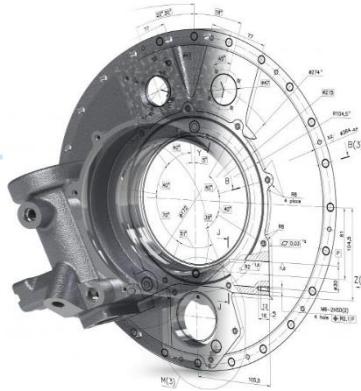




What is Industry 4.0

- An Introduction to Industry 4.0



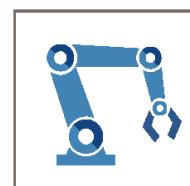
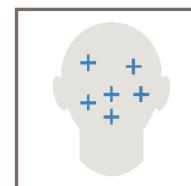
Dr Leo Chen

leo.chen@ieee.org

24/Oct/2022

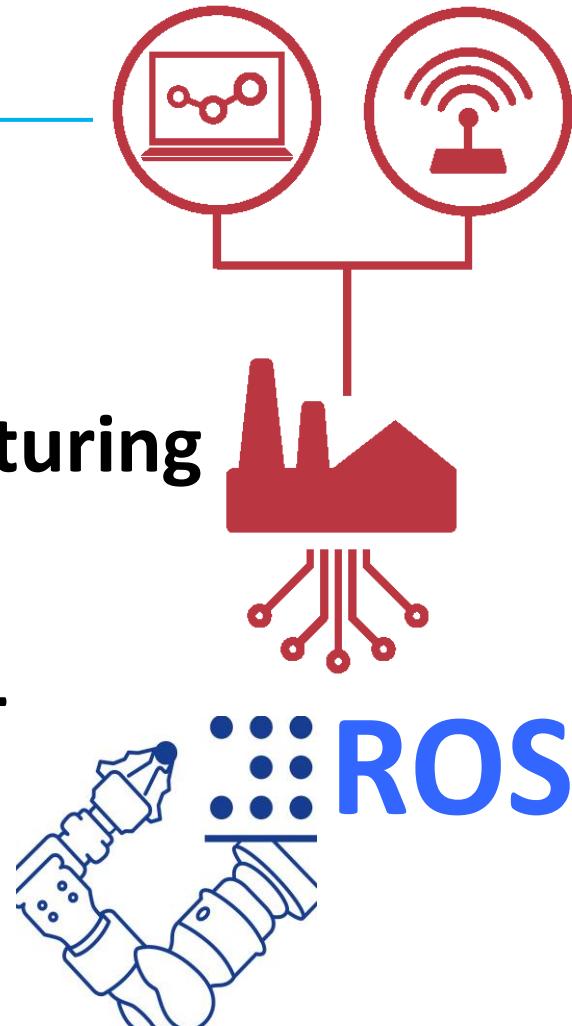
Module Contents

1. Introduction
2. Evolutionary Computation
3. Artificial Neural Network
4. Fuzzy Logic and Fuzzy Systems
5. More AI Subsets
6. AI and Industry 4.0
7. AI Applications
8. Labs
9. Courseworks



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- 2. Basic Steps**
- 3. Traditional vs Digital Manufacturing**
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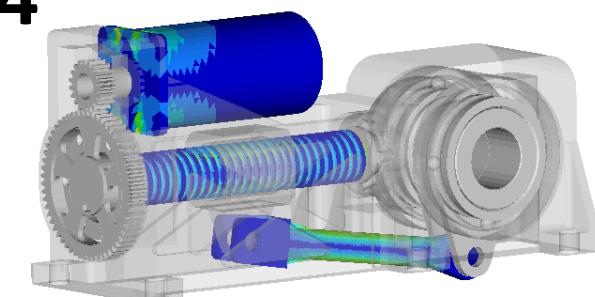
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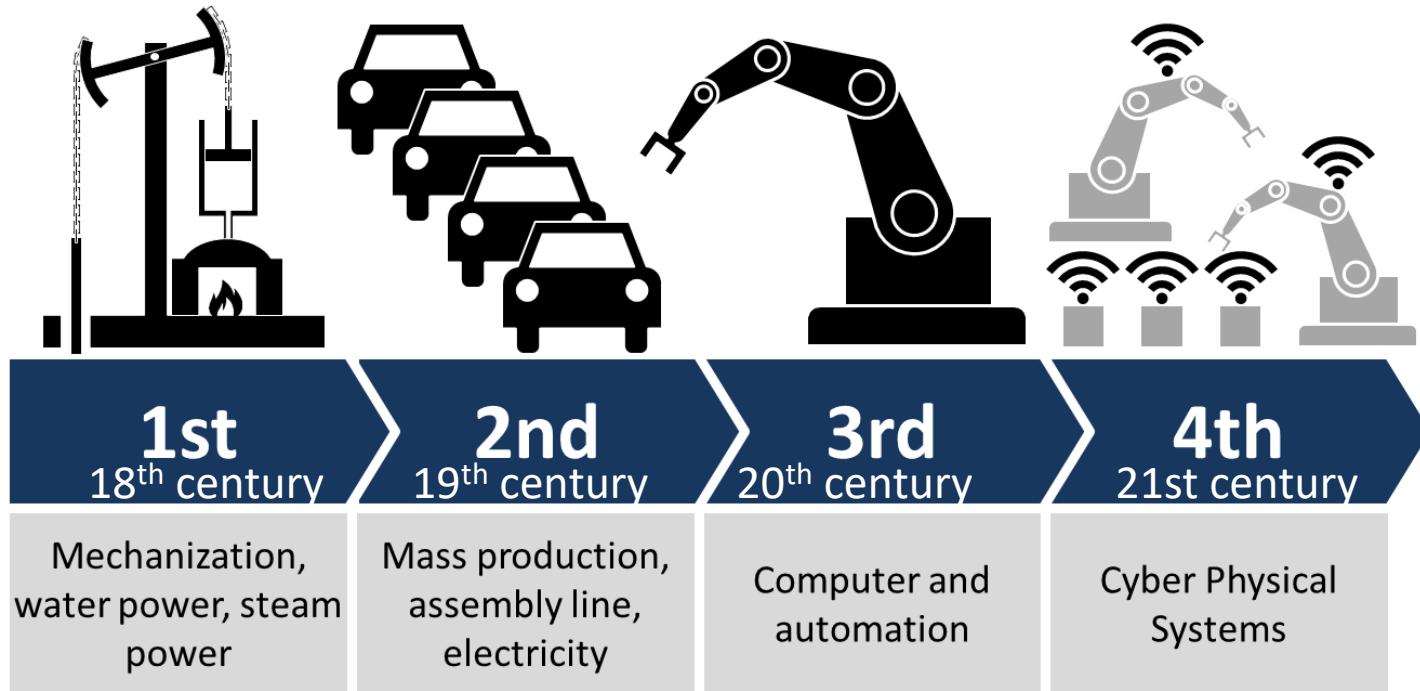
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What is industry 4.0 (i4 == 4IR)

Industry 4.0 (i4) is commonly referred to as **the fourth industrial revolution (4IR)**^[1] has already begun



The 1st Industrial Revolution^[11]

- Steam Power
- Water Power
- Mechanisation



The 1st Industrial Revolution

- Began in **mid-18th century** England
- Invention of the **steam engine**, converting **heat energy into movement** (**energy conversion**)
- Beforehand people were almost completely dependent of **plants as primary sources of energy**.
- Steam power was used to directly **drive spinning and weaving equipment** of the growing **textile** industry in England.

Textile industry in the 1st Industrial Revolution

- The **textile industry** was experiencing a steep rise thanks to the large supply of cotton imported from **Britain's colonies in North America**.
- The cotton was **cheap** as it was almost completely grown by slaves.
- The colonies **supplied** British textile industry with cotton and provided a **market** to sell the **finished goods**.

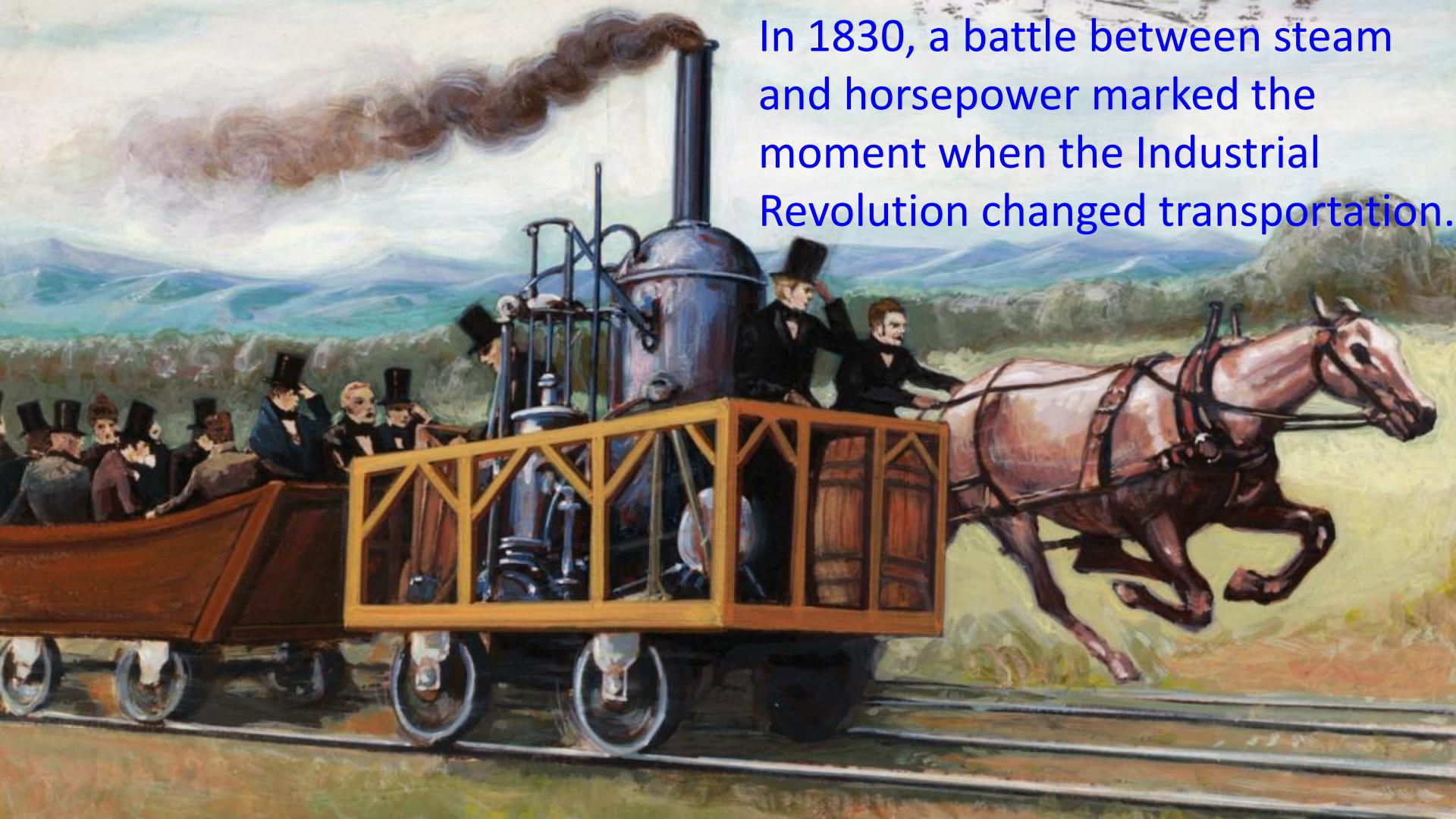
A few Key Inventions [13-18]

- 1733 flying shuttle *John Kay*
- 1763 steam engine *James Watt*
- 1764-1765 spinning jenny *James Hargreaves*
- 1779 spinning mule *Samuel Crompton*
- 1785 rude power loom *Edmund Cartwright*
- 1789 wool-combing machine *Edmund Cartwright*
- 1825 the first Railway (**Locomotive**)

telegraph communications, dynamite, photograph,
typewriter, electric generator, etc.

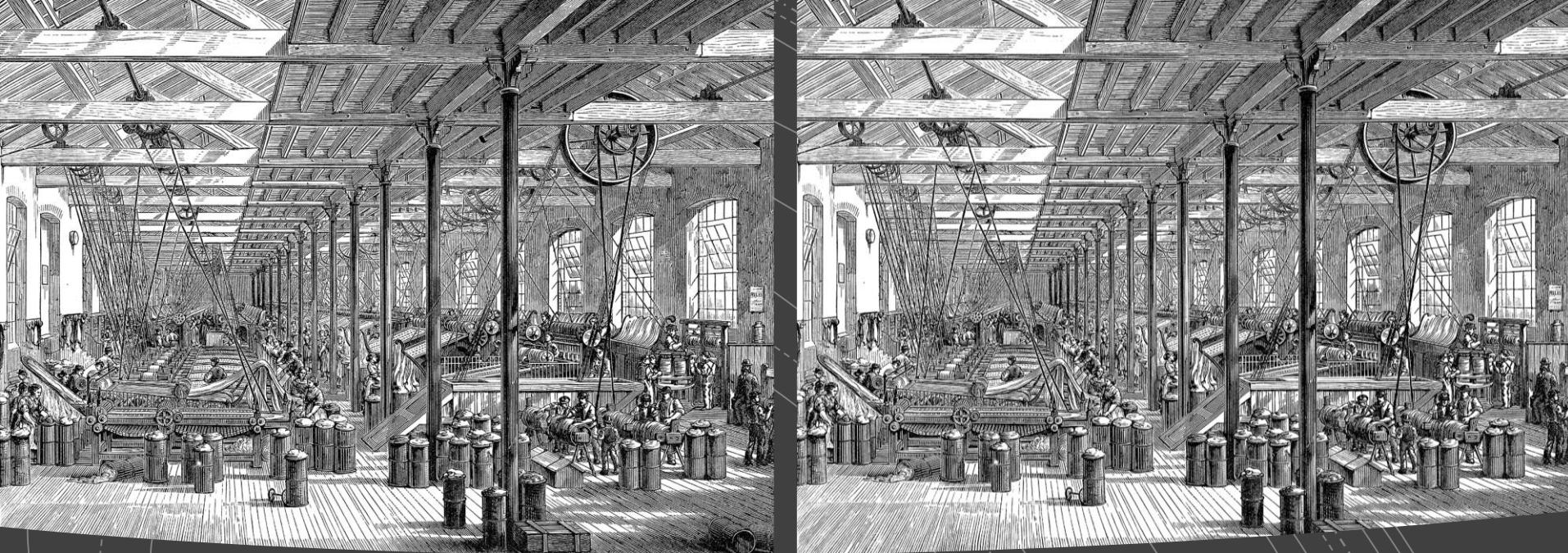


Spinning Jenny



In 1830, a battle between steam and horsepower marked the moment when the Industrial Revolution changed transportation.

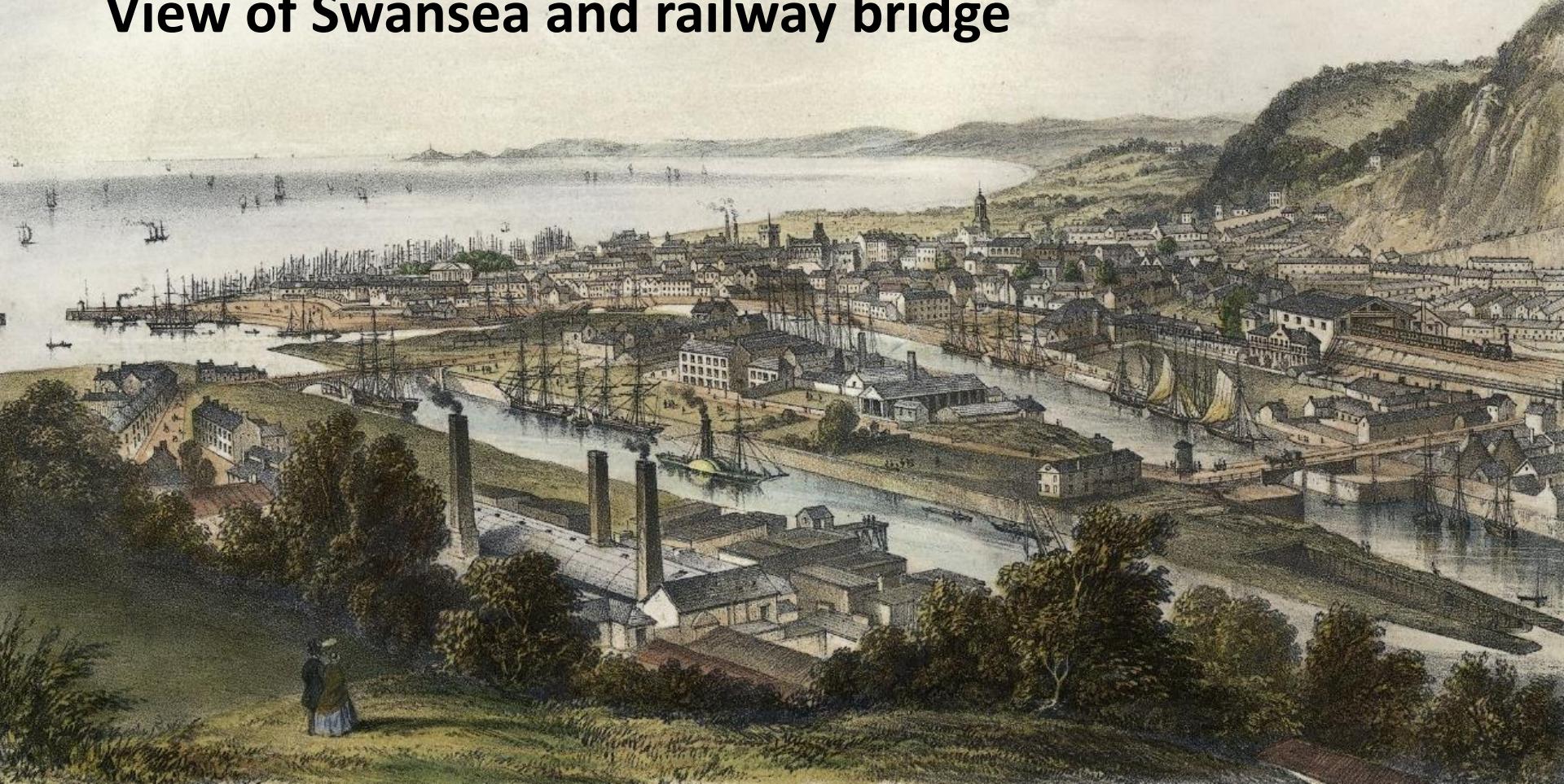


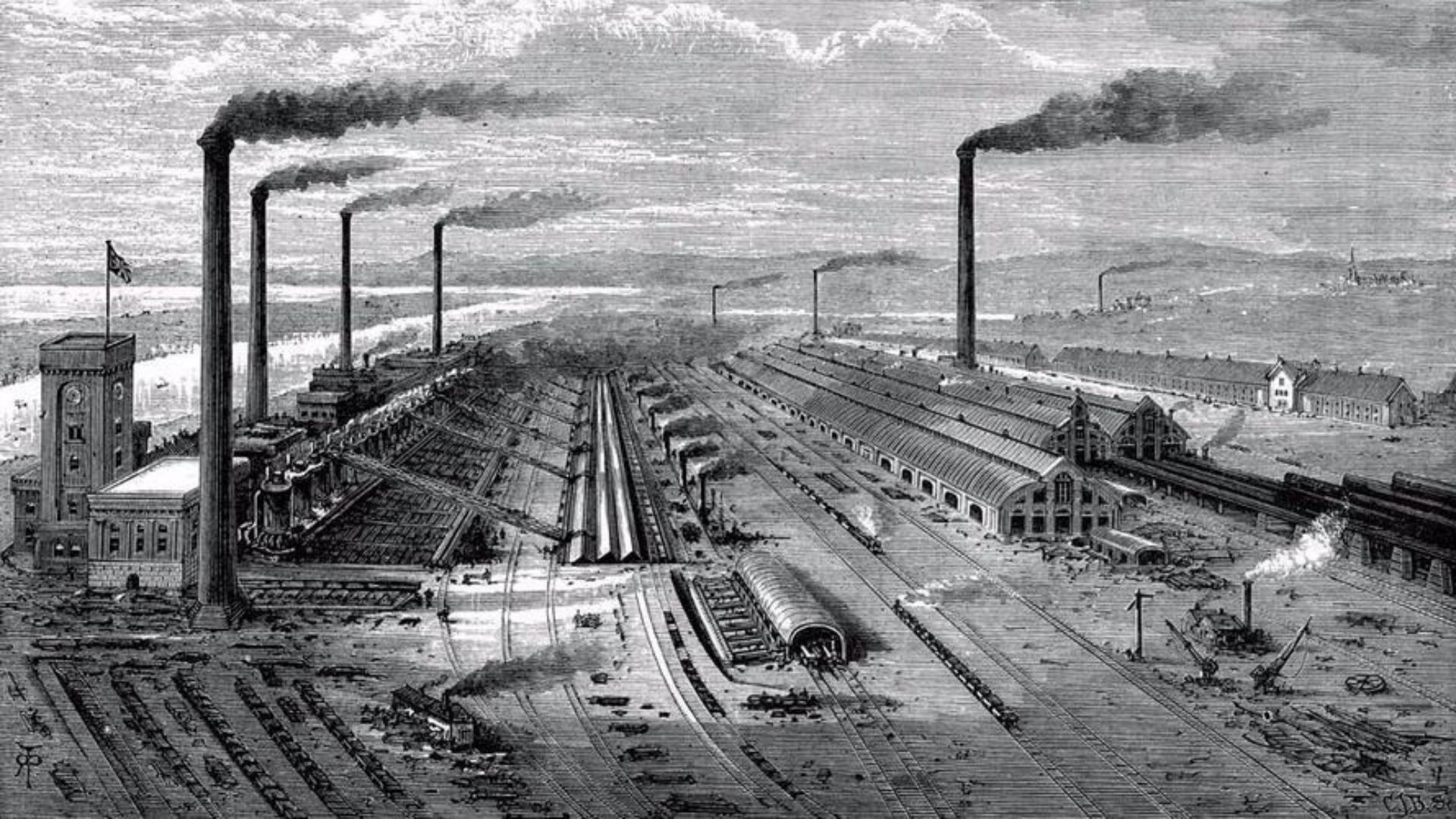


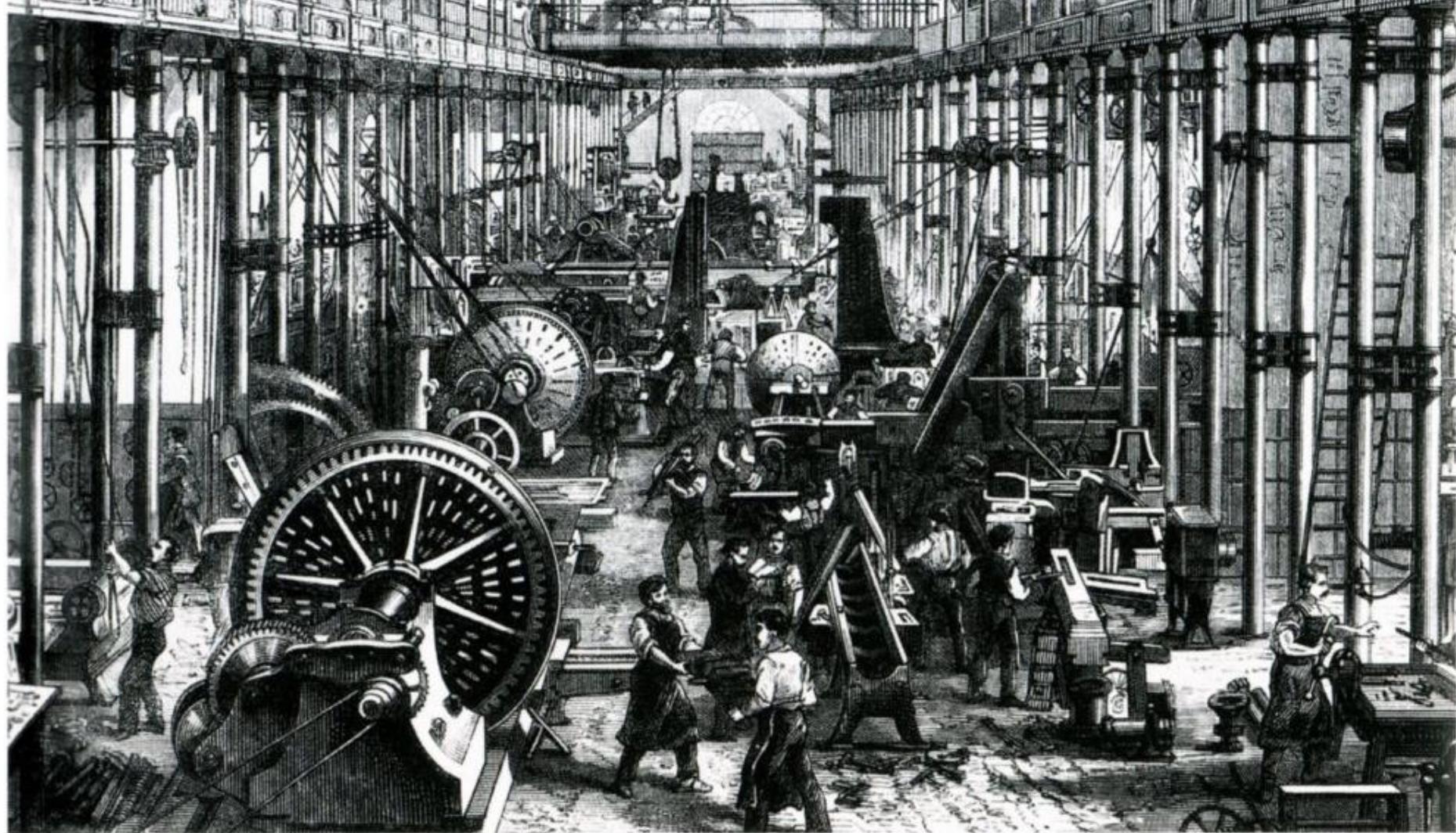
The 2nd Industrial Revolution

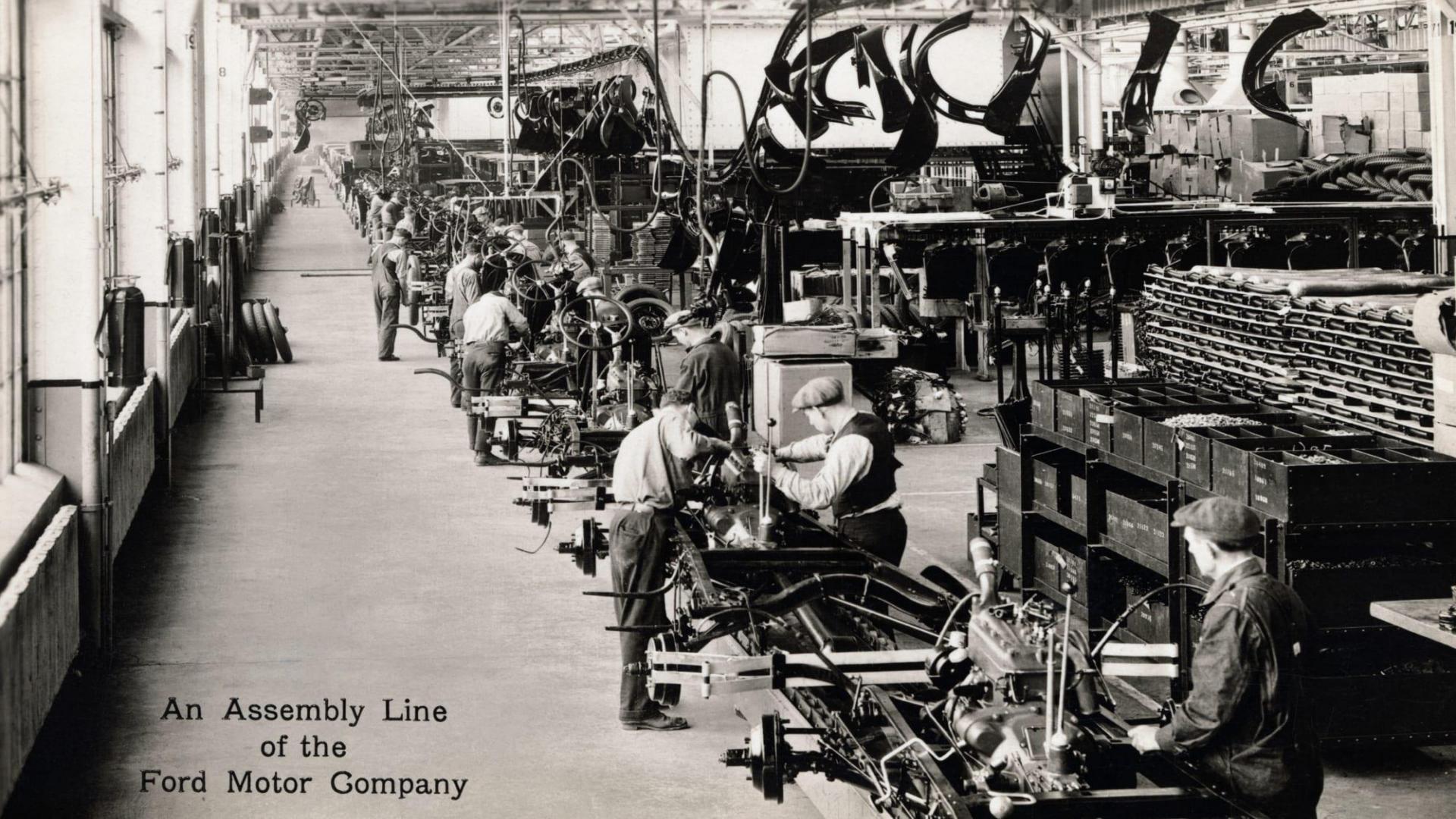
- Electricity
- Mass production
- Assembly Line

View of Swansea and railway bridge









An Assembly Line
of the
Ford Motor Company



Morning Brief: The Third Indus...

cfr.org



The Fourth Industrial Revolutio...
arabnews.com



How Industry 4.0 affects SME...
researchoutreach.org



Indonesia May Become Asean ...
jakartaglobe.id



The third industrial revolution ...
engineeringcolleges.video.blog



Pakistan lagging behind in em...
tribune.com.pk



Opinion: The Industrial Revolut...
marketwatch.com



The story about: The third indu...
trendlog.dk



The 3rd Industrial Revolution

- Computer, Internet
- Automation, Robotics

Jobs with Wozniak (right) in in the garage of Jobs' parents in 1976







5K
ADVANTAGE

flex

Control Number
FLURC104

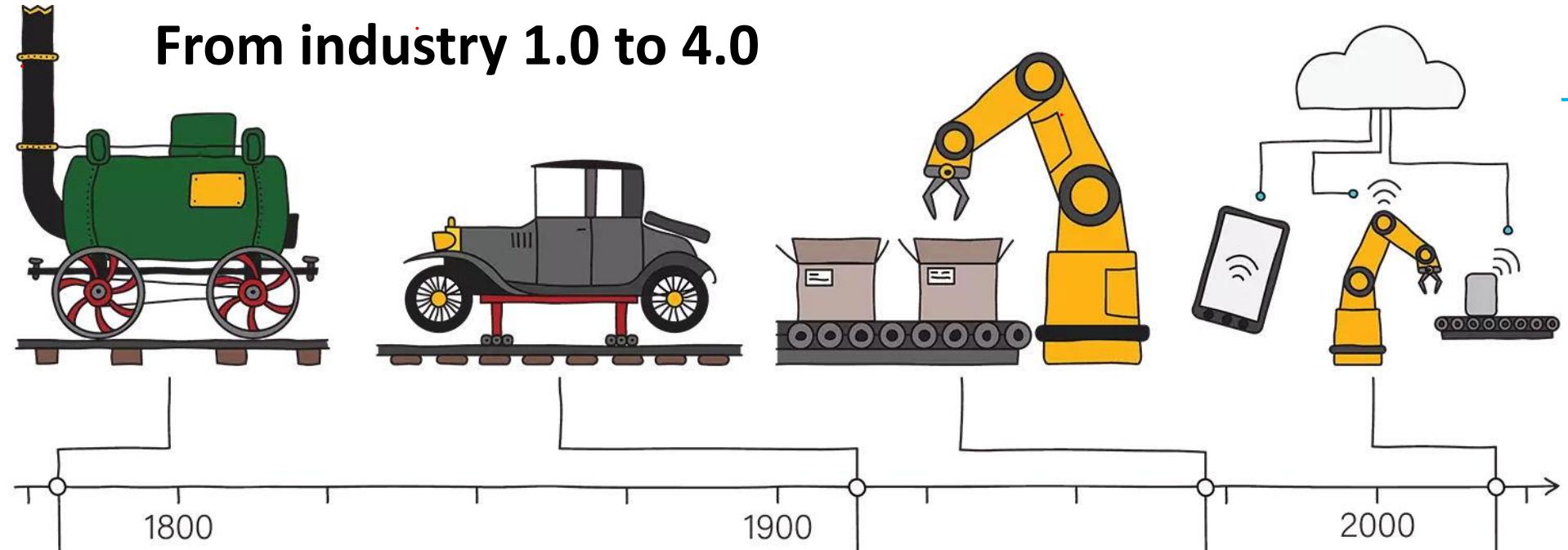


The 4th Industrial Revolution

- Cyber-physical system



From industry 1.0 to 4.0



Industry 1.0

The Industrial Revolution begins.
Mechanization of manufacturing with
the introduction of steam and water
power

Industry 2.0

Mass production assembly lines using
electrical power

Industry 3.0

Automated production using electronics,
programmable logic controllers (PLC), IT
systems and robotics

Industry 4.0

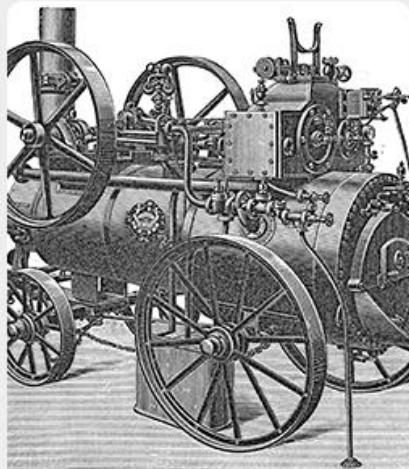
The 'Smart Factory'. Autonomous decision
making of cyber physical systems using
machine learning and Big Data analysis.
Interoperability through IoT and cloud
technology.

From industry 1.0 to 4.0

FIRST

Mechanical Production

steam, water

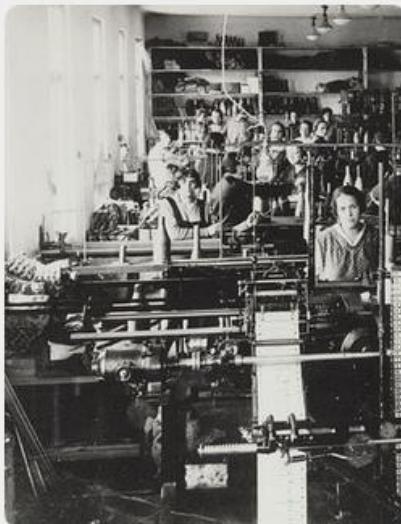


1784: First power loom

SECOND

Mass Production

electricity



1870: First assembly line

THIRD

Digital

IT, Electronics



1969: First programmable logic controller

FOURTH

Cyber physical systems

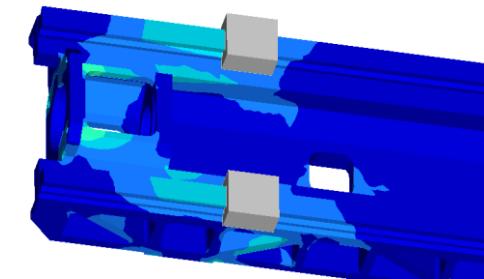
physical, digital, biological



Today: Robots learning from humans

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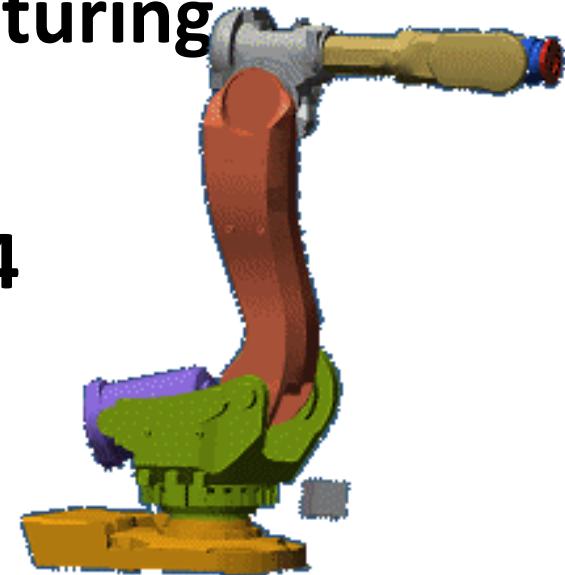
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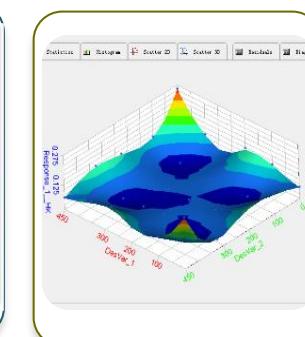
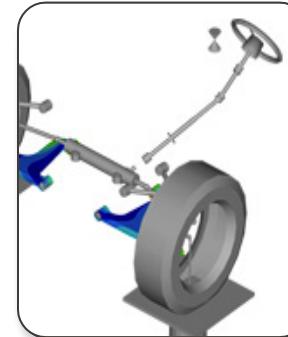
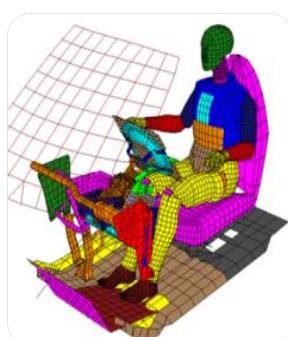
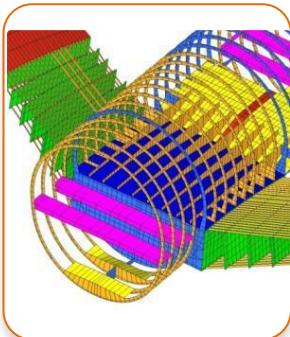
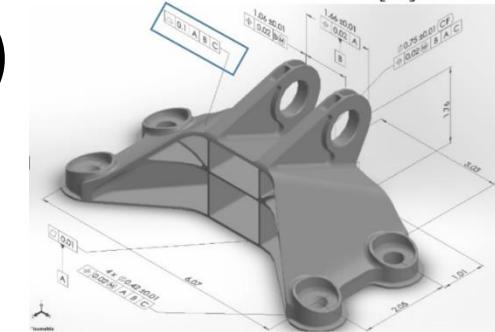
7. Reference



Basic Steps

Basically, 4IR can be summarised as the following steps:

1. Virtual Prototype (e.g. Digital prototype)
2. **Digital Manufacturing**
3. Physical Prototype or Products
4. Intelligent Service (e.g. Product Lifecycle Management)



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Contour Plot
Stress(vonMises, Max)
Analysis system
2.060E+04
1.831E+04
1.602E+04
1.374E+04
1.145E+04
9.157E+03
6.868E+03
4.578E+03
2.289E+03
5.906E-11
No result
Max = 2.060E+04
Flexbody Elements 1417
Min = 5.906E-11
Flexbody Elements 226



Contour Plot
Displacement(Mag)
Analysis system
6.246E+01
4.164E+01
3.470E+01
2.776E+01
2.082E+01
1.410E+01
1.010E+00
0.000E+00
No result
Max = 6.246E+01
Flexbody Nodes 1157
Min = 0.000E+00
Flexbody Nodes 3

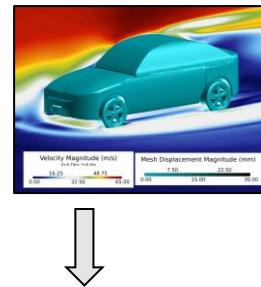
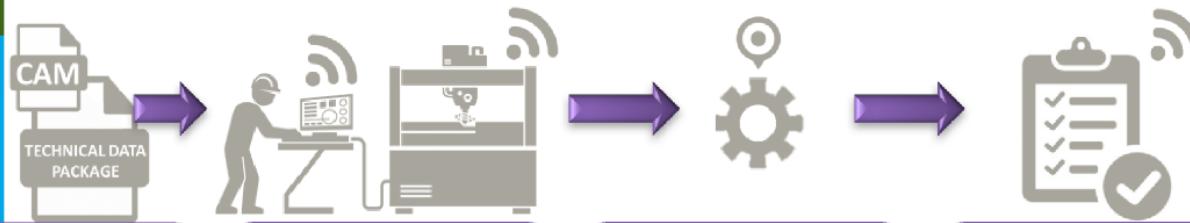


Traditional vs Digital Manufacturing

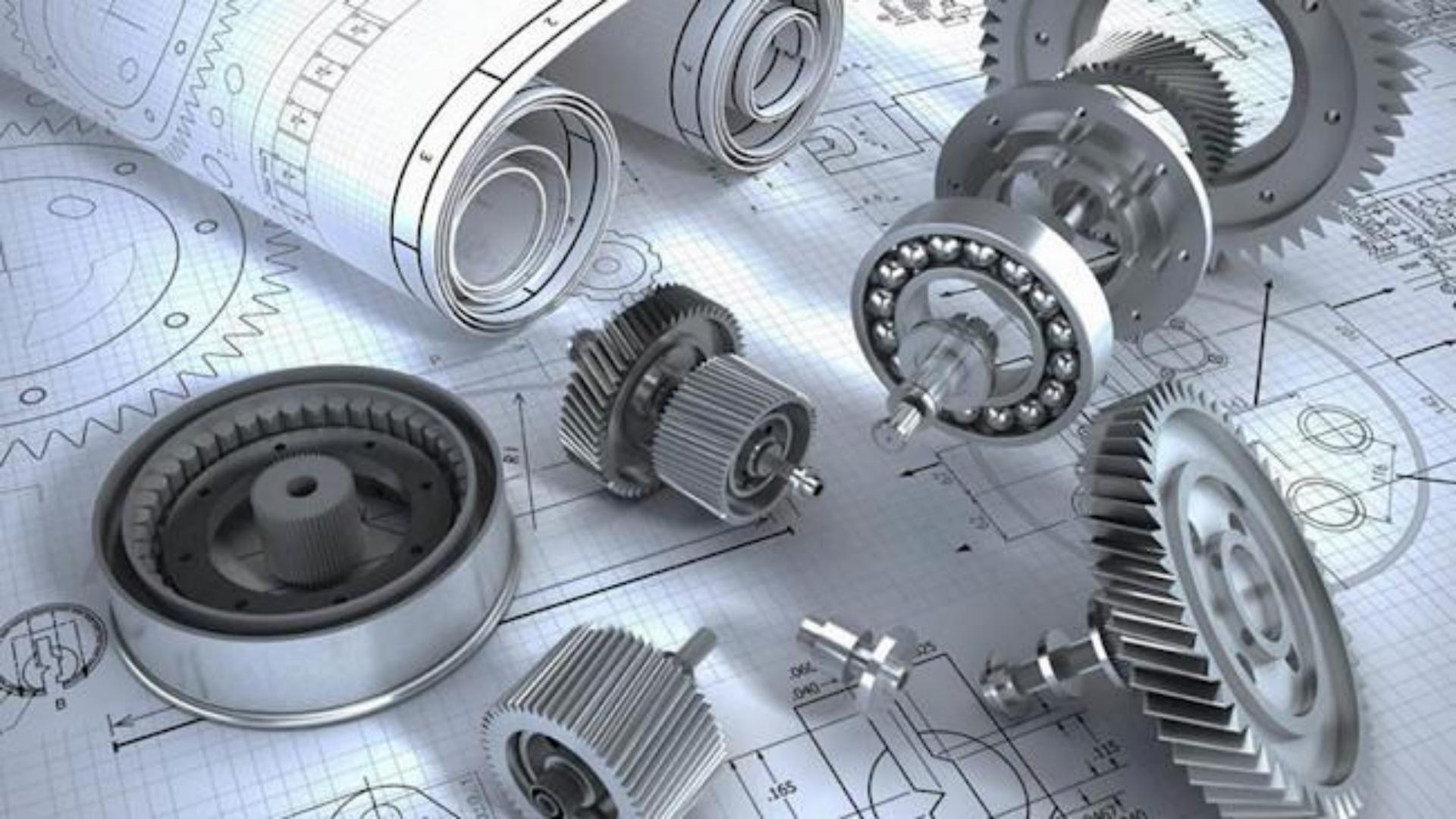
Traditional



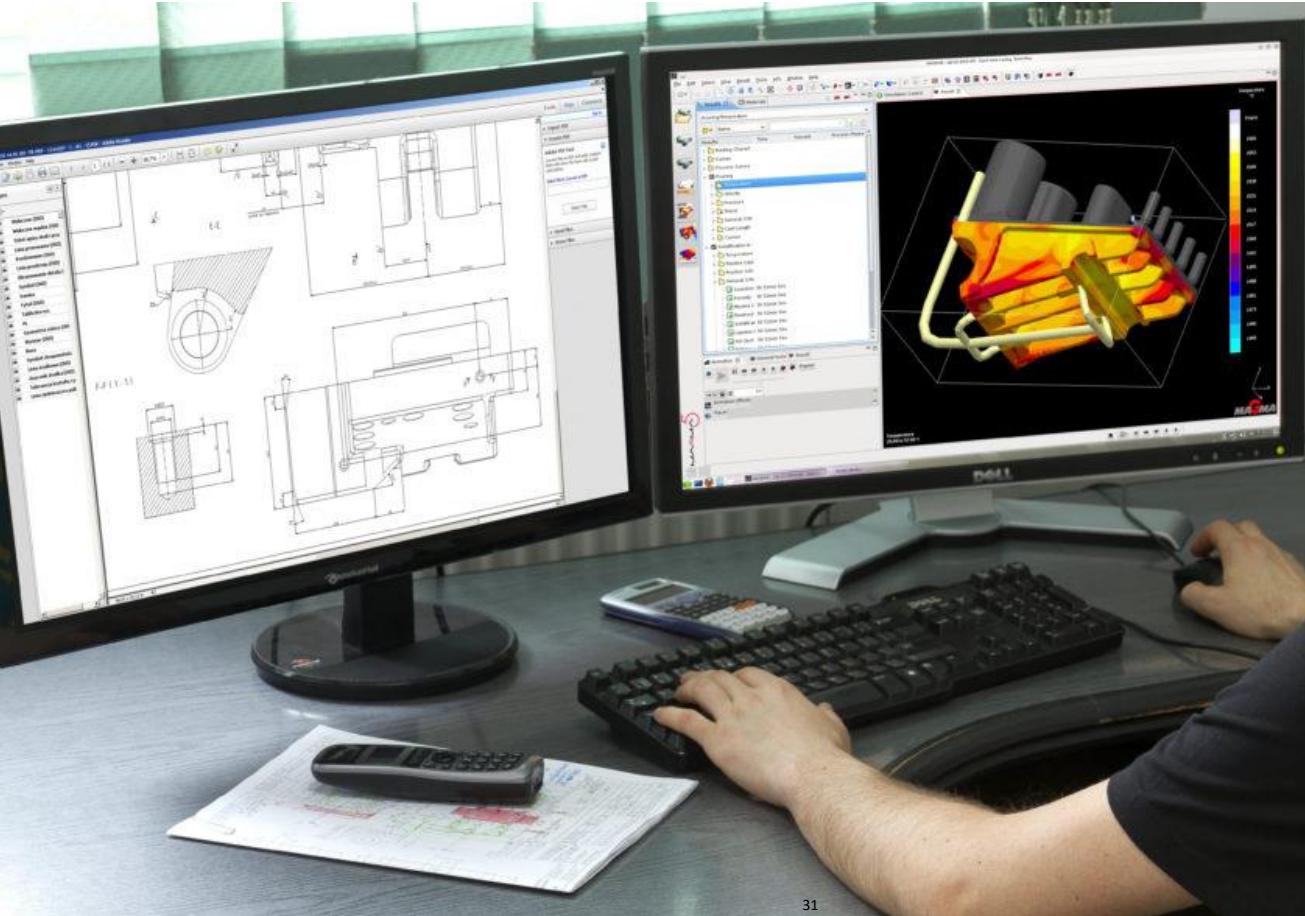
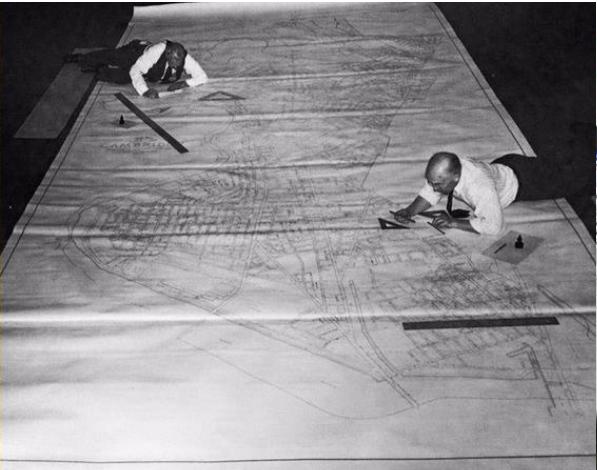
Digital



3D printing and CNC machining



Traditional vs Digital Manufacturing



Industry 4.0



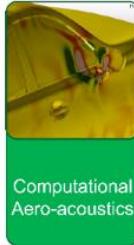
Conceptual Thoughts



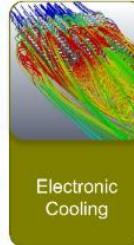
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Thermal Management



Computational
Aero-acoustics



Fluid-
Structure
Interaction



Non-
Newtonian
Flow
Simulation

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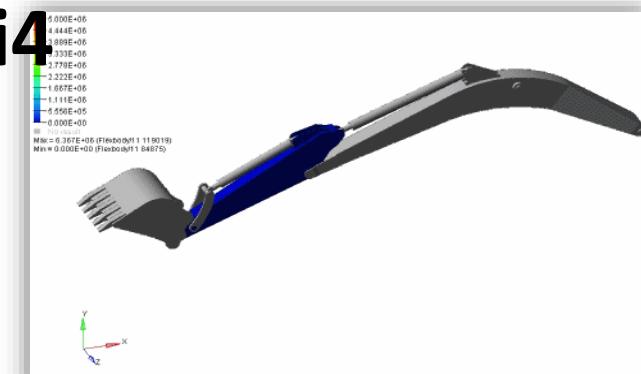
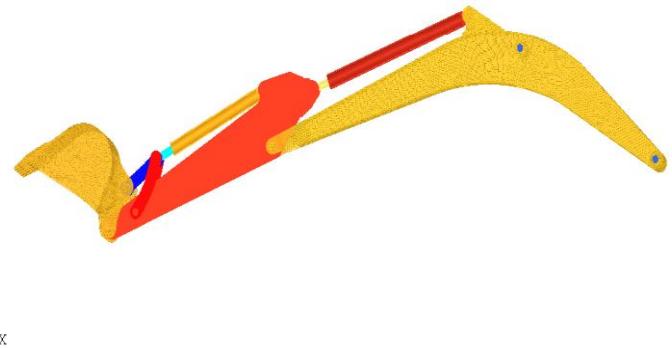
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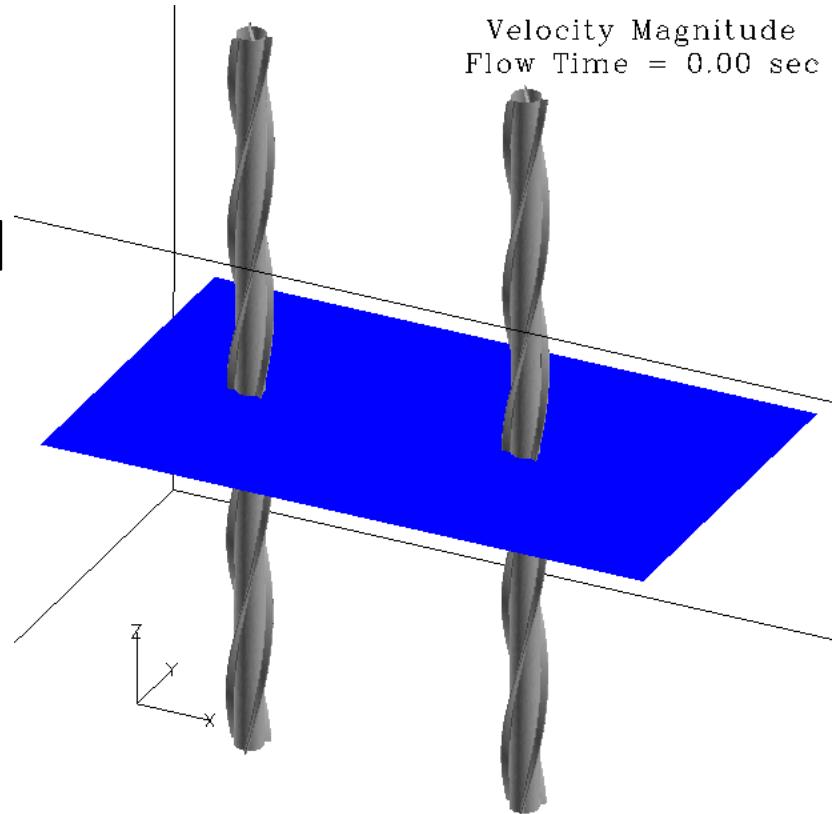
6. Tutorials and Courseworks

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Key Benefits

- **Fast Production**
- **High Performing Prototypes and Productivity**
- **Real-time Inventory Monitoring**
- **Cost Reduction**
- Close-to-reality **Testing**
- **Market Success Predictability**



Automotive^[9]

The benefits of digitalisation for the UK Automotive Industry.

Interviews with vehicle manufacturers and suppliers suggested that the following benefits

Productivity increase

3-5%



Reduction in machine downtime

20-35%



Increase in productivity of technical disciplines such as production planning

30-50% Two teal upward-pointing arrows icon, indicating increased productivity in technical disciplines.

Inventory reduction

12-20%



Cost of poor quality reduction

5-12%



Forecasting accuracy improvement – up to

80%



Reduction in time to market

15-25%

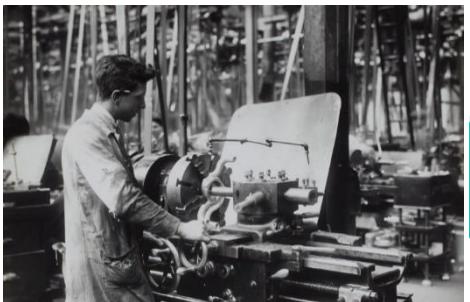


Reduction in plant maintenance costs

15-25%



Automotive^[9]



Castle Bromwich

Jaguar Land Rover

£600 million – Expand its West Midlands manufacturing

Wolverhampton

Jaguar Land Rover

£450 million – Engine Manufacturing Centre

Solihull

Jaguar Land Rover

1,300 new jobs investment in lightweight technologies
I-PACE electric concept car announced

Swindon

Honda 500 new employees – Support production of the new 5-door Honda Civic

Honda £200 million – Manufacturing centre in Swindon to produce the next generation 5-door Civic

Sunderland



Nissan £100 million – Production of the new Juke

Nissan New Qashqai and X-Trail models safeguard over 700 jobs into next decade

Infiniti 300 new jobs – Production of the Q30 and QX30 models



Annual total economic benefit by 2035
£8.6 billion



Coventry



London Taxi Company

1,000 new jobs/£250 million investment
Ultra-low emission taxis

£4.3 billion of which relates to vehicle manufacturers



Warwickshire



Zhejiang Geely Holding Group

£50 million – Turn Warwickshire production site into the Group's R&D headquarters

£2.6 billion to suppliers



Bridgend



Ford

£181 million – New low-emission engines at Bridgend plant

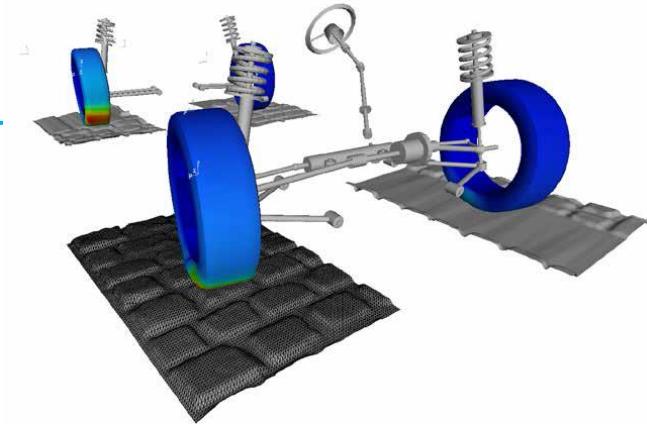
£1.7 billion and relates to the wider economy

Cumulative total economic benefit by 2035
£74 billion



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Supporting Technologies for i4 (a few keywords)

- Cyber-physical Systems (**CPS**)

- **Digital Twins**^[3]

digital twin is a **real-time mapping** of all **components** in the product life cycle using **physical** data, **virtual** data and **interaction** data between them

- Internet of Things (**IoT**)

- **Big Data/Cloud/Blockchain**

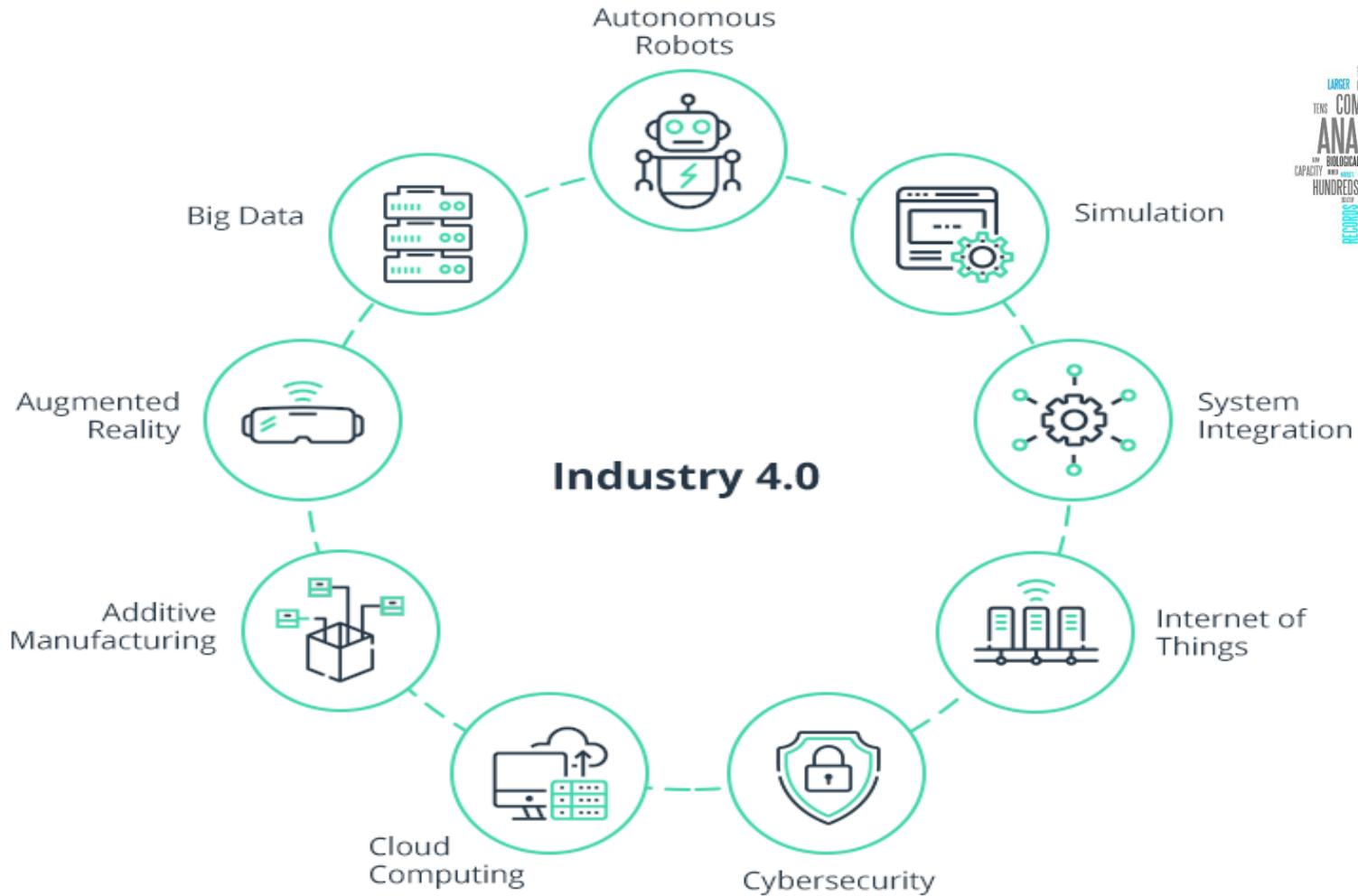
- Artificial Intelligence (**AI**)

- High Performance Computing (**HPC**)

- **5G** Communication

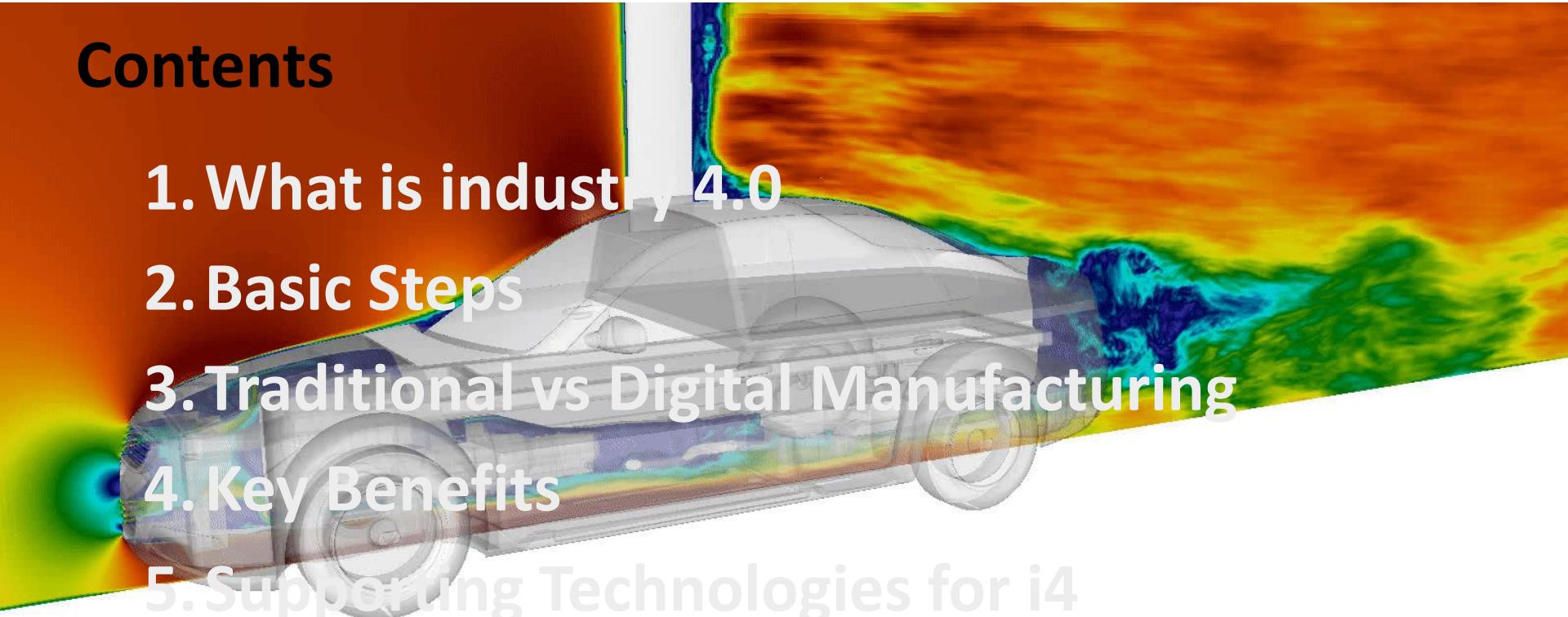
- Virtual Reality (**VR**) and Augmented Reality (**AR**)





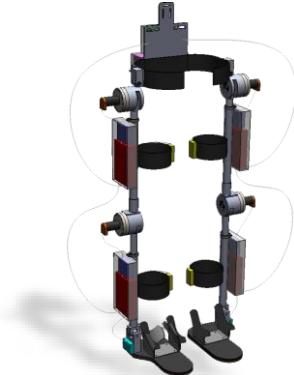
9 Core Technologies that are dominating in Industry 4.0 (3:24)

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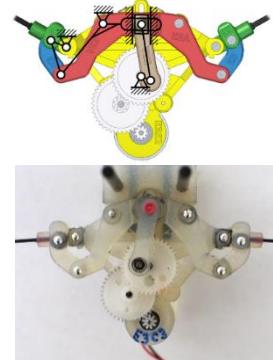
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Tutorials and Course Works

- Tutorials (CAD/CAE, MATLAB,etc.)
- Courseworks: Intelligent Design for Robotics (3 Case Studies
 - Virtual Prototype (CAD Tools, Solideworks, Ansys, etc.,)
 - Physical Prototyping (3D Printing)



1 Exoskeleton



2 MAV



3 Social Service (CAD)



An Introduction to Industry 4.0

(3 Case Studies)

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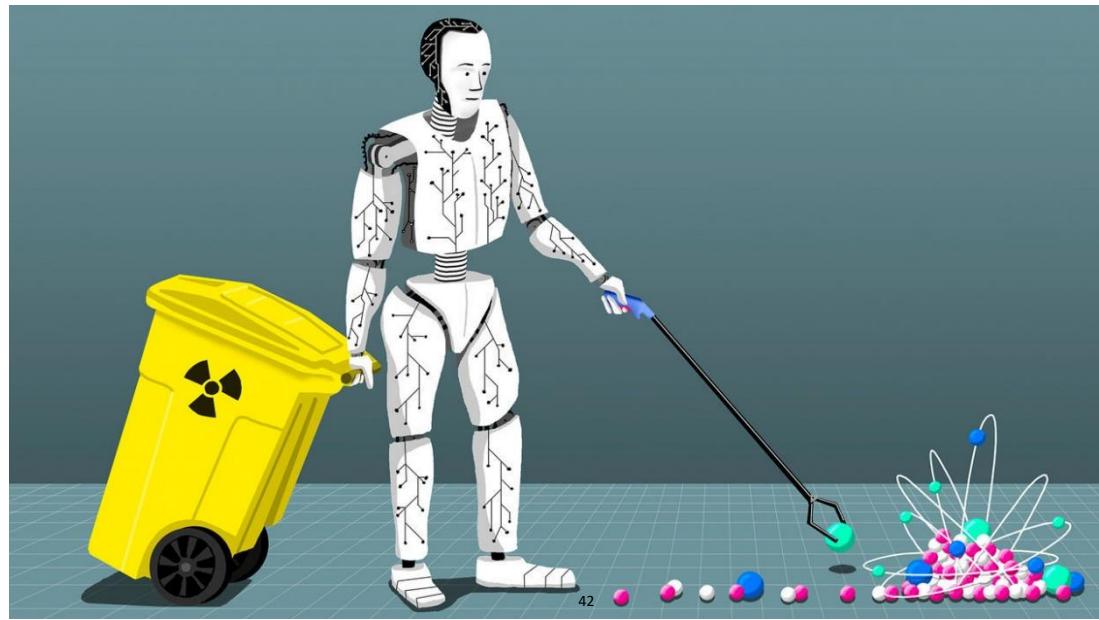
1 Background

2 Tasks

3 Assessment

4 Submission

References

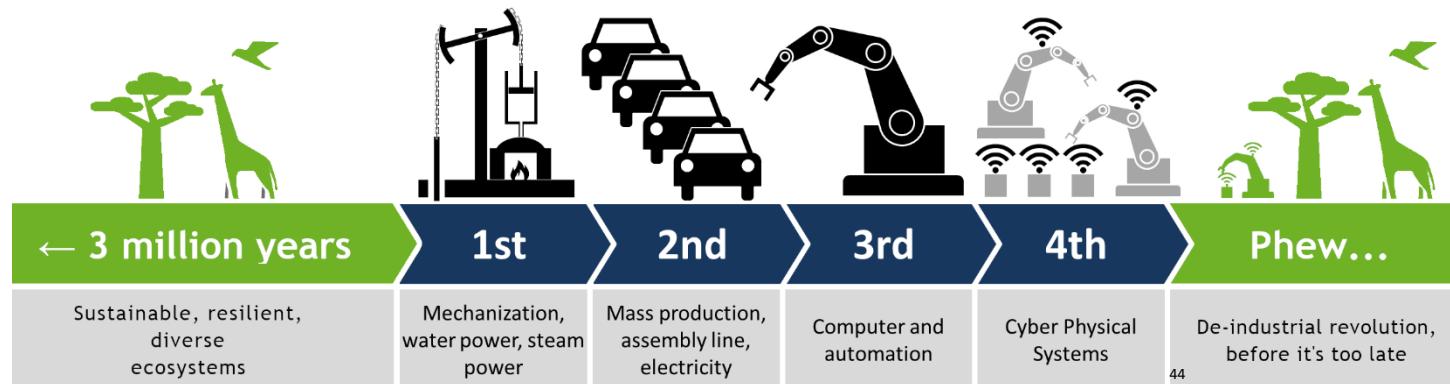


Class Break and Discussions



Discussion:

1. How COVID-19 is Affecting Industry 4.0? [4,5]
2. What is the Industry 1.0 to 5.0? [6,7]
3. Industry 4.0 responding to COVID-19 outbreak
4. The Smart Industry Readiness Index (SIRI)
5. Why did the 1st industrial revolution start in Britain?
6. What is China's/UK's/EU's position out of the gate to industry 4.0?



Tip 1: How COVID-19 is Affecting Industry 4.0?



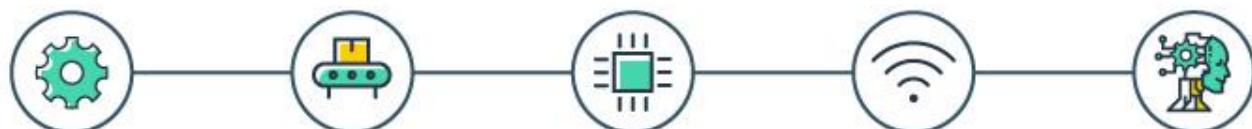
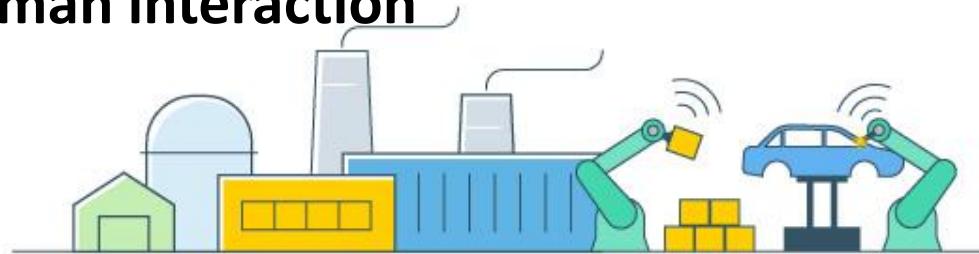
- Planning of activities regarding COVID-19
- Providing a better experience without imposing the risks to healthcare and other workers
- Manufacturing of precautionary item related to this virus
- Provide medical part in time using smart supply chain
- Used robotic based treatment of the infected patient to reduce doctors risk
- Used virtual reality for training purpose
- Promote a flexible working environment of treatment
- These digital technologies help people to perform daily life work during the lockdown

Tip 2: Industry 1.0 to 5.0^[6,7]

Industry 5.0 = Industry 4.0 + AI/Human-in-the-loop

Industry 4.0 :: robotic capabilities + IoT(Cyber-physical System)

Industry 5.0 :: robotic-human interaction



Industry 1.0

Mechanization,
water power,
steam power

Industry 2.0

Mass production,
assembly line,
electricity

Industry 3.0

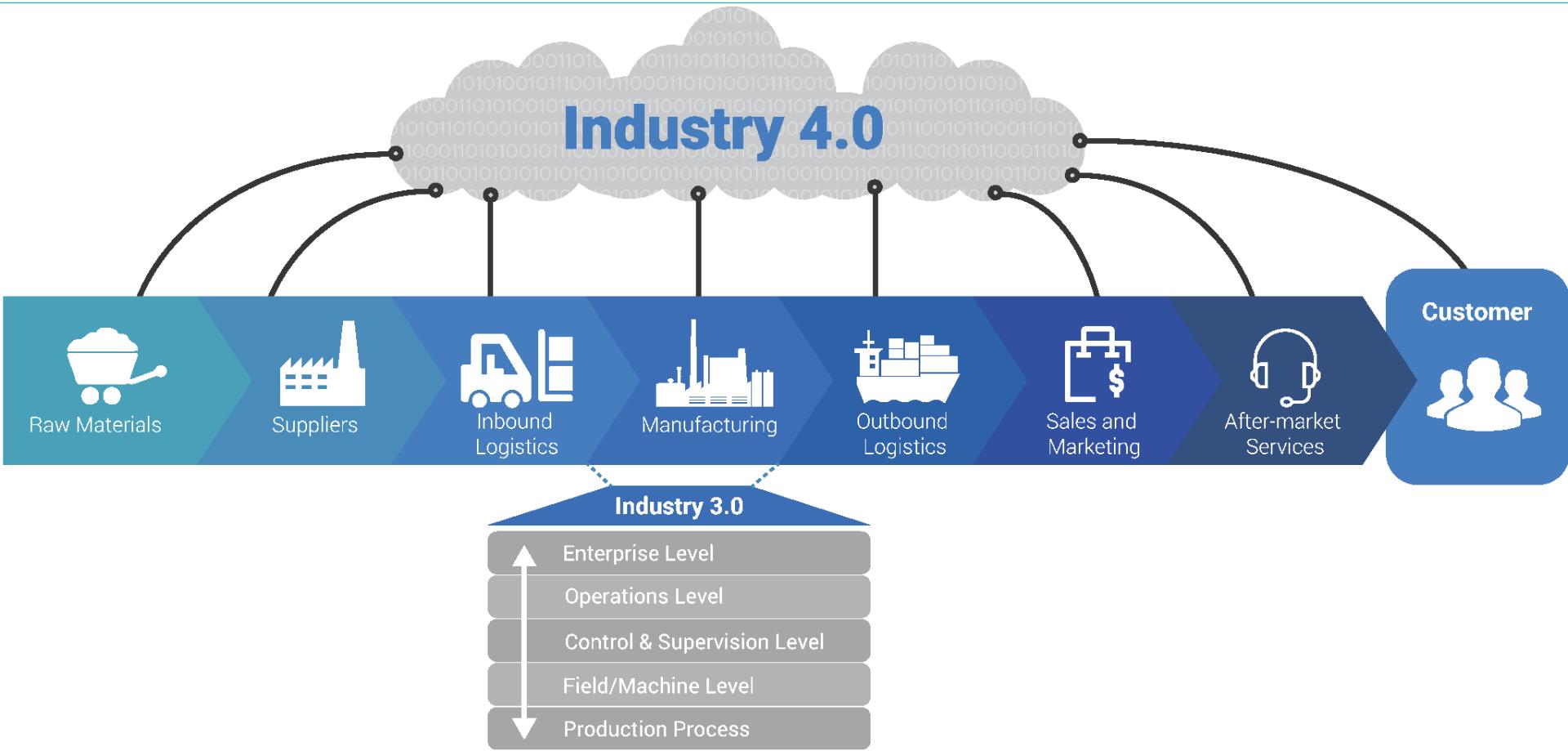
Computer and
automation

Industry 4.0

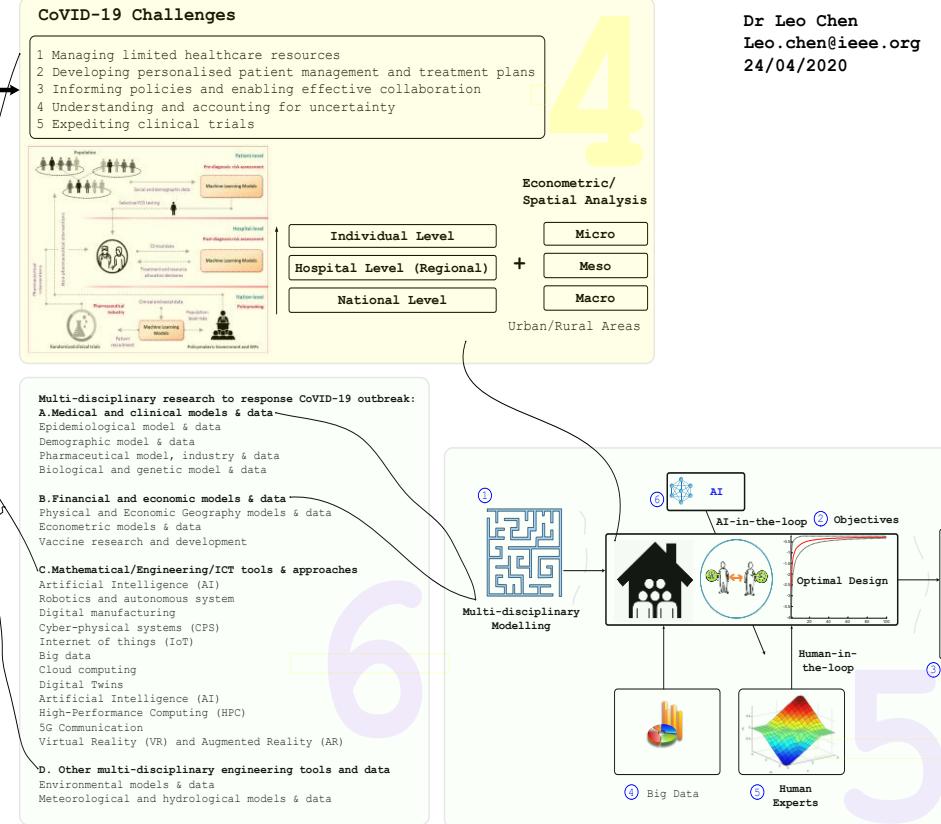
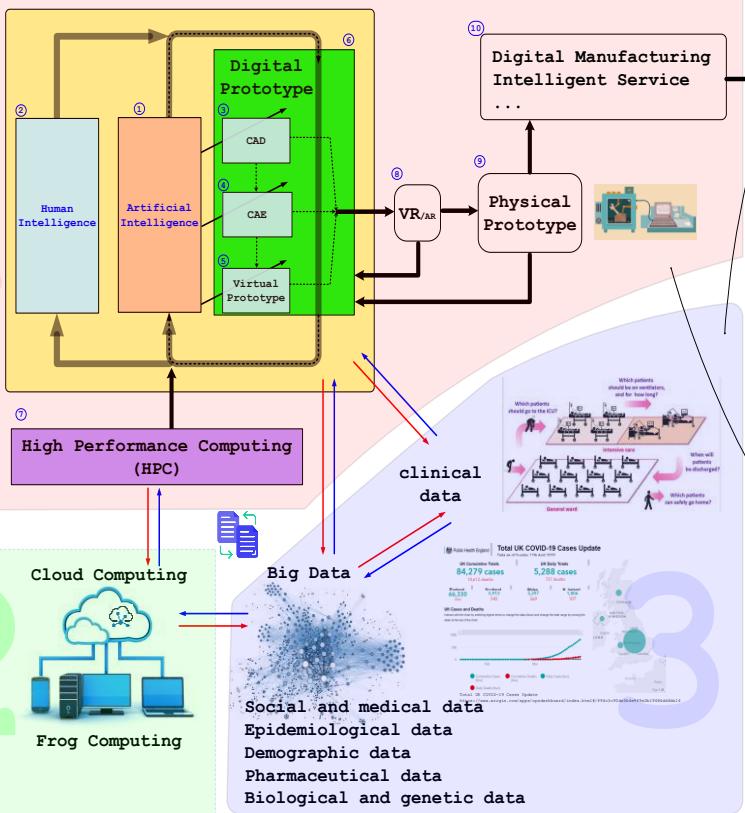
Cyber physical
systems

Industry 5.0

Mass customization
& cyber physical
cognitive systems



Tip 3: Industry 4.0 responding to COVID-19 outbreak



Dr Leo Chen
 Leo.chen@ieee.org
 24/04/2020

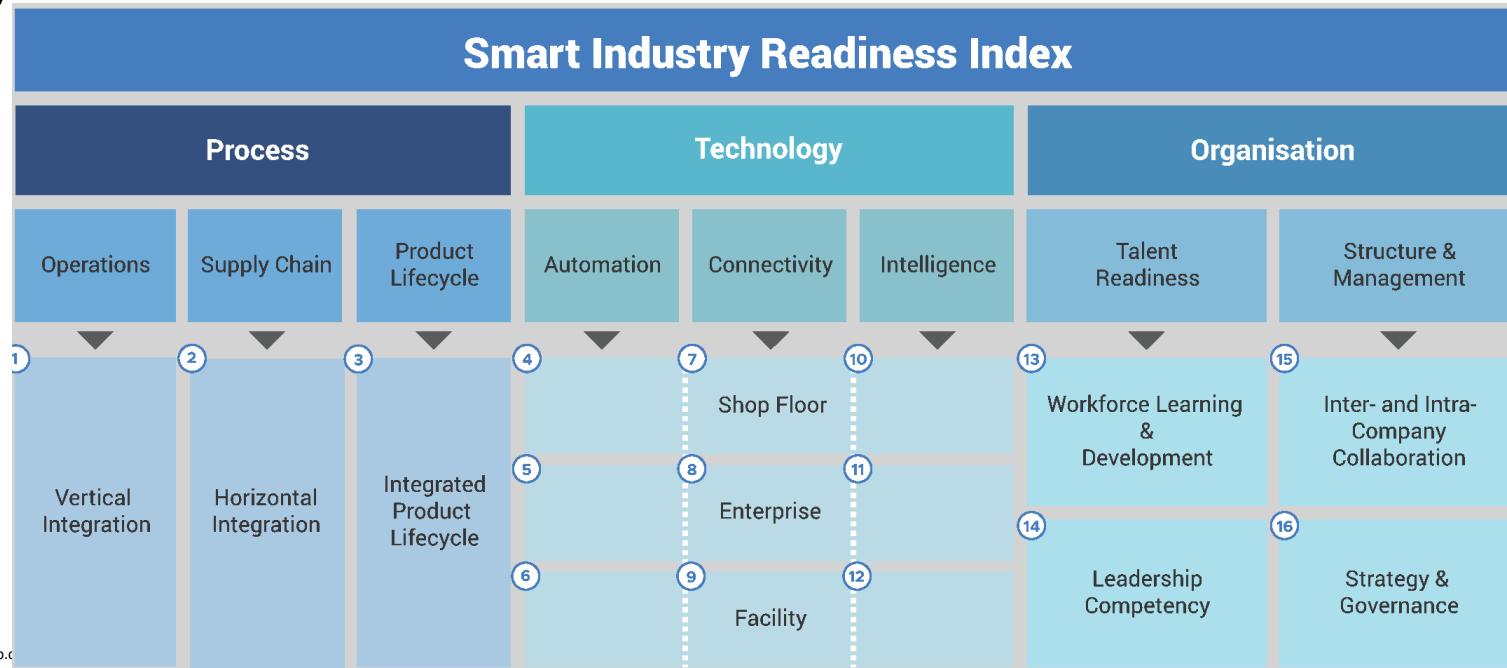
Using Supporting Technologies for I4, we can do:

- Smart Devices: PPE(Self-cleaning mask)/Ventilator/Quick surface disinfectant device
- Collaborative System
- Safe Work Place
- Remote monitor of staff health
- Support Frontline Workers
- Travel Safe
- Dynamic distance marker
- Sustainable COVID products
- Changing Ventilators for different medical purposes
- PPE material recycle
- Society Impacts
- Enablers for positive thinking
- Models for forecasting the spread of virus on the basis of age, health index, resilience based on ethnicity, air pollution and population density.



Tip 4. The Smart Industry Readiness Index (SIRI)^[10]

The Smart Industry Readiness Index (SIRI) Framework - Catalysing the transformation of manufacturing towards industry 4.0



Tip 5. Why did the 1st industrial revolution start in Britain? [11-13]

The Industrial Revolution began first in Britain in the **1700s**. Historians have identified several reasons for why the Industrial Revolution began first in Britain, including:

- *the effects of the Agricultural Revolution*
- *large supplies of Natural Resources(coal, cotton)*
- *geography of the country*
- *a positive political climate, a stable Government and Economy*
- *a vast colonial empire (market)*
- *Inventions and Innovations*

Tip 6. What is China's position out of the gate to industry 4.0?^[14]

As evidenced by official numbers, factory activity in China contracted at the fastest pace on record in February this year.^[14]

Is China the first out of the gate to Industry 4.0^[15]?

Navigating the next industrial revolution

Revolution Year Information



1 1784 Steam, water, mechanical production equipment



2 1870 Division of labour, electricity, mass production



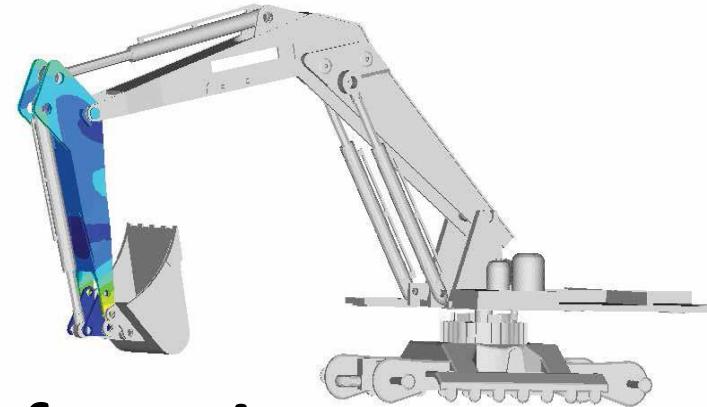
3 1969 Electronics, IT, automated production



4 ? Cyber-physical systems

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Reference

- [1] https://en.wikipedia.org/wiki/Industry_4.0
- [2] <https://www.industryweek.com/technology/digital-manufacturing-factory-future-here-today>
- [3] https://en.wikipedia.org/wiki/Digital_twin
- [4] How COVID-19 is Affecting Industry 4.0 and the Future of Innovation,
<https://transmitter.ieee.org/how-covid-19-is-affecting-industry-4-0-and-the-future-of-innovation/>
- [5] Industry 4.0 technologies and their applications in fighting COVID-19 pandemic, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7180383/>
- [6] Welcome to Industry 5.0, <https://www.qualitymag.com/articles/95450>Welcome-to-industry-50>

Reference

- [7] <https://www.robotics.org/blog-article.cfm/What-is-Industry-5-0-and-How-Will-Industrial-Robots-Play-a-Role/99>
- [8] Yi Chen, Yun Li, (2018), Computational Intelligence Assisted Design (In the Era of Industry 4.0), CRC Press (ISBN 978-1-4987-6066-9)
<https://www.crcpress.com/Computational-Intelligence-Assisted-Design-In-the-Era-of-Industry-40/Chen-Li/p/book/9781498760669>
- [9] The benefits of digitalisation for the UK Automotive Industry.
https://www.smmt.co.uk/wp-content/uploads/sites/2/smmt_the-digitalisation-of-the-uk-auto-industry_kpmg-apr-2017.pdf
- [10] The Smart Industry Readiness Index (SIRI) Framework - Catalysing the transformation of manufacturing, 2020, Singapore Economic Development Board. www.edb.gov.sg

Reference

[11] Why Was Britain The First Country To Industrialize?

<https://www.historycrunch.com/why-was-britain-the-first-country-to-industrialize.html#/>

[12] Why Did the Industrial Revolution Start in Britain?

<https://interestingengineering.com/innovation/why-did-the-industrial-revolution-start-in-britain>

[13] The Beginning of the Industrial Revolution

<https://www.studentsofhistory.com/why-the-industrial-revolution-began-in-england>

[14] <https://www.cushmanwakefield.com/en/insights/covid-19/lessons-from-china/looking-beyond-covid-19-going-for-industry-4-0-in-china>

Reference

- [15] <https://asiatimes.com/2021/06/china-is-first-out-of-the-gate-to-industry-4-0/>
- [16] **The Fourth Industrial Revolution: what it means, how to respond**
<https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/>
- [17] A review Cyber of Industry 4.0 (Cyber-Physical Systems (CPS), the Internet of Things (IoT) and the Internet of Services (IoS)): Components, and Security Challenges.
<https://iopscience.iop.org/article/10.1088/1742-6596/1424/1/012029>

Reference

- [18] <https://blog.isa.org/cyber-physical-systems-the-core-of-industry-4.0>
- [19] Top 7 Manufacturing Trends for 2022
<https://www.beekeeper.io/blog/manufacturing-trends/>
- [20] The top 8 latest trends in manufacturing for 2022
<https://www.advancedtech.com/blog/manufacturing-trends/>
- [21]
<https://www.gray.com/insights/sustainable-manufacturing-is-the-wave-of-the-future/>

FAQs

FAQ 01 Industry 4.0 == the fourth industrial revolution?

FAQ 02 What is Cyber-physical System

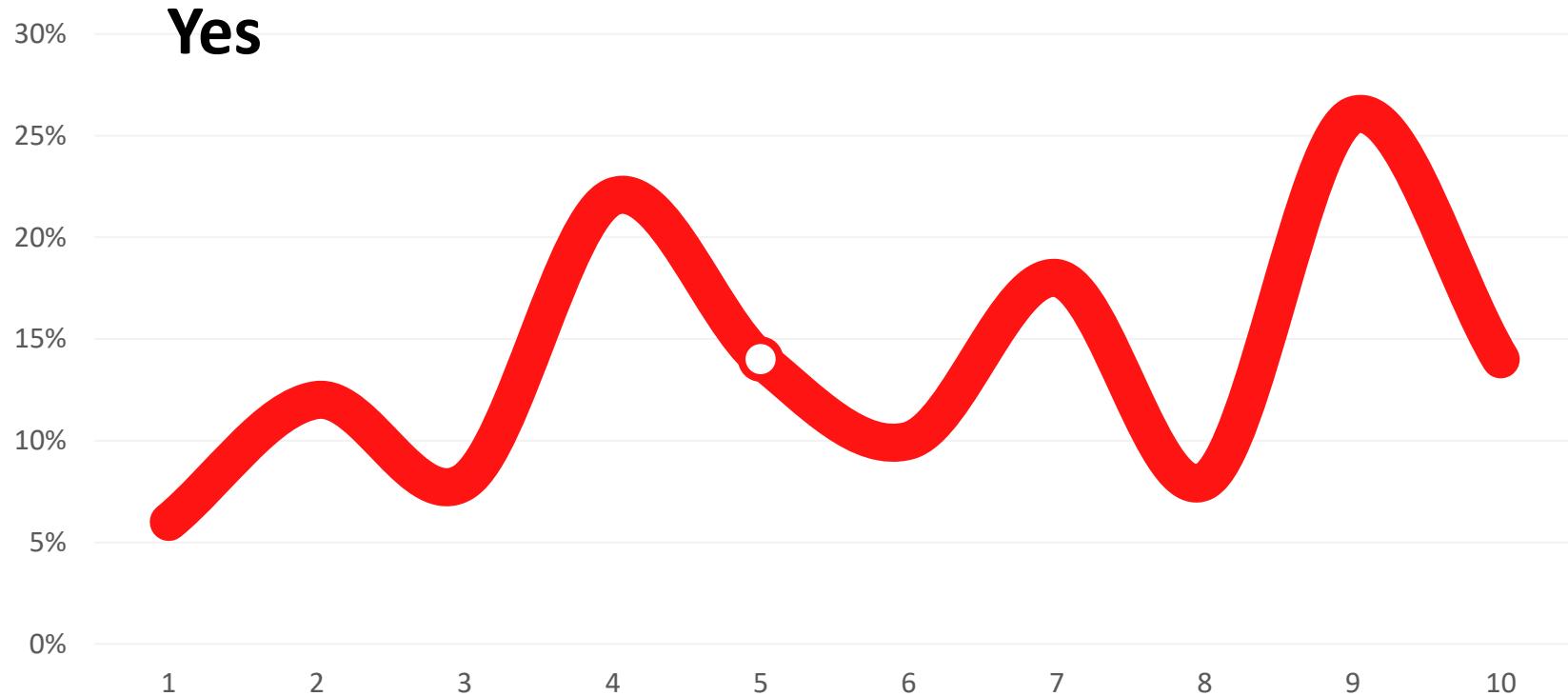
FAQ 03 Industry 4.0 and Cyber-physical System

FAQ 04 Industry 5.0

FAQ 05 Current and emerging trends in Digital
Manufacturing

FAQ 06 Current and emerging trends in Sustainable
Manufacturing

FAQ 01 Industry 4.0 == the fourth industrial revolution?



FAQ 02 What is Cyber-physical System

- The cyber-physical systems are **smart systems that include engineered interacting networks of physical and computational components.** [18]
- Acatech (National Academy of Science and Engineering, Germany), in its report *Cyber-Physical Systems*, describes CPS as follows: *cyber-physical systems are systems with embedded software (as part of devices, buildings, means of transport, transport routes, production systems, medical processes, logistic processes, coordination processes, and management processes).*

FAQ 02 What is Cyber-physical System

- From a *manufacturing industry perspective*, a cyber-physical system is an **internet-enabled physical entity**, such as a pump or compressor, embedded with computers and control components consisting of sensors and actuators

FAQ 03 Industry 4.0 and Cyber-physical Systems

Industry 4.0 = CPS + IoT + IoServices



FAQ 04 Industry 5.0

- Industry 5.0

FAQ 05 Trends in Digital Manufacturing (2022)

1. 2022: The year of **smart factories**
2. Increased focus on **sustainability** and **carbon neutrality**
3. **Supply chain** reassessment
4. The ongoing **importance** and **permanence** of reshoring
5. **Employee safety and health**
6. **Data-driven maintenance** as a margin enhancer
7. Increased reliance on **virtual** processes
8. Meeting increased demand with a **decreased labour force**
9. Automation and Robotics are **Redefining** Manufacturing Worker Roles
- 10 . **Employees Participating in Continuous Learning and Improving Skills**

FAQ 06 Trends in Sustainable Manufacturing (2022)

Sustainable manufacturing is **defined** as “the creation of manufactured products through **economically-sound** processes that **minimise** negative environmental impacts while conserving energy and natural resources.” [21]

1. *Manufacturing “At Home” in Smaller Batches*
2. *Using Recycled Materials and Recyclable Packaging*
3. *Investing in Biodegradable Plastics*
4. *Reducing Waste in Creative Ways*
5. *Offsetting Manufacturing Processes*

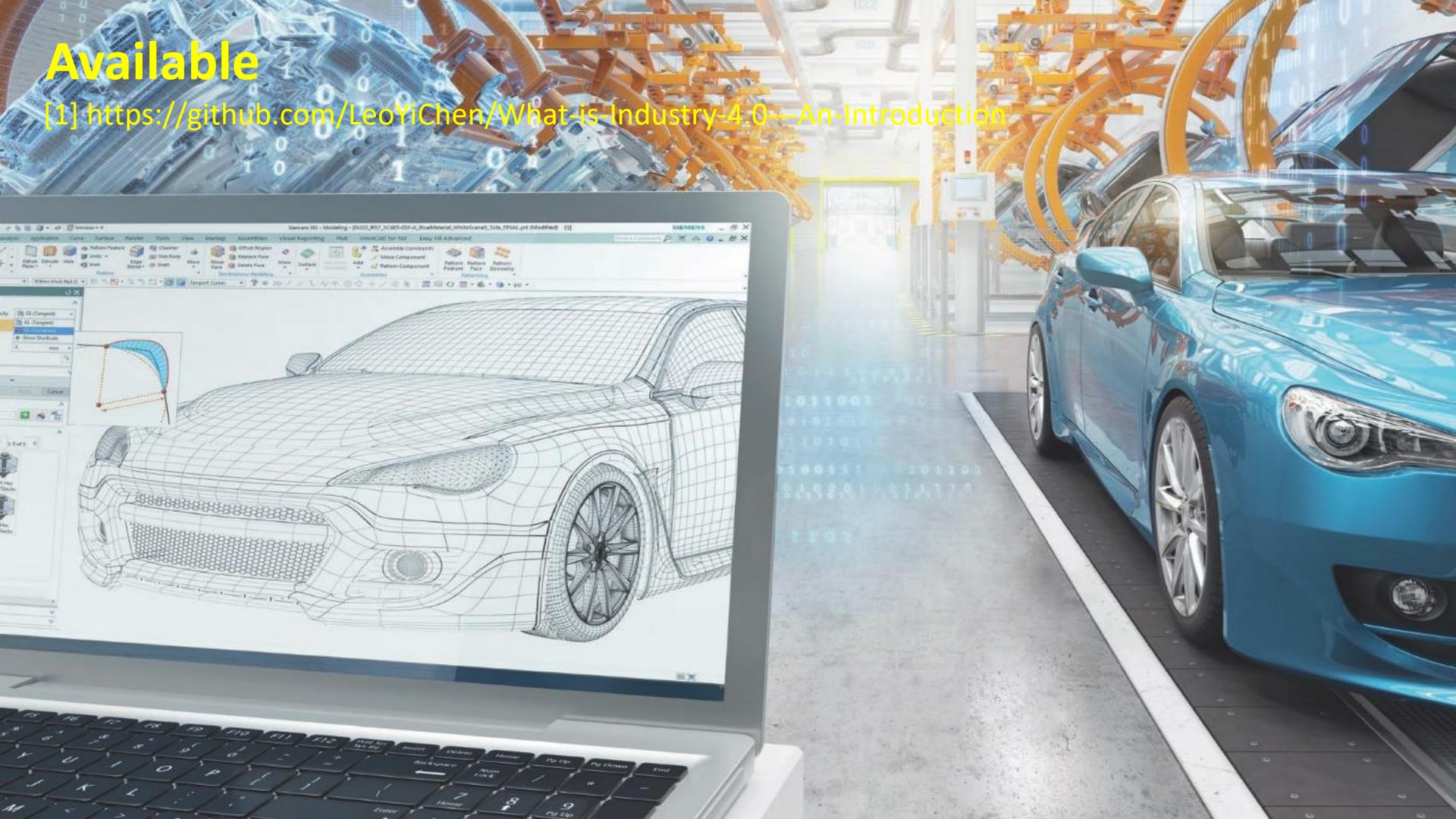
FAQ 06 Trends in Sustainable Manufacturing (2022)

Key benefits to sustainability

- Improved operational efficiency by reducing costs and waste
- Long-term business viability and success
- Lower regulatory compliance costs
- Improved sales and brand recognition
- Greater access to financing and capital
- Easier employee hiring and retention

Available

[1] <https://github.com/LeoYiChen/What-is-Industry-4.0--An-Introduction>



Videos – industry 1.0

1. The Industrial Revolution (3:58)
2. What was the Industrial Revolution (5:30)
3. What was the Industrial Revolution-History in a Nutshell (4:34)
4. History of Industrial Revolution (41:56)
5. The Industrial Revolution – Crash Course (17:05)
6. Captivating History -The Industrial Revolution (16:38)
7. The Industrial Revolution (18-19th Century) (3:57)
8. Causes of the Industrial Revolution (4:24)

Videos – industry 1.0

9. How did the Industrial Revolution Actually Happen (11:39)

10. The impact of the Industrial Revolution (3:42)

11. The Industrial Revolution Mankind (44:22)

12. What Hygiene Was Like During the Industrial Revolution
(12:07)

Videos – industry 2.0

The 2nd Industrial Revolution Innovations in Europe (12:12)



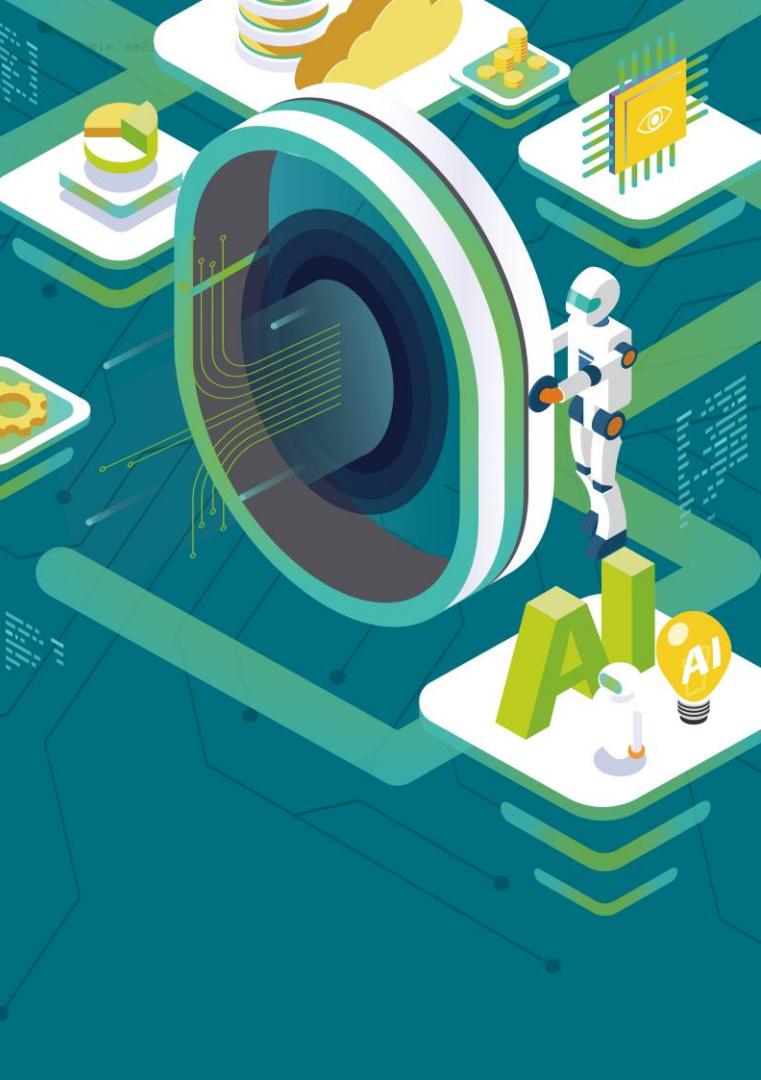
Videos – industry 3.0

[What If There Was a 3rd Industrial Revolution \(03:44\)](#)



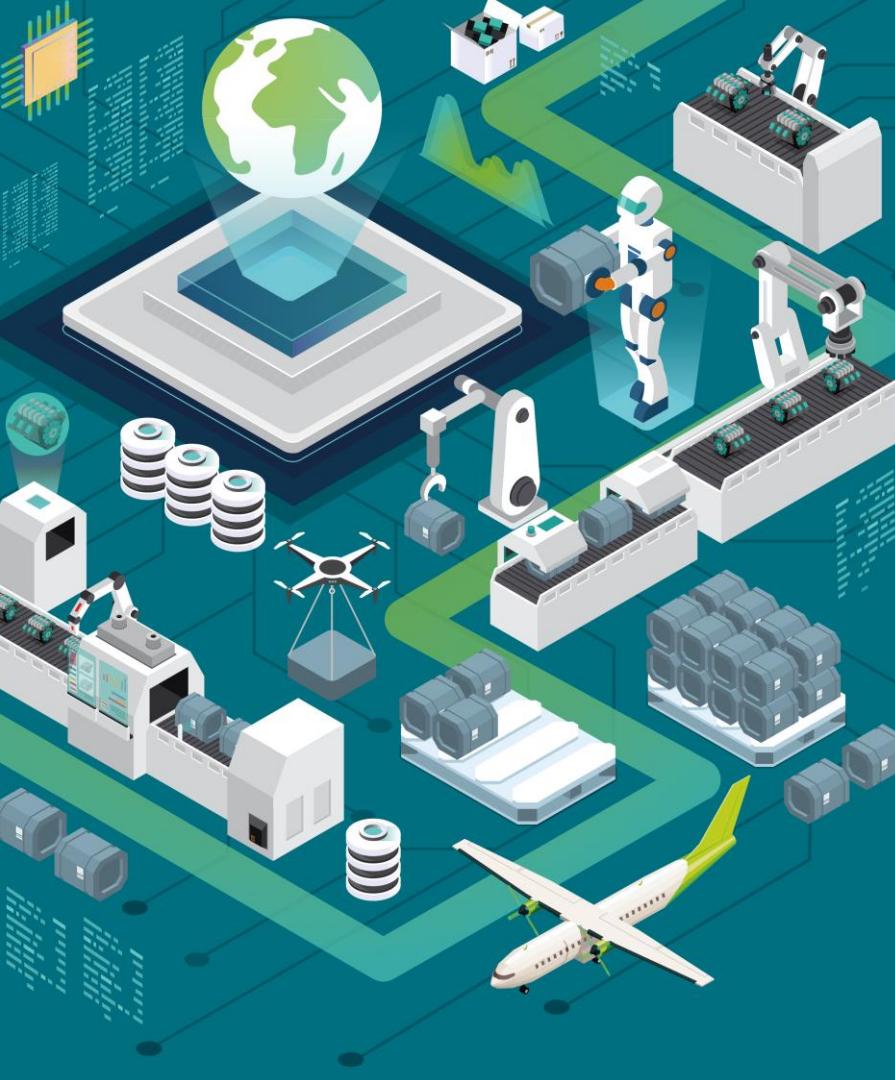
Videos – industry 4.0

- [What is i4 \(4:17\)](#)
- [INDUSTRIE 4.0 - THE FOURTH INDUSTRIAL \(5:00\)](#)
- [Industry 4.0 - no need people \(7:48\)](#)
- [Power Industry 4.0 with Artificial Intelligence \(2:15\)](#)

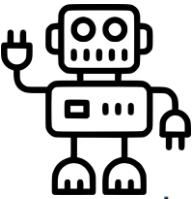


Videos – industry 5.0

9 Core Technologies that are
dominating in Industry 4.0 (3:26)



INDUSTRY 4.0



AUTOMATION



CONNECTION



CLOUD COMPUTING



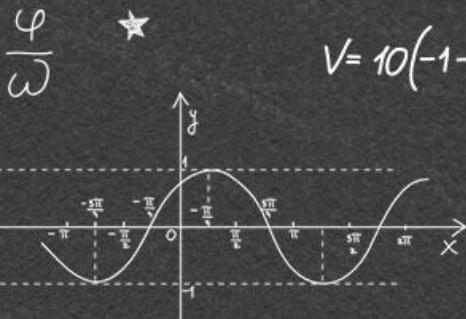
IOT



BIG DATA



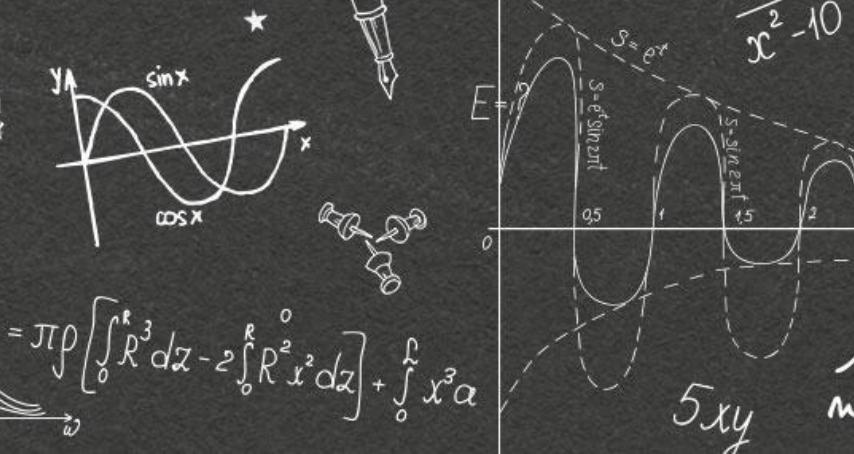
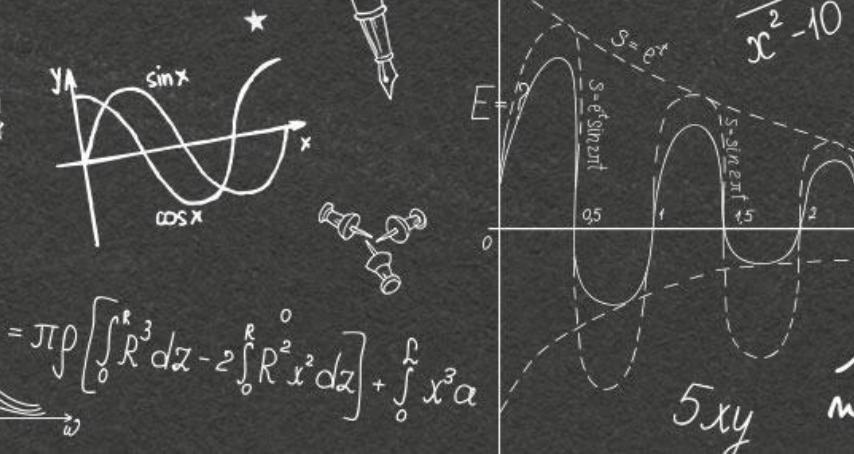
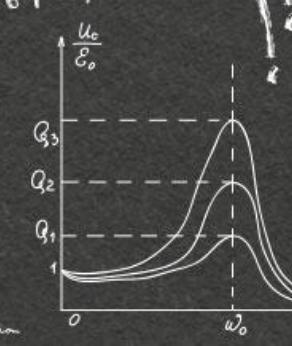
SYSTEM INTEGRATION

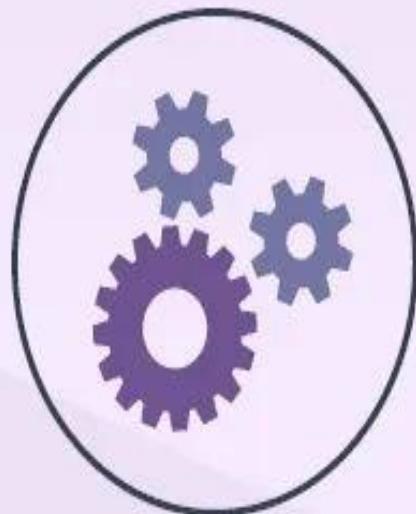


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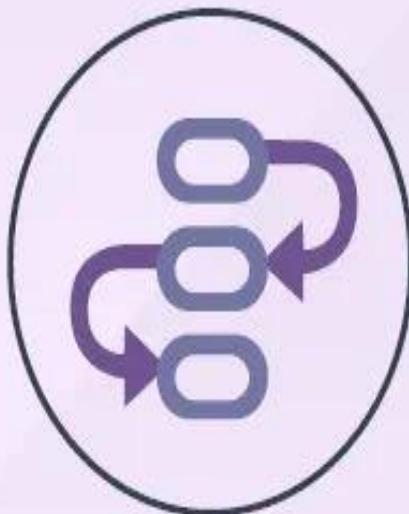
a concept on mental impression





Industry 1.0

Mechanisation and the introduction of steam and water power



Industry 2.0

Mass production assembly lines using electrical power



Industry 3.0

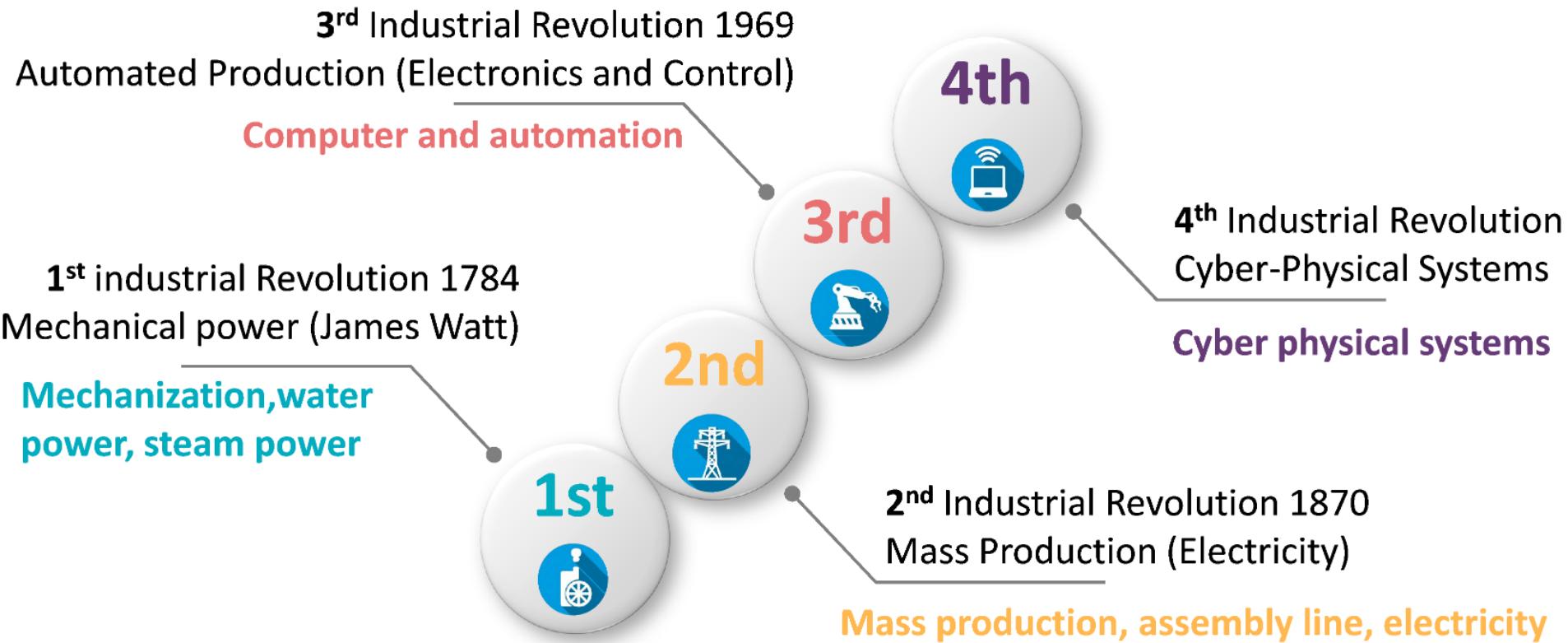
Automated production, computers, IT-systems and robotics



Industry 4.0

The Smart Factory. Autonomous systems, IoT, machine learning

The Industrial Revolution



Pictures From the Industrial Revolution [19]

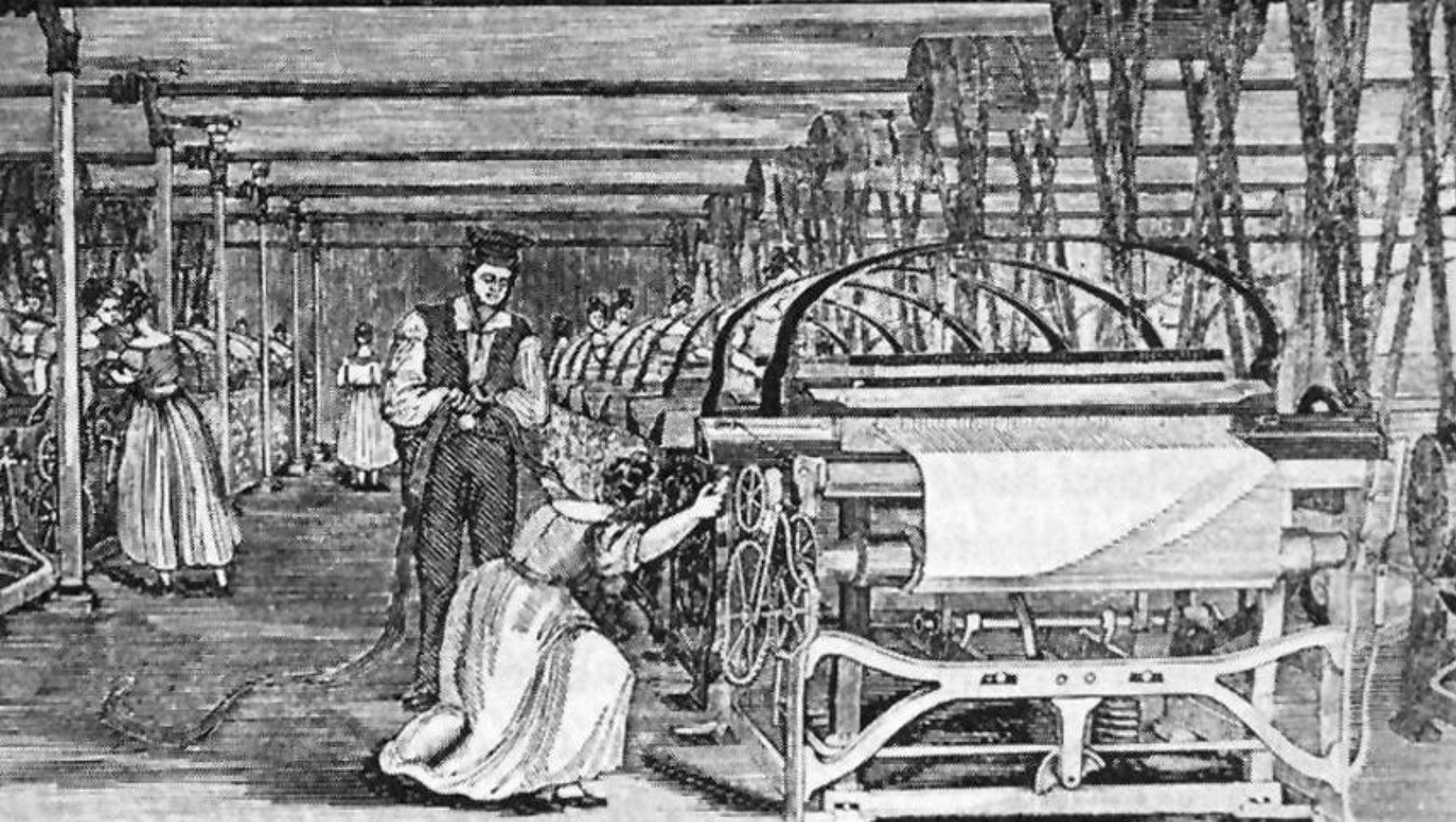
1712:

Newcomen

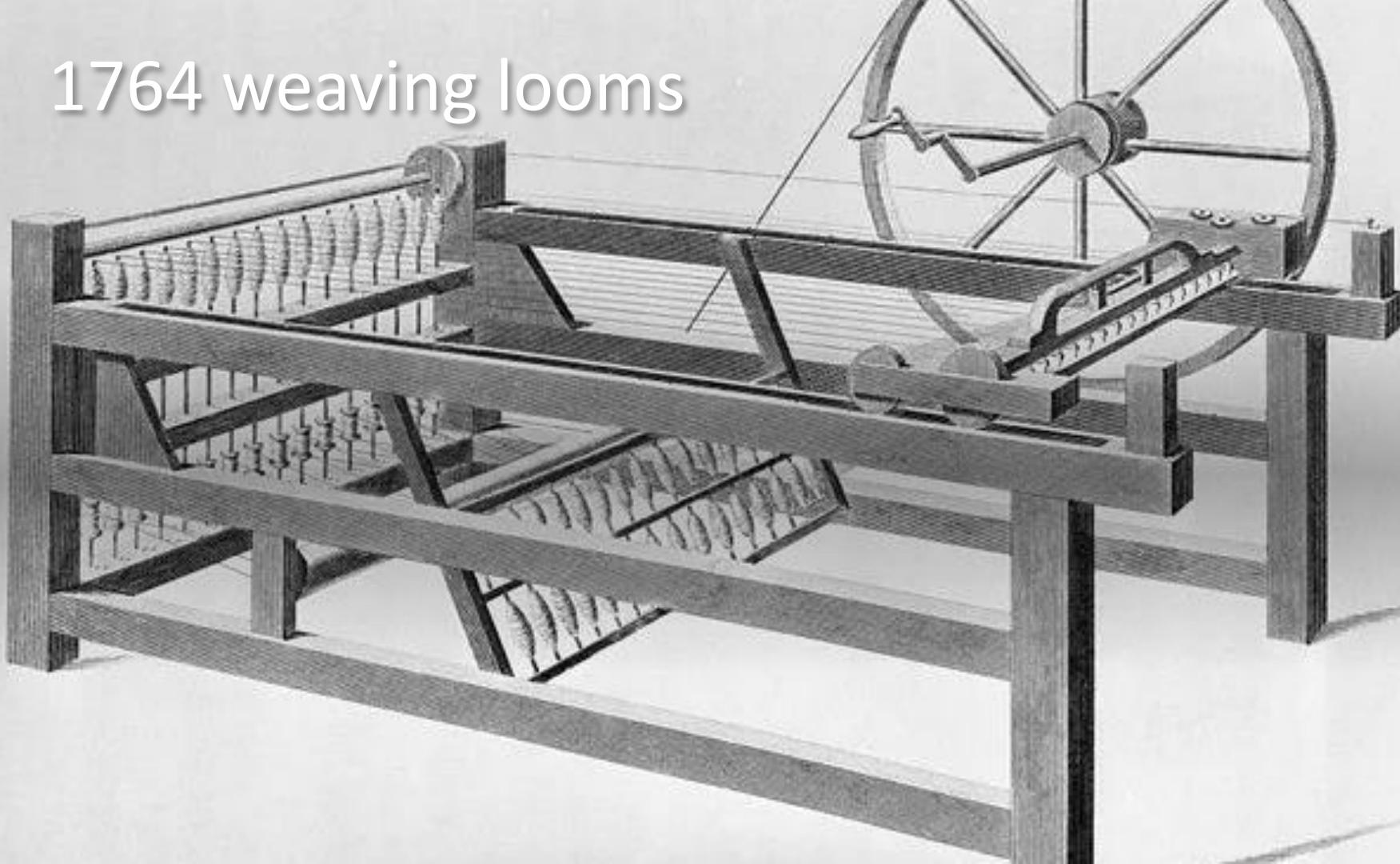
Steam

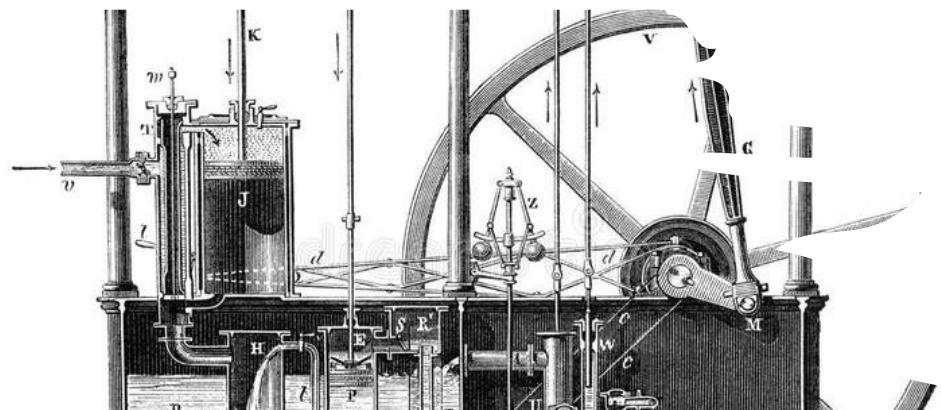
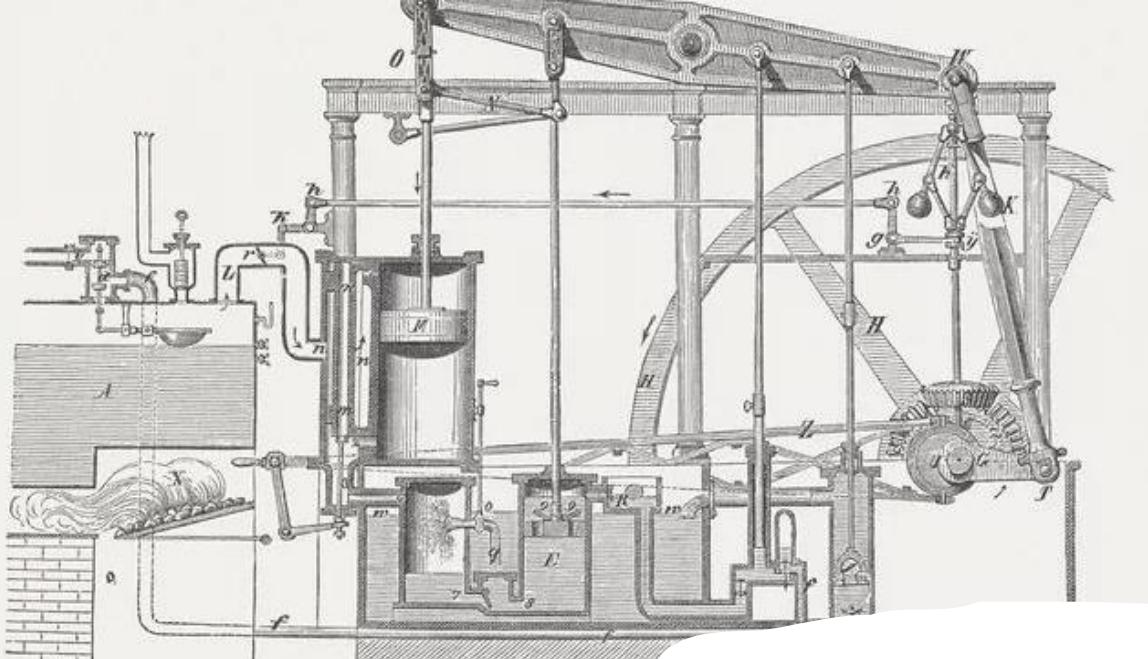
Engine and
the Industrial
Revolution



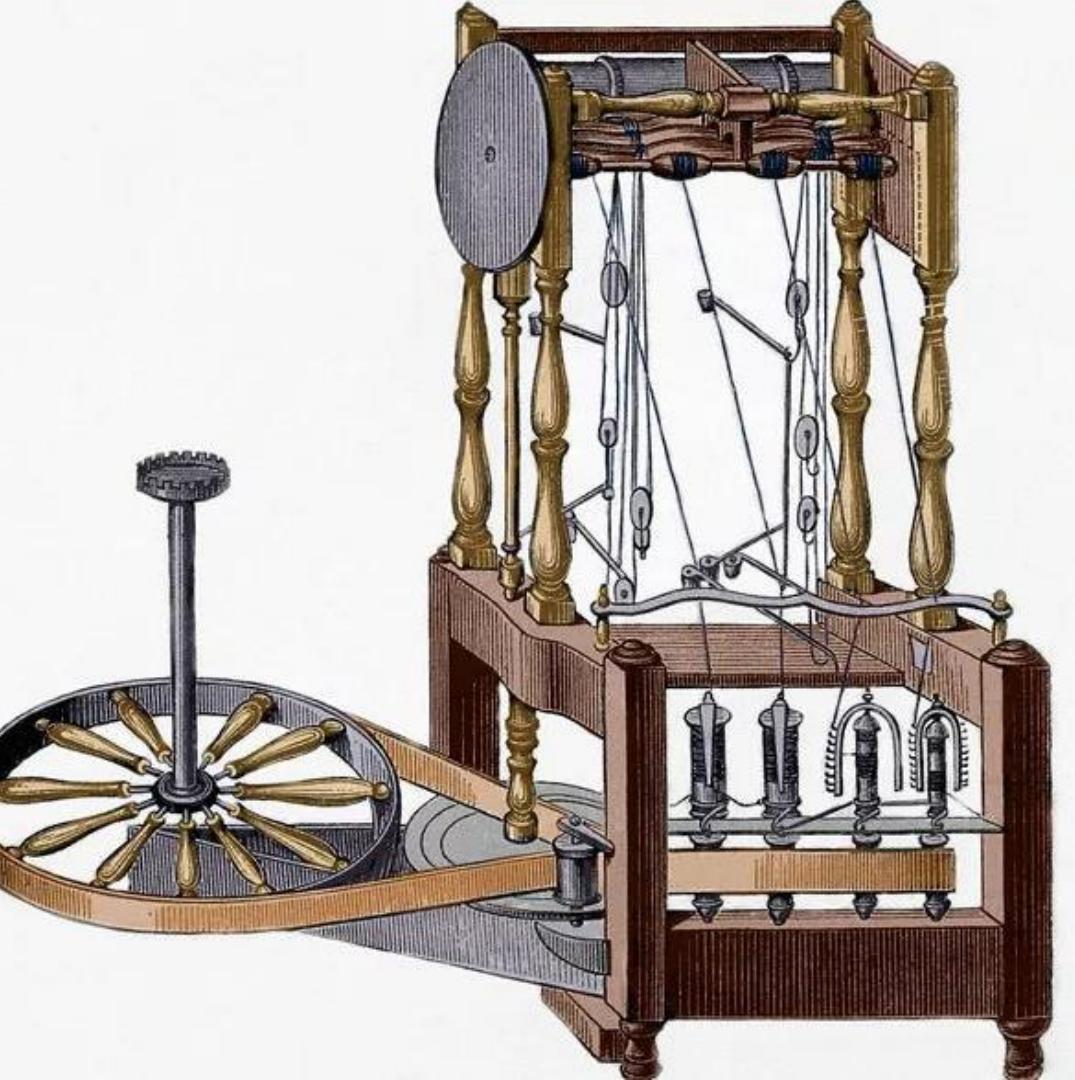


1764 weaving looms





1769: James Watt's Improved Steam Engine Powers the Industrial Revolution



1769: Spinning
Frame or Water
Frame





What is Industry 4.0 - An Introduction to Industry 4.0

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