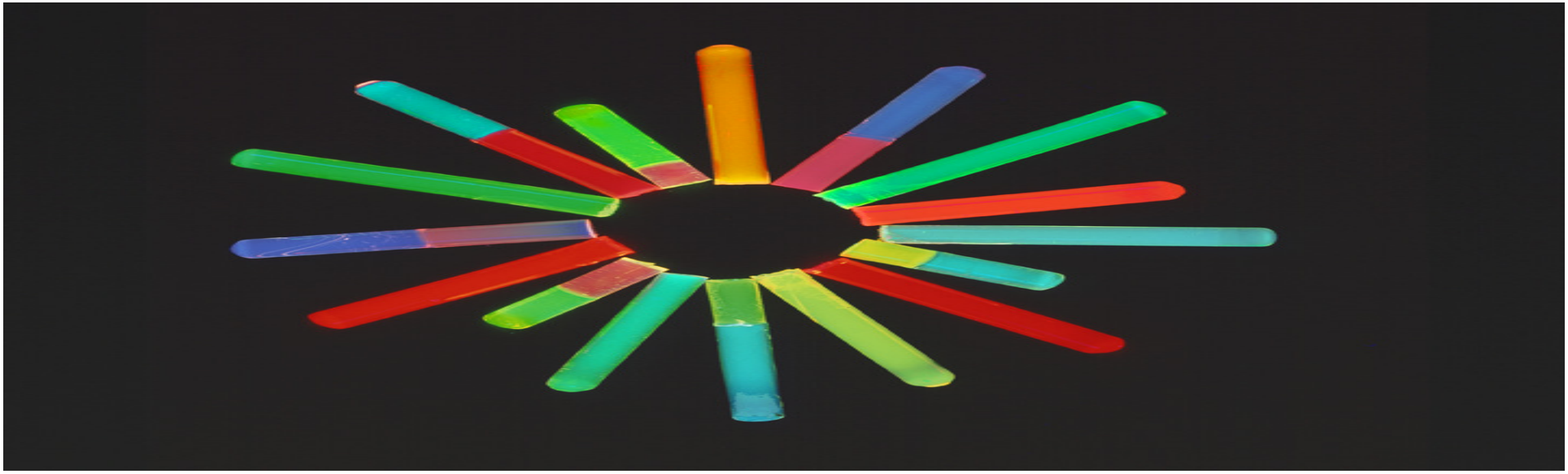


# COHERENCE AND DIVERGENCE OF MEGATRENDS IN SCIENCE AND ENGINEERING

**M.C. Roco**

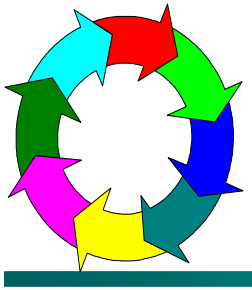
**Chair, National Science and Technology Committee's Subcommittee on Nanoscale Science, Engineering and Technology;**

**Senior Advisor, National Science Foundation**

CASS, December 1, 2000

# *Topics to be addressed*

- **Six interconnected megatrends in the next 20 years; Identification process; Related to human perception**
- **Example: National Nanotechnology Initiative (the concept, approval PCAST, OMB, Congress)**
- **Coherence and synergism among major trends - the role of macroscale managing decisions.**

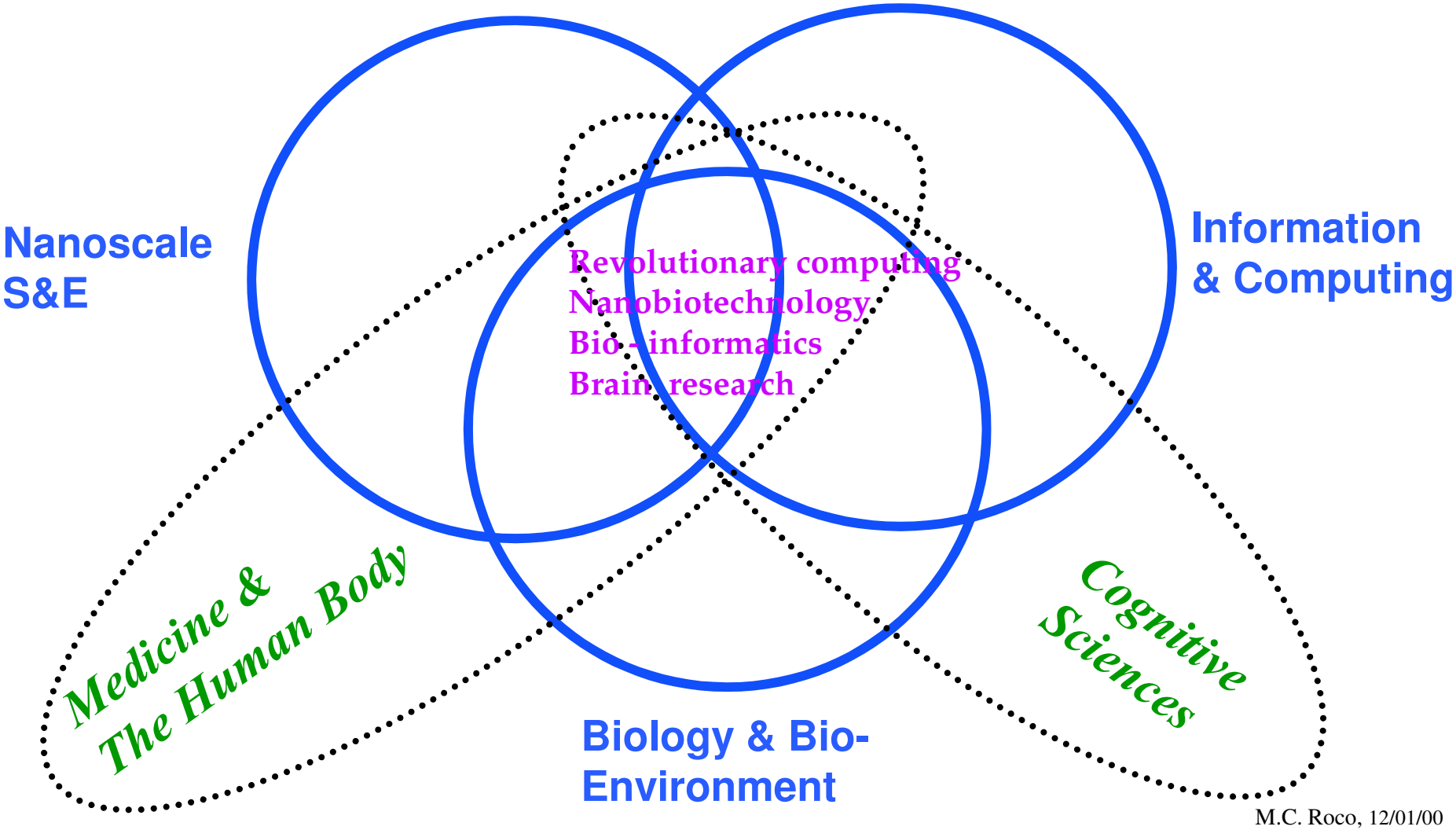


# Interconnected S&E trends

- Information and computing
- Nanoscale  science and engineering
- Biotechnology and bio-environmental issues
- Medicine and the human body
- Cognitive sciences - enhancing human abilities
- Collective behavior
  in nature, technology and society

# Crossing of Science & Engineering Streams: *coherence and synergism*

*Collective Behavior & Dynamic System Approach*




M.C. Roco, 12/01/00

# Megatrends in S&E as related to human perception

- *"..**Your left brain** is your verbal and rational brain; it thinks serially and reduces its thoughts to numbers, letters, and words. . **Your right brain** is your non-verbal and intuitive brain; it thinks in patterns, or pictures, composed of 'whole things',. ."* *(Bergland, 1985).*

| World | Left Brain | Right Brain | S&E Trend |
|---|---|---|---|
| *Objective* | DNA | Biosystems | Modern Biology |
| | Atoms | Patterns | Nanoscale S&E |
| *Chosen* | Bits | Networking | Information Technology |

- **The length scale - moving further from human perception size**
  *- smaller: stone age, classical mechanics, microscale, nanoscale, ...*
  *- larger: sustainable environment, global change, space exploration,..*

# Origin of national S&E initiatives in U.S.

- **Make time for looking ahead -**
- **No unique process of identification of U.S. national programs**

  - "Information Technology" (1999 - ) -- proposed by PITAC
  - "National Nanotechnology Initiative" (2000 - )
    -- intellectual drive from bottom-up
  - Medicine (NIH) - public interest in health, aging population
  - Cognitive -- not yet well recognized, included in education
  - Collective behavior -- not yet focused, included in others

  Others in the last 50 years:

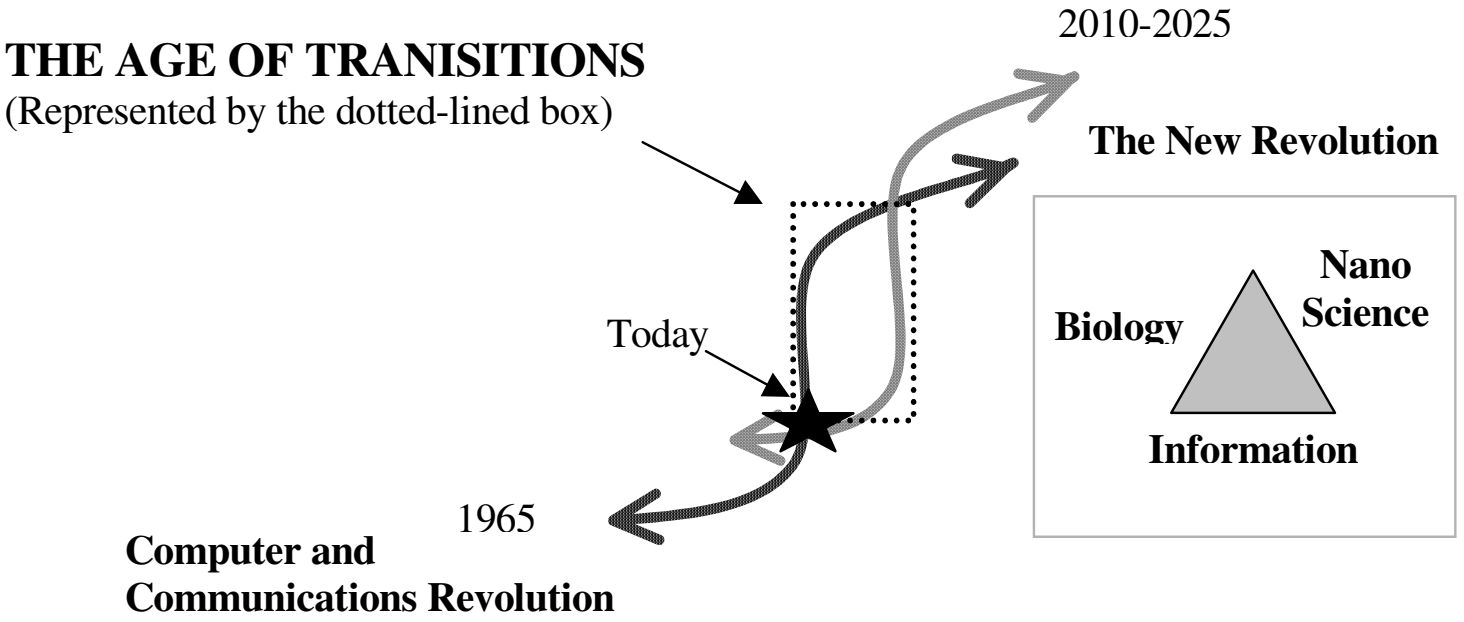
  - Nuclear program -- national security
  - Space exploration -- international challenge
  - Global change -- international participation

# A view from U.S. Congress

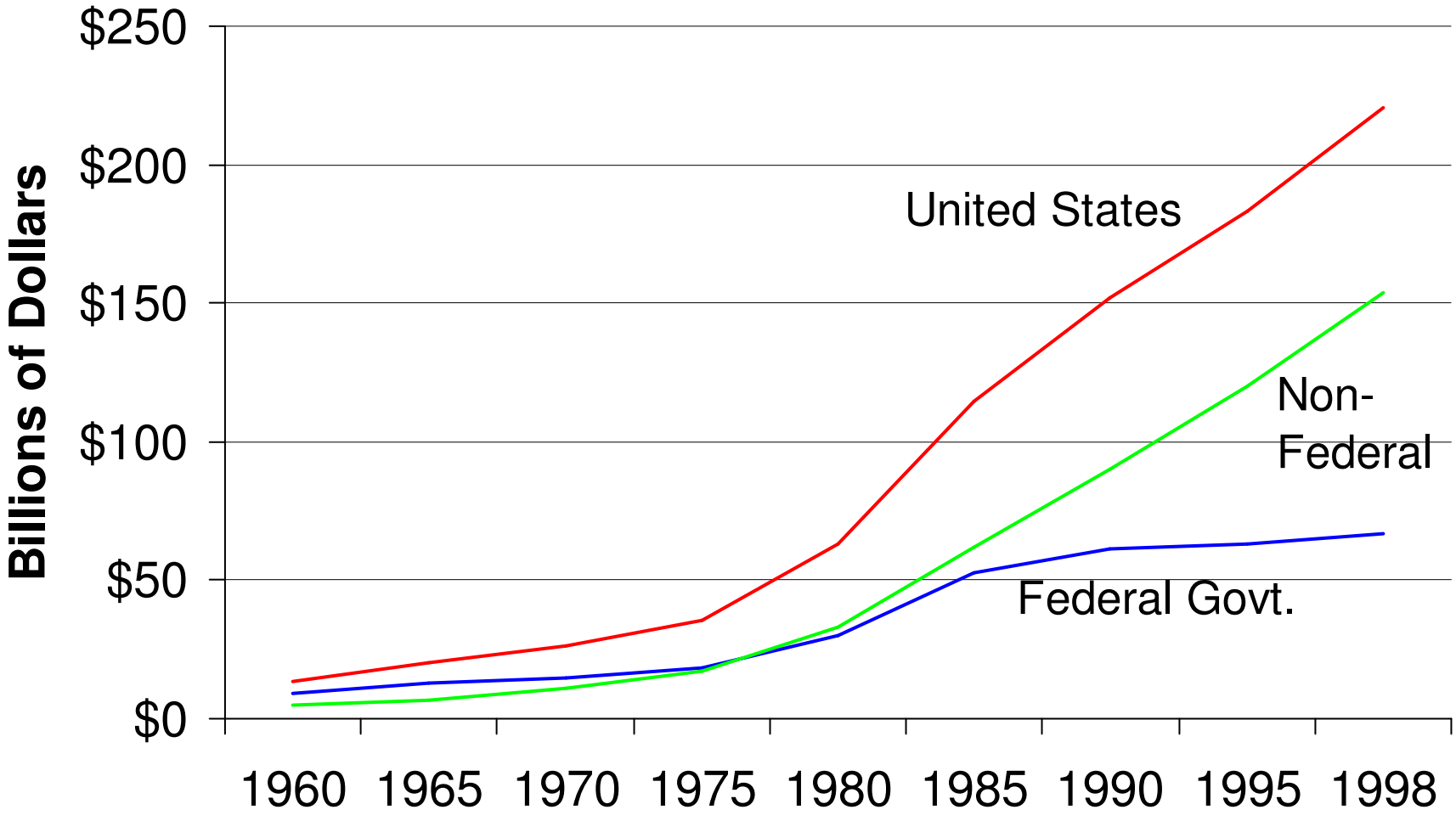
***Information Technology:*** **FY 2000 $1,721 (+32%)**
**FY 2001 (proposed) $2,315 (+35%)**

***Nanotechnology:*** **FY 2001 (proposed) $495M (+83%)**

Newt Gingrich (in Societal Implications of Nanotechnology, 2000):



# National R&D Funding by Source: 1960 - 1998



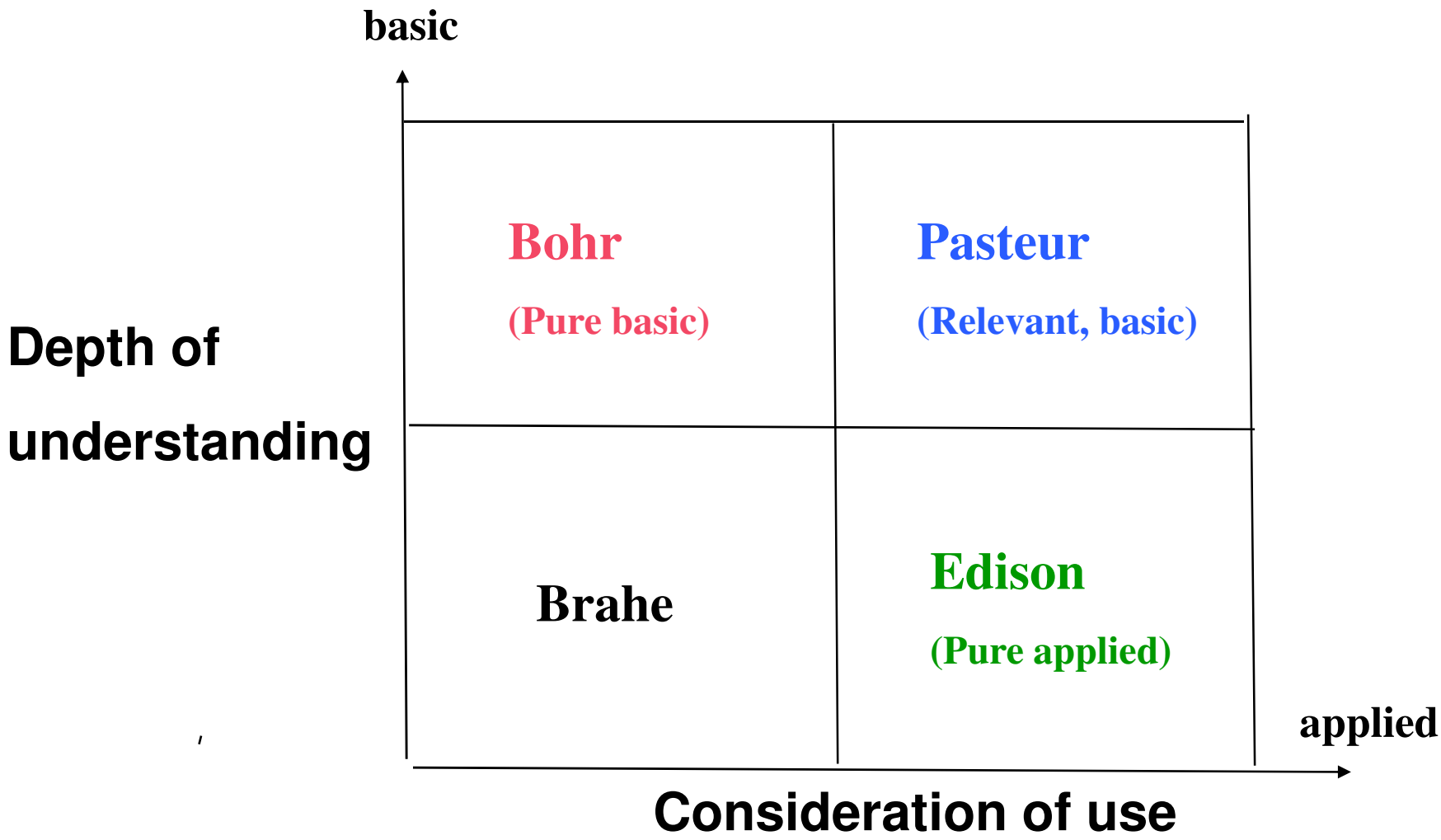

NSF/SRS Publ.

Note: Federal Govt. ~ 26.7% in fiscal year 1999

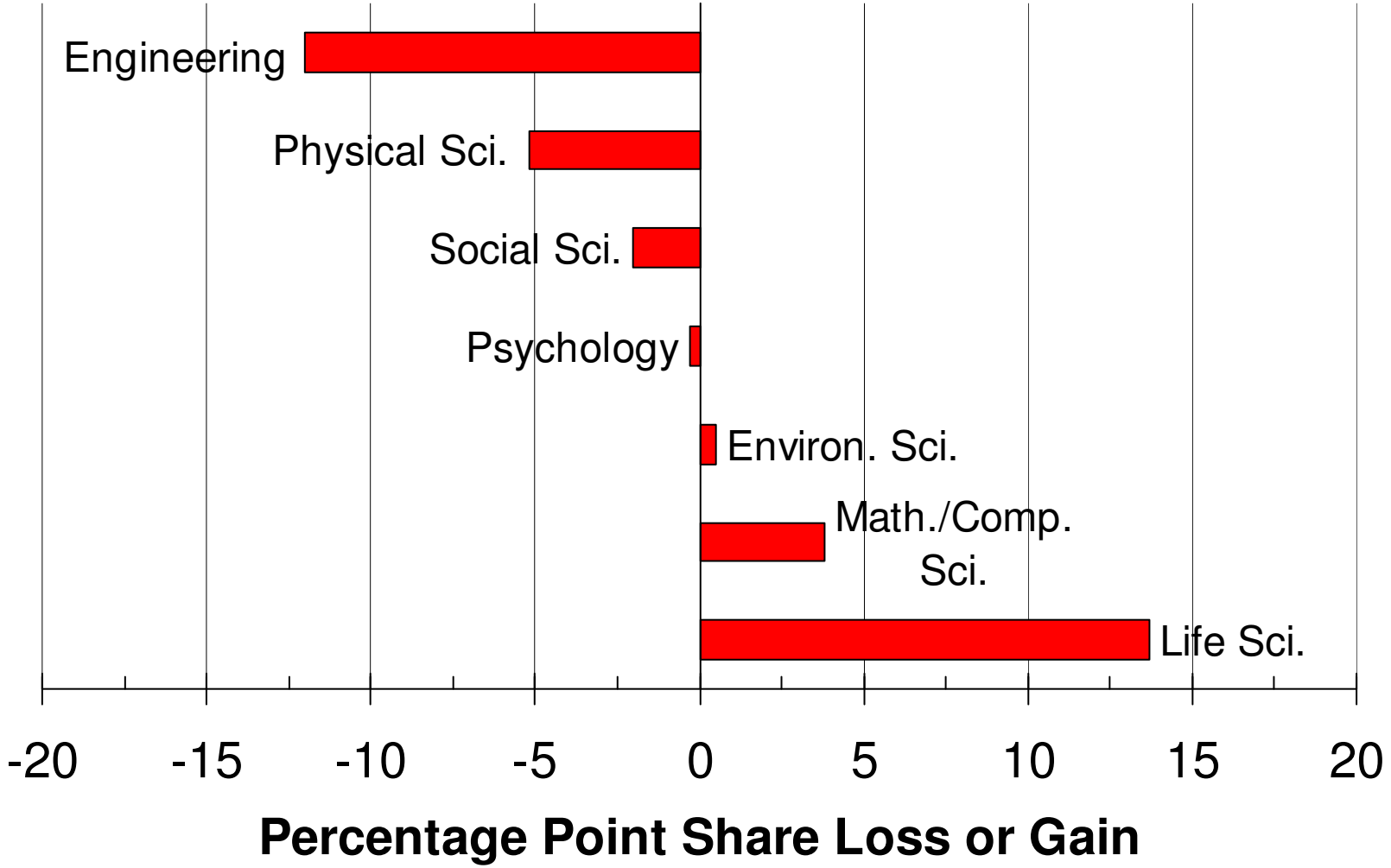
M.C. Roco, 12/01/00

# Pasteur's Quadrant:

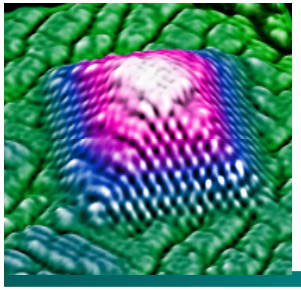
## Redirecting investments, New role for engineering



# Changes in Field Shares of Total Federal Research Funding: 1970 - 1997




NSF/SRS Publ.



# HISTORY -
## National Nanotechnology Initiative Timeline

- November 1996 — Nanotechnology Group (bottom-up)
- September 1998 — NSTC establishes IWGN

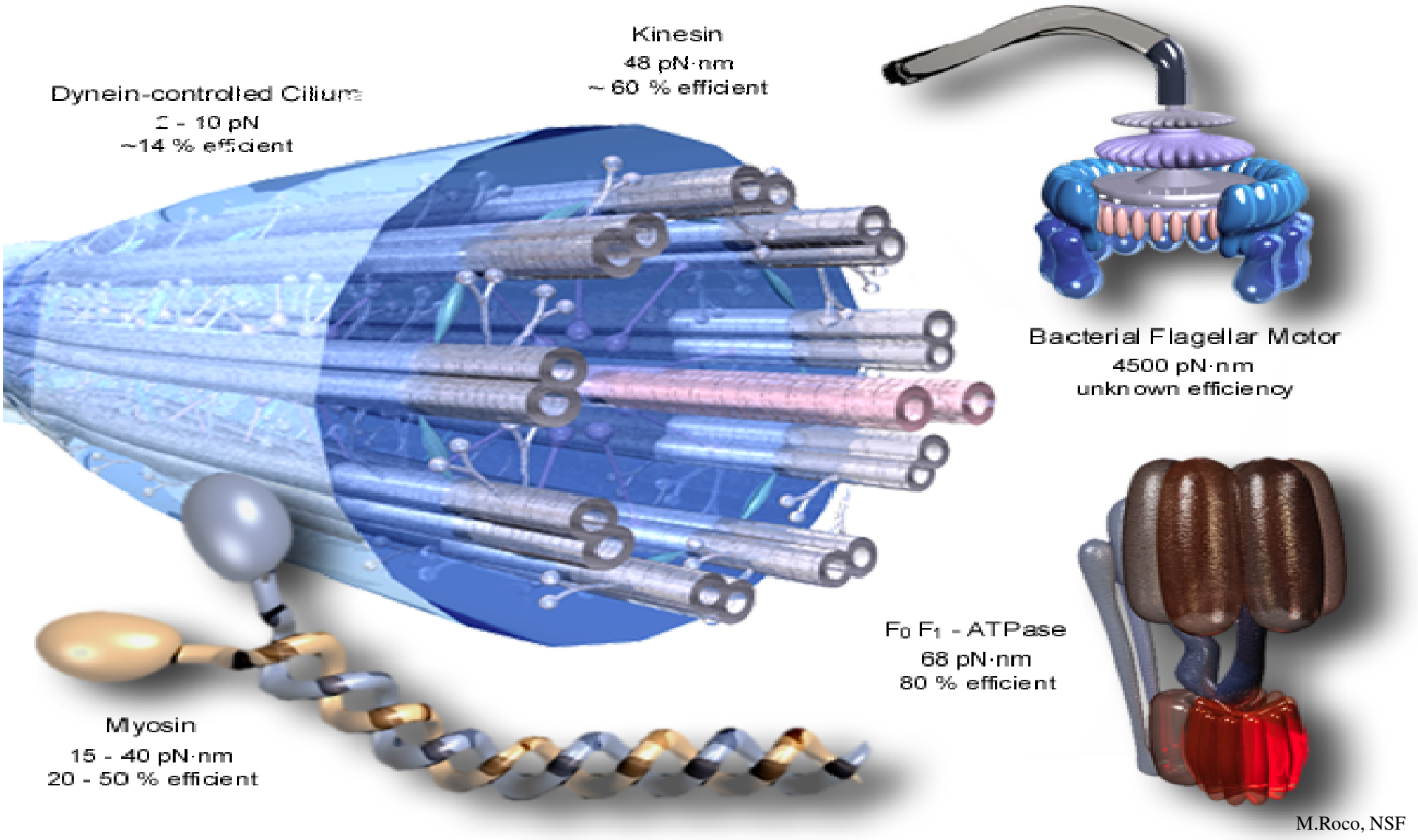
- March 1999 — OSTP/CT presentation on NNI
- May-June 1999 — Congress hearings
- July-Sept. 1999 — Three background publications
- August 1999 — First draft of the IWGN Plan

- Oct. - Nov. 1999 — PCAST Nanotech Panel Review
- December 1999 — PCAST Full Committee; OMB
- January 2000 — OSTP and WH Approval

- February 2000 — WH Release of NNI Initiative
- November 2000 — Congress enacts the NNI budget

# Nanobiomotors

*(Cornell University)*




M.Roco, NSF

# Elements of NNI Initiative in FY 2001

Request by the President - $495 million (see nano.gov)

- **Fundamental Research - $170 million** (NSF: $122 million)
  Provides sustained support to individual investigators and small groups doing fundamental, innovative research
- **Grand Challenges - $140 million** ($12M)
  for research on major, long-term objectives
- **Centers and Networks of Excellence - $77 million** ($37M)
  for interdisciplinary research, networking, industry partnerships
- **Research Infrastructure - $80 million** ($24.7M)
  metrology, instrumentation, modeling/simulation, user facilities
- **Societal Implications and Workforce Education and Training - $28 million** ($21M)
  for a new generation of skilled workers; the impact of nanotechnology on society (legal, ethical, social, economic)

M.Roco, NSF, 12/01/00

# Nanotechnology R&D Funding by Agency

(FY 2001 budget enacted by Congress)

| | FY 2000 ($M) | FY 2001 ($M) | % Increase |
|---|---|---|---|
| National Science Foundation | $97M | $150M | 55% |
| Department of Defense | $70M | $110M | 57% |
| Department of Energy | $58M | $93M | 60% |
| NASA | $5M | $20M | 300% |
| Department of Commerce | $8M | $10M | 25% |
| National Institutes of Health | $32M | $39M | 22% |
| TOTAL | $270M | $422M | 56% |

**Other five departments (EPA, DOJ, DOT, Dtreas, USDA) participate**

# **Nanotechnology in the world**
# Comparison for industrialized countries

**Estimated government sponsored R&D in $ millions/year**

| | 1997 | 2000 | 2001 |
|---|---|---|---|
| W. Europe | 126 | 184 | |
| Japan | 120 | 245 | |
| USA | 116 | 270 | 422 |
| Total | 362 | 624 | |

# Annual Nanoforum C.H. - U.S. on Nanoscale S&E

- **Nanoforum in Zurich, September 1999**

  **Focus on Experimental and Simulation Tools**

  Co-sponsored by the Swiss Academy of Engineering Sciences, Swiss NSF, Swiss Association for Nanoscience and Technology, MINAST and U.S. NSF

- **Nanoforum in Princeton, December, 2000**
  **Focus on Nanobiotechnology and Pharmaceutical Processes at Nanoscale**

  Co-sponsored by the U.S. NSF, NASA, Swiss Academy of Engineering Sciences and Swiss NSF

- **Planned Nanoforum in Switzerland in 2001**

# S&E macroscale management decisions

- There is no single way of development of S&T, and here is the role of taking visionary measures. The coherence and synergism of various S&E trends, rate of implementation and utilization, are affected by macroscale managing decisions (see increases in productivity and economic returns)

- Significant S,E&T developments inevitably have both desired and undesired consequences. Dramatic discoveries and innovations may create a tension between societal adoption of revolutionary new technologies in the future and our strong desire for stability and predictability in the present

# S&E macroscale management decisions

- The chief aim is to create the knowledge base and institutional infrastructure necessary to accelerate the beneficial use of the new knowledge and technology and reduce the potential for harmful consequences

- To achieve this
  - the entire scientific and technology community must set broad goals
  - involve all participants, including the public
  - and creatively envision the future