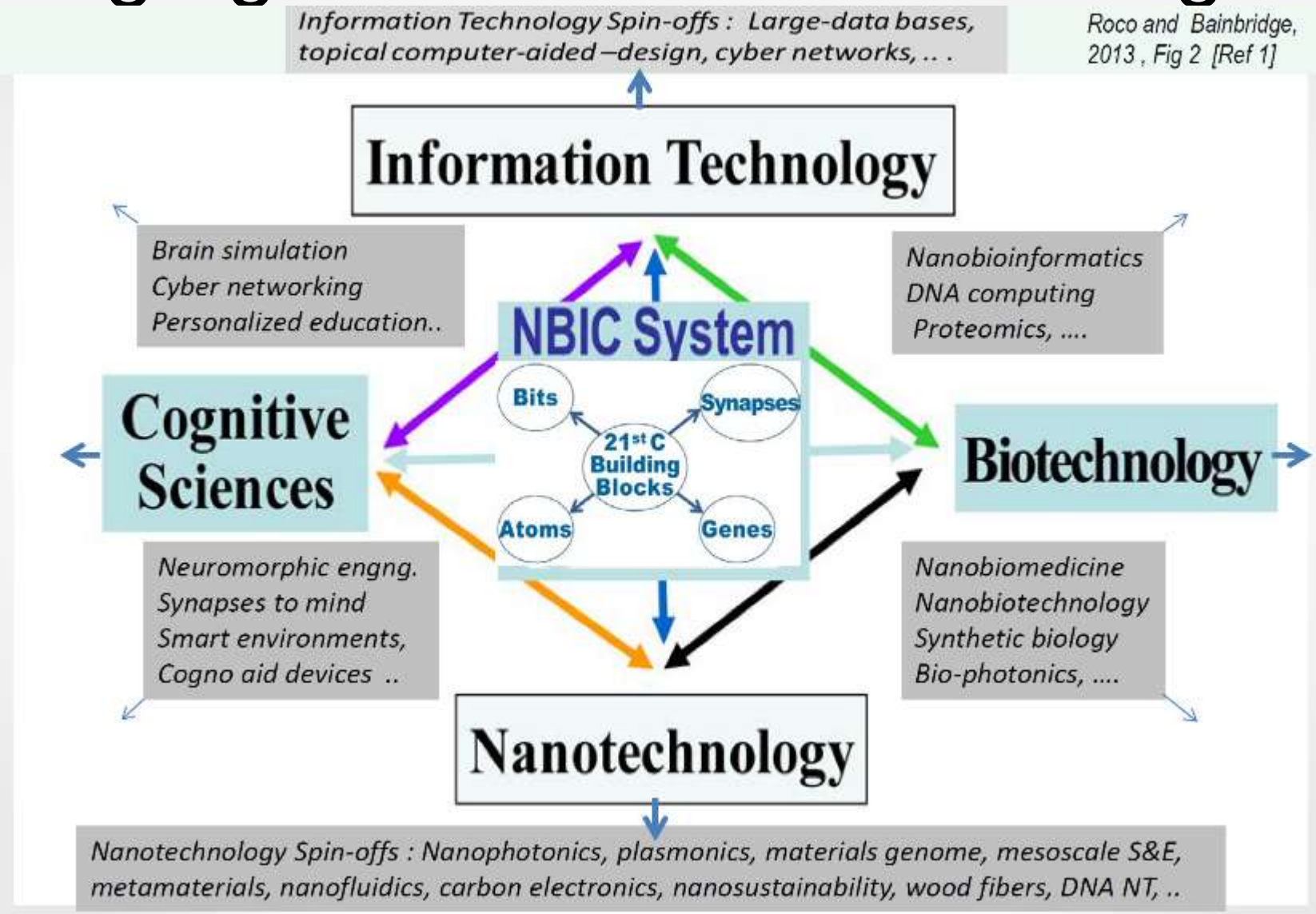
Data explosion



Data explosion



Converging foundational technologies - NBIC



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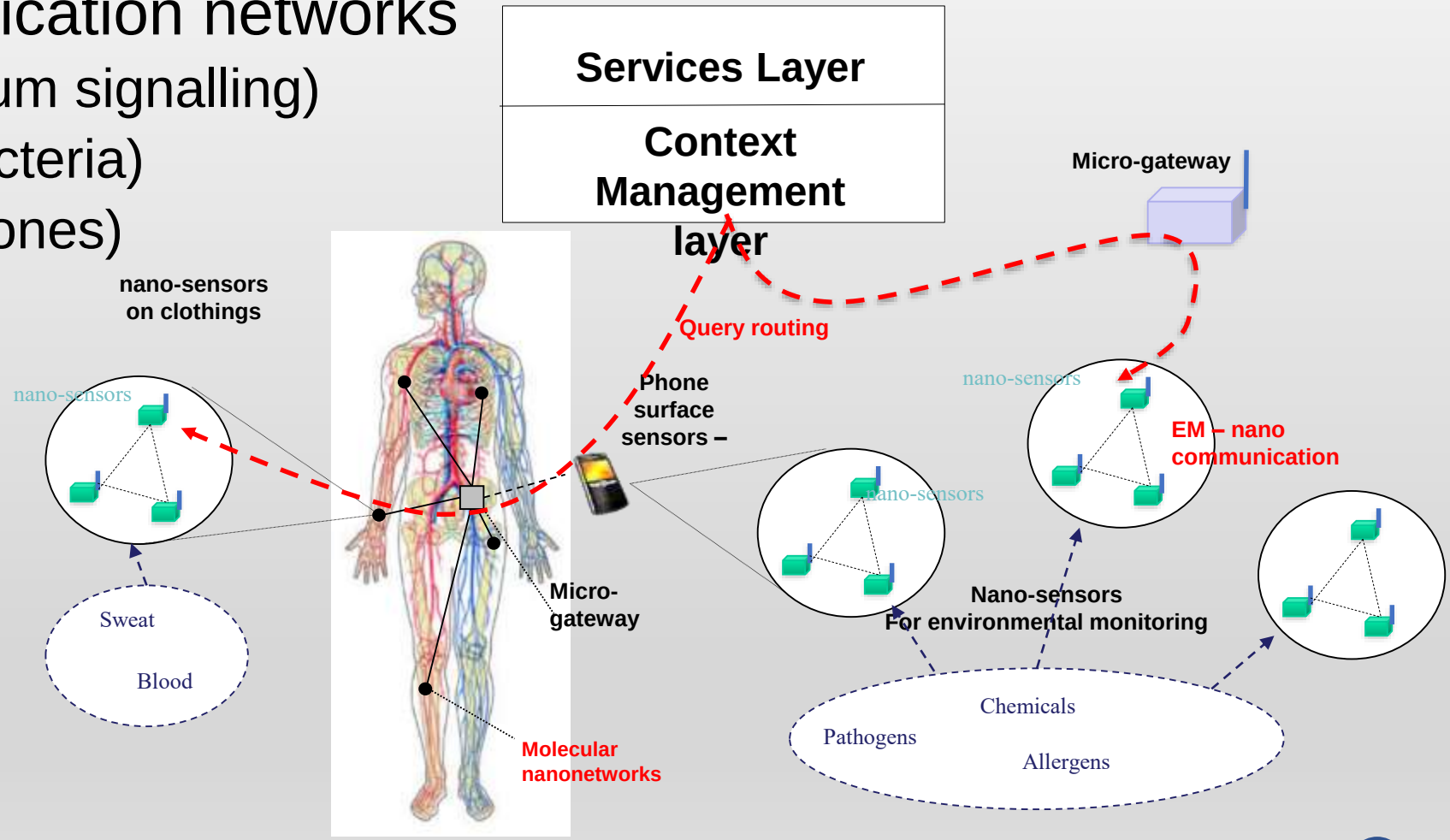
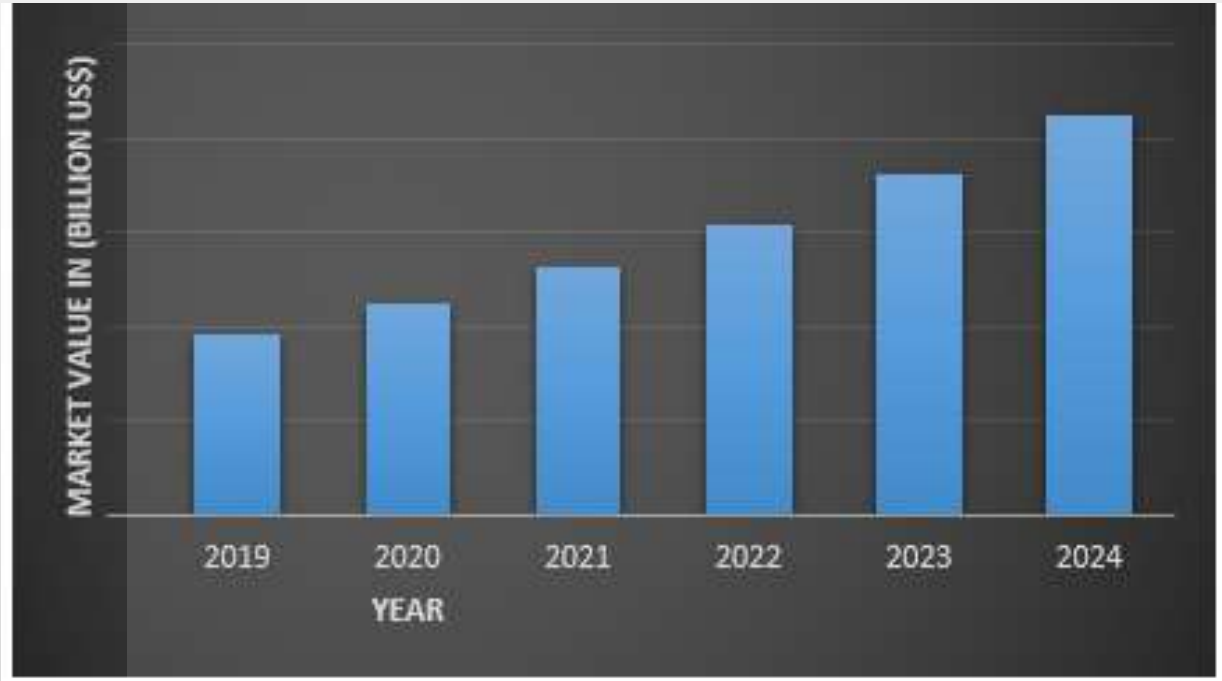
Internet of Nano Things (IoNT) for healthcare applications

- Molecular communication networks
  - Short range (Calcium signalling)
  - Medium range (Bacteria)
  - Long range (Hormones)



Global IonT market size



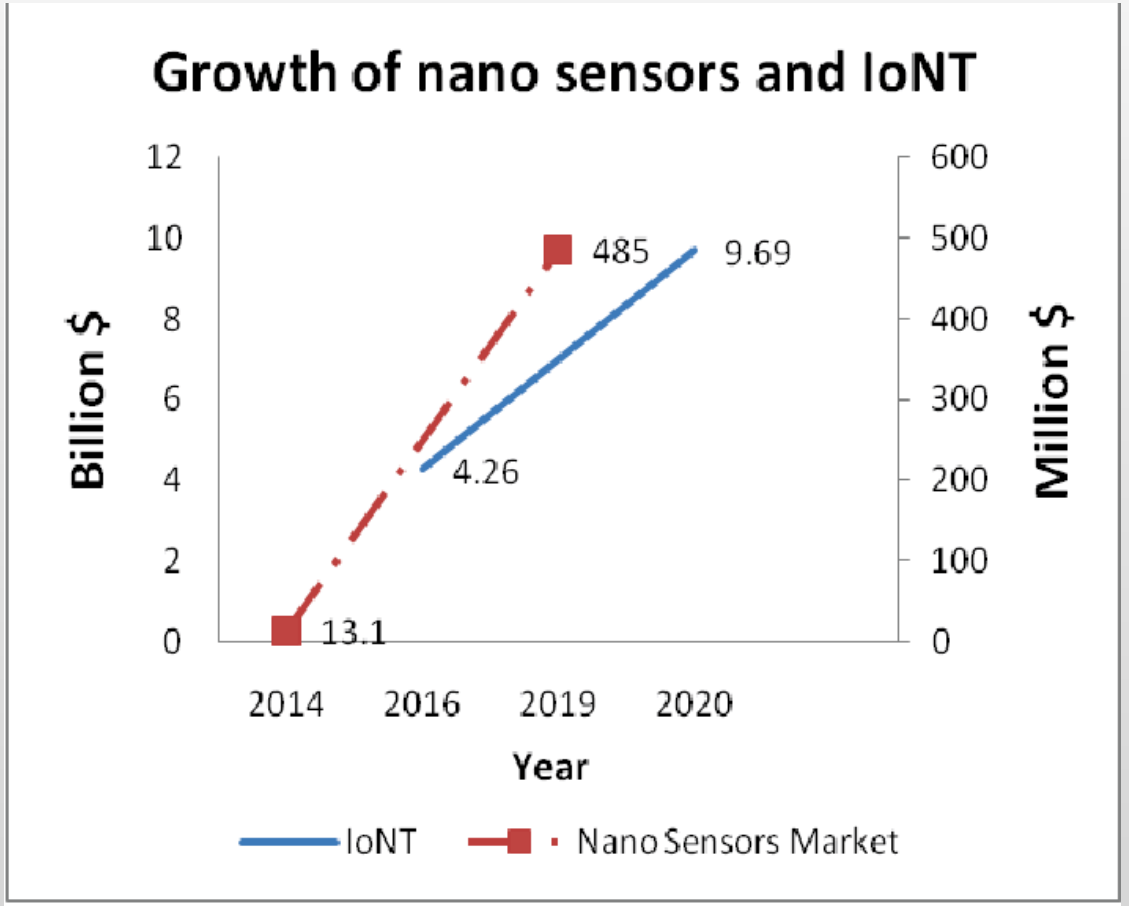
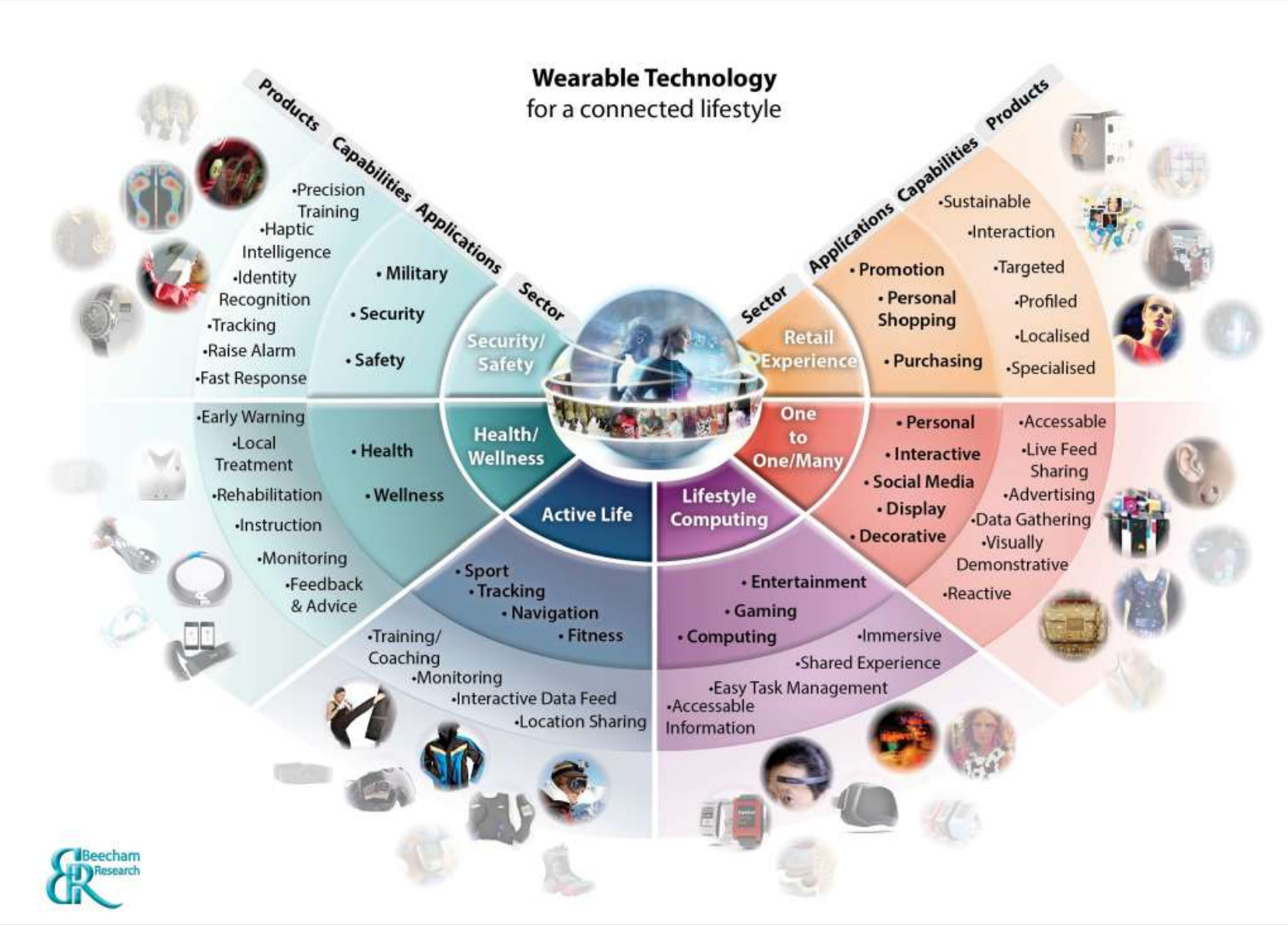


Fig. 1. Expected growth of Nano sensors and IoNT

Wearable technology



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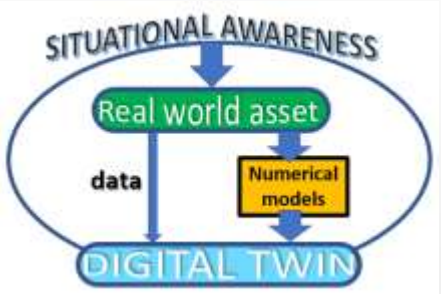
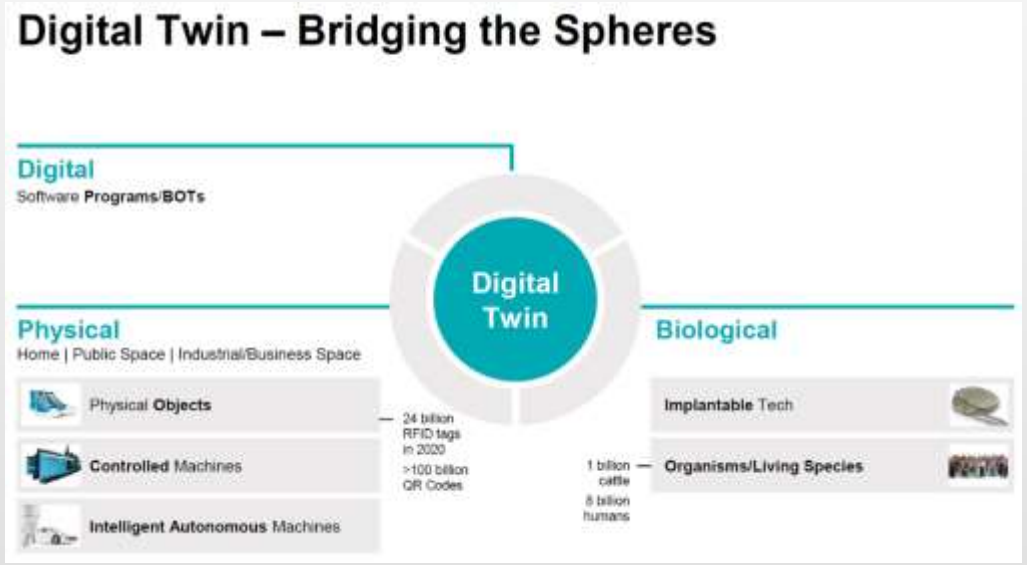
Digital twins





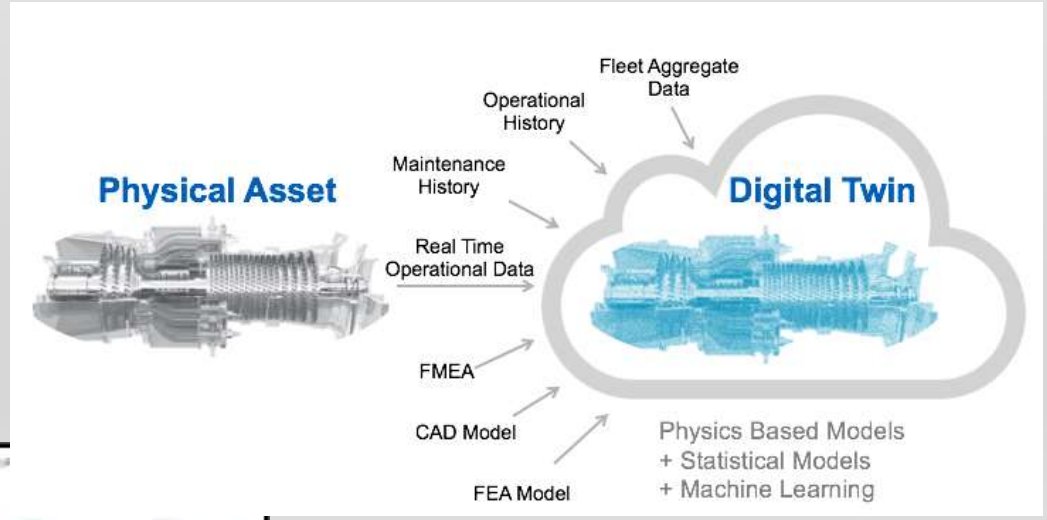
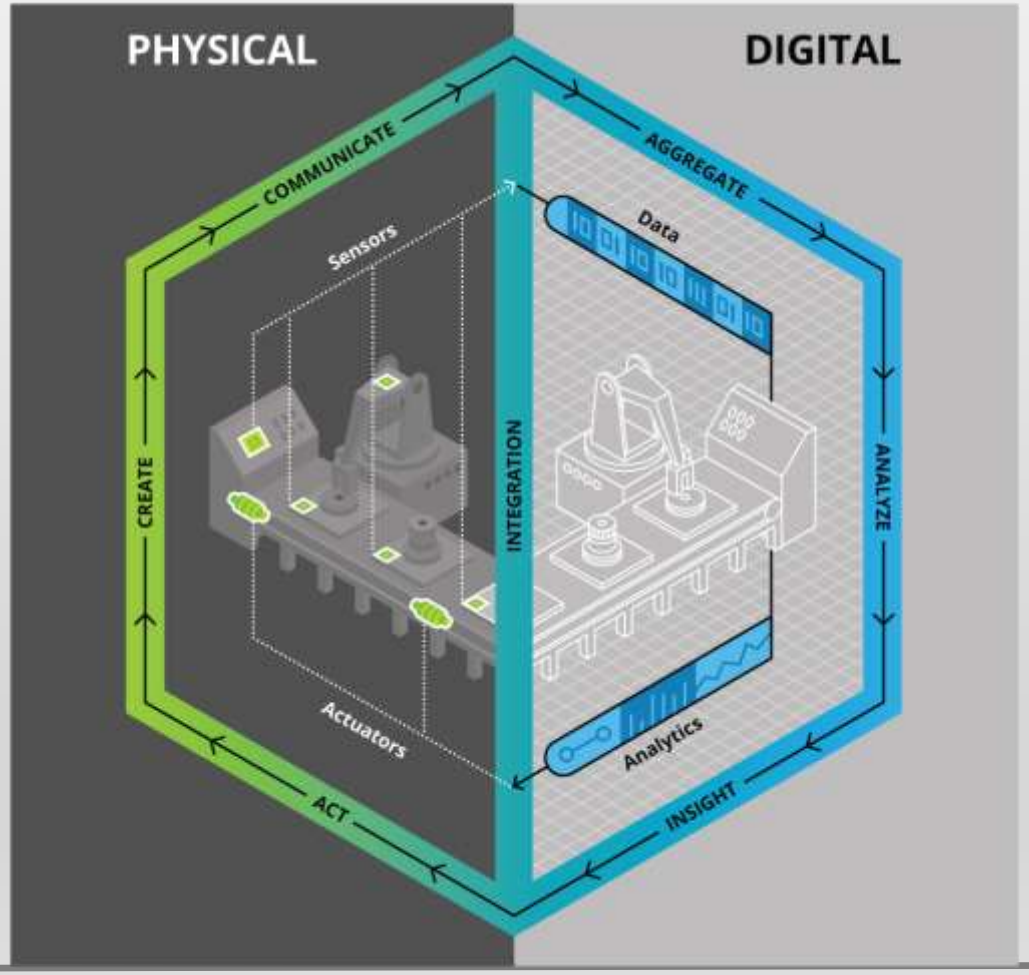
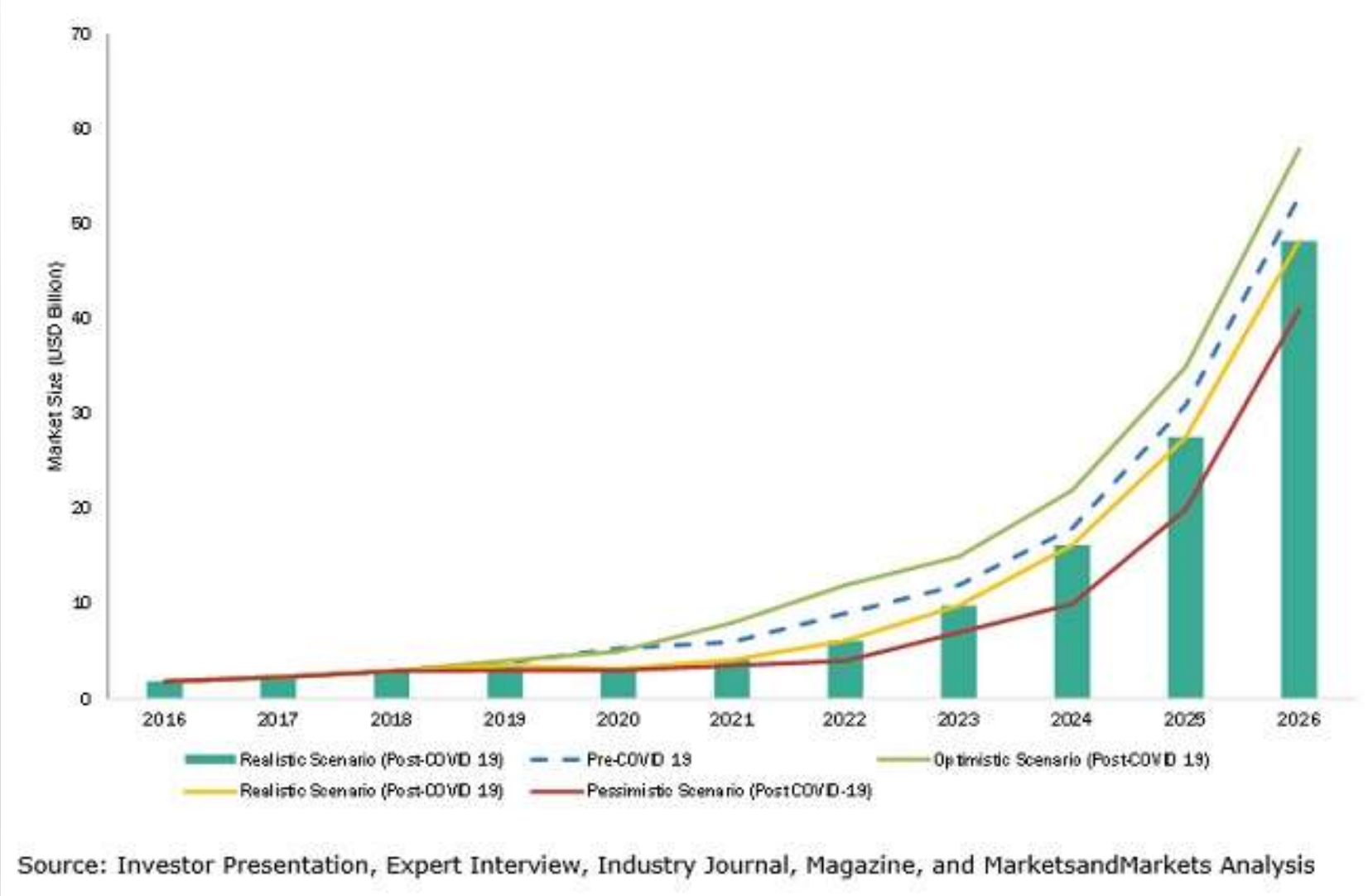


Figure 1. Manufacturing process digital twin model



Source: Deloitte University Press.

Digital Twins: market Size



Source: Investor Presentation, Expert Interview, Industry Journal, Magazine, and MarketsandMarkets Analysis

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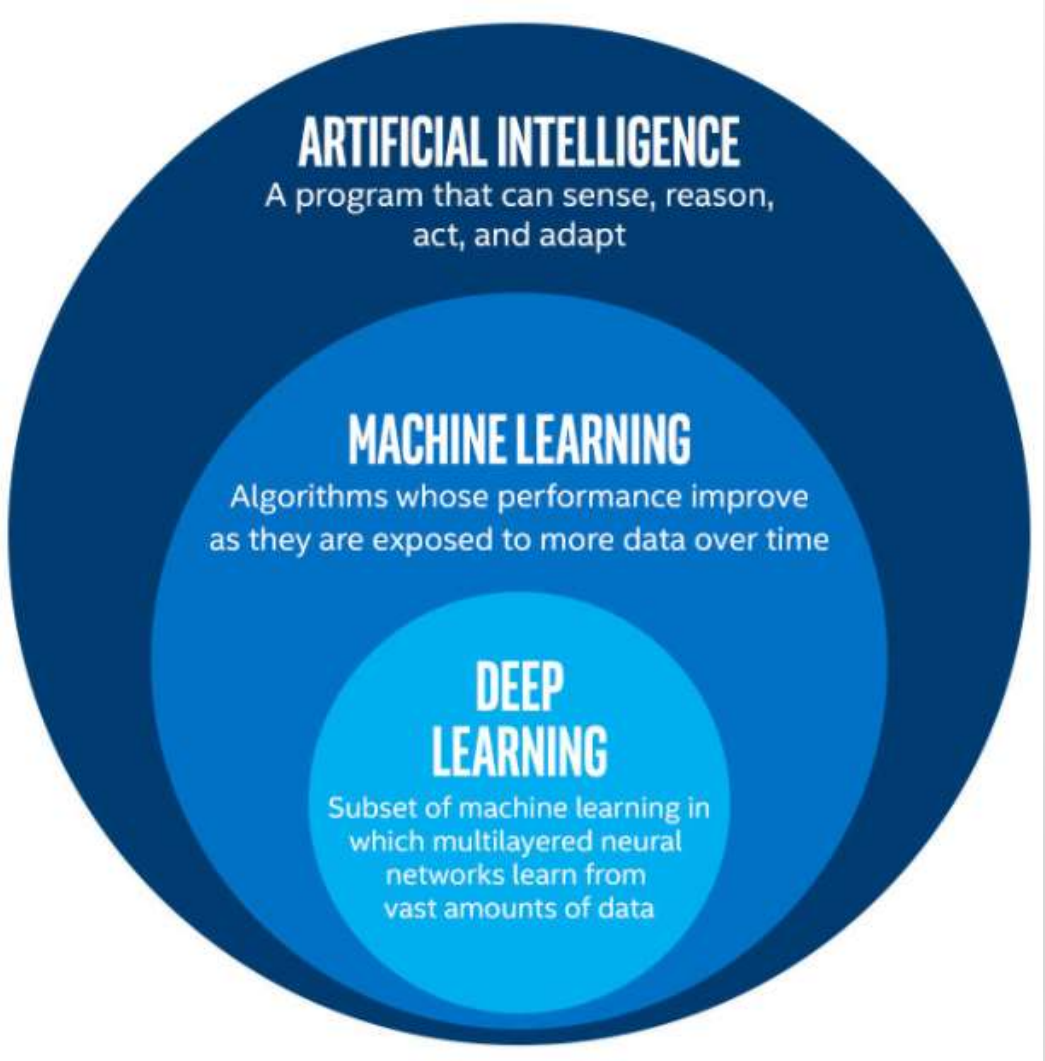
Computer intelligence vs. human intelligence

- No generalized intelligence
  - Is intelligent but remains an object
  - Useful for repetitive tasks
  - How about 5 senses? And sixth sense?



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… but what is intelligence?

- Meaning of word intelligence has changed in the years
  - Oxford: the ability to learn, understand and think in a logical way about things; the ability to do this well
- What was intelligence years ago is not anymore today
  - In the past a chess champion was considered intelligent … today?
- Is moving toward creativity
  - … and therefore is moving away from AI
- And in the future???

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Outline of talk

- Digitalization
  - New industry, new manufacturing
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  - HPC and Big Data … towards quantum computing
  - Convergence of technology
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- The future of jobs
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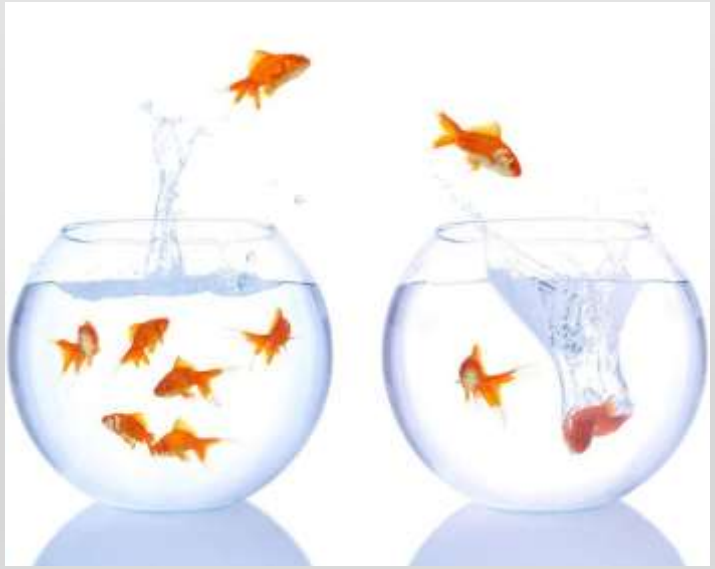

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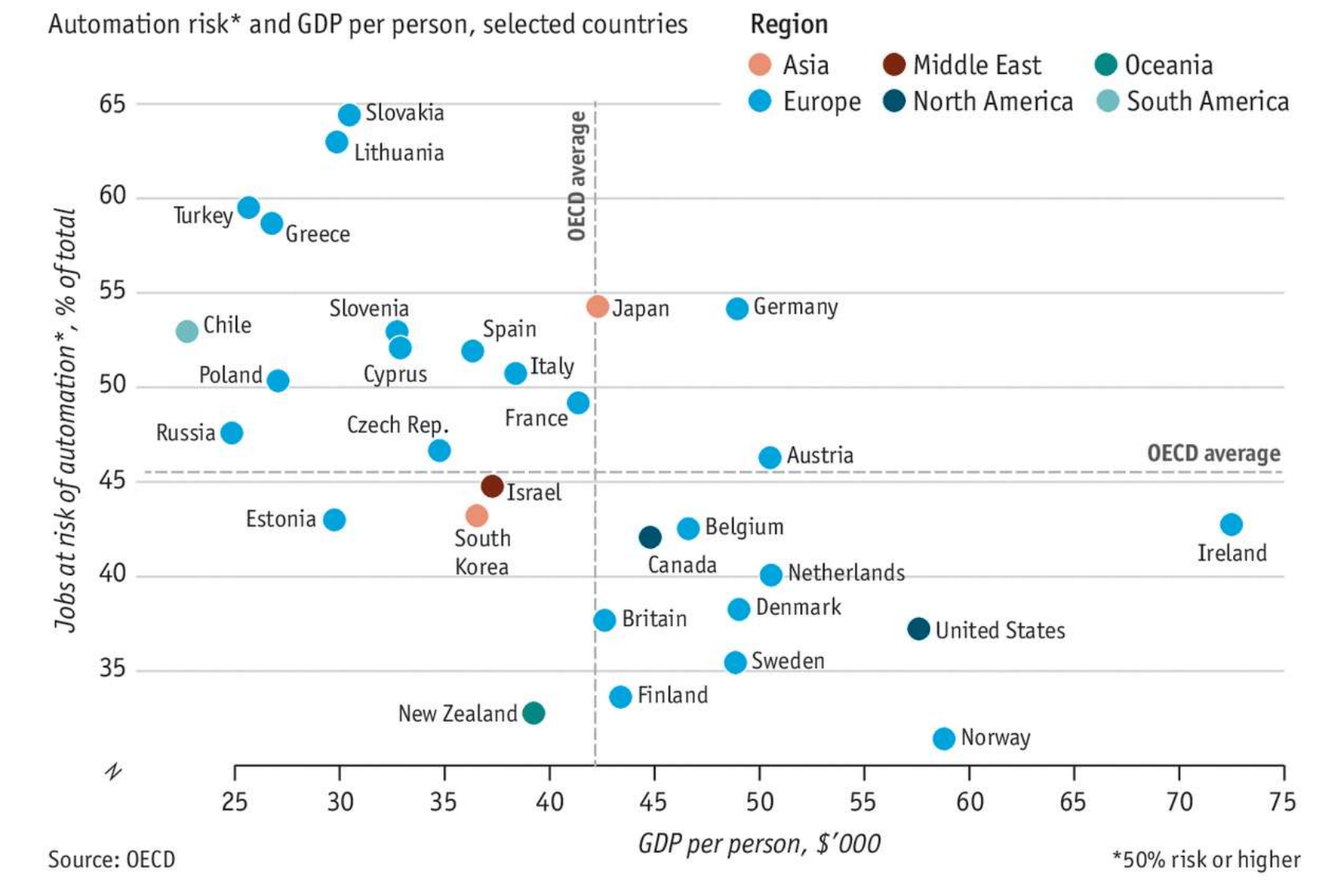
A study finds nearly half of jobs are vulnerable to automation

The Economist



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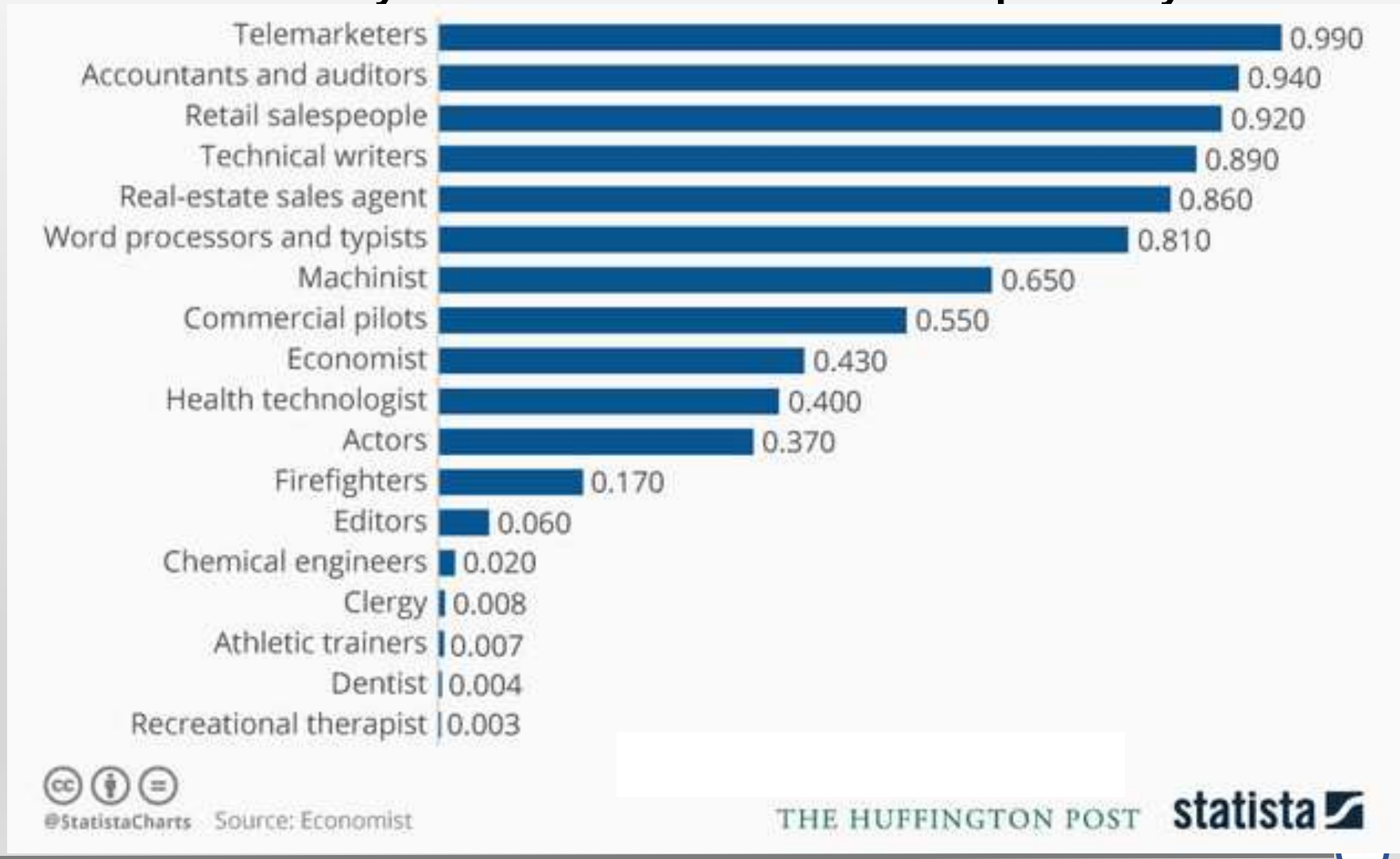
The future of employment



Source: Bureau of labor statistics, the Future of Employment (Frey & Osborne, 2013)

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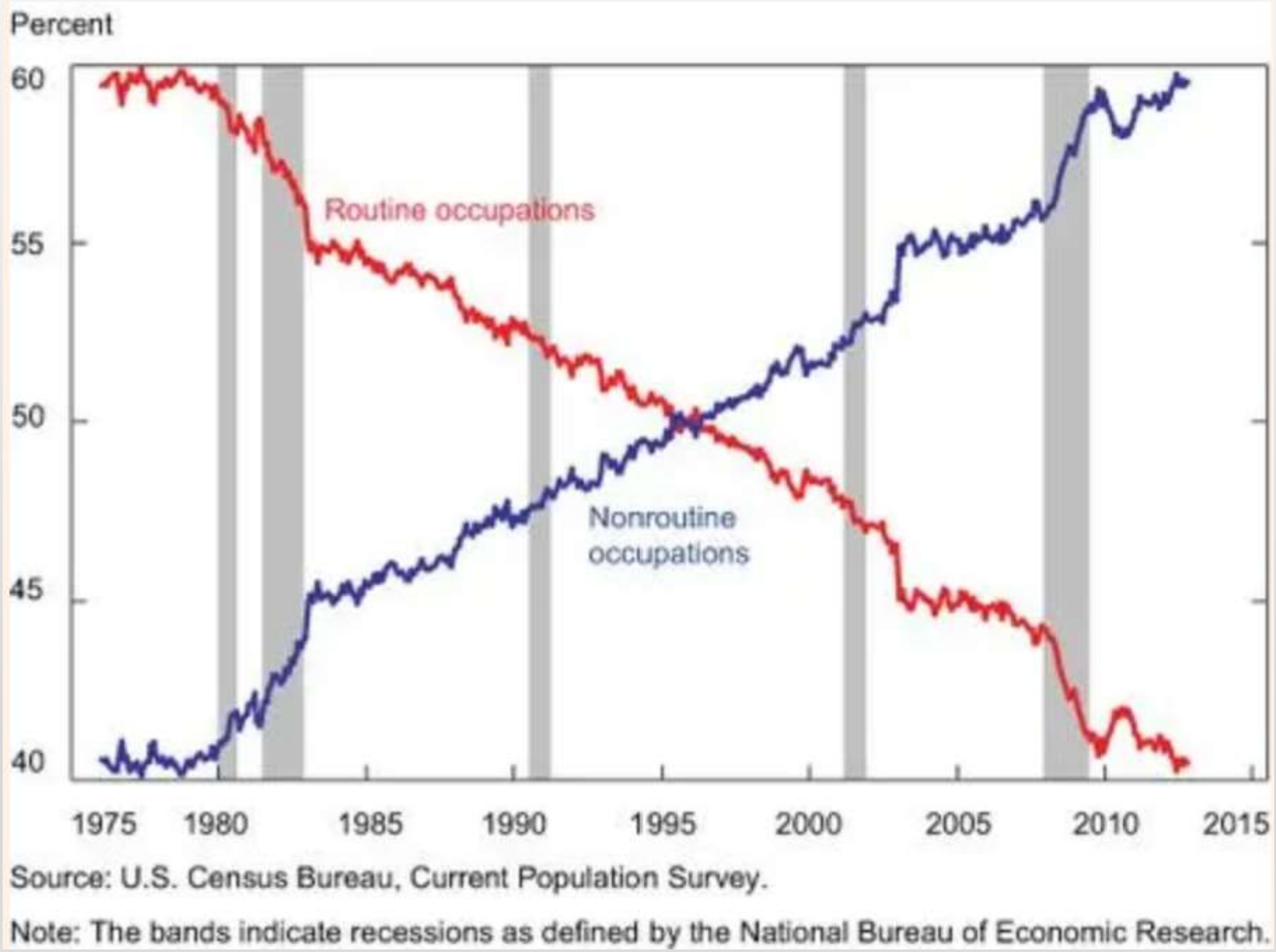
The future of employment

- Employment share



Source: US census Bureau.
Current population survey

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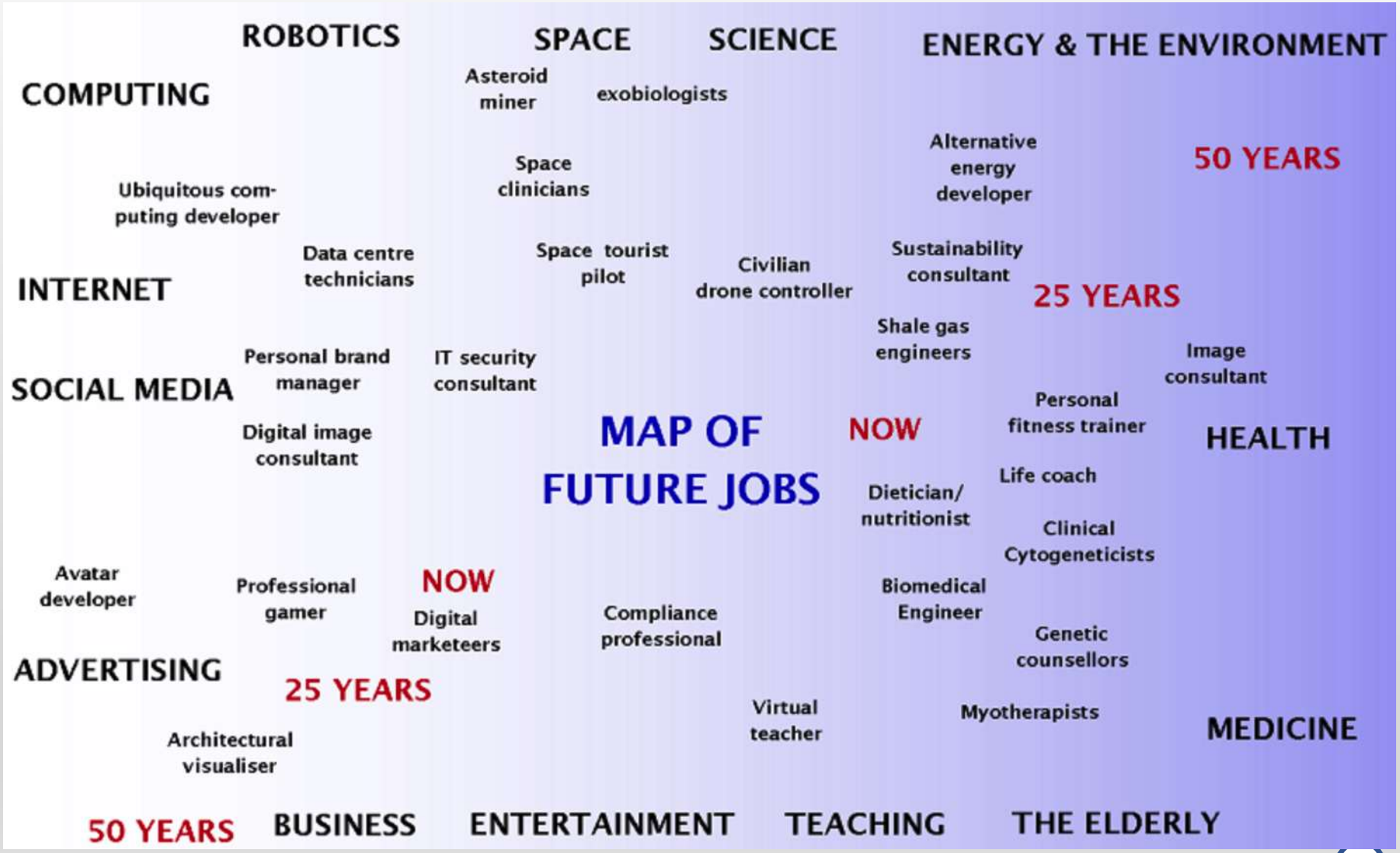
Jobs of the future



(https://www.kent.ac.uk/careers/Choosing/future-jobs.htm)

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Growing and Decreasing job demand

WORLD ECONOMIC FORUM

Growing job demand:

1. Data Analysts and Scientists
2. AI and Machine Learning Specialists
3. Big Data Specialists
4. Digital Marketing and Strategy Specialists
5. Process Automation Specialists
6. Business Development Professionals
7. Digital Transformation Specialists
8. Information Security Analysts
9. Software and Applications Developers
10. Internet of Things Specialists

Decreasing job demand:

1. Data Entry Clerks
2. Administrative and Executive Secretaries
3. Accounting, Bookkeeping and Payroll Clerks
4. Accountants and Auditors
5. Assembly and Factory Workers
6. Business Services and Administration Managers
7. Client Information and Customer Service Workers
8. General and Operations Managers
9. Mechanics and Machinery Repairers
10. Material-Recording and Stock-Keeping Clerks

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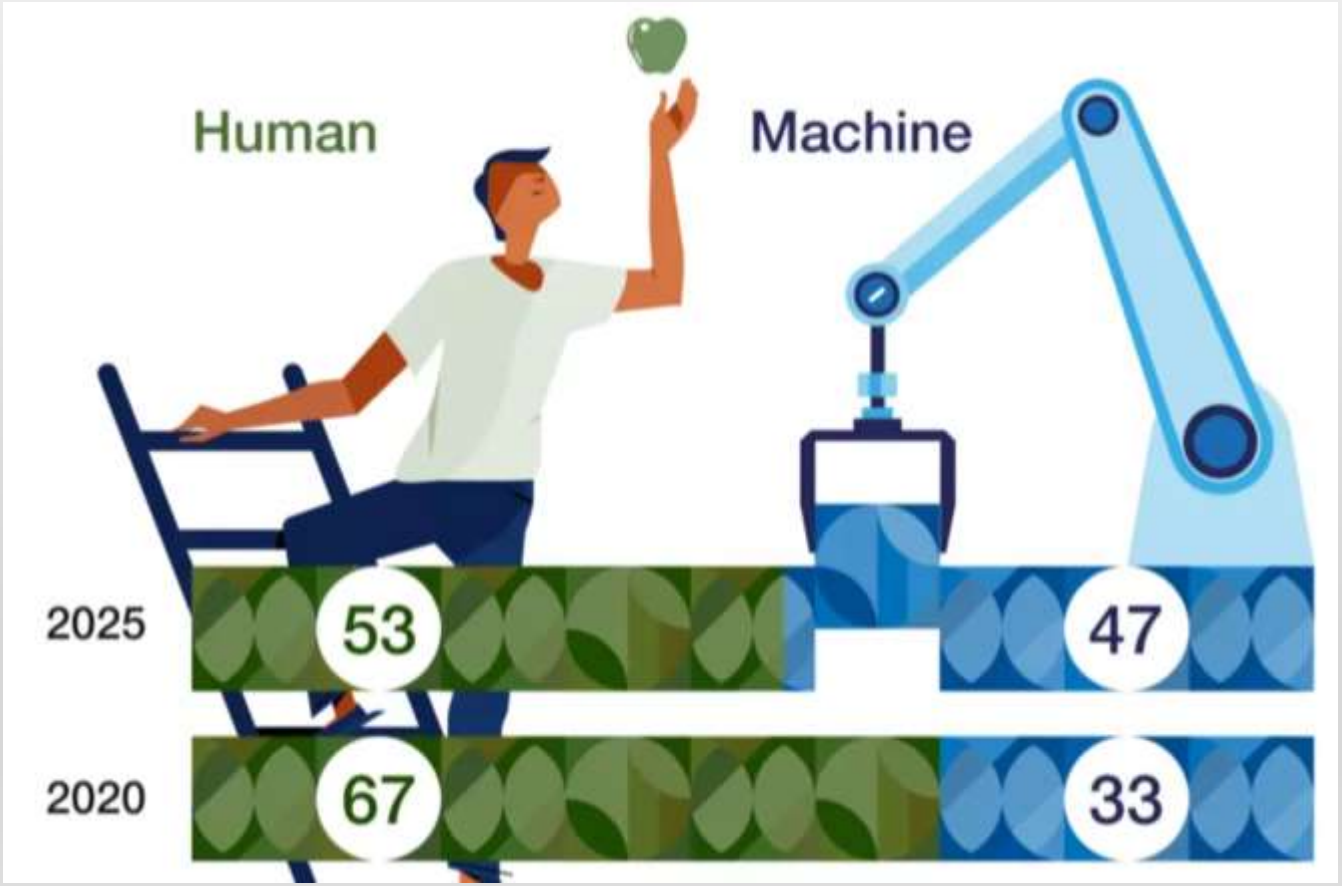
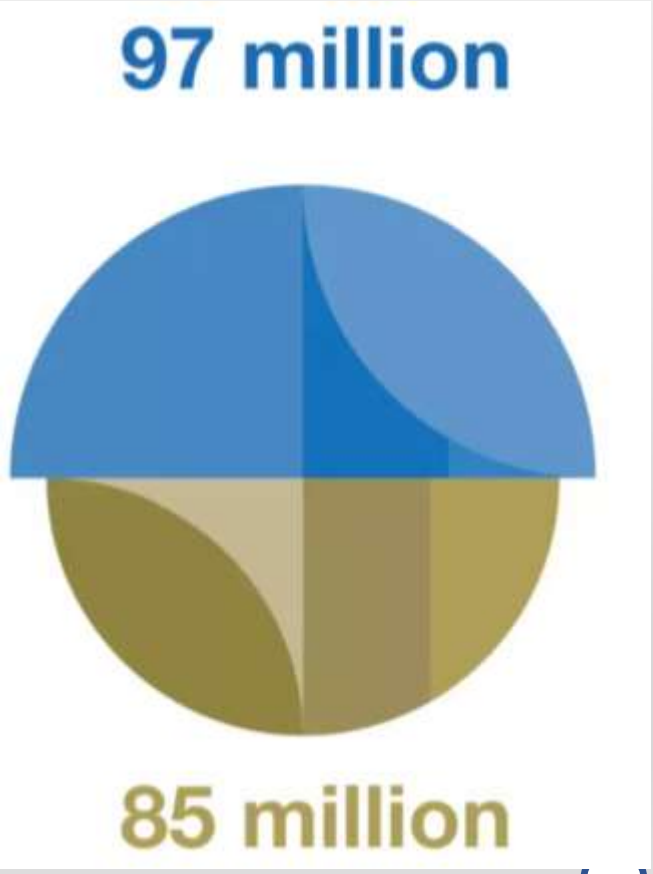
The job landscape in 2025

Rate of Automation

Division of labor as share of hours spent (%)





WORLD ECONOMIC FORUM

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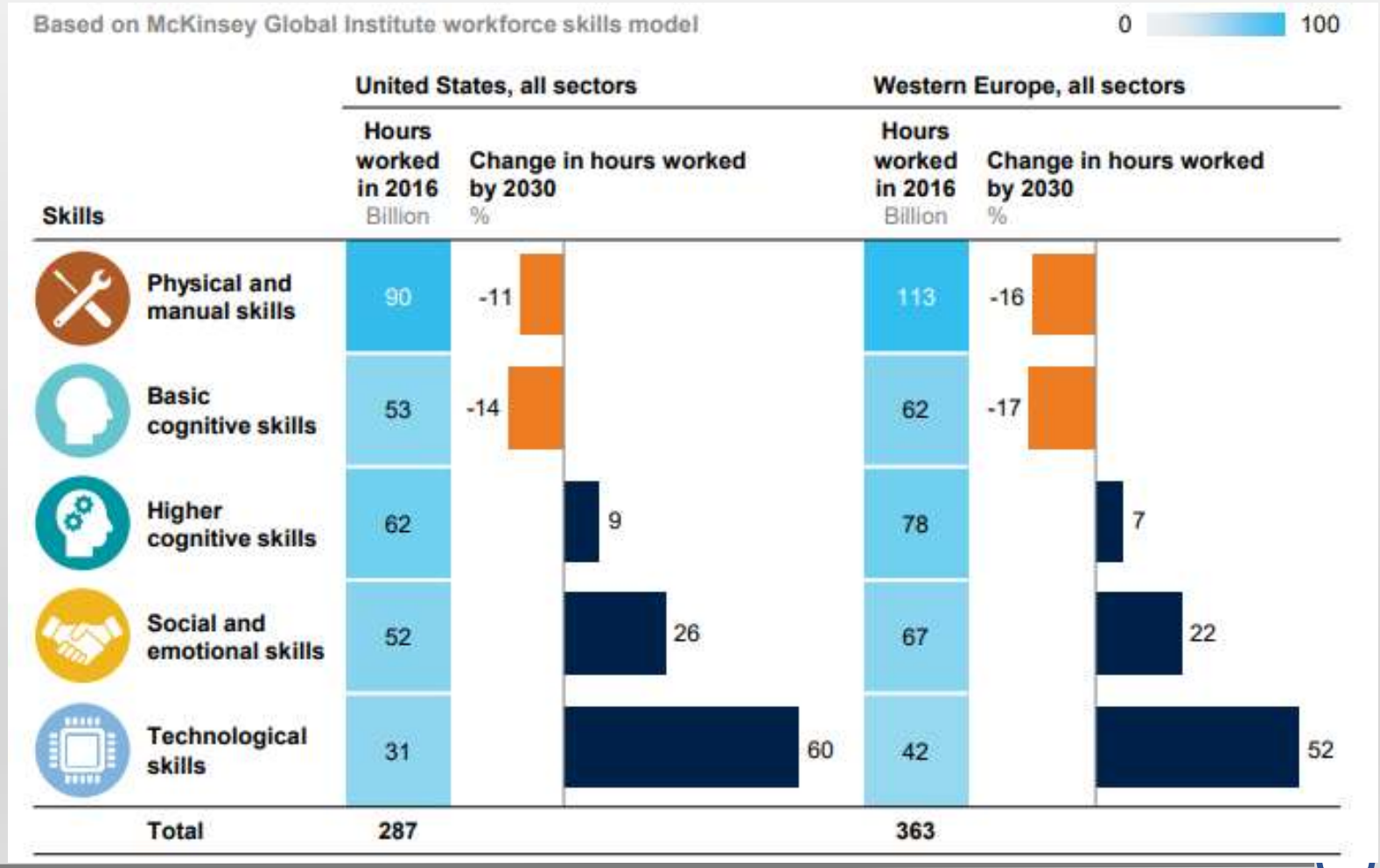
The job landscape in 2025

Automation and AI will accelerate the shift in skills that the workforce needs.



Source: McKinley Global Institute workforce skill model

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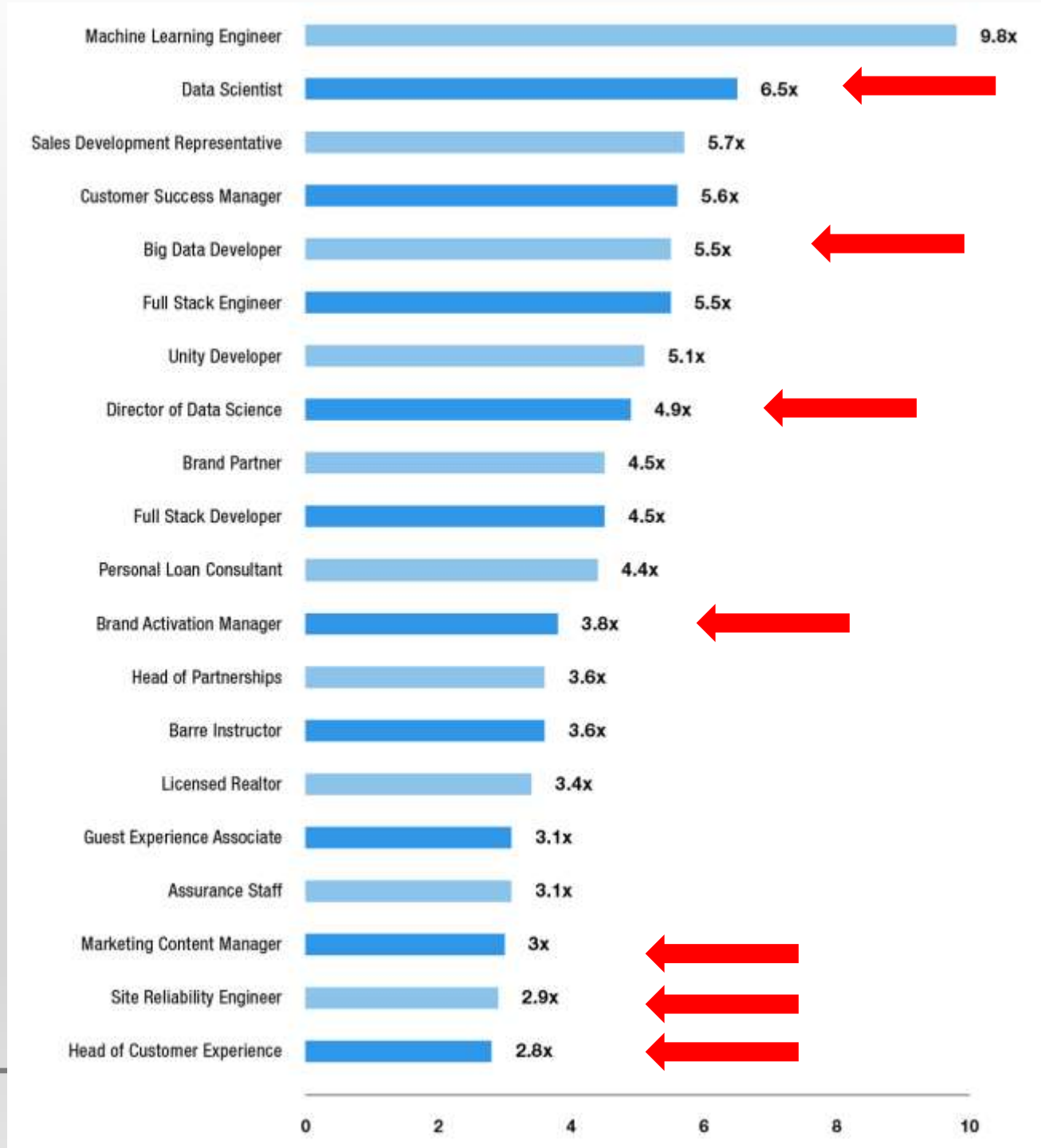
Top 20 emerging jobs:

rate of growth from 2012 to 2017

In evidence jobs related to AI

Source: Linkedin. 2019



Italy: emerging and redundant job roles

Source: *Future of Jobs Survey 2020, World Economic Forum.*

EMERGING

1.	AI and Machine Learning Specialists
2.	Internet of Things Specialists
3.	Data Analysts and Scientists
4.	Digital Transformation Specialists
5.	Assembly and Factory Workers
6.	Project Managers
7.	Process Automation Specialists
8.	General and Operations Managers
9.	Big Data Specialists
10.	Application engineers

REDUNDANT

1.	Data Entry Clerks
2.	Administrative and Executive Secretaries
3.	Accounting, Bookkeeping and Payroll Clerks
4.	Business Services and Administration Managers
5.	Assembly and Factory Workers
6.	Accountants and Auditors
7.	Human Resources Specialists
8.	Financial and Investment Advisers
9.	Electronics and Telecommunications Installers and Repairers
10.	Credit and Loans Officers

Top 15 emerging competences in 2025

- New categories of jobs will emerge, partly or wholly displacing others
- 65% of children entering primary school today will ultimately end up working in completely new job types that don’t yet exist.

1	Analytical thinking and innovation
2	Active learning and learning strategies
3	Complex problem-solving
4	Critical thinking and analysis
5	Creativity, originality and initiative
6	Leadership and social influence
7	Technology use, monitoring and control
8	Technology design and programming
9	Resilience, stress tolerance and flexibility
10	Reasoning, problem-solving and ideation
11	Emotional intelligence
12	Troubleshooting and user experience
13	Service orientation
14	Systems analysis and evaluation
15	Persuasion and negotiation

Source: *Future of Jobs Survey 2020, World Economic Forum.*

WORLD ECONOMIC FORUM

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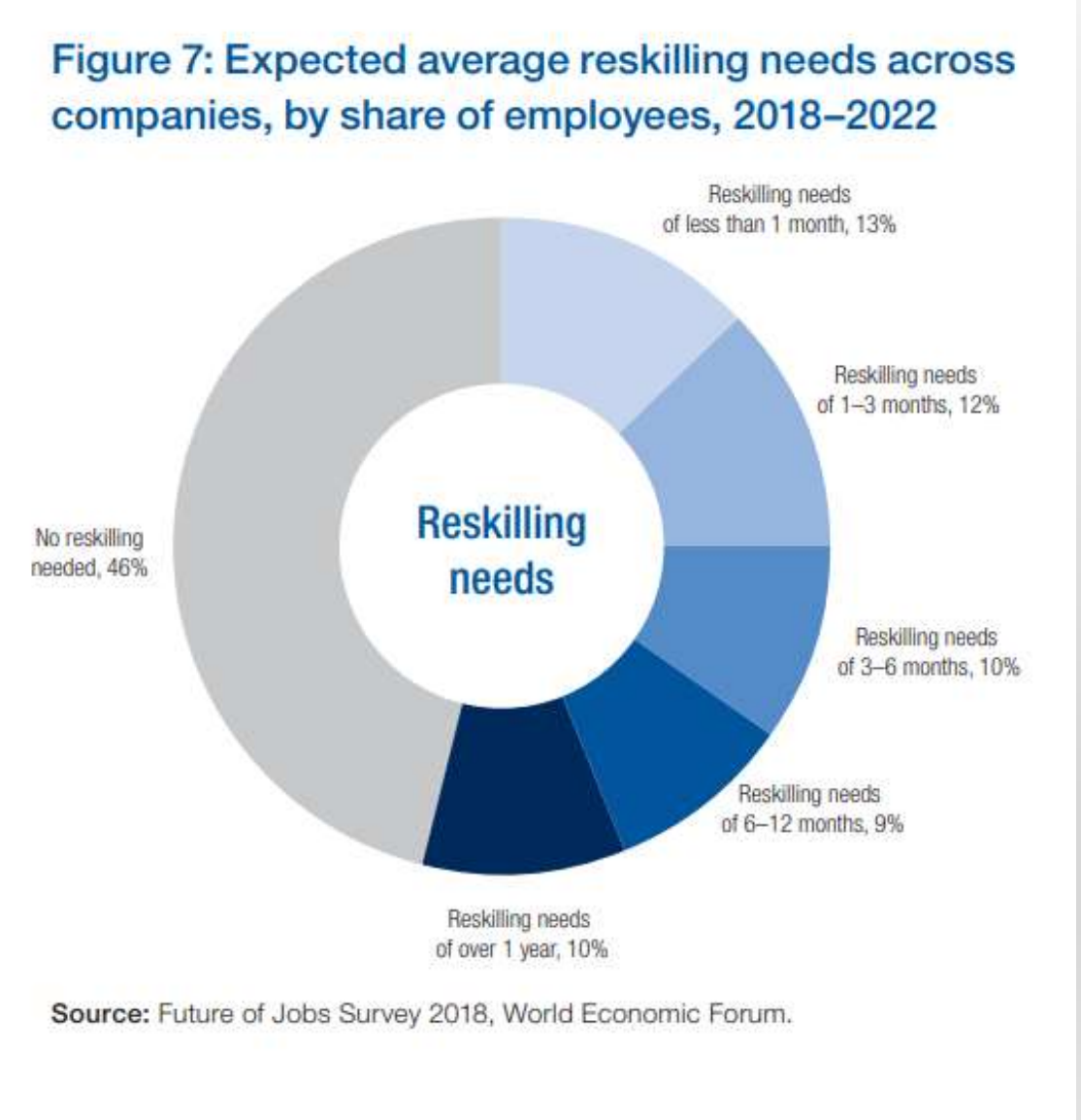
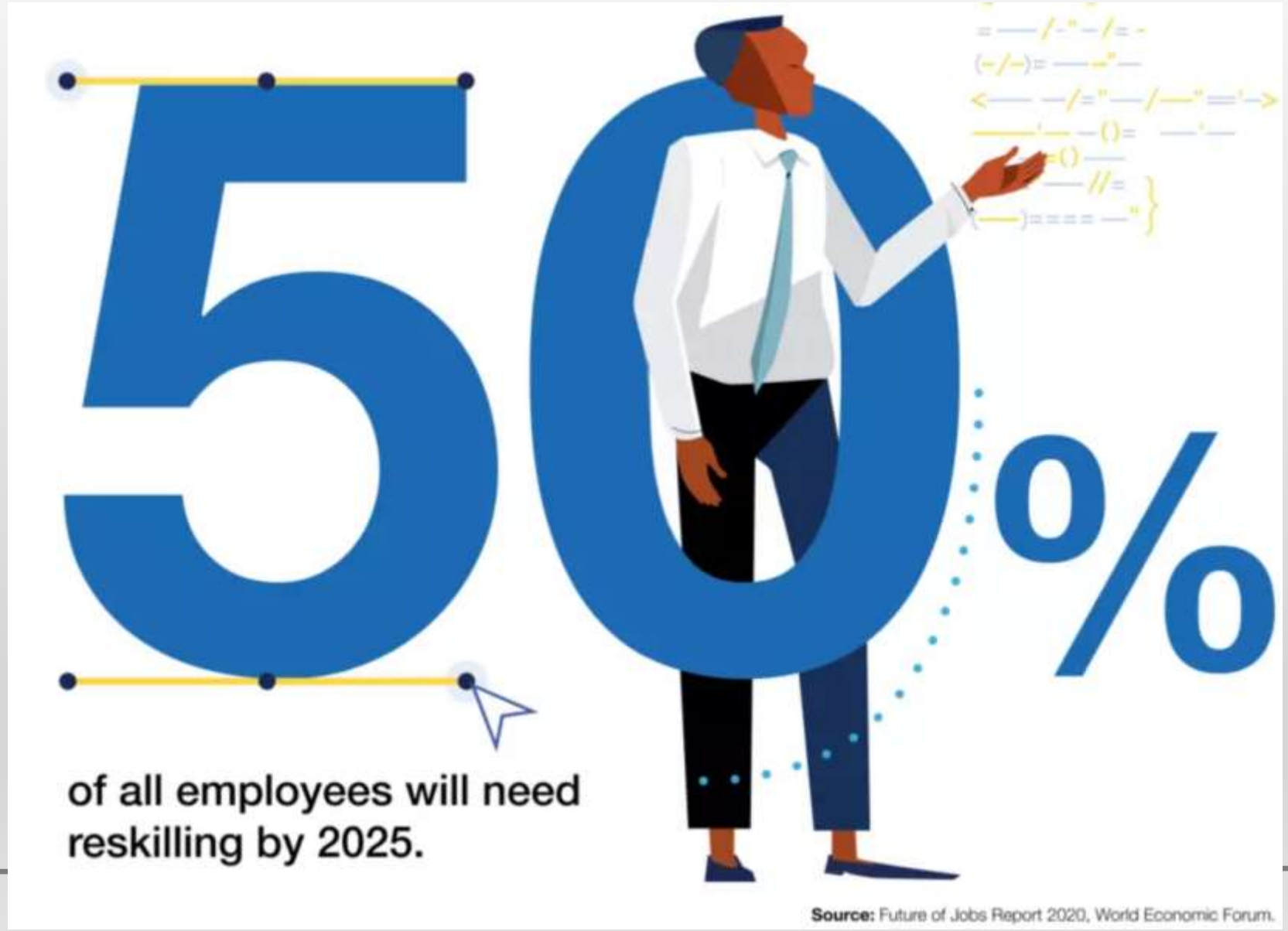
Robots are coming !!!! Reskilling needs

- there's a "growing skills instability"
  - where technology changes the profiles of many current jobs
  - different competencies are required.
- It estimates that more than half of all employees will require significant re- and upskilling in the coming years.



Reskilling needs by 2025



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Optimization vs. creativity and Compassion

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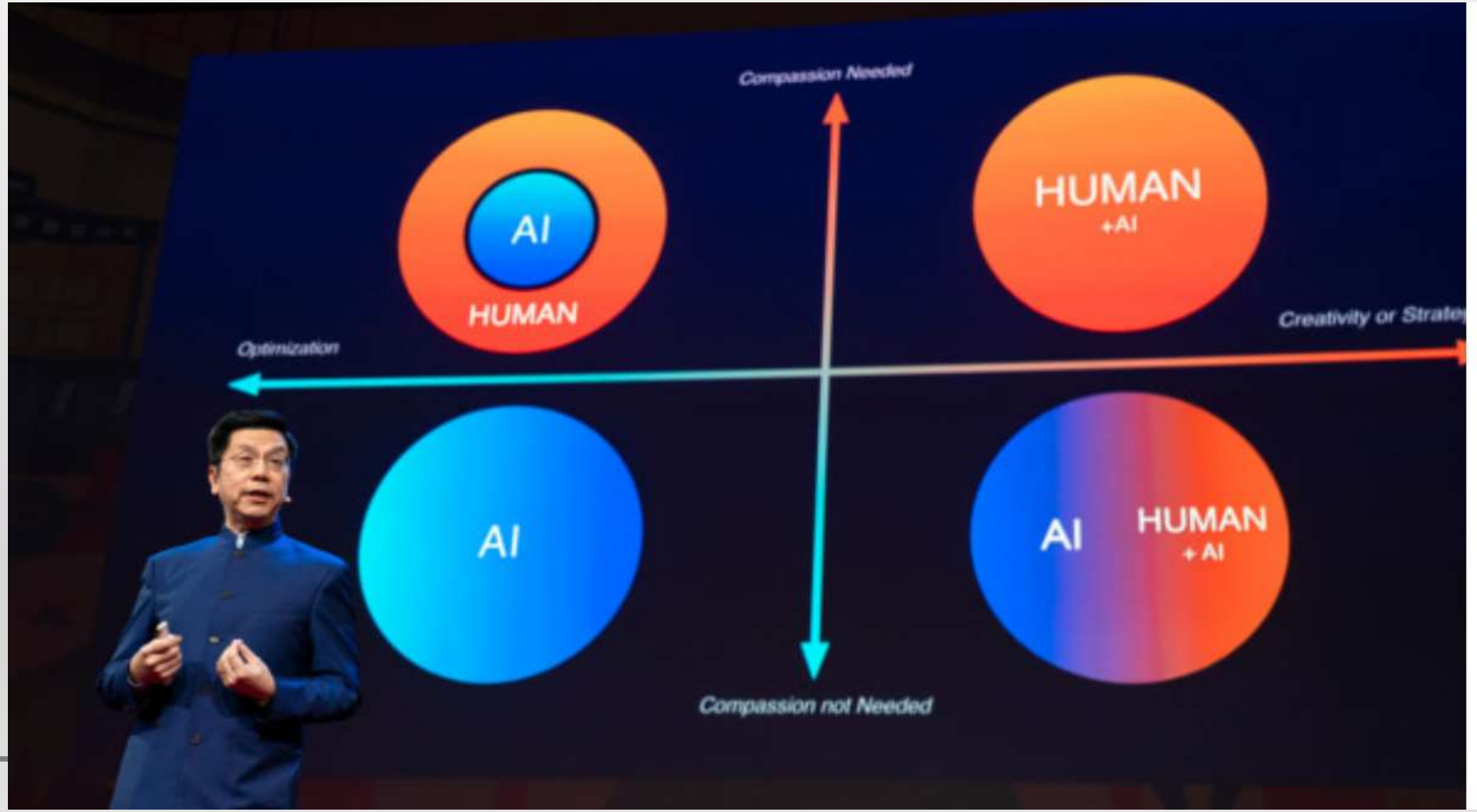
Artificial intelligence and future of jobs

- Kai-Fu Lee: TED 2018 - Vancouver



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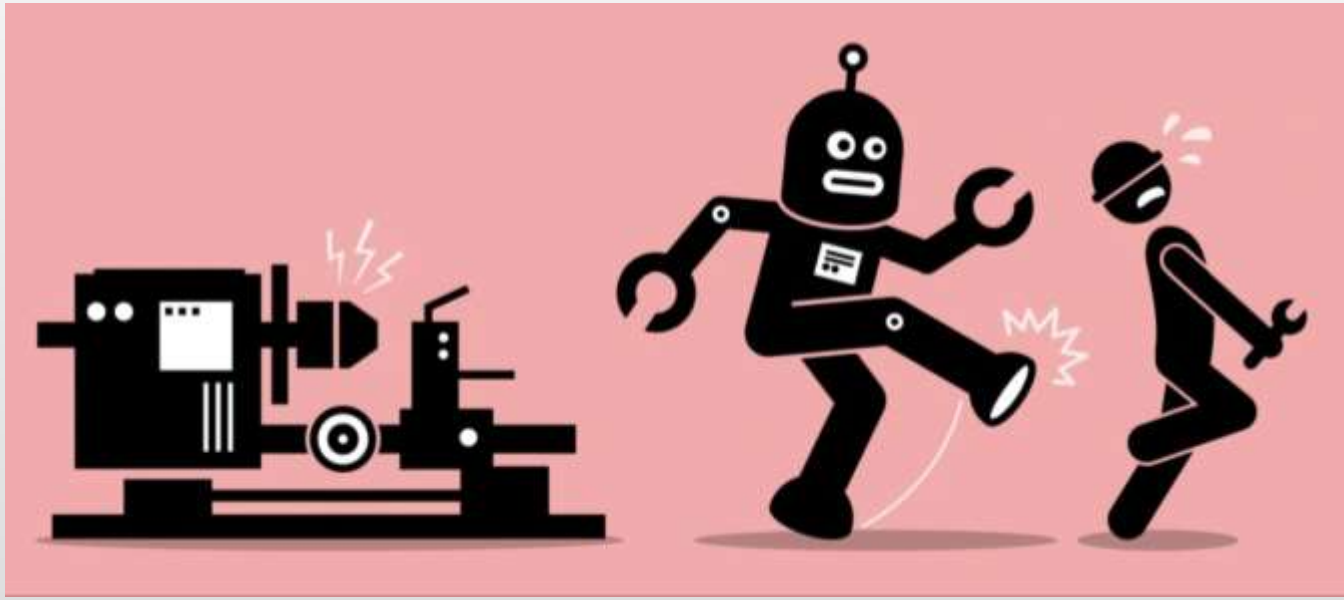
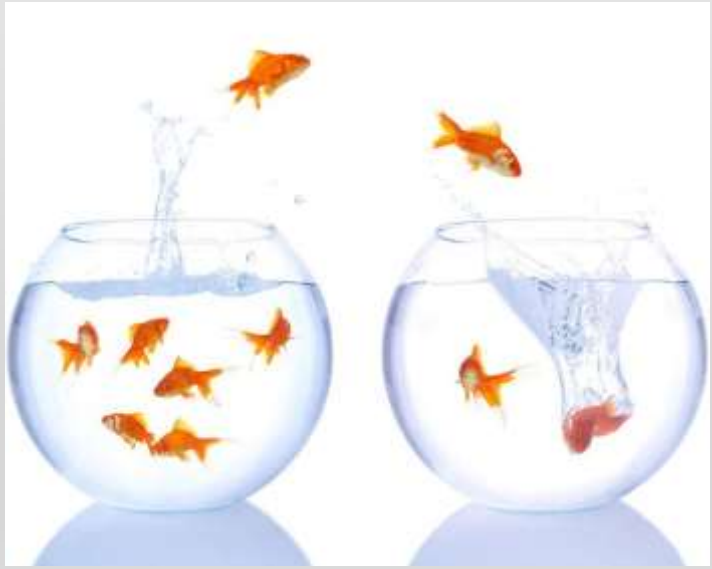
5 new jobs for humans (…when robots will conquer the world)



1. Singing teacher for robots
2. Plastic surgeon for robots.
3. Nurse for robots.
4. Travel agent for robots.
5. Organizers and referees of contests for robots.

Outline of talk

- Digitalization
  - New industry, new manufacturing
  - Technology (r)evolution
  - Theory experiments and simulation
  - HPC and Big Data … towards quantum computing
  - Convergence of technology
  - Digital twins, IoNT and AI
- The future of jobs
  - The job market in 2030
  - Skills and competences required
  - The effect of artificial intelligence
- The role of higher education
  - Science, technology and society
  - Indicators pushing economy



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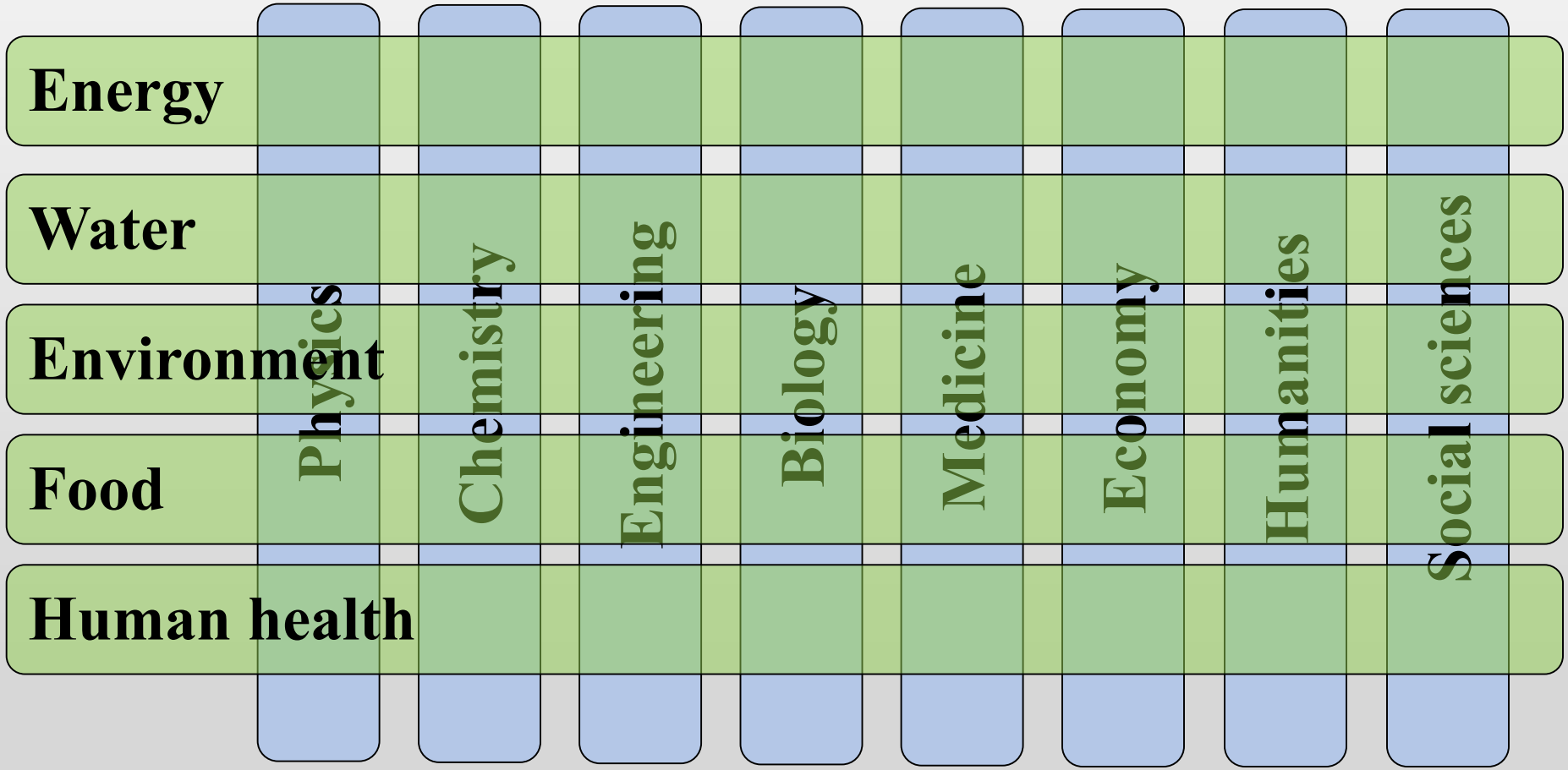
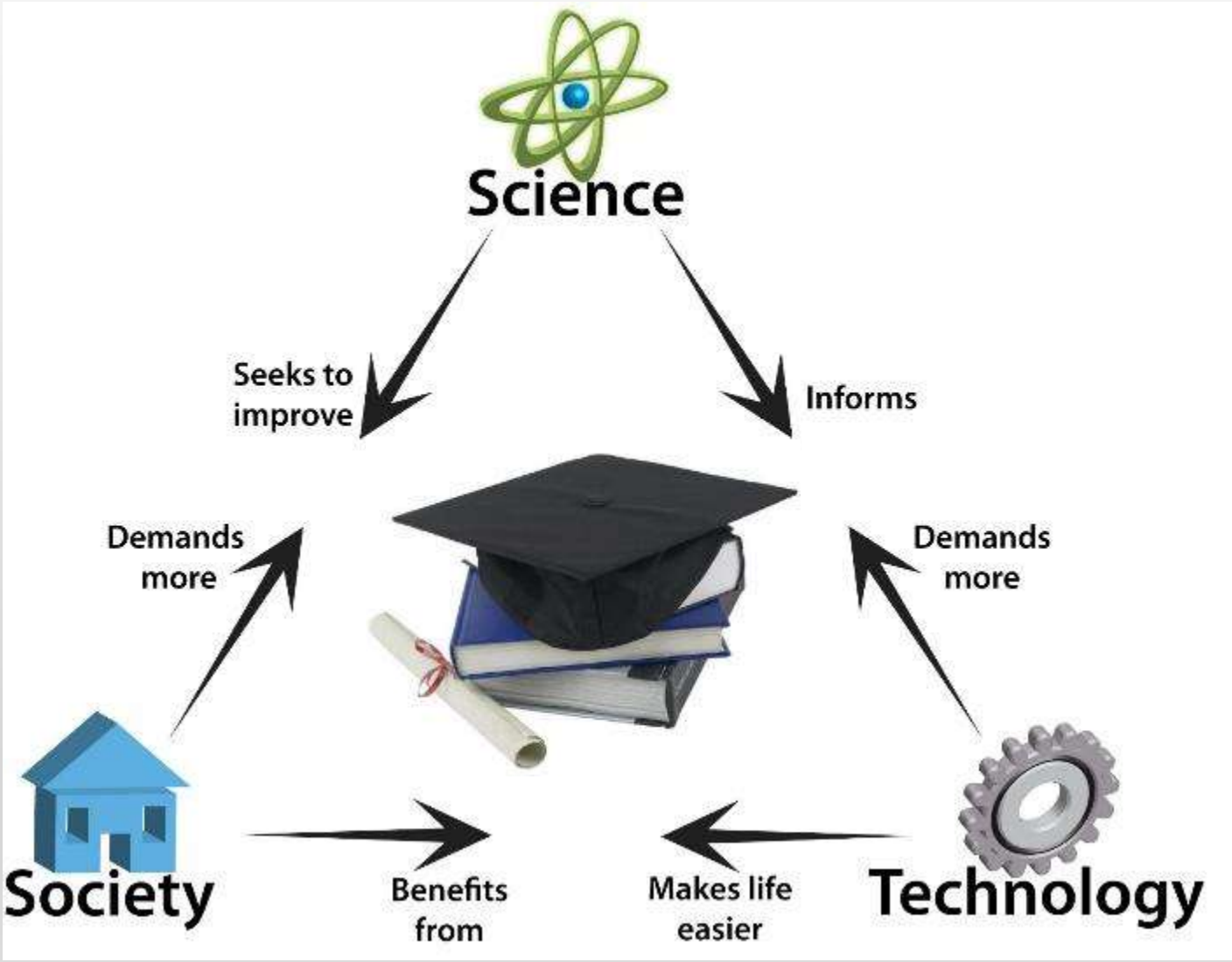
Disciplines …. & challenges for 2020



Science, technology & society



Innovation in Science: role of SSH

Culture

Curiosity

Creativity

Competency

- An investment for the future should stress:
- Blue sky research
- A multidisciplinary advantage
- Creation of critical mass on global challenges – group work
- Research and education and culture
- Knowledge transfer for a competitive economy

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The ‘digital humanism’ of Julian Nida-Rümelin

- XXI century challenge is not technology, **but ethics**
- Hal in 2001: Space Odissey
  - Intelligence hovering **between delirious of omnipotence and childish stupidity** ... nightmare of submission to machines
- Computer is **NOT a semantic machine**:
  - Follows algorithms …
  - … does not understand the meaning of a language
  - ... nor intentions of a human being.

Life is …

Michelangelo, Sistine Chapel: “The Creation of Adam ”, 1510

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Life is … knowledge!

Michelangelo, Sistine Chapel: “The Creation of Adam ”, 1510

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… anyway!!

"If you think education is expensive, try ignorance"

Derek Bok - Presidente of Harvard University 1971-1990

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