Centro de Física Aplicada y
Tecnología Avanzada, UNAM Juriquilla

La metrología en el siglo XXI: una visión desde la historia y la gestión del conocimiento

Víctor Manuel Castaño

Globalización

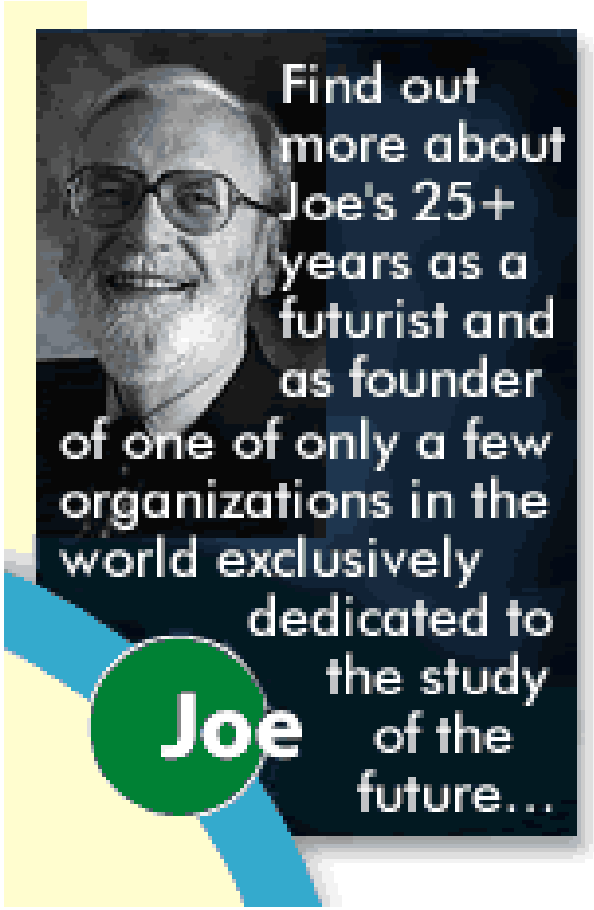
- Un concepto antiguo que se vuelve viable
- La idea de contemplar al mundo como un gran mercado
- Remoción de barreras al comercio
- División del mundo ya no solamente entre los que tienen y los que no tienen, sino también entre los que saben y los que no saben

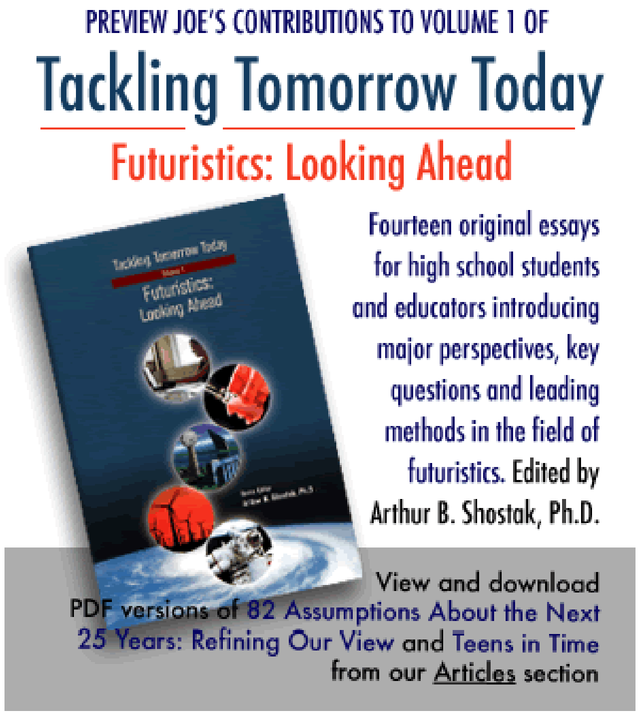
La fabrica del futuro es...

...un sistema de información altamente integrado que combine tecnologías avanzadas de producción con estrategias innovadoras, como producción “ligera”, justo a tiempo y gestión total de calidad.

Joseph Coates (2000)

Joseph Coates





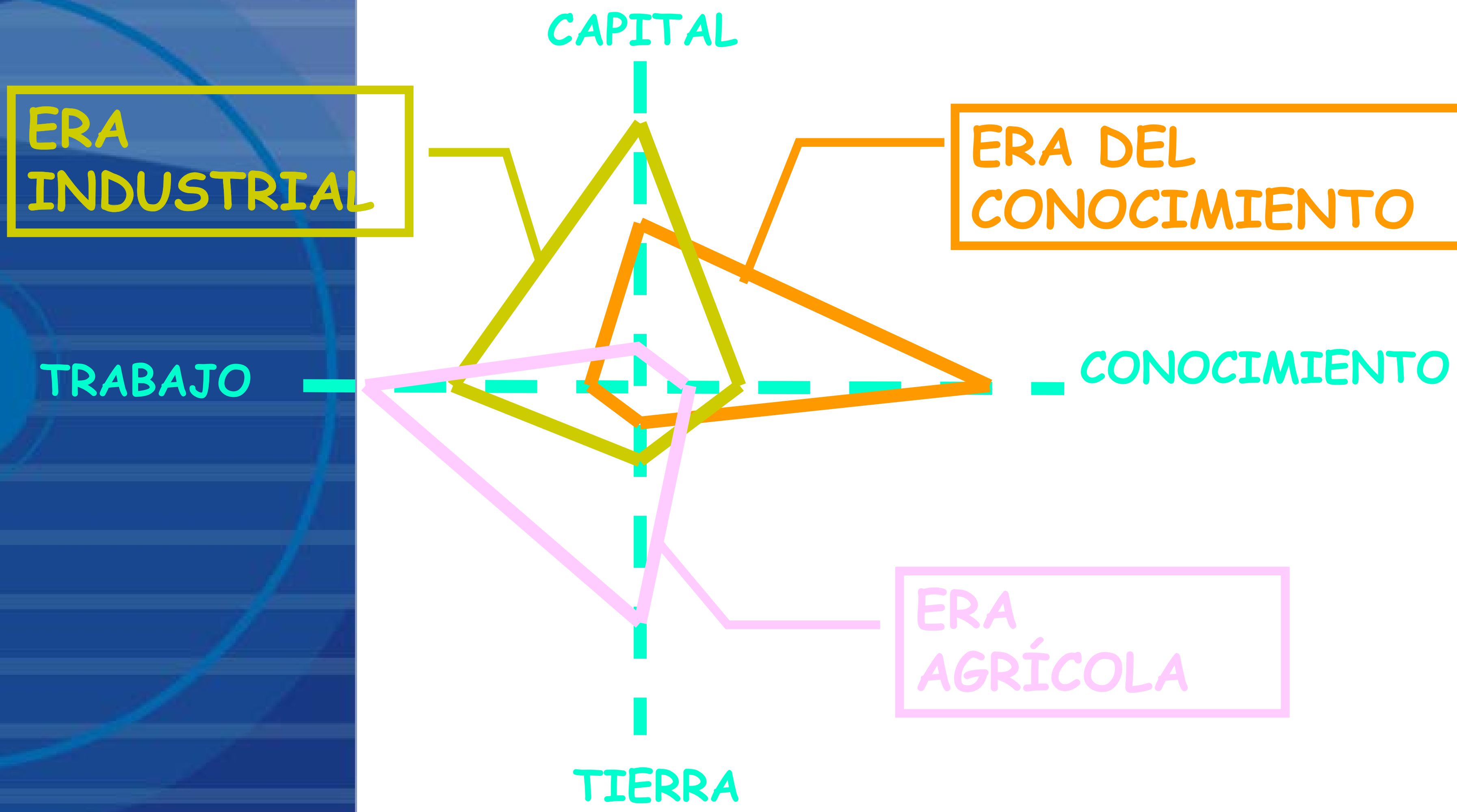
Tendencias en la producción

- Computadoras y redes para todos los aspectos de manufactura y distribución
- Enfoque sistémico para lidiar con la complejidad
- Producción a la medida del cliente
- Reconocimiento del papel de factores no tecnológicos (estrategia y globalización)
- Desarrollos científicos y tecnológicos.

Factores determinantes

- Globalización de negocios
- TICs
- Preocupación ambiental
- Respuesta a la medida del cliente
- Alianzas
- Empresa virtual
- Materiales nuevos (polímeros, cerámicos, biológicos)
- Nanotecnologías
- Logística
- Fábrica del futuro
- Empresa ágil
- Mercados de segunda mano.
- Estandarización con diferenciación

Evolución de la Economía



Breve historia de la evolución

Billion Years Ago	
12	Big Bang (MEST)
11.5	Milky Way (Atoms)
8	Sun (Energy)
4.5	Earth (Molecules)
3.5	Bacteria (Cell)
2.5	Sponge (Body)
0.7	Clams (Nerves)
0.5	Trilobites (Brains)
0.2	Bees (Swarms)
0.100	Mammals
0.002	Humans, Tools & Clans Co-evolution

Breve historia de la evolución

Generations Ago	
100,000	Speech
750	Agriculture
500	Writing
400	Libraries
40	Universities
24	Printing
16	Accurate Clocks
5	Telephone
4	Radio
3	Television
2	Computer
1	Internet/e-Mail
0	GPS, CD, WDM

Breve historia de la tecnología

3 million years ago	collective rock throwing; early stone tools
1.5 million years ago	lever, wedge, inclined plane
500,000 years ago	control of fire
50,000 years ago	bow and arrow; fine tools
5,000 years ago	wheel and axle; sail
500 years ago	printing press with movable type; rifle
50 years ago	commercial digital computers
10 years ago	commercial internet

información vs. conocimiento

"(El conocimiento) es una forma de alto valor de la información que está lista para ser aplicada a decisiones y acciones."

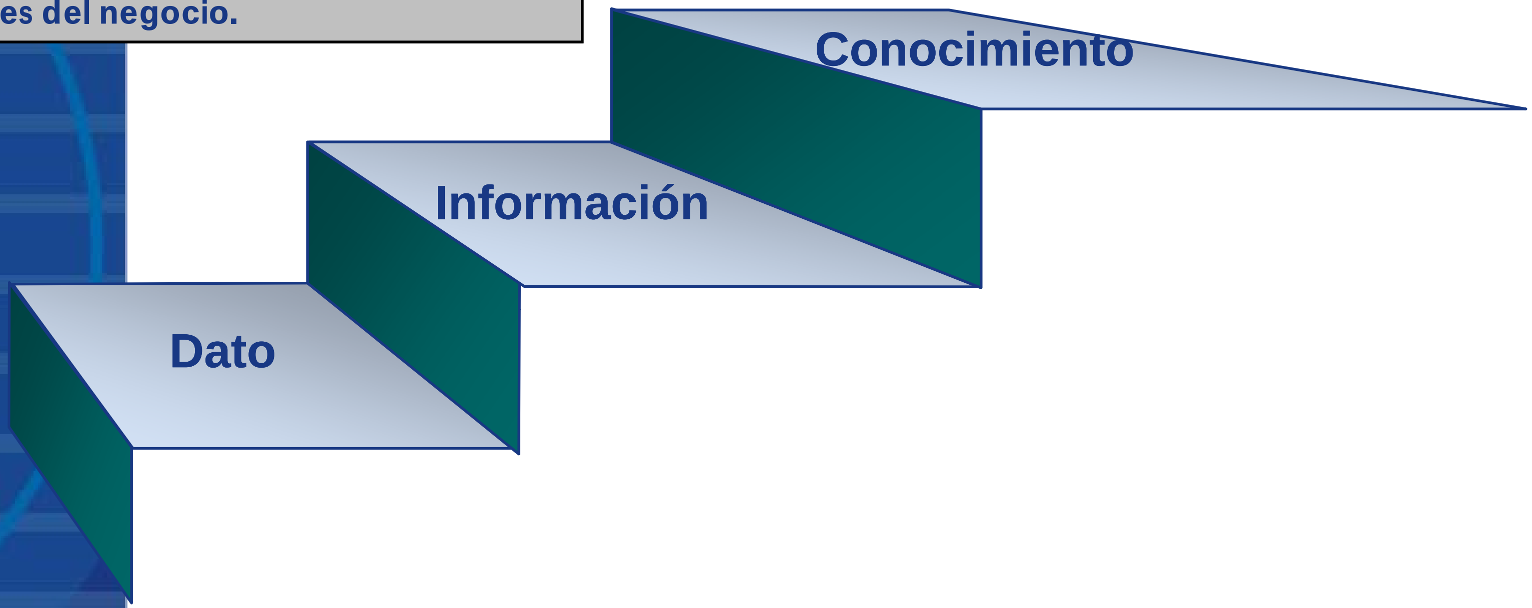
Thomas H. Davenport / David W. De Long

"Successful Knowledge Management Projects"

Esta definición otorga un valioso carácter operativo al conocimiento en tanto lo asume como dinámico. Desde esta perspectiva, el conocimiento es un "estado" que sólo se alcanza en tanto es útil a las decisiones, y que al dejar de serlo, vuelve a "degradarse" en información.

Evolución

El Conocimiento puede ser visto como la evolución natural de los conceptos de Dato e Información. Muchas opiniones coinciden en que el Conocimiento irrumpe como concepto operativo porque hoy el problema no es obtener información, sino cómo, desde su superabundancia, “filtrar” aquella realmente útil a las decisiones del negocio.



Las “leyes” de la evolución del conocimiento

- **Moore's Law - Miniaturization**
  - ➔ Processing, Storage, ...
  - ➔ Price/Performance 2X over 12-18 months
- **Metcalf's Law - Interconnection**
  - ➔ Economic value of a network increases as the square of the number of connections
- **Gilder's Law - Quantization**
  - ➔ Bandwidth increases 3X every 36 months
- **Negroponte's Law - Digitization**
  - ➔ Superiority of "bits over atoms"
  - ➔ Profound impact felt in "Knowledge Economy" where ideas are ultimate raw material

Las "leyes" de la evolución del conocimiento

- **Smith's Law - Simulation**

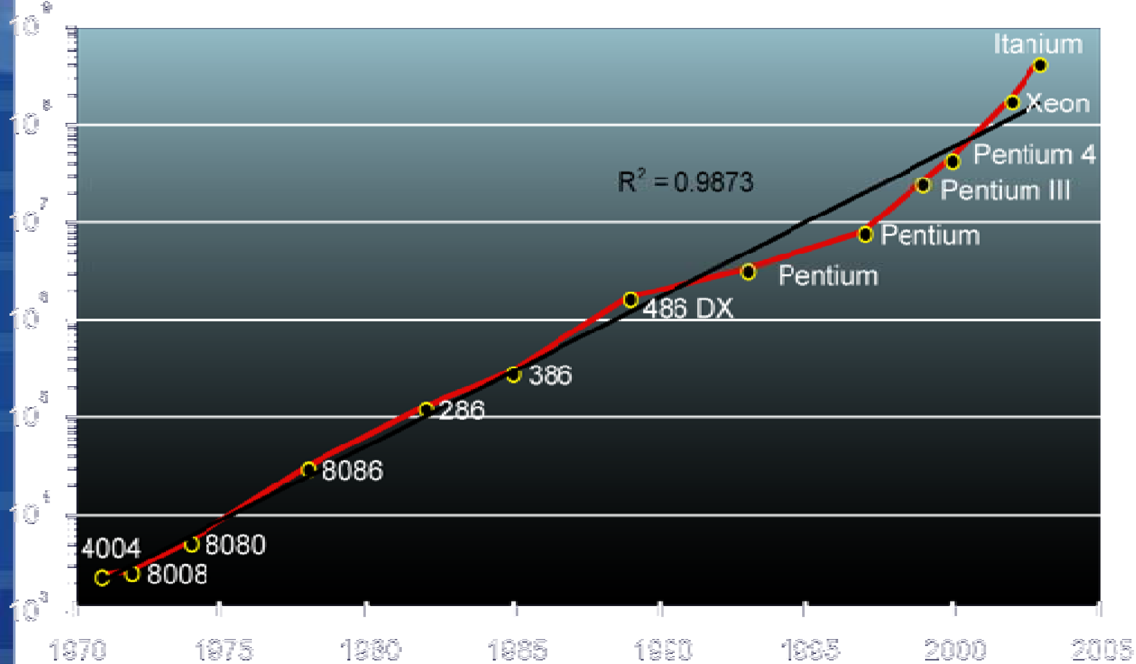
Alvy Ray Smith, Microsoft Research (to Howard Rheingold)
"Reality is 80 million polygons a second."

➔ **A demand saturation threshold, like CPUs and productivity apps (which human-saturated in 1990's).**

➔ **No market saturation until we reach this point**

Transistors (Intel processors)

Transistors per chip



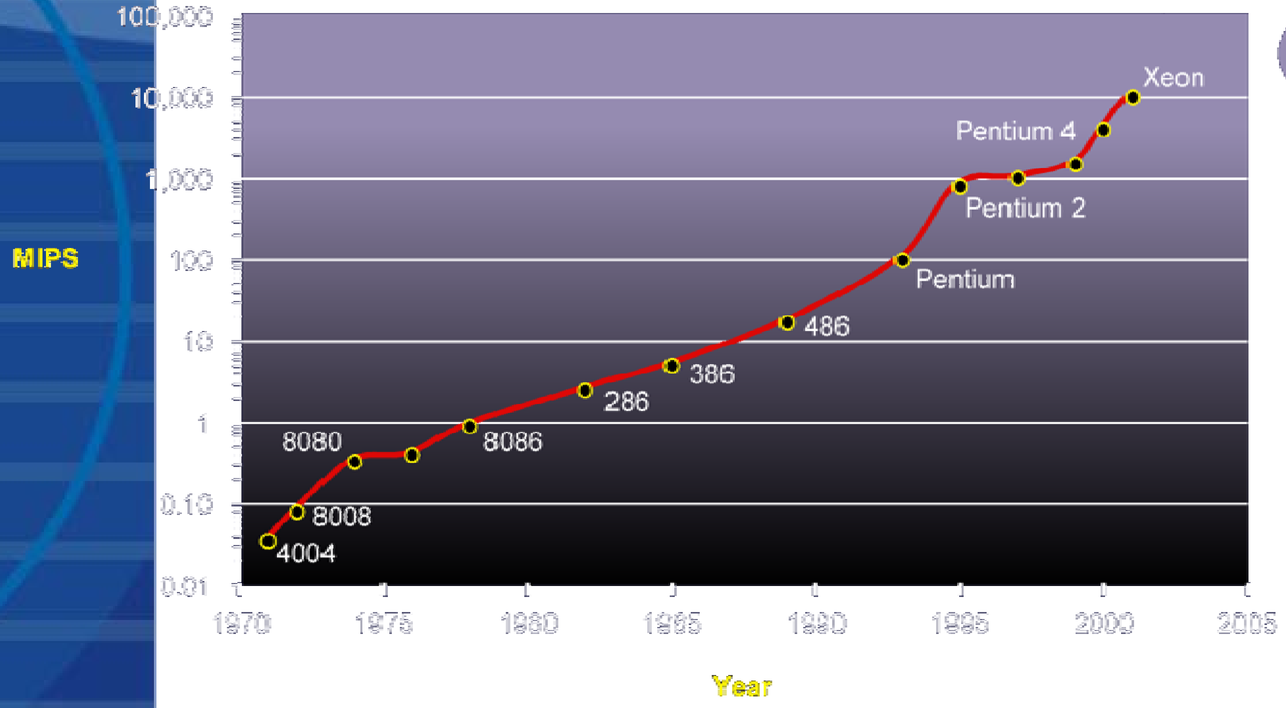
Year

Logarithmic Plot

Source: Intel Research

Doubling time: 2 years

Processor Performance (MIPS)

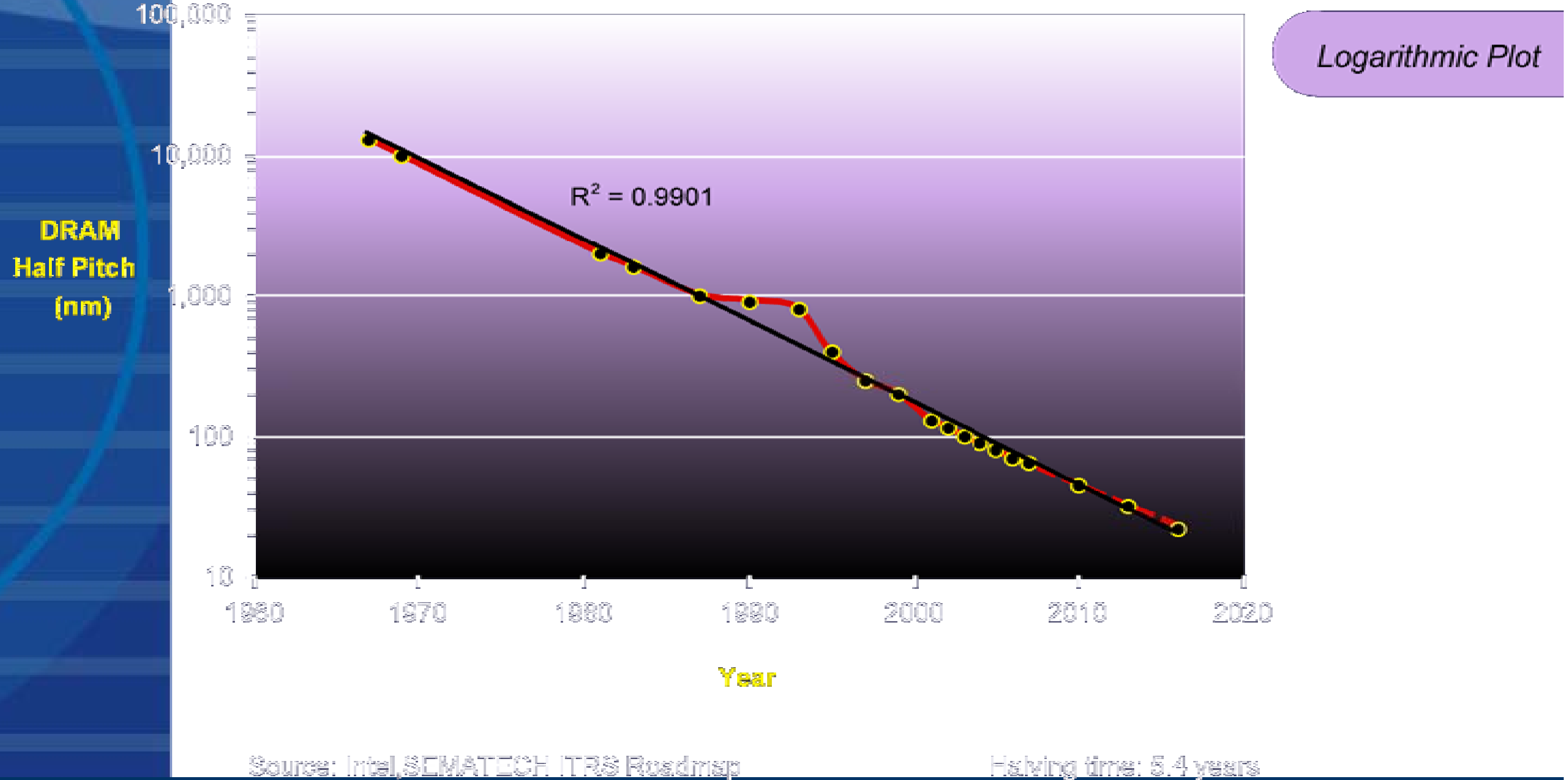


Logarithmic Plot

Source: Intel

Doubling time: 1.8 years

Dynamic RAM Memory "Half Pitch" Feature Size



Leyes de este tipo, como la de Moore se aplican también en la ciencia y la tecnología

Moore's Law describes a long-term trend in thehistory of computing hardware, in which the number of transistors that can be placed inexpensively on an integrated circuit has doubled approximately every two years

Rather than being a naturally-occurring "law" that cannot be controlled, however, Moore's Law is effectively a business practice in which the advancement of transistor counts occurs at a fixed rate.

The capabilities of many digital electronic devices are strongly linked to Moore's law: processing speed, memory capacity, sensors and even the number and size of pixels in digital cameras.

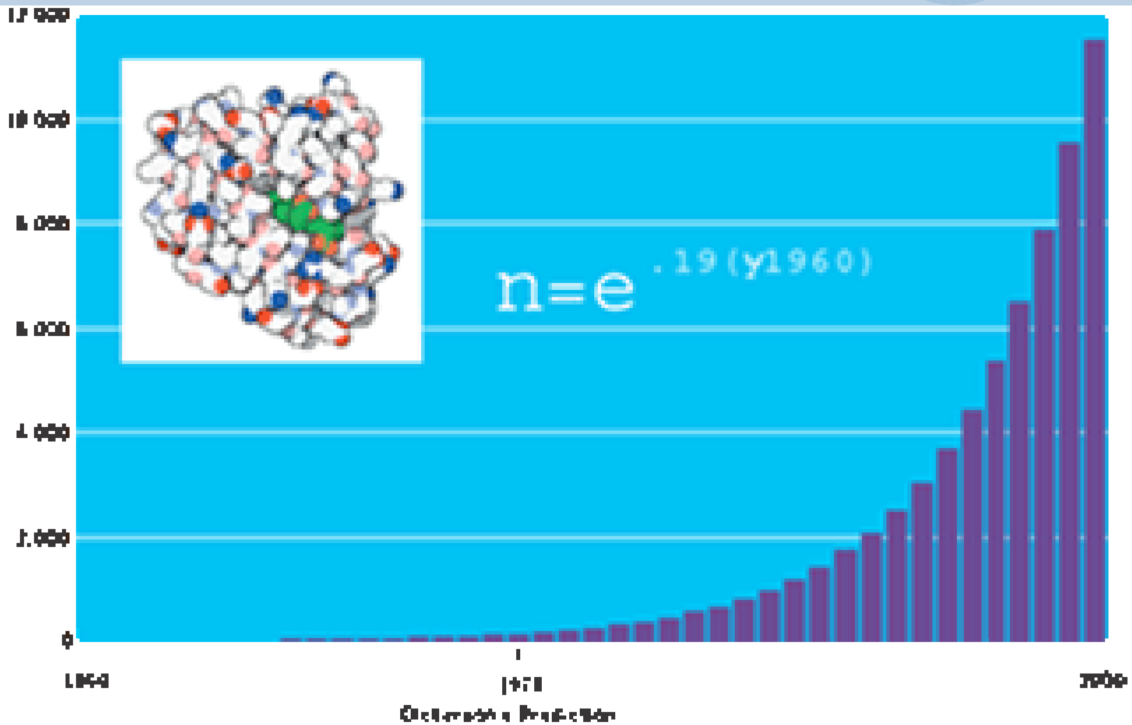
All of these are improving at (roughly) exponential rates as well.
This has dramatically increased the usefulness of digital electronics in nearly every segment of the world economy.

Moore's law precisely describes a driving force of technological and social change in the late 20th and early 21st centuries. The trend has continued for more than half a century and is not expected to stop until 2015 or later.
The law is named for Intel co-founder Gordon E. Moore, who introduced the concept in a 1965 paper.It has since been used in the semiconductor industry to guide long term planning and to set targets for research and development.

Leyes de este tipo, como la de Moore se aplican también en la ciencia y la tecnología

Richard Dickerson **1978**, Cal Tech:

Protein crystal structure solutions grow according to n=exp(0.19y1960)



Dickerson's law predicted **14,201** solved crystal structures by 2002. The actual number (in online Protein Data Bank (PDB)) was **14,250**. Just 49 more.

Macroscopically, the curve has been quite consistent.

Ley de Icaza-Castaño sobre publicaciones en nanotecnoloigía

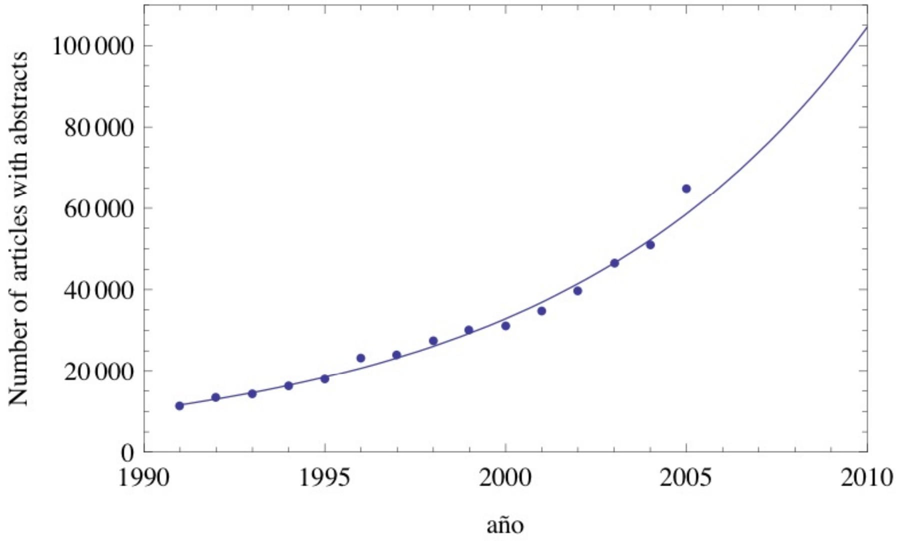


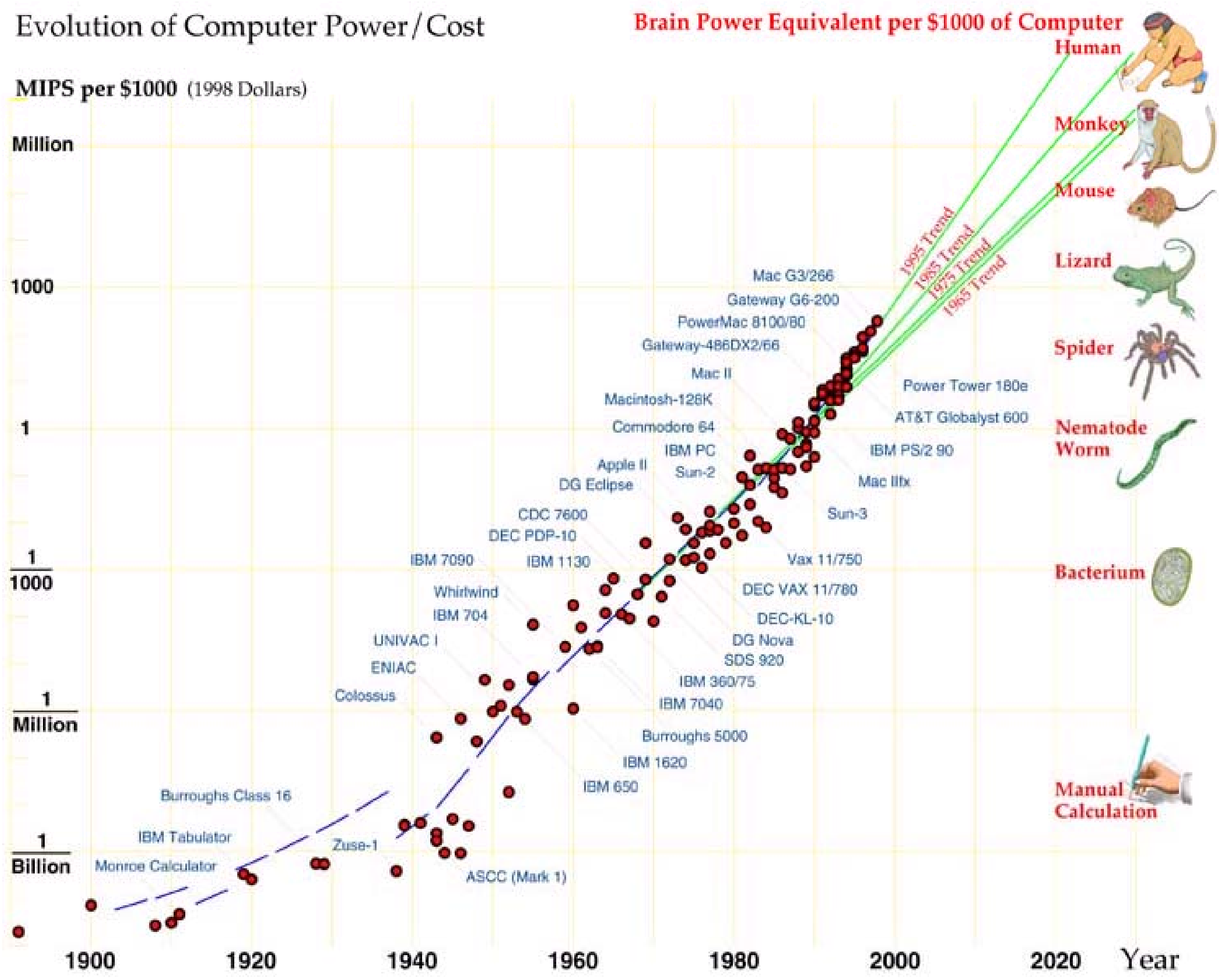
Figura 1: Nanotechnology is booming! In the fundamental nanotechnology research literature as represented by the Science Citation Index/Social Science Citation Index (SCI/SSCI) (SCI 2006), nanotechnology publications grew from 11,265 records (classified as Articles or Reviews) in 1991 to 64,737 records in 2005.

Figura tomada de: Technical structure of the global nanoscience and nanotechnology literature. Ronald N. Kostoff, Raymond G. Koytcheff & Clifford G. Y. Lau J Nanopart Res 9,701, 2007.

El trazo continuo de esta gráfica corresponde a:

$$N(x) = e^{-221 + 0.1157\, t}, \qquad (1)$$

donde t es la expresión decimal del tiempo en años.



Evolution of Computer Power/Cost
Brain Power Equivalent per $1000 of Computer
MIPS per $1000 (1998 Dollars)
Million
1000
1
1/1000
1/Million
1/Billion
Human
Monkey
Mouse
Lizard
Spider
Nematode Worm
Bacterium
Manual Calculation
1995 Trend
1985 Trend
1975 Trend
1965 Trend
Mac G3/266
Gateway G6-200
PowerMac 8100/80
Gateway-486DX2/66
Mac II
Macintosh-128K
Commodore 64
IBM PC
Sun-2
Apple II
DG Eclipse
CDC 7600
DEC PDP-10
IBM 7090
IBM 1130
Whirlwind
IBM 704
UNIVAC I
ENIAC
Colossus
Burroughs Class 16
IBM Tabulator
Monroe Calculator
Zuse-1
ASCC (Mark 1)
Power Tower 180e
AT&T Globalyst 600
IBM PS/2 90
Mac IIfx
Sun-3
Vax 11/750
DEC VAX 11/780
DEC-KL-10
DG Nova
SDS 920
IBM 360/75
IBM 7040
Burroughs 5000
IBM 1620
IBM 650
1900
1920
1940
1960
1980
2000
2020
Year

La evolución CONTINUA de la tecnología

Technological or Sociotechnological Innovation	Date (A.D.), Location
Alchemy (pre-science) develops a wide following	410, Europe
Constantinople University	425, Turkey
Powers and Roots (Arybhata)	476, India
Heavy plow; horse shoes; practical horse harness	500, Europe
Wooden coffins (Alemanni)	507, Germany
Draw looms (silk weaving)	550, Egypt
Decimal reckoning	595, India
Canterbury Monastery/University	598, England
Book printing	600, China
Suan-Ching (Science Encyclopedia)	619, China
Originum Etymologiarum Liibri XX (Sci. Encyc.)	622, Spain
First surgical procedures	650, India
Water wheel for milling (Medieval energy source)	700, Europe
Stirrup arrives in Europe from China	710, Europe
Early Chemistry (Abu Masa Dshaffar)	720, Mid-East

Medicine, Astronomy, Math, Optics, Chemistry	750, Arab Spain
Hanlin Academy	750, China
Pictorial Book Printing	765, Japan
Iron and smithing become common; felling ax	770, Europe
Chemistry (Jabir)	782, Mid-East
Mayan Acropoli (peak)	800, Mexico
Algebra (Muhammed al Chwarazmi)	810, Persia

Ptolemaic Astronomy; Soap becomes common	828, Europe
Rotary grindstone to sharpen iron	834, Europe
Paper money	845, China
Salerno University	850, Italy
Iron becomes common; Trebuchets	850, Europe
Astrolabe (navigation)	850, Mid-East
Angkor Thom (city)	860, Cambodia
New Mathematics and Science (Jahiz, Al-Kindi)	870, Mid-East
Viking shipbuilding	900, Europe
Paper arrives in Arab world	900, Egypt

Salerno Medical School	900, Italy
Linens and woolens	942, Flanders
First European bridges	963, England
Arithmetical notation brought to Europe by Arabs	975, Europe
1,000 volume encyclopedia	978, China
First Mayan and Tiuanaco Civilizations	1000, Cent./S.America
Horizontal loom	1000, Europe

Astrolabe arrives in Europe	1050, Europe
Greek medicine arrives in Europe (Constantine)	1070, Europe
Water-driven mechanical clock	1090, China
Antidotarum (2650 medical prescriptions)	1098, Italy
Bologna University	1119, Italy
Mariner's compass	1125, Europe
Town charters granted (protecting commerce)	1132, France
Al-Idrisi's "Geography"	1154, Italy
Oxford University	1167, England
Vertical sail windmills	1180, Europe

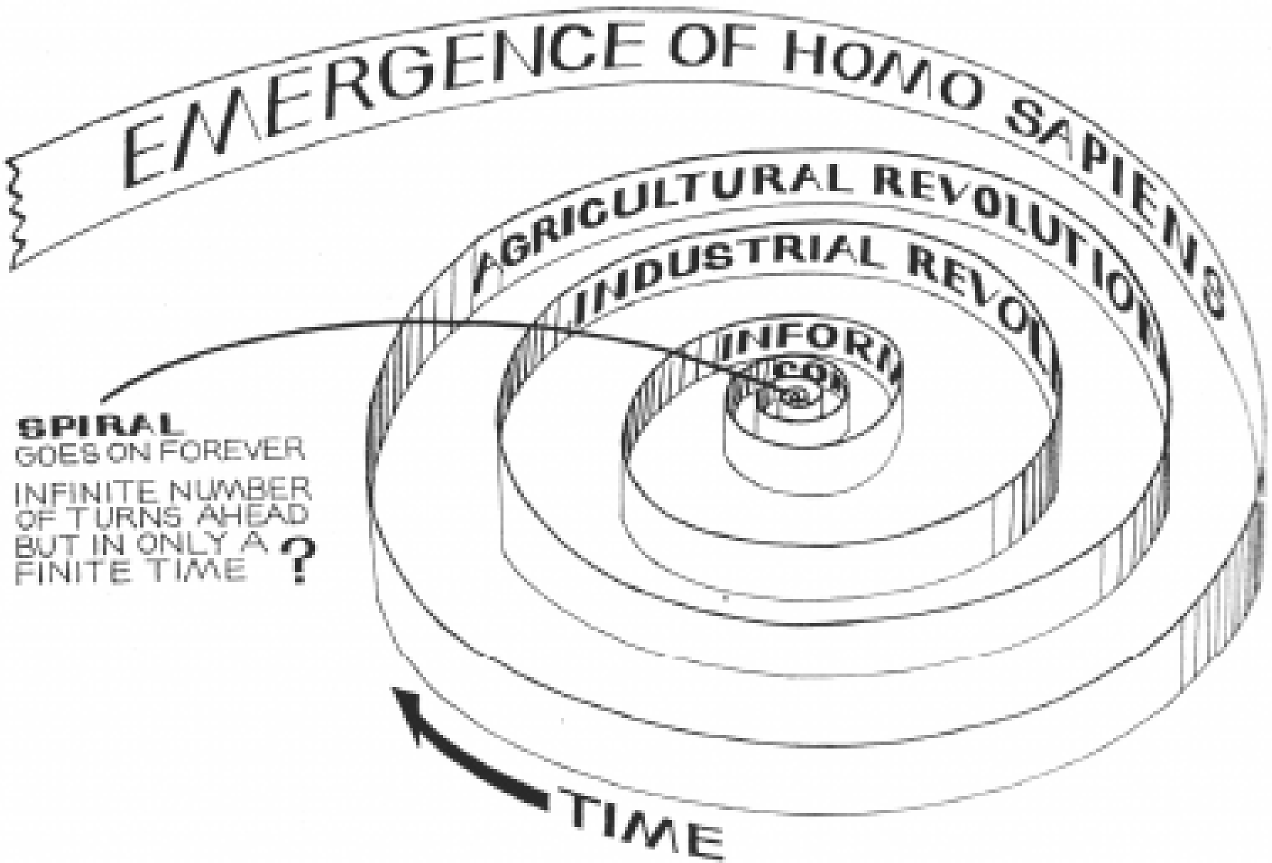
Glass mirrors	1180, England
Second Mayan Civilization	1190, Cent. America
Cambridge University	1200, England
Arabic numerals in Europe (Leonardo Fibonacci)	1202, England
Tiled roofs	1212, England
Cotton manufacture	1 225, Spain
Coal mining	1233, England
Roger Bacon, our first scientist (Opus; Communia)	1250, England

Goose quill writing pen	1250, Italy
The inquisition begins using instruments of torture	1252, Spain
Tradesman guilds engage in street fighting over turf	1267, England
Toll roads	1269, England
Human dissection	1275, England
Wood block printing; spectacles	1290, Italy
Standardization of distance measures (yard, acre)	1305, England
Use of gunpowder for firearms (Berthold Schwarz)	1313, Germany
Sawmill; wheelbarrow; cannon (large and hand)	1325, Europe

Pisa and Grenoble Universities; Queens College	1330, Europe
First scientific weather forecasts (William Merlee)	1337, England
Mechanical clock reaches Europe	1354, France
Blast furnaces; cast iron explodes across Europe	1360, Europe
Steel crossbow first used in war	1370, Europe
Vienna, Hiedelberg, and Cologne Universities	1380, Europe
Incorporation of the Fishmonger's Company	1384, England
Johann Gutenberg, inventor of mass printing, born	1396, Germany

- Lesson: Tech innovation appears to be a **developmental** process, independent of Wars, Enlightenments, Reformations, Inquisitions, Crusades, Subjugations, and other aspects of our cyclic **evolutionary** ideological, cultural, and economic history.

- Tech advances are something we consistently choose, even unconsciously, regardless of who is in power, because they have strong "non-zero sum" effects on human aspirations.


EMERGENCE OF HOMO SAPIENS
AGRICULTURAL REVOLUTION
INDUSTRIAL REVOL
INFORM
SPIRAL
GOES ON FOREVER
INFINITE NUMBER
OF TURNS AHEAD
BUT IN ONLY A
FINITE TIME ?
TIME

Henry Brooks Adams (1838 –1918)

- In 1910, Adams printed and distributed to university libraries and history professors the small volume *A Letter to American Teachers of History proposing a "theory of history" based on the second law of thermodynamics and the principle of entropy. This, essentially, states that all energy dissipates, order becomes disorder, and the earth will eventually become uninhabitable. In short, he applied the physics of dynamical systems of Rudolf Clausius, Hermann von Helmholtz, and William Thomson to the modeling of human history.In his manuscript The Rule of Phase Applied to History, Adams attempted to use Maxwell's demon as an historical metaphor. Adams interpreted history as a process moving towards "equilibrium," but he saw militaristic nations (he felt Germany pre-eminent in this class) as tending to reverse this process, a "Maxwell's Demon of history."Adams made many attempts to respond to the criticism of his formulation from his scientific colleagues, but the work remained incomplete at Adams' death in 1918. It was only published posthumously.*

"Our Power Is Always Running Ahead of Our Mind": Henry Adams's Phases of History

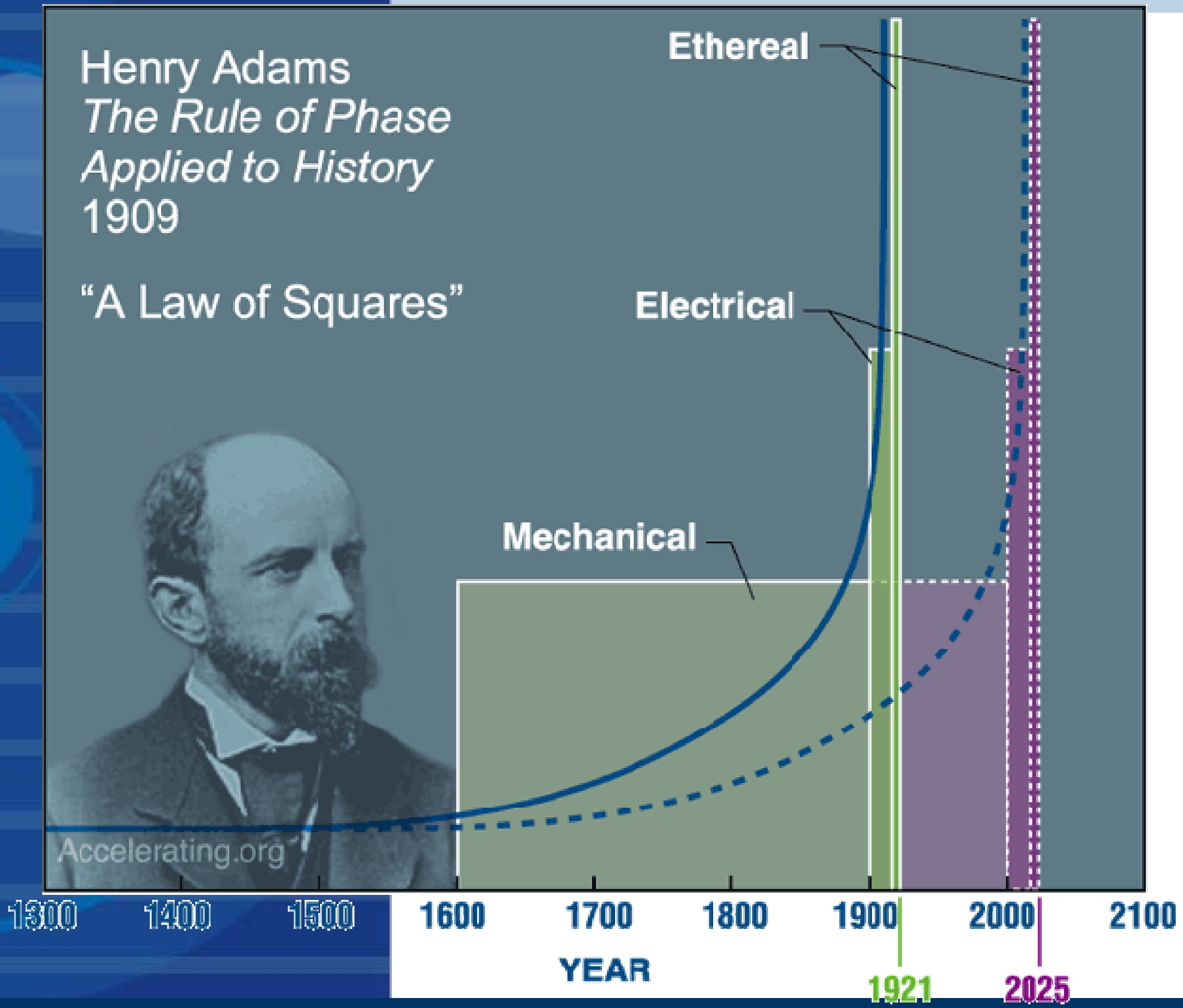
KEITH R. BURICH

WHEN Henry Adams composed "The Rule of Phase Applied to History" in 1909, he intended it as a good-natured but pointed jab at his fellow historians for naively assuming that the future is determined by the past. The message, unfortunately, was lost. Leaving "The Rule of Phase" unpublished, Adams abandoned it to pursue the more dramatic and frightening consequences predicted by the second law of thermodynamics which he set forth in "A Letter to American Teachers of History" in 1910. Sandwiched between *The Education of Henry Adams*, which Adams had privately printed in 1907, and the "Letter," "The Rule of Phase Applied to History" has never been the subject of serious scholarly analysis. Instead, it has been casually regarded as another, if more obtuse, version of Adams's obsessive search for the universal, immutable laws that govern men and molecules alike and, of course, presage the inevitable and irreversible degradation of the universe, including mankind. A close examination of the phase rule itself, the physical principle upon which the essay was predicated, suggests on the contrary that Adams was not attempting to demonstrate that history is a continuous, deterministic process, whether of infinite upward progression or ultimate degradation. A careful analysis of the first draft of "The Rule of Phase," which has generally been ignored by Adams's biographers, supports the contention.[1] Although

[1]Henry Adams, "The Rule of Phase Applied to History," in *The Degradation of the Democratic Dogma* (New York: Macmillan Co., 1920), pp. 267–311. All references to "The Rule of Phase Applied to History," henceforth to appear in the text, will be to the draft typescript in the Henry Adams Papers, Massachusetts Historical

163

Henry Adams, 1909:
The First Singularity Theorist



The final Ethereal Phase would last only about four years, and thereafter "bring Thought to the limit of its possibilities."

Wild speculation or computational reality?

Still too early to tell, at present.

Ambientalismo: las 3 Rs

- ❖ Reciclamiento: del reuso a la rehabilitación de materiales
- ❖ Recuperación: reintroducción de componentes usados en el proceso
- ❖ Remanufactura: reacondicionamiento de productos.
  - Responsabilidad del productor en cuanto a la disposición de desechos o productos fuera de su ciclo de vida

Retos sociales inmensos

- La crisis de empleo
- La brecha tecnológica y la asimetría de la información
- Deterioro de términos de intercambio
- Países en desarrollo con muy escasa cobertura de necesidades básicas
- Pobre formación de capacidades
- Seguridad pública y seguridad social

Competitividad y desempeño social

- **Dependen de la preparación de gente.**
- **Capacidad de investigación e innovación.**
- **Acceder, guardar, procesar y usar información.**
- **Empleos de alta remuneración**
- **Búsqueda de la sustentabilidad: utilizar racionalmente recursos para las generaciones de hoy y mañana.**

Sociedad del conocimiento

Cambio en el modelo de producción y uso del conocimiento (Gibbons, 1994).

- **Transdisciplinario e interinstitucional.**
- **Contexto de aplicación.**
- **Nueva contabilidad social (rendición de cuentas).**
- **Nuevo sistema de control de calidad.**
- **Sistema socialmente distribuído.**

Modo 2. Nuevo proceso de producción de conocimiento

Atributo	Modo 1	Modo 2
Participación	Disciplinaria	Transdsiciplinaria - Marco evolutivo para solución de problemas - Componentes teóricos y empíricos - Dinámico
Comunicación	Canales institucionales Revistas científicas y conferencias	Redes complejas
Organización	Alrededor de disciplinas y líderes científicos	Heterogénea Sistema socialmente distribuido Múltiples lugares de generación de conocimiento Interconexión de los sitios Determinada por el context socioeconómico
Evaluación	Por la comunidad científica Juicio de pares	En el context de la aplicación
Control de calidad	Indicadores científicos tradicionales Juicio de pares	Interés intelectual Efectividad económica Aceptación social Competitividad Rendición de cuentas a la sociedad

Consecuencias

- Expansión y diversificación de fuentes de conocimiento
- Demanda por conocimiento especializado
- Necesidad de respuesta rápida
- Permeabilidad al contexto
- Formación y participación en redes
- Avance hacia sistemas de innovación

Los centros de I&D y la innovación abierta

- **La interdependencia en cuanto a conocimiento crea nuevos retos directivos**
- Los riesgos y dificultades de las transacciones de conocimiento
- El establecimiento de relaciones interorganizacionales diversas para adquirir conocimiento y habilidades
- En América Latina, la cooperación entre empresas y centros apenas está en estado incipiente
- Falta experiencia institucional, orientación a la solución de problemas de usuarios y traducción adecuada de conocimiento en activos intelectuales


Crear y capturar
Crea y genera nuevo conocimiento
Captura de conocimiento interno y externo
Almacena conocimiento
Renovación
Cuando el conocimiento se reutiliza, se genera conocimiento nuevo
Inteligencia
Transformación de conocimiento tácito en explícito
Reutilizar y renovar
Reutiliza conocimiento existente
Renueva conocimiento obsoleto a través de mejora continua
medición
Mapa de conocimientos
Fuentes de aprendizaje
Indicadores de capital intelectual
Distribuir y compartir
Hacer el conocimiento accesible
Distribuir, difundir y transmitir
Asimilar y aplicar
Las personas necesitan acceder al conocimiento, interpretarlo y asimilarlo para luego aplicarlo
Aprendizaje
Distribución