

Electrical, Computer, Software, and Bio-Inspired Engineering

- a historical perspective -

Emil M. Petriu,
School of Electrical Engineering and Computer Science
University of Ottawa

Engineering Design

“Engineering design integrates mathematics, natural sciences, engineering sciences, and complementary studies in order to develop elements, systems, and processes to meet specific needs. It is a creative, iterative, and open-ended process, subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may also relate to economic, health, safety, environmental, societal or other interdisciplinary factors.

[CEAB – Accreditation Criteria and Procedures, sections 3.4.4.3 and 3.4.4.4]

Time

Science

➤ Antiquity

- Mathematics,
- Philosophy



True Mathematical Table
Surviving from Old
Babylonian Mathematics ;
circa 1,822 BCE – 1,784 BCE



Euclid's of Alexandria (approx. 300 BCE), *Elements*, a logic and coherent framework, including rigorous mathematical proofs.

Value	0	1	2	3	4	5	6	7	8	9
Western Arabic	.	١	٢	٣	٤	٥	٦	٧	٨	٩
Eastern Arabic	.	١	٢	٣	٤	٥	٦	٧	٨	٩
Devanagari	०	१	२	३	४	५	६	७	८	९
Gujarati	૦	૧	૨	૩	૪	૫	૬	૭	૮	૯
Gurmukhi	੦	੧	੨	੩	੪	੫	੬	੭	੮	੯
Limbu	᱆	᱇	᱈	᱉	᱊	᱋	᱌	ᱍ	ᱎ	ᱏ
Bengali	০	১	২	৩	৪	৫	৬	৭	৮	৯
Oriya	୦	୧	୨	୩	୪	୫	୬	୭	୮	୯
Telugu	౦	౧	౨	౩	౪	౫	౬	౭	౮	౯
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Burmese	၀	၁	၂	၃	၄	၅	၆	၇	၈	၉
Thai	๐	๑	๒	๓	๔	๕	๖	๗	๘	๙
Khmer	០	១	២	៣	៤	៥	៦	៧	៨	៩
Lao	໐	໑	໒	໓	໔	໕	໖	໗	໘	໙

Hindu-Arabic numeral system.
The inscriptions on the edicts of Ashoka (1st mill. BCE) display this number system used by the Imperial Mauryas.

Time

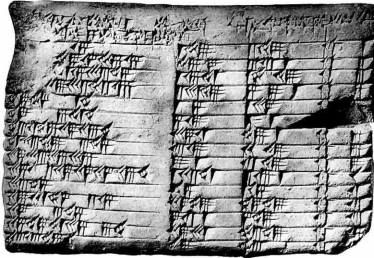
Science

Production of Goods and Services

➤ Antiquity

- Mathematics,
- Philosophy

➤ **Craftsmanship:**
 * Artisans
 * Guilds



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Time

Science

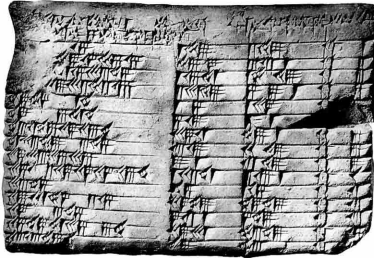
Production of Goods and Services

Engineering

➤ Antiquity

- Mathematics,
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Pyramid of Giza / Pyramid of Khufu 2589–2566 BCE



South Pointing Chariot one of the most complex geared Mechanisms, approx 2600 BCE, during the reign of mythical Yellow Emperor of China

The Four Great Inventions of ancient China are the Compass, Gunpowder, Papermaking, Printing.



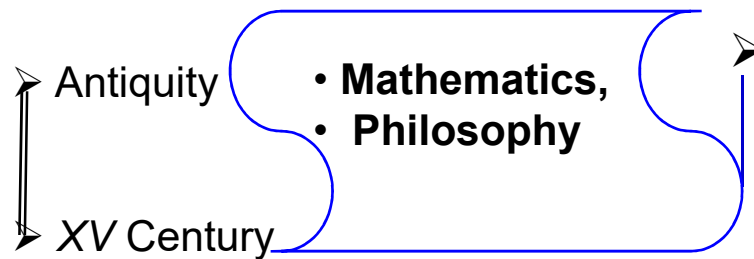
Roman aqueduct - approx 19 BCE. Pont du Gard, France,

Time

Science

Production of
Goods and Services

Engineering



- Mathematics,
- Philosophy

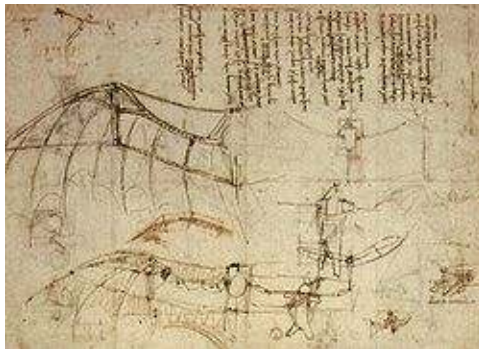
Craftsmanship

- * Artisans
- * Guilds

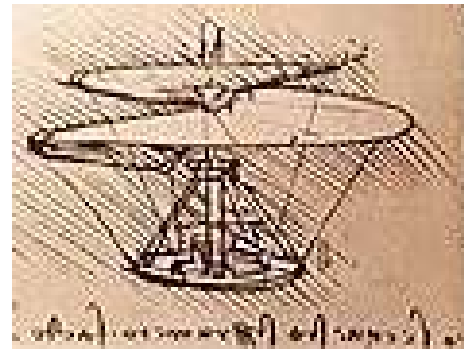


Leonardo da Vinci (1452 –1519), polymath: painter, sculptor, architect, musician, scientist, mathematician, engineer, inventor, anatomist, geologist, cartographer, botanist and writer..

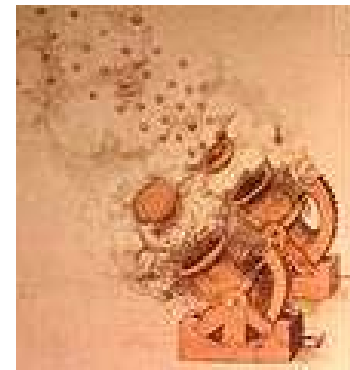
Military Eng..



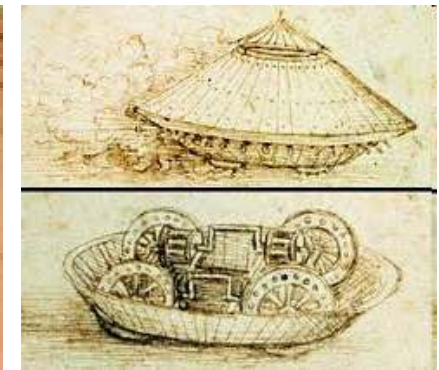
Design for a flying machine with wings based upon a bat's wings model.



"Aerial Screw", an early helicopter.



Cannons



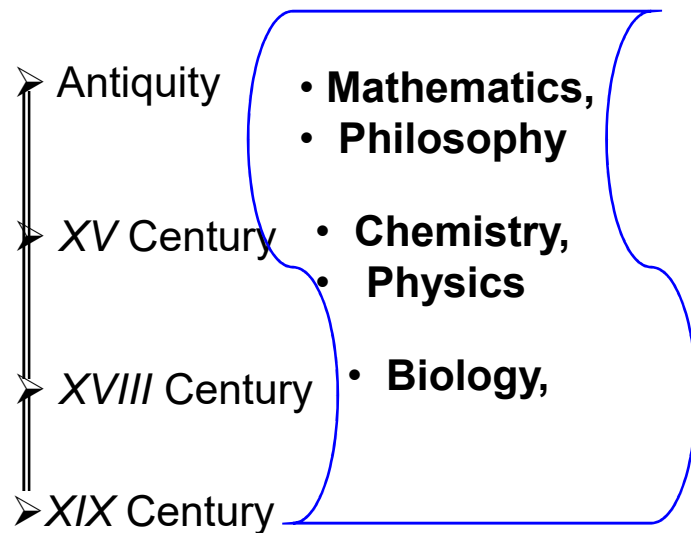
Tank

Time

Science

Production of
Goods and Services

Engineering



- **Mathematics,**
- **Philosophy**

- **Chemistry,**
- **Physics**

- **Biology,**

➤ **Craftsmanship:**
* *Artisans*
* *Guilds*

Industrial Revolution:
mechanization of
industry; late 1800s
- early 1900s

➤ **Industry:**
- Engineers/
Product Develop.
- Capitalists
- Workers



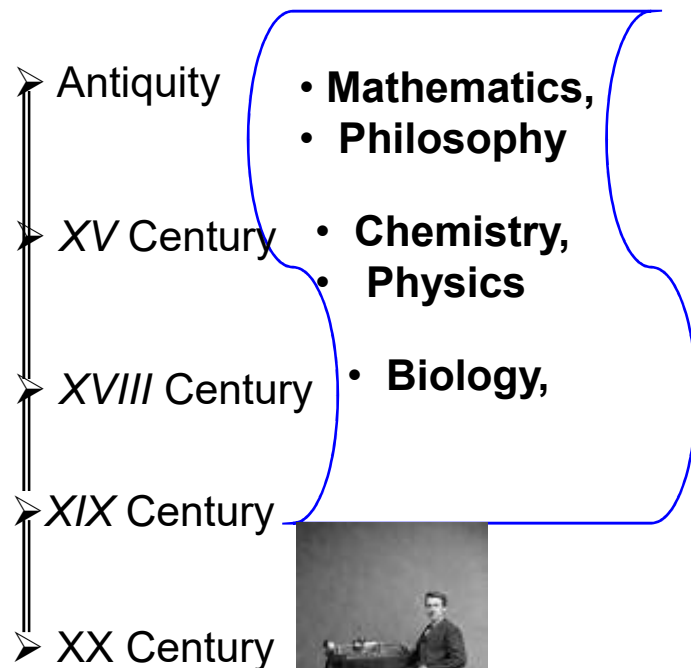
- Military Eng..**
- Civil Eng..**
- Mechanical Eng..**
- Chemical Eng..**

Time

Science

Production of
Goods and Services

Engineering



- **Mathematics,**
- **Philosophy**

- **Chemistry,**
- **Physics**

- **Biology,**



➤ **Craftsmanship:**
* *Artisans*
* *Guilds*

Industrial Revolution:
mechanization of
industry; late 1800s
- early 1900s

➤ **Industry:**
- Engineers/
Product Develop.
- Capitalists
- Workers
- **Entrepreneurs**



1946 ...

Military Eng..

Civil Eng..

Mechanical Eng..

Chemical Eng..

Electrical Eng..

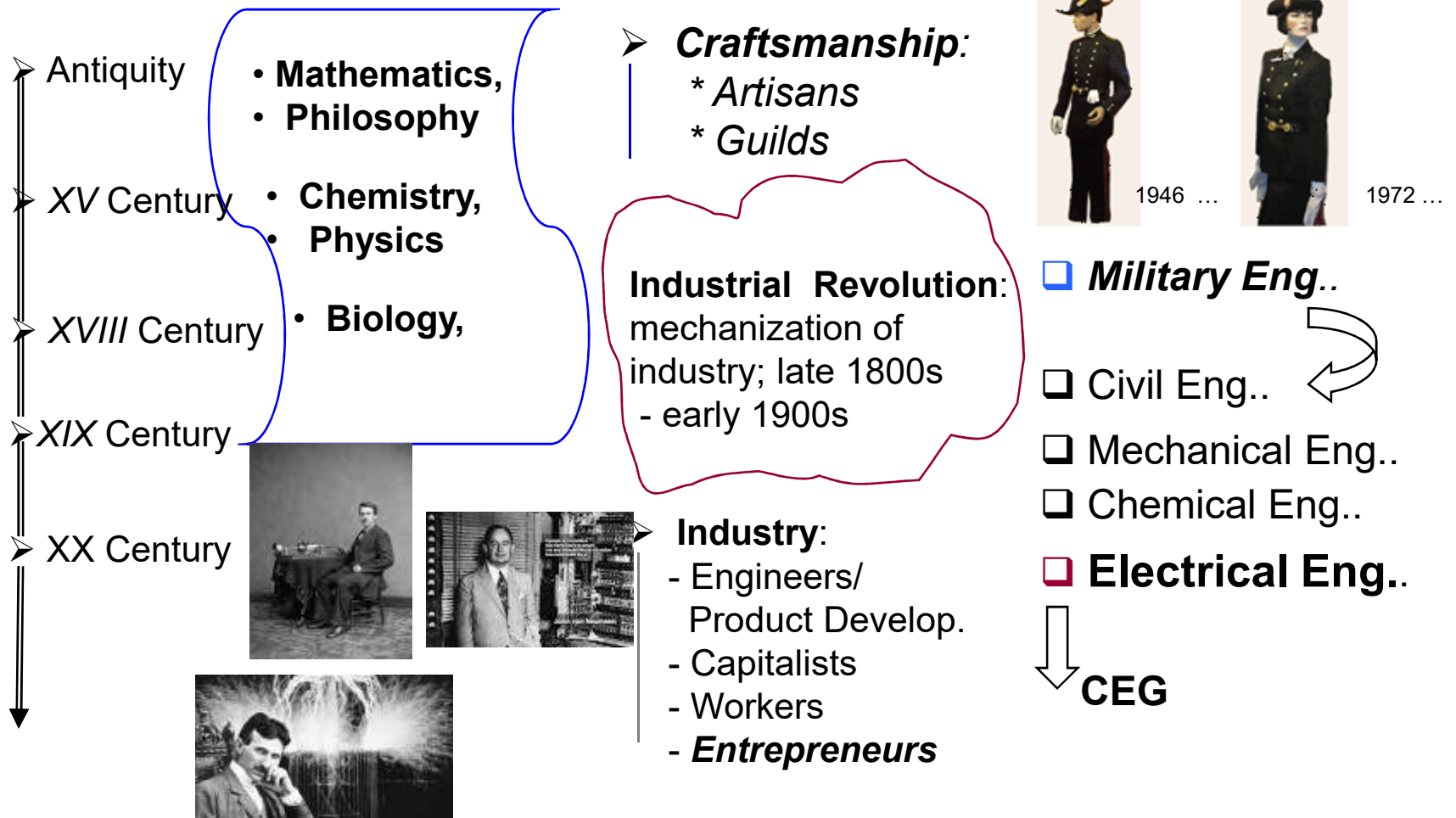


Time

Science

Production of Goods and Services

Engineering

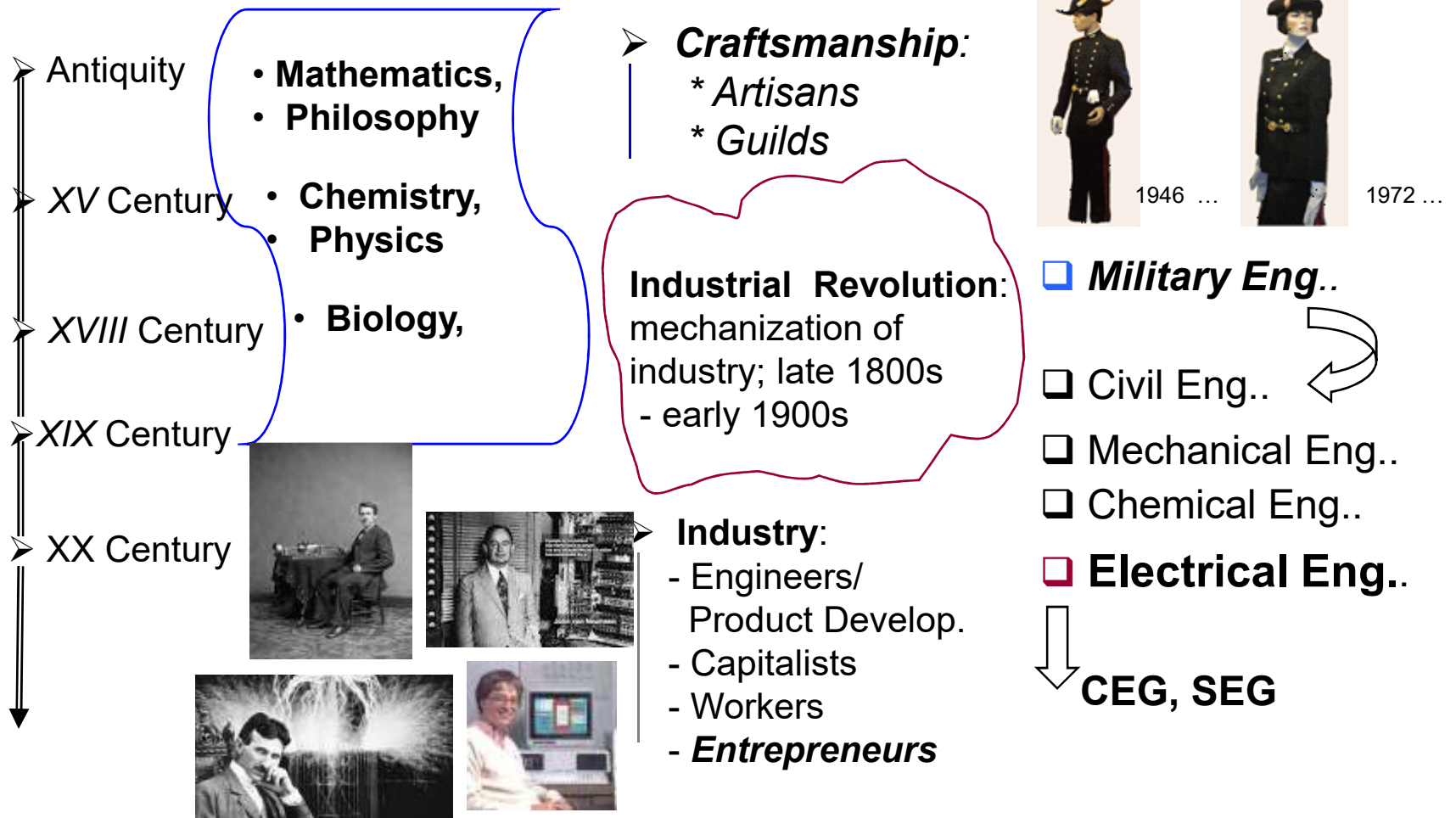


Time

Science

Production of Goods and Services

Engineering

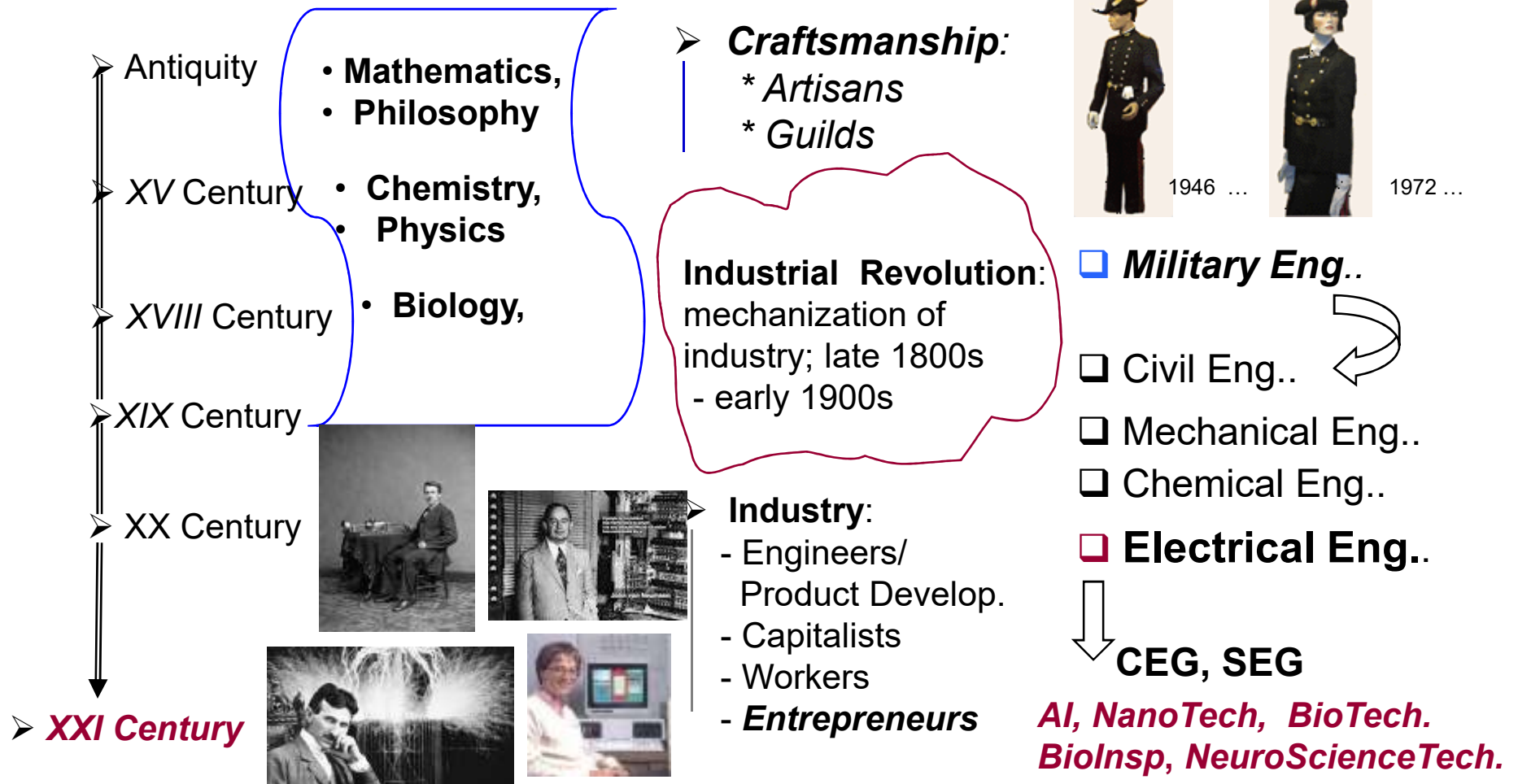


Time

Science

Production of Goods and Services

Engineering



INDUSTRY

Electrical (Electric Power Production & Utilization)

ENGINEERING

Methodologies for the application of the scientific principles to industrial production :

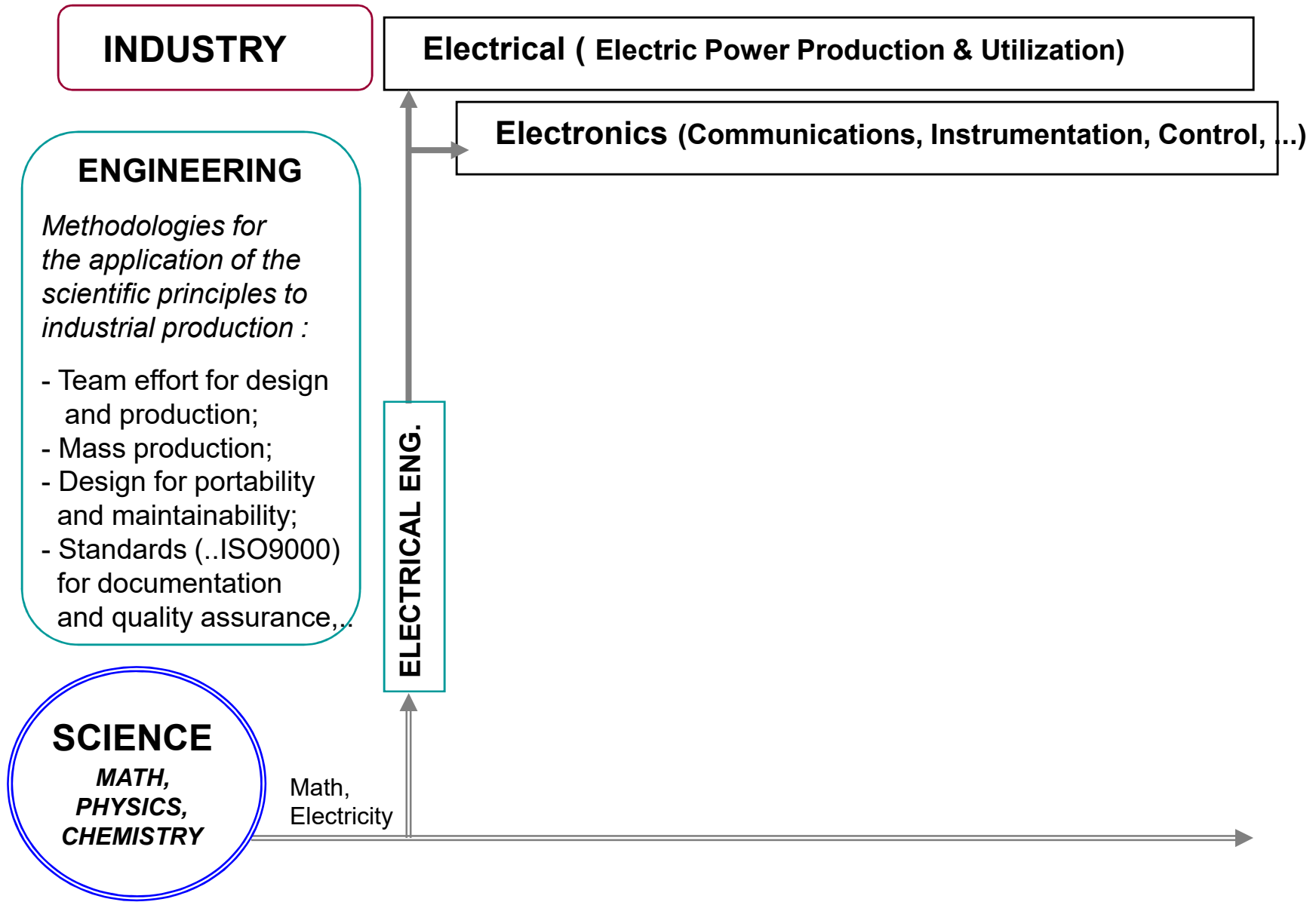
- Team effort for design and production;
- Mass production;
- Design for portability and maintainability;
- Standards (..ISO9000) for documentation and quality assurance,...

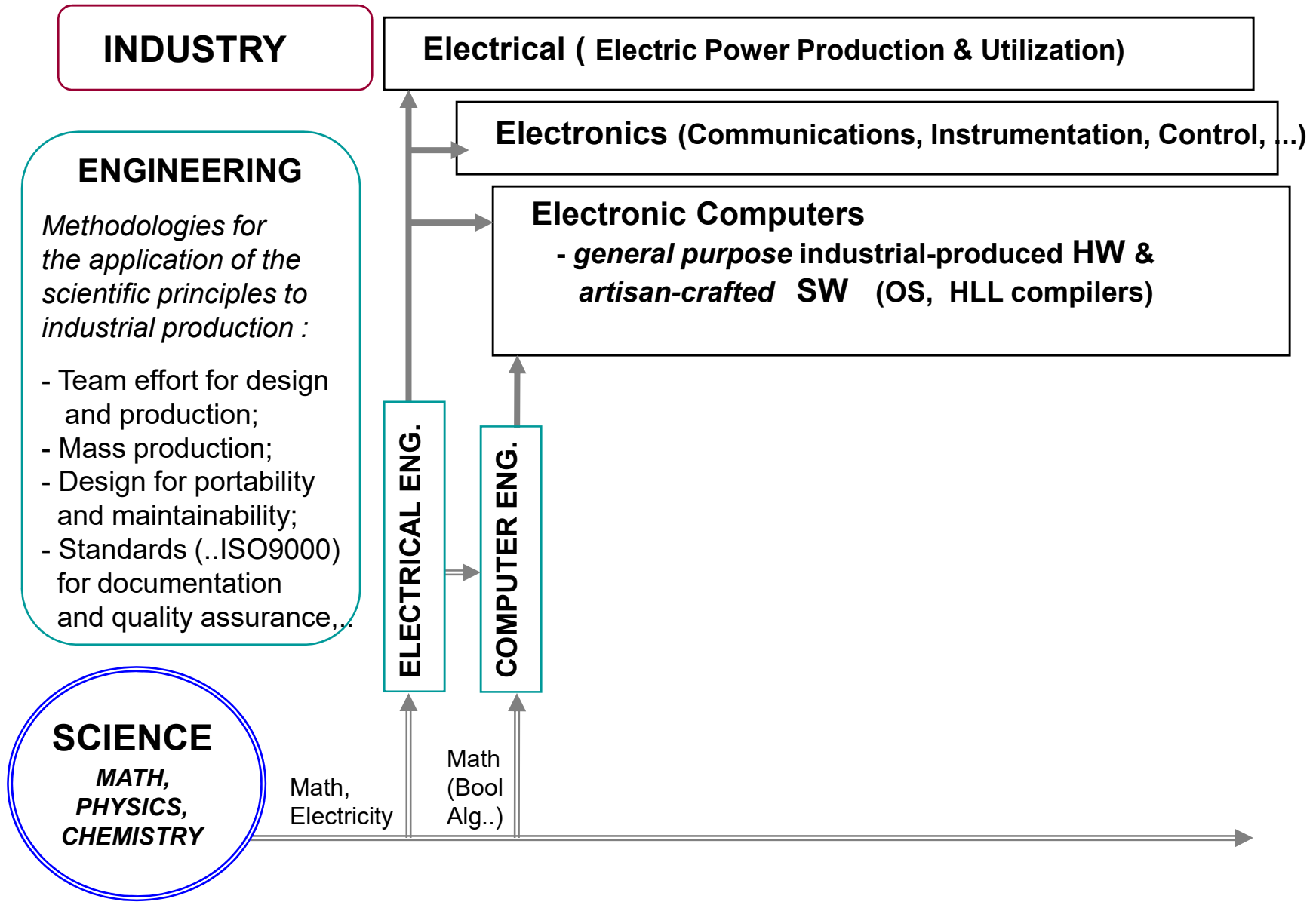
ELECTRICAL ENG.

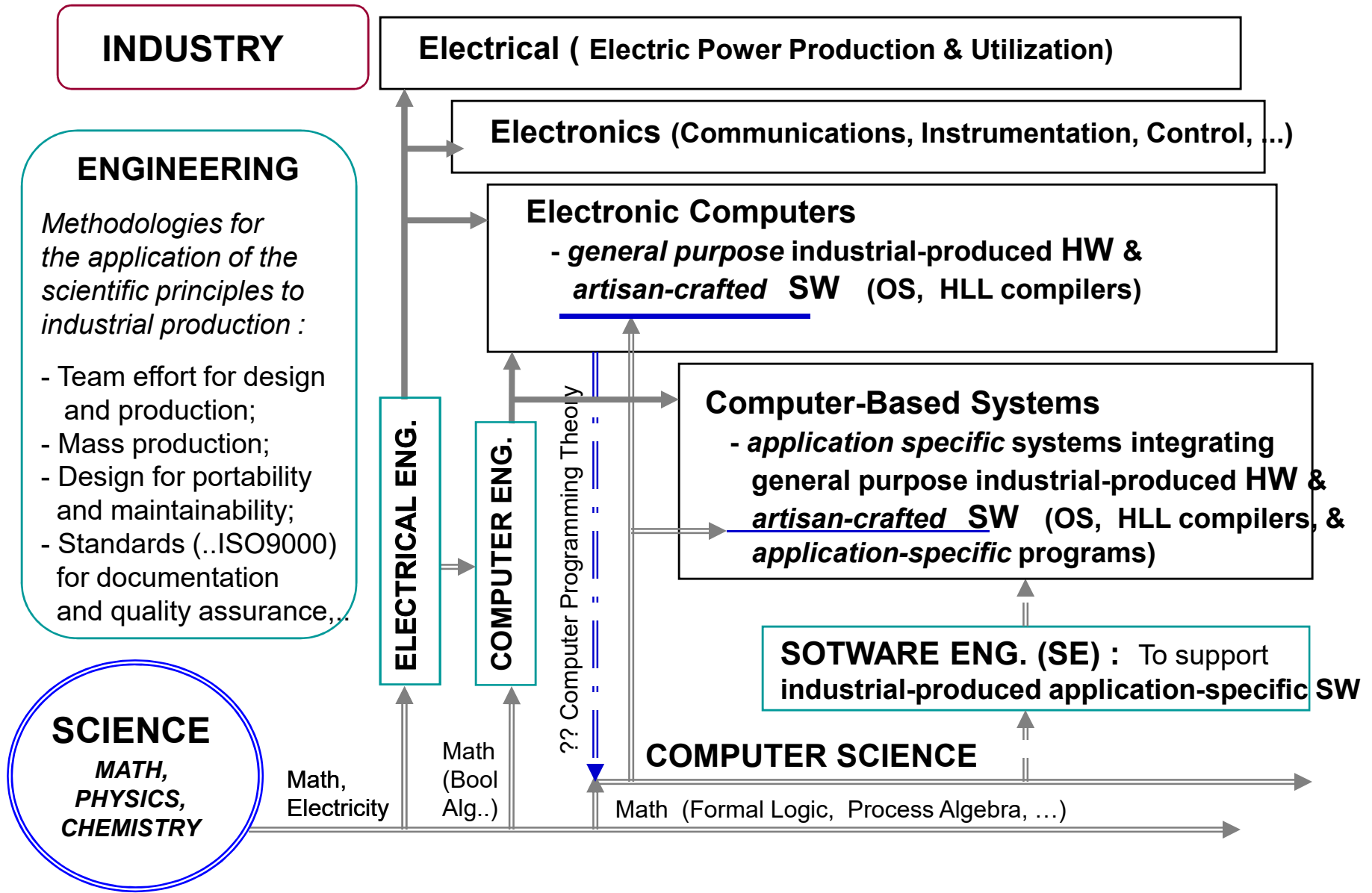
SCIENCE

**MATH,
PHYSICS,
CHEMISTRY**

Math,
Electricity

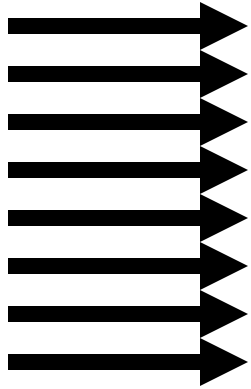






IT as an Enabler

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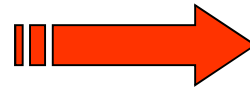
IT Enabler



e-Society



Bio & Health Engineering.



Infrastructure
Preparedness

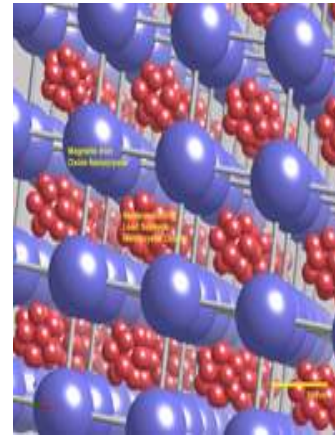


Environmental Technologies

Environmental Technologies



Environmental
Technologies



Advanced
Materials

Infrastructure Preparedness



Robotics
and
Automation



Mobile and
Sensor
Networks



Infrastructure
Protection and
Emergency
Preparedness

Bio and Health Engineering



IT in Health



Biomedical
Engineering

e-Society



Telecom Systems
And Networks



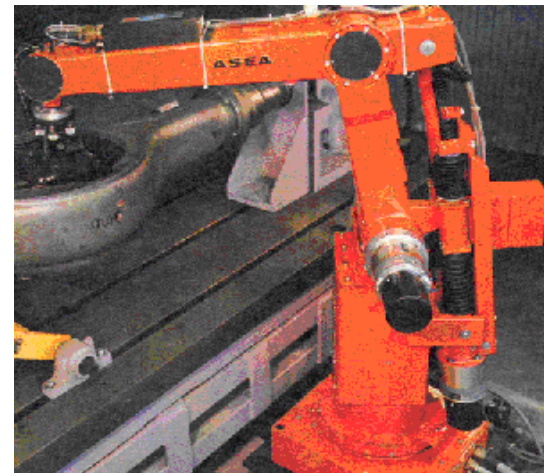
Wireless
Technologies



Information
Security and
Privacy



Multimedia, Virtual
Environments and
Haptics



ASEA robot performing mechanical assembly tasks.



Canadian Space Agency:

In 1981, Canada confirmed its position as a world leader in space technology with the development of the Remote Manipulator System, or **Canadarm**.

The RMS can be used: to deploy and retrieve satellites, to hold targets, to explore samples, and to manipulate hardware for the Space Shuttle.

In 1988, Canada agreed to join the international partners to build a permanently inhabited Space Station. Canada's contribution is to design, manufacture, and operate a robotic system, the **Mobile Servicing System (MSS)**, for assembly, maintenance, and servicing tasks on the Space Station.

Vision-Based Sensing and Control for Space Robotics Applications

Michael E. Stieber, *Member, IEEE*, Michael McKay, George Vukovich, *Member, IEEE*, and Emil Petriu, *Senior Member, IEEE*

Abstract—The following problems arise in the precise positioning of payloads by space manipulators:

- 1) the precise measurement of the relative position and motion of objects in the workspace of the robot;
- 2) the design of a control system, which is robust and performs well in spite of the effects of structural flexibility and oscillations typically associated with space robots.

This paper discusses the solution to the measurement problem by a vision system using photogrammetric image processing to determine the motion of objects in real time. Performance characteristics are presented. The control problem is addressed by a new technique dealing effectively with the challenge posed by the noncollocated sensor/actuator configuration on the flexible robot structure. The laboratory implementation of the measurement and control concepts is discussed. Preliminary results validate the concepts.

Index Terms—Artificial vision, control, measurement of motion, photogrammetry, robotics.

I. INTRODUCTION

ROBOTIC systems will play an important role in reducing hazards and increasing productivity of humans in space. A prime example is the Mobile Servicing System (MSS) shown in Fig. 1 which is presently being developed by the Canadian Space Agency for the assembly and external maintenance of the International Space Station (ISS) [1]. As the tasks performed by space robots become more complex, the need for more human-like characteristics emerges. As with humans, the sense of sight is essential to enabling efficient interaction with the environment. More important than the sense of sight per se is the ability to process images in such a way as to enable more efficient, accurate and autonomous control of the robot.

This paper addresses measurement and control problems associated with the precise positioning of large space robot manipulators like the Space Station Remote Manipulator System (SSRMS) shown in Fig. 1, which typically have a very high payload-to-manipulator mass ratio (e.g. 116 000 kg/1500 kg for SSRMS) and relatively low stiffness, resulting in highly time-variant dynamic behavior with significant low-frequency oscillations. A theoretical concept for the systematic design of an instrumentation architecture for such systems

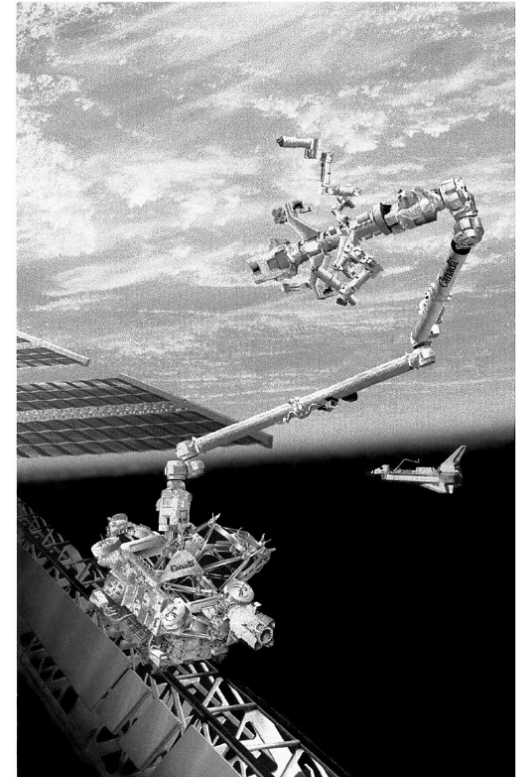


Fig. 1. Mobile Servicing System on the International Space Station.

was presented in [2]. This paper discusses the experimental implementation and evaluation of this concept in a laboratory setting. Section II discusses the measurement of the manipulator payload motion, including the contributions due to structural flexibility, relative to other objects in the manipulator workspace using a vision system. In Section III we extend the theoretical concept of [2] to the case of partially noncollocated sensor/actuator configurations on flexible structures and discuss the design and performance of a control system for the laboratory robot.

Manuscript received May 23, 1996; revised April 12, 1999.

M. E. Stieber and G. Vukovich are with the Canadian Space Agency, St. Hubert, P.Q., Canada.

M. McKay is with the Department of National Defense, Ottawa, Ont., Canada.

E. Petriu is with the University of Ottawa, Ottawa, Ont., K1N 6N5, Canada. Publisher Item Identifier S 0018-9456(99)06676-0.

Da Vinci Surgical System is a robotic surgical system made by the American company Intuitive Surgical. Approved by the Food and Drug Administration (FDA) in 2000, it is designed to facilitate complex surgery using a minimally invasive approach, and is controlled by a surgeon from a console.



Da Vinci System allows the surgeon's hand movements to be translated into smaller, precise movements of tiny instruments inside the patient's body.

As of June 30, 2014, there were installed 3,102 units worldwide. an estimated 200,000 surgeries conducted in 2012

**Machines that can learn could replace
half of American jobs in the next decade or two:
Oxford study**

Financial Post, March 14, 2014

http://business.financialpost.com/executive/smart-shift/machines-that-can-learn-could-replace-half-of-american-jobs-in-the-next-decade-or-two-oxford-study?_lsa=49b3-ca79

Robots are so much smarter than they used to be

Financial Post, April 22, 2014

http://business.financialpost.com/2014/04/22/robots-are-so-much-smarter-than-they-used-to-be/?_lsa=f517-4a4b

Bio-Inspired Engineering

Robotics, an emerging digital technology of major strategic importance to Canada, as recognized in *MetaScan 3: Emerging Technologies*, by Policy Horizons Canada, Government of Canada, Sept. 2013 which states that “**Robots help with or take the place of humans in dangerous environments or manufacturing processes, and/or resemble humans in appearance, behaviour or cognition. Increasingly, robots are designed to act in roles complementary to humans.**”

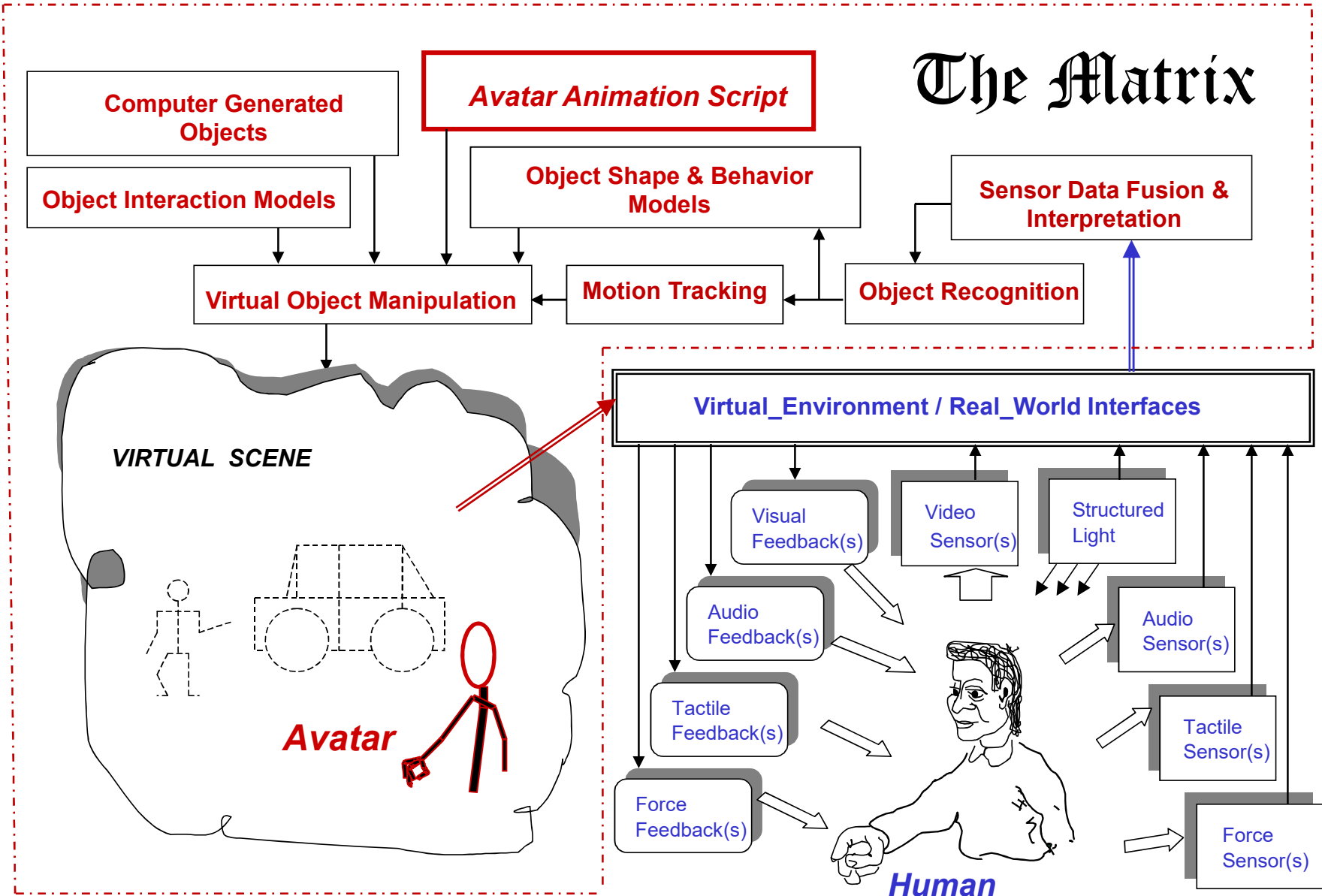
A new generation of intelligent robots with advanced, human-like, tactile perception capabilities, enabling them to perform complex in-hand telemanipulation operations under poor or nonexistent visibility conditions, such as underwater, in space, in hazardous or high-risk security operational environments like nuclear power stations, highly infectious hospital rooms, war zones, robotic surgery, or elder care robots, where touch feeling is of a paramount importance.

For many centuries, engineers were building upon **mathematics** and **natural science principles from mechanics, electricity, and chemistry** in order to develop an ever growing variety of more efficient and smarter industrial artefacts and machines.

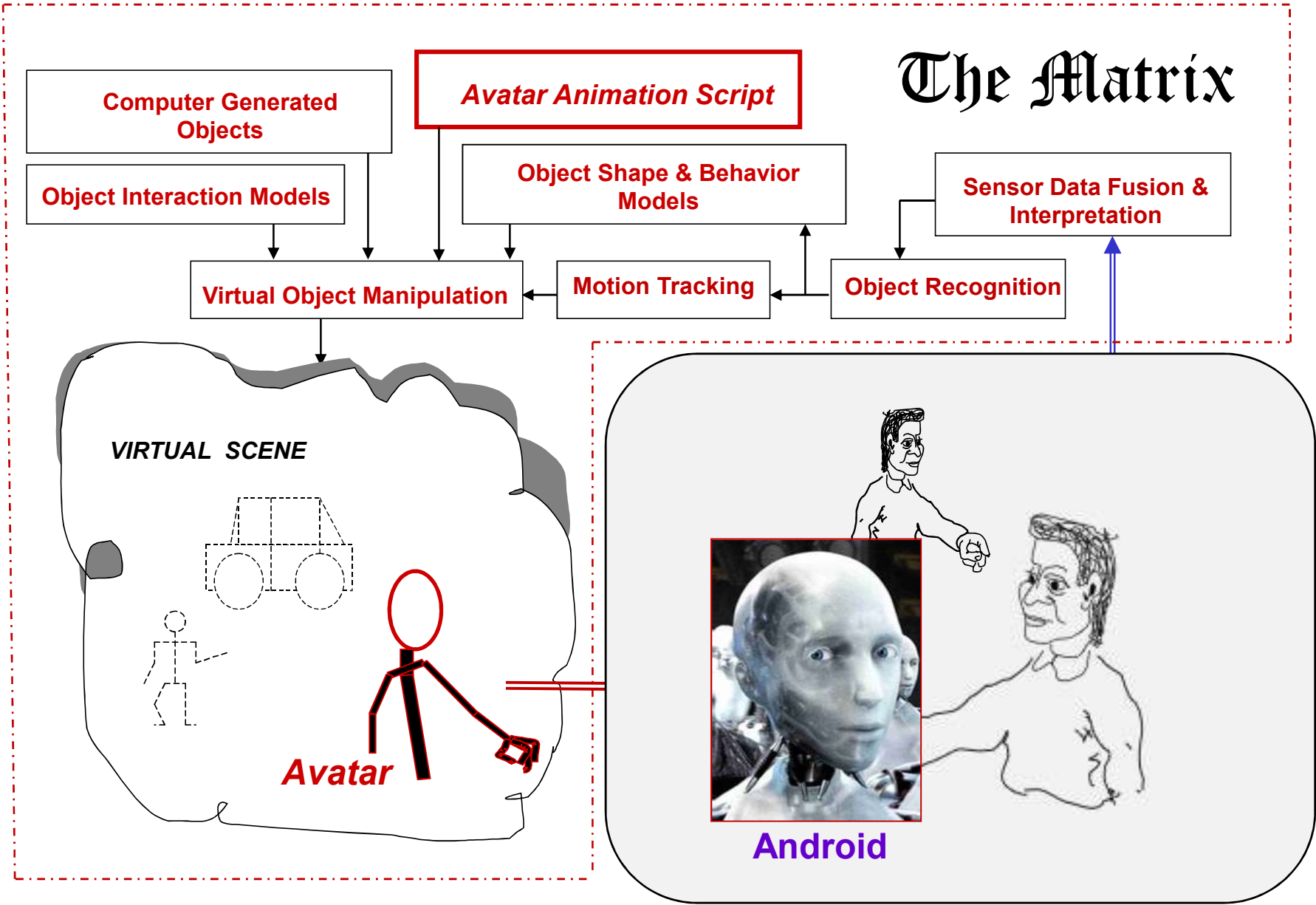
The time has now arrived to **add biology** - and more specifically, **human anatomy, physiology and psychology** – to the scientific sources of knowledge for engineers to develop a **new generation of bio-inspired intelligent machines**.



The Matrix

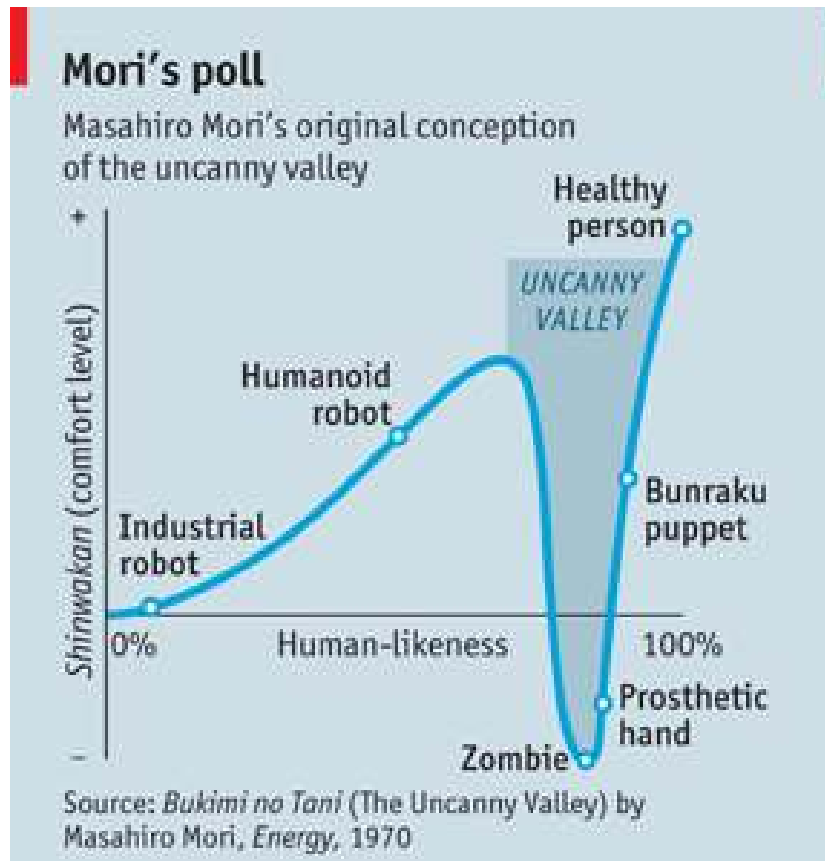


The Matrix



Crossing the uncanny valley: As computer graphics and robots get more human, they often seem more surreal

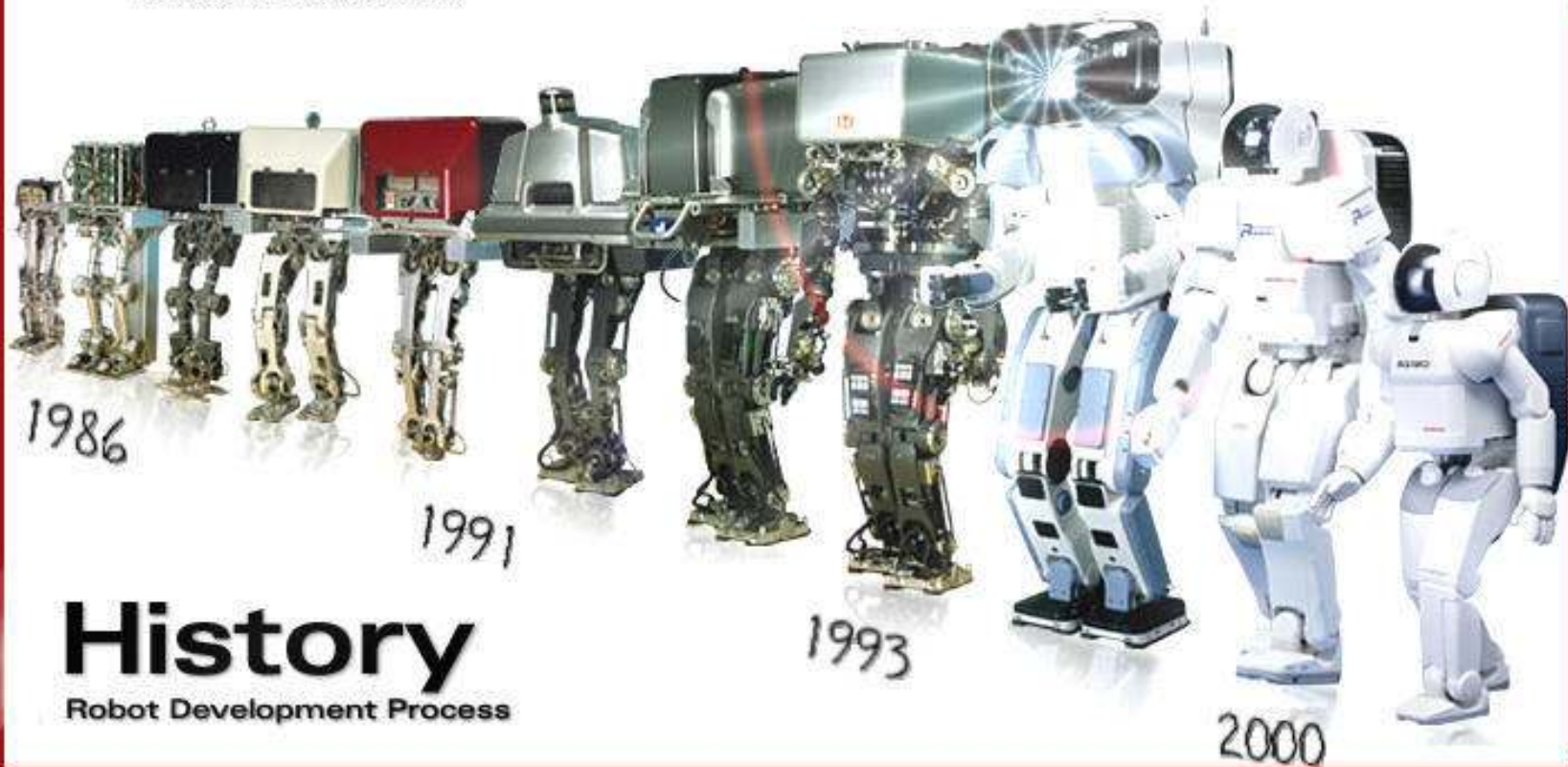
[The Economist, Nov 18th 2010 , <http://www.economist.com/node/17519716>]



“The idea of the **uncanny valley** was proposed by Masahiro Mori in 1970. His idea was that **increasing humanness in a robot was positive only up to a certain point** beyond which, the not-quite-human object strikes people as creepy.”

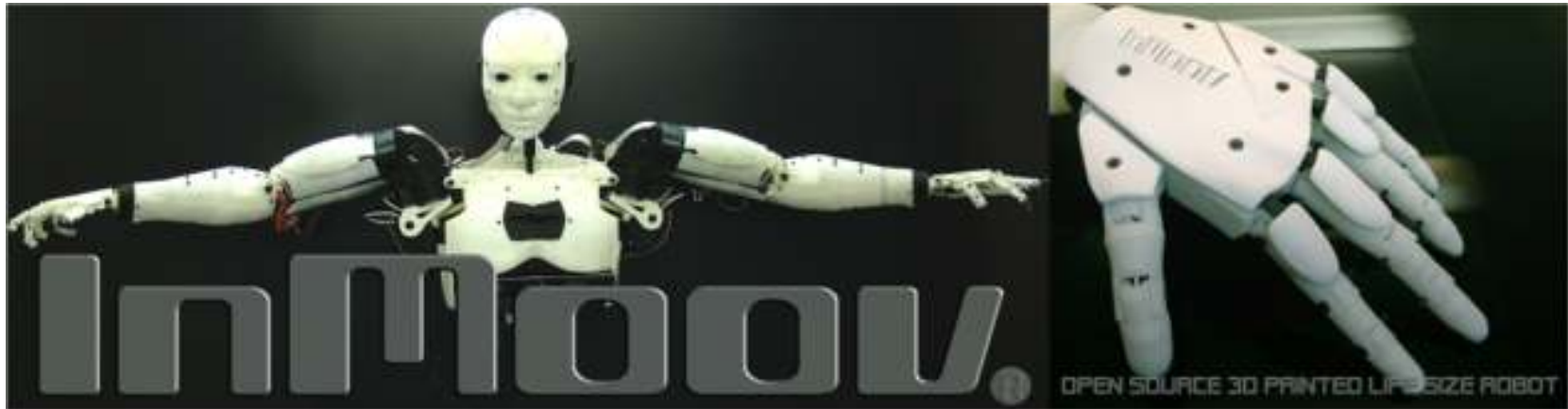
ASIMO
The Honda Humanoid Robot ASIMO

"While we were sleeping"



History
Robot Development Process

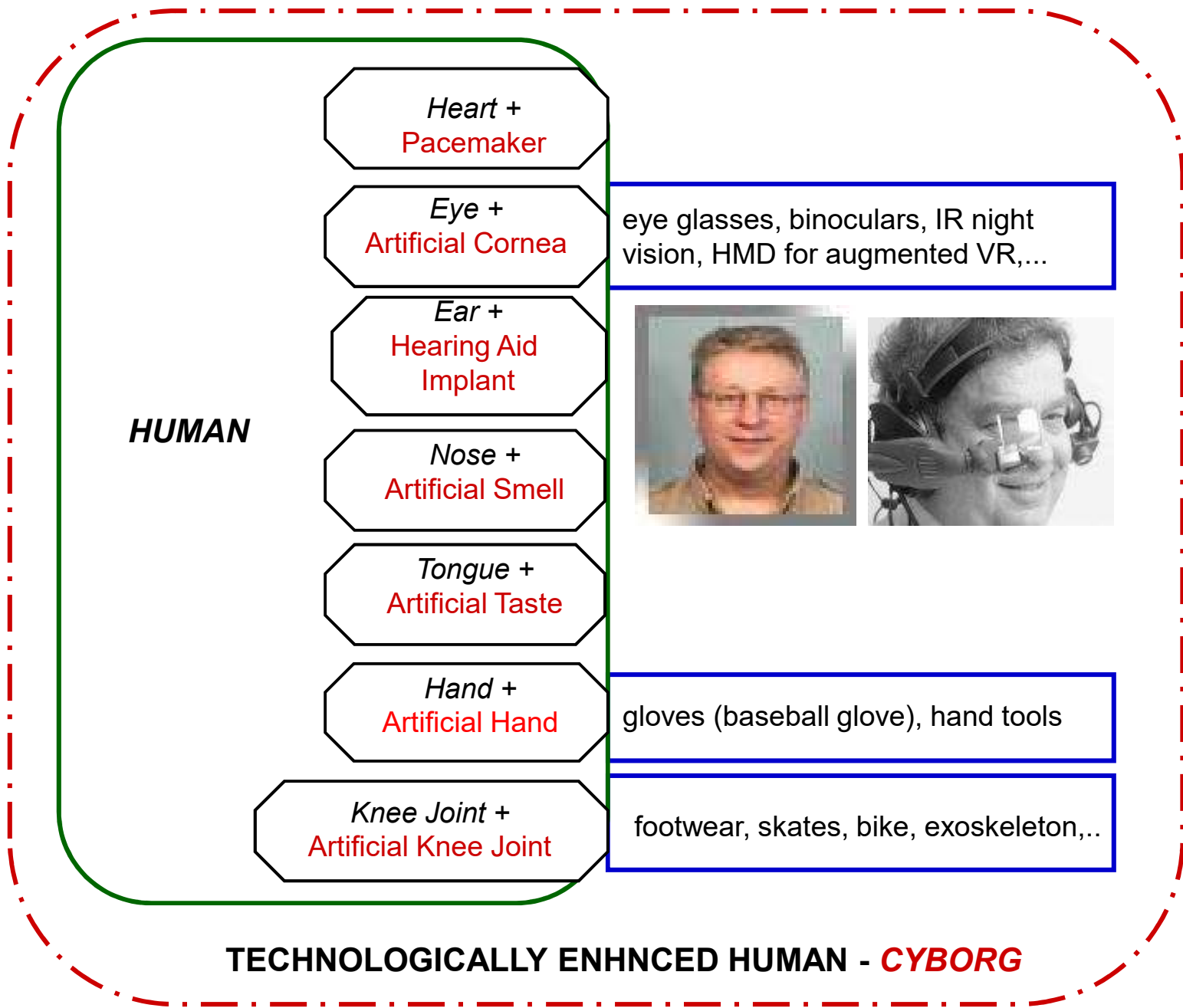
2000



“InMoov”, the first Open Source life size humanoid robot you can 3D print and animate, *Gael Langevin’s project, January 2012*
<http://www.inmoov.fr/project/>

“Gael Langevin is a French modelmaker and sculptor. He works for the biggest brands since more than 25 years. InMoov is his personal project, it was initiated in January 2012

InMoov is the first Open Source 3D printed life-size robot. Replicable on any home 3D printer with a 12x12x12cm area, it is conceived as a development platform for Universities, Laboratories, Hobbyist, but first of all for Makers. It’s concept, based on sharing and community, gives him the honor to be reproduced for countless projects through out the world.”



HUMAN

Heart +
Pacemaker

Eye +
Artificial Cornea

Ear +
Hearing Aid Implant

Nose +
Artificial Smell

Tongue +
Artificial Taste

Hand +
Artificial Hand

Knee Joint +
Artificial Knee Joint

eye glasses, binoculars, IR night vision, HMD for augmented VR,...



gloves (baseball glove), hand tools

footwear, skates, bike, exoskeleton,...

TECHNOLOGICALLY ENHANCED HUMAN - *CYBORG*



Brain Prosthesis

“Immortality by 2045 or bust: Russian tycoon wants to transfer minds to machines

Russian billionaire Dmitry Itskov speaks to the Global Future 2045 Congress, Saturday, June 15, 2013 at Lincoln Center in New York. Some of humanity’s best brains are gathering in New York to discuss how our minds can outlive our bodies.” [Ottawa Citizen, June 15, 2013,

<http://www.ottawacitizen.com/business/Immortality+2045+bust+Russian+tycoon+wants+transfer+minds/8531949/story.html>]

Brain Prosthesis which learns/models with an ever increasing fidelity the behaviour of the natural brain so it can be used as *behavioural-memory prosthesis* (**BMP**) to make up for the loss in the natural brain’s functions due to dementia, Alzheimer disease, etc. It is quite conceivable that such a BMP could arrive in extremis to complete replace the functions of the natural brain.

***Asimov's laws of the
robotics:***

1st law: "A robot must not harm a human being or, through inaction allow one to come to harm".

2nd law: "A robot must always obey human beings unless that is in conflict with the 1st law".

3rd law: "A robot must protect itself from harm unless that is in conflict with the 1st and 2nd law".



Cyber/Machine
Society/World
{**Intelligent Androids**}

Human
Society/World
{**Human Beings**}

Asimov's laws of the robotics:

0th law: "A robot may not injure humanity or, through inaction, allow humanity to come to harm."

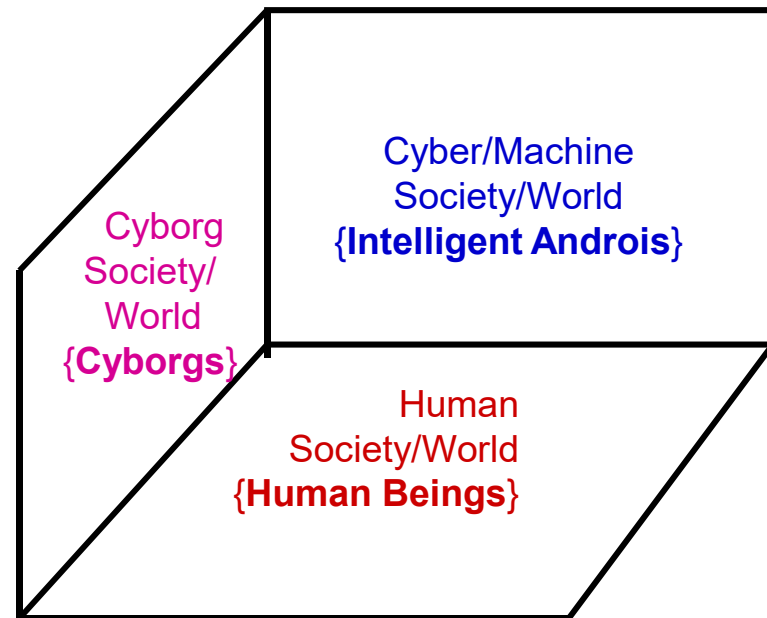
1st law- updated: "A robot must not harm a human being or, through inaction allow one to come to harm, unless this would violate the 0th law."

2nd law: "A robot must always obey human beings unless that is in conflict with the 1st law".

3rd law: "A robot must protect itself from harm unless that is in conflict with the 1st and 2nd law".

[] I. Asimov, Robots and Empire, Doubleday & Co., NY 1985, p.291*

**Moral, Ethical,
Theological, Legal, Biological,
Psychological Social,
Economic Challenges**



**Machines that can learn could replace
half of American jobs in the next decade or two:
Oxford study**

Financial Post, March 14, 2014

http://business.financialpost.com/executive/smart-shift/machines-that-can-learn-could-replace-half-of-american-jobs-in-the-next-decade-or-two-oxford-study?_lsa=49b3-ca79

Special Report:
**Trusting Robots - Robots will soon have the power of
life and death over human beings. Are they ready?
Are we?**

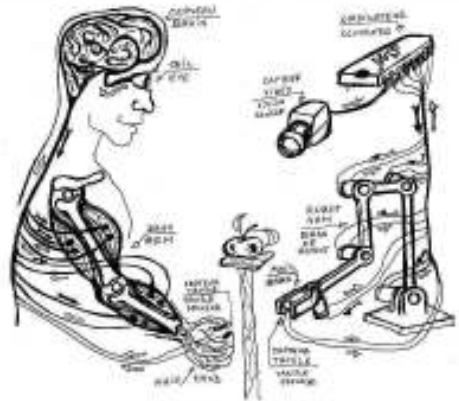
IEEE Spectrum, May 2016

<http://spectrum.ieee.org/robotics/artificial-intelligence/can-we-trust-robots>

The IEEE Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems released, on 13 December 2016, the first version of its document, Ethically Aligned Design intended to provide a key reference for Artificial Intelligence and Autonomous Systems (AI/AS) technologists to help them prioritize values-driven, ethically aligned design in their work.

Ethically Aligned Design: A Vision for Prioritizing Human Wellbeing with Artificial Intelligence and Autonomous Systems

http://standards.ieee.org/develop/indconn/ec/ead_brochure.pdf



Thank You!