The Position of Mathematics in the History of Technology

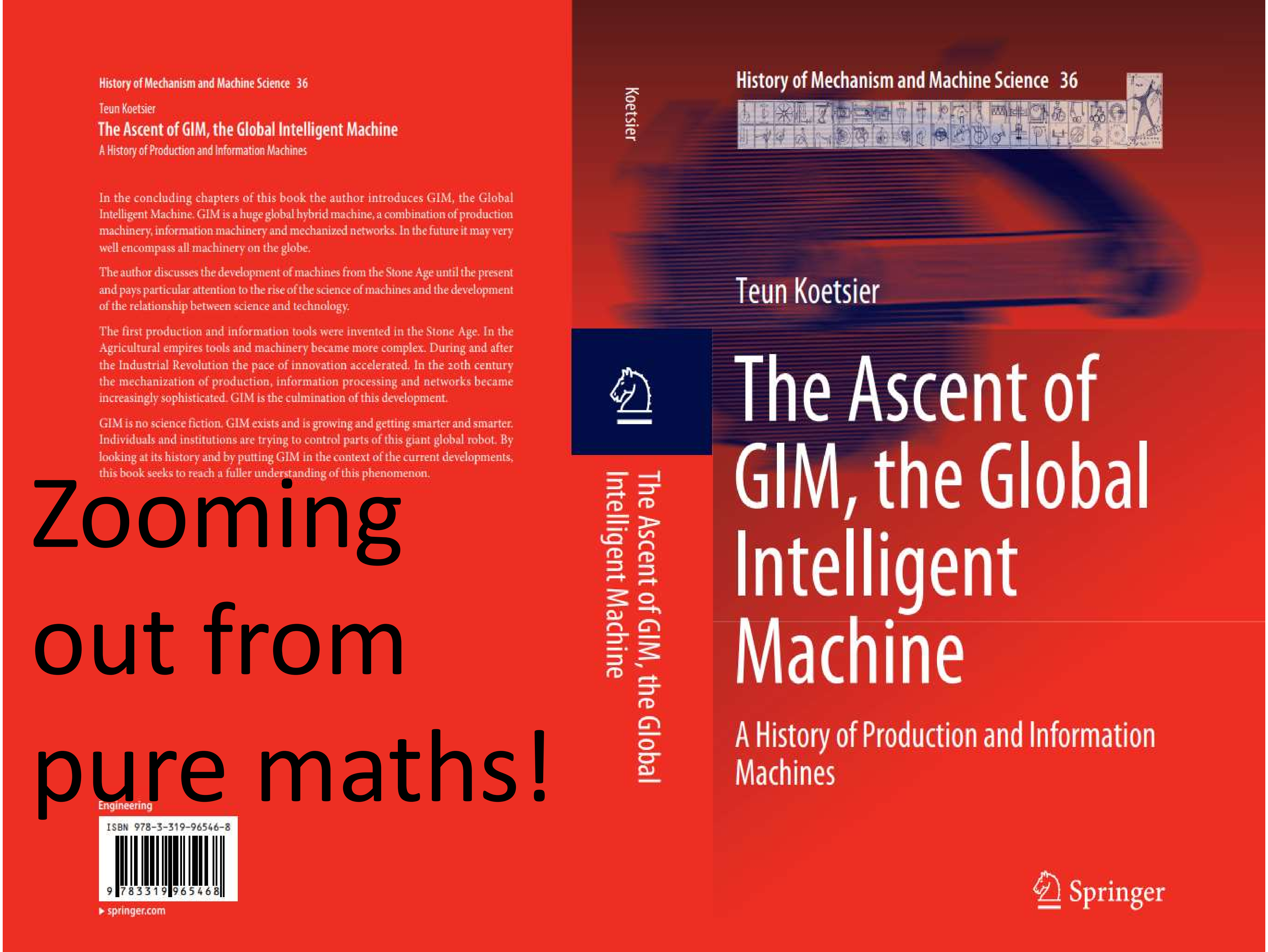
A Eulogy on Pure Mathematics

Teun Koetsier

Amsterdam, October 2022

vrije Universiteit amsterdam

Pure maths: When Godfrey Harold Hardy (1877–1947) was asked during World War I to work in ballistics, he answered that *“He was prepared to go off and have his body shot at; he was not prepared to prostitute his brain for the purposes of war”.*



History of Mechanism and Machine Science 36

Teun Koetsier

The Ascent of GIM, the Global Intelligent Machine

A History of Production and Information Machines

In the concluding chapters of this book the author introduces GIM, the Global Intelligent Machine. GIM is a huge global hybrid machine, a combination of production machinery, information machinery and mechanized networks. In the future it may very well encompass all machinery on the globe.

The author discusses the development of machines from the Stone Age until the present and pays particular attention to the rise of the science of machines and the development of the relationship between science and technology.

The first production and information tools were invented in the Stone Age. In the Agricultural empires tools and machinery became more complex. During and after the Industrial Revolution the pace of innovation accelerated. In the 20th century the mechanization of production, information processing and networks became increasingly sophisticated. GIM is the culmination of this development.

GIM is no science fiction. GIM exists and is growing and getting smarter and smarter. Individuals and institutions are trying to control parts of this giant global robot. By looking at its history and by putting GIM in the context of the current developments, this book seeks to reach a fuller understanding of this phenomenon.

Engineering

ISBN 978-3-319-96546-8

springer.com

Koetsier

The Ascent of GIM, the Global Intelligent Machine

History of Mechanism and Machine Science 36

Teun Koetsier

The Ascent of GIM, the Global Intelligent Machine

A History of Production and Information Machines

Springer

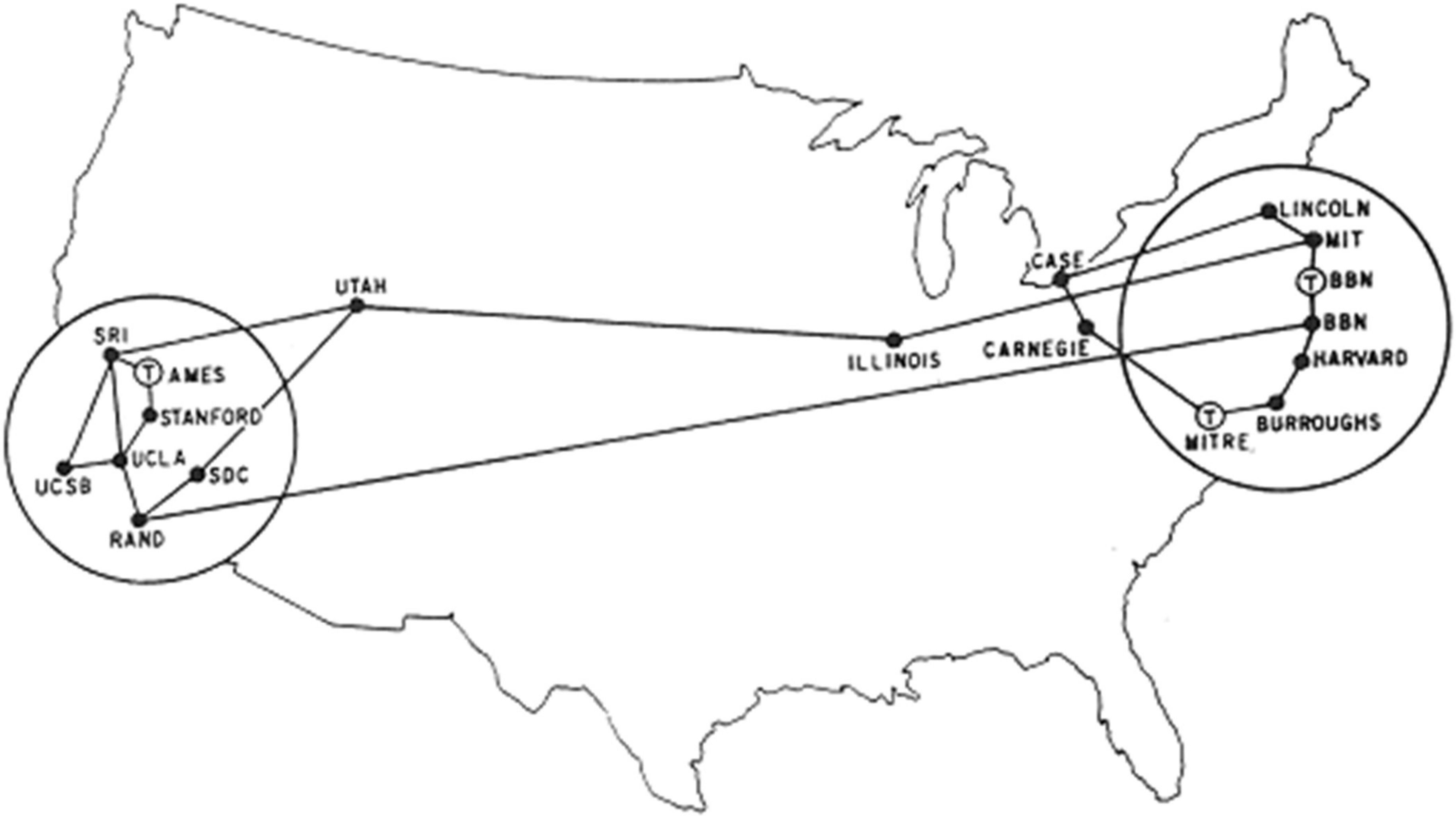
Zooming out from pure maths!

Structure of talk

- The ascent of the Global Intelligent Machine or THE MACHINE 
- Exponential growth 
- The history of technology
- The history of mathematics against the background of technology 
- An example: external ballistics

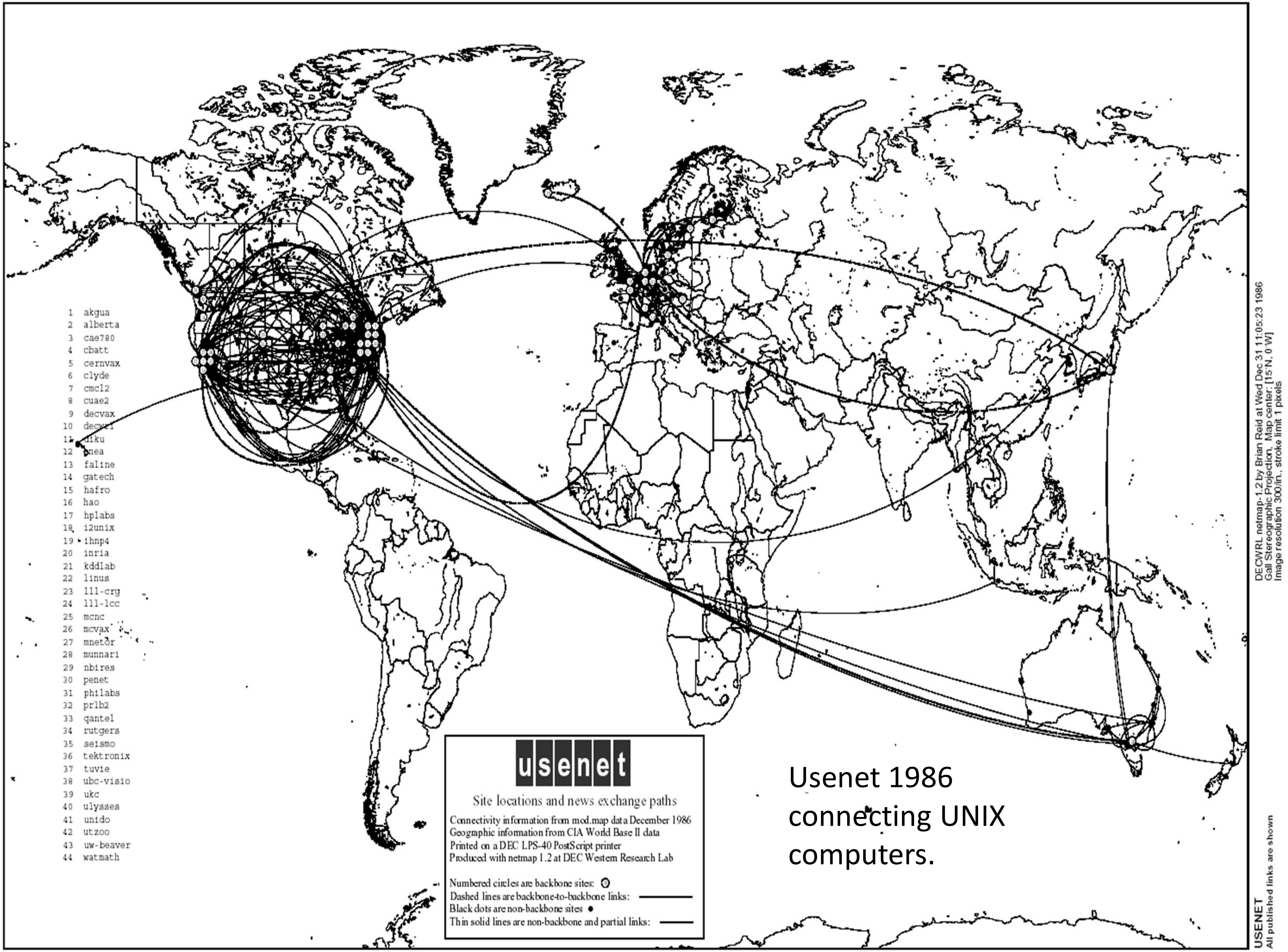
1. The Machine

In Edward Morgan Forster's novel from 1909, *The Machine Stops,* mankind lives inside a huge machine that controls all aspects of their lives. In the story The Machine breaks down and many people are killed. Yet the protagonist Kuno escapes and …..



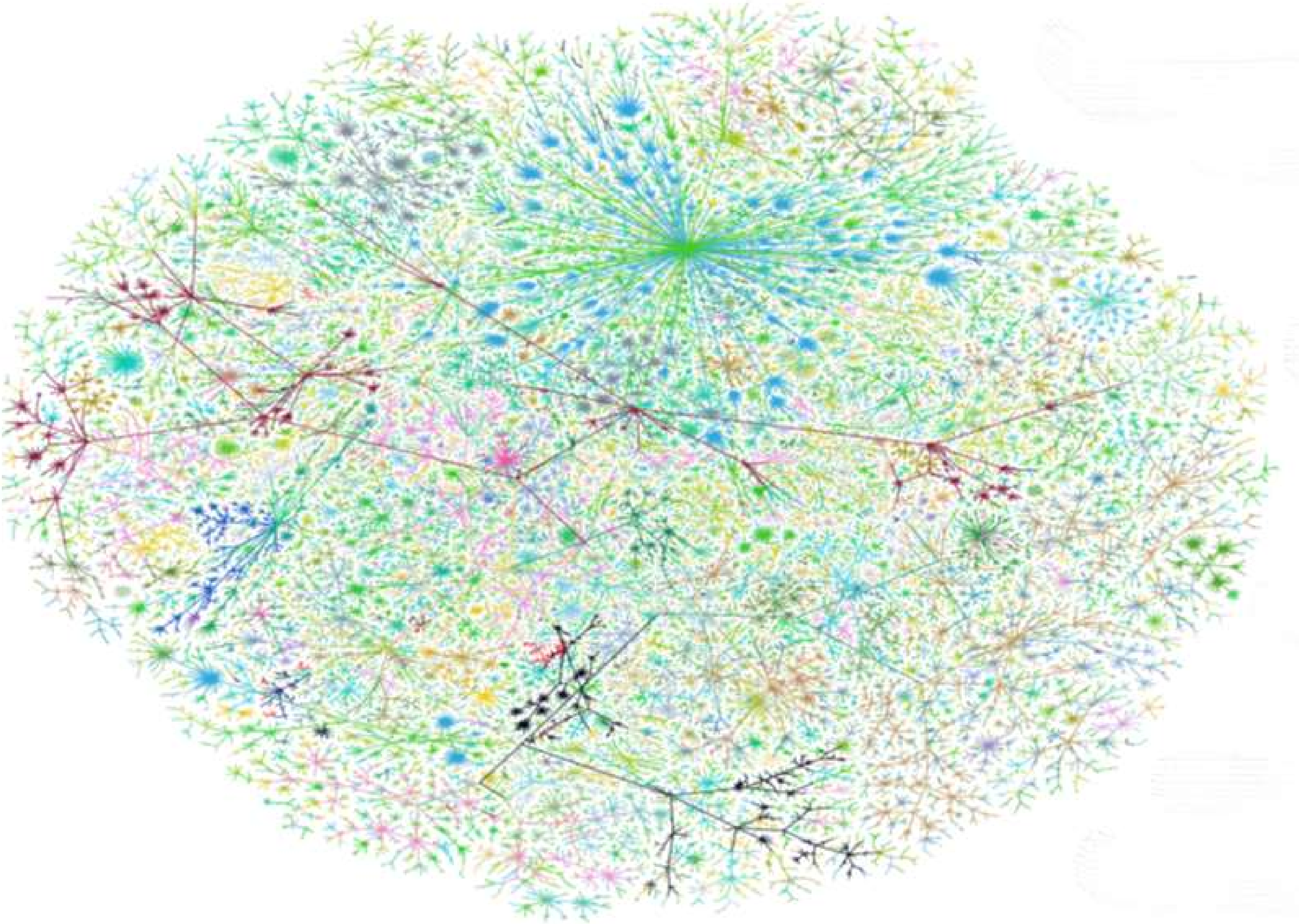
MAP 4 September 1971

ARPANET in September 1971.



Usenet 1986 connecting UNIX computers.

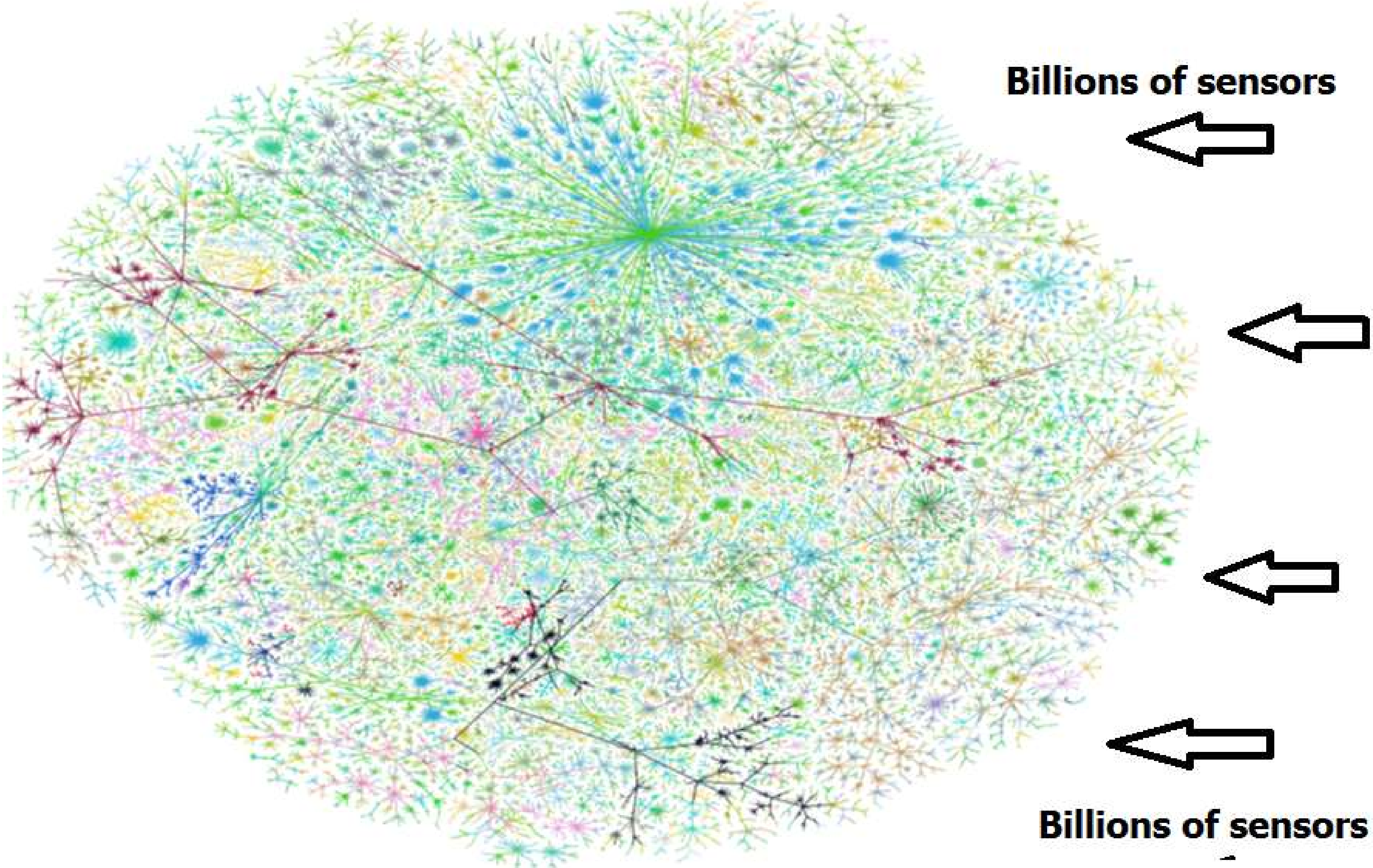
The Internet



The Internet of Things

Kevin Ashton in 1999: *“The Internet is almost wholly dependent on human beings for information. […] We need to empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves”.*

The Internet of Things



Source of picture: **The Internet Mapping Project**

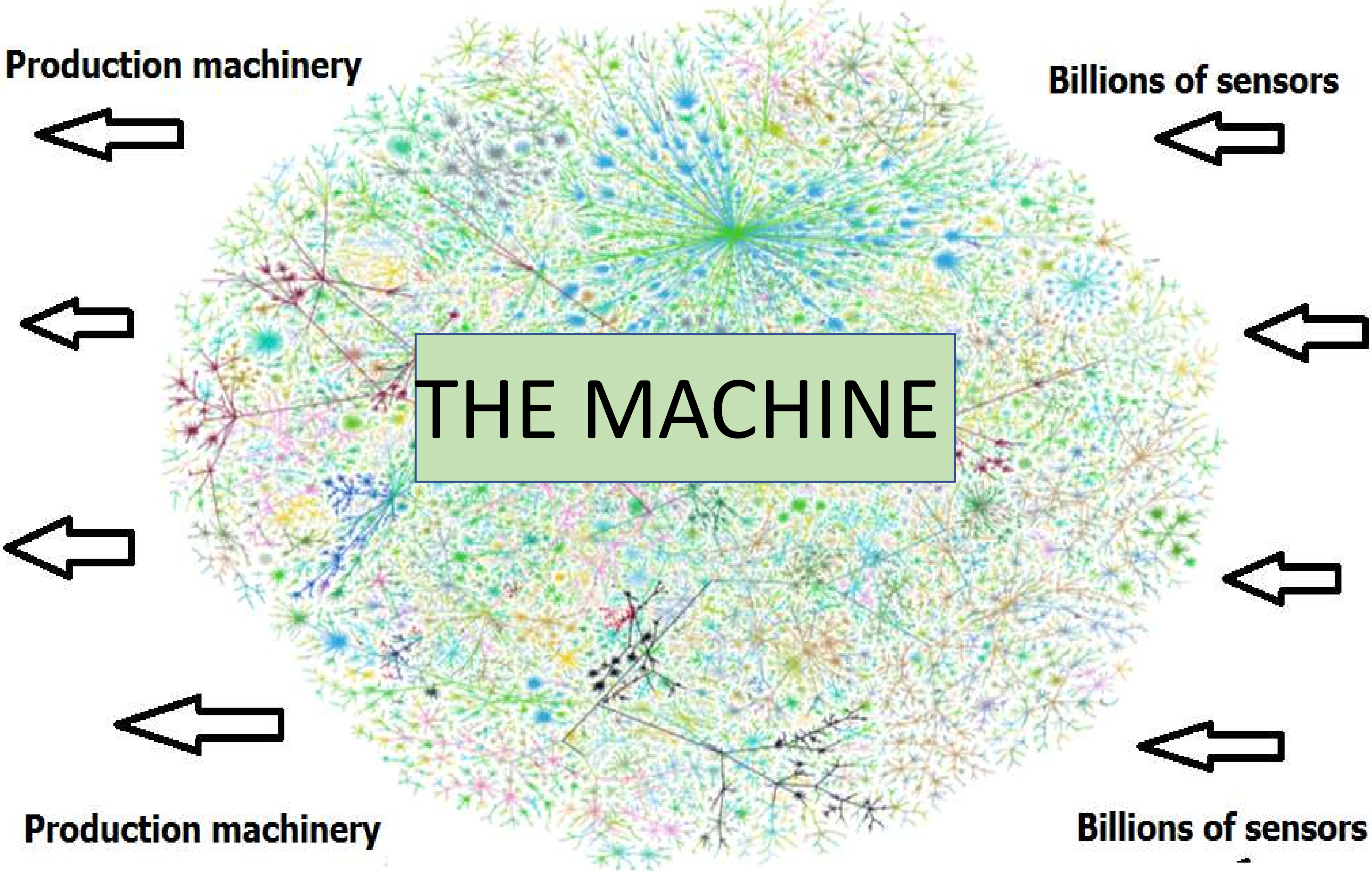
Towards THE MACHINE

For now, the IoT is primarily a giant information machine.

The IoT will be increasingly connected to production devices.

Until now the information gathered and processed by the IoT in general leads to a response in which machinery and human intervention are both involved. In the future we will often let machines autonomously do the work.

The IoT will develop into the Global Intelligent Machine or THE MACHINE.


Production machinery
Billions of sensors
THE MACHINE
Production machinery
Billions of sensors

One Entity

THE MACHINE is **one entity.** Moreover, it possesses **brains** in the form of very smart and very fast processing units. It has an **enormous memory capacity.** THE MACHINE is getting **more and more intelligent.**

No central control

No central entity that controls the whole. Many different actors, individuals, companies, states, and other institutions or organizations control parts of THE MACHINE.

Improbable that in the near future one actor will gain complete control. Yet, small-scale MACHINES are imaginable.

Robot industries

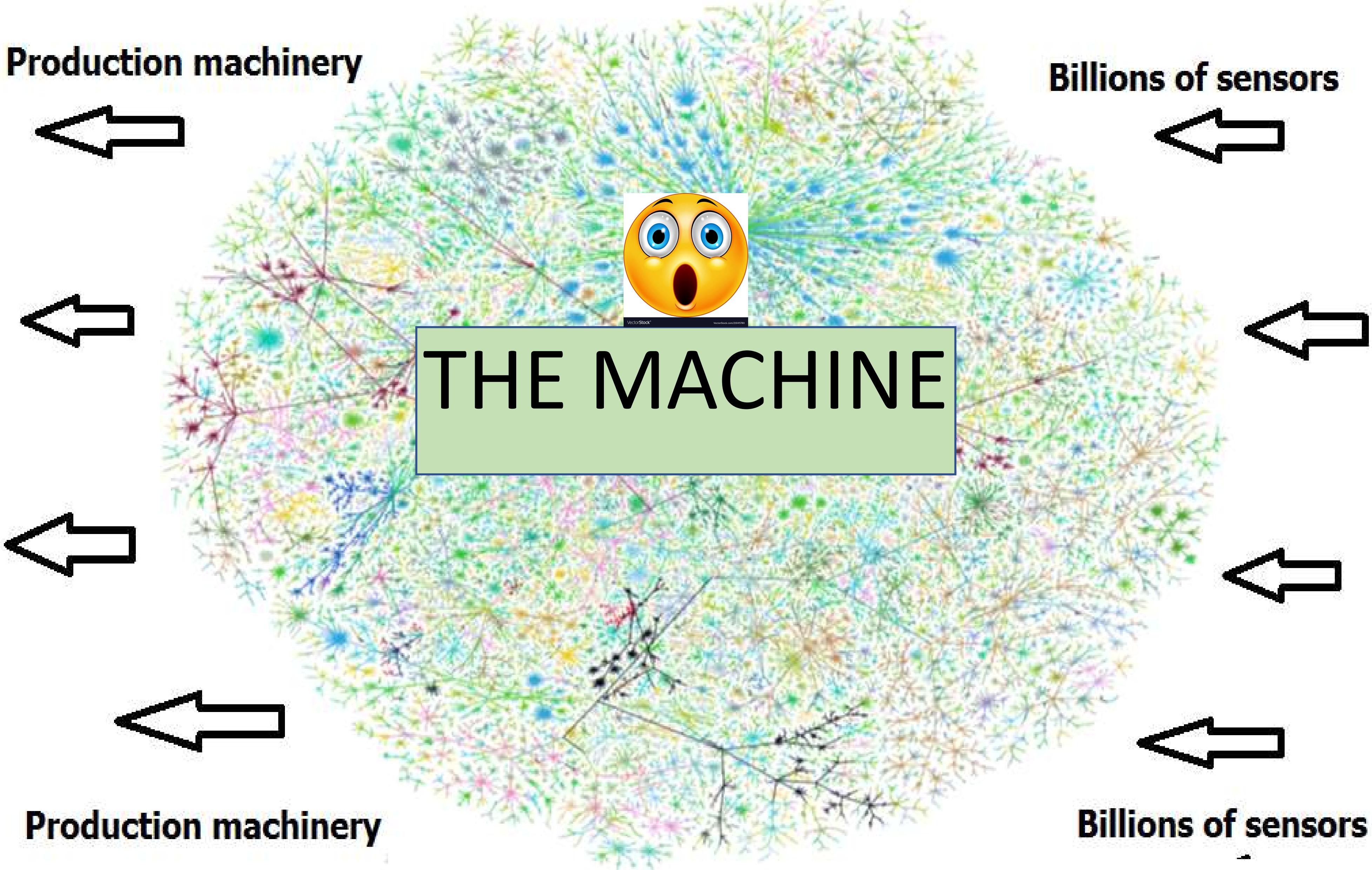
Fully automated prisons are conceivable.

Robot factories, farms.

Robot law enforcement?

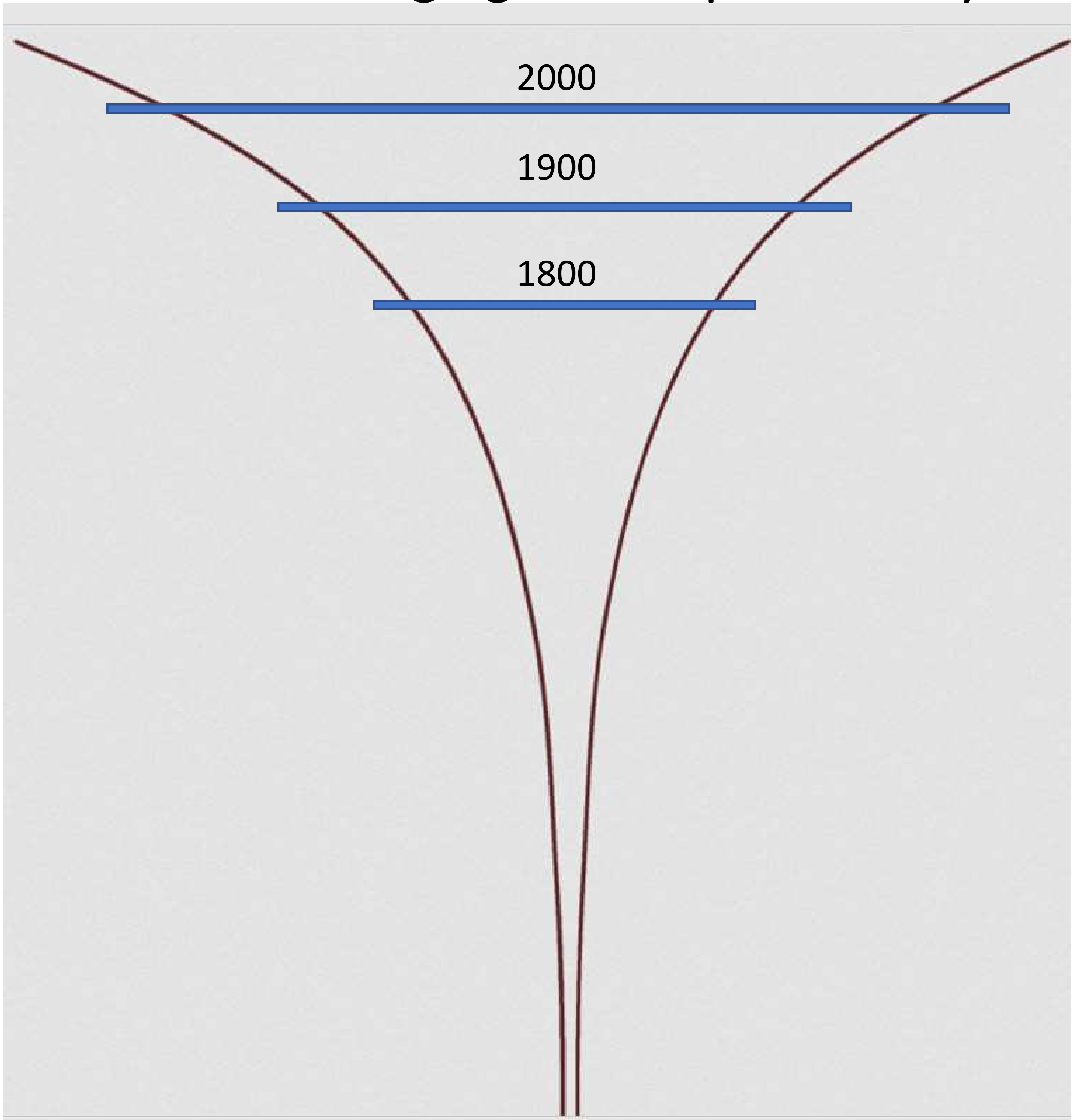
Robot armies.

THE MACHINE will in the future encompass all new machines.



2. Exponential growth

Our knowledge grows exponentially



Derek de Solla Price: After the Scientific Revolution the number of scientific publications doubled every 15 years.

Copernicus' *De Revolutionibus* of 1543 -> Present

(2022-1543)/15=32

$$1 + 2 + 2^2 = 2^3\text{-}1$$

$$1 + 2 + 2^2 + 2^3 = 2^4 - 1$$

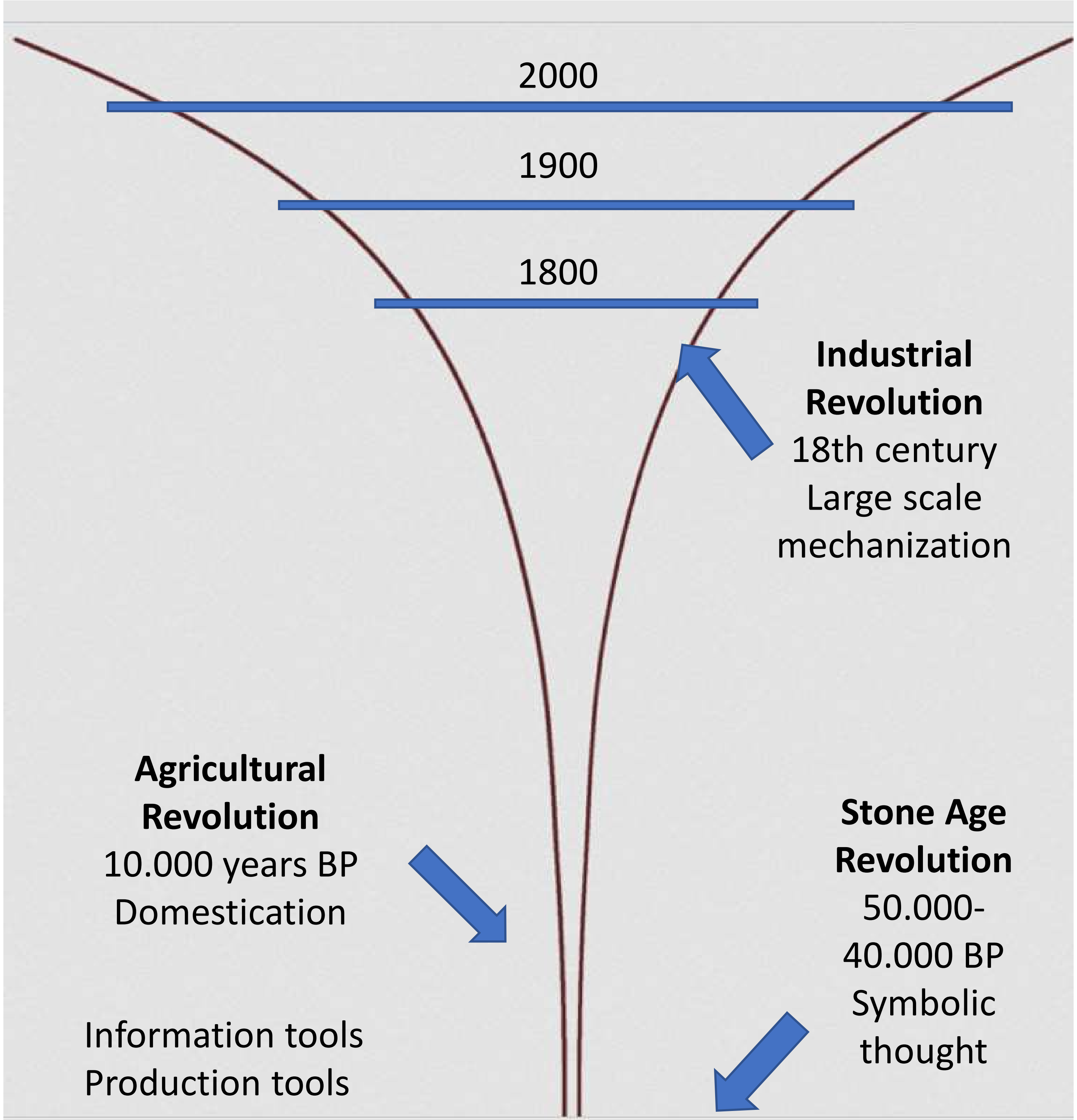
$$1 + 2 + 2^2 + 2^3 + 2^5 = 2^6 - 1$$

$$1 + 2 + 2^2 + 2^3 + \cdots 2^{32} = 2^{33} - 1 = 8.589.934.591$$

In the next 15 years, just as much new knowledge will be produced as in the entire period before that!

3. The history of technology

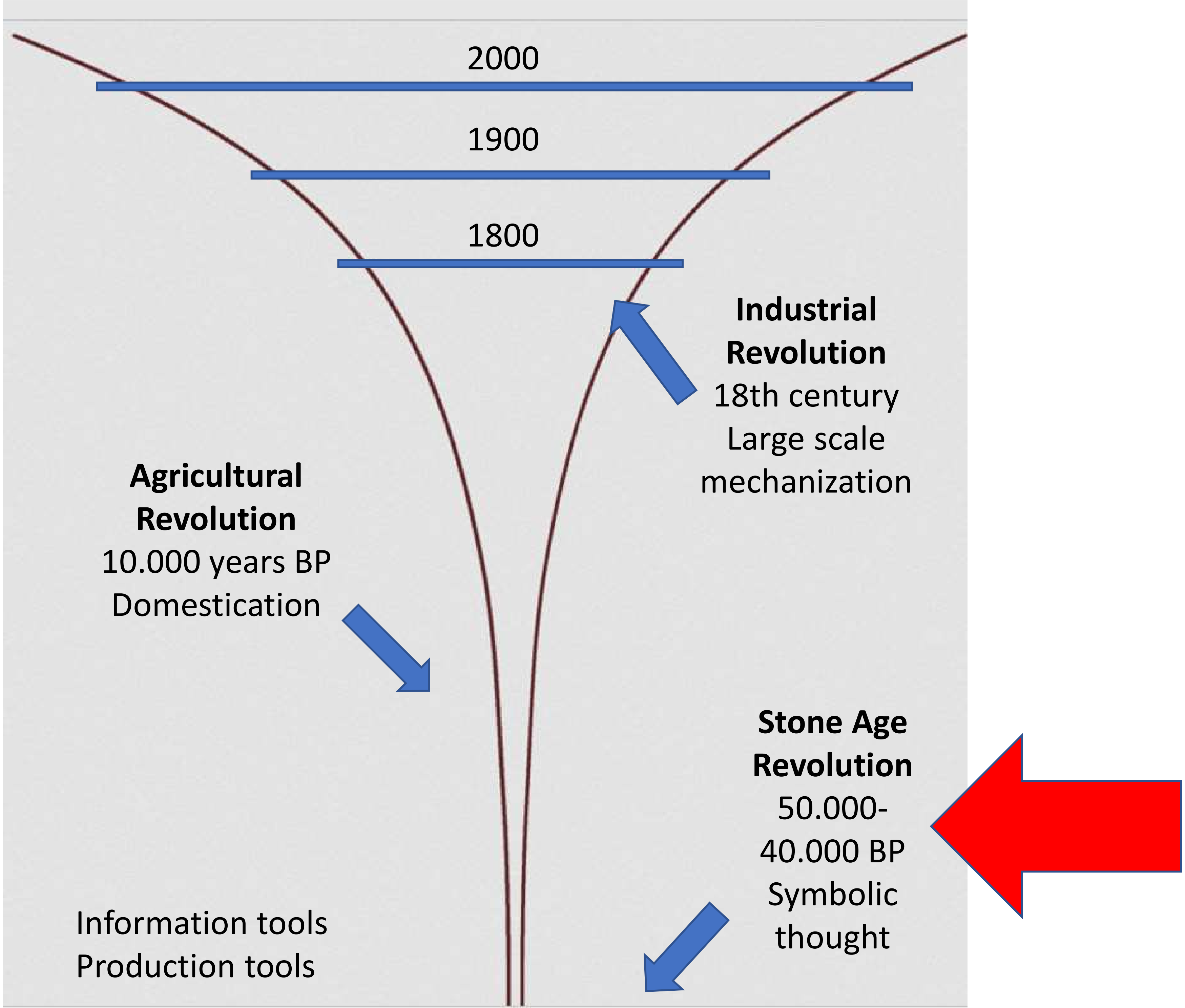
THE MACHINE



Periodization: defining 'moments'.

The Greek Miracle: the birth of pure mathematics.

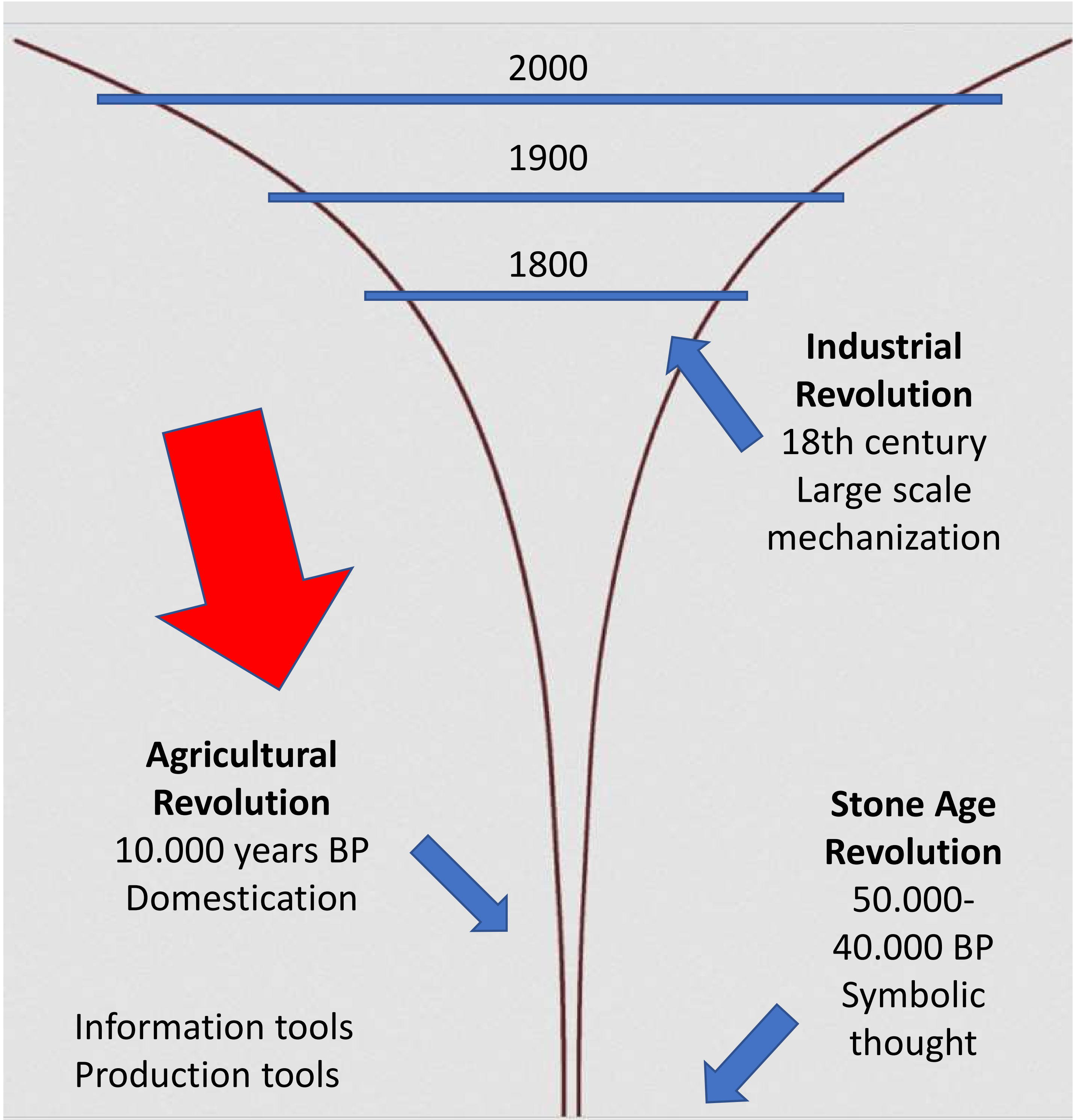
THE MACHINE


2000
1900
1800
Industrial Revolution
18th century
Large scale mechanization
Agricultural Revolution
10.000 years BP
Domestication
Stone Age Revolution
50.000-40.000 BP
Symbolic thought
Information tools
Production tools

Stone Age Revolution (50.000-40.000 BP)

- Stone Age information tools: Symbolic thought and in particular this fantastic information tool called **language.**
- Language a female invention?

THE MACHINE

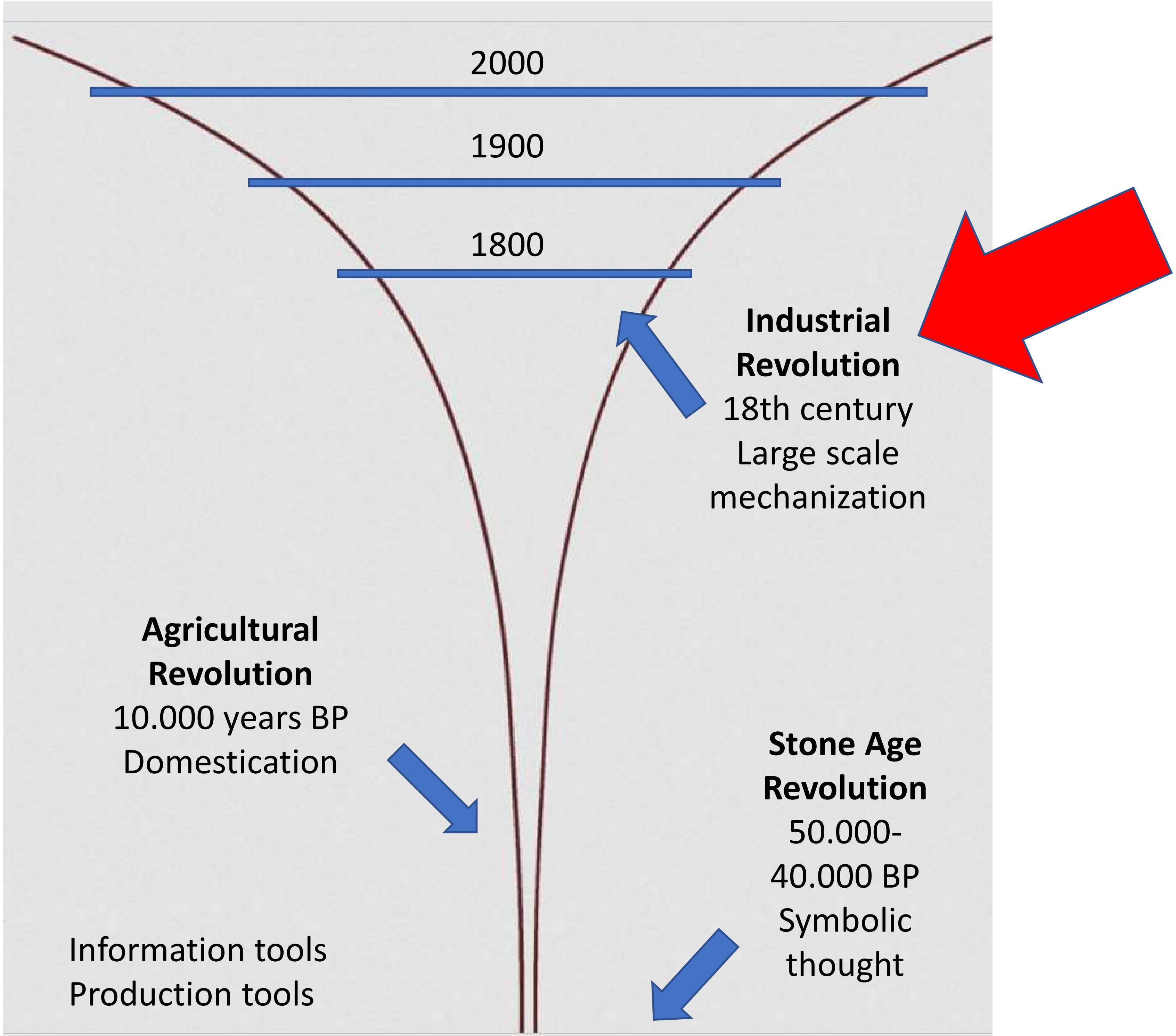


Agriculture a female invention?

Agricultural Revolution (10.000 BP)

- Information tools: Full writing (all the words of a language can be represented) and later printing, but also planetaria, clocks, the abacus and the earliest mechanical calculators.

THE MACHINE


2000
1900
1800
Industrial Revolution
18th century
Large scale mechanization
Agricultural Revolution
10.000 years BP
Domestication
Stone Age Revolution
50.000-40.000 BP
Symbolic thought
Information tools
Production tools

The Industrial Revolution (18th century)

- First large-scale mechanization of production: production machinery.
- Then large-scale mechanization of information processing: information machinery.

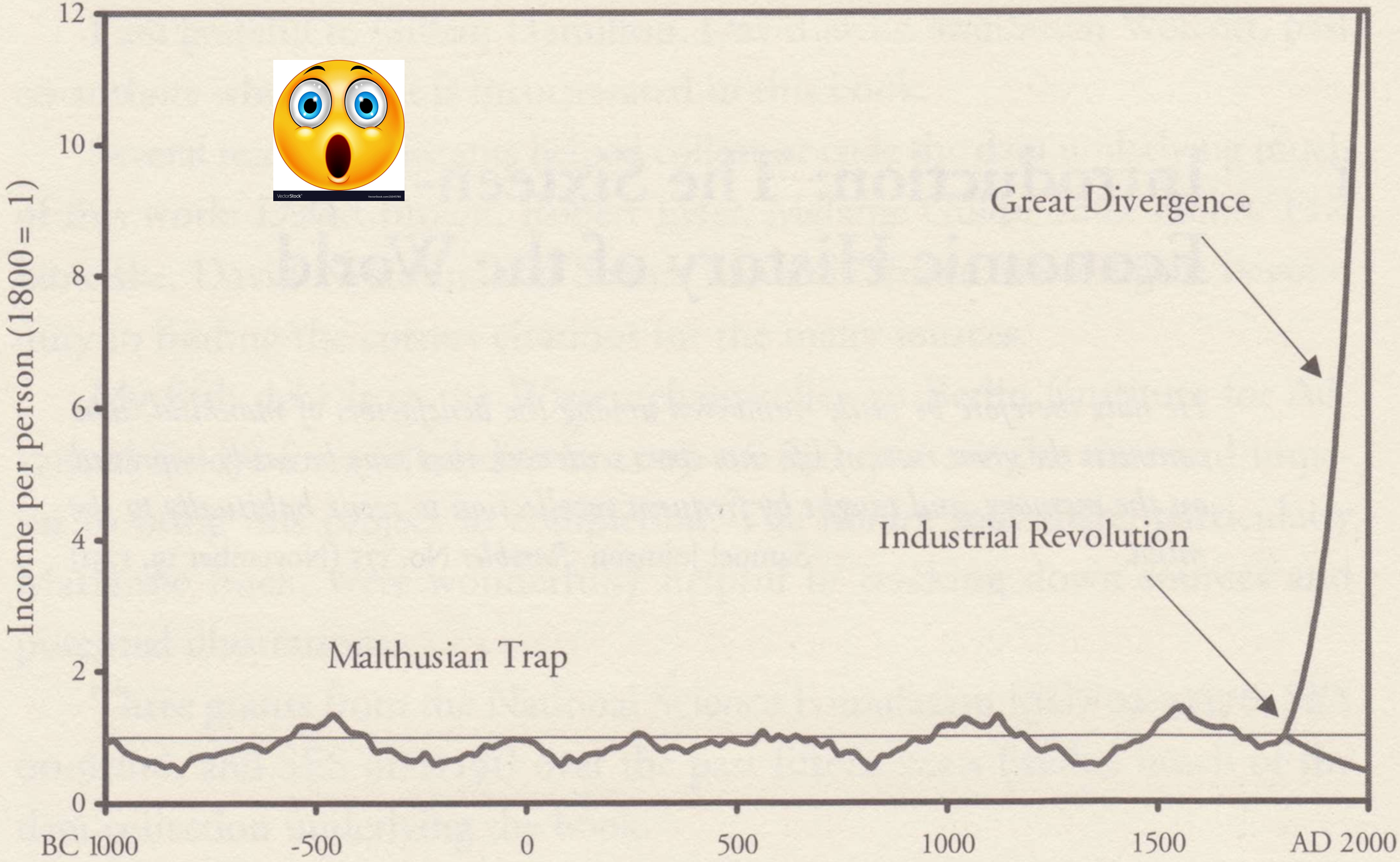
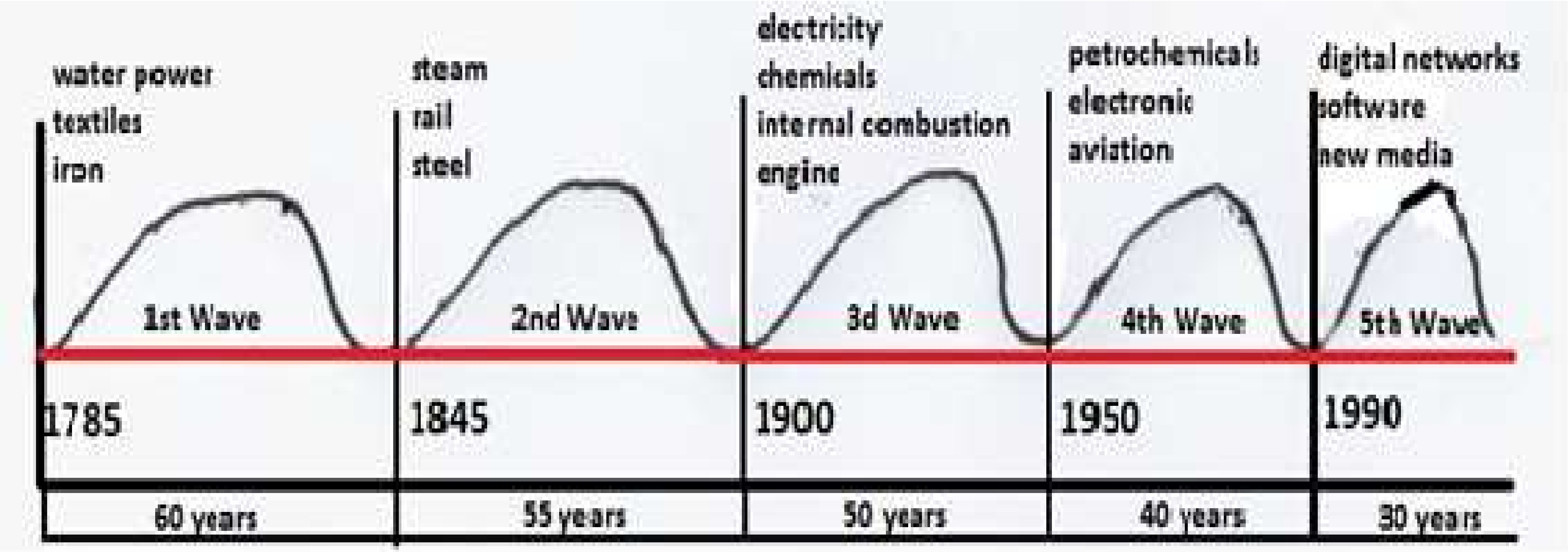


Figure 1.1 World economic history in one picture. Incomes rose sharply in many countries after 1800 but declined in others.

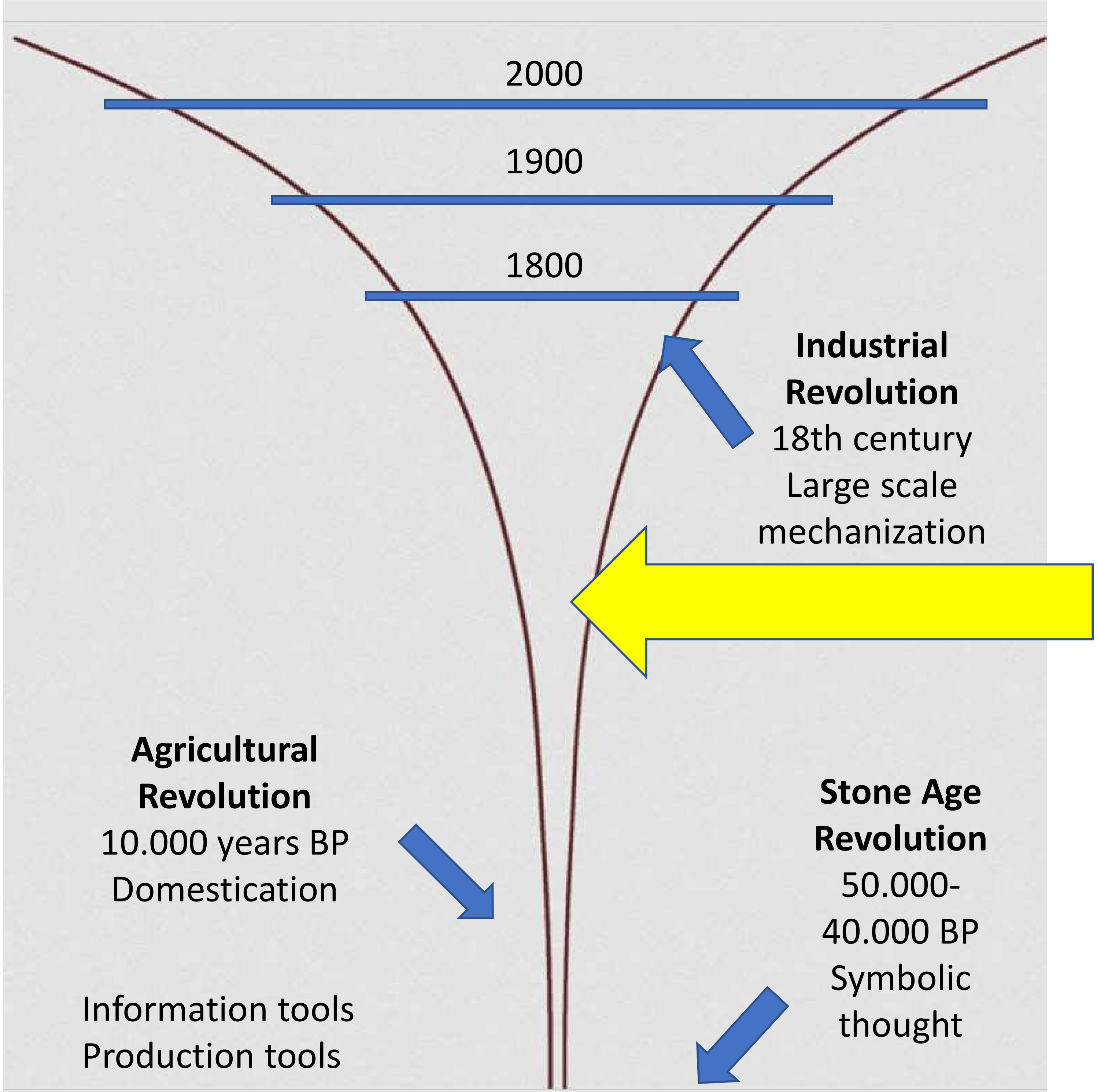
Gregory Clark

Accelerating waves of Industrial Revolution.



4. The history of mathematics against the background of technology

THE MACHINE



Periodization: defining ‘moments’.

The Greek Miracle: the birth of (science and) pure mathematics.

- **The beginning**: Prehistorical time and in the agricultural societies. Maths = technology

- **From Pythagoras until 1900:**

Classical antiquity: The deductive method (the Greeks)

16th -18th centuries: Algebra and analytical methods: (Descartes, Leibniz, Euler, Lagrange)

Rigorous 19th century maths: analysis, geometry.

Maths and technology are disjunct.

- **20th century**

Age of scientific technology

Only at the end of the 19th century science and mathematics start to play a significant role in technology!

In the centuries before 1900 from the point of view of technology science and pure mathematics look like an anomaly.

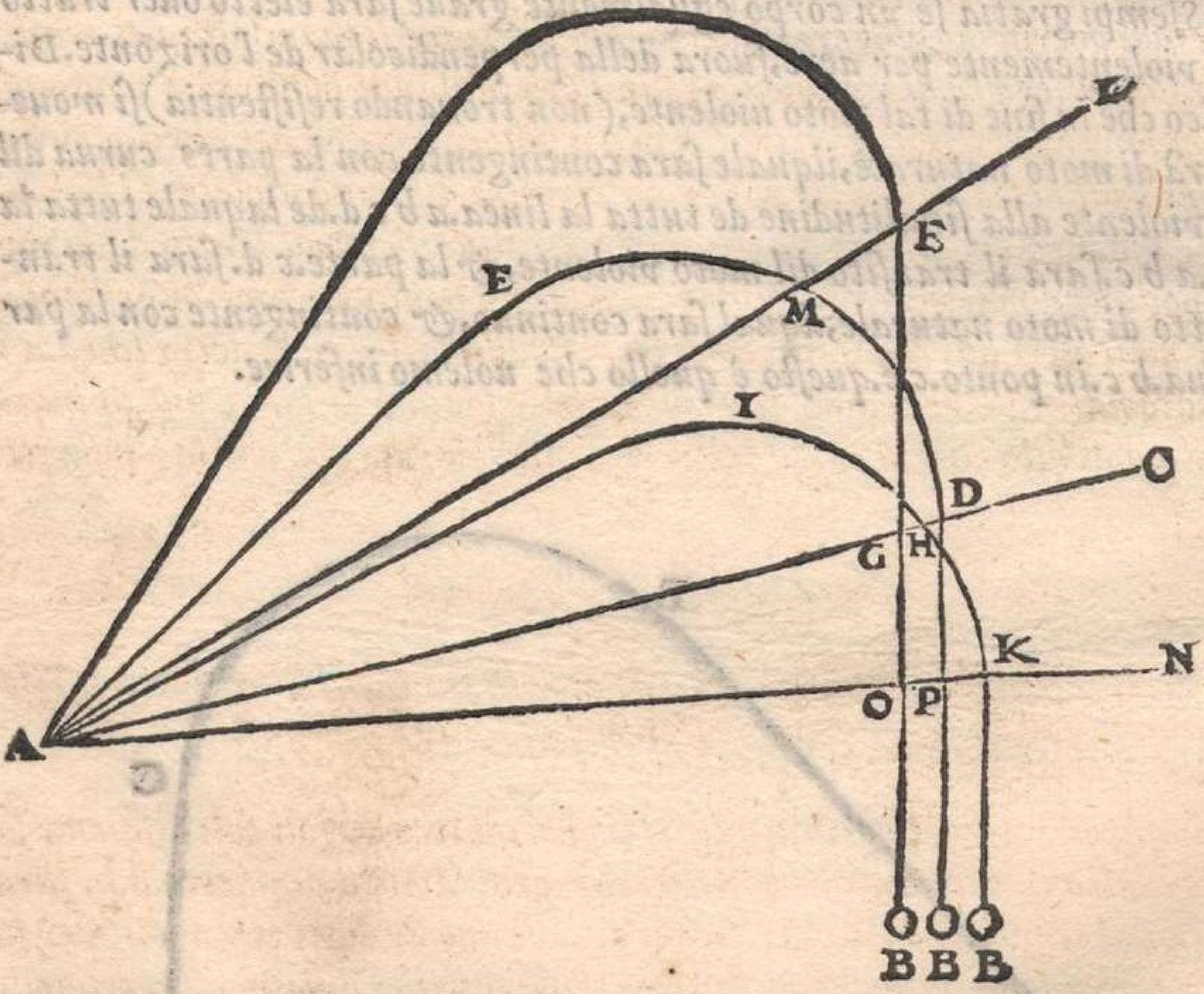
Until 1900 there is hardly mathematics in technology.

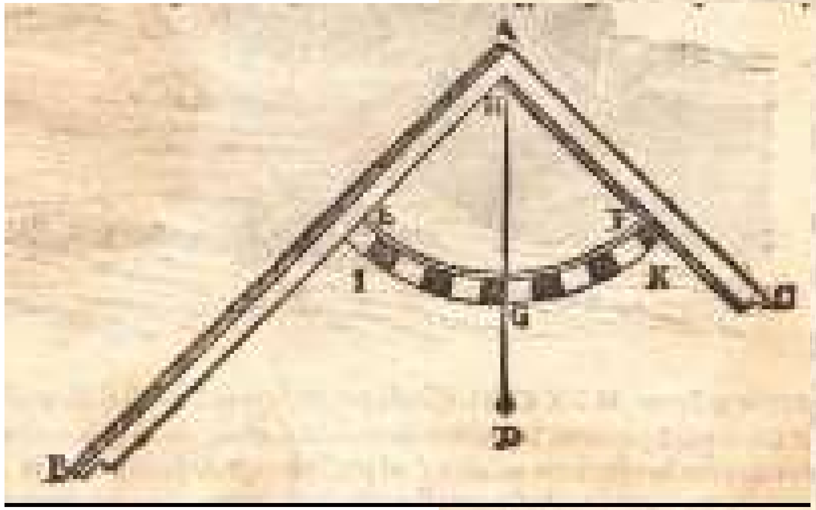
The origin of pure science

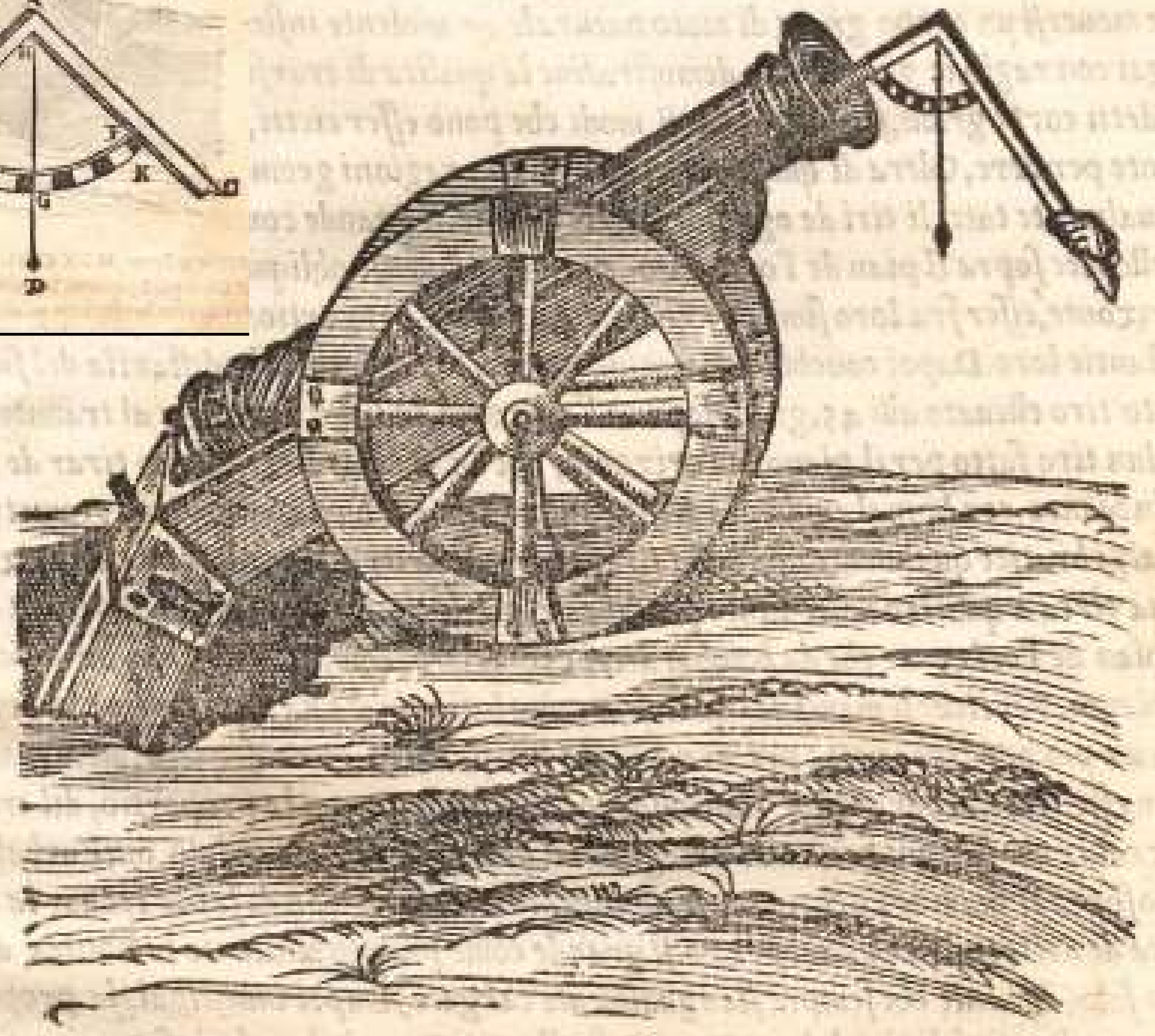
- Man is an intelligent problem-solver: What should we do? **Leads to technology.**
- We are, however, also curious: Why are things the way they are? What is true? **Leads to science.**
- Moreover, we love challenges, we like to play and win.

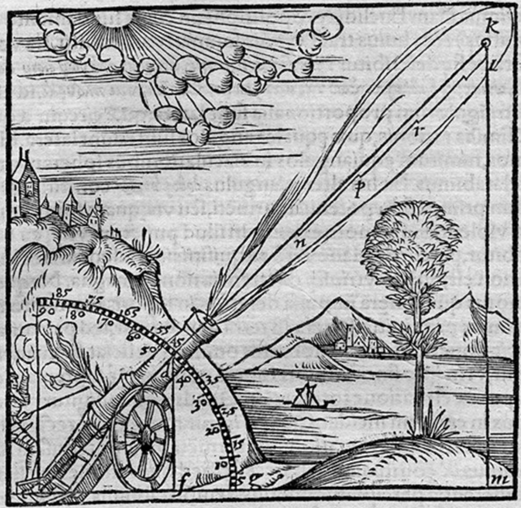
5. An example: external ballistics

- Niccolo Tartaglia (1499/1500-1557),
- *Nueva Scienza*, 1537
- First mathematical approach of trajectory of bullet.


A
E
M
F
I
D
G
H
K
N
O
P
B B B


A
I
K
G
C
D
B





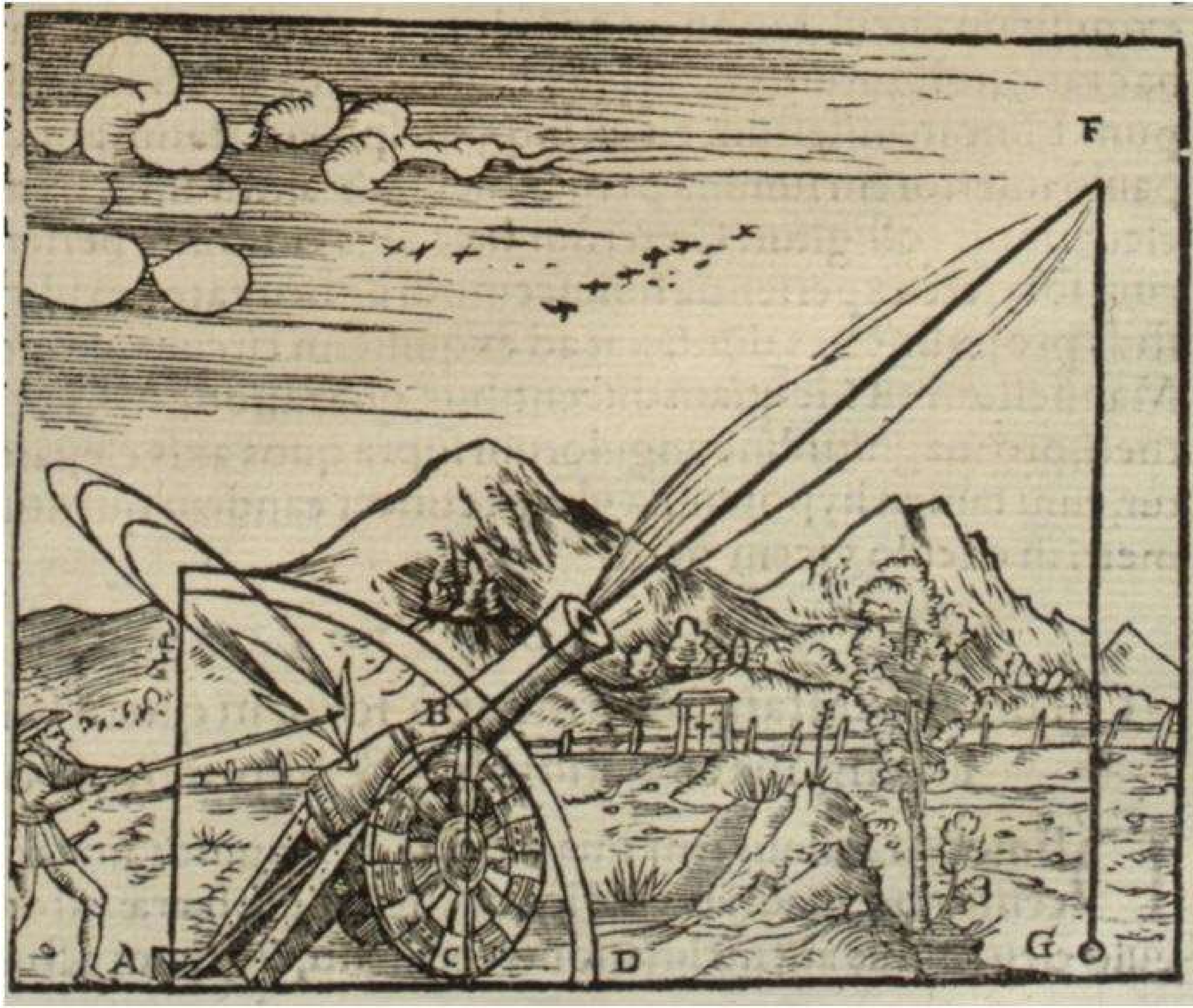
centrum ſphæræ d ſignum exquiſitè præteriiſſe. Qua ratione ſint hæc exploranda paulò poſt aperiemus. Conſtat igitur d f ſinum rectum circumferentię eleuationis d g παραλλήλου eſſe k m perpendiculari. Inſuper aſſumamus c k rectam loco c l hypotenuſæ. Habemus hîc iam duos trigonos rectãgulos, quorum vnus c k m, alter c f d, cum d f ipſi k m æquidiſtet: nam d f eſt ſinus arcus c d, & c f æqualis ſinui complementi, & angulus k c m vtriq; eſt communis. Quare duo reliqui anguli c d f & c k m inter ſe æquales erunt. Eſt igitur per 4 ſexti Elementorum eadem ratio lateris c f ad f d, quæ eſt c m ad m k. Et his ita conſtitutis, manifeſtum eſt ſatis exquiſitè inueniri poſſe c k & k m, verùm c l & l m non ita facilè deprehenduntur, attamen quomodo k l differentia proximè inueniatur, inferius oſtendemus. Porro hîc conſiderandum eſt, quoties ſphæra ſit extorquenda, vt per cathetum in ſubiectum locum deferatur, vt centrum tormẽti exactè eleuetur iuxta lineam c k, ne inferius inclinetur ad c l hypotenuſam veram. Nam hac ratione futurum eſt, vt perpendicularem l m ſphæra rectius decurrat, ne vltra aut citra præſcriptum terminum deuoluatur.

PROPOSITIO CXV.

Obſeruationes quædam ad certas collocationes & omnem uſum tormenti neceſſariæ, ne à ſcopo multum aberremus.

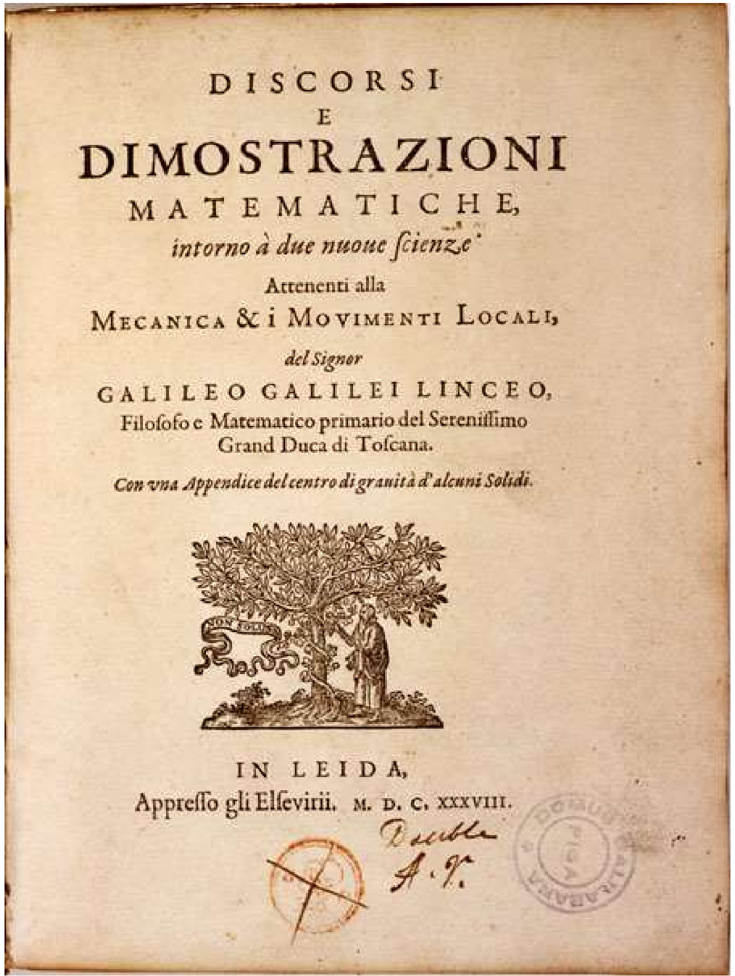
CVm demonſtrauerimus præcipuum vſum tormentorum ex conſideratione trianguli ὀρθογωνίου extructum eſſe, ſequitur etiam, vt explicemus quænam obſeruationes hîc neceſſariæ ſint, vt ne obliqua aut diſtorta collocatione tormẽti huius trianguli ſtructura perturbetur. Nam in hoc præcipuè incumbendum eſt, vt ex certa eleuatione tormenti ad Quadrantem & eiuſdem diſtantia à loco delapſæ ſphæræ hypotenuſam ex ſinuum tabulis inuenias. In primis huc requiritur, vt baſis Quadrantis exquiſitè occupet planam Horizontis ſuperficiem: id quod facillimè (ſicut alibi demonſtrauimus) expedire licet, ſi perpendiculum ex ſupremitate ſuſpenſum alterum latus, quod eſt erectum exactè contingat. Hoc ita conſtituto, dicimus axem tormenti, ſiue lineam,

- Page from Daniel Santbech, *Problematum astronomicorum et geometricorum sectiones septem* (Basel, 1561). Did the Dutchman Santbech (fl 1561) know Tartaglia's work? Model of two straight lines.


F
B
A
C
D
G

Galilei

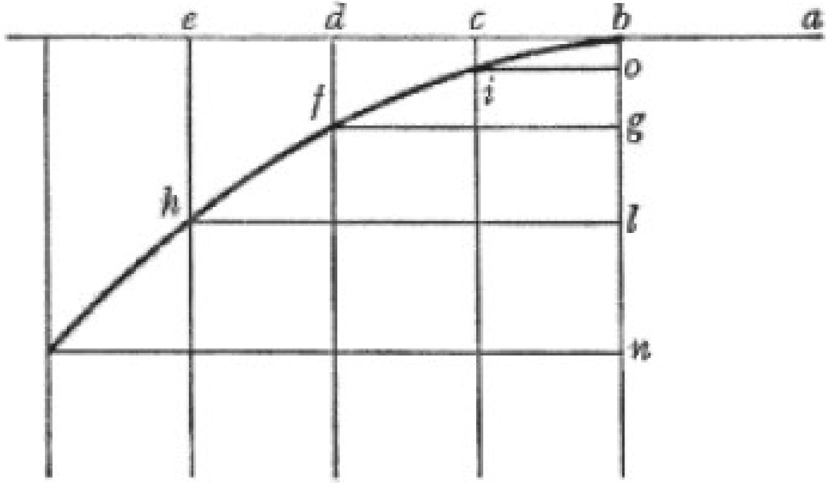
Galileo Galilei, *Discorsi e dimostrazioni matematiche, intorno à due nuove scienze*, 1638: In vacuum the trajectory is a parabola.


DISCORSI
E
DIMOSTRAZIONI
MATEMATICHE,
intorno à due nuoue scienze
Attenenti alla
MECANICA & i MOVIMENTI LOCALI,
del Signor
GALILEO GALILEI LINCEO,
Filosofo e Matematico primario del Serenissimo
Grand Duca di Toscana.
Con vna Appendice del centro di grauità d'alcuni Solidi.

IN LEIDA,
Appresso gli Elsevirii. M. D. C. XXXVIII.

TEOREMA 1. PROPOSIZIONE 1

Un proietto, mentre si muove di moto composto di un moto orizzontale equabile e di un moto *deorsum* naturalmente accelerato, descrive nel suo movimento una linea semiparabolica.



Torricelli

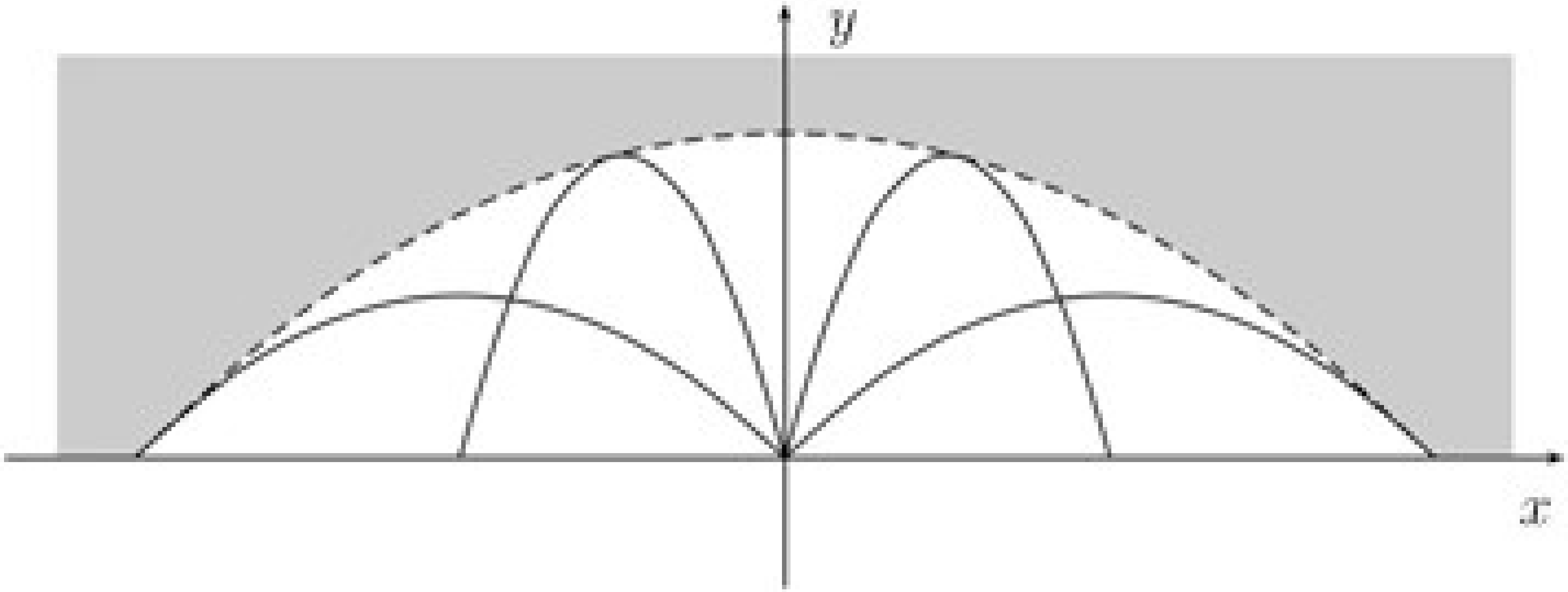
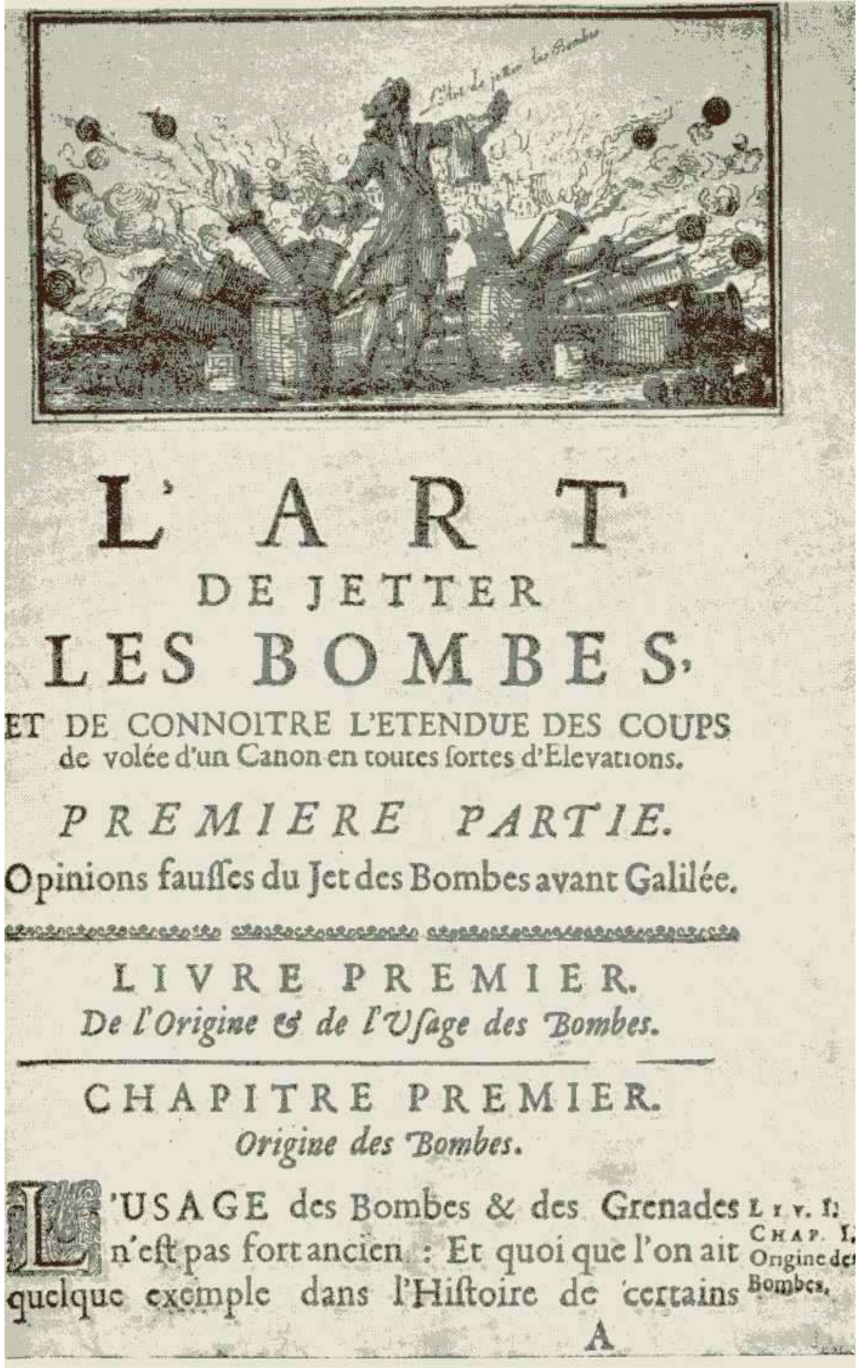


Figure 1 - Illustration of the safety domain. The solid lines represent some possible trajectories and the dashed line delimits the safety domain. If a projectile fired with initial speed v_0, it can only reach a target in the white area.



L'ART
DE JETTER
LES BOMBES,
ET DE CONNOITRE L'ETENDUE DES COUPS
de volée d'un Canon en toutes ſortes d'Elevations.

PREMIERE PARTIE.

Opinions fauſſes du Jet des Bombes avant Galilée.

LIVRE PREMIER.

De l'Origine & de l'Uſage des Bombes.

CHAPITRE PREMIER.

Origine des Bombes.

L'USAGE des Bombes & des Grenades n'eſt pas fort ancien : Et quoi que l'on ait quelque exemple dans l'Hiſtoire de certains

LIV. I. CHAP. I. Origine des Bombes.

A

François BLONDEL L'Art de jetter les bombes, 1683

18^{th} century:

$$F = m.a$$

gives

$$d^2x/dt^2 = -F(v)dx/dt$$
$$d^2y/d\tau^2 = -F(v)dy/dt - g$$

$$v=\sqrt{}[(dx/dt)^2 +dy/dt)^2]$$

18th century mathematicians working in ballistics:

Varignon, Johann Bernoulli, Bélidor, Daniel Bernoulli, D’Alembert, Euler, Lambert, Bossut, Borda, Gassendi, Legendre, Vandermonde

Analytical solution for simple polynomial F(v)

In his 18th century *Manuel de l'artilleur* d'Urtubie wrote: *"The elevation and the charge to use are hard to find. Numerous causes spread uncertainty about this service: the resistance of the air, always heterogeneous; the quantity and quality of the powder, never well proportioned; bombs, all of them defective in weight, in shape, in dimensions; the construction of the mortar, of the gun carriage, of the platform inevitably disturbed after the first shot, the impossibility of placing the bomb precisely, so that its axis and that of the mortar are one and that both are coincide with goal alignment. Each of these two causes alone produces astonishing variations. It is therefore only by force of the theory, attention in practice and accuracy, that we can profit the most from the mechanism of throwing bombs"*. D'Urtubie wrote about mortars (that use high arching ballistic trajectories), but his remarks were also valid for regular artillery.

In 1908 the German Carl Julius Cranz explained the slow development of ballistics:
i) The extreme mathematical complexity. Finding good approximate solutions requires great ingenuity. Francesco Siacci (1839-1907).
ii) It took long before a good formula for $F(v)$ could be determined experimentally. Experimentally determining the initial velocity was also complicated.
iii) It took long before the mass production of identical parts of constant quality got started.

https://de.wikipedia.org/wiki/Carl_Cranz

Wikipedia: Siacci is well known for his contributions in the field of ballistics, distinguishing himself with a famous treatise *Balistica*, published in 1888 and translated to French in 1891. Of great importance is an approximation method he devised to calculate bullet trajectories of small departure angles. Known as Siacci's method, it was a major innovation in exterior ballistics and was widely used almost exclusively at the beginning of World War I.

On the 21st of October 1914 a shot was fired at Krupp's firing grounds near Meppen, probably with a Big Bertha, a 42 cm mortar built by Krupp. Instead of the calculated 38 kilometers the grenade travelled 49 kilometers. The investigation revealed that no one had considered the fact that the density of the air is almost negligible at great heights.

This created new opportunities. In 1916 Fritz Rausenberger of Krupp was ordered to build a gun with a 120 kilometers range. These 36-meter-long guns were built and used against Paris in 1918.

Thank you!