Strengthening the Connections: Research, Innovation, and Economic Growth

Patrick Gallagher

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Department of Commerce

www.nist.gov

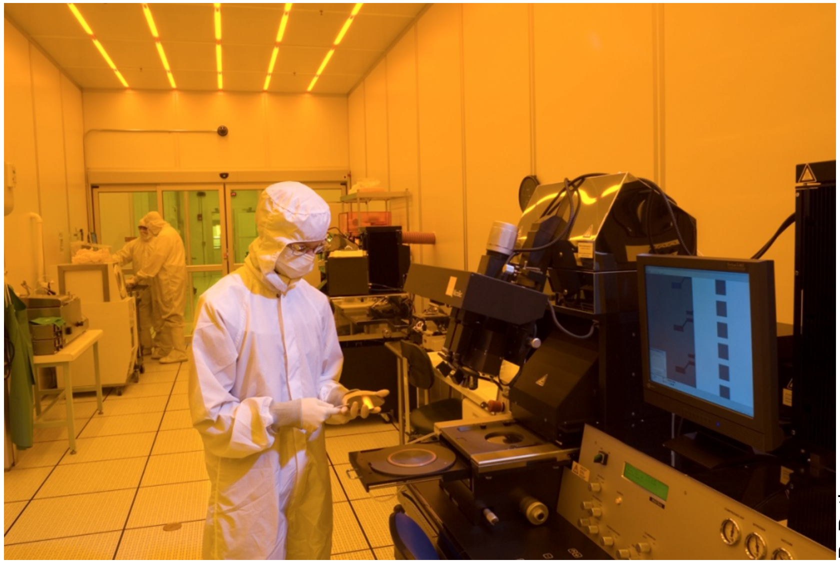
NIST
National Institute of Standards and Technology
U.S. Department of Commerce

NIST at a Glance

Major assets

- ~ 2,800 employees
- ~ 2,600 associates and facilities users
- ~ 1,600 field staff in more than 400 partner organizations (Hollings Manufacturing Extension Partnership)

R. Rathe



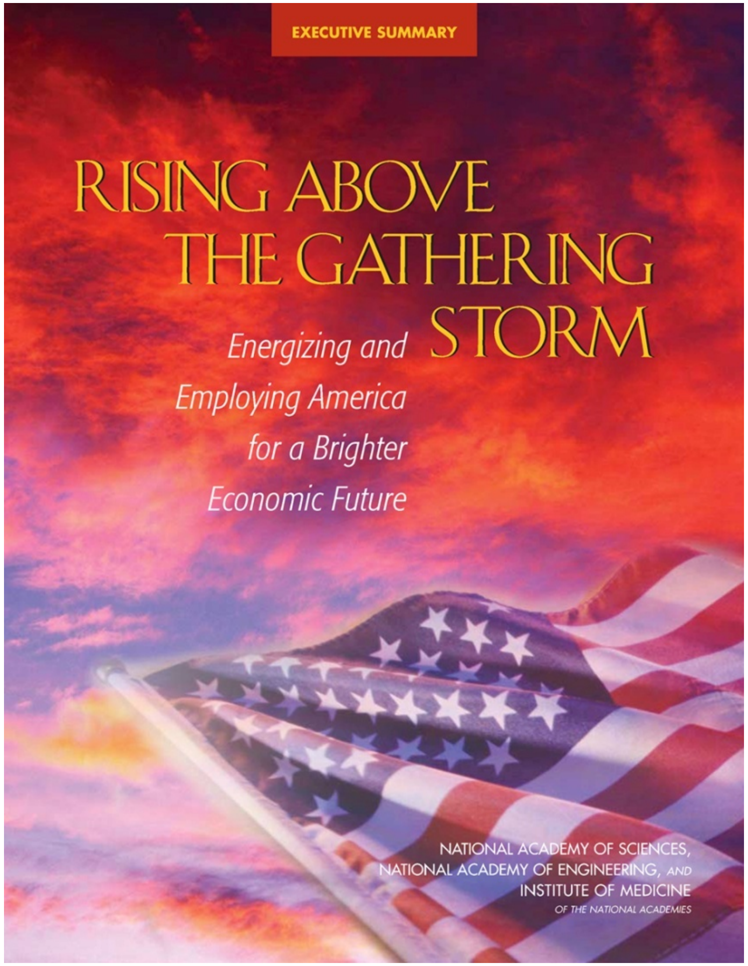
R. Rathe

Major programs

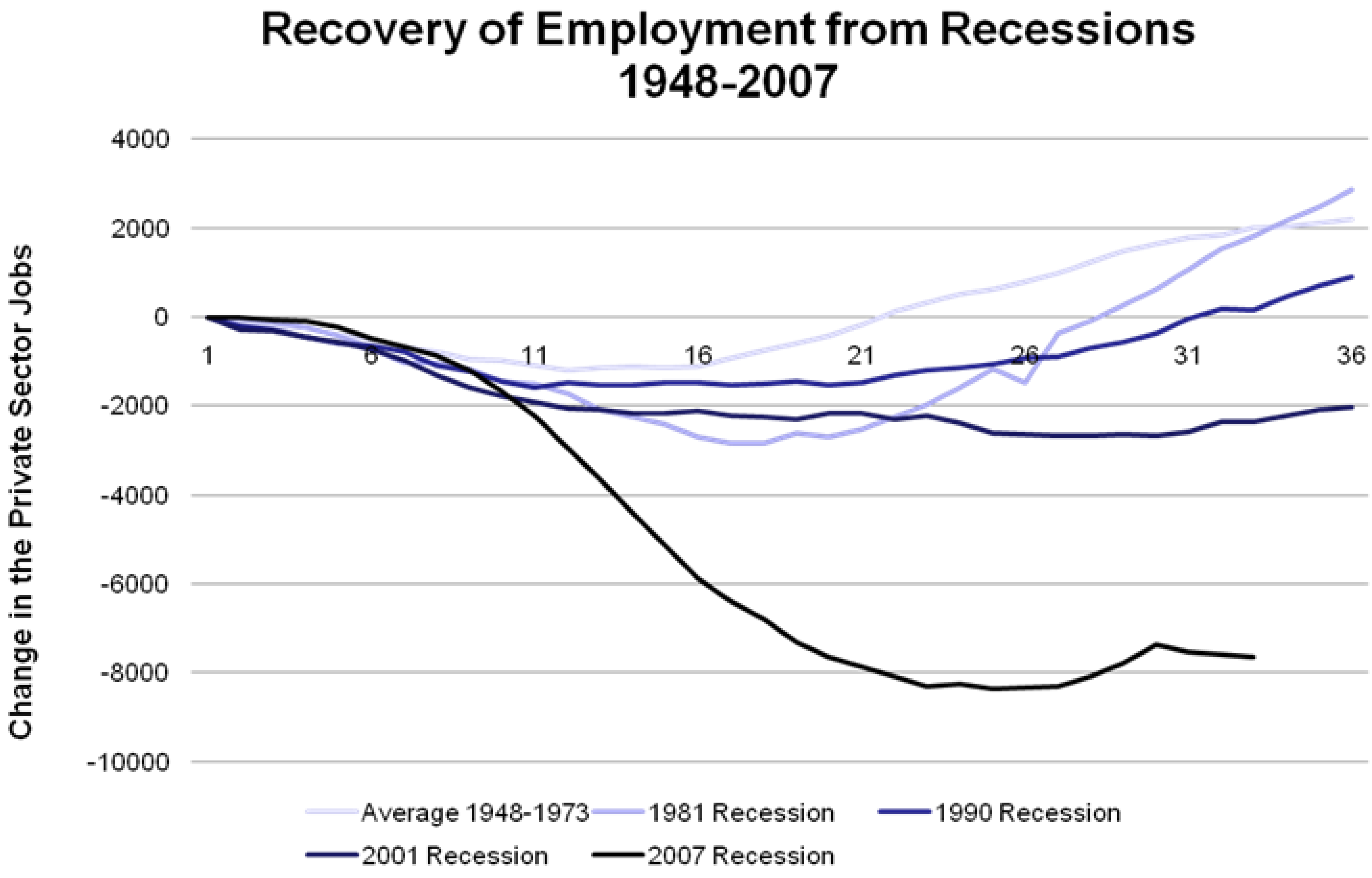
- NIST Laboratories
- Baldrige Performance Excellence Program
- Hollings Manufacturing Extension Partnership
- Technology Innovation Program

Importance of Innovation

- Half of economic growth due to technology in most industrialized nations[1]
- U.S. productivity advantage = 75% of positive difference in per capita income[2]
- R&D investment accounts for half of output growth and 75% of productivity growth[3]
- 70 of 71 of technology-oriented occupations exceed median earnings for all workers[4]
  - For half these occupations, incomes are 2x to 3x higher
- 84% of companies say innovation is “extremely important” or “very important” to their growth strategy



Problem: Employment recovery increasingly slow



Source: Bureau of Labor Statistics and NBER

Innovation and business

Company type	Companies (thousands)	New or significantly improved product: Any good/ service Yes	No	Goods Yes	No	Services Yes	No	New or significantly improved process: Any process Yes	No	Manufacturing / production methods Yes	No	Logistics/delivery/ distribution methods Yes	No	Support activities Yes	No
All companies[a]	1,545.1	9	86	5	91	7	88	9	86	4	91	3	92	7	88
With R&D activity[b]	46.8	66	30	52	45	38	58	51	44	34	62	20	76	36	60
< $10 million	44.8	66	31	51	45	38	58	51	45	33	63	19	77	35	61
≥ $10 but < $50 million	1.3	70	25	64	31	42	52	56	38	44	50	30	64	43	51
≥ $50 but < $100 million	0.3	76	18	71	24	51	43	69	25	57	36	43	50	55	38
≥ $100 million	0.4	81	15	77	19	56	37	71	22	60	34	54	40	61	32
Without R&D activity	1,498.3	7	88	3	92	6	89	8	87	3	92	3	93	6	89

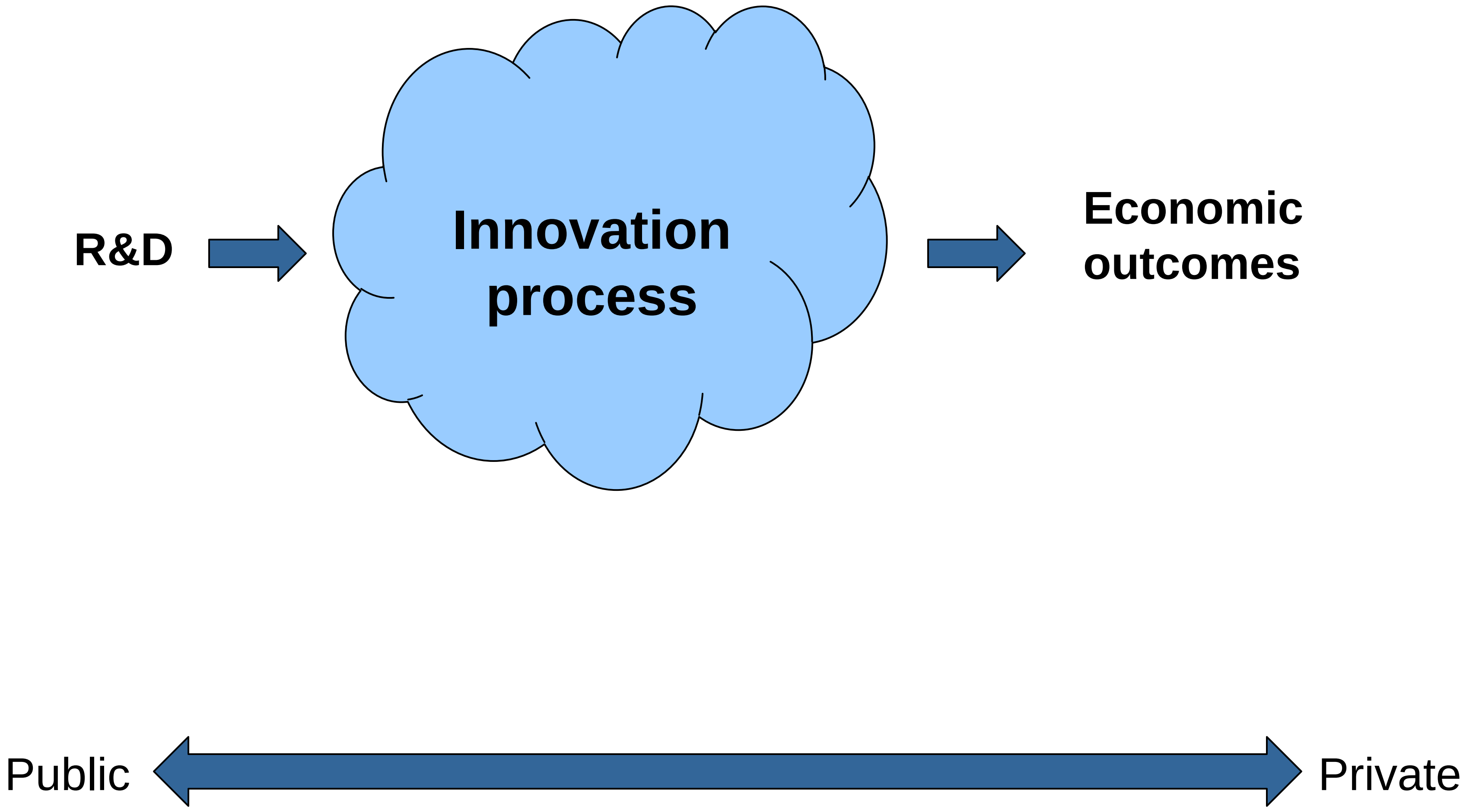
[a] Weighted totals for companies that reported on the 2008 Business R&D and Innovation Survey whether they did or did not perform/fund R&D. Weighted totals do not include the estimated 327,300 non-responding companies for whom an R&D status was not reported.

[b] Dollar ranges determined by total worldwide R&D expense plus total worldwide R&D cost funded by others.

NOTES: Survey asked companies to identify innovations introduced in 2006–08. Sum of yes and no percentages may not add to 100% due to item non-response to some innovation question items. Figures are preliminary and may later be revised.

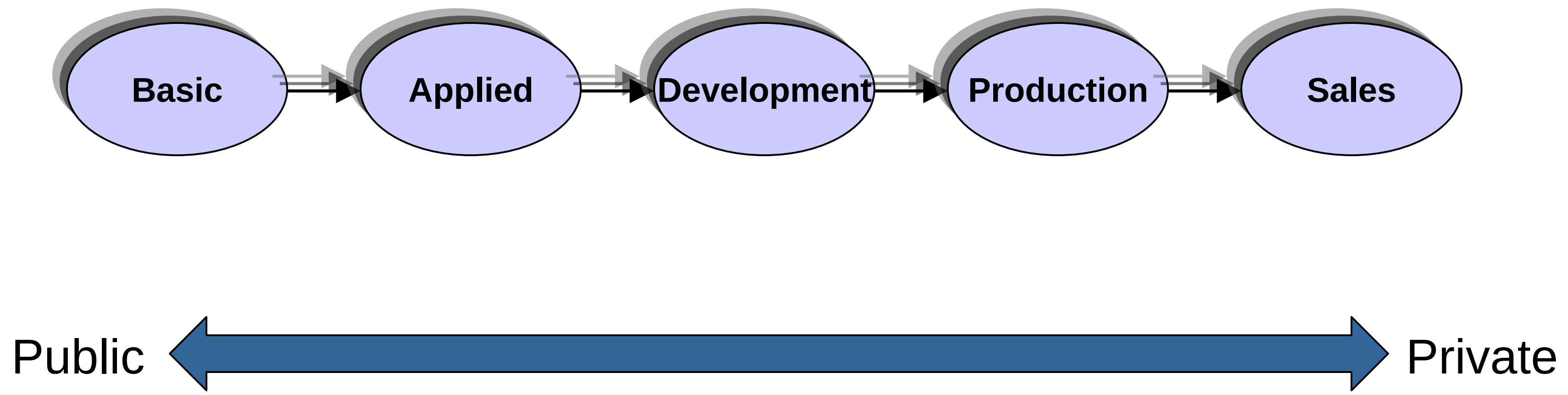
SOURCE: National Science Foundation/Division of Science Resources Statistics, Business R&D and Innovation Survey, 2008.

Innovation models



Basic models of innovation

Linear model… (circa 1945)



Elements of Innovation Systems

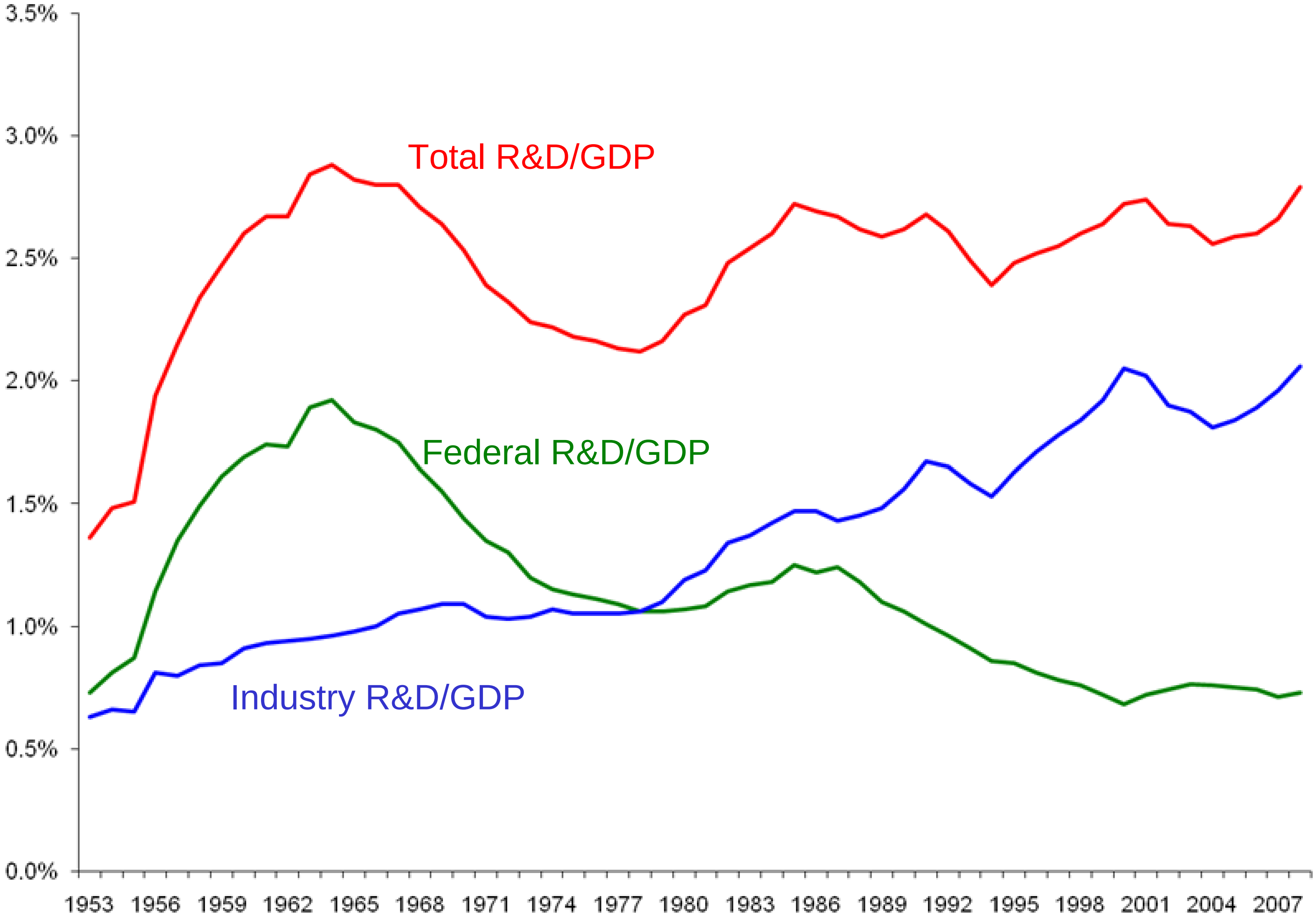
By performer

- Government
- Universities
- Industry
- Consortia
- Investors

By stage/process

- Discovery
- Tech transfer
- Commercialization
- Entrepreneurship
- Manufacturing
- Distribution/sales
- Marketing

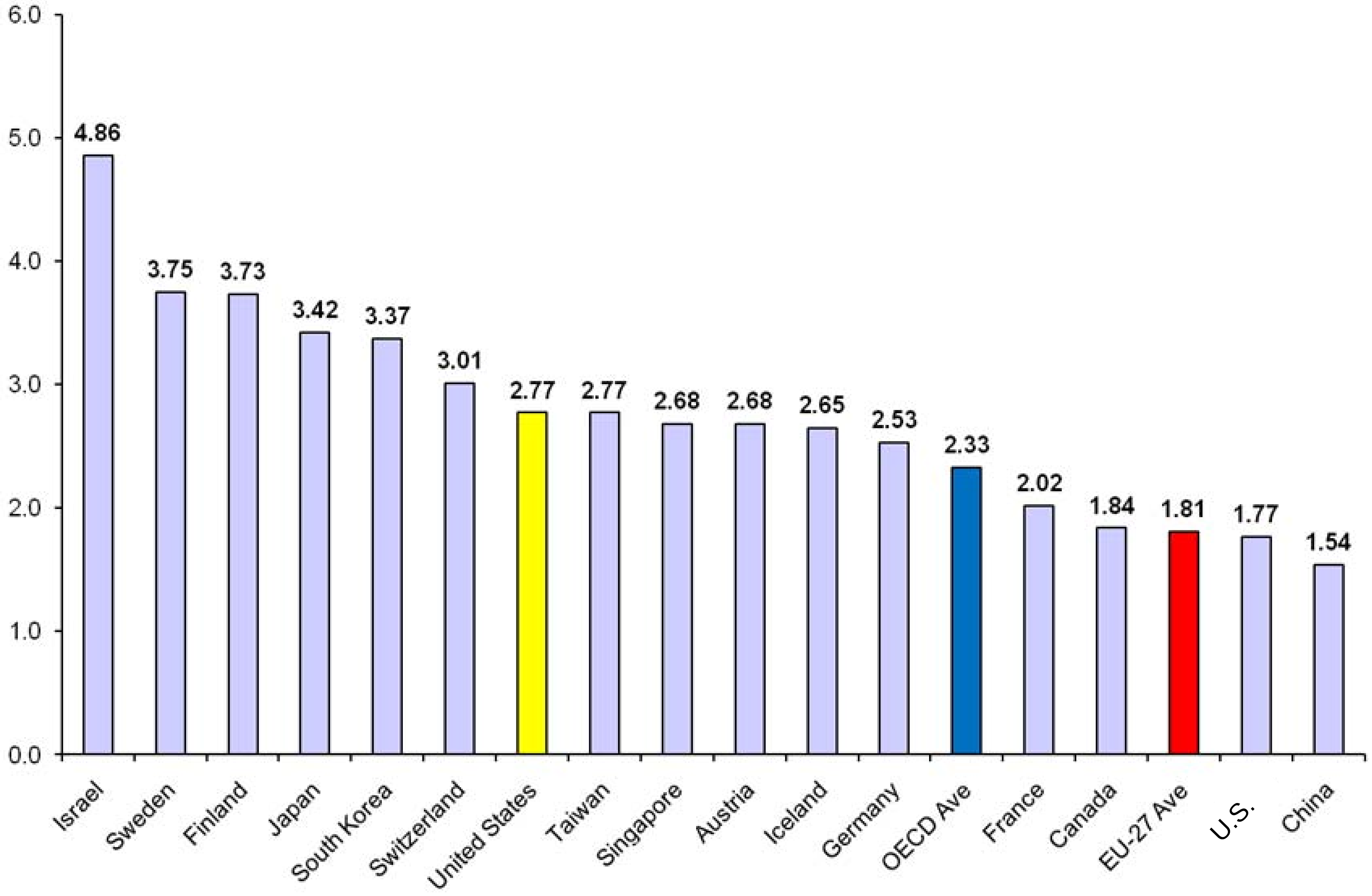
U.S. R&D Intensity: Funding as a Share of GDP, 1953-2008



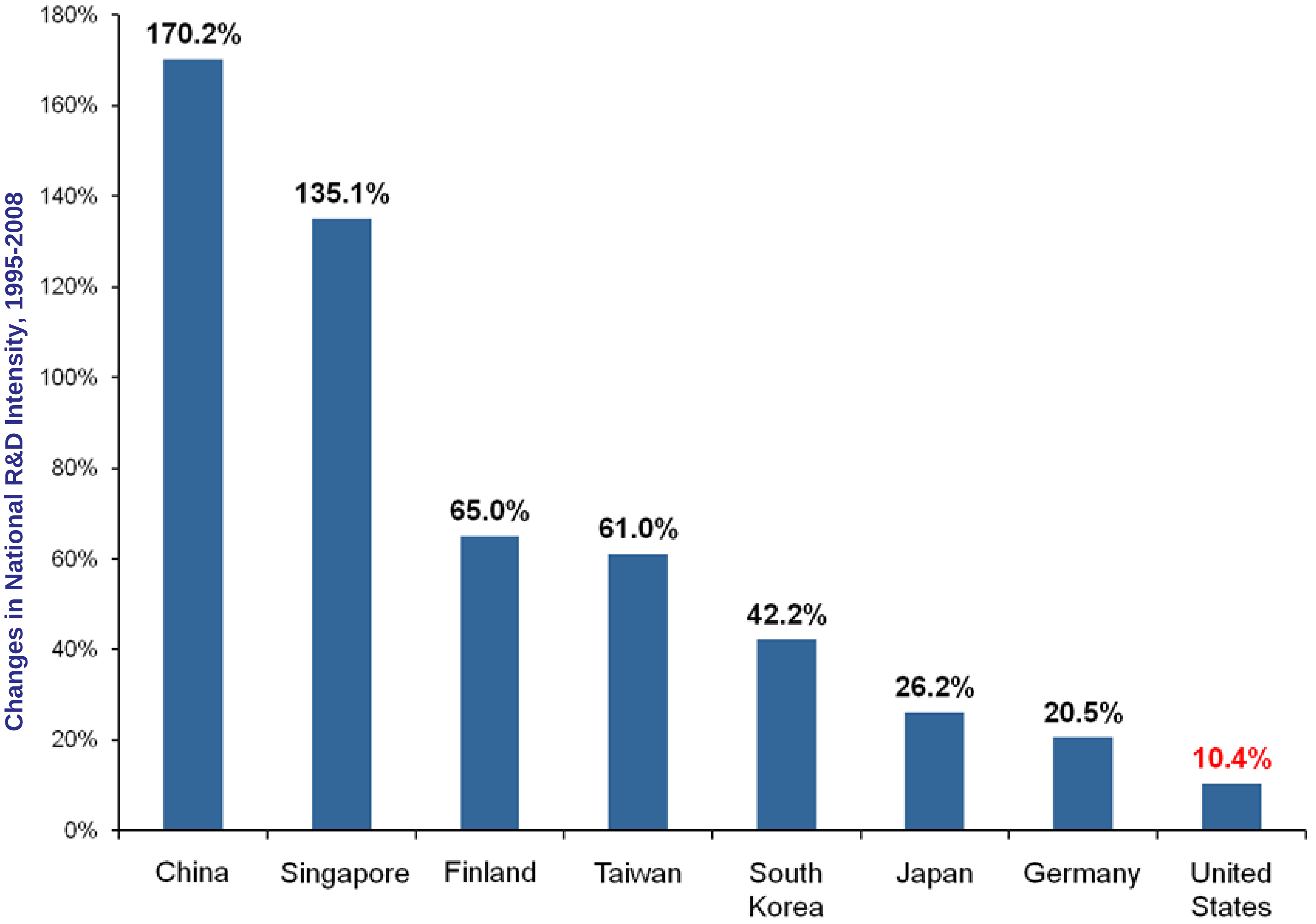
Source: National Science Foundation

National R&D Intensities, 2008

Gross R&D Expenditures as a Percentage of GDP

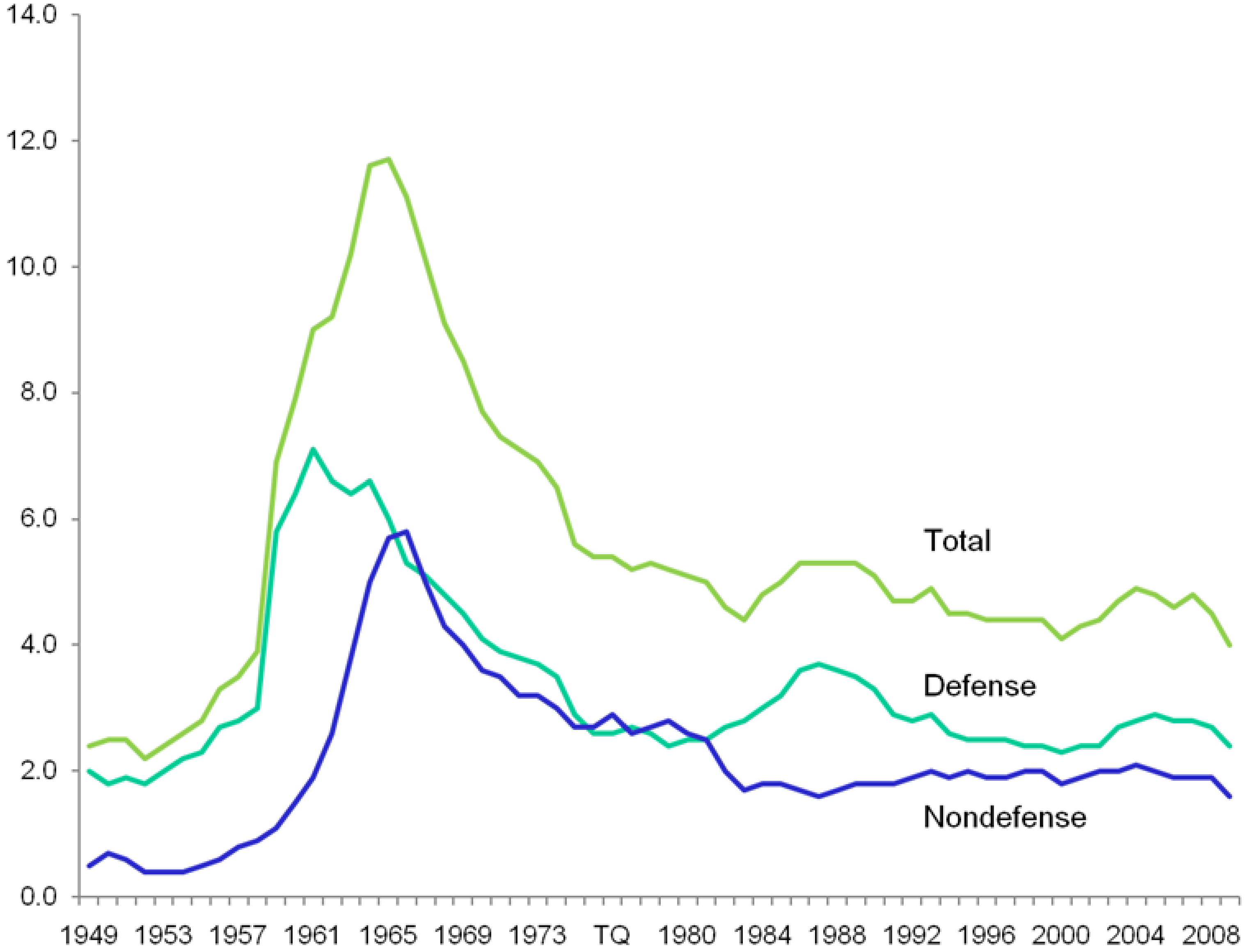


Source: OECD, *Main Science and Technology Indicators*, 2010.



Sources: OECD, *Main Science and Technology Indicators*, 2010/1

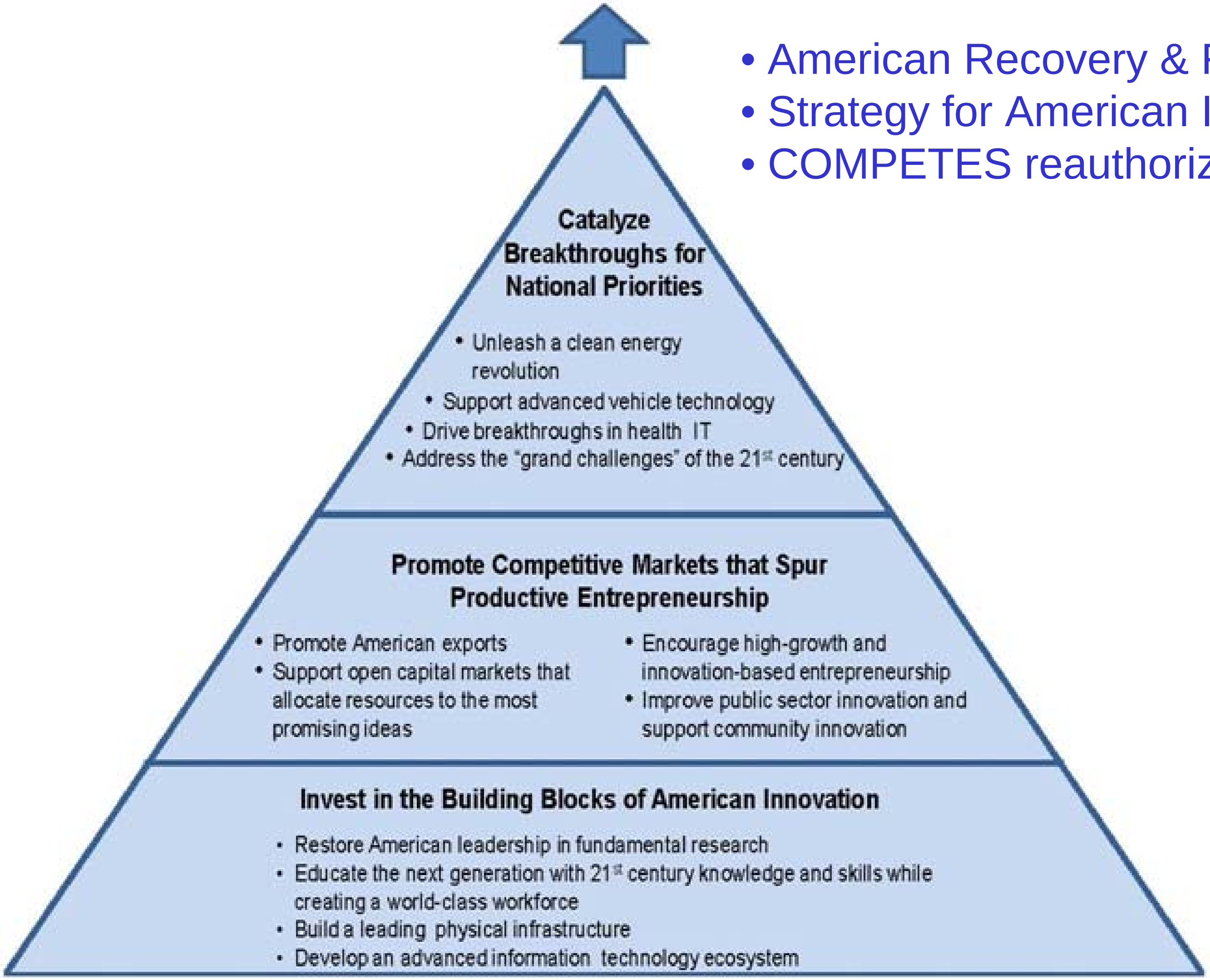
Federal R&D Spending as a Percent of Total Outlays, 1949-2009



Source: OMB Historical Table 9.7

Policy responses

- American Recovery & Reinvestment Act
- Strategy for American Innovation
- COMPETES reauthorization



University/college S&E expenditures

FY 2004–09
(Millions of current dollars)

Source of funds and character of work	2004	2005	2006	2007	2008	2009	% change 2004–09
All R&D expenditures	43,258	45,799	47,751	49,493	51,934	54,935	27%
Source of funds							
Federal government	27,644	29,209	30,128	30,443	31,281	32,588	18%
State and local government	2,879	2,940	2,962	3,143	3,452	3,647	27%
Industry	2,129	2,291	2,402	2,670	2,865	3,197	50%
Institutional funds	7,753	8,266	9,062	9,705	10,408	11,198	44%
Other	2,852	3,093	3,196	3,533	3,928	4,305	51%
Character of work							
Basic research	31,968	34,367	36,076	37,725	39,408	40,955	28%
Applied research and development	11,290	11,432	11,674	11,768	12,526	13,980	24%

S&E = science and engineering.

NOTE: Because of rounding, detail may not add to total.

SOURCE: National Science Foundation/Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges: FY 2009.

University Roles in Innovation

Education of the Future Workforce

- Best university system in the world attracts many of the best and brightest from around the globe.[1]
    - 7 U.S. universities in the top 10
    - 27 in the top 50
    - 72 in the top 200
- But, the U.S. ranks 7th in the world in proportion of the national population with a college degree; 16th in college completion rate; and 27th in the proportion of college undergraduates receiving degrees in science or engineering.[2]

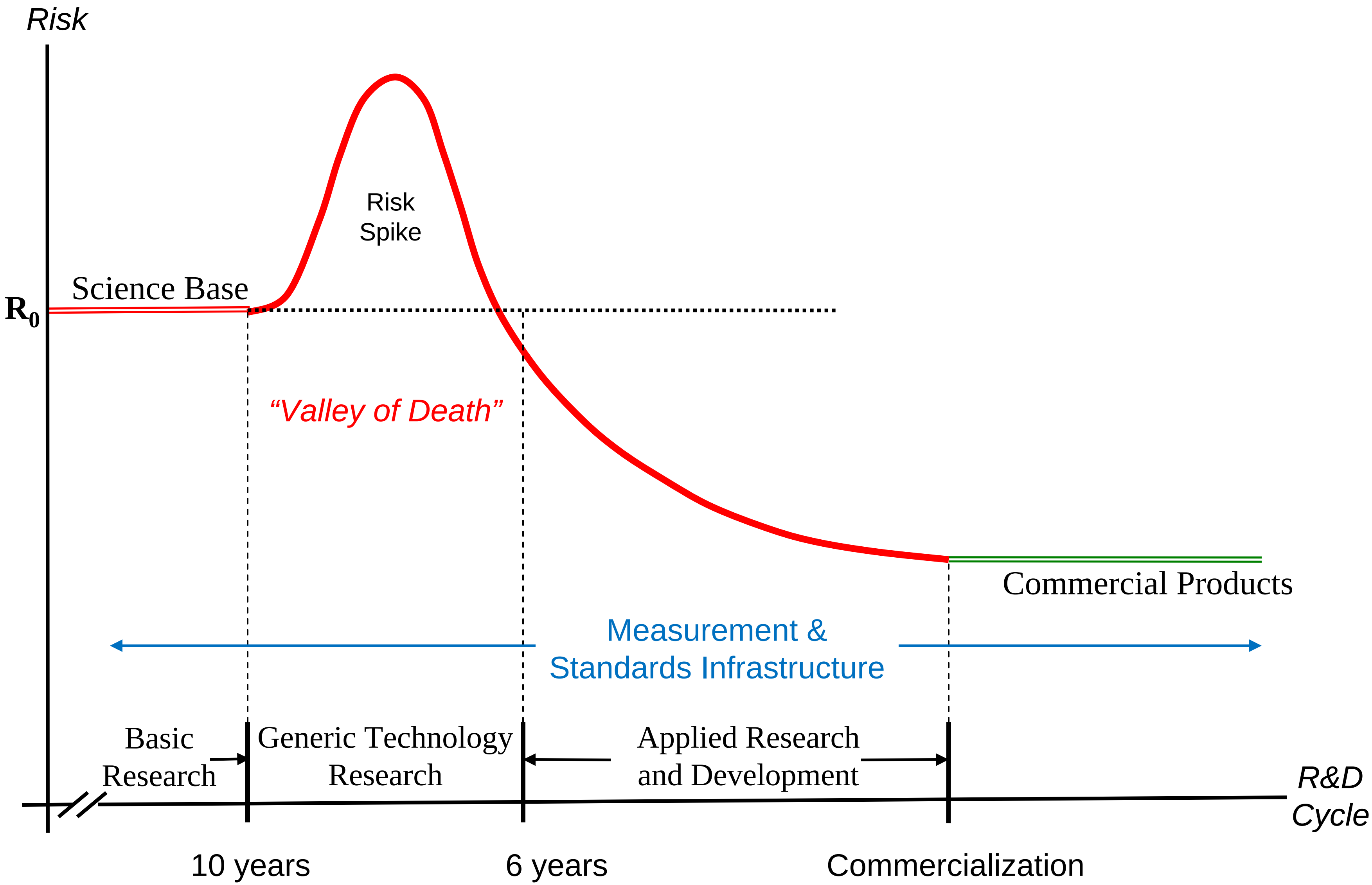
Primary Performer of Basic Research

- Universities perform over 40% of federally funded research
- Knowledge spillovers
- Increase national and regional capacity to absorb and apply new ideas

Economic Returns

- High rates of return: Average of 28% annually[3]
- More than 70% of “R&D 100” award winners (2006) based on university or other publically supported research (full or partial funding)
- Hubs of regional innovation networks

Overcoming the Innovation Risk Spike ("Valley of Death")



Source: G. Tassey, "Underinvestment in Public Good Technologies," *Journal of Technology Transfer 30: 1/2* (January 2005); and, "Modeling and Measuring the Economic Roles of Technology Infrastructure," *Economics of Innovation and New Technology 17* (October 2008)

Universities and Entrepreneurship

- Universities conducted more than $30 billion in federally supported R&D in FY 2008
- University Innovation Forums
  - Hosted by Secretary Locke, additional high-level participation by WH, DOE, NIH, NSF, etc.
  - D.C., Boston, L.A., Ann Arbor, Atlanta
  - Nearly 400 university leaders participated
  - How do we maximize the economic impact from federally funded university research?
- Areas identified for action:
  - Process improvements
  - Celebrating entrepreneurship
  - Expanded ecosystems

Case for a Domestic Manufacturing Technology Strategy

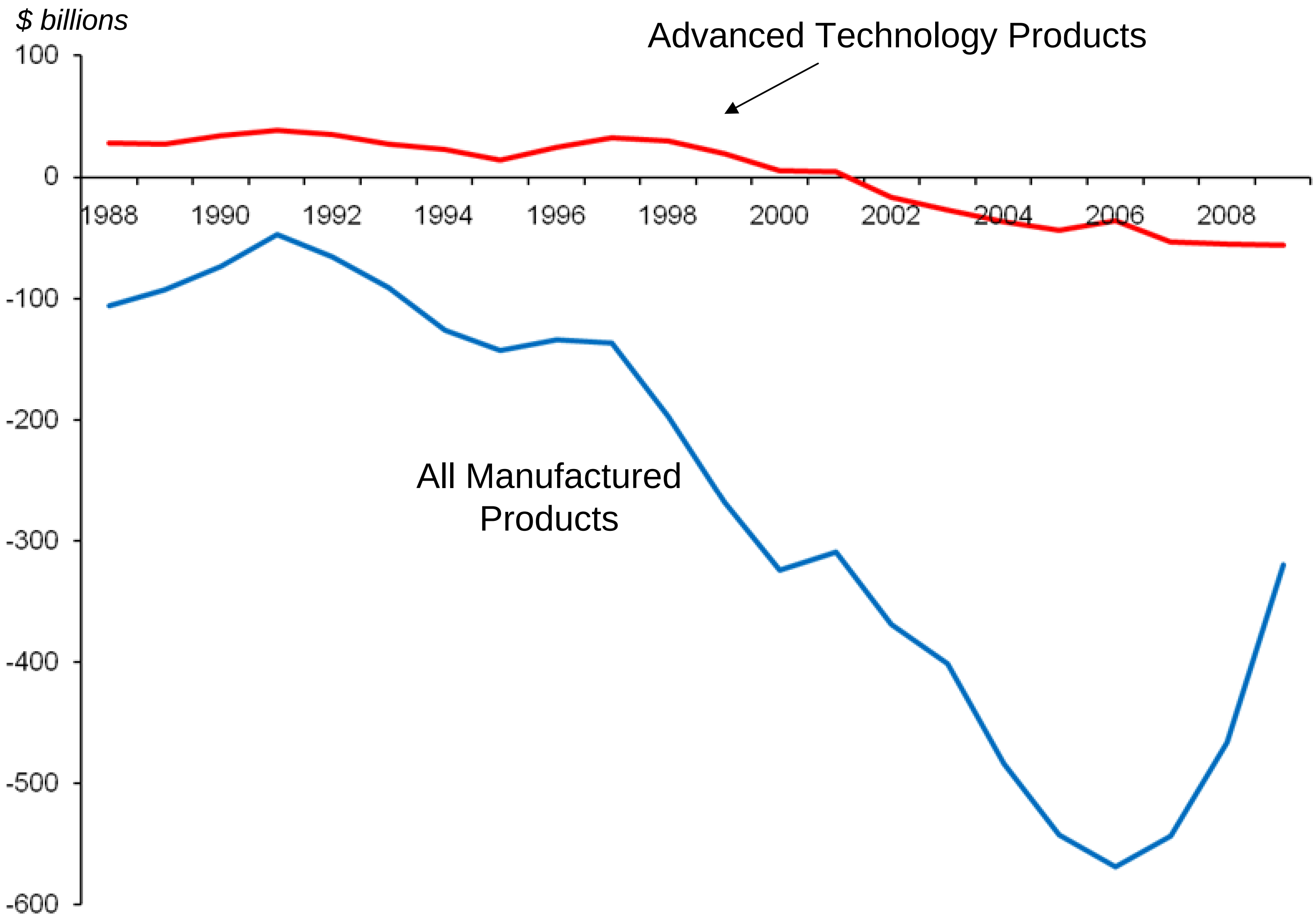
- Manufacturing contributes $1.6 trillion to GDP and employs 11 million workers
- High-tech service jobs are increasingly ''tradeable'' and 30 economies have policies in place to promote service exports

M. Malyshev

A. Pidjass

- Manufacturing accounts for 70% of U.S. industry R&D and of scientists/engineers
- High-tech workers paid substantially more and some of most technology-intensive industries are in manufacturing
- Majority of trade is in manufactured products

U.S. Trade Balances for High-Tech vs. All Manufactured Products, 1988-2009



Source: Census Bureau, Foreign Trade Division

R&D Intensive Industries Grow Faster

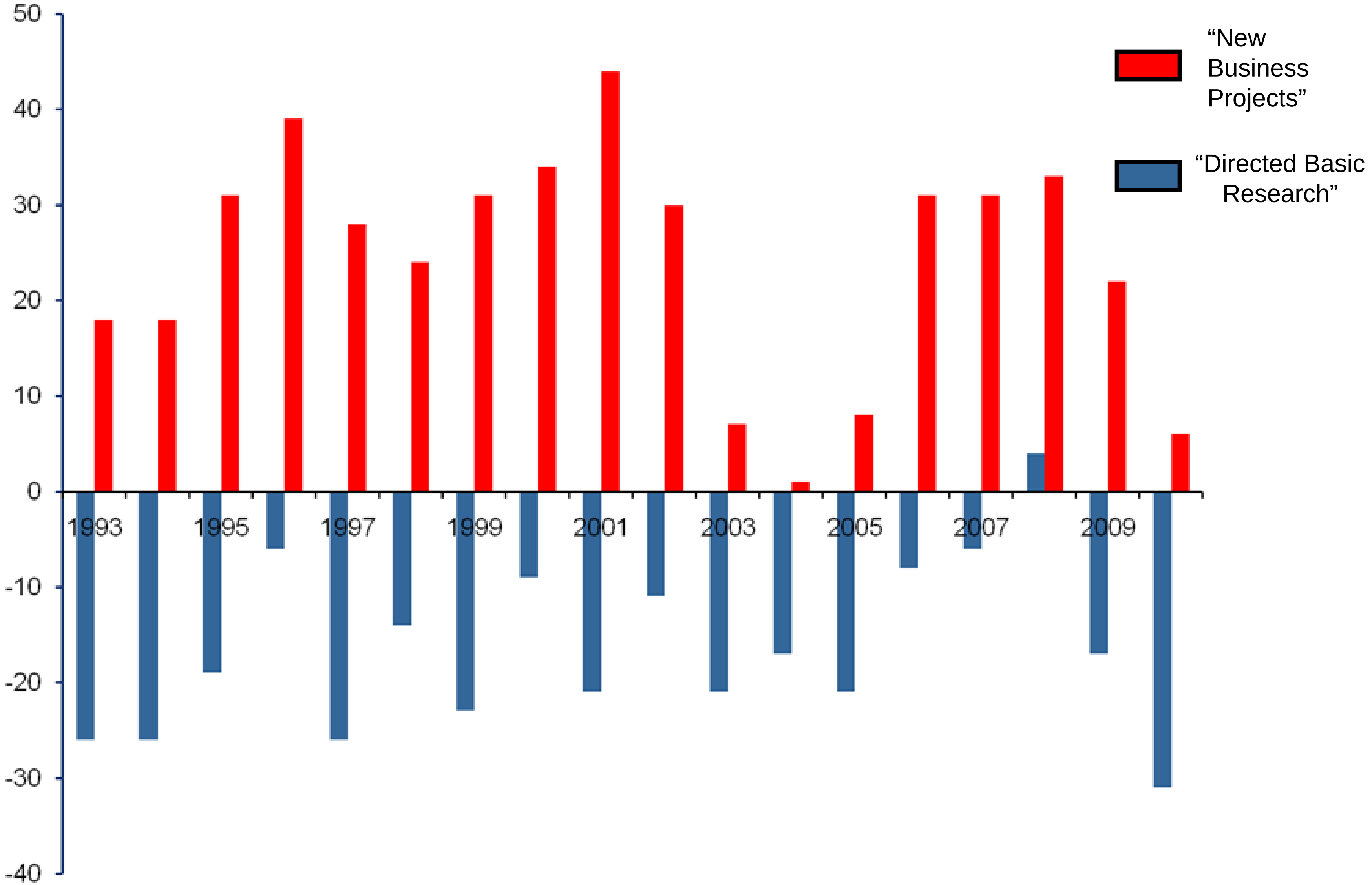
Relationship Between R&D Intensity and Real Output Growth

Industry (NAICS Code)	Average R&D Intensity 1999-2007	Percent Change in Real Output, 2000-2007
R&D Intensive:		
Pharmaceuticals (3254)	10.5	19.1
Semiconductors (3344)	10.1	15.4
Medical Equipment (3391)	7.5	28.4
Computers (3341)	6.1	106.2
Communications Equip (3342)	13.0	-42.3
	Group Ave: 9.5	**Group Ave: 25.4**
Non-R&D Intensive:		
Basic Chemicals (3215)	2.2	25.5
Machinery (333)	3.8	2.4
Electrical Equipment (335)	2.5	-13.6
Plastics & Rubber (326)	2.3	-4.5
Fabricated Metals (332)	1.4	4.9
	Group Ave: 2.5	**Group Ave: 2.9**

Sources: NSF for R&D intensity and BLS for real output.

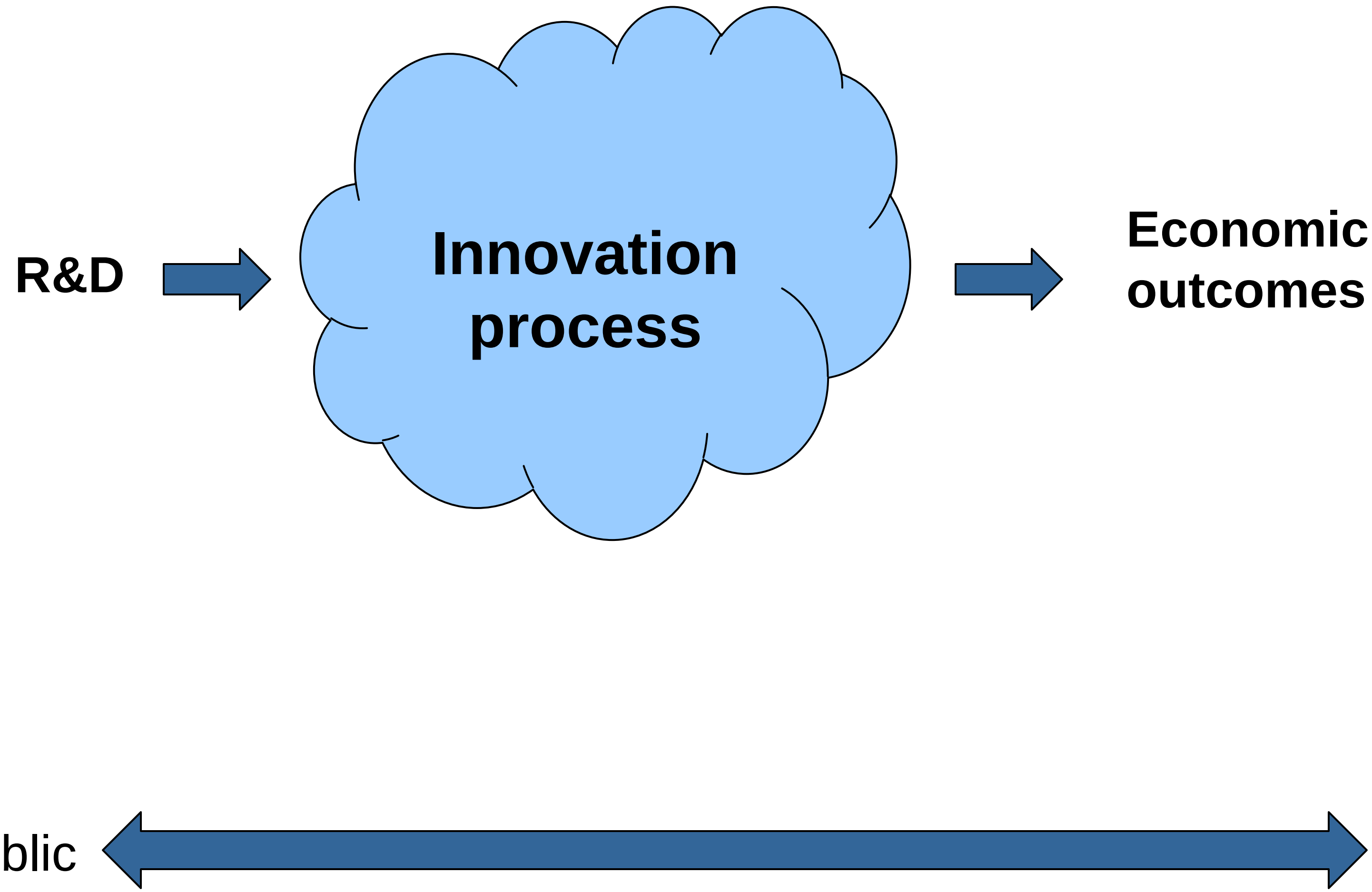
The "Valley of Death" is Getting Wider

Trends in Short-Term vs. Long-Term US Industry R&D, 1993-2010

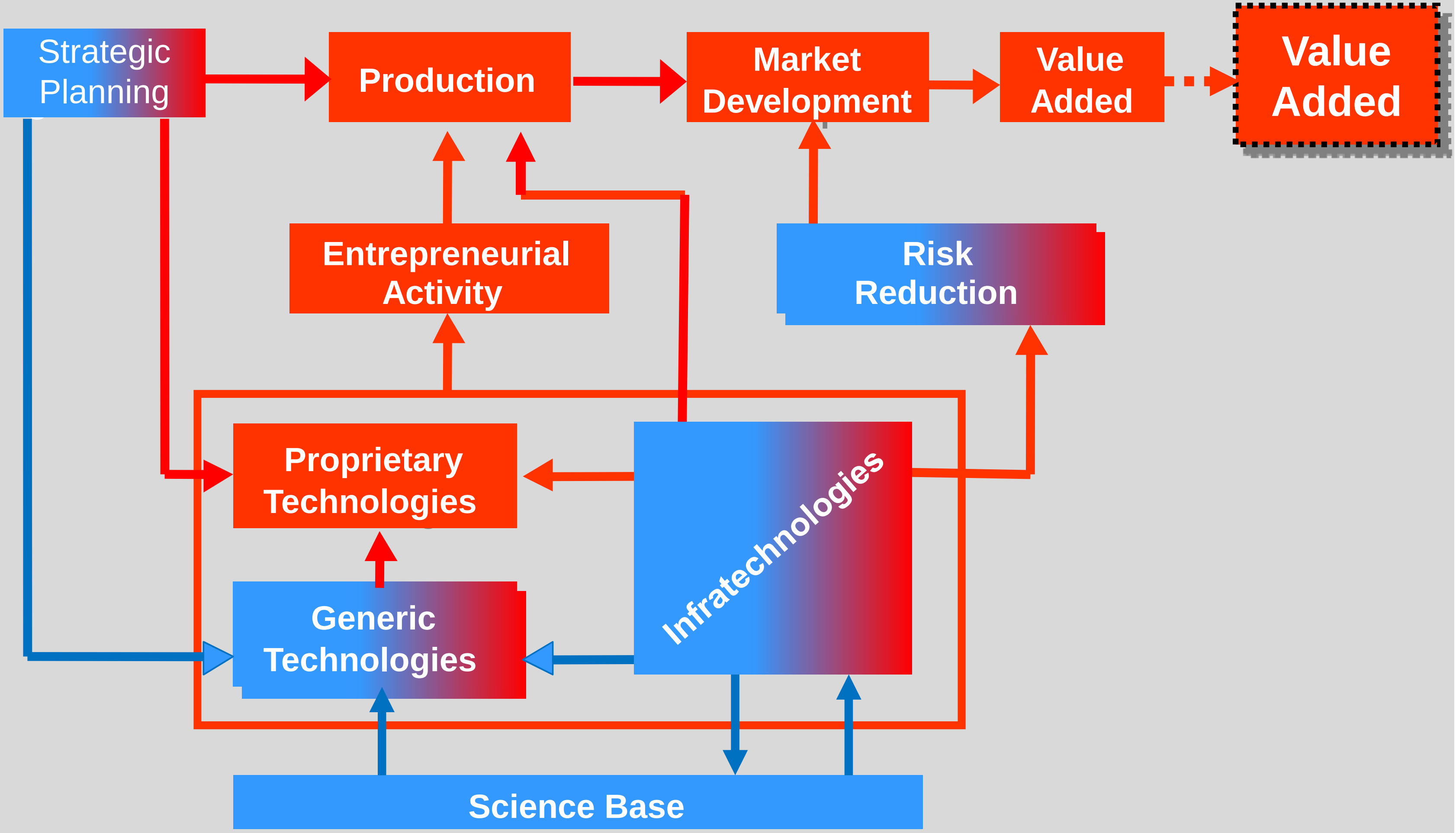


Source: Industrial Research Institute's annual surveys and calculation of "Sea Change Indices". A Sea Change Index is calculated by subtracting the percent of respondents reporting a planned decrease in the particular category of R&D spending from the percent planning an increase of greater than 5 percent. Sample size and respondents vary from year to year.

Innovation models

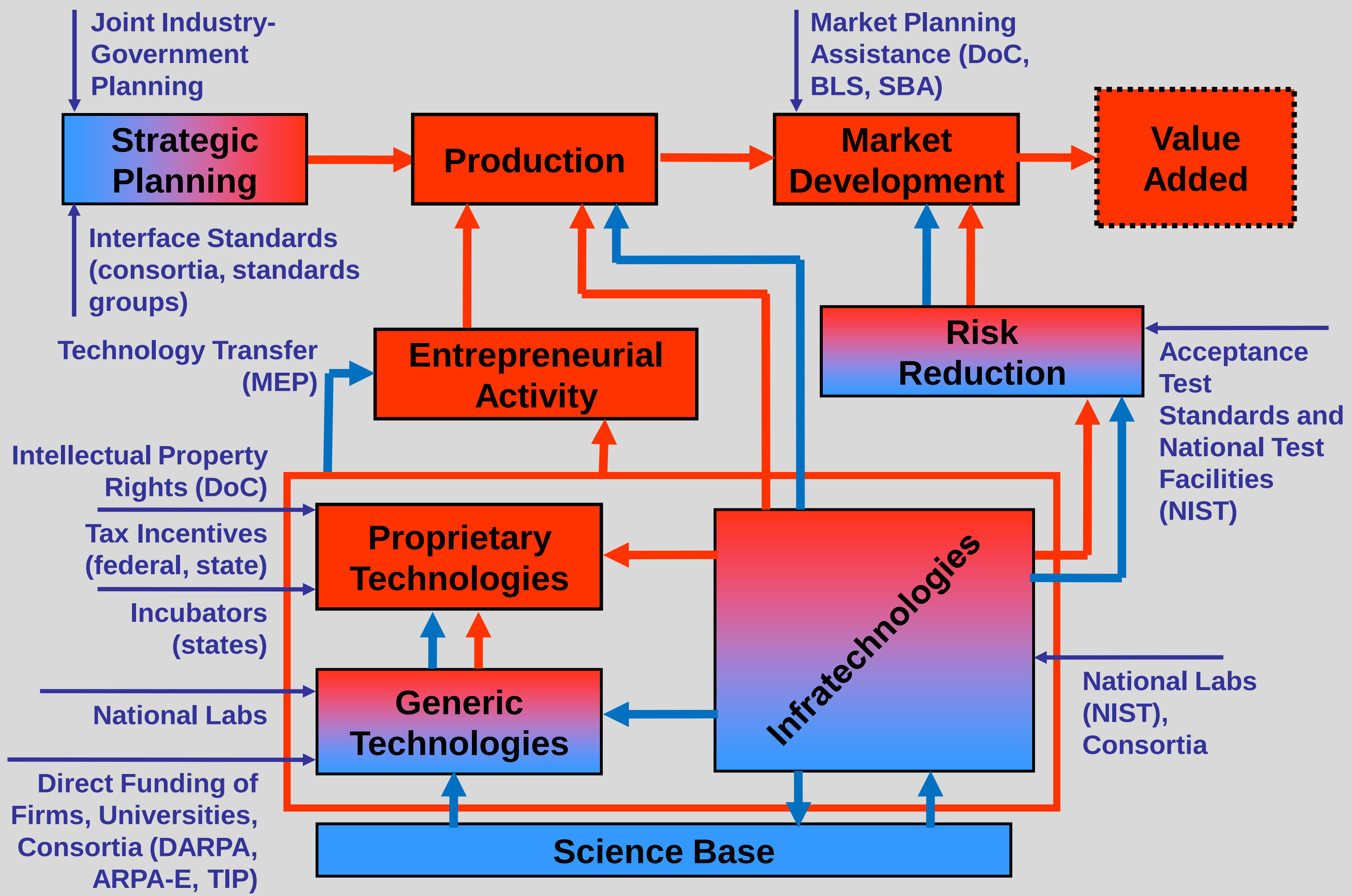


Economic Model of a Technology-Based Industry



Gregory Tassey, *The Technology Imperative*, 2007; and, "The Disaggregated Technology Production Function: A New Model of Corporate and University Research", *Research Policy*, 2005.

Science, Technology, Innovation, Diffusion (STID) Policy Roles



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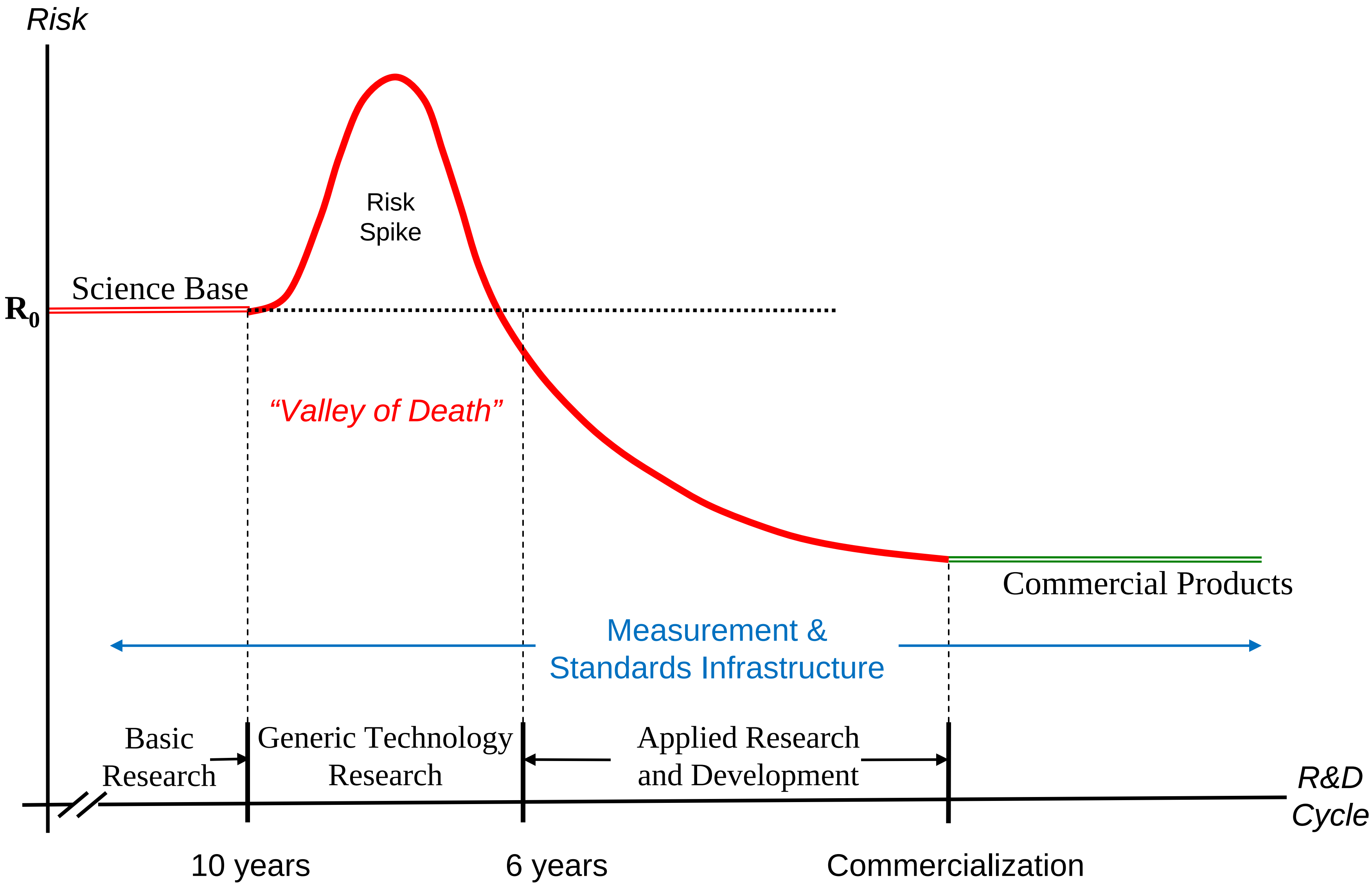

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Pilot Program with Nanoelectronics Research Initiative (NRI) Initiated in 2007

For pilot, NIST sought public-private partnerships to accelerate the support of research and innovation in nanoelectronics, an emerging area that exploits unique properties of nanometer-scale materials

Competition announced in Federal Register May 4, 2007

NIST/NRI partnership announced September 13, 2007

- The NRI is a collaborative effort between industry, government, and academia to support world-class research in nanoelectronics.
- NRI is part of the Semiconductor Research Corporation (SRC), which is part of the Semiconductor Industry Association (SIA)
- NRI goal: Demonstrate novel yet practical computing devices capable of replacing conventional chip technology by 2020

Cooperative agreement, renewable for up to five years

NIST provides funds combined and competitively awarded for research at U.S. universities to meet industry's long term needs

$2.76 million per year; six NRI partners match with at least 25% each

NIST NRI anoelectronics RESEARCH INITIATIVE SRC

NIST/NRI Funding

NIST NRI

AMD freescale semiconductor IBM intel Texas Instruments Micron

Strategic Planning and Evaluation

International Technology Roadmap for Semiconductors

POST-CMOS: NRI Defined 13 Research Vectors of primary importance for finding the next switch

$2.75M per year NIST

$5M per year Industry Partners

$15M per year States

$110M / over 5 years States & Private

University-Based Research

- **INDEX: Institute for Nanolectronics Discovery and Exploration**
- **MIND: Midwest Institute for Nanoelectronics Discovery**
- **SWAN: South West Academy of Nanoelectronics**
- **WIN: Western Institute of Nanoelectronics**

Research Results

Business Start-up, Development, and Commercialization

Regional Government Contributions:
- Grants
- Tax Incentives

Industry Contributions
- VC Funds
- Direct Investment

4 Centers, 35 Universities, 20 States

Nanoelectronics • Architectures

MIND

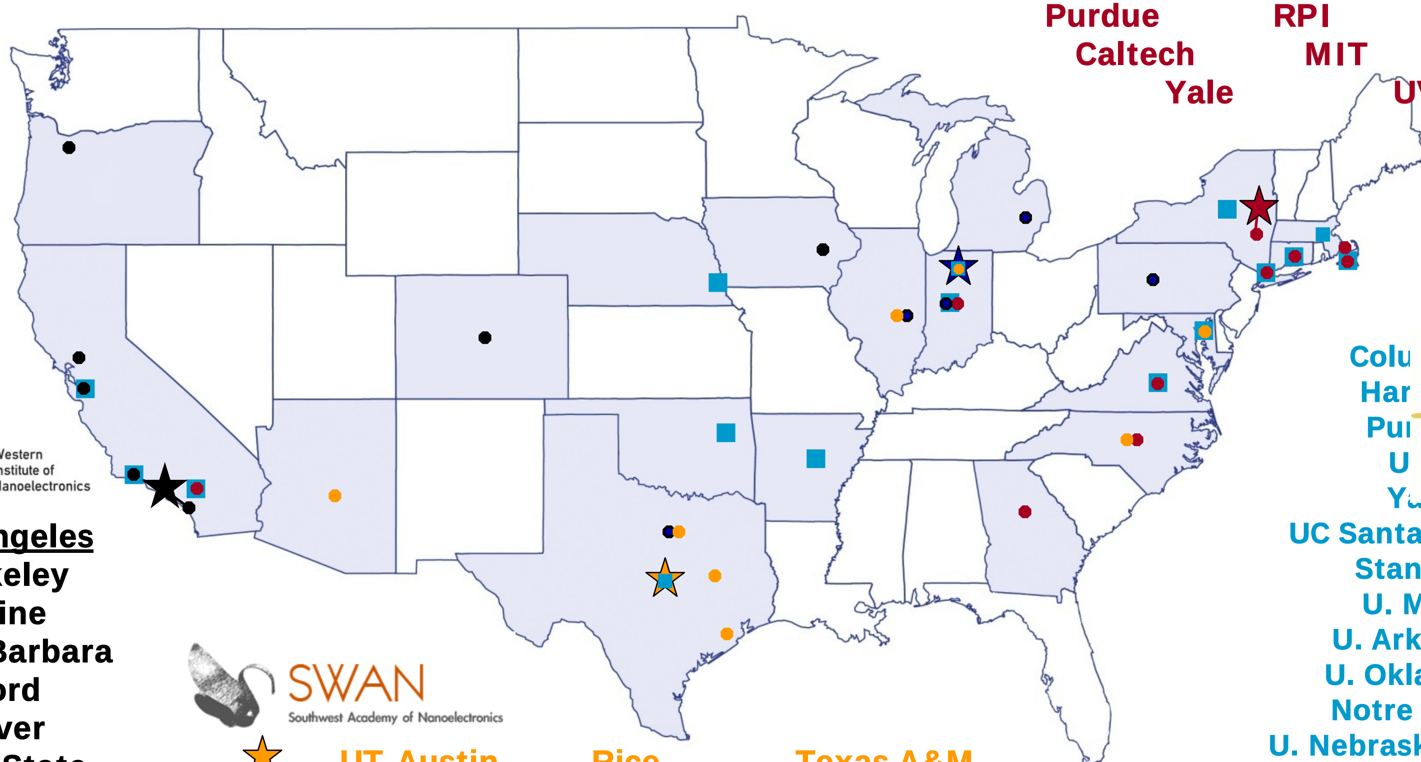
MIDWEST INSTITUTE FOR NANOELECTRONICS DISCOVERY

★ Notre Dame
Illinois-UC
Michigan

Purdue
Penn State
UT-Dallas

INDEX
INSTITUTE FOR NANOELECTRONICS DISCOVERY AND EXPLORATION

★ SUNY-Albany
Purdue
Caltech
GIT
RPI
MIT
Yale
Harvard
Columbia
NCSU
UVA



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U. Arkansas
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Notre Dame
U. Nebraska/Lincoln
U. Maryland
Cornell
UT Austin
Caltech

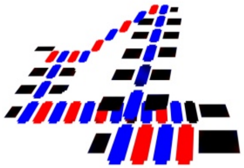
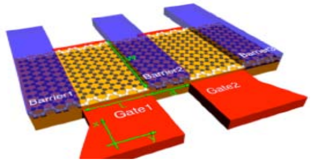
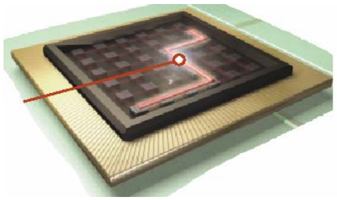
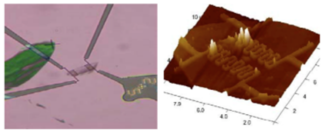
WIN
Western Institute of Nanoelectronics

★ UC Los Angeles
UC Berkeley
UC Irvine
UC Santa Barbara
Stanford
U Denver
Portland State
U Iowa

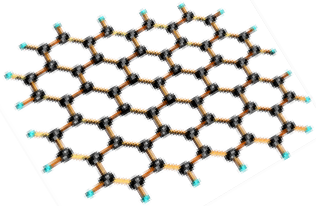
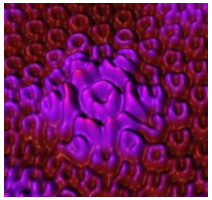
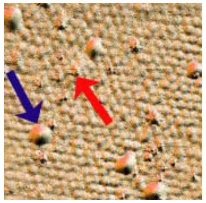
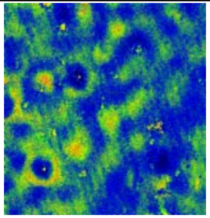
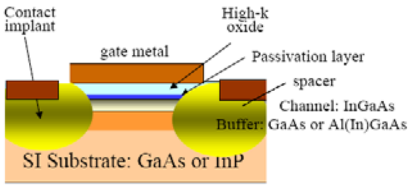
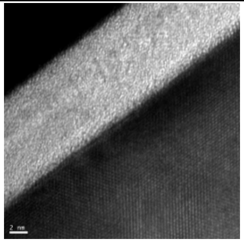
SWAN
Southwest Academy of Nanoelectronics

★ UT-Austin
UT-Dallas
U. Maryland
Rice
ASU
NCSU
Texas A&M
Notre Dame
Illinois UC

NRI Research Centers and Collaborations

NRI Center	WIN Western Institute of Nanoelectronics	INDEX Institute for Nanoelectronics Discovery and Exploration	SWAN Southwest Academy of Nanoelectronics	Nanoelectronics • Architectures MIND Midwest Institute for Nanoelectronics Discovery
Sample General Project	Spintronics	Post-CMOS Switches	Novel structures and architecture	Energy-Efficient Devices
Sample Individual Project	Magnetic Dot Logic 	**Graphene-based Quantum Devices** 	 **NanoPlasmonics**	**Thermal Transport and Thermal Logic Gates** ***Chen et al.*** **Purdue and NML**  Patterned graphene nanostructures

Credits (left to right): J. Bokor/Berkeley et al.; C. Marcus/Harvard et al.; Y. Massoud, Rice et al.; Chen et al., Purdue/NML

NIST-Georgia Tech Measurements of electrical conductivity in graphene	   
NIST/Notre Dame and NIST/UT-Dallas Characterizing the interface between III-V substrates and gate electrode in next generation high-mobility transistors	 

Credits (left to right): Rutter et al., Georgia Tech/NIST; UT-Austin

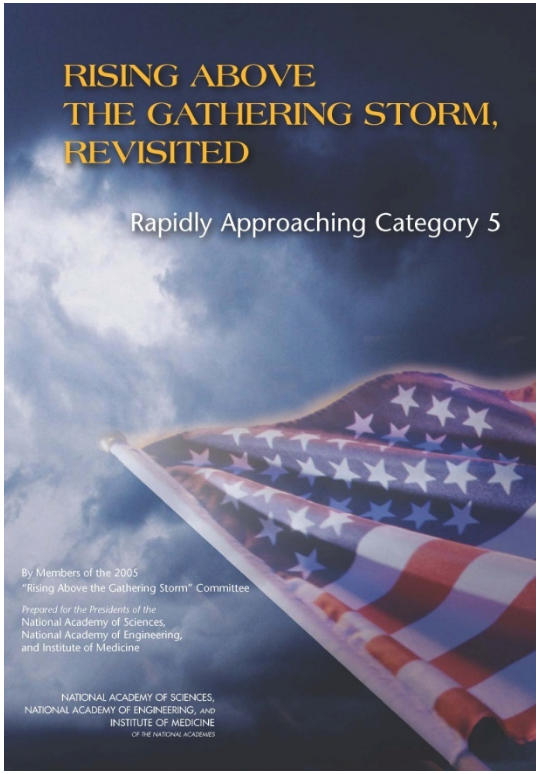
Innovation Cluster: NIST/NRI Partnership 2007-2009

- NIST/NRI supports PIs from over 30 universities to work at 4 regional centers
- Supports 128 graduate students, 24 post docs
- Produced 239 publications in last two years
- Applied for 13 patents

Regional centers	Graduate Students	Post Docs
Western Institute of Nanoelectronics (WIN)	38	6
Institute for Nanoelectronics Discovery and Exploration (INDEX)	24	2
Southwest Academy of Nanoelectronics (SWAN)	26	11
Midwest Institute for Nanoelectronics Discovery (MIND)	40	5

A call to action

- In 2009, 51% of US patents were awarded to non-US companies
- There are 16 energy companies with larger reserves than the largest US company
- Manufacturing in the US computer industry is now lower than when the first PC was made in 1975
- China has now surpassed the US as the world's number one *high technology* exporter.
- Survey of global firms planning to build new R&D facilities say 77% plan to build in China or India
- The US ranks 27th among developed nations in the proportion of college students receiving undergraduate degrees in science or engineering.
- Over past 15 years, China has moved from 14th to 2nd place, behind the US, in the number of published research papers



Moving forward

"The unanimous view of the committee members participating in the preparation of this report is that our nation's outlook has worsened."

"The only promising avenue for achieving [American prosperity]… is through innovation."