# Future

Over the Horizon

# Cosmic Paradigm Shifts

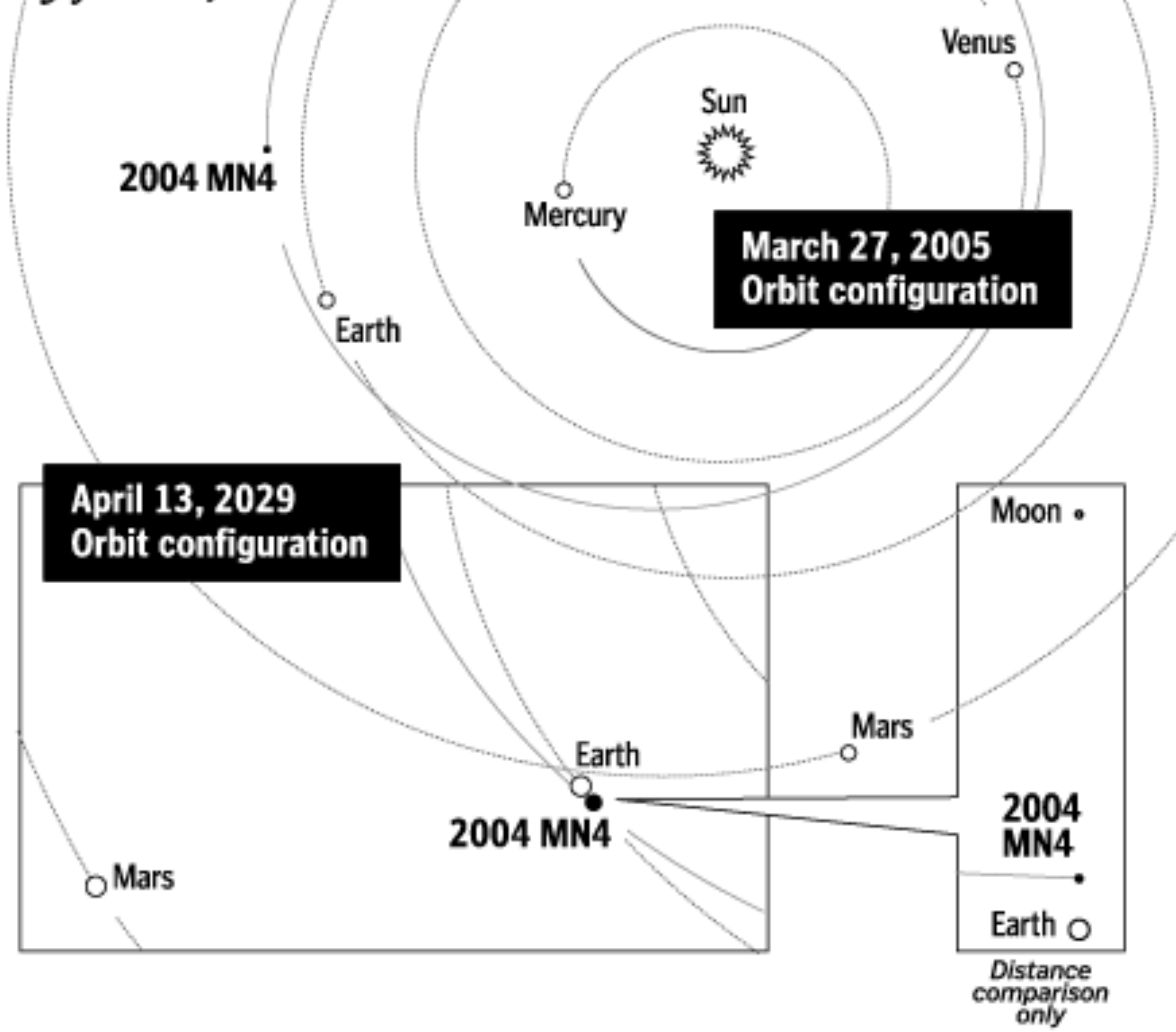
- Global Catastrophes
  - Meteor impact, volcano eruption, nuclear war, plague (e.g., airborne AIDS)
- Evolutionary Punctuation Points
  - Global change, population explosion, immortality, machine intelligence, neuromancer (sim-stim)
- Breaking the Bonds of Planet Earth
  - Resumption of space exploration, contact with extraterrestrial intelligent life, exobiology

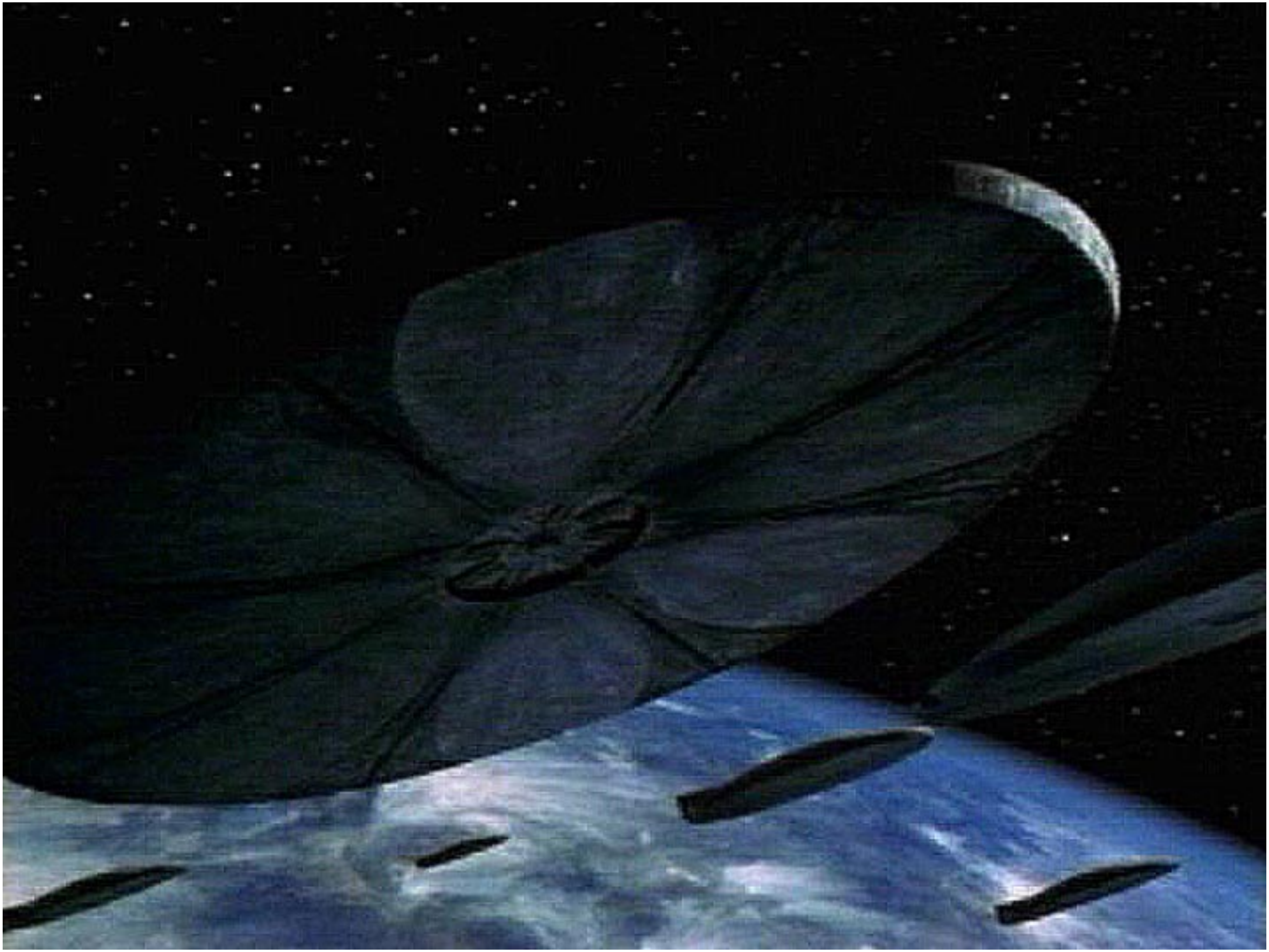
# *Global Catastrophes (Game over, man…)*


U-HAUL
U-HAUL

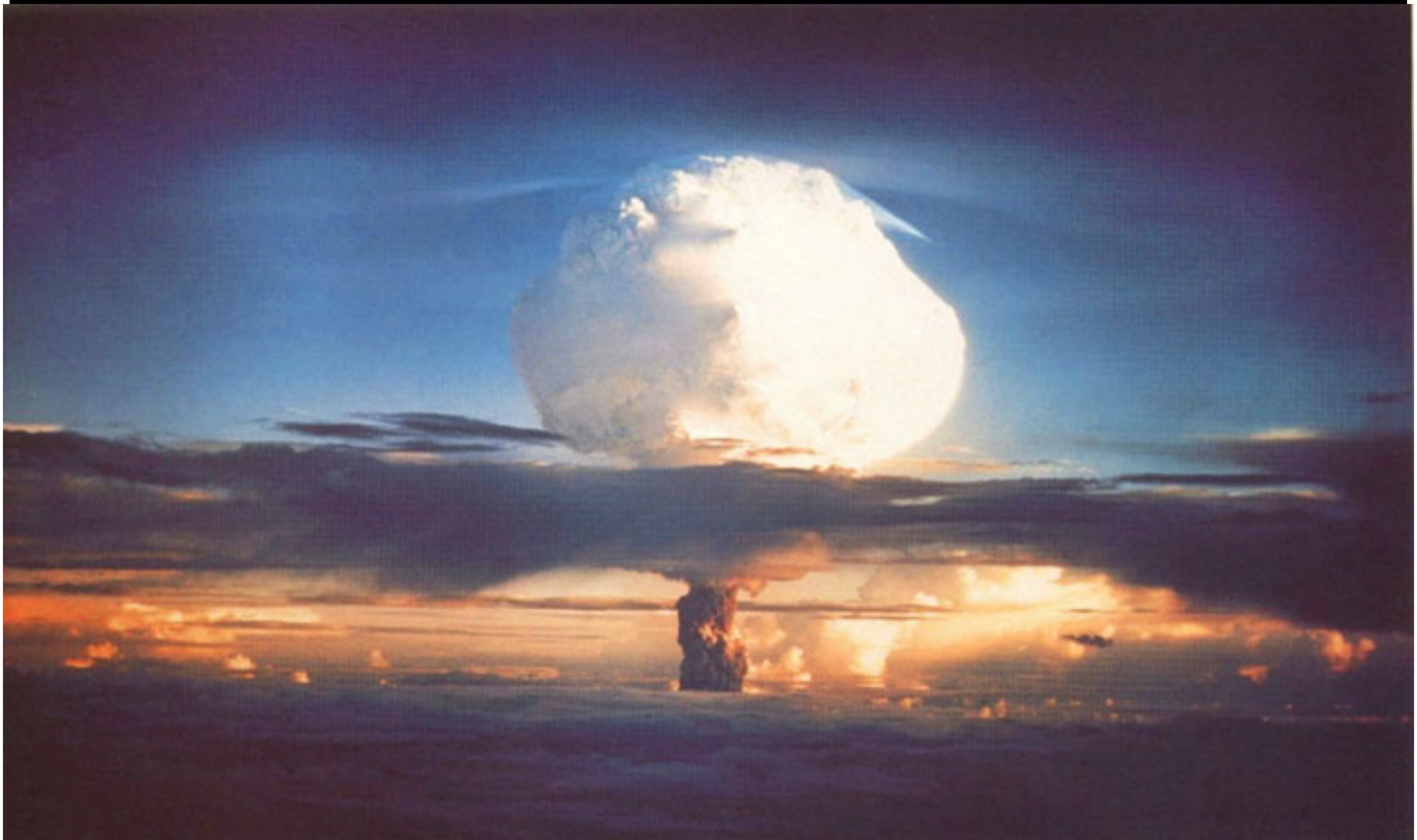
# Close Call Coming

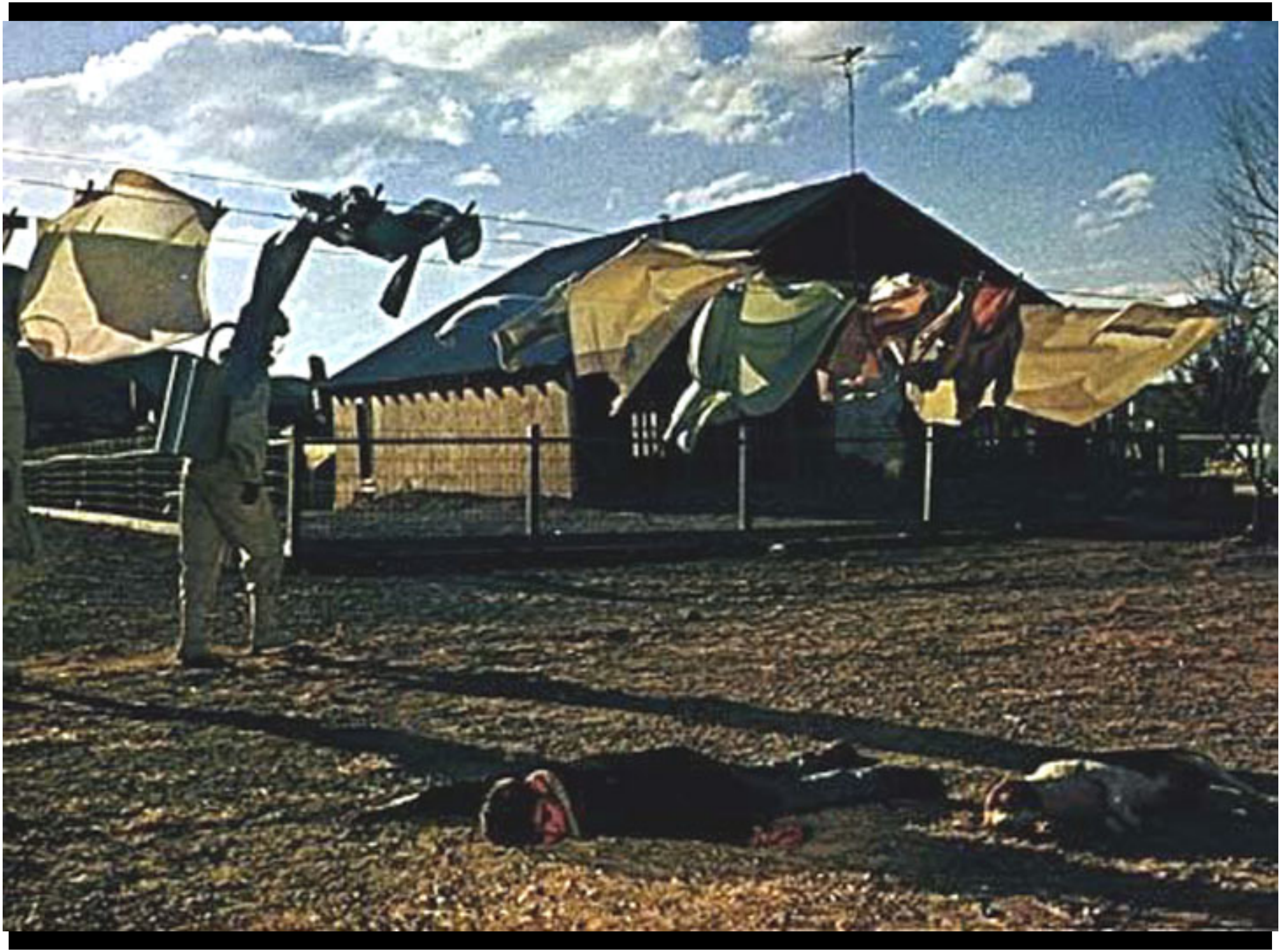
*Scientists are concerned that a large asteroid or comet could strike Earth, causing catastrophic damage. One 1,000-foot-wide object, the "2004 MN4," will miss Earth by just 25,000 miles in 2029.*

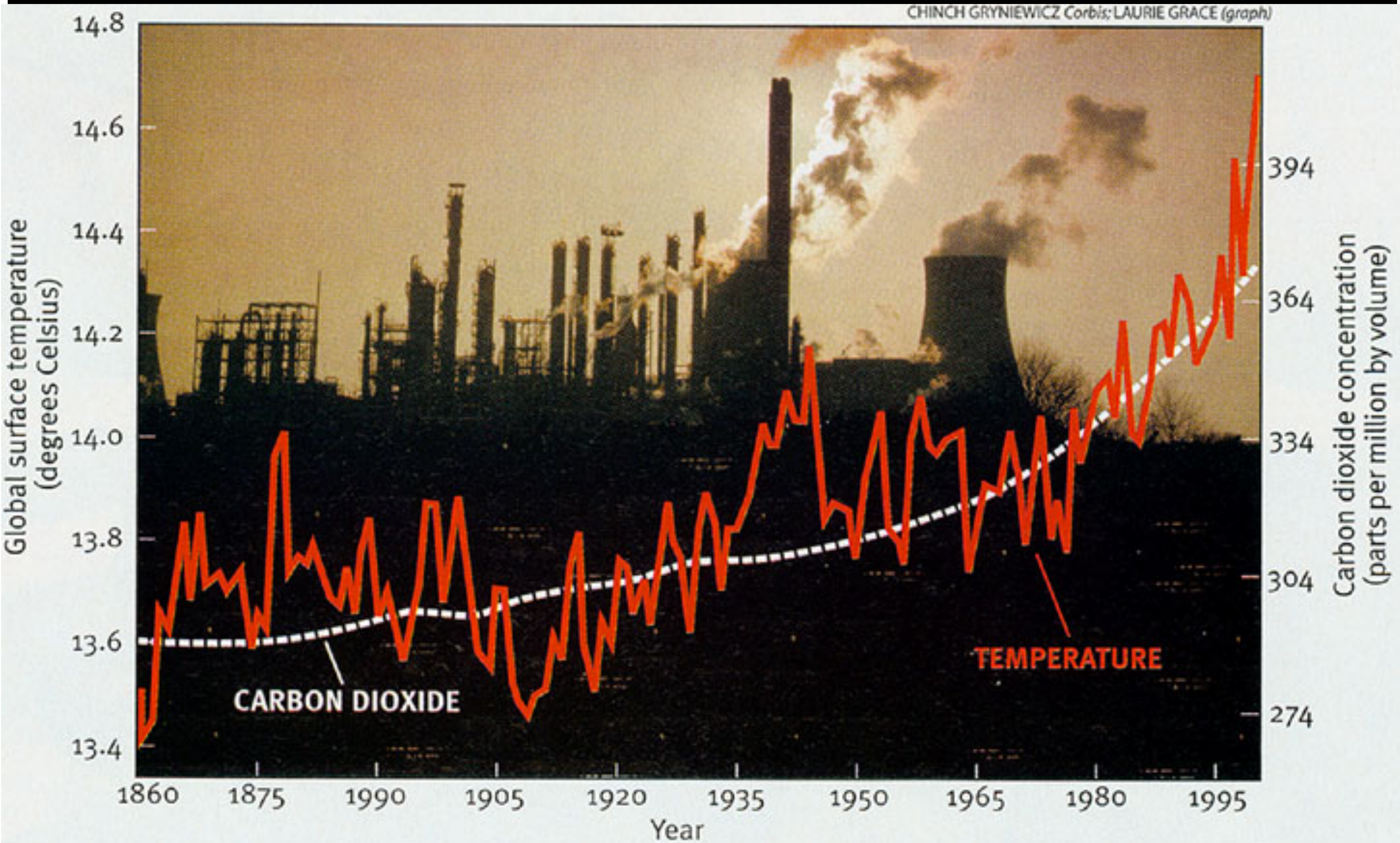




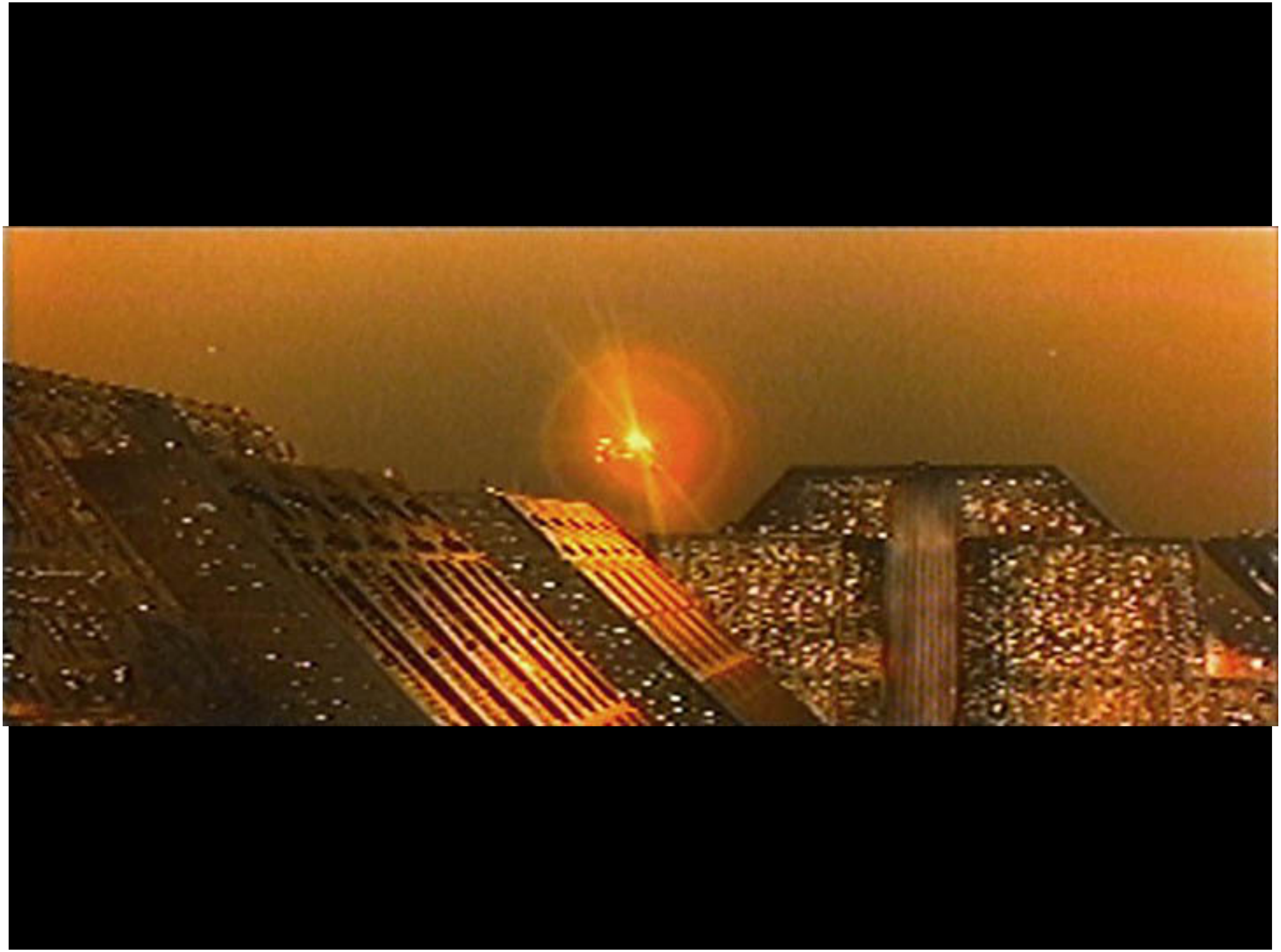
GRAND
FORKS
26
25
24
22
21
27
28



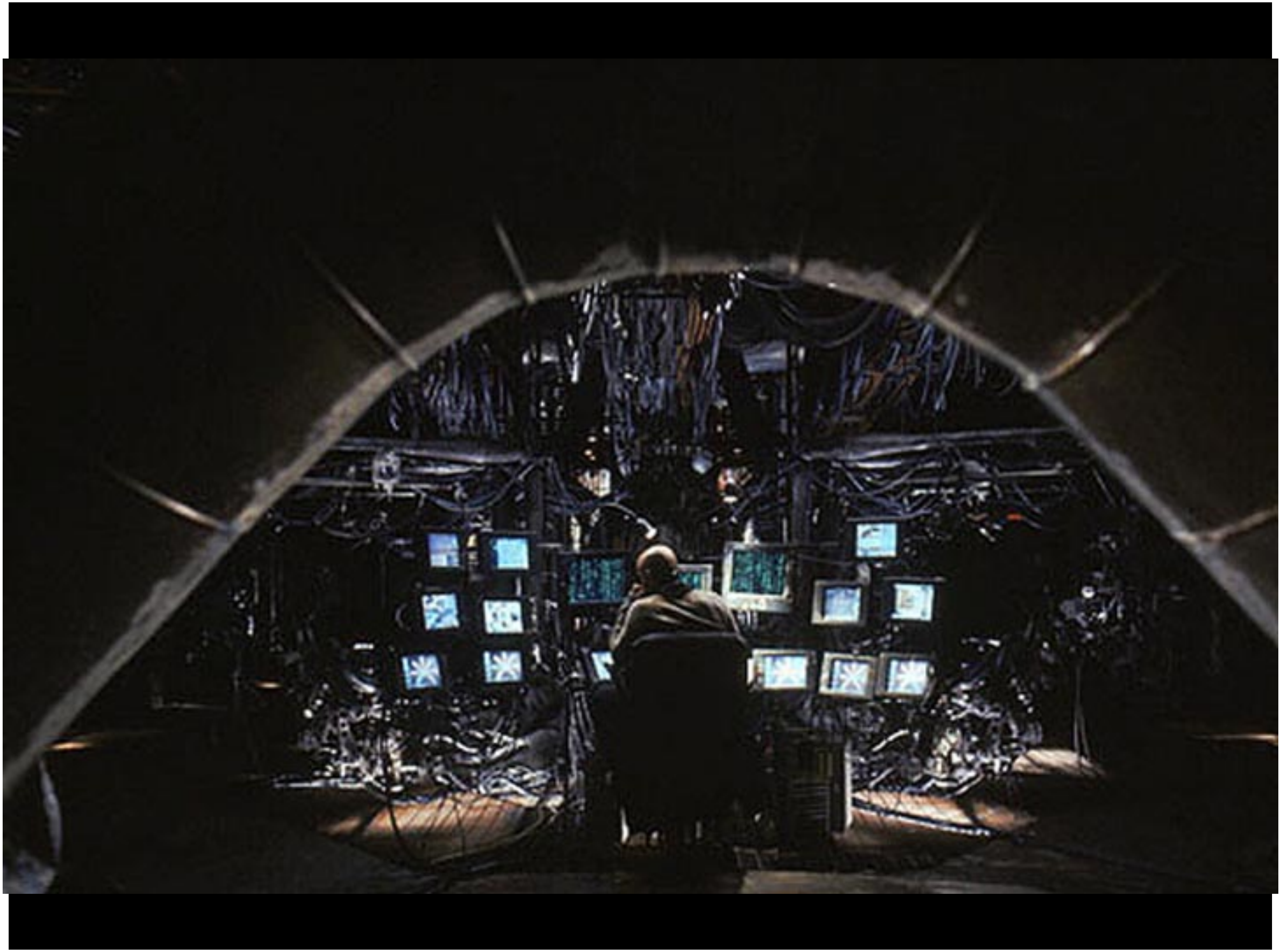



CHINCH GRYNIEWICZ Corbis; LAURIE GRACE (graph)
Global surface temperature (degrees Celsius)
14.8
14.6
14.4
14.2
14.0
13.8
13.6
13.4
Carbon dioxide concentration (parts per million by volume)
394
364
334
304
274
TEMPERATURE
CARBON DIOXIDE
1860
1875
1990
1905
1920
1935
1950
1965
1980
1995
Year

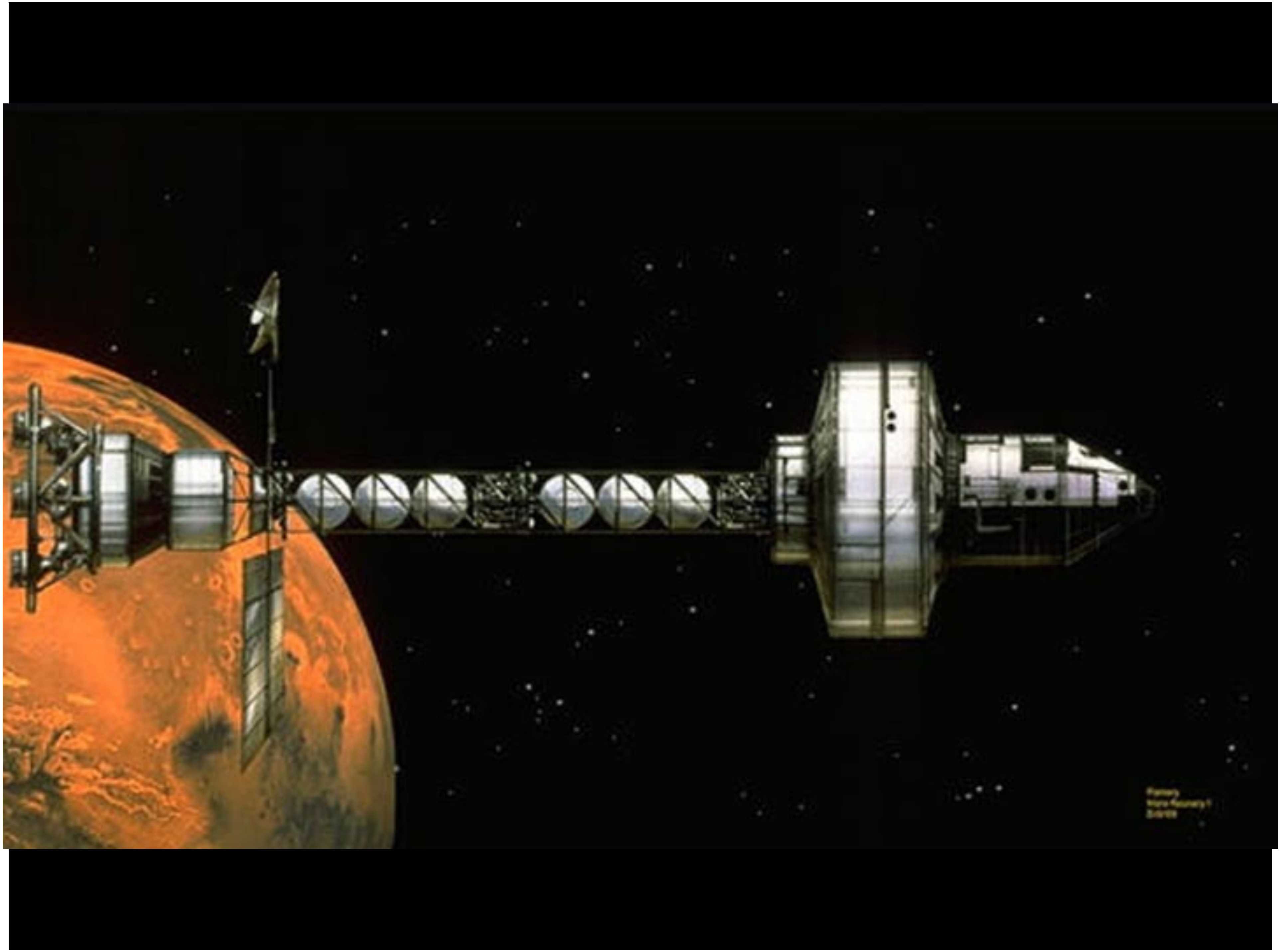
# *Evolutionary Punctuation Points*

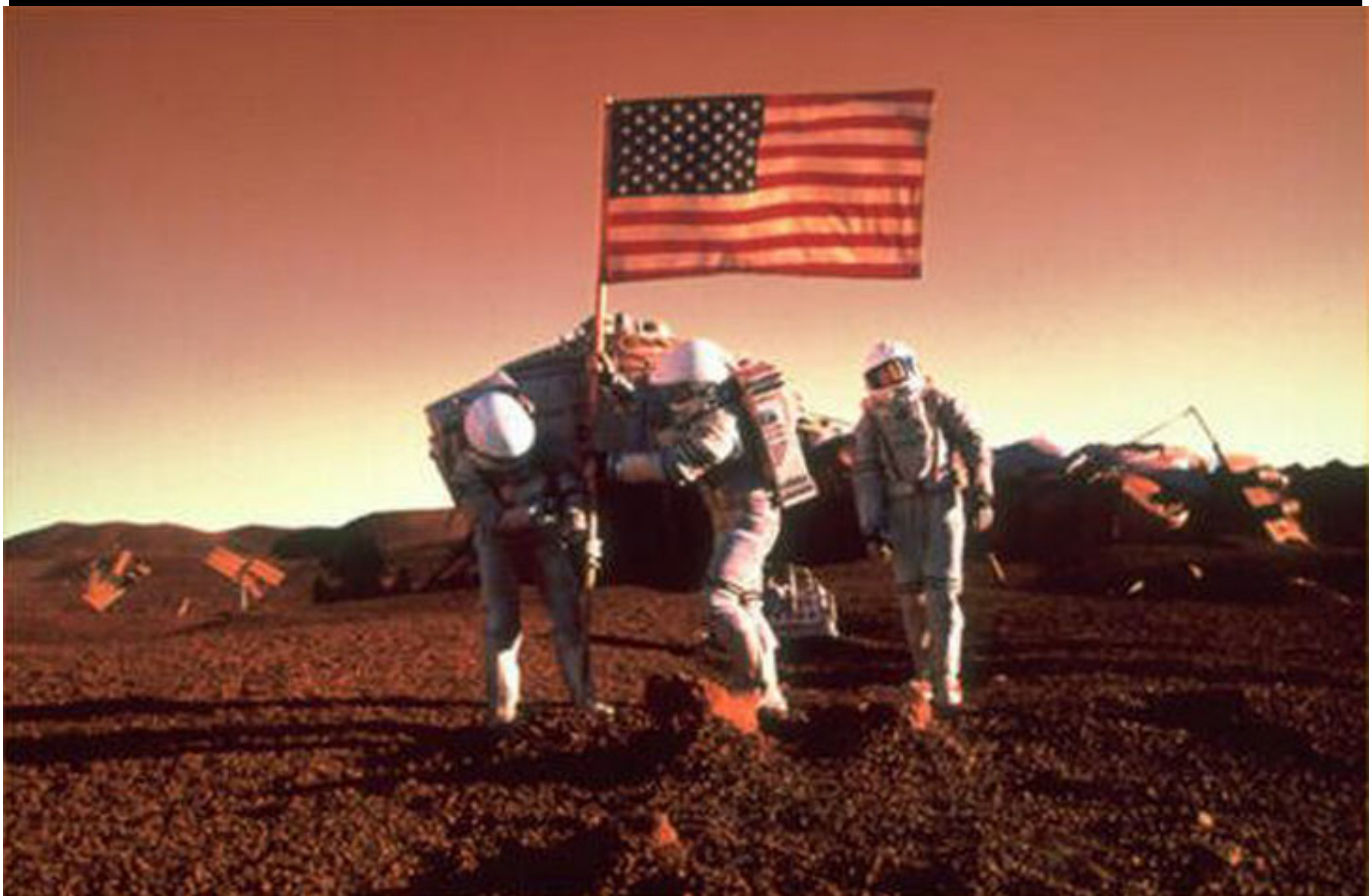


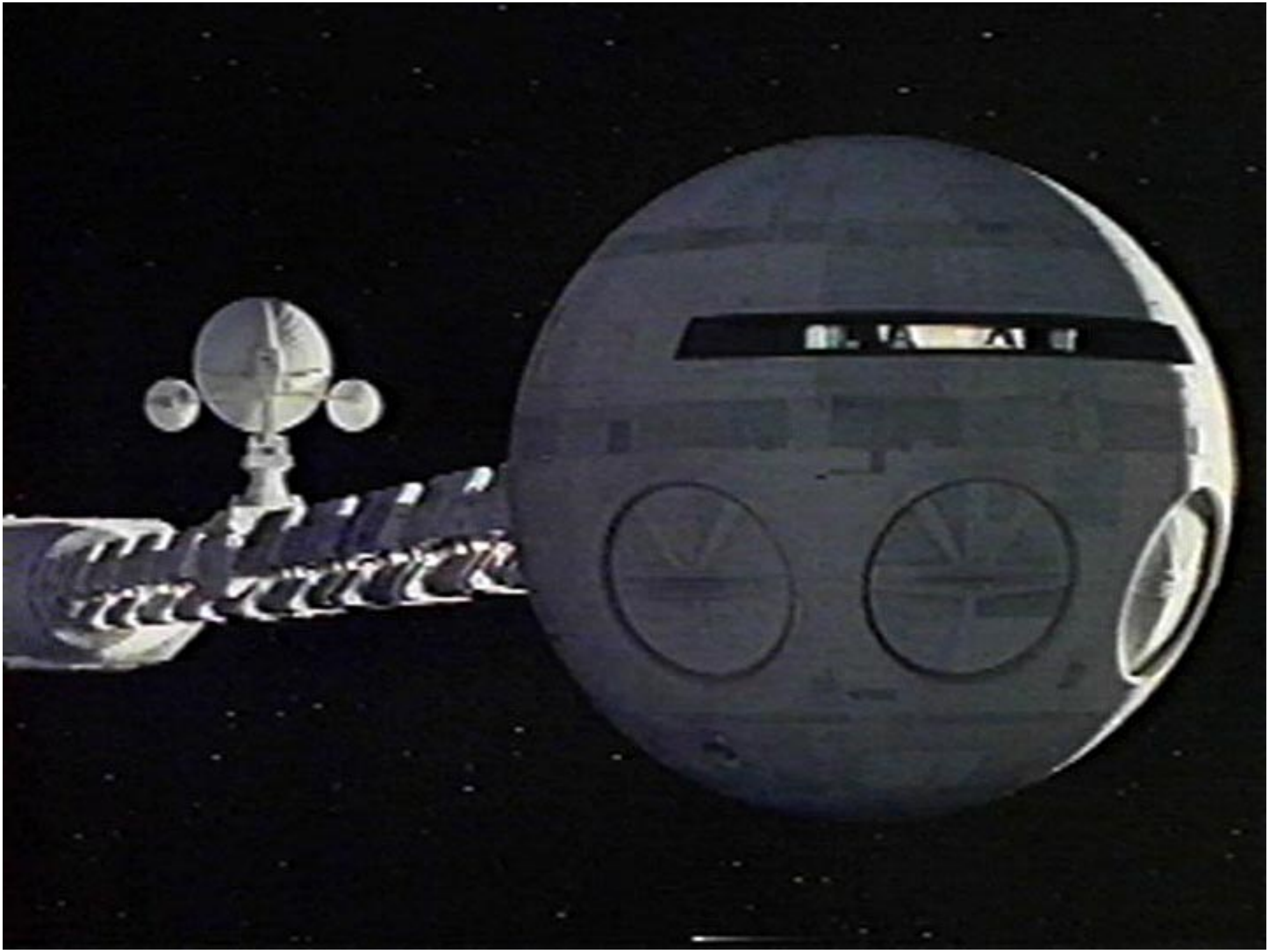

G A T T A C A

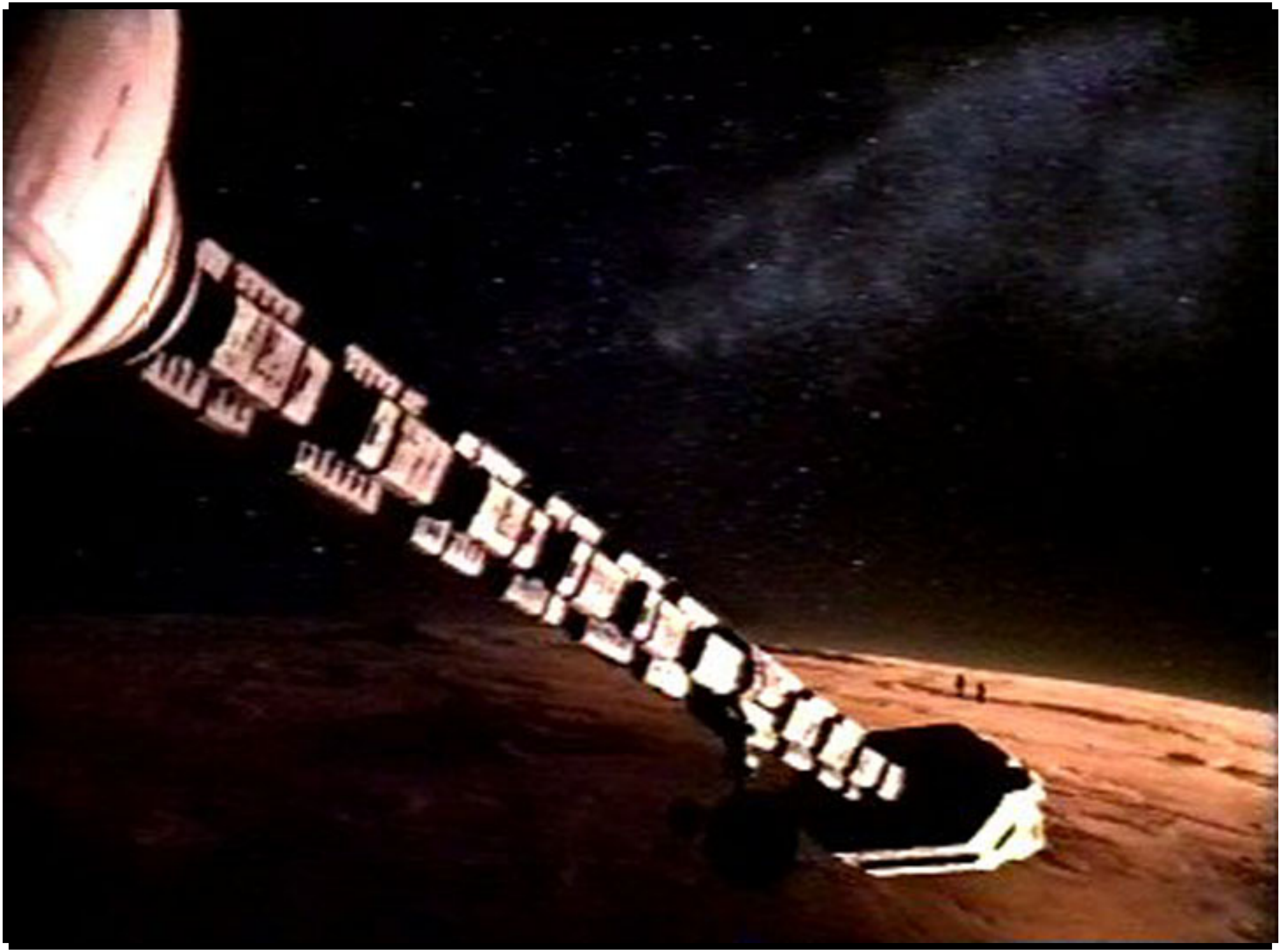


# *Breaking the Bonds of Planet Earth*









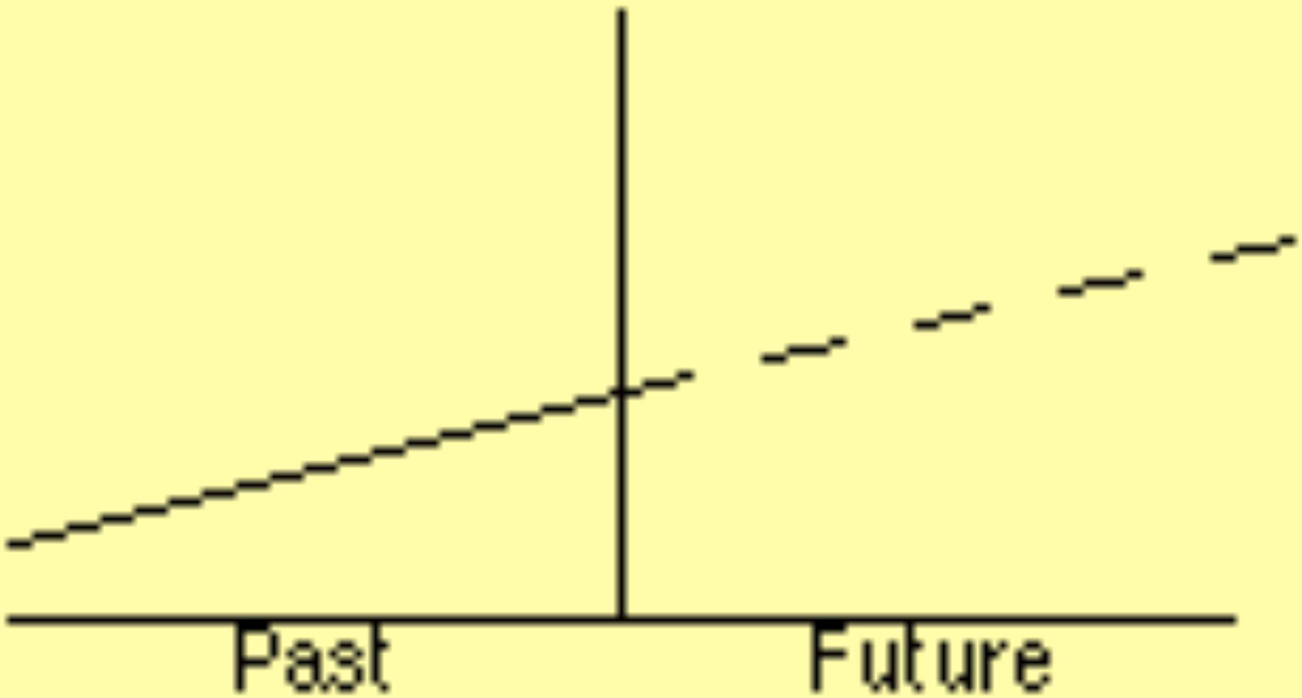

2 + 3 = 4 = False
2 + 3 = 5 = True
2 + 2 = 4 = True

# *Peering over the Horizon*

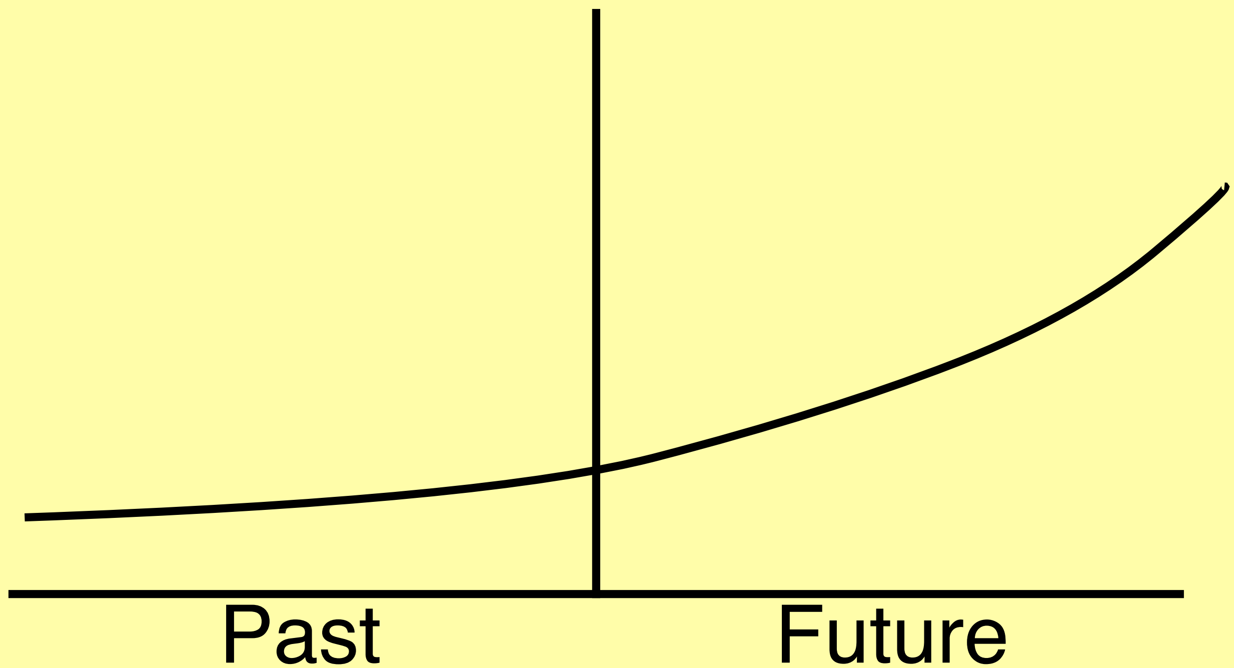
# The pace of change

- Earlier social transformations (Renaissance, Age of Discovery, Industrial Revolution) took place over decades or centuries
- Today's transformations occur on time scales of years … or even less

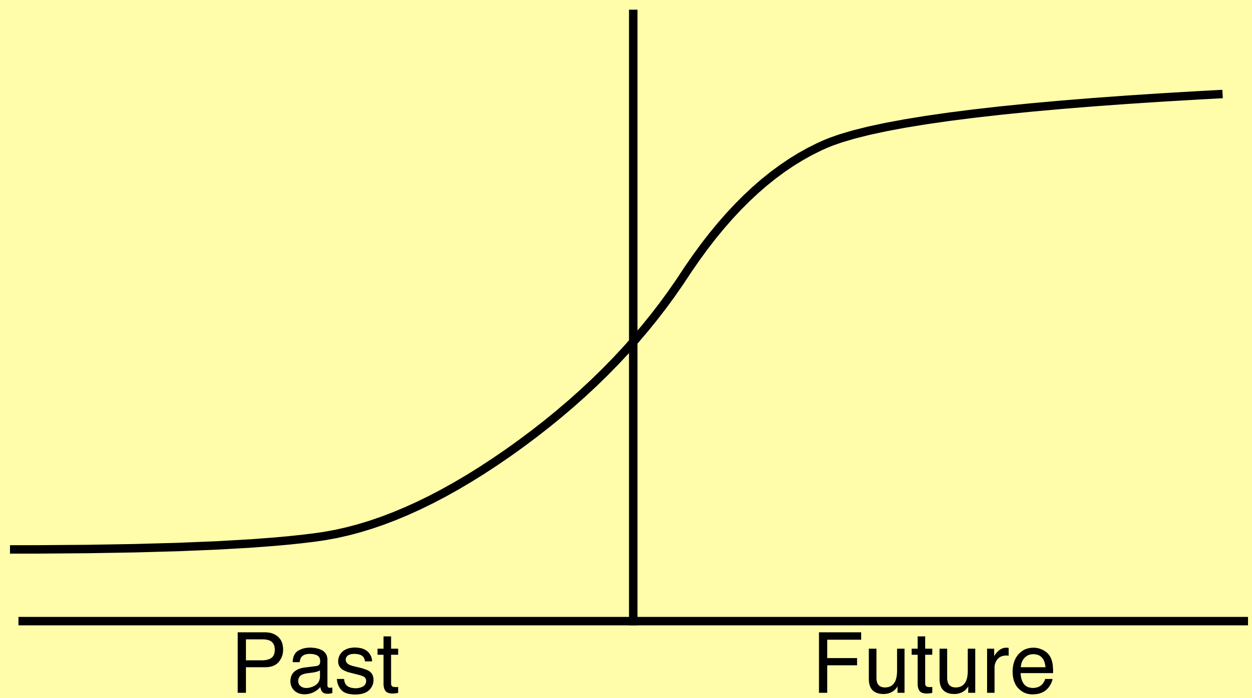
# Linear Change



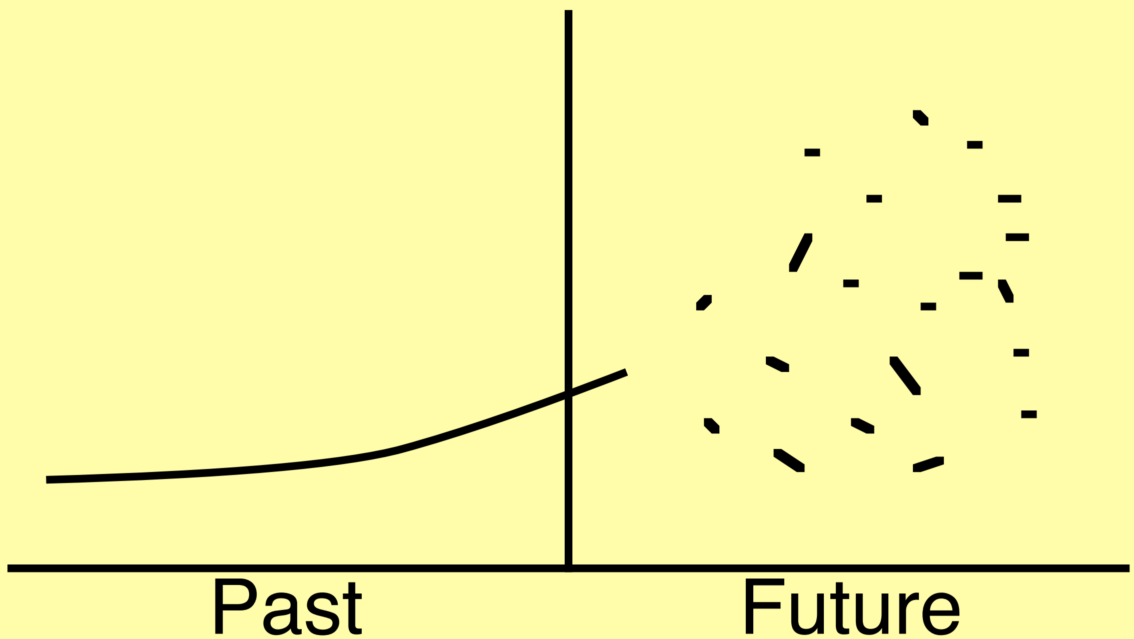
# Exponential Change



# Saturation



# Chaos



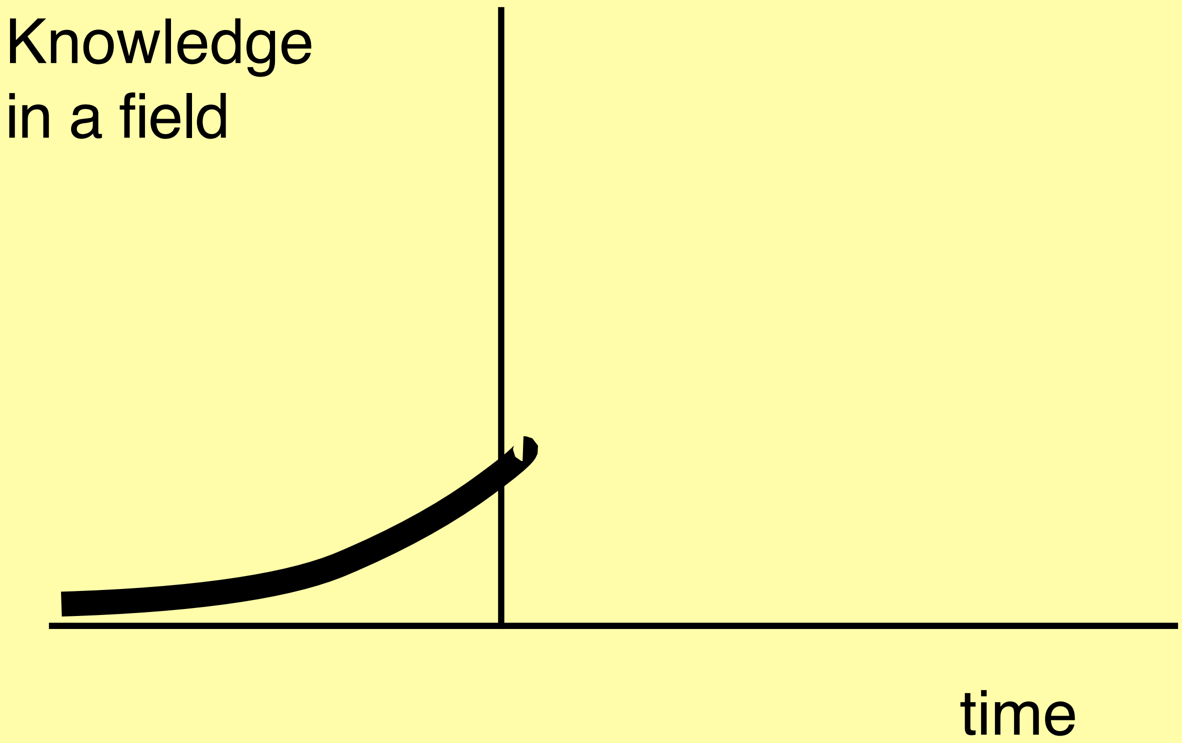
# The Learning Curve

As we learn a new skill, the acquired ability builds on itself, so that the learning curve looks like exponential growth.

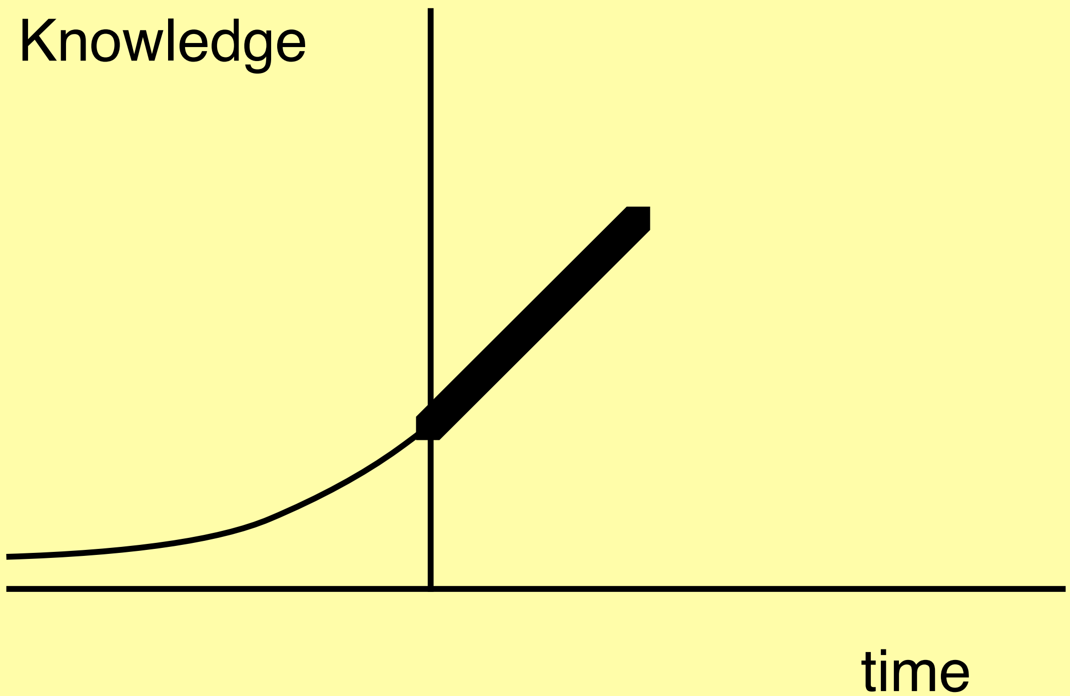
But skills tend to be bounded, so as the new expertise is mastered the law of diminishing returns sets in and growth in mastery levels off.

Hence the learning curve has an S-shape.

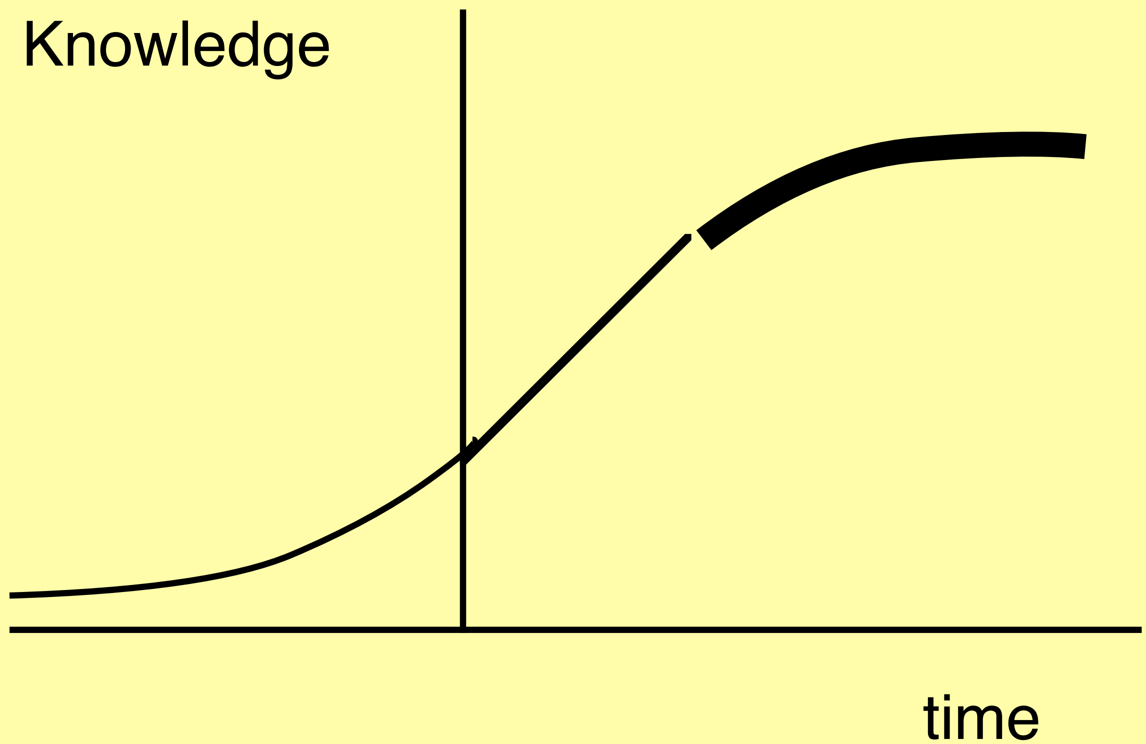
# Exponential Growth



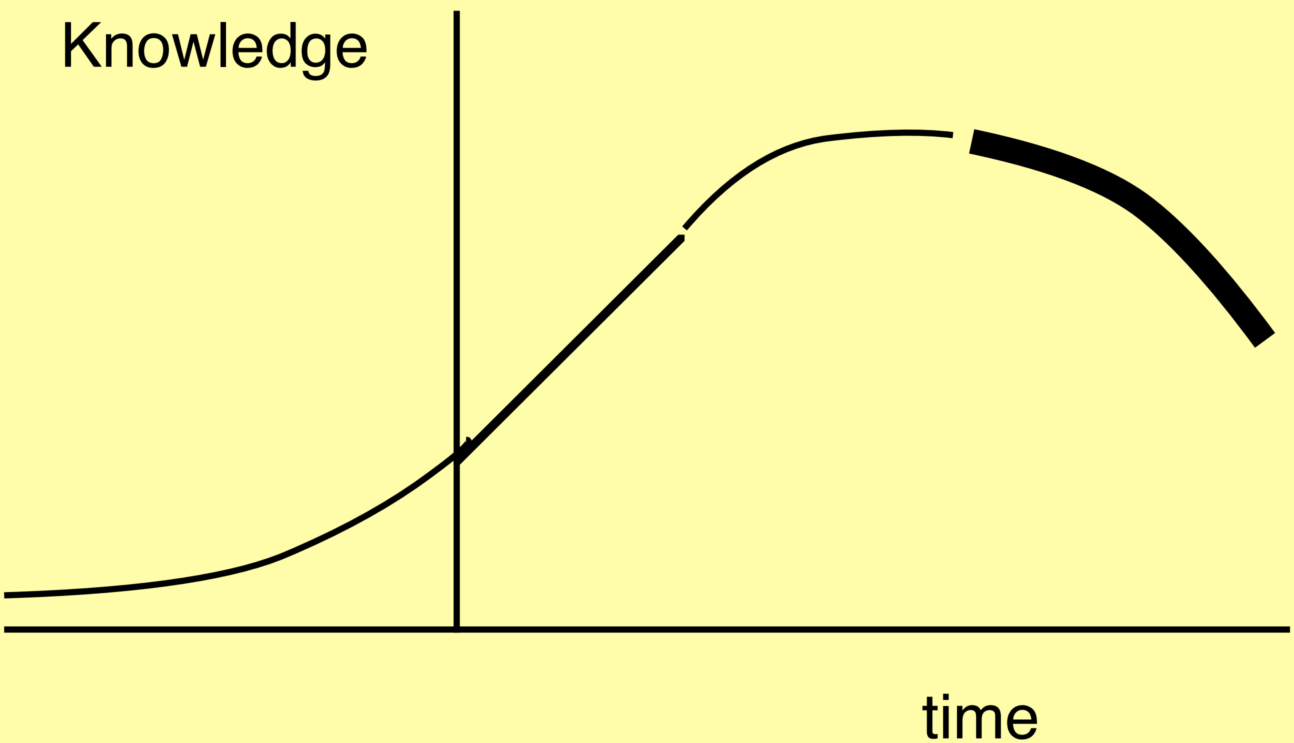
# Linear Growth



# Trapped in a rut...



# Senility



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Overcoming the S-curve shape is a way to express the unique status of the human species!

# Paradigm shifts in electronics

- Electromechanical calculators
- Relay based computers
- Vacuum tubes
- Discrete transistors
- Integrated circuits
- …3-D integrated circuits?
- …molecular computers?
- …quantum computers?

# Software Evolution

- Recursive procedures
- Neural net paradigms
- Evolutionary (or genetic) algorithms

Neural nets and genetic algorithms are considered self-organizing “emergent” methods because the results are not predictable and are often surprising to the human designers of these systems.

# *Exponentiating Technologies*

# Three examples

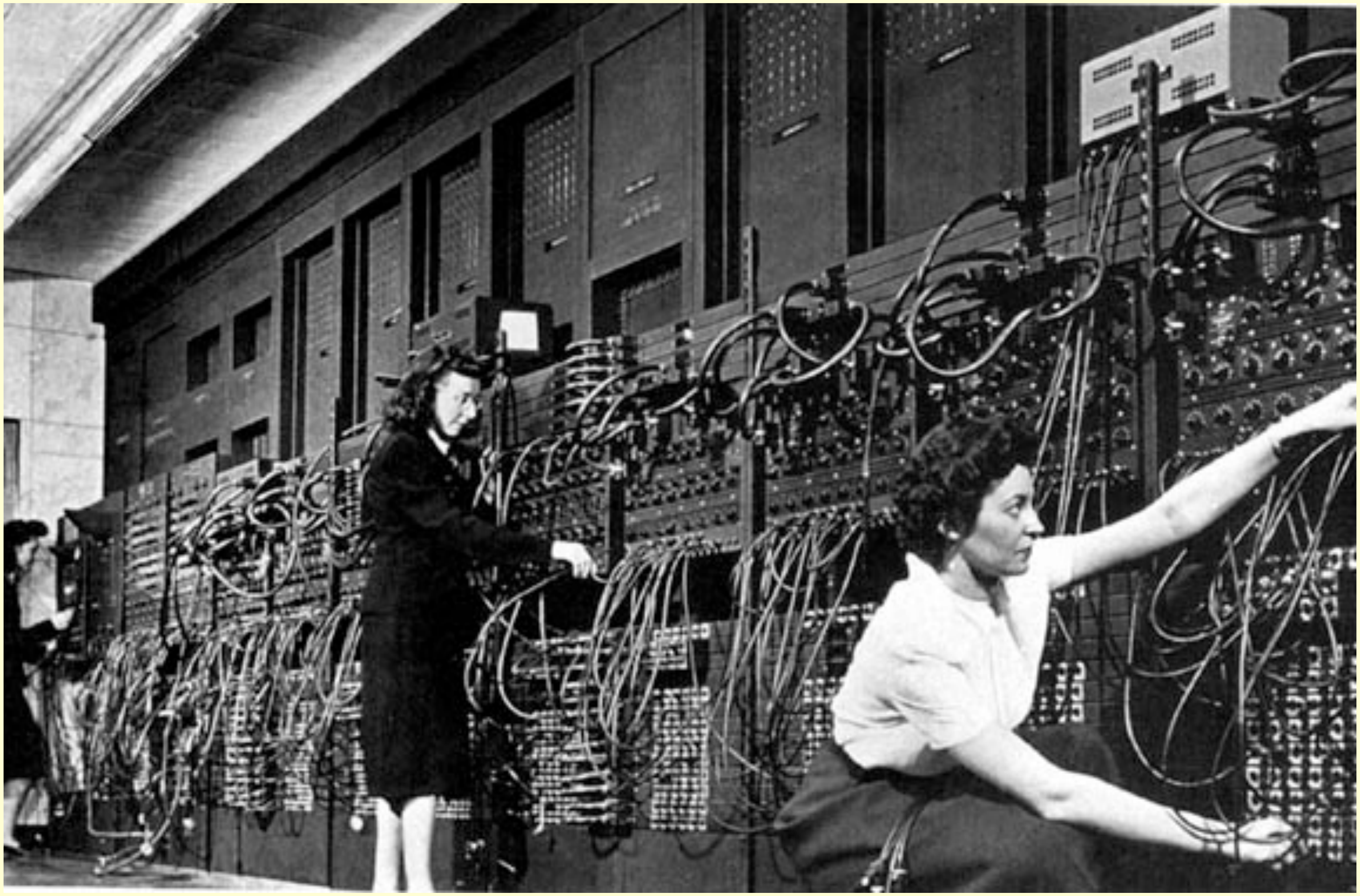
- Information Technology
- Biotechnology
- Nano Technology

# Exponentiating Technologies

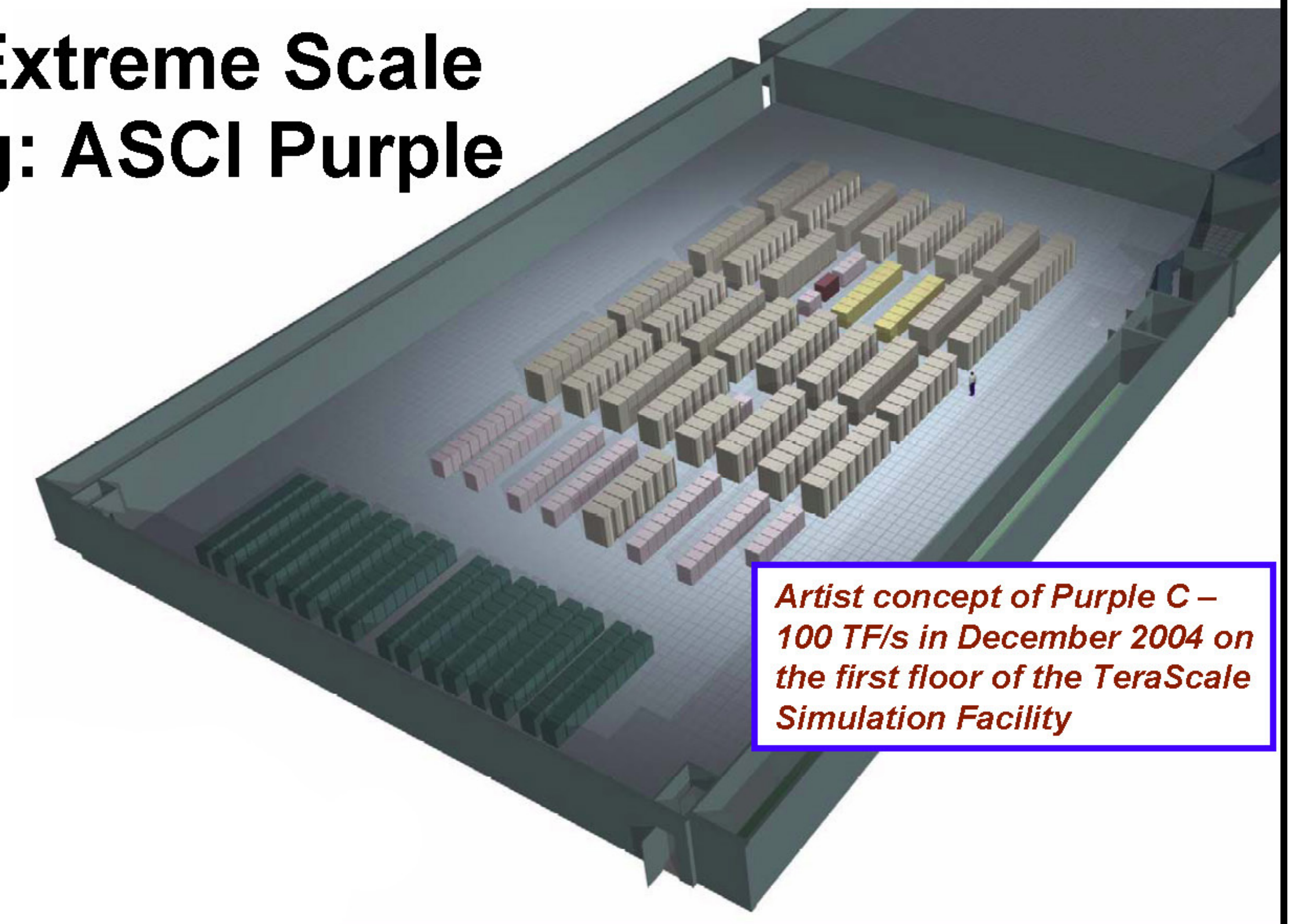
- The technologies driving such profound changes in our world, technologies such as information technology, biotechnology, and soon nanotechnology, are all characterized by exponential growth.
- When applied to computers, this remarkable property, known as Moore’s Law, suggests that every 18 months computing power for a given price doubles. Other aspects such as memory, bandwidth, and miniaturization, are evolving even more rapidly, 100 or a 1,000 fold every decade.
- In fact, scientists and engineers today believe that the exponential evolution of these microscopic technologies is not only likely to continue for the foreseeable future, but the pace may be accelerating.

# *Information Technology*

# From Eniac



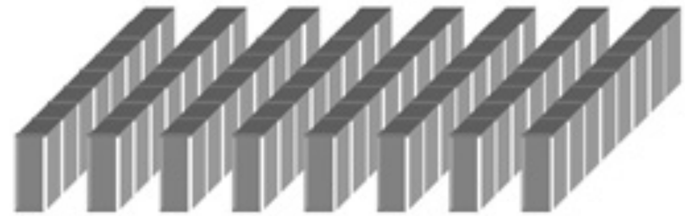
# Defining Extreme Scale Computing: ASCI Purple



*Artist concept of Purple C – 100 TF/s in December 2004 on the first floor of the TeraScale Simulation Facility*

*Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

# Building BlueGene/L



**System**

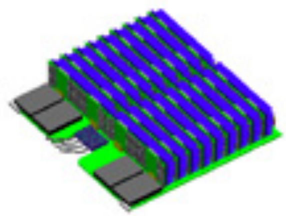
64 cabinets
65,536 nodes
(131,072 CPUs)
(32x32x64)
180/360 TF/s
16 TiB*
1.2 MW
2500 sq.ft.

**Cabinet**

2 midplanes
1024 nodes
(2,048 CPUs)
(8x8x16)
2.9/5.7 TF/s
256 GiB* DDR
15-20 kW

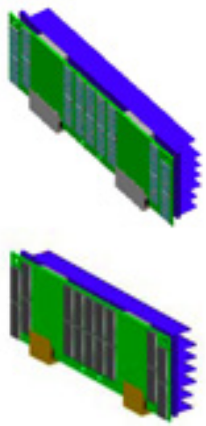
**Midplane**

SU (scalable unit)
16 node boards
512 nodes
(1,024 CPUs)
(8x8x8)
1.4/2.9 TF/s
128 GiB* DDR
7-10 kW



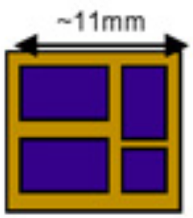
**Node Card**

16 compute cards
0-2 I/O cards
32 nodes
(64 CPUs)
(4x4x2)
90/180 GF/s
8 GiB* DDR



**Compute Card**
**I/O Card**

FRU (field replacable unit)
25mmx32mm
2 nodes (4 CPUs)
(2x1x1)
2.8/5.6 GF/s
256/512 MiB* DDR
15 W




**Compute Chip**

2 processors
2.8/5.6 GF/s
4 MiB* eDRAM

(compare this with a 1988 Cray YMP/8 at 2.7 GF/s)

* http://physics.nist.gov/cuu/Units/binary.html

Curve 3

ASCI Purple (2004):

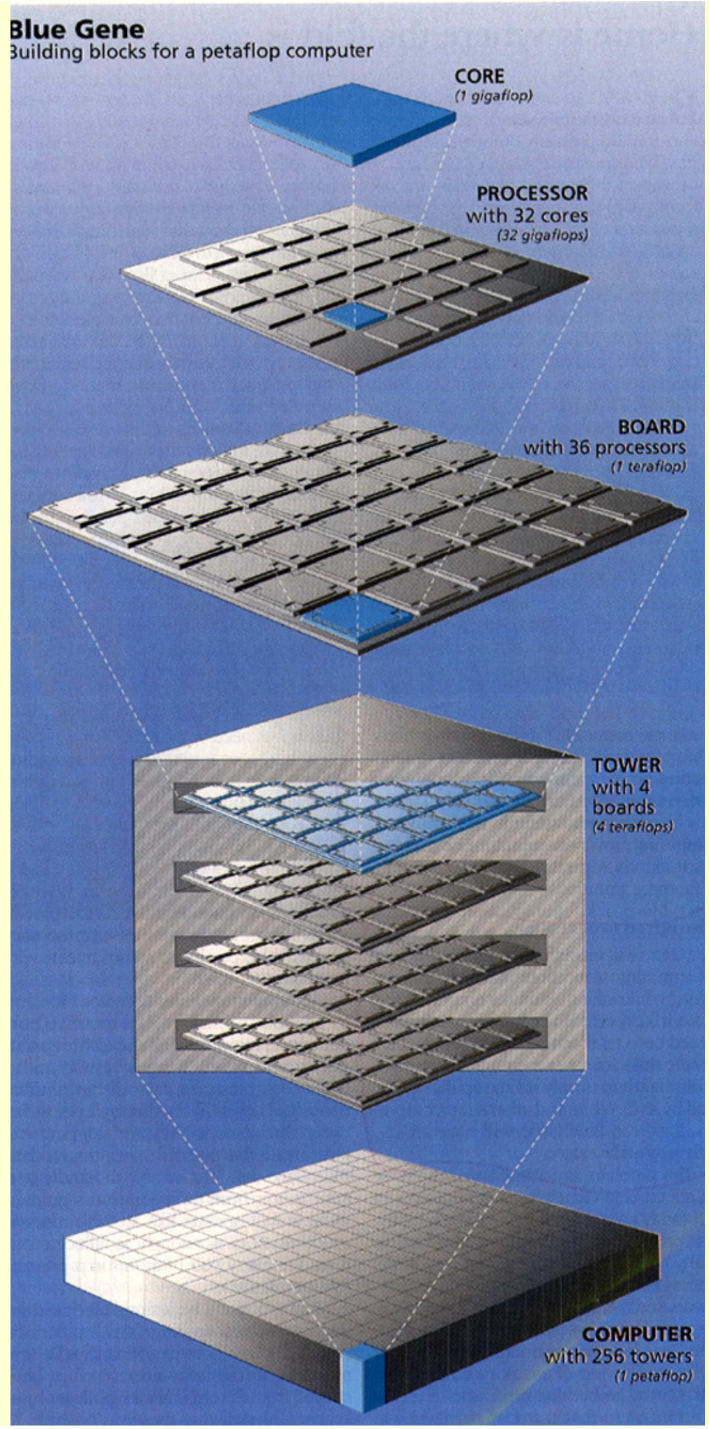
100 TeraFlops

IBM Blue Gene L (2004):

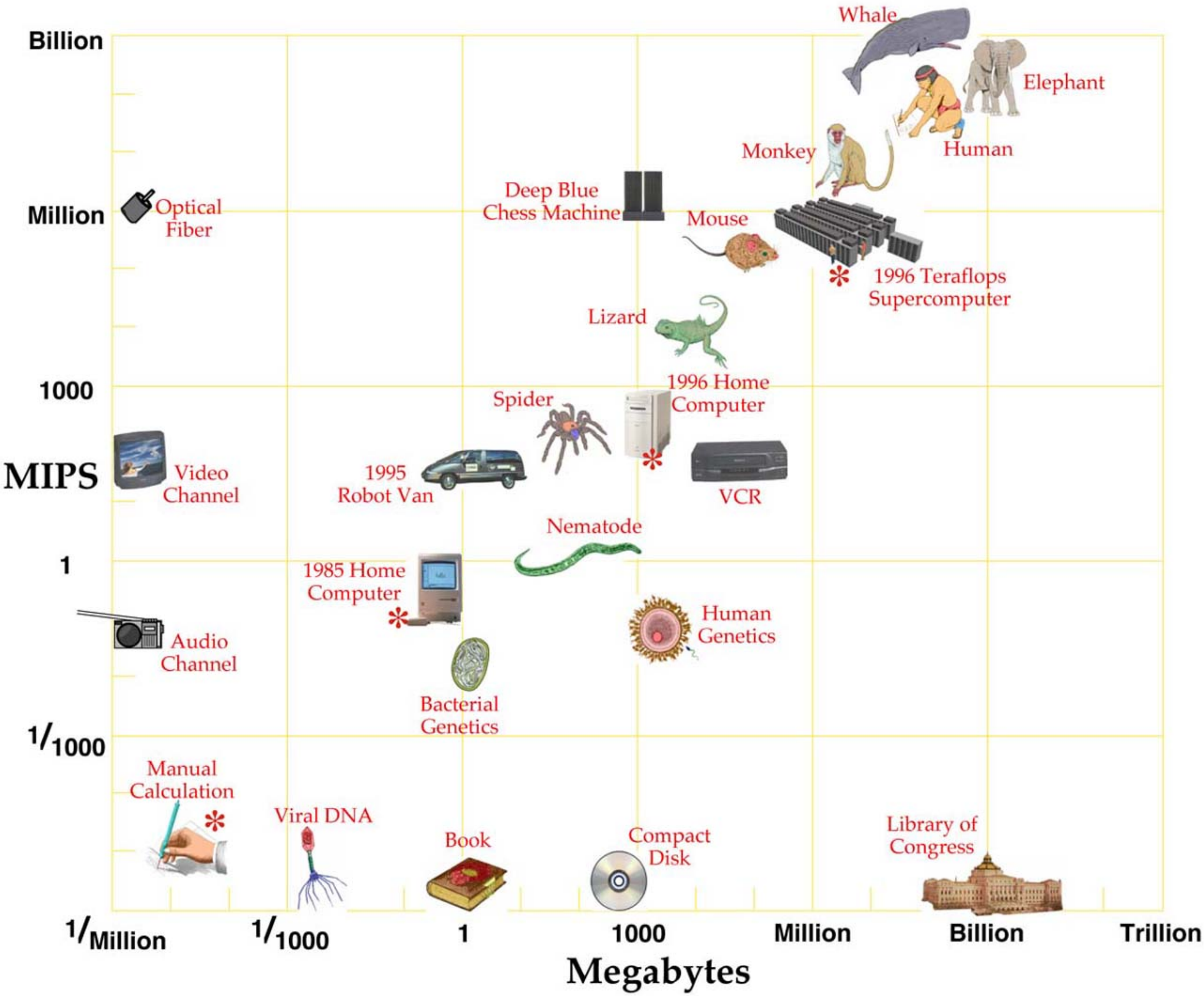
360 TeraFlops

IBM Blue Gene P (2006):

"Several" PetaFlops



All Thinks, Great and Small



# Computer Evolution

By 2020 a $1,000 computer should have the capacity (both memory and processing speed) of a human brain.

By 2030, a $1,000 computer should be able to simulate the brainpower of a small village.

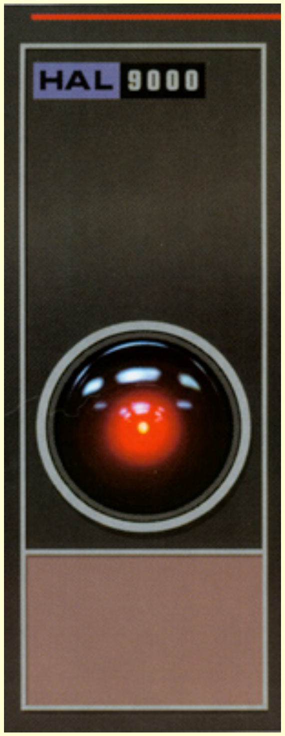
By 2050, a $1,000 computer will have the brainpower of the population of the United States.

By 2100, one penny's worth of computer will have a billion times greater computing capacity than all the humans on earth...

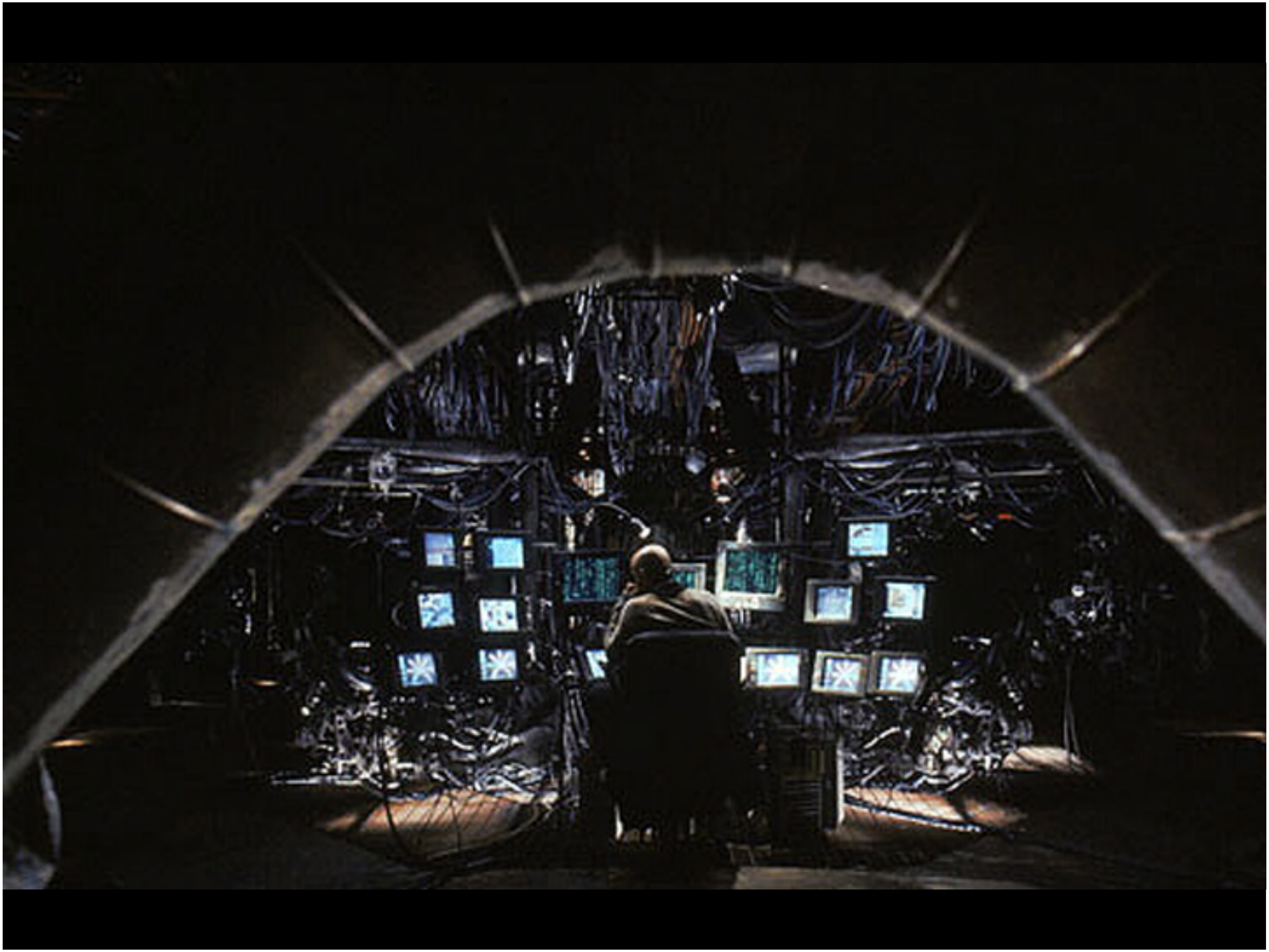
# Evolution of the Net

- Already beyond human comprehension
- Incorporates ideas and mediates interactions among millions of people
- more than 1 billion in 2005
- Internet II, Project Abilene

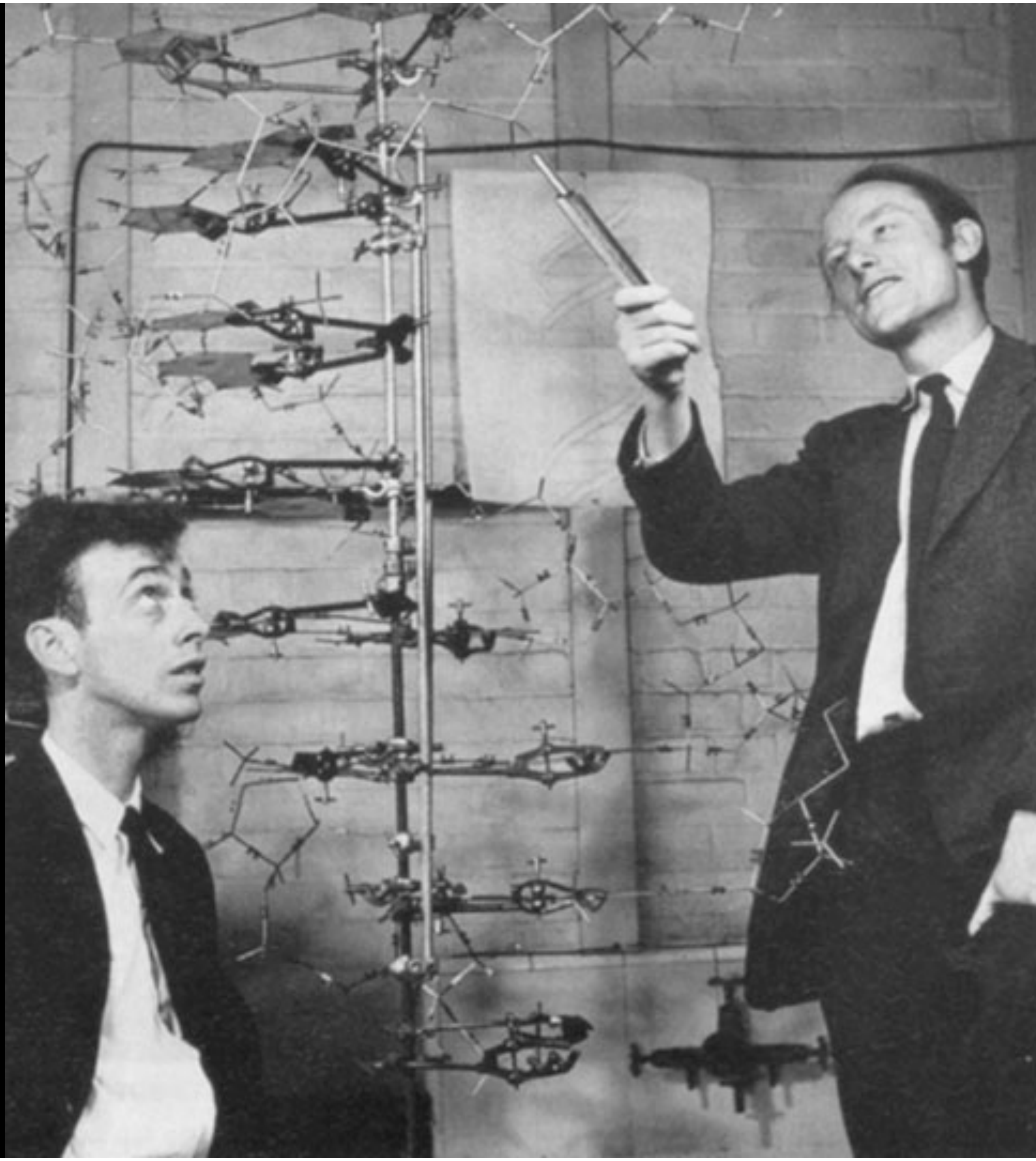
# Some Other Possibilities

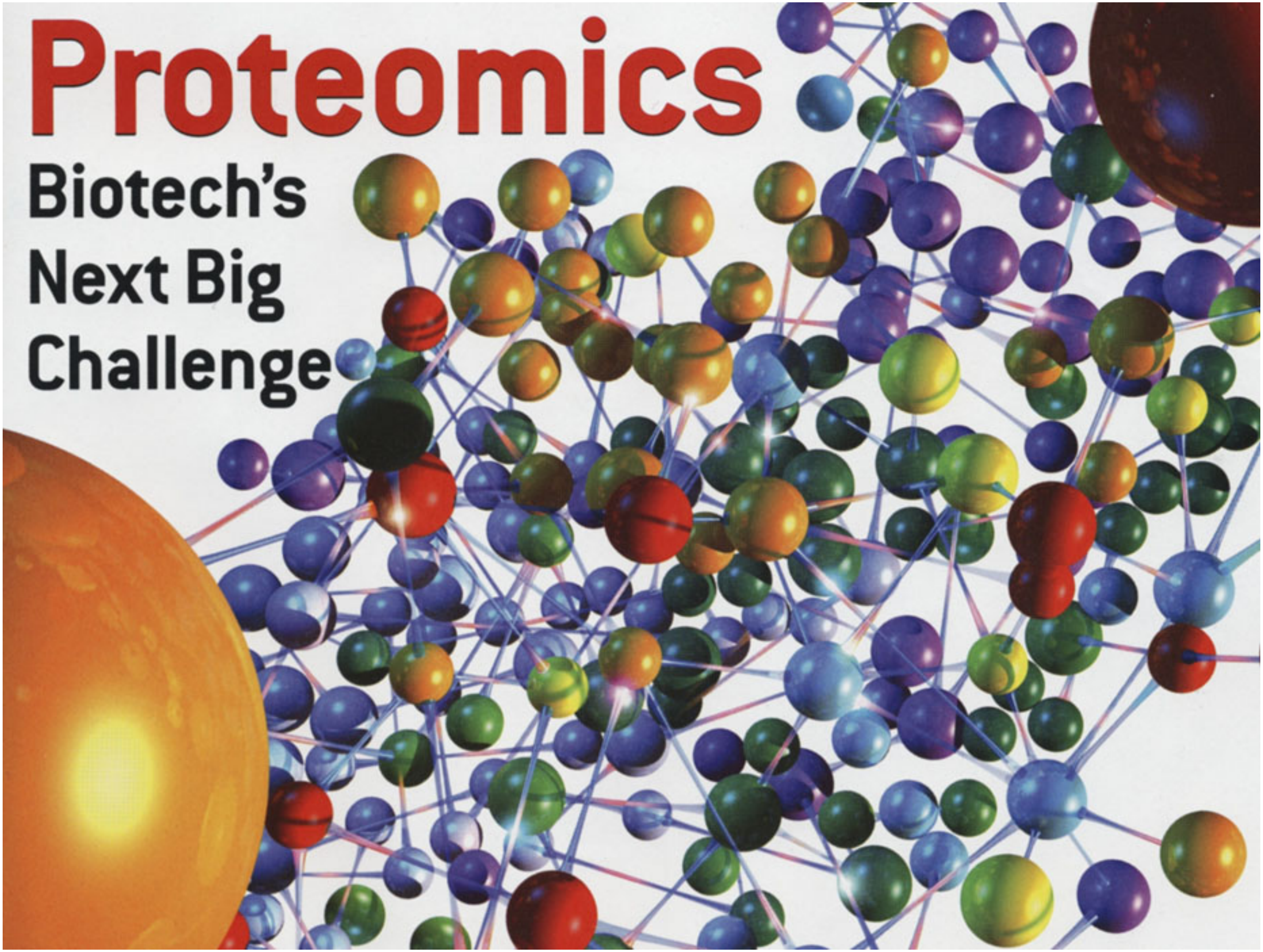



- **Ubiquitous computing?**
  - Computers disappear (just as electricity)
  - Calm technology, bodynets
- **Agents and avatars?**
  - Fusing together physical space and cyberspace
  - Plugging the nervous system into the Net
- **Emergent behavior?**
  - … Self organization
  - … Learning capacity
  - … Consciousness (HAL 9000)



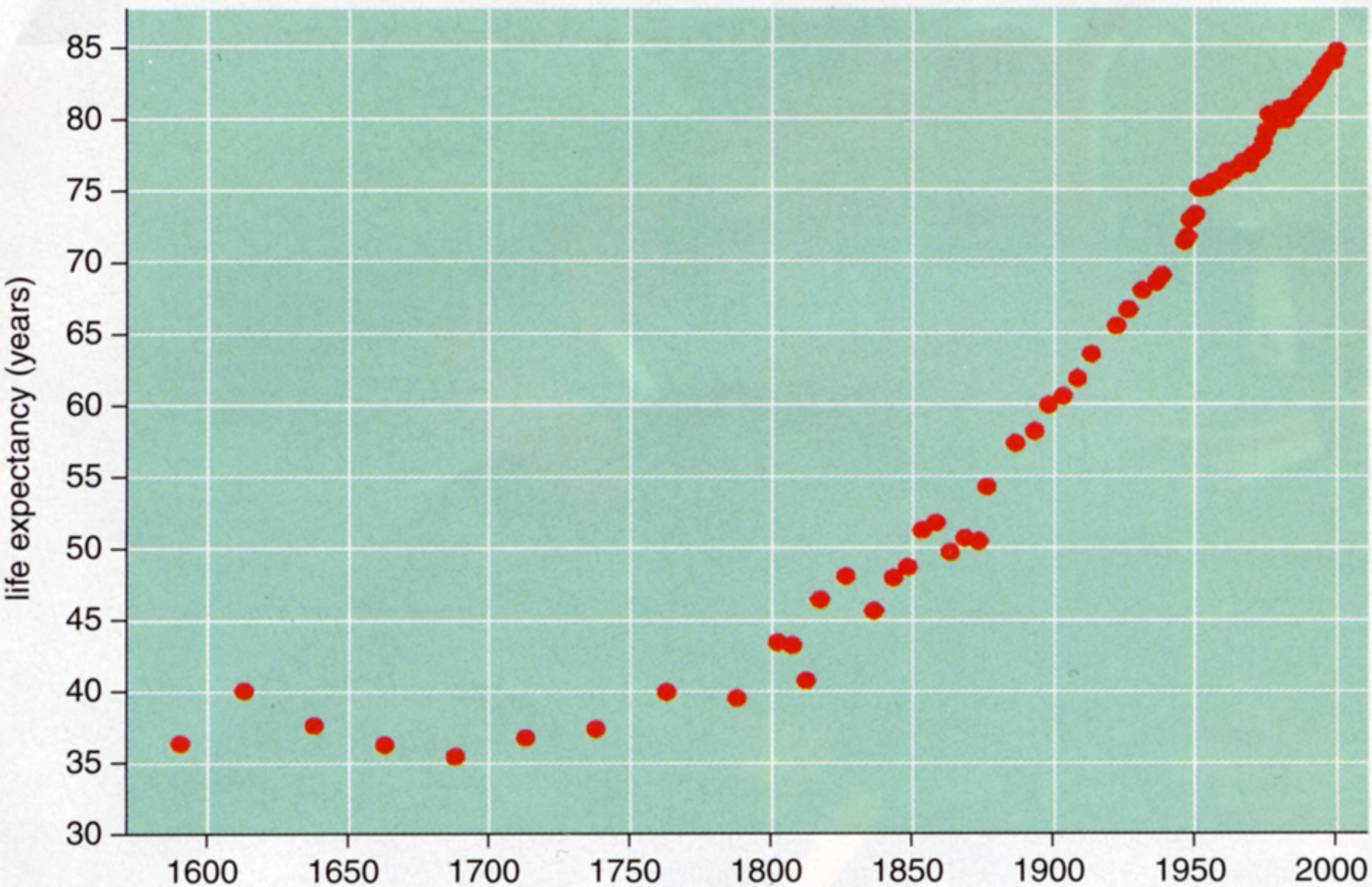
# Biotechnology




Proteomics
Biotech's
Next Big
Challenge

# Over the next two decades

- Medicine will evolve from:
  - "reactive" medicine (curing disease)
  - "predictive" medicine (using genetic information to predict susceptability to particular diseases and adjusting lifestyles accordingly)
  - "preventive" medicine (using human gene therapy to correct genes)
- But what about aging? Survival beyond child-bearing and rearing age was not favored by natural selection…



life expectancy (years)
85
80
75
70
65
60
55
50
45
40
35
30
1600
1650
1700
1750
1800
1850
1900
1950
2000

# Changing the aging process

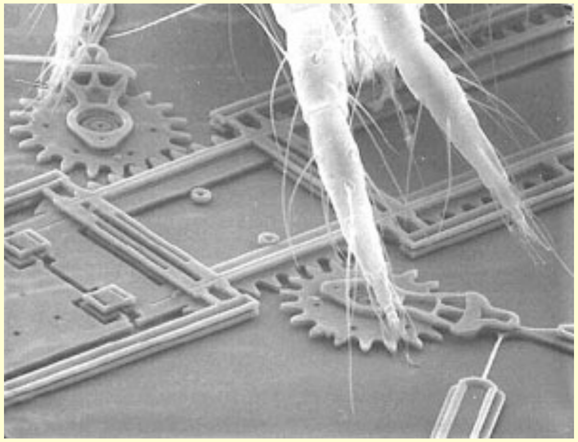
- Some experts believe that within 20 years, the life span will have increased by 10 years or more.
- Indeed, some believe that biotechnology will soon be adding more than a year to human life expectancy every year.
- Eventually, nanotechnology will allow us to repair at the microscopic level cell structure.
- “Life expectancy will be in the region of 5,000 years by the year 2100.” Aubrey de Grey (Cambridge)

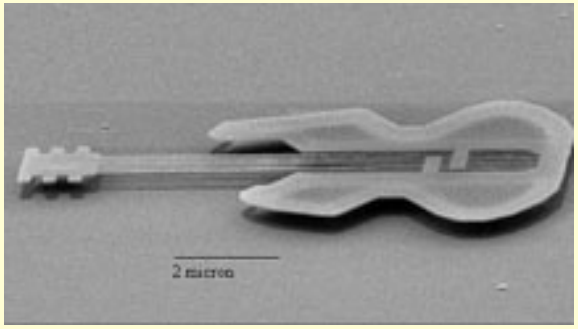
# *Nanotechnology*

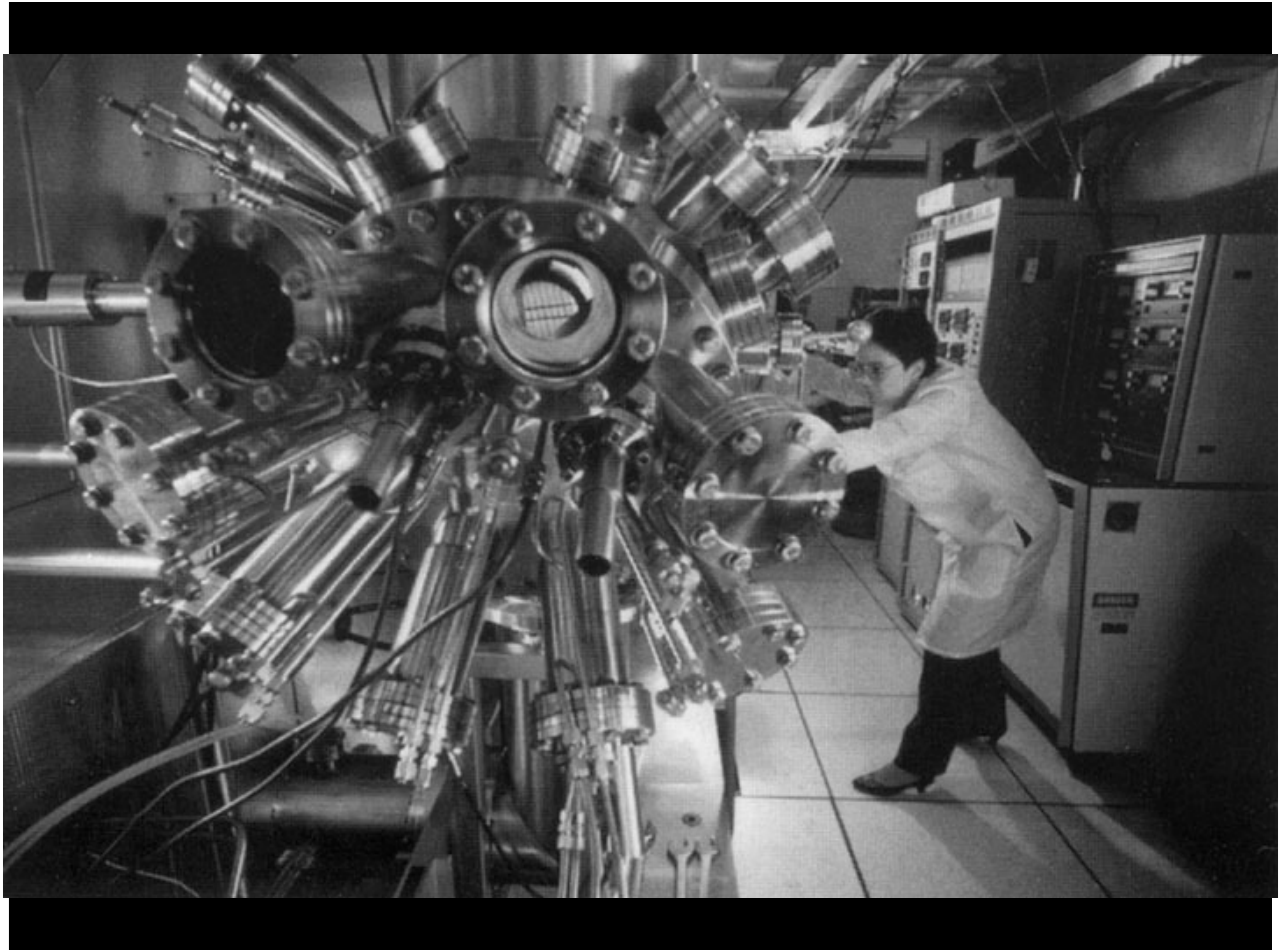
# MEMS

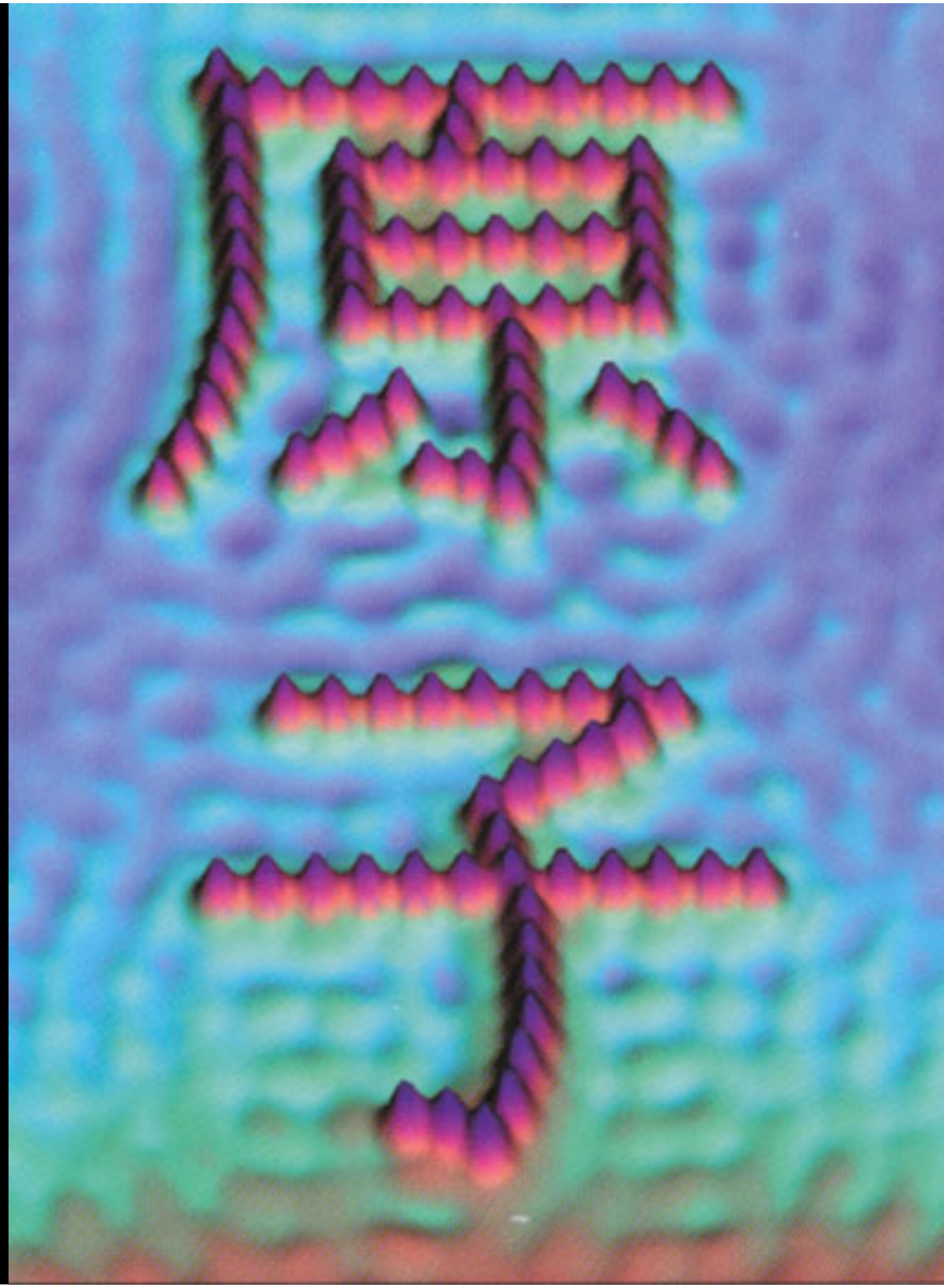
MEMS: Micro electromechanical machines

Engineers have developed the capacity to fabricate microscopic gears, machines, and motors out of silicon, much as they do electronic circuits. These are typically of submicron size.

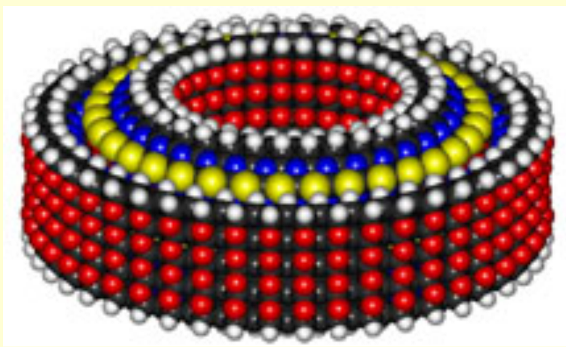




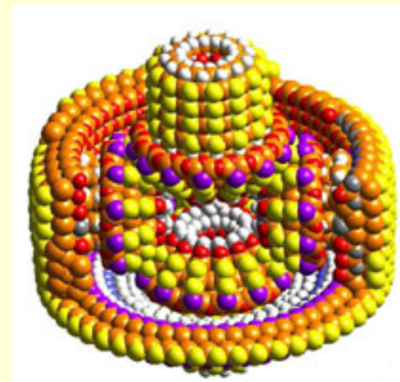



原子

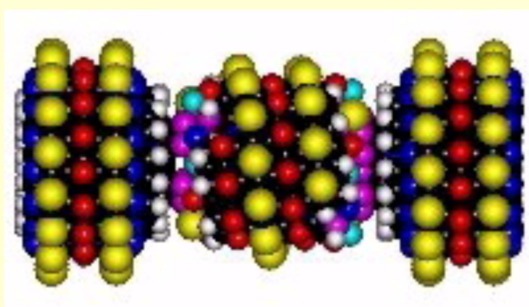
# Molecular Nanomachines



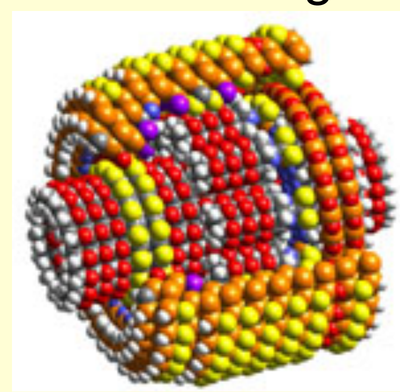
Bearing



A differential gear



Pump

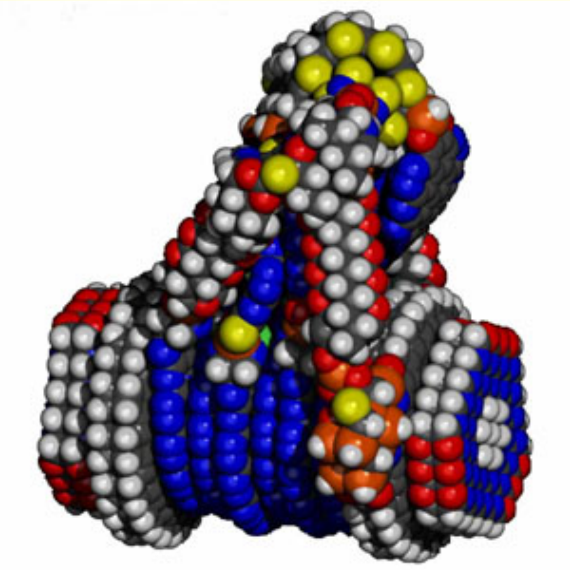


A planetary gear

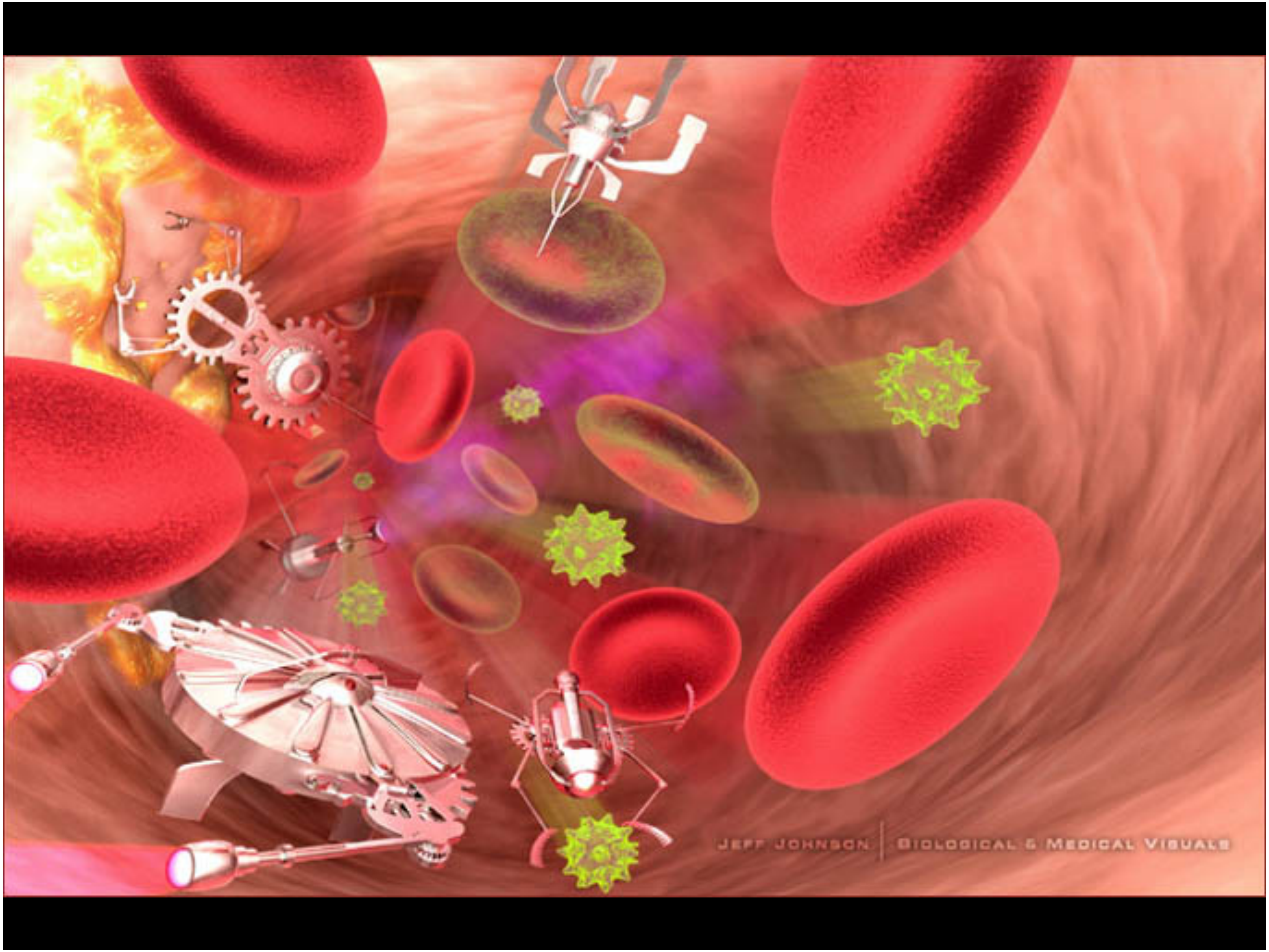
# Nano Assemblers

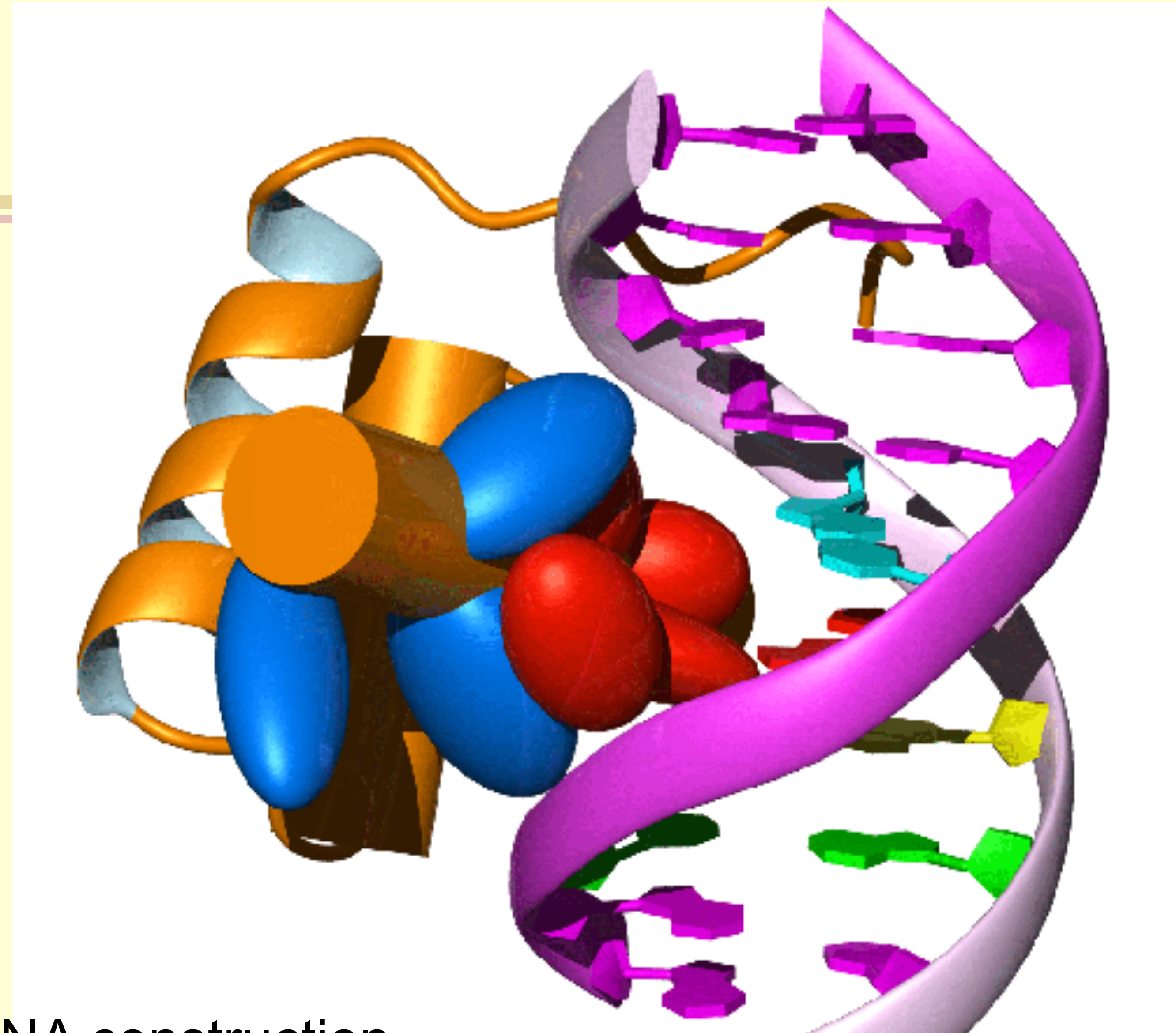
These second generation nanomachines will do all that protein machine can do and more.  They will be able to bond atoms together in virtually any stable pattern, adding a few at a time to the surface of a workpiece until a complex structure is complete.

Think of such nanomachines as assemblers.



Nano Assembler
(Stewart Platform)


JEFF JOHNSON | BIOLOGICAL & MEDICAL VISUALS



DNA construction

# *The Convergence of Info-Bio-Nano and Disruptive Technologies*

# Disruptive Technologies

- Beyond this fact, there is another important characteristic of such technologies: they are disruptive! Their impact on social institutions such as corporations, governments, and learning institutions is profound, rapid, and quite unpredictable.
- As Clayton Christensen explains in *The Innovator's Dilemma*, while many of these new technologies are at first inadequate to displace today's technology in existing applications, they later explosively displace the application as they enable a new way of satisfying the underlying need. If change is gradual, there will be time to adapt gracefully, but that is not the history of disruptive technologies.

# *Technological Singularities*

# Technological Singularities

- The acceleration of technological progress has been the central feature of the past century and is likely to be even more so in the century ahead. John von Neumann once speculated that “the ever accelerating progress of technology and changes in the mode of human life gives the appearance of approaching some essential singularity in the history of the race beyond which human affairs, as we know them, could not continue.”
- Some futurists such as Ray Kurzweil and Werner Vinge have even argued that we are on the edge of change comparable to the rise of human life on Earth.

# So what might happen?

- The precise cause of this change is the imminent creation by technology of entities with greater than human intelligence. For example, as digital technology continues to increase in power a thousand-fold each decade, at some point computers (or large computer networks) might "awaken" with superhuman intelligence. Or biological science may provide the means to improve natural human intellect.
- When greater-than-human intelligence drives technological evolution, that progress will be much more rapid, including possibly the creation of still more intelligent entities, on a still shorter timescale.

# The Learning Curve

As we learn a new skill, the acquired ability builds on itself, so that the learning curve looks like exponential growth.

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Hence the learning curve has an S-shape.

Overcoming the S-curve shape is a way to express the unique status of the human species!

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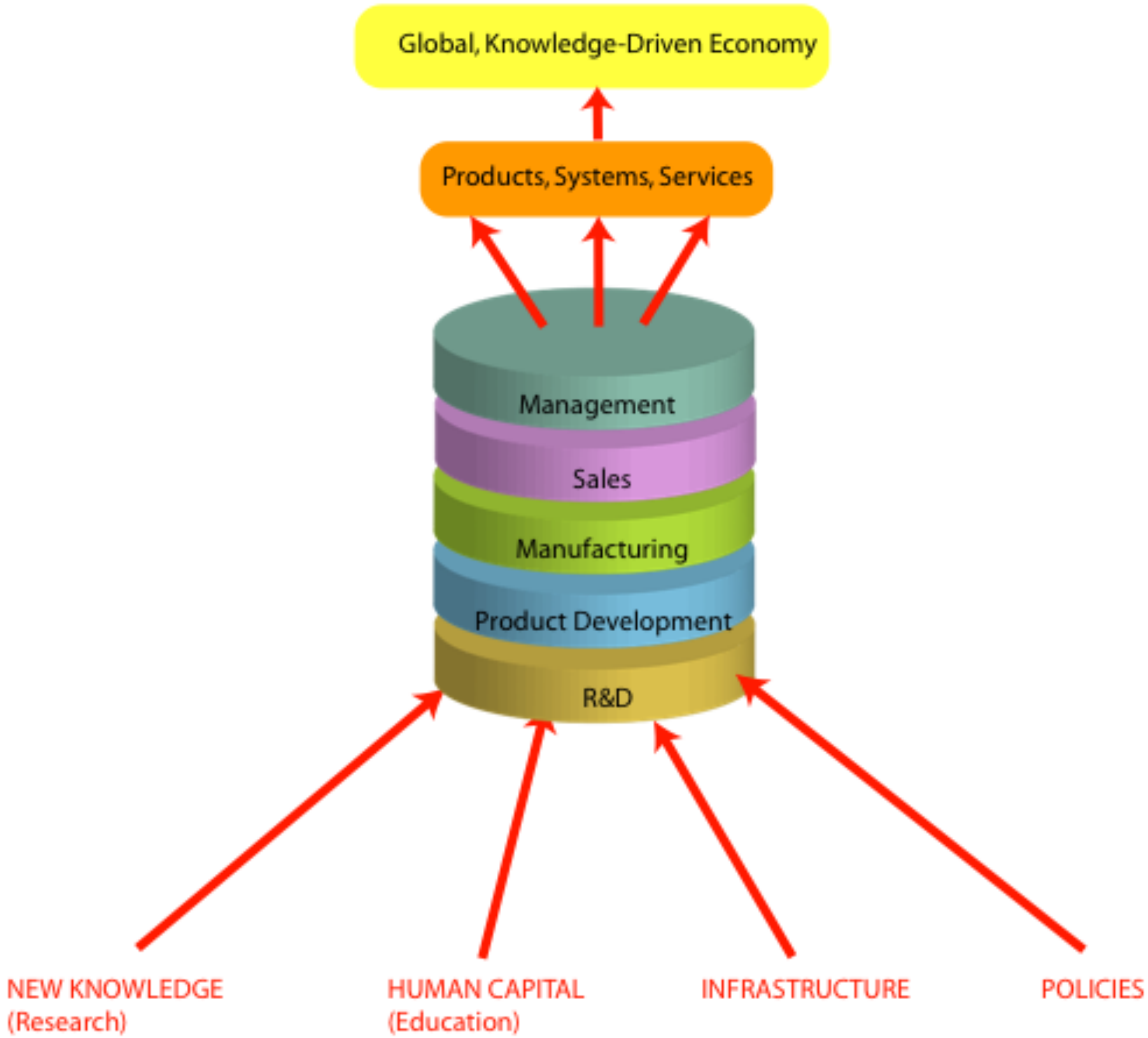
**Someday machines may join us in this ability.**

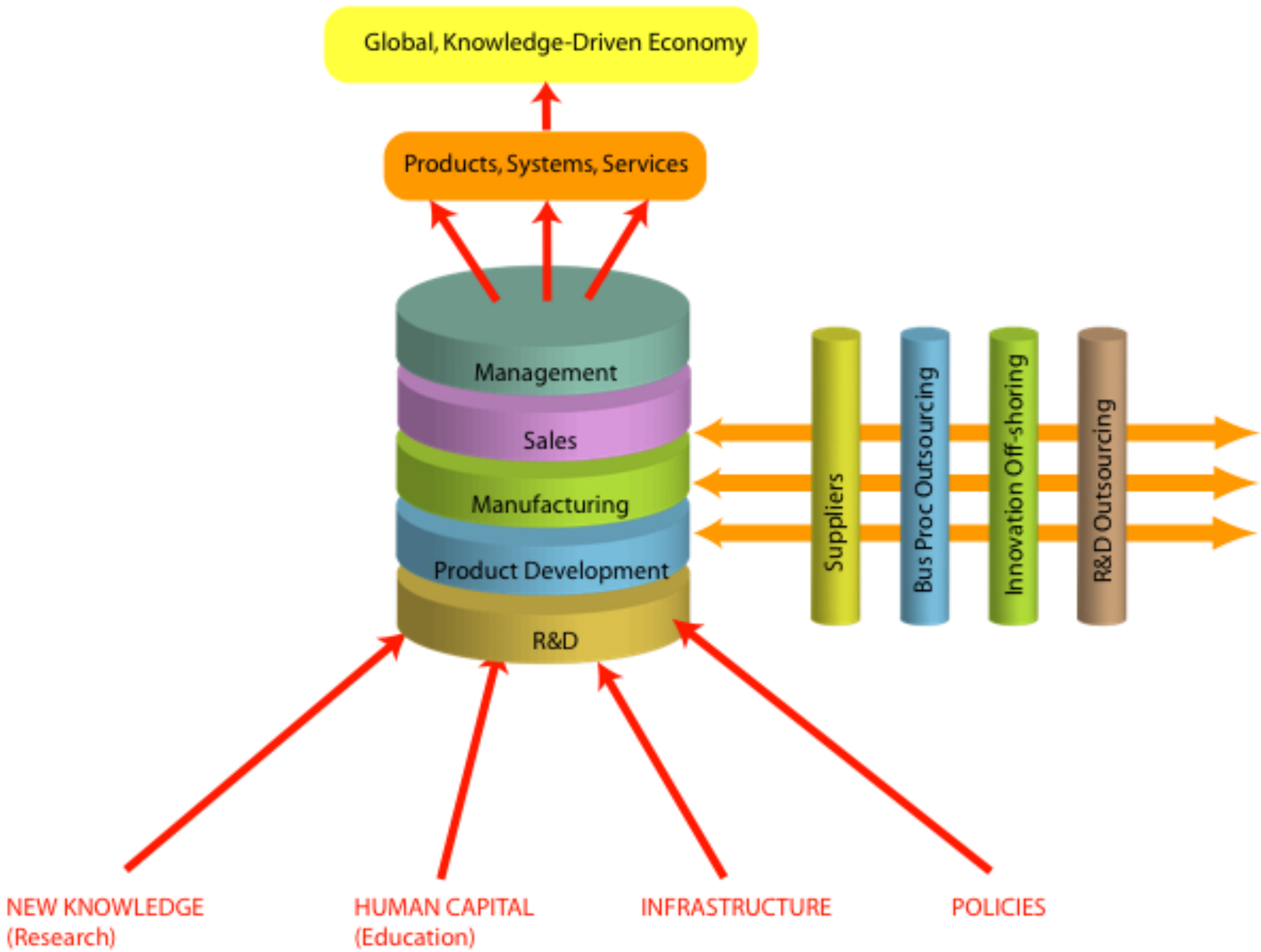
# 21st C Engineering
# The New Profession

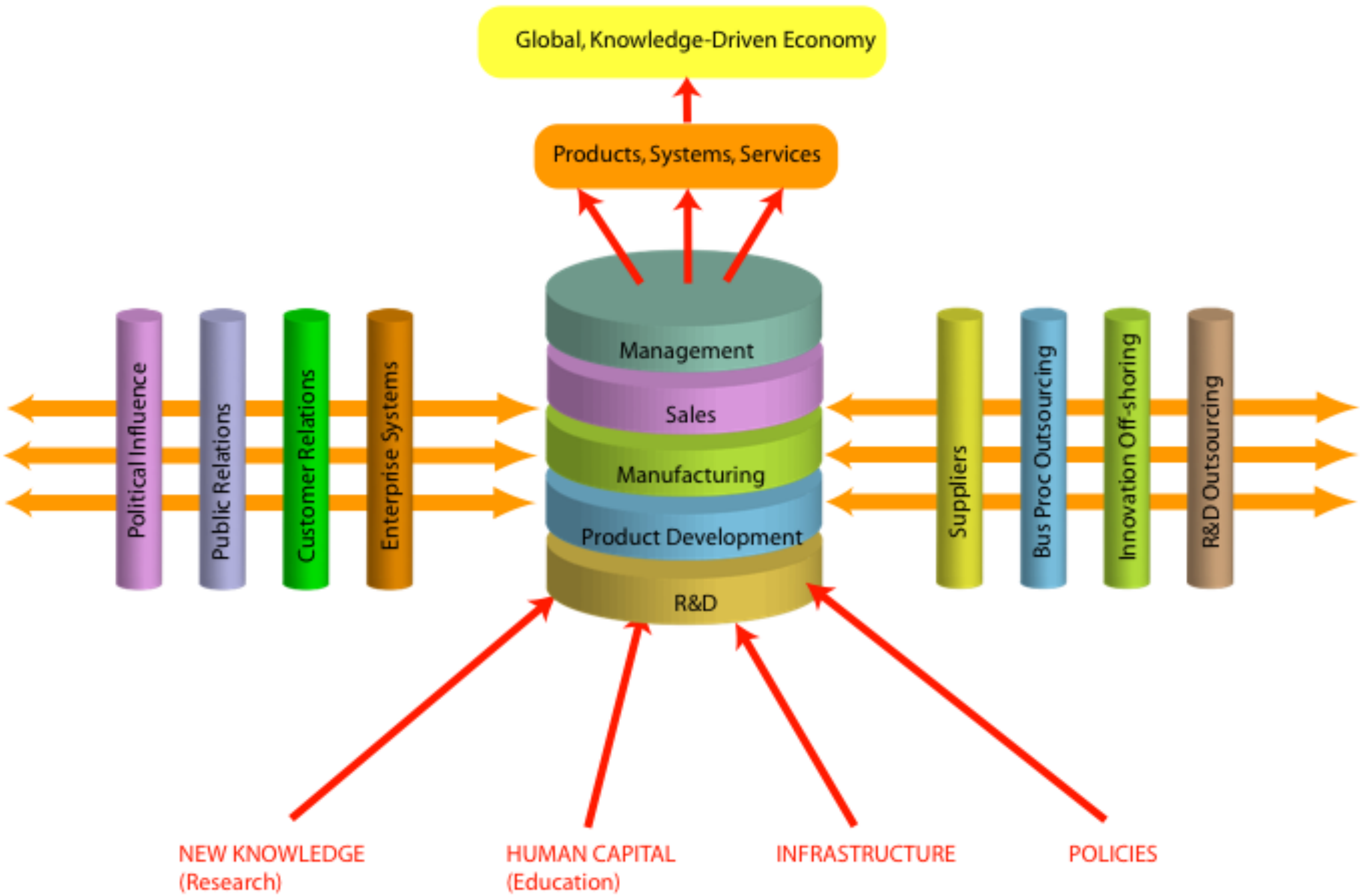
# The need for new paradigms

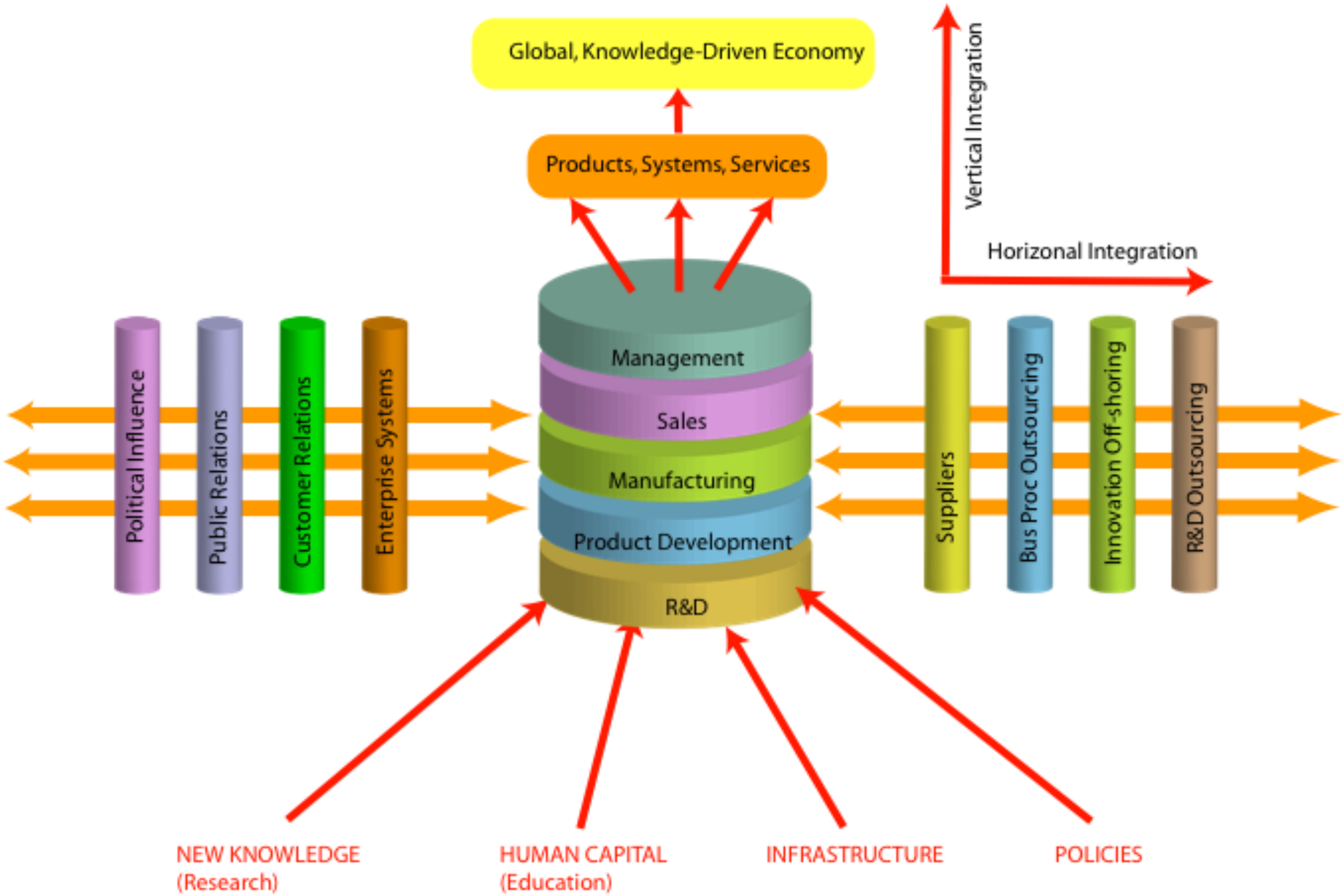
- Incredible pace of intellectual change (from reductionism to complexity, analysis to synthesis, disciplinary to multidisciplinary)
- Exponentiating technologies (info-nano-bio)
- A more holistic approach to addressing social needs and priorities, linking social, economic, environmental, legal, and political considerations with technological design and innovation

# Vertical vs. Horizontal Engineering

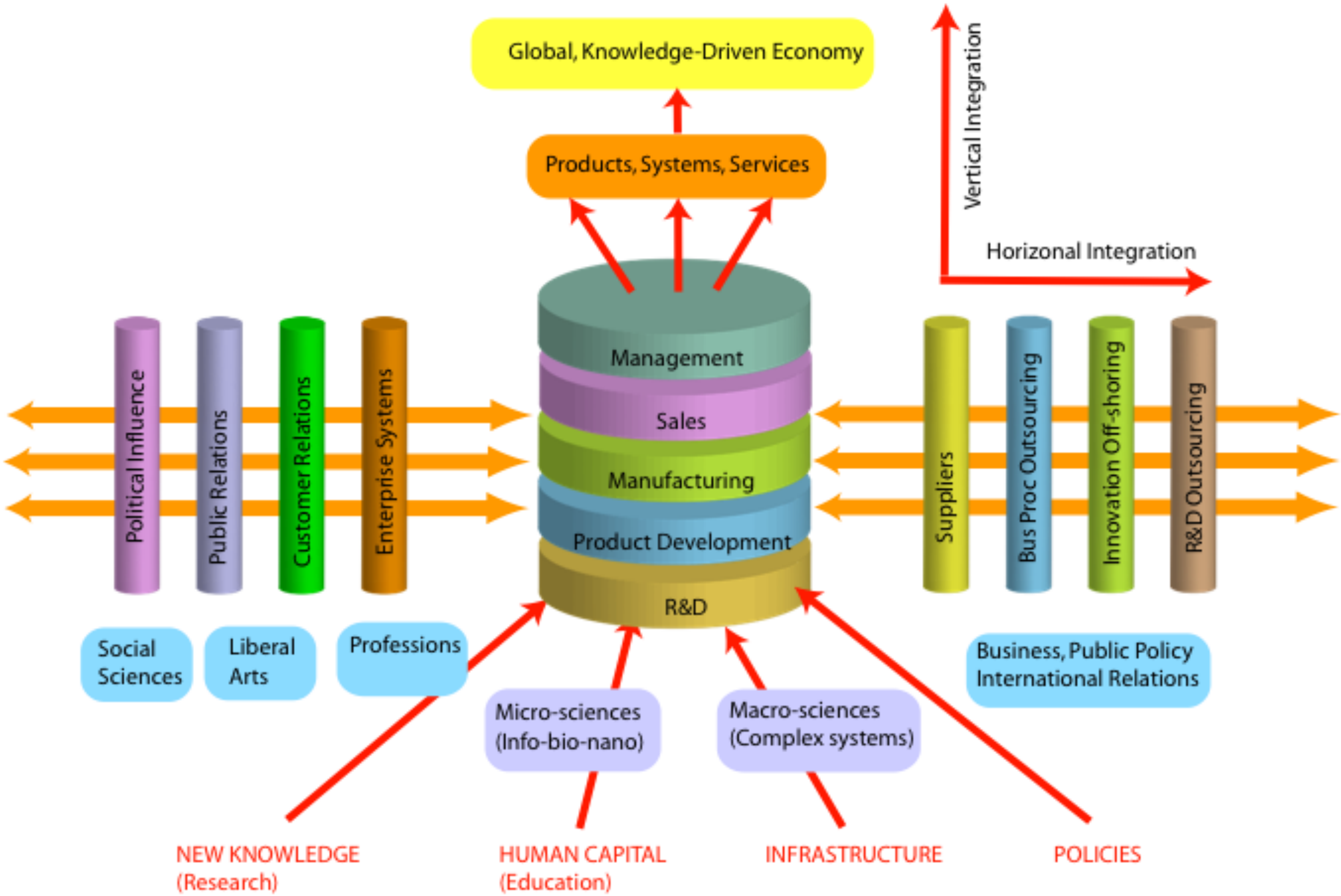

Global, Knowledge-Driven Economy
Products, Systems, Services
Management
Sales
Manufacturing
Product Development
R&D
NEW KNOWLEDGE
(Research)
HUMAN CAPITAL
(Education)
INFRASTRUCTURE
POLICIES


Global, Knowledge-Driven Economy
Products, Systems, Services
Management
Sales
Manufacturing
Product Development
R&D
Suppliers
Bus Proc Outsourcing
Innovation Off-shoring
R&D Outsourcing
NEW KNOWLEDGE
(Research)
HUMAN CAPITAL
(Education)
INFRASTRUCTURE
POLICIES


Global, Knowledge-Driven Economy
Products, Systems, Services
Management
Sales
Manufacturing
Product Development
R&D
Political Influence
Public Relations
Customer Relations
Enterprise Systems
Suppliers
Bus Proc Outsourcing
Innovation Off-shoring
R&D Outsourcing
NEW KNOWLEDGE
(Research)
HUMAN CAPITAL
(Education)
INFRASTRUCTURE
POLICIES



Global, Knowledge-Driven Economy
Products, Systems, Services
Vertical Integration
Horizonal Integration
Management
Sales
Manufacturing
Product Development
R&D
Political Influence
Public Relations
Customer Relations
Enterprise Systems
Suppliers
Bus Proc Outsourcing
Innovation Off-shoring
R&D Outsourcing
NEW KNOWLEDGE (Research)
HUMAN CAPITAL (Education)
INFRASTRUCTURE
POLICIES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Social Sciences
Liberal Arts
Professions
Micro-sciences (Info-bio-nano)
Macro-sciences (Complex systems)
Business, Public Policy International Relations
NEW KNOWLEDGE (Research)
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INFRASTRUCTURE
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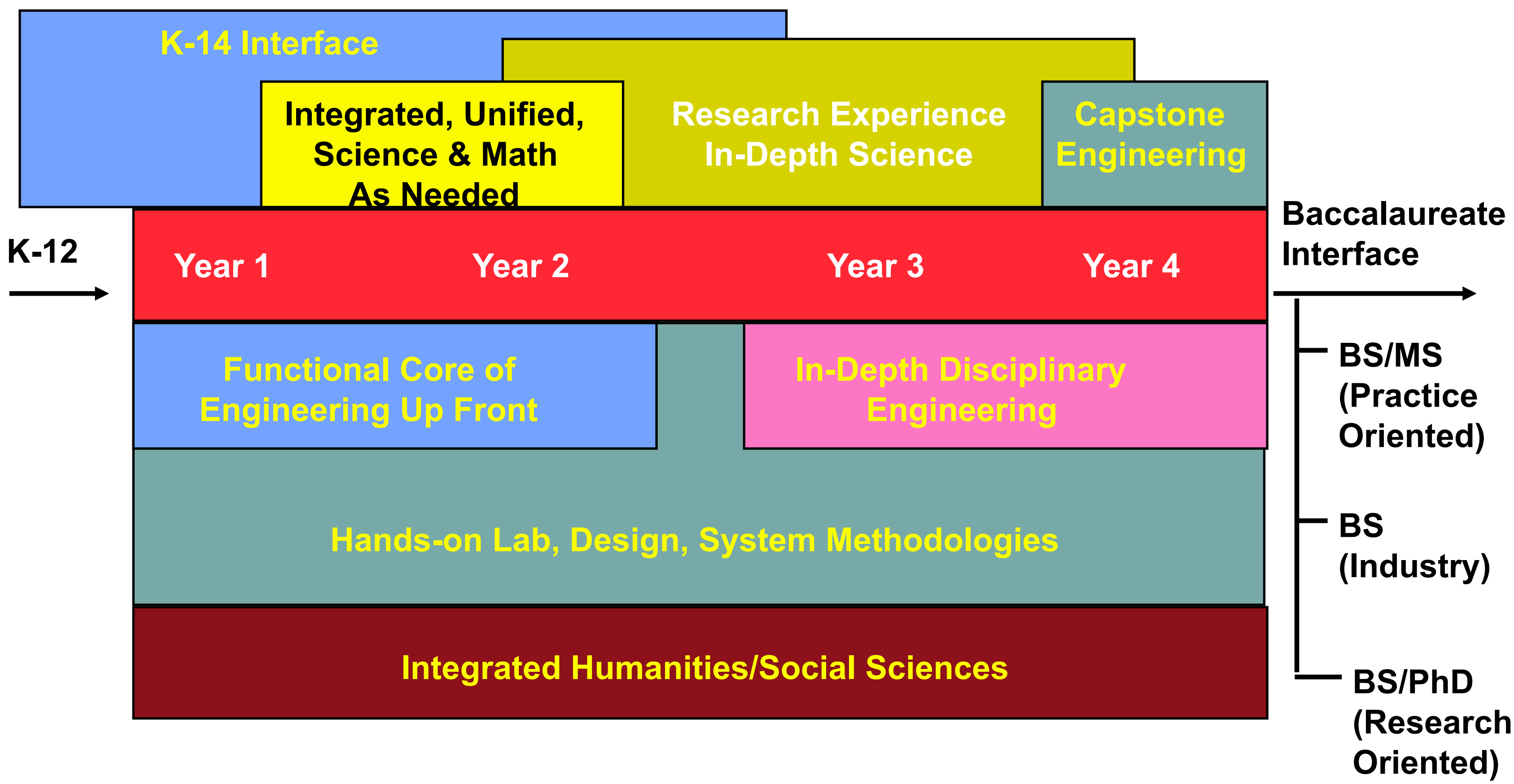
# Holistic Engineering Curriculum




Bordogna, NSF

# More fundamentally…

Less emphasis on “reductionist” science (e.g., physics)
More emphasis on “information -rich” sciences (e.g., biology)

Less emphasis on technical material
More emphasis on humanities, arts, and social sciences

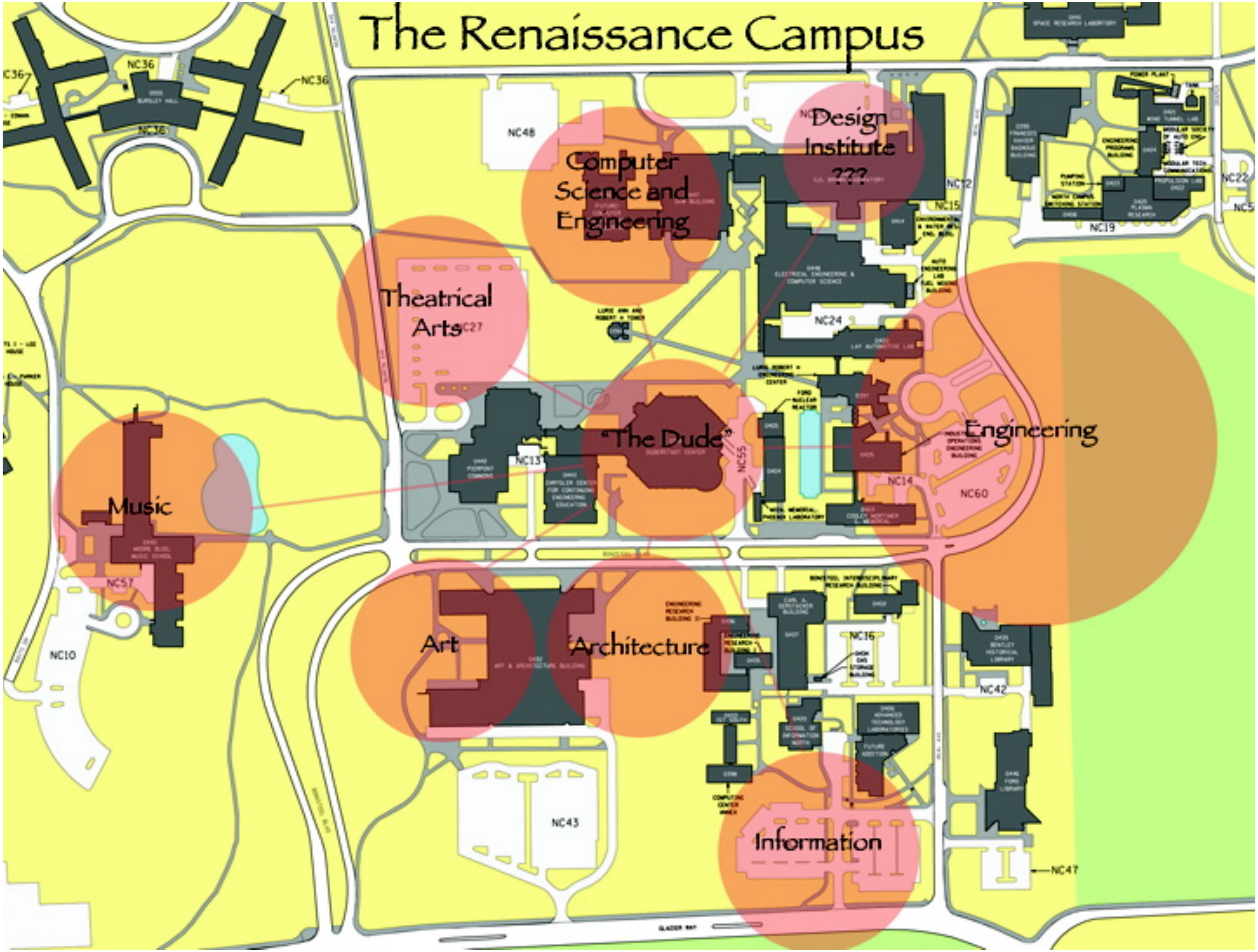
Less emphasis on analysis
More emphasis on synthesis

# Other Possibilities

- Perhaps it is time that engineering takes a more formal approach to lifelong learning similar to other professions such as medicine and law.
- Our engineering science-dominated curricula need to be broadened considerably if we are to provide students with the opportunity to learn innovation and entrepreneurial skills.
- An even bigger challenge: How do we develop skills in innovation and creativity? (We are experienced in teaching analysis, NOT synthesis and creativity.)

# Some ideas

- Shifting from study and problem solving to the active discovery and application of knowledge–e.g., the "constructionist" learning of Dewey and Piaget.
- Perhaps it is time to rip instruction out of the classroom and place it instead in the discovery environment of the laboratory or the experiential environment of professional practice.
- And perhaps it is time that we looked to our neighboring disciplines in which creativity is the dominant intellectual activity–music, the fine arts, architecture, creative writing, etc.–transforming engineering back into a Renaissance discipline!



The Renaissance Campus
Computer Science and Engineering
Design Institute ???
Theatrical Arts
"The Dude"
Engineering
Music
Art
Architecture
Information

# The Usual Questions

- What engineering majors are the most attractive?
- What kinds of jobs will provide the best opportunities for rewarding careers?
- How does one get the most out of an engineering education?
- How does one get the most out of a Michigan education.

# Some More Basic Questions

- How can American engineers produce five times the "value added" of their counterparts in China and India?
- How can engineering students assure that their engineering education won't become obsolete within a few years following graduation?
- How does one prepare for a future likely to be characterized by rapid change and great uncertainty?

# Consilience

"Most of the issues that vex humanity daily cannot be solved without integrating knowledge from the natural science with that of the social sciences and humanities. Only fluency across the boundaries will provide a clear view of the world as it really is, not as seen through the lens of ideologies and religious dogmas or commanded by myopic response to immediate needs."

E. O. Wilson

# A Definition

Polymath: Somebody who is knowledgeable in a variety of fields, particularly in both arts and sciences.

Examples: Leonardo da Vinci, Benjamin Franklin, Thomas Jefferson, Kelly Johnson, …

And perhaps the American engineer of the 21st century!!!

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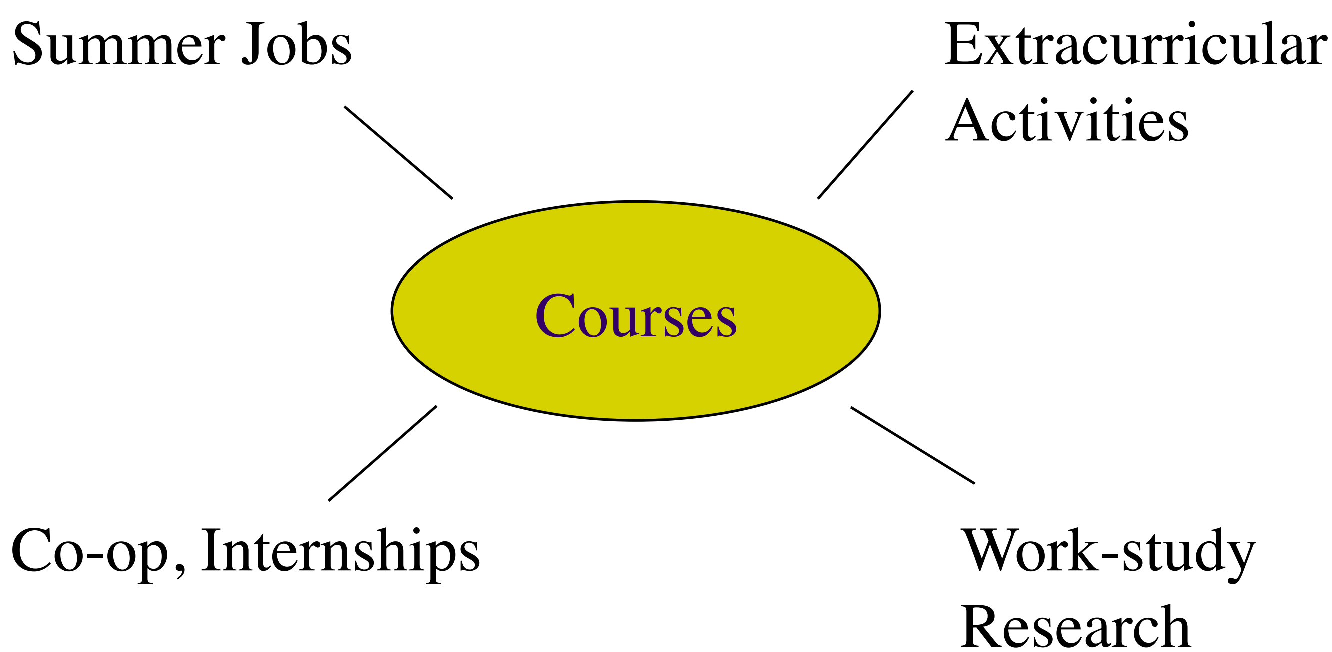
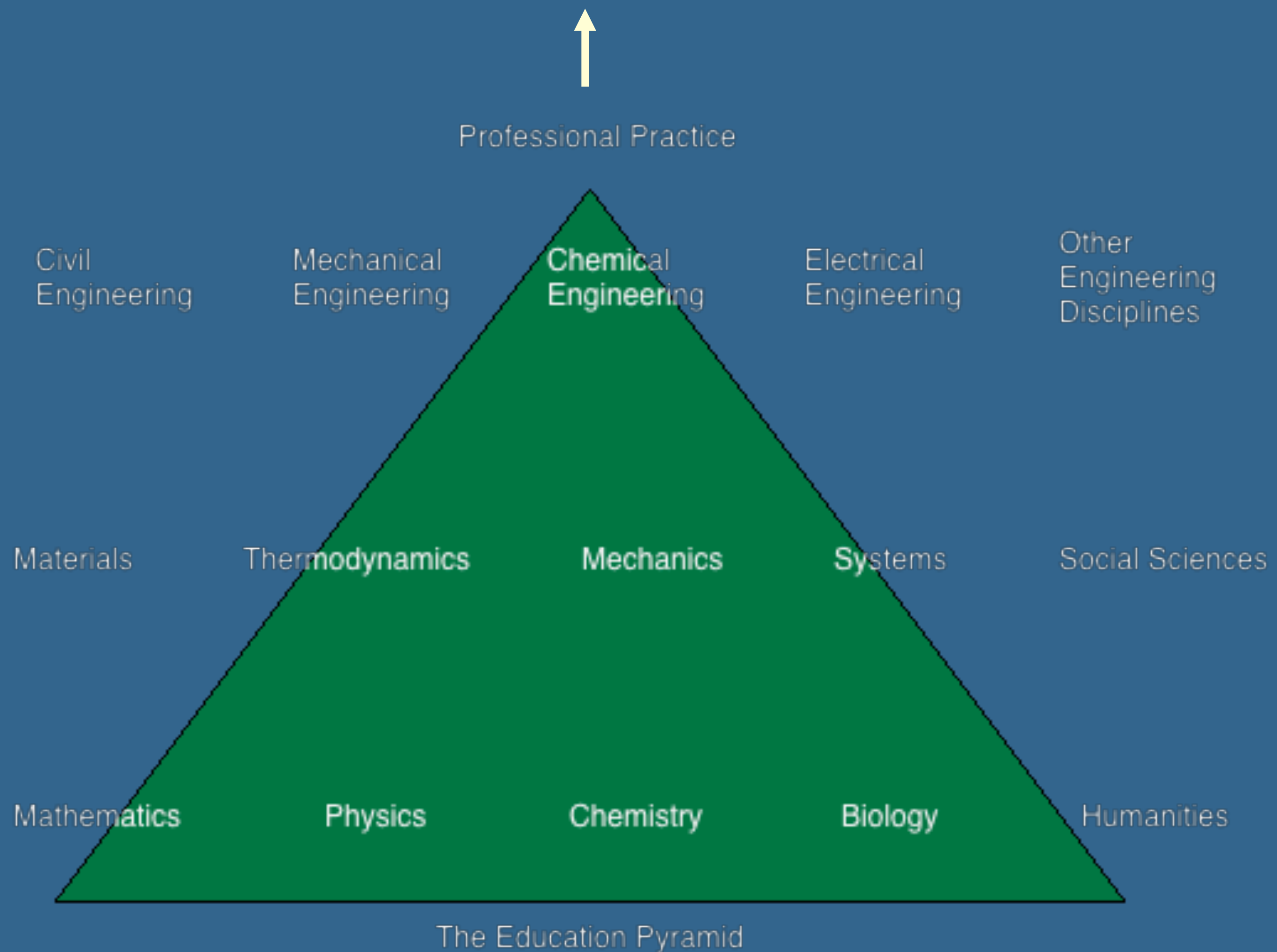
**But how???**

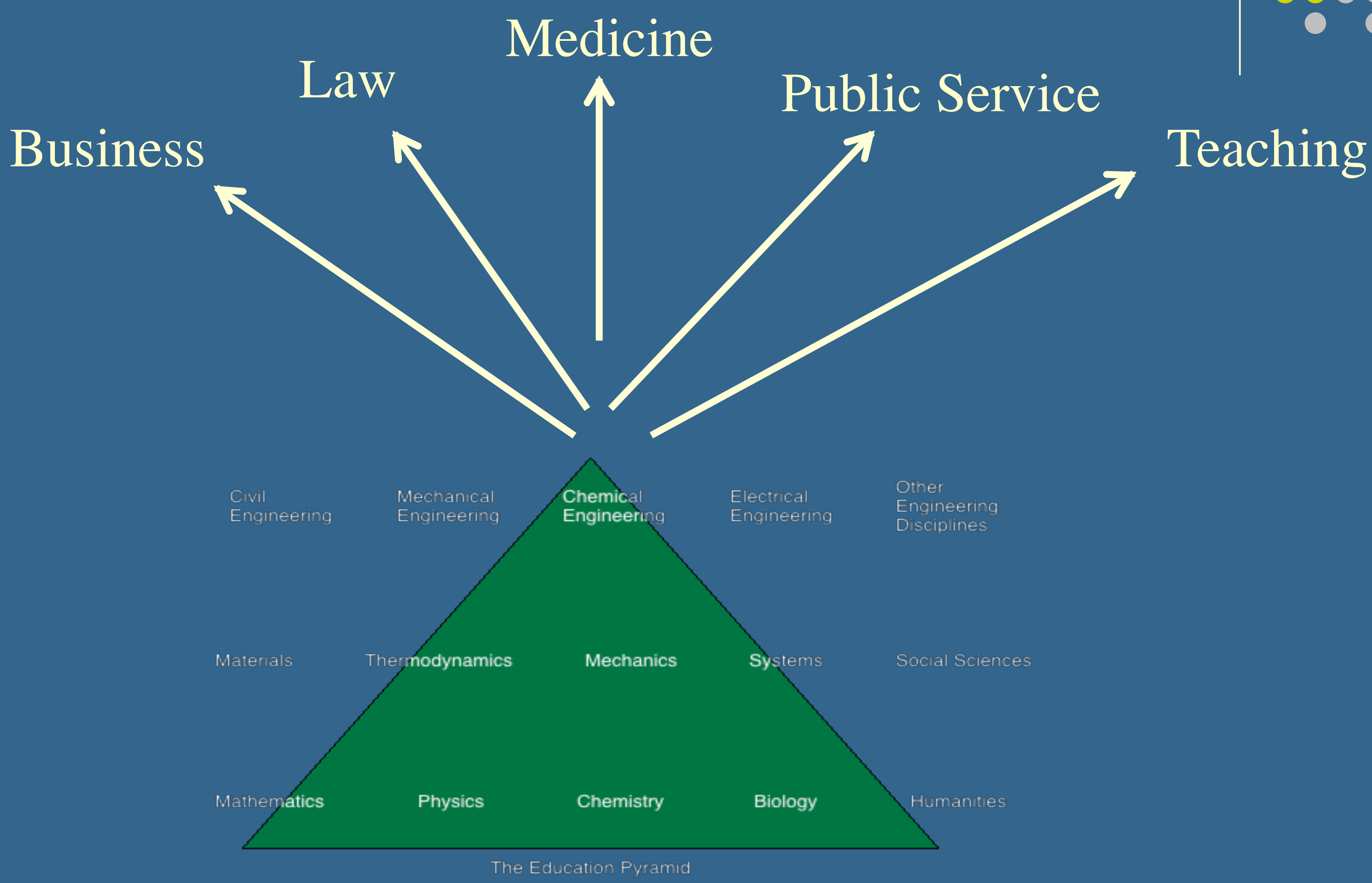
# Look at entire college experience

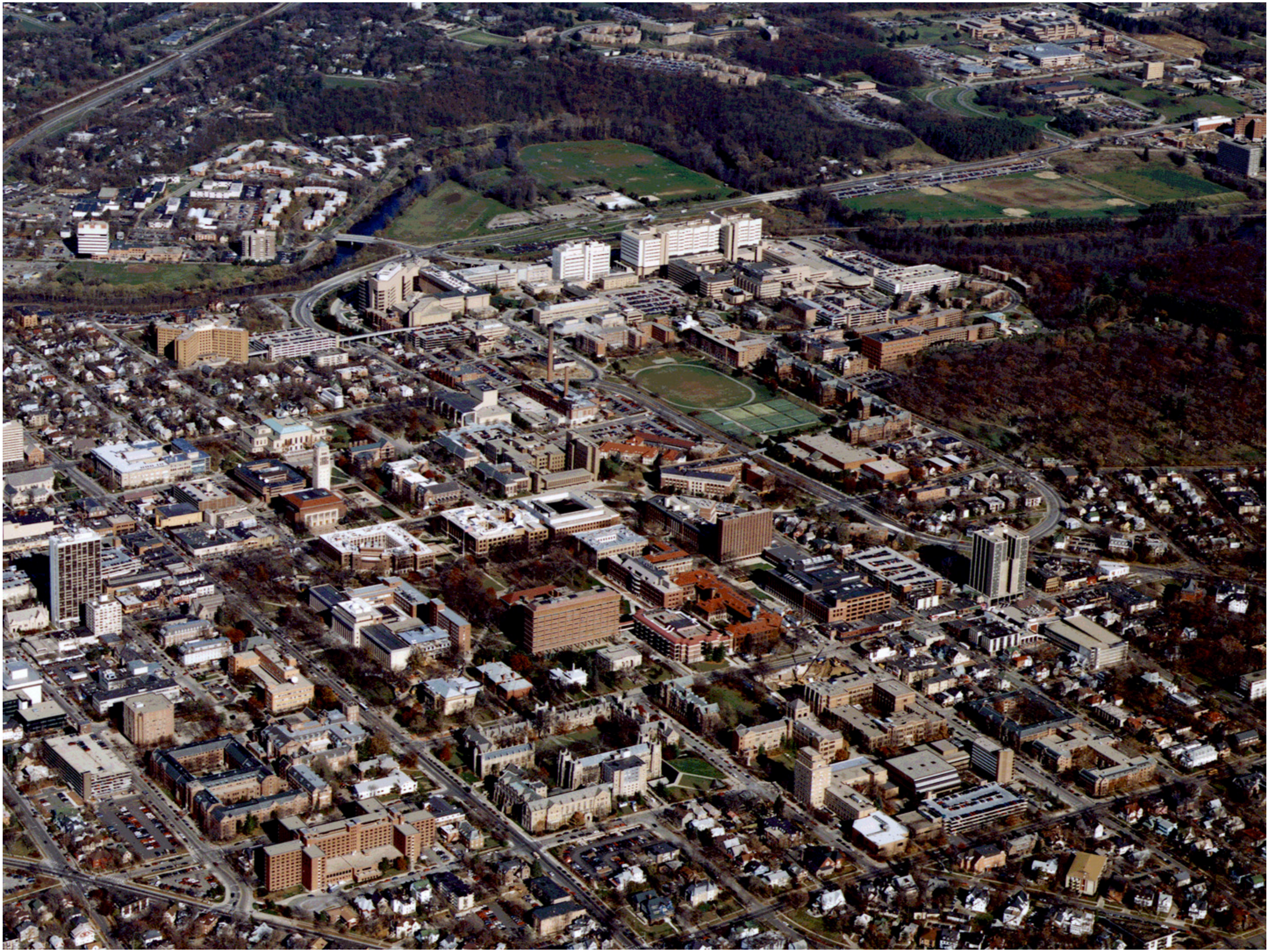


# An Engineering Career



# Alternative Careers





# The University of Michigan

The University of Michigan is probably the most comprehensive university campus in the world, with not only high quality programs in essentially every academic and professional discipline, but an unusually broad array of opportunities –music, arts, politics, athletics, cyberspace, etc.–as well as off-campus opportunities about the globe.

It provides an extraordinary environment for learning, both in the classroom and beyond.

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Your challenge: to take advantage of these opportunities!