光學檢測
Optical Methodologies for Mechanics and Industrial Applications

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About Myself

- Researcher Fellow, Taiwan Instrument Research Laboratory, NARLabs
- AdCom Member, IEEE Instrumentation and Measurement Society, 2016-2024
- Chair of Optical Methods Technical Division, Society of Experimental Mechanics, 2023/06-2025/05
- Chair of TC 18, IEEE Instrumentation and Measurement Society
- Secretary, IEEE Taipei Section Instrumentation and Measurement Society Chapter
- Board Members, Taiwan Photonics Society, 2017-2019
- Vice President for Education, IEEE Instrumentation and Measurement Society, 2023-2024
- Vice President for Conferences, IEEE Instrumentation and Measurement Society, 2017-2018
- Associate Editor-in-Chief, IEEE Transections on Instrumentation and Measurement, 2024/05-
- Associate Editor, IEEE Transections on Instrumentation and Measurement, 2020-2024

Topics

- General Introduction
- Why optical methodologies?
- Define Requirement-Knowing Limitation of a Method
- Key Element
  - Light Source
  - Sensors
  - Optical Lens& Optical Components
- Principle of Basic Interferometry
- Spectrum and Its Applications
- Laser Triangulation Measurement Method
- Structure Lights and Its Application
- Moiré Method/ Sampling Moiré Method
- Astigmatic Method and Applications
- Principle of White Light Scanning Interferometer and its Applications
- Principle of Confocal Microscopy and its applications
- Principle of Conoscopic Holography and its applications
- Introduction to optical image processing and deep learning

Grading Policy (1)

Two Reports Required

First Report (40%)

Due: 2024/10/23 (-10% for a week delay)

Topic: <u>Proposal for implementing an optical inspection system</u>

Content Required:

Figure out a scenario for implementing optical measurement to replace/ to upgrade/ to be installed to a machine for on-machine measurement; the reports should include the following items;

(1) Descriptions for current problems/ limitations/ requirements;

(2) Discussion for candidate methods based on description (1);

(3) Detail working principle of selected method;

(4) Risk/ Risk mitigation/ residual risk
(risk can be associated with technology, finance, operation(bottleneck introduced), ...);

(5) Conclusions-convince your "*virtual boss*" !

Possible Topics

- 3D based AI online inspection System
- Robot-Based Bin Picking System
-

Grading Policy (2)

Final Report (60%)

- Due: 2024/12/25 (No delay is allowed)
- Topic: Self-Defined
- Content Required:
  - (1) Selecting an optical measurement method;
  - (2) $\geq$ 30 papers are required;
  - (3) Working principle, milestones (roadmap..), progressing, applications …;
  - (4) Potential application/ new chance for on-machine measurement with possible technical barriers included

Review Article—Example

Journal of Manufacturing Systems 57 (2020) 1–18

Contents lists available at ScienceDirect

Journal of Manufacturing Systems

journal homepage: www.elsevier.com/locate/jmansys

Application of sensing techniques and artificial intelligence-based methods to laser welding real-time monitoring: A critical review of recent literature

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ARTICLE INFO

Keywords:
Laser welding
Real-time monitoring
Sensing techniques
Multi-sensor fusion technology
Artificial intelligence
Multi-monitoring objectives

ABSTRACT

Laser welding has been widely utilized in various industries. Effective real-time monitoring technologies are critical for improving welding efficiency and guaranteeing the quality of joint-products. In this paper, the research findings and progress in recent ten years for real-time monitoring of laser welding are critically reviewed. Firstly, different sensing techniques applied for welding quality monitoring are reviewed and discussed in detail. Then, the advanced technologies based on artificial intelligence are summarized which are exploited to realize varied objectives of monitoring such as process parameter optimization, weld seam tracking, weld defects classification, and process feedback control. Finally, the potential research problems and challenges based on real-time intelligent monitoring are discussed, such as intelligent multi-sensor signal acquisition platform, data depth fusion method and adaptive control technology. This fundamental work aims to review the research progress in laser welding monitoring and provide a basis for follow-on research.

1. Introduction

Laser welding is an efficient joining technique, owning to numerous advantages such as higher productivity, flexibility and effectiveness, deeper penetration of the weld seam, higher welding speeds, and power density [1–3]. That is why it obtains an increasingly widespread application in the automotive [4,5], shipbuilding [6], aerospace [7,8], micro-electronics [9,10], and other industries [11,12]. The welding quality can be disturbed by various factors during welding process, such

filters are applied to capture the images of the keyhole, molten pool, spatters and plasma. Spectrometers [25], and photodiodes [26] are utilized to collect the optical signals include visible light (VIS), infrared light (IR), and ultraviolet light (UV). The IR cameras [27], near-infrared (NIR) cameras [28], and pyrometers [29] can be exploited to gather the thermal signal. Complex monitoring system usually consists of the above-mentioned sensors and the welding signals will be more comprehensively collected. [30,31].

According to different monitoring objectives [32–34], there are

Review Article—Example

IEEE Access

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SURVEY

Printed Circuit Board Defect Detection Methods Based on Image Processing, Machine Learning and Deep Learning: A Survey

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ABSTRACT Printed circuit boards (PCBs) are a nearly ubiquitous component of every kind of electronic device. With the rapid development of integrated circuit and semiconductor technology, the size of a PCB can shrink down to a very tiny dimension. Therefore, high-precision and rapid defect detection in PCBs needs to be achieved. This paper reviews various defect detection methods in PCBs by analysing more than 100 related articles from 1990 to 2022. The methodology of how to prepare this overview of the PCB defect detection methods is firstly introduced. Secondly, manual defect detection methods are reviewed briefly. Then, traditional image processing-based, machine learning-based and deep learning-based defect detection methods are discussed in detail. Their algorithms, procedures, performances, advantages and limitations are explained and compared. The additional reviews of this paper are believed to provide more insightful viewpoints, which would help researchers understand current research trends and perform future work related to defect detection.

INDEX TERMS Defect detection, PCB, image processing, machine learning, deep learning.

I. INTRODUCTION

The printed circuit board (PCB) is one of the most vital units in the electronic industry [1]. It plays a key role in electronic devices, mechanically holding up and electrically connecting various electronic parts together. PCBs are used in almost every kind of electronic equipment, from electronic

During the Fourth Industrial Revolution (Industry 4.0) [3], PCB manufacturing is facing new challenges and opportunities. The core premise of Industry 4.0 is automated industrial processing with high quality, precision and reliability [4]. Therefore, the producing process of tiny complex PCB boards is required to be more stable and reliable with higher speed, Report Template

光學量測課程期中/期末報告格式

姓名
學號
*Email:

程應於 2020 年 5 月 1 日 與 2020 年 6 月 30 日 以電子郵件方式將告繳交至 wang@gmail.com。所有報告之格式皆需符合本文中所規範，並於截止日前24時前寄出，律扣10%配分比。

字：報告、格式、光學量測課程(最少3個關鍵字)

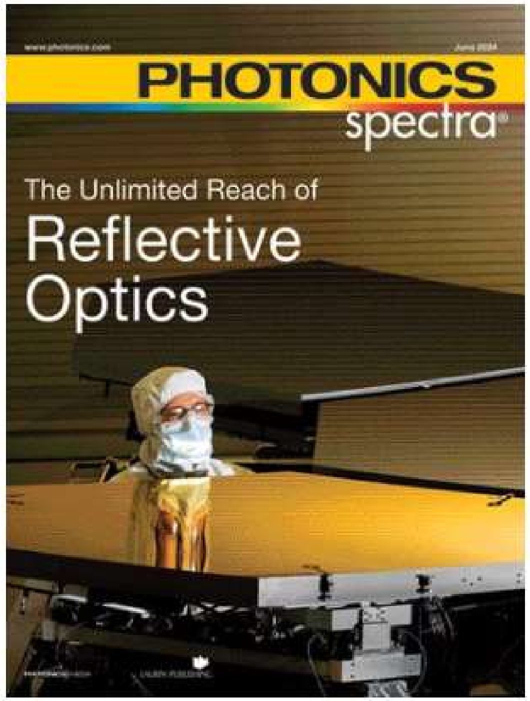
1. 前言

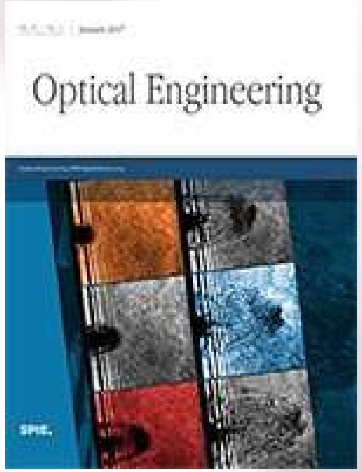
期中報告必須包含現有技術描述，取代方法描述，取代過程所引入之時間成本與投資成本支出，並說明短中長期可能之影響；期末報告所討論之論文不得少於30篇。作者應遵守本樣板所規範之格式，並自行將文件轉換成**PDF**格式檔案後以E-mail方式傳送至 chihunghwang@gmail.com 完成

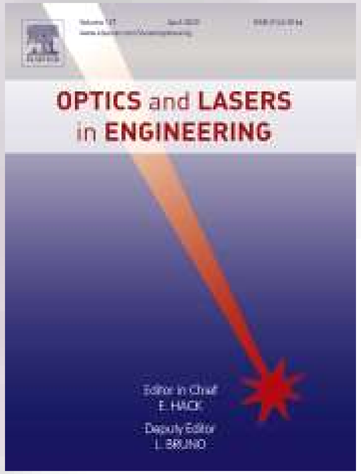
Reference materials

Journal

1. Optics and Lasers in Engineering
2. Optical Engineering
3. Applied Optics
4. Vision Systems Design (Free)
5. Photonics Spectra(Free)







Societies

- **AOIEA 自動光學檢測設備聯盟**

  https://aoiea.itri.org.tw/tc/index.aspx

- **中華民國光電學會(Taiwan Photonics Society)**

  https://www.photonics.org.tw/tw/

- **中華民國計量工程學會(Chinese Metrology Society)**

  https://www.tcms.org.tw/

- **OPTICA (formerly Optical Society of America)**

  https://www.optica.org/

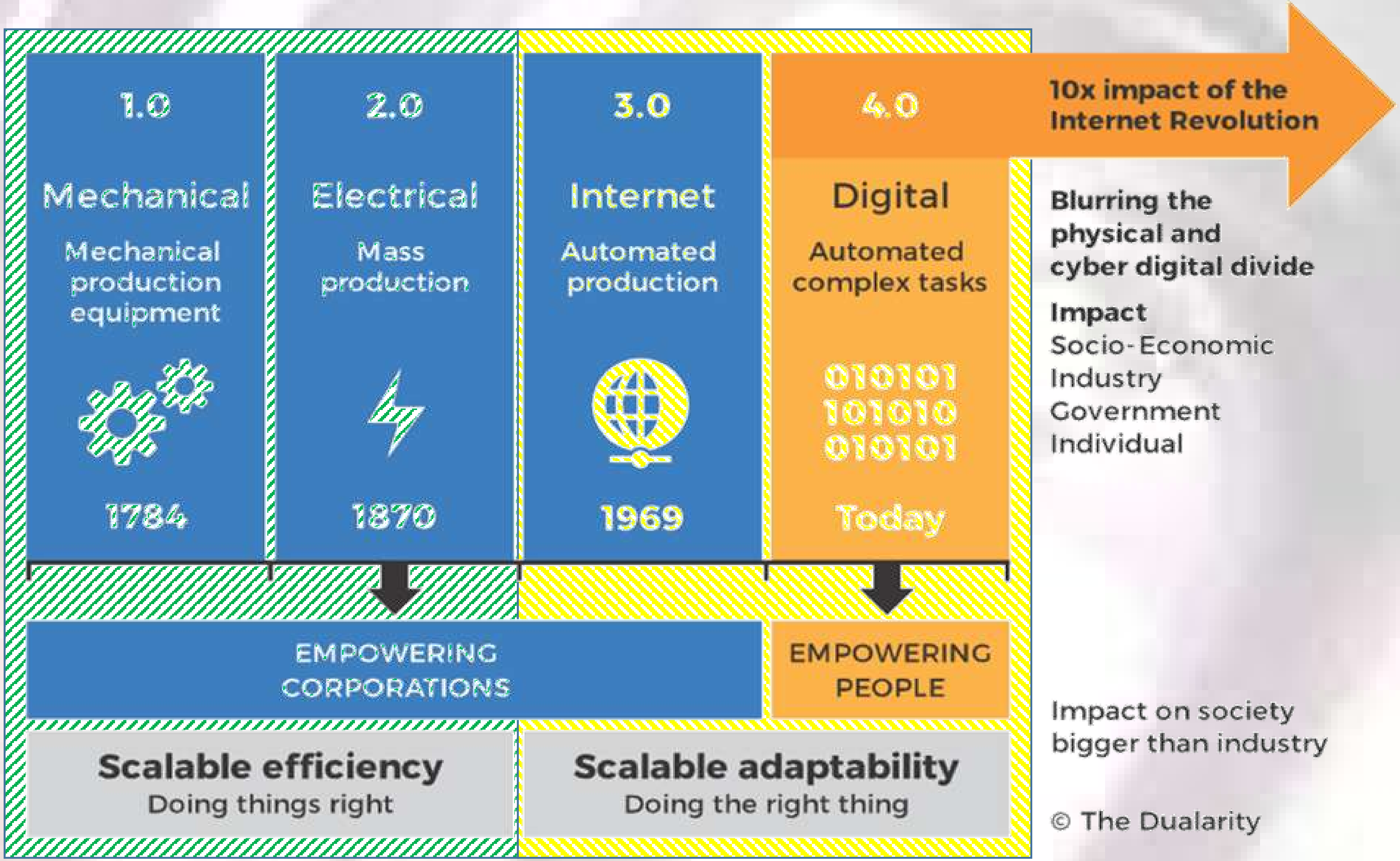
- **SPIE (The International Society for Optics and Photonics)**

  https://spie.org/#_=_

- **IEEE Photonics Society**

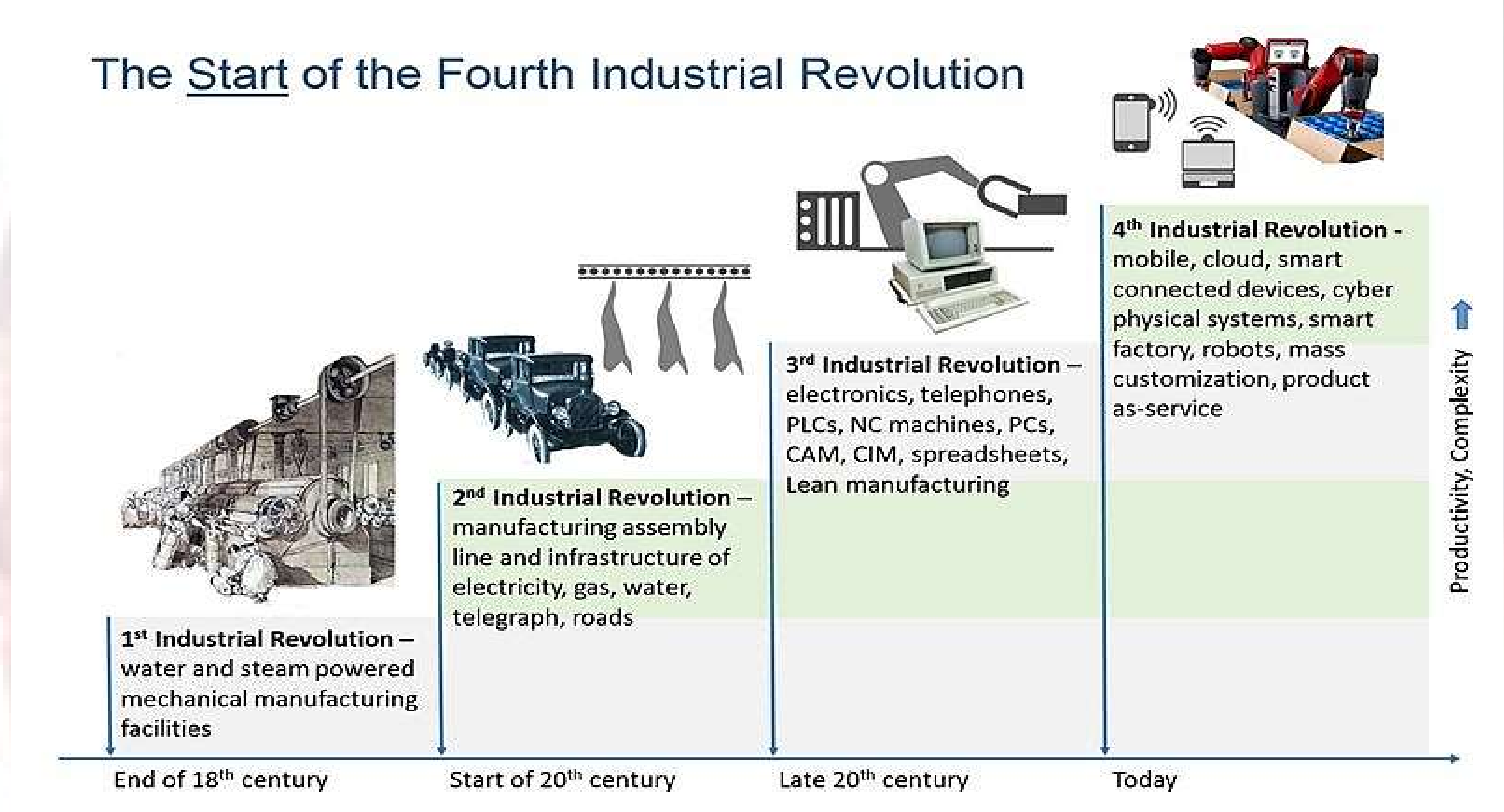
  https://ieeephotonics.org/

Industrial Revolutions



https://www.thedualarity.com/industrial-revolution-4-0-2/

Industrial Revolutions-manufacturing aspects



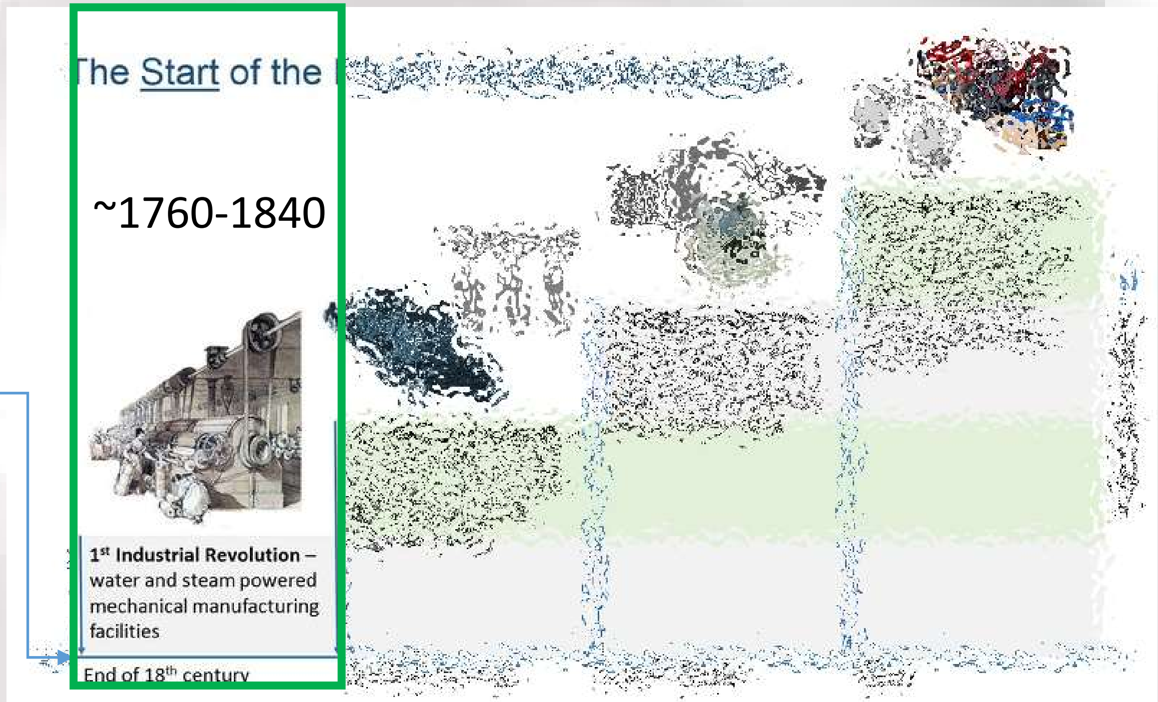
http://www.manufacturing-operations-management.com/manufacturing/2015/07/you-say-you-want-a-fourth-industrial-revolution-industrie-4.html

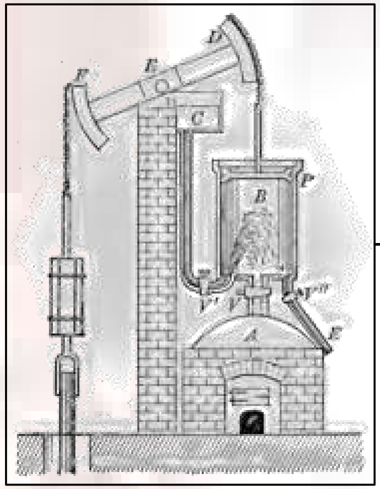
Industrial Revolution

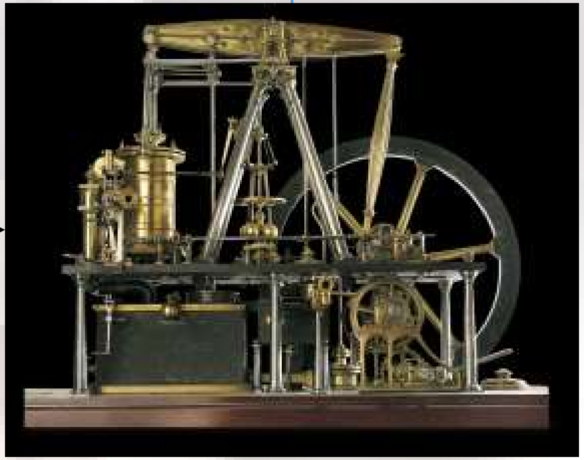
Important Technological Developments

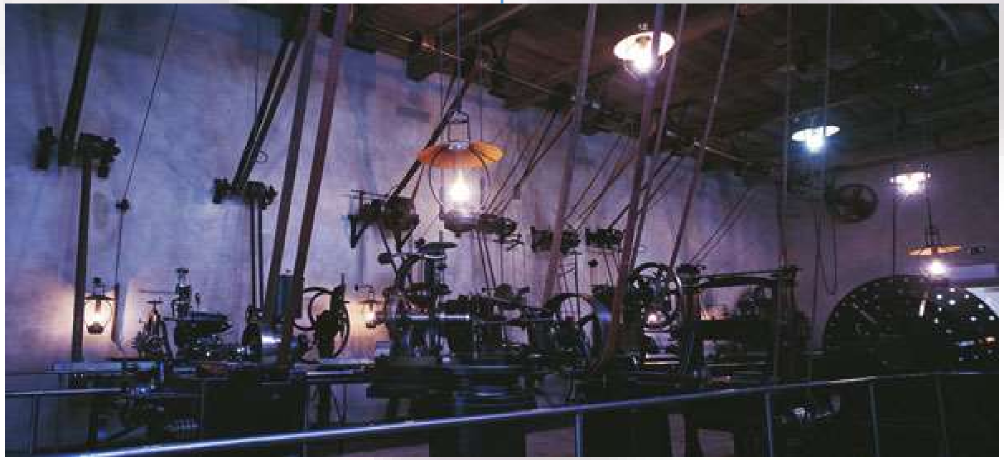
- **Textiles**
- **Steam power**
- **Iron making**
- **Invention of machine tools**


Prior to 18th-century workshop



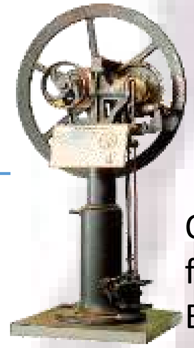

Newcomen steam engine
Invented in 1712


Watt Engine, 1763 to 1775
Milestone for Industrial Revolution

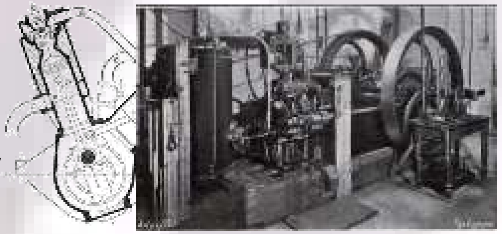

19th-century workshop

2nd Industrial Revolution

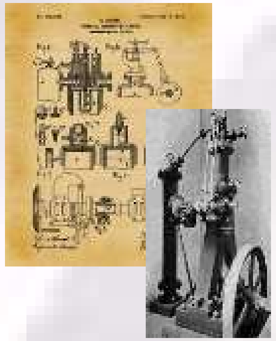
Internal combustion Engine



Otto ngine/ four stoke Engine, 1867



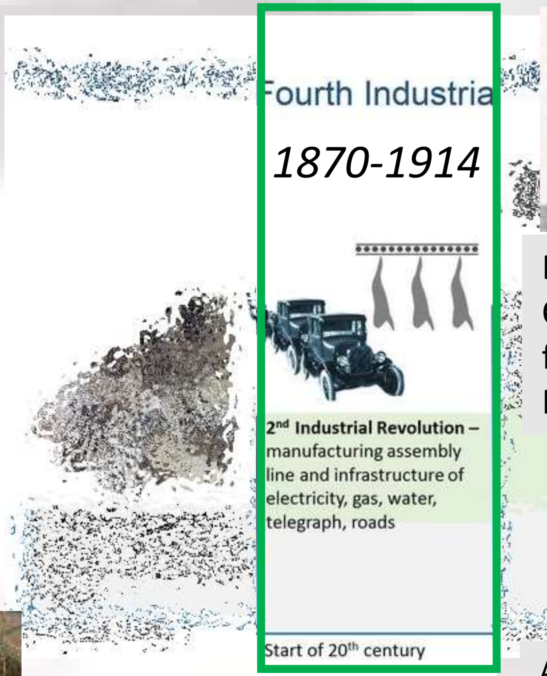
Dugald Clerk's two cycle engine in 1879

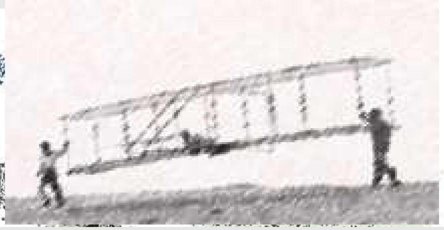


Rudolf Diesel, Patented 1892

Iron to Steel

Steel produced by Bessemer process, patented 1856





December 17, 1903, Orville Wright piloted the first powered airplane in North Carolina.

Assembly Line, 1901
Olds patented the assembly line concept, which he put to work in his Olds Motor Vehicle Company factory in 1901.

Transportation

Karl Benz made four-stroke engine was used for automobile, 1886

Steam Locomotive, 1830

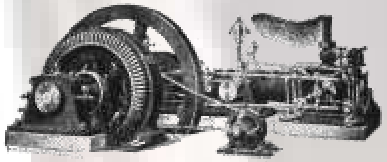
Virginia & Truckee "Tahoe", 1875

Electric Power

Electric generator

earliest generator for industrial process, 1844

high-current dynamo, 1917 310A/ 7V



Early 1900s 75 kVA direct-driven power station AC **alternator**

Nikola Tesla, Induction **Electric Motor, 1888**

dynamo, first electrical generator power for industry

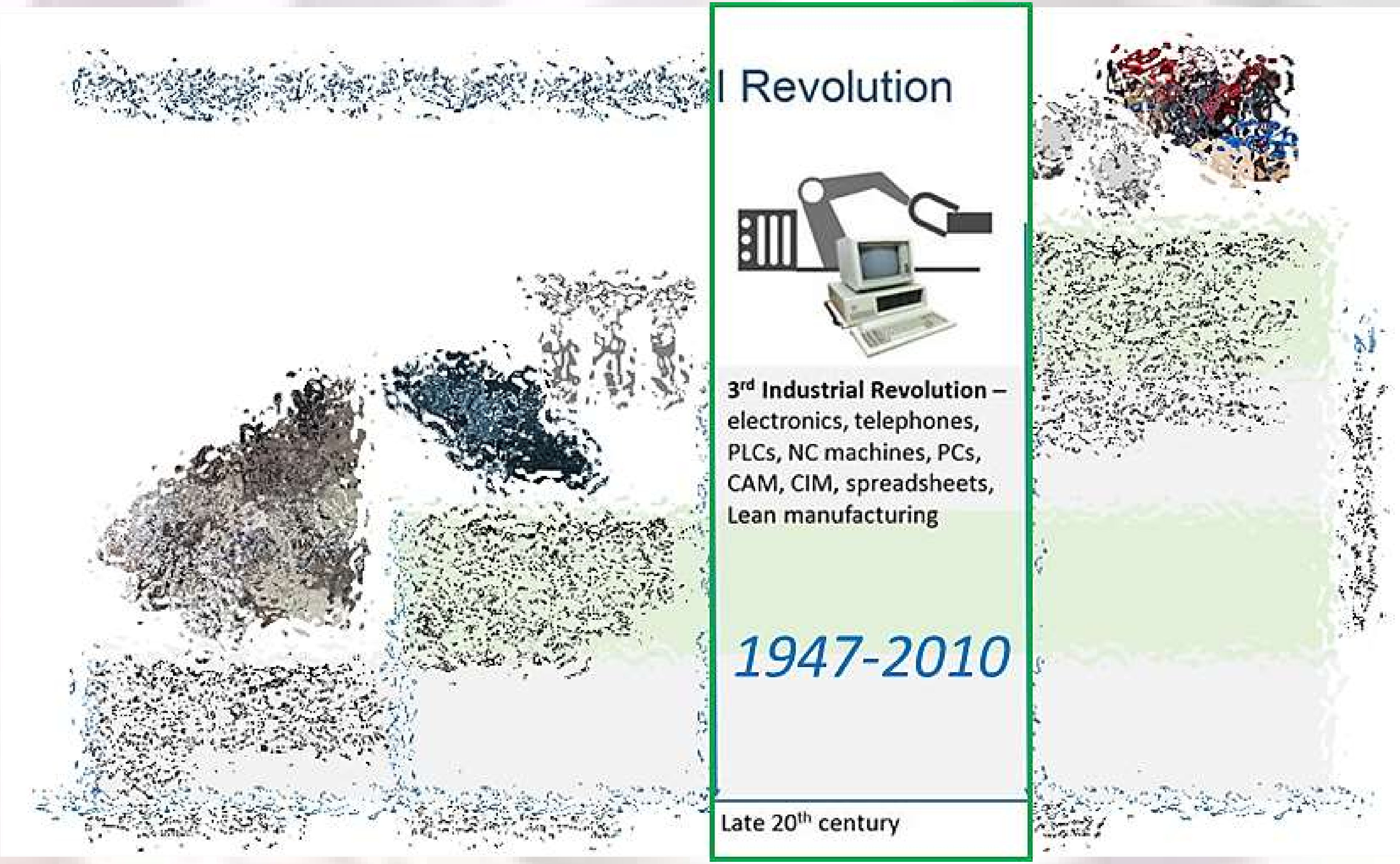
Communication

Telegraph, 1836

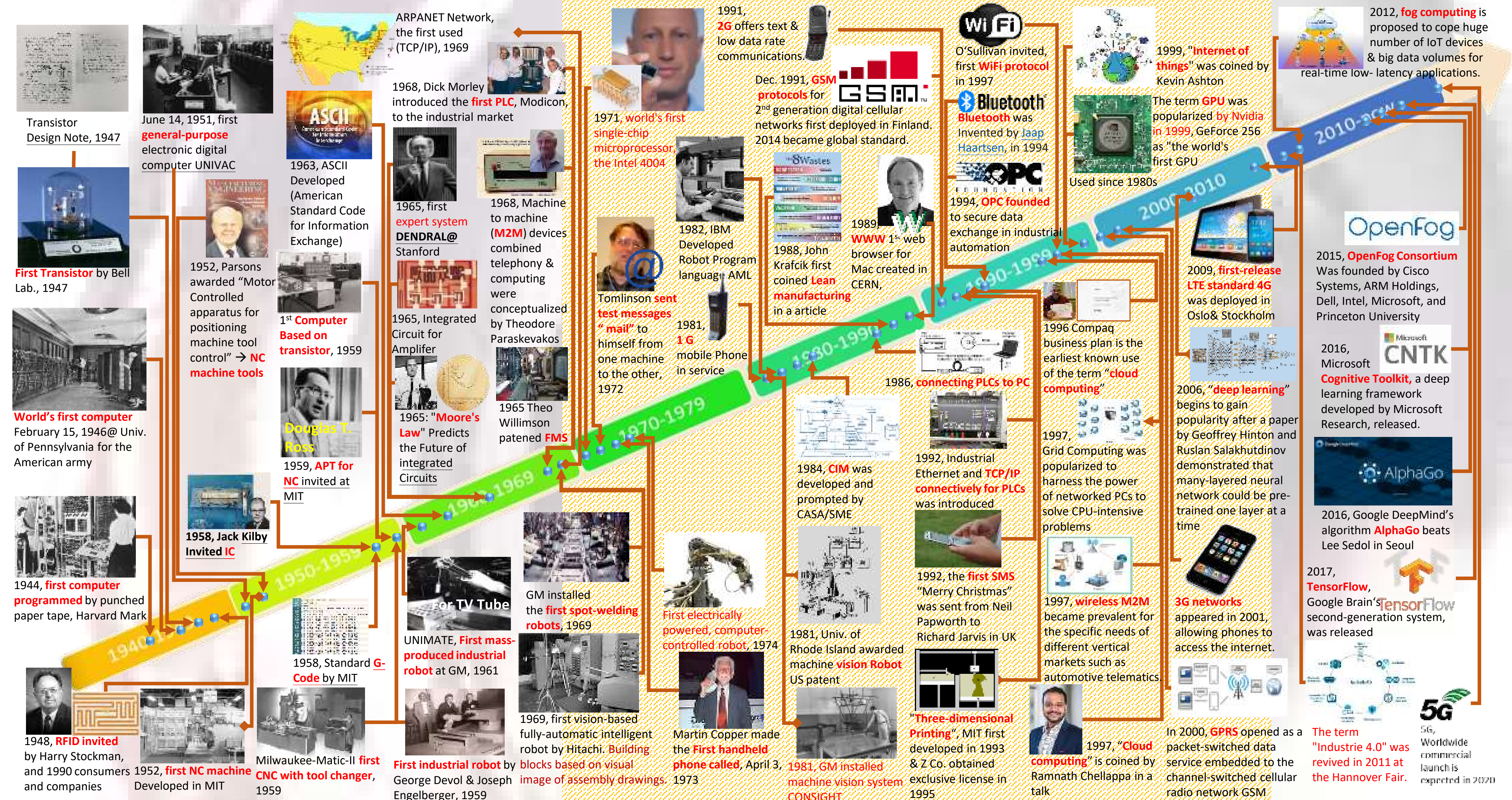
Telephone, 1876

Motor Driving Machine tool

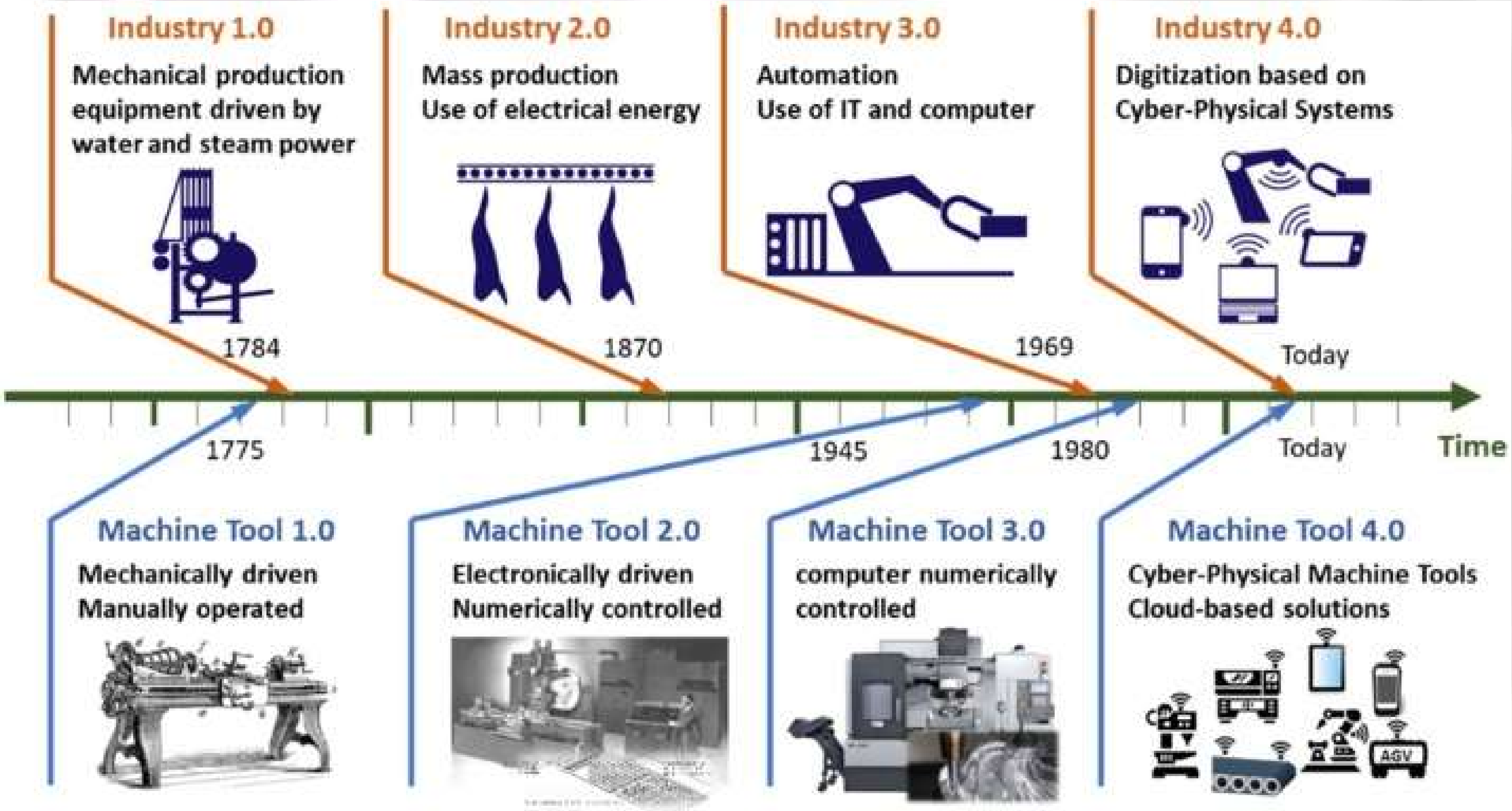
3rd Industrial Revolution—IT systems & digital technology overtaking analog & mechanical technology



3rd Industrial Revolution& Beyond—IT systems & digital technology overtaking analog & mechanical technology



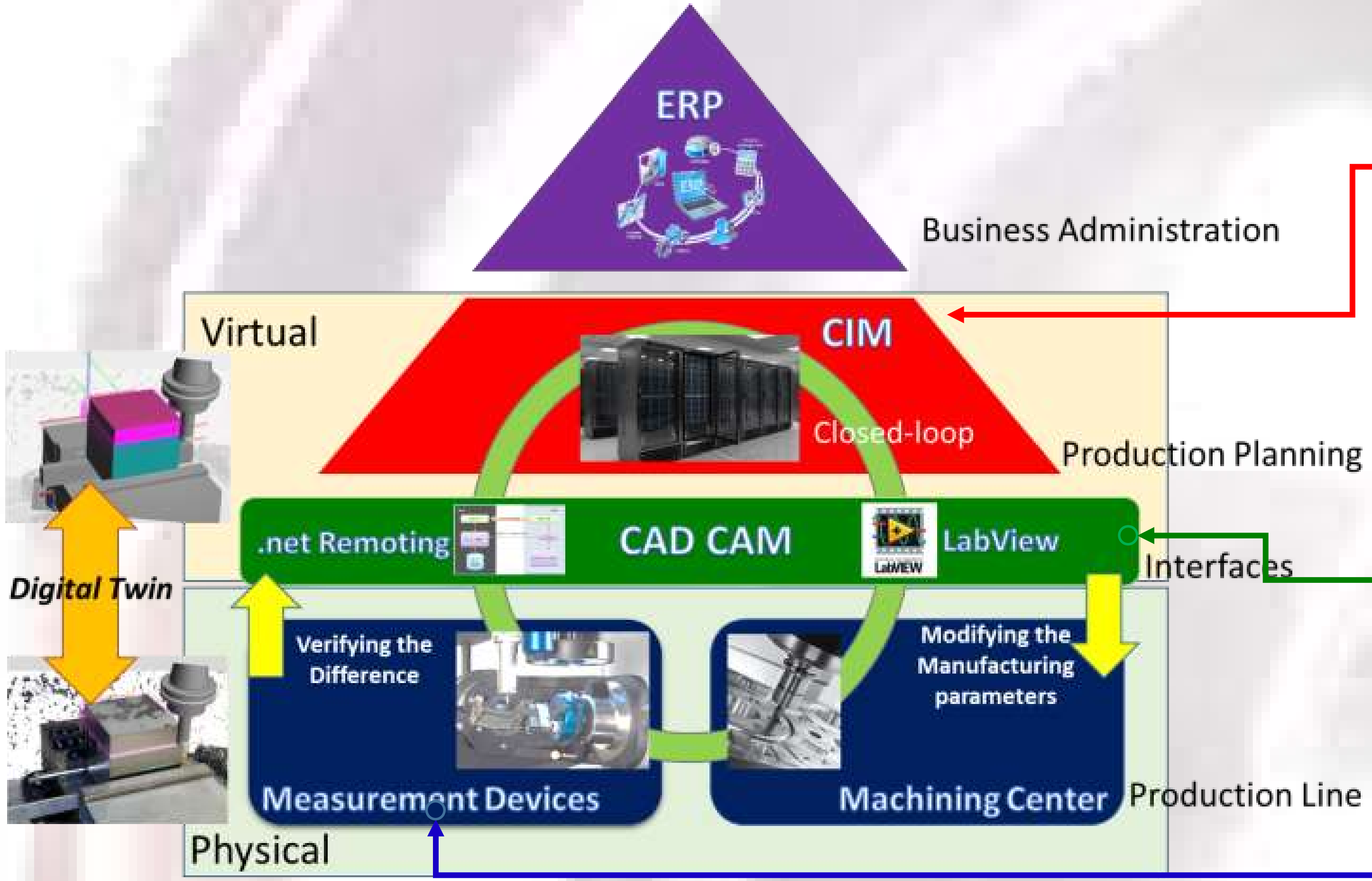
Machine tools vs. Industry Revolutions



Chao Liu, Hrishikesh Vengayil, Ray Y. Zhong, Xun Xu, “A systematic development method for cyber-physical machine tools”, Journal of Manufacturing Systems, 2018 (https://doi.org/10.1016/j.jmsy.2018.02.001)

Industrie 4.0

“strategic initiative to establish Germany as a lead market and provider of advanced manufacturing solutions. Industrie 4.0 represents **a paradigm shift from centralized to decentralized smart manufacturing and production**. Smart production becomes the norm in a world **where intelligent ICT-based machines, systems and networks are capable of independently exchanging and responding to information to manage industrial production processes**.”



Measurement processes are combined into current production planning and control systems (CIM) and ERP systems.

The measurement processes are integrated into CIM& ERP by LabView Interface, .net Remoting and CAD/CAM.

1. All the systems involved interact in a closed loop,
2. Be possible to intervene in production at any time,
3. Manufacturers can plan and manage production on a flexible basis based on the production measurement data

The role of optical measurement technology is to verify the Tolerances, Dimensions, Surface quality, & ….

Purpose/Goal:

Small batch quantities even with tight tolerances can be manufactured to a high level of precision & high quality

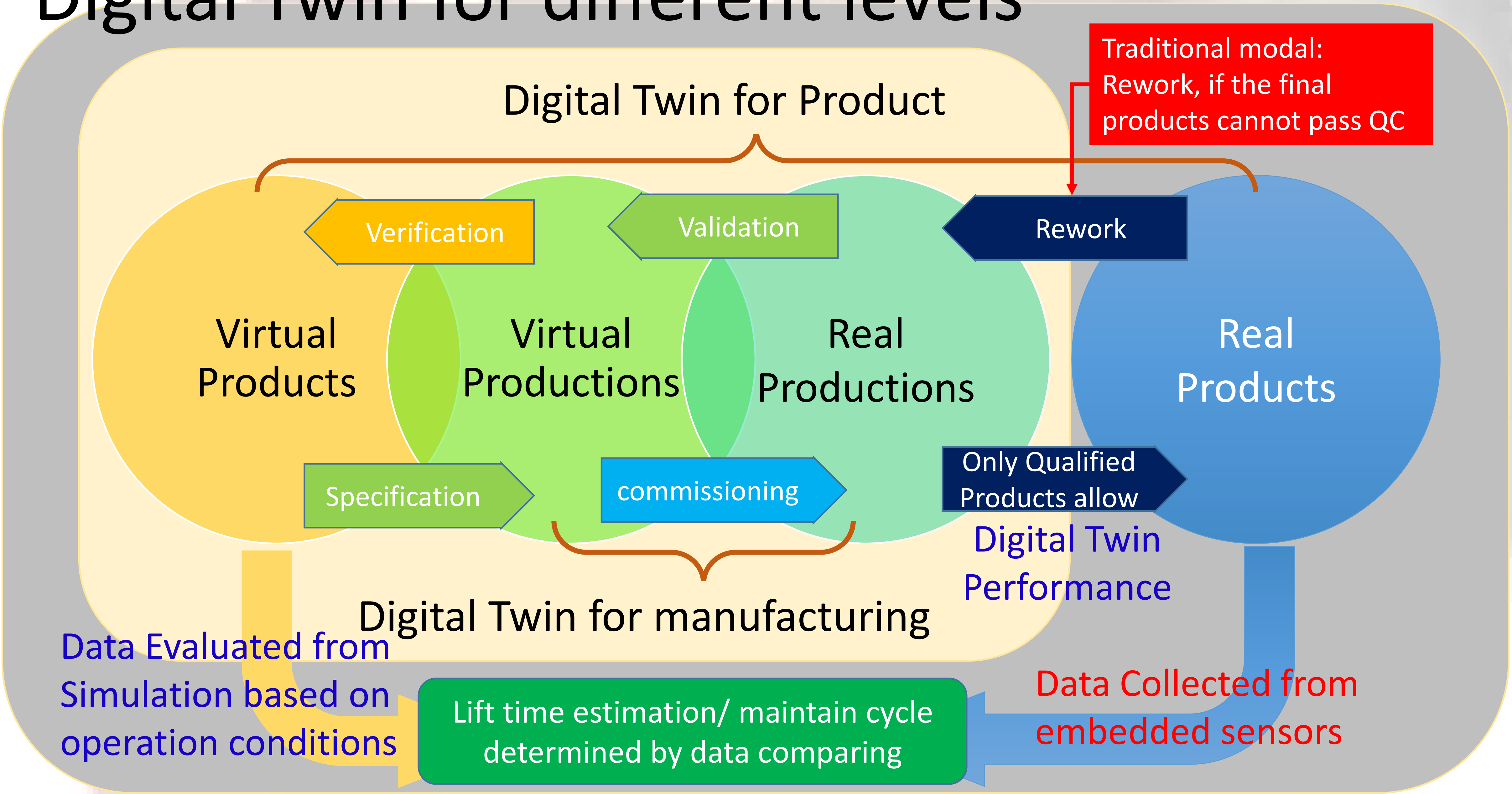
To make Smart Manufacturing work efficiently:

1. measurement sensors shall be integrated into the production line
2. The metrology equipment could be both capable of networking with current production systems and being expanded by the manufacturer

https://www.azom.com/article.aspx?ArticleID=13890

https://www.pmh.itm.kth.se/projekt/public-projects/digital-tvilling-for-ett-skarverktyg-avslutat-1.747323

Digital Twin for different levels



Digital Twin for different levels

Digital Twin for Product

Traditional modal: Rework, if the final products cannot pass QC

What we need to have—

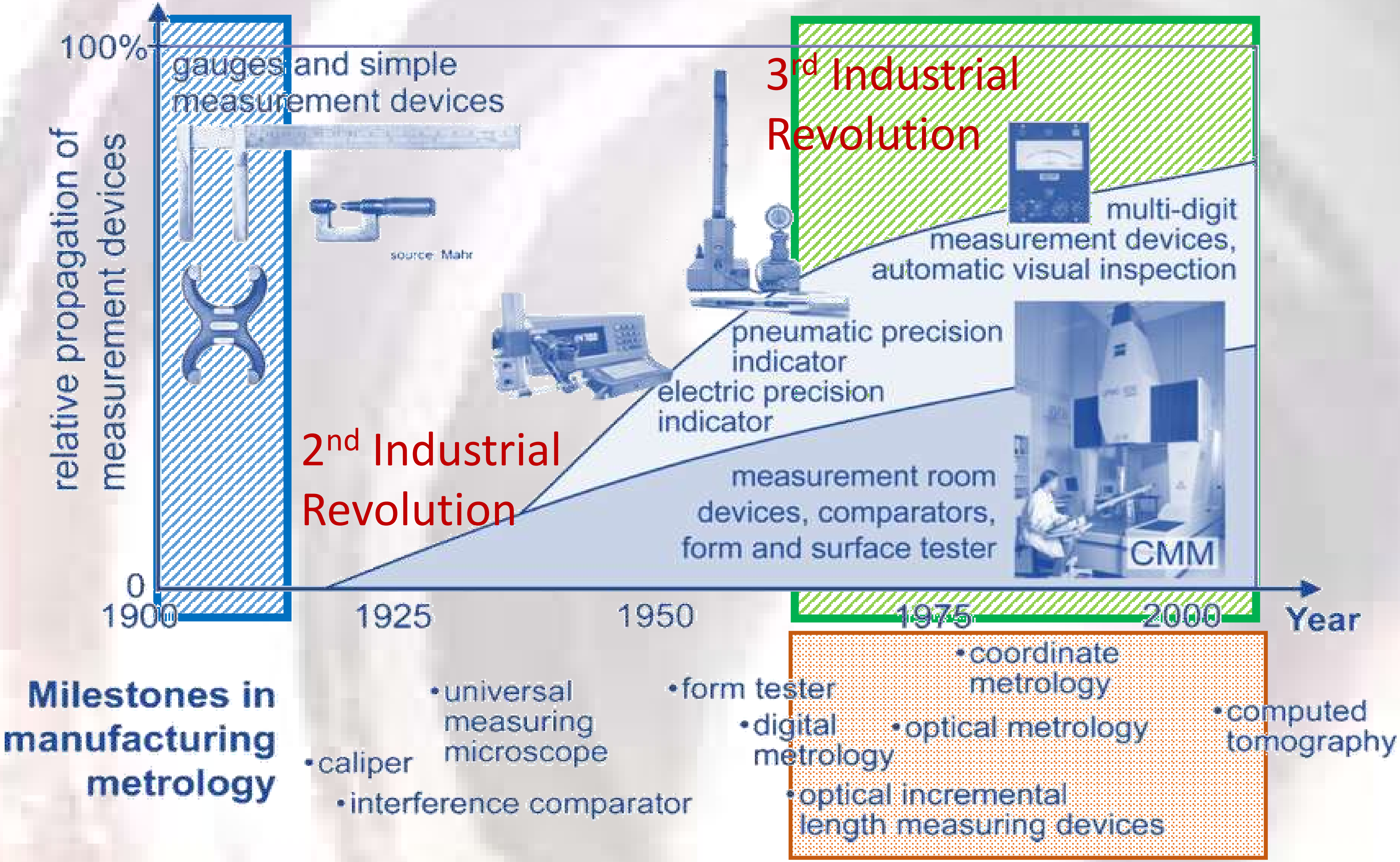
1. **On Machine Measurement technologies/ Metrologies**
2. Computing Capability
3. Well developed (wireless) Communication Environment
4. Prices for Sensors must be low
5. Capability for managing big data

….

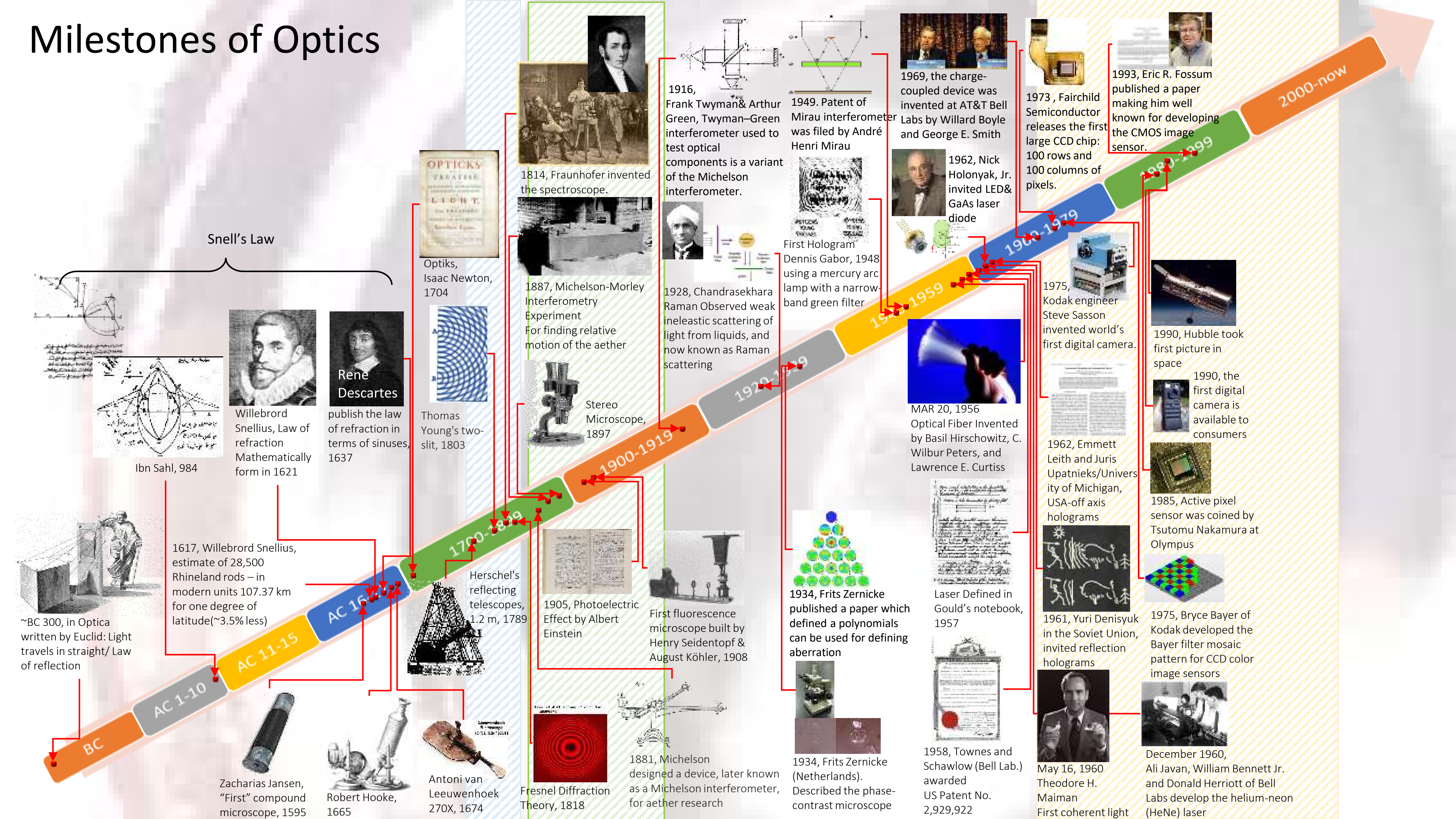
Data Evaluated from Simulation based on operation conditions

Lift time estimation/ maintain cycle determined by data comparing

Data Collected from embedded sensors



Weckenmann, A., & Krämer, P. (2009). Application of Computed Tomography in Manufacturing MetrologyAnwendung der Computer-Tomographie in der Fertigungsmesstechnik. Tm - Technisches Messen, 76(7-8). doi:10.1524/teme.2009.0969



Milestones of Optics
Snell's Law
BC
AC 1-10
AC 11-15
AC 16
1700-1899
1900-1919
1920-1939
1940-1959
1960-1979
1980-1999
2000-now
~BC 300, in Optica written by Euclid: Light travels in straight/ Law of reflection
Ibn Sahl, 984
1617, Willebrord Snellius, estimate of 28,500 Rhineland rods – in modern units 107.37 km for one degree of latitude(~3.5% less)
Willebrord Snellius, Law of refraction Mathematically form in 1621
Rene Descartes
publish the law of refraction in terms of sinuses, 1637
Zacharias Jansen, "First" compound microscope, 1595
Robert Hooke, 1665
Antoni van Leeuwenhoek 270X, 1674
Optiks, Isaac Newton, 1704
Thomas Young's two-slit, 1803
Herschel's reflecting telescopes, 1.2 m, 1789
1814, Fraunhofer invented the spectroscope.
Fresnel Diffraction Theory, 1818
1881, Michelson designed a device, later known as a Michelson interferometer, for aether research
1887, Michelson-Morley Interferometry Experiment For finding relative motion of the aether
Stereo Microscope, 1897
1905, Photoelectric Effect by Albert Einstein
First fluorescence microscope built by Henry Seidentopf & August Köhler, 1908
1916, Frank Twyman& Arthur Green, Twyman–Green interferometer used to test optical components is a variant of the Michelson interferometer.
1928, Chandrasekhara Raman Observed weak ineleastic scattering of light from liquids, and now known as Raman scattering
1934, Frits Zernicke published a paper which defined a polynomials can be used for defining aberration
1934, Frits Zernicke (Netherlands). Described the phase-contrast microscope
First Hologram Dennis Gabor, 1948 using a mercury arc lamp with a narrow-band green filter
1949. Patent of Mirau interferometer was filed by André Henri Mirau
MAR 20, 1956 Optical Fiber Invented by Basil Hirschowitz, C. Wilbur Peters, and Lawrence E. Curtiss
Laser Defined in Gould's notebook, 1957
1958, Townes and Schawlow (Bell Lab.) awarded US Patent No. 2,929,922
May 16, 1960 Theodore H. Maiman First coherent light
December 1960, Ali Javan, William Bennett Jr. and Donald Herriott of Bell Labs develop the helium-neon (HeNe) laser
1961, Yuri Denisyuk in the Soviet Union, invited reflection holograms
1962, Emmett Leith and Juris Upatnieks/University of Michigan, USA-off axis holograms
1962, Nick Holonyak, Jr. invited LED& GaAs laser diode
1969, the charge-coupled device was invented at AT&T Bell Labs by Willard Boyle and George E. Smith
1973 , Fairchild Semiconductor releases the first large CCD chip: 100 rows and 100 columns of pixels.
1975, Kodak engineer Steve Sasson invented world's first digital camera.
1975, Bryce Bayer of Kodak developed the Bayer filter mosaic pattern for CCD color image sensors
1985, Active pixel sensor was coined by Tsutomu Nakamura at Olympus
1990, Hubble took first picture in space
1990, the first digital camera is available to consumers
1993, Eric R. Fossum published a paper making him well known for developing the CMOS image sensor.

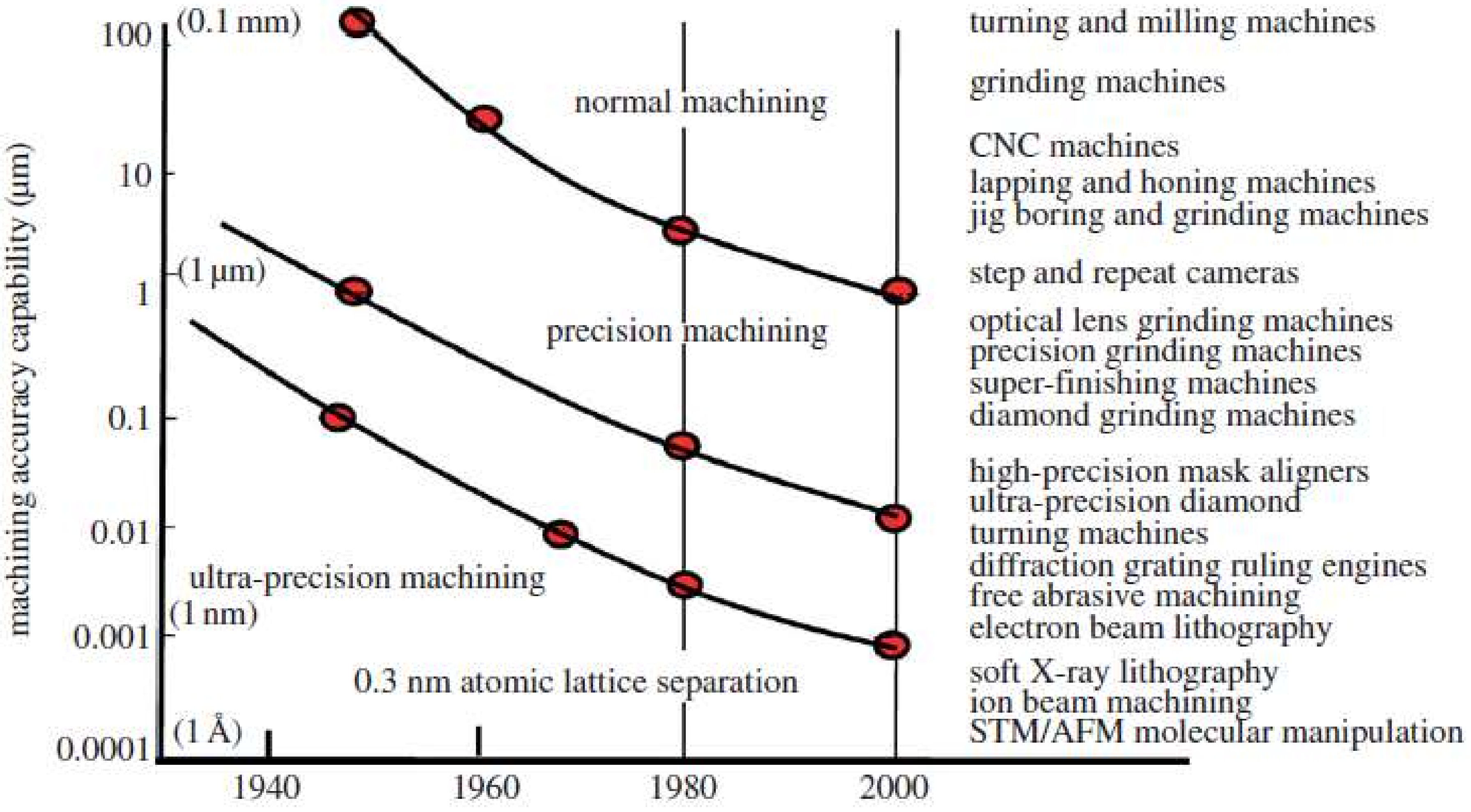
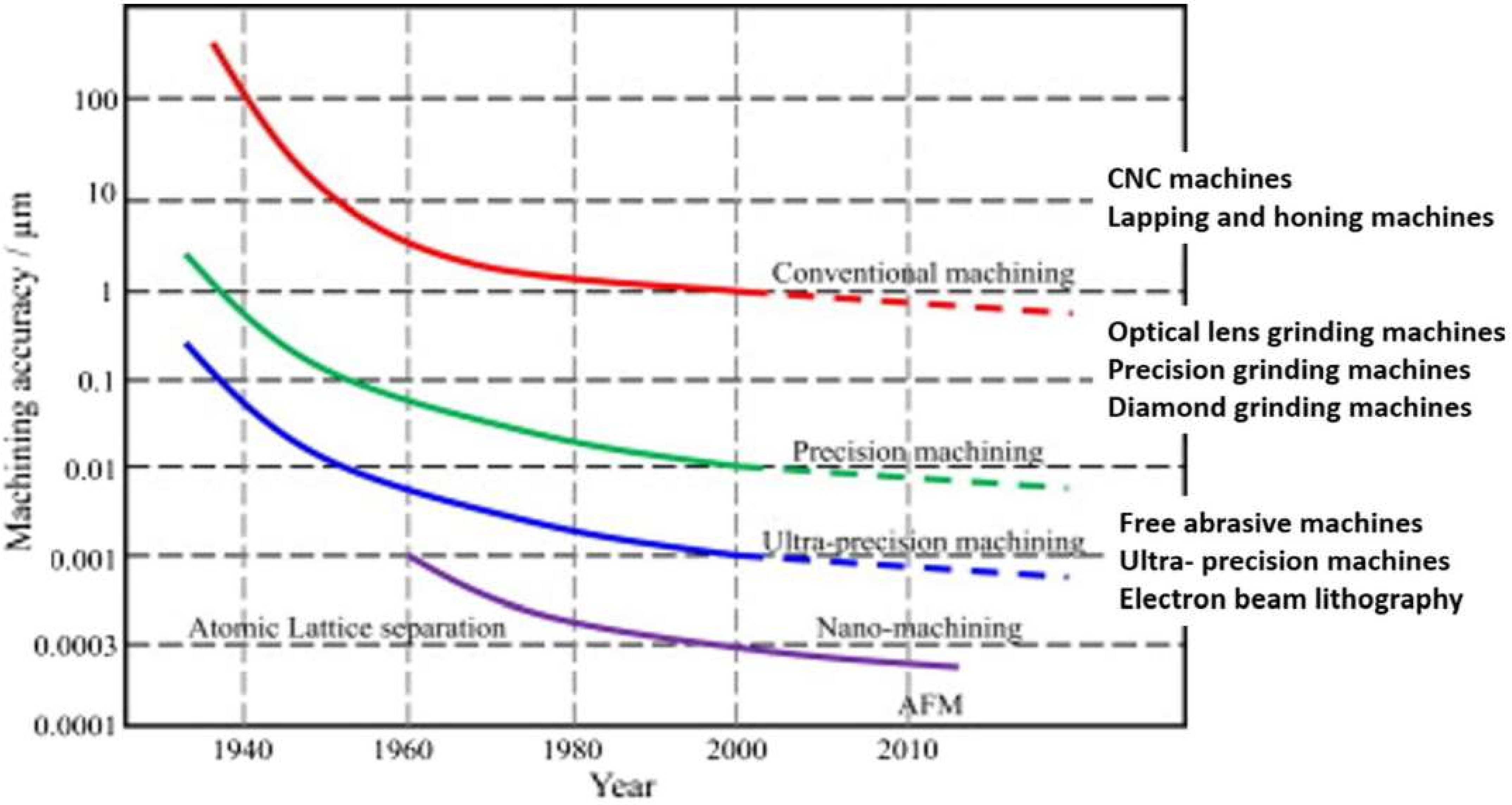


Figure 3. An interpretation of the Taniguchi curves, depicting the general improvement of machine accuracy capability with time during much of the twentieth century.

Paul Shore and Paul Morantz, Ultra-precision: enabling our future, Phil. Trans. R. Soc. A, vol. 370, pp. 3993–4014, 2012



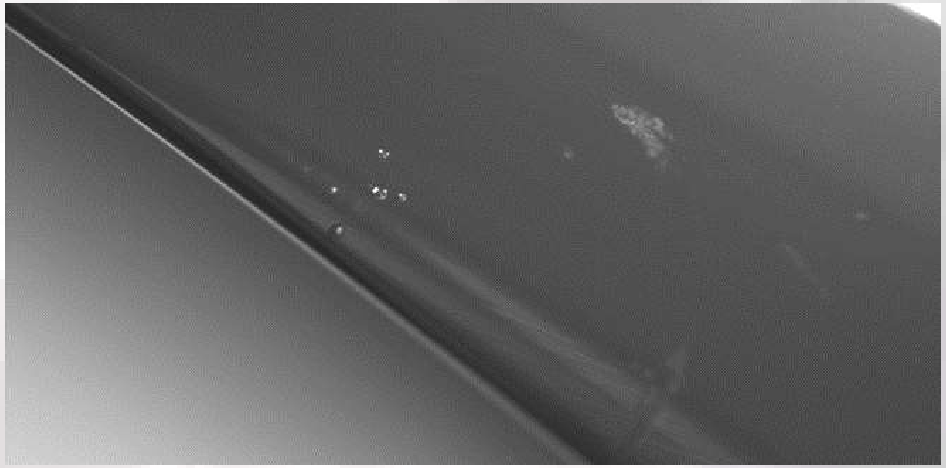
https://doi.org/10.1007/s10845-021-01782-3

General Descriptions of Optical Methods

- None-Contact vs. Contact
- Full Field vs. Line/ Point
- High Resolution— Spatial? Time domain?
- High Sensitivity—noise sources/ how to filter the noise

Highly Reflective Surface Defects


Scratch


Pitted


Combination Defects