Evaluating Research & Science Based Programs

Crossing the Valley of Death:
The Challenge of Early-Stage Finance

Cambridge-MIT Institute
Cambridge, England
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Director, Technology and Innovation
National Research Council

Presentation

- The US Innovation Ecosystem
  - The Aggregate Picture: Trends & Anomalies
  - Myths and Realities about the US Innovation Ecosystem
  - Importance of Small Business in the US Innovation Ecosystem
- Crossing the Valley of Death
  - Multiple Sources of Funding
  - US Innovation Programs—SBIR and ATP
  - The Role of Universities
- The Challenge for the United Kingdom
- Conclusions

The U.S. National Academies

NAS

NAE

IOM

NRC

NRC Mission:

- The NRC is the Operating Arm of the National Academies; it includes 1300 Staff and a Budget of $160 Million
- The NRC Mission is the Advise the Government on Science, Engineering, and Medicine: 270 Reports Each Year

US-UK Cooperation in S&T

- Shared goals and collaborations
  - Common interest in vaccines, biometric idenfiers, and other counterterrorism technologies
  - Shared collaboration in scientific research continues in the tradition of Watson and Crick's discovery of DNA structure
  - Institutional collaboration—Cambridge-MIT Institute
- Shared Preeminence in Science
  - The UK is second only to the US in the volume and influence it scientific publications
- Shared interest in building the knowledge economy
  - Active policy interest in fostering SME's, licenses, and patents from research
  - New focus on linking university research with entrepreneurship within national innovation systems

"Government and scientific research is not enough on its own. We also need to make sure that scientific innovation gets translated into applied uses in business"

"Science Matters"

Speech by Rt. Hon. Tony Blair, PM

10 April 2002

What is a National Innovation System?

- A network of institutions in the public and private sectors whose activities and interactions initiate, develop, modify, and commercialize new technologies
  - Governments increasingly seek to transform such systems to promote innovation—to improve return on R&D investments in terms of improved competitiveness, welfare and wealth
  - Can be better understood as an Eco-system

Why National Innovation "Eco-Systems"?

- "Eco-Systems" Because Innovation Systems Grow and Evolve
  - They are not constructed by an engineering team to reach a fixed point
  - Ecosystem characterized by dynamic linkages among multiple sub-systems
- The Good News: New policies and institutional change can help ecosystem to grow in new ways for new needs

National Innovation "Eco-Systems"

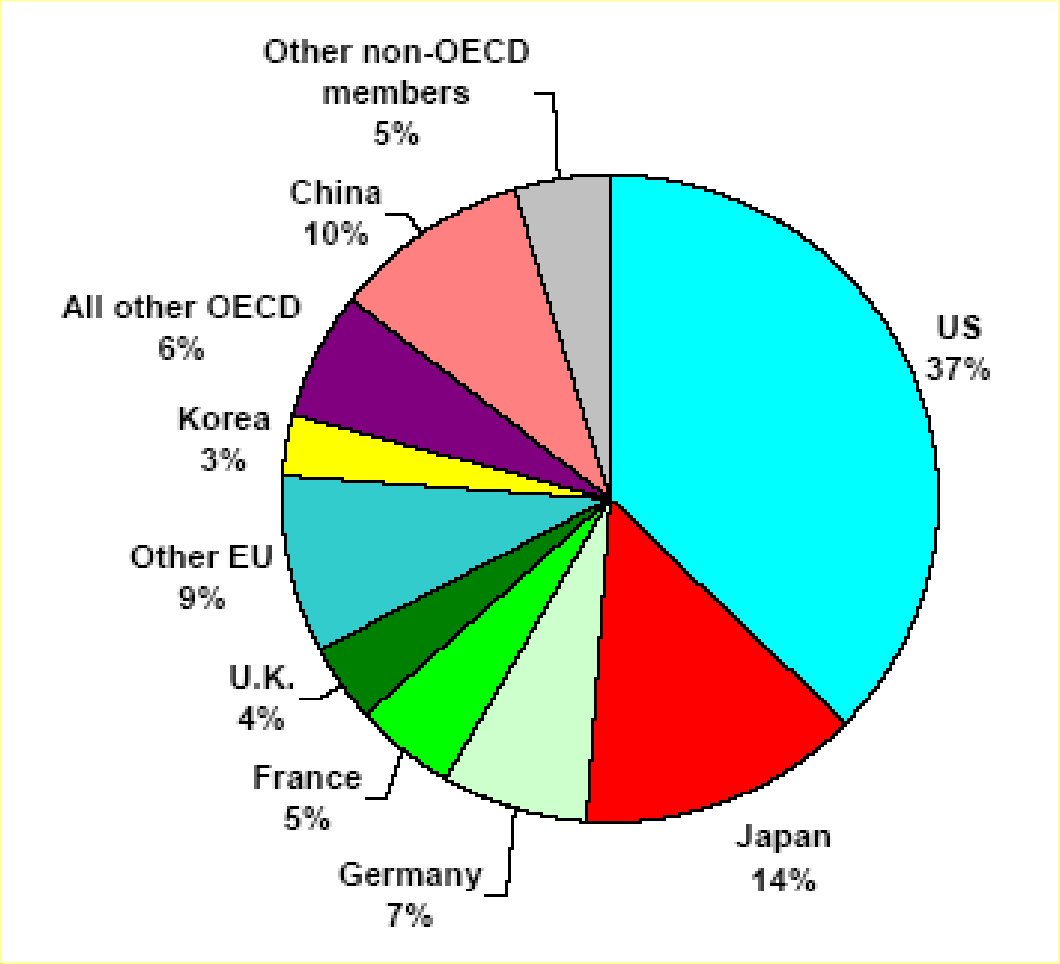
- Ecosystem strengthened through better linkages among a Nation's
  - Human Resource base,
  - Information Infrastructure
  - Universities and Research Institutes,
  - A Positive Business Environment
  - Enabling Government Policies and Programs
- The Policies drive the System

The U.S. Innovation Ecosystem

The Aggregate Picture

Strong U.S. Commitment to R&D

Shares of Total World R&D, 2001



Total World R&D = $746.7 billion

U.S. share = $276 billion

EU share = $187 billion

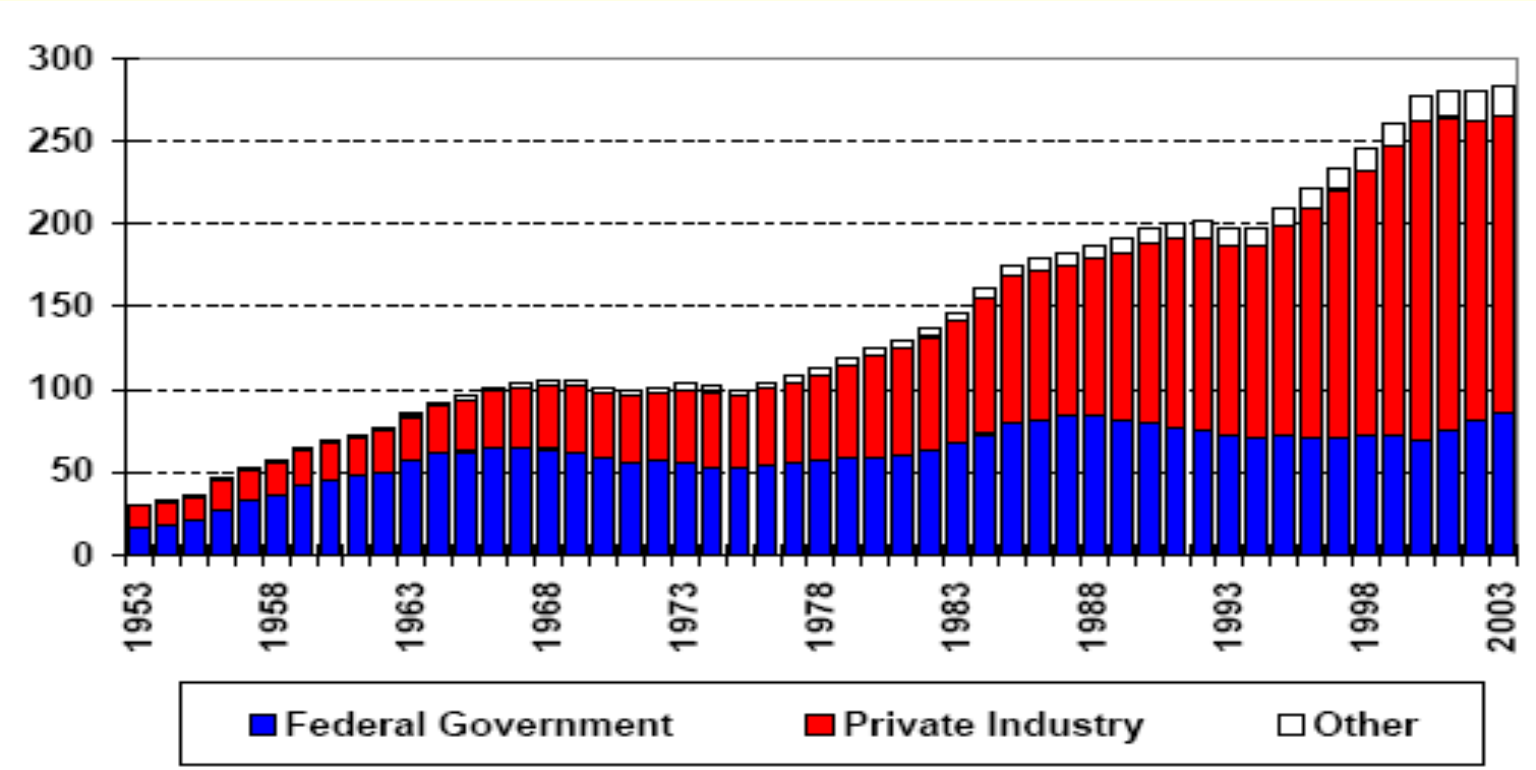
Source: OECD Main S&T Indicators, 2004; AAAS, 2004

Calculated using purchasing power parities, Jan 2004

Trends in U.S. R&D Funding

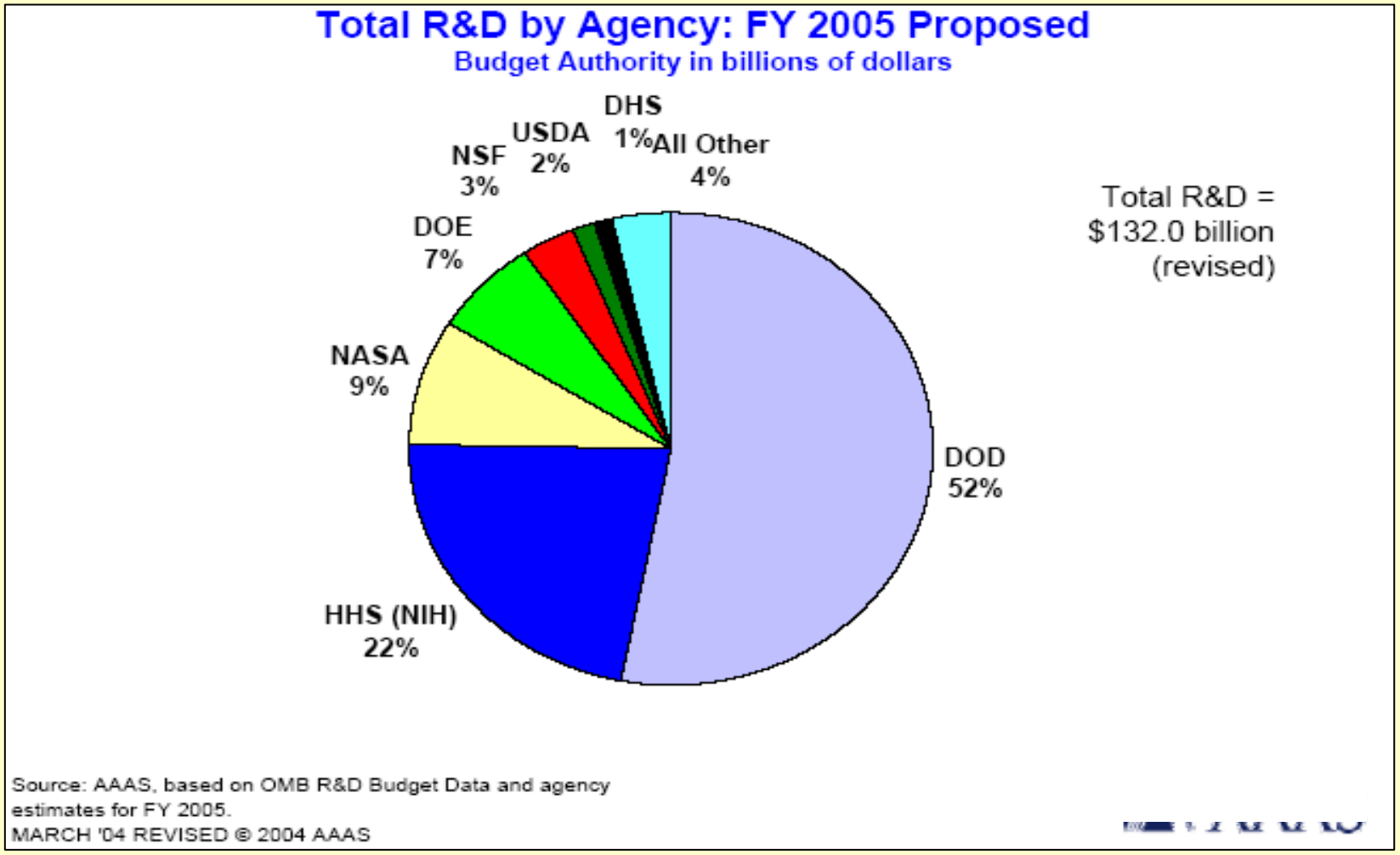
There is Good News, but...

Total R&D is Rising (but Federal R&D Spending is flat)



Source: NSF, Division of Science Resources Statistics. (Data for 2002 and 2003 are preliminary.)
FEB. '04 © 2004 AAAS

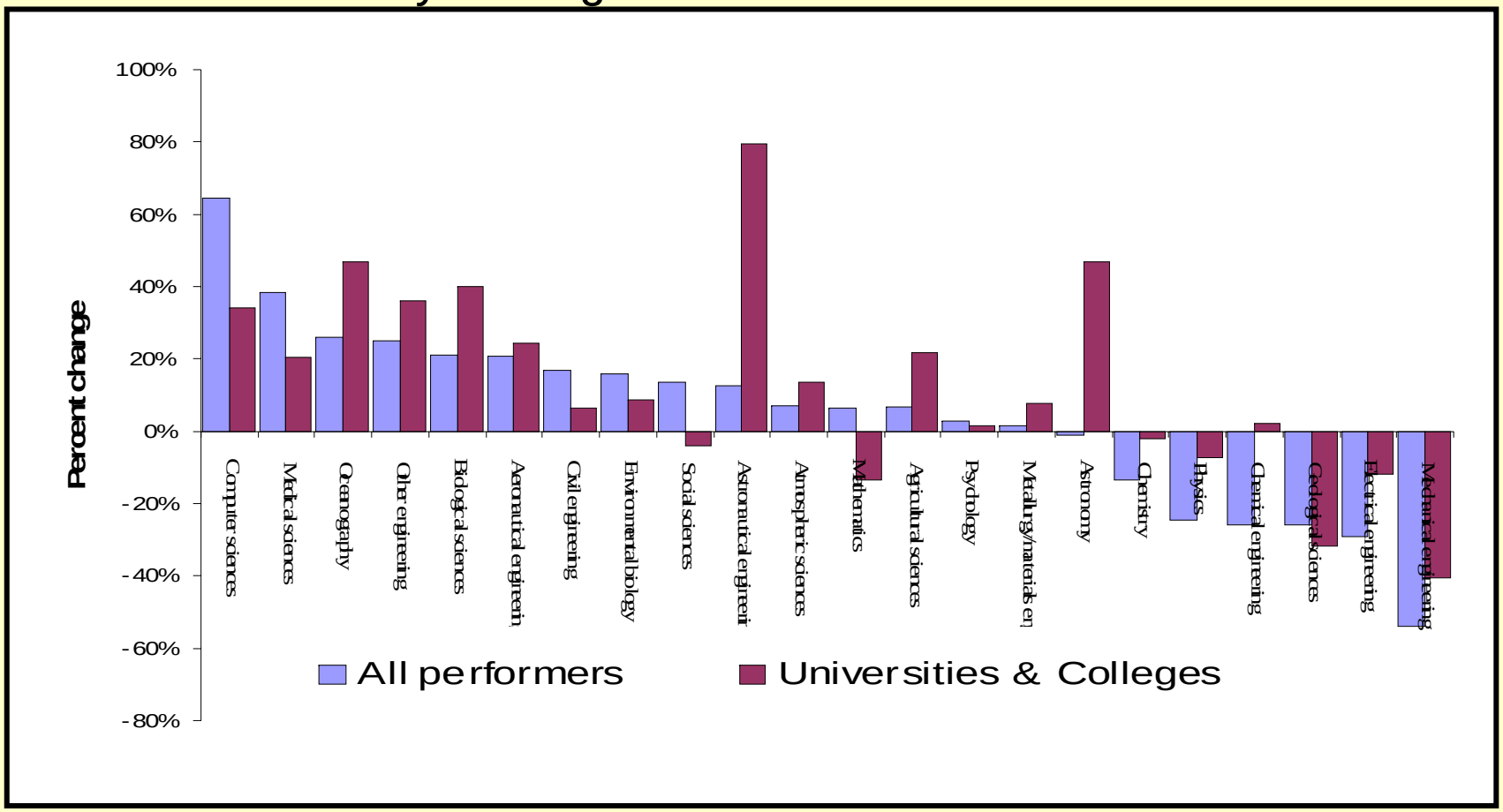
Total R&D by Government Agency



Trends in U.S. R&D Funding

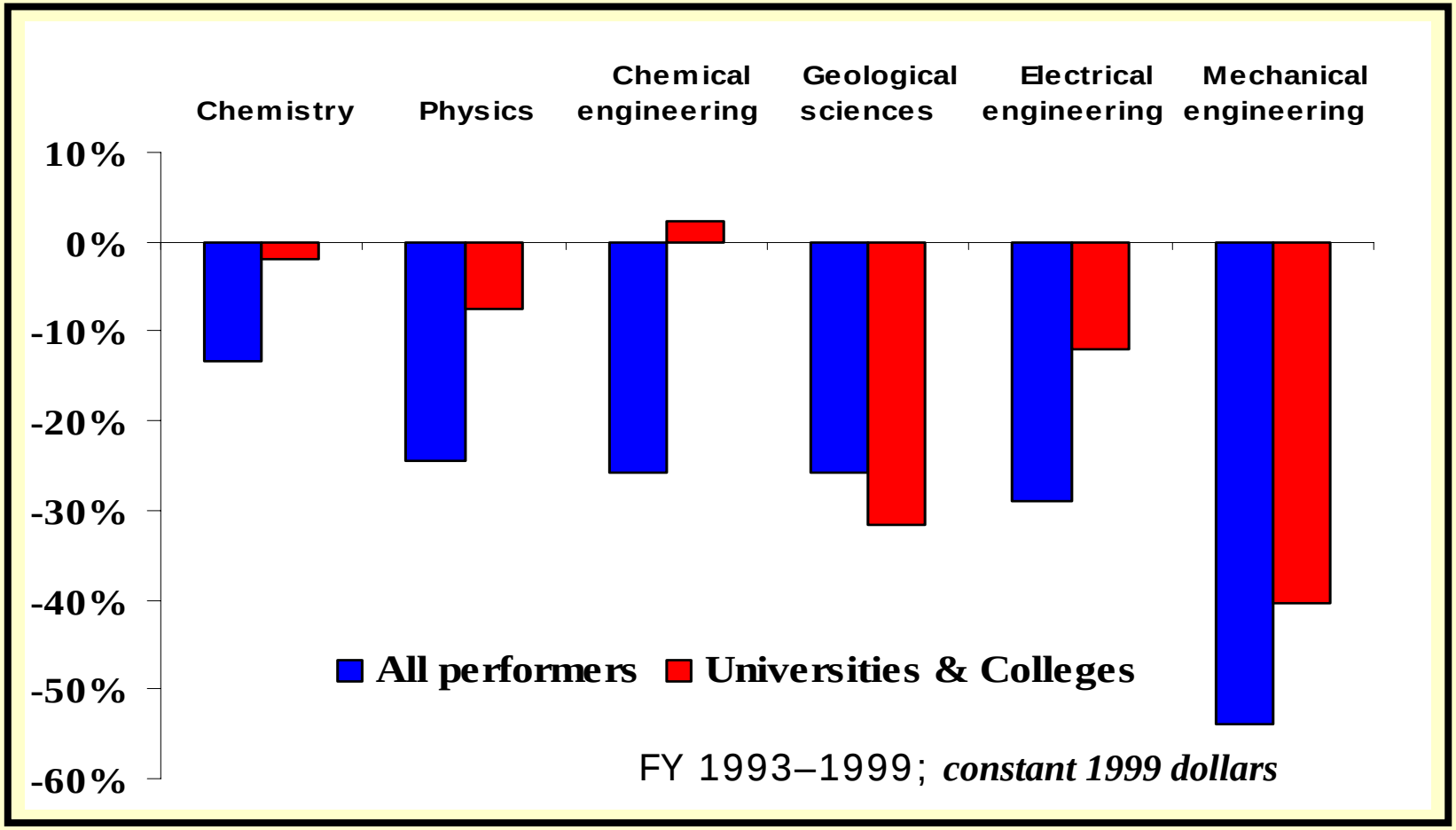
The Bad News: An Uneven Record

Changes in Federal Research Obligations for All Performers and University/College Performers FY 1993–1999



The Really Bad News

Random Disinvestment: Real Declines for Research in Physics, Chemistry, & Engineering Risk a Lag Effect



Criticisms of the U.S. Innovation System

- Overall R&D Spending is Inadequate
  - Insufficient R&D investment in the future
  - 2% in the 1960's—now 0.8% of GDP
- Too Much Concentration on Military R&D – 52%
  - Low-utility for civilian economy
  - Slow or No spin-out for most R&D investments
- Too Much Focus on Health Research at NIH and Not Enough on the Necessary Information Technologies
  - Advances in Bio-medicine, diagnostics, and human genome dependent on new information technologies
- Inadequate Commercialization Mechanisms
  - Ideological/political blockages for effective programs
  - U.S. myths about perfect markets and role of venture capital prevent effective policy making
  - U.S. Award Programs are too few and under-funded

History vs. Ideology

Deep Ambivalence about Government Intervention in Markets but

Long Tradition of Successful

US Public-Private Partnerships

Precedents for Public Role in Commercialization of Science in the U.S.

- 1798 - Grant to Eli Whitney to produce muskets with interchangeable parts, founds first machine tool industry
- 1842 - Samuel Morse receives award to demonstrate feasibility of telegraph
- 1903 – Wright Brothers fly, fulfilling the terms of an Army contract!
- 1915 – National Advisory Committee for Aeronautics instrumental in rapid advance in commercial and military aircraft technology

Precedents for Public Role in Commercialization of Science in the U.S.

- 1919 – Radio manufacturing (RCA) founded on initiative (equity and Board Membership) of U.S. Navy with commercial and military rationale.
- 1940s, '50s, '60s – Jet Aircraft, Semiconductors, Computers, Satellites, Nuclear Energy
  - "The Foundations of the Modern Economy," Cohen & Noll
- 1969-1990s - Government investment in forerunners of the Internet (Arpanet) and establishment of the Global Positioning System
- Today: Current investments in genomic and biomedical research, advanced computing and new materials, e.g., nanotechnology initiatives

Understanding the U.S. Innovation System: Policy Myths & Market Realities

The Myth of the Rational Policy Framework

The Myth of Linear Innovation

The Myth of Military Spin-Offs

The Myth of Perfect Markets

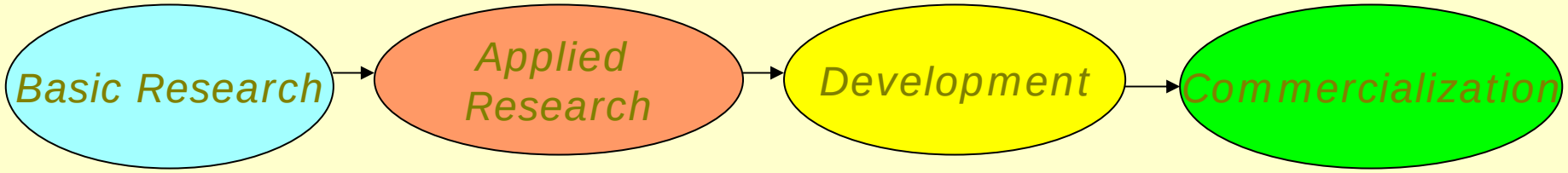
The Myth of the Venture Capital Solution

The Myth of the Rational Policy Framework

- Euro Myth: U.S. Innovation Policy is based on a coherent National Innovation Agenda
- Reality: There is no U.S. Ministry of Science
  - ➢ Multiple sources of policy making
    - Congressional Committees,
    - Federal Agencies—NSF, NIH, others
    - State Governments
  - \+ Positive: Multiple sources of experimentation means that the system can be more adaptive; responsive to new challenges
  - – Negative: Lack of coherence can lead to de facto outcomes that can hurt innovation
    - Example: Falloff in U.S. investments in Science & Engineering Education was not a product of rational U.S. policymaking.

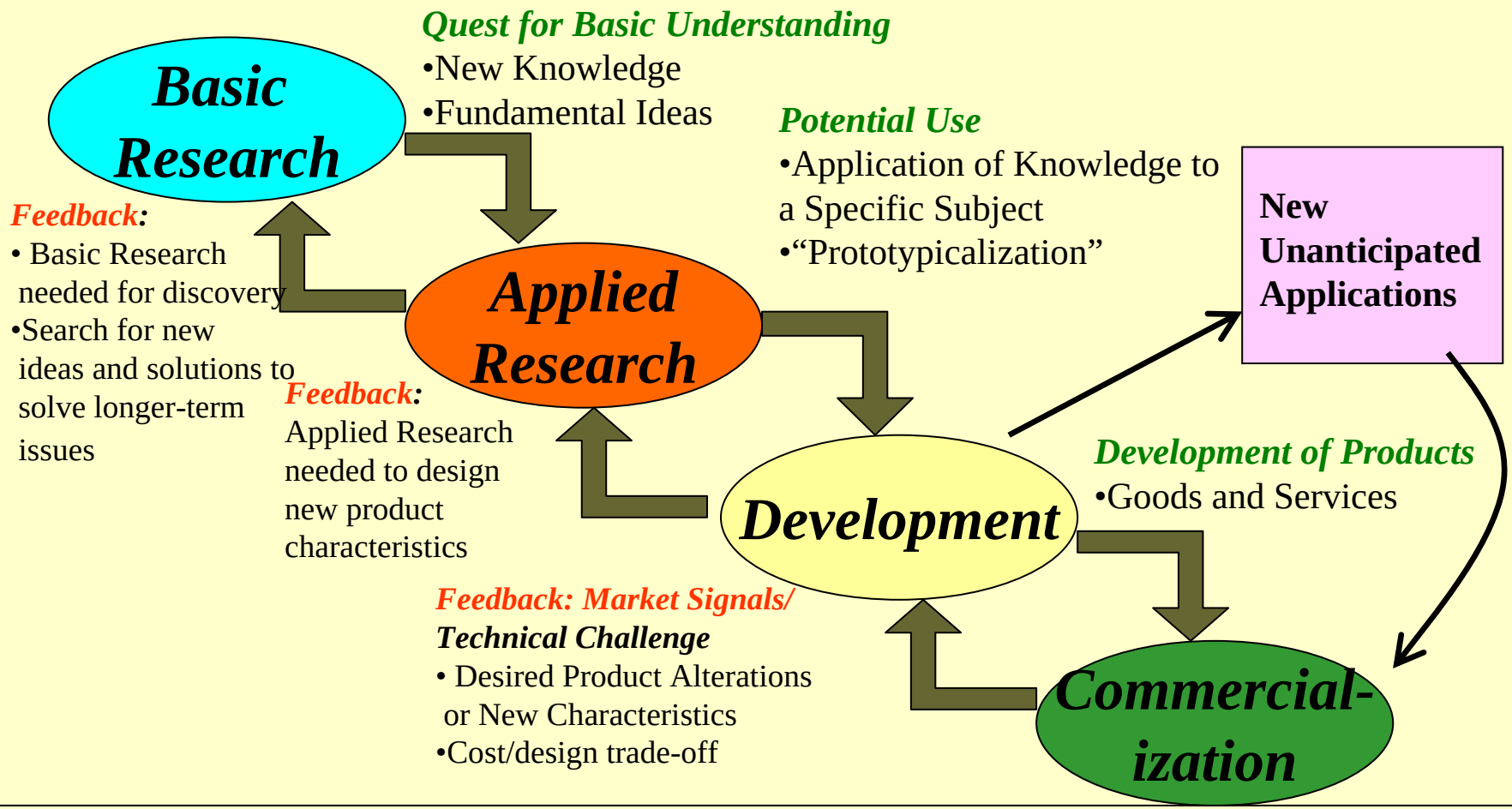
The Myth of the Linear Model of Innovation

- Myth: Innovation is a Linear Process



- Reality: Innovation is a Complex Process
  - Major overlap between Basic and Applied Research, as well as between Development and Commercialization
  - Principal Investigators and/or Patents and Processes are Mobile, i.e., not firm-dependent
  - Many Unexpected Outcomes
  - Technological breakthroughs may precede, as well as stem from, basic research

Non-Linear Model of Innovation



The Myth of Military Spin-Offs

- Euro Myth: "U.S. Defense Research/Procurement Directly Funds Civilian Technologies"
- Reality: "Very few technologies proceeded effortlessly from defense conception to commercial application."
  - Secrecy, military specs, and long lead times slow diffusion of new defense technologies
    - Billions for Stealth Technologies: What civilian market?
  - Even efforts to use low-cost civilian technologies for defense use, i.e., "spin-ins," are often blocked by complicated military procurement system

Beyond Spin-off, John Alic, Lewis Branscomb, et al.

The Myth of Military Spin-Offs

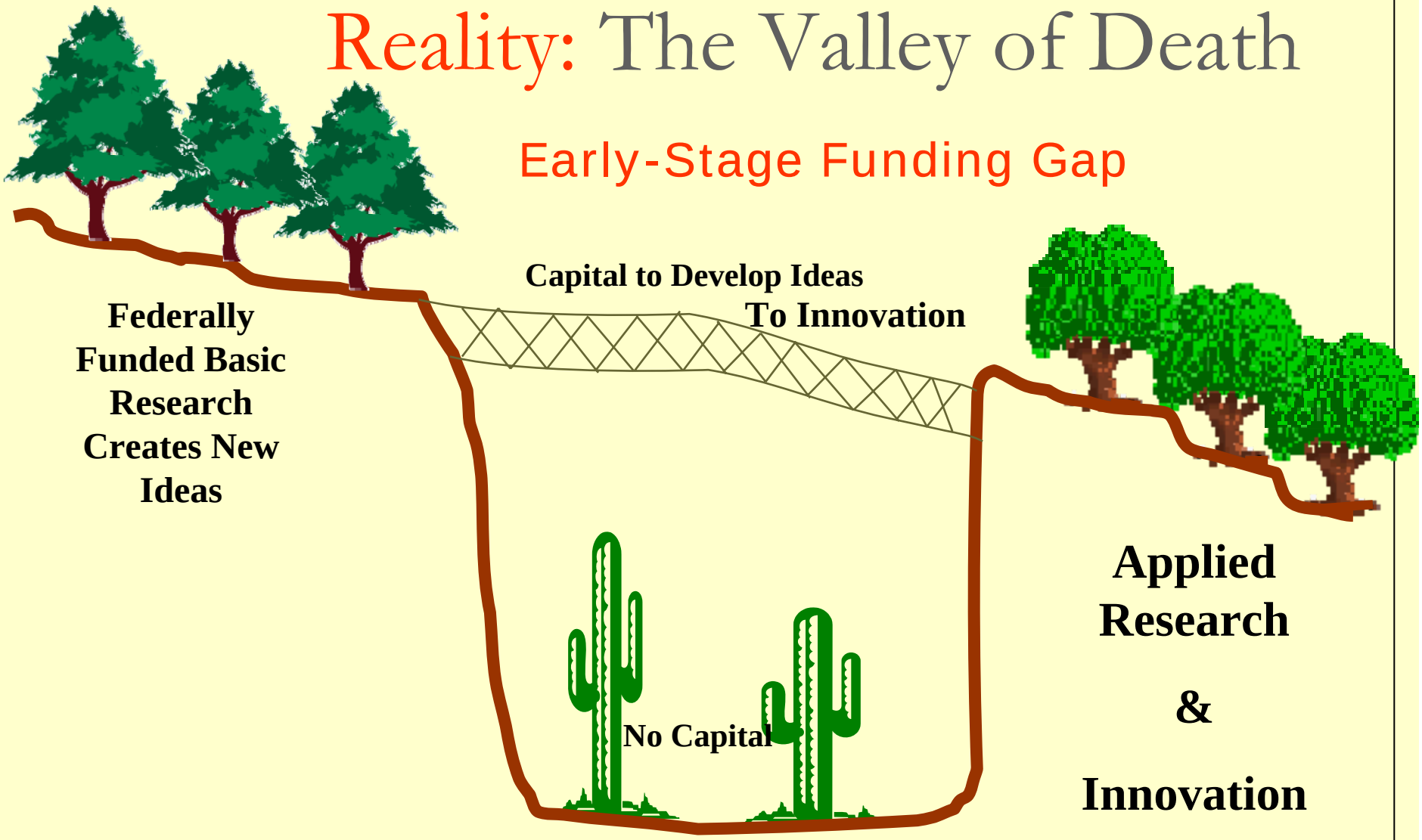
- Defense Industry is Smaller. It Contracted Sharply in Ten Years after End of Cold War
  - Major American Contractors dropped from 15 to 5
  - Industry is detached from mainstream U.S. economy
  - Dedicated programs with limited spin-off now compounded by long-term, slow moving contracts
- Defense R&D Funds Concentrated on Small Number of Engineers with Strong Applied Focus
  - Issue of scale: Intel at $100 Billion value vs. top three defense groups combined is $50 Billion
- Spin-Off of Platform Technologies is Diffused
  - Semiconductors and Internet applied widely
  - Engines and Airframe: Spillovers are substantial

The Myth of Perfect Markets

- Strong U.S. Myth: "If it is a good idea, the market will fund it."
- Reality:
  - Potential Investors have less than perfect knowledge, especially about innovative new ideas
  - "Asymmetric Information" leads to suboptimal investments
    - This means that it is hard for small firms to obtain funding for new ideas

Reality: The Valley of Death

Early-Stage Funding Gap



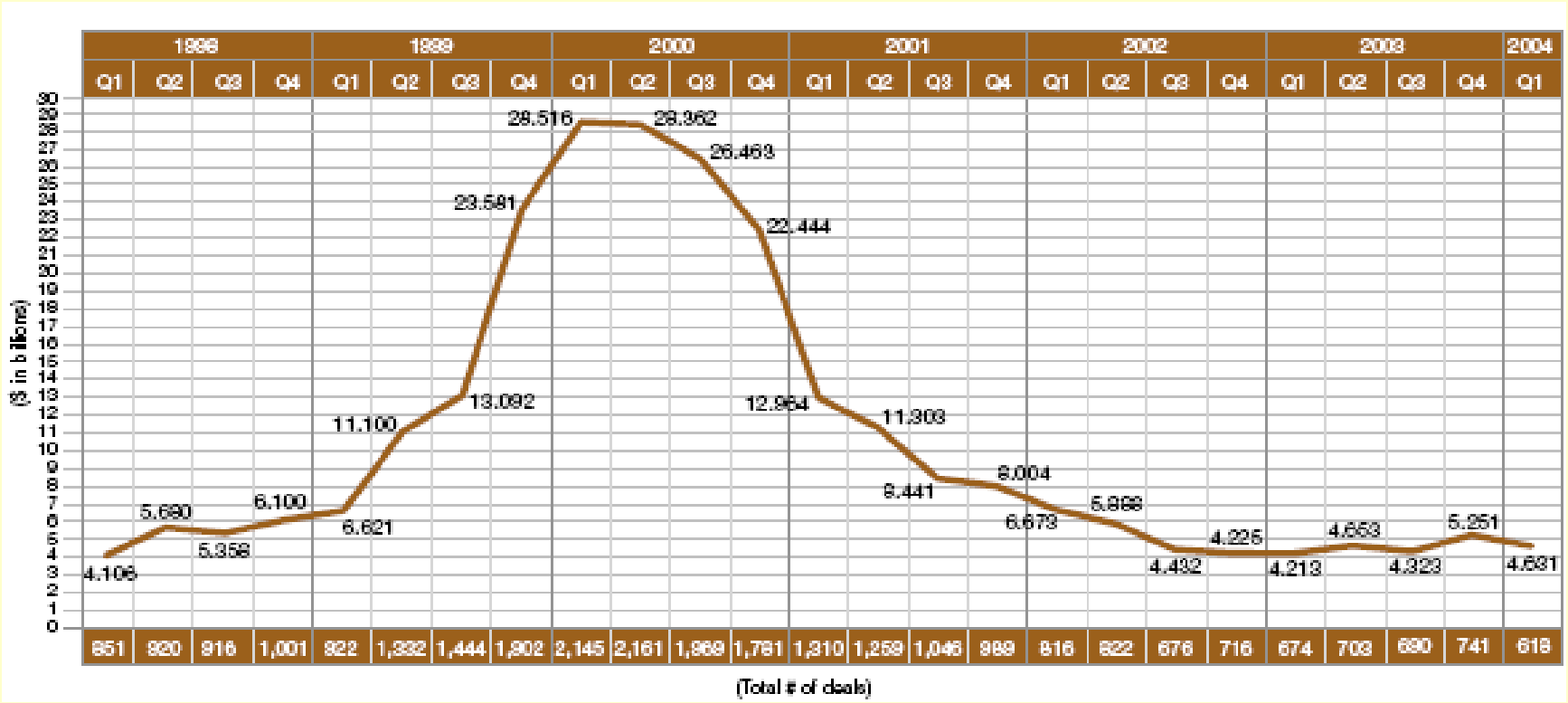
The Valley of Death

- A Series of Gaps
  - Gap in Available Cash Necessary to develop technology to Proof of Principle, Prototype, and/or Product
  - Gaps in Information between Entrepreneur and potential Investor and Partner about
    - Technology—What is it?
    - Potential of Technology—What can it do?
    - Business Opportunity—What size market?

The Myth of U.S.Venture Capital Markets

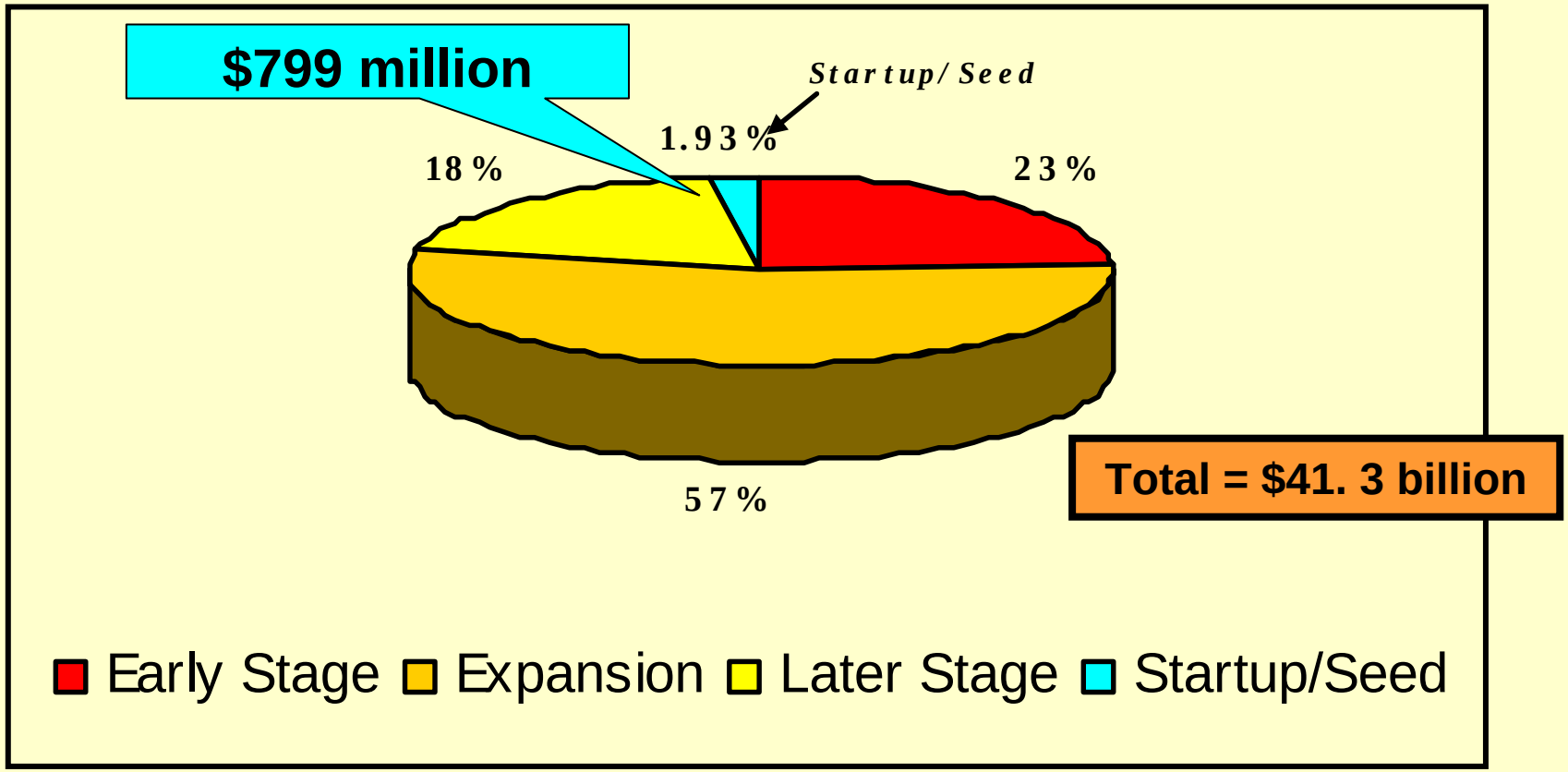
- Myth: "U.S. VC Markets are broad & deep, thus there is no role for government awards"
- Reality: Venture Capitalists have
  - Limited information on new firms
  - Prone to herding tendencies
  - Focus on later stages of technology development
  - Most VC investors seek early exit
- Large U.S. Venture Capital Market is Not Focused on Early-Stage Firms

VC Markets More Risk Averse



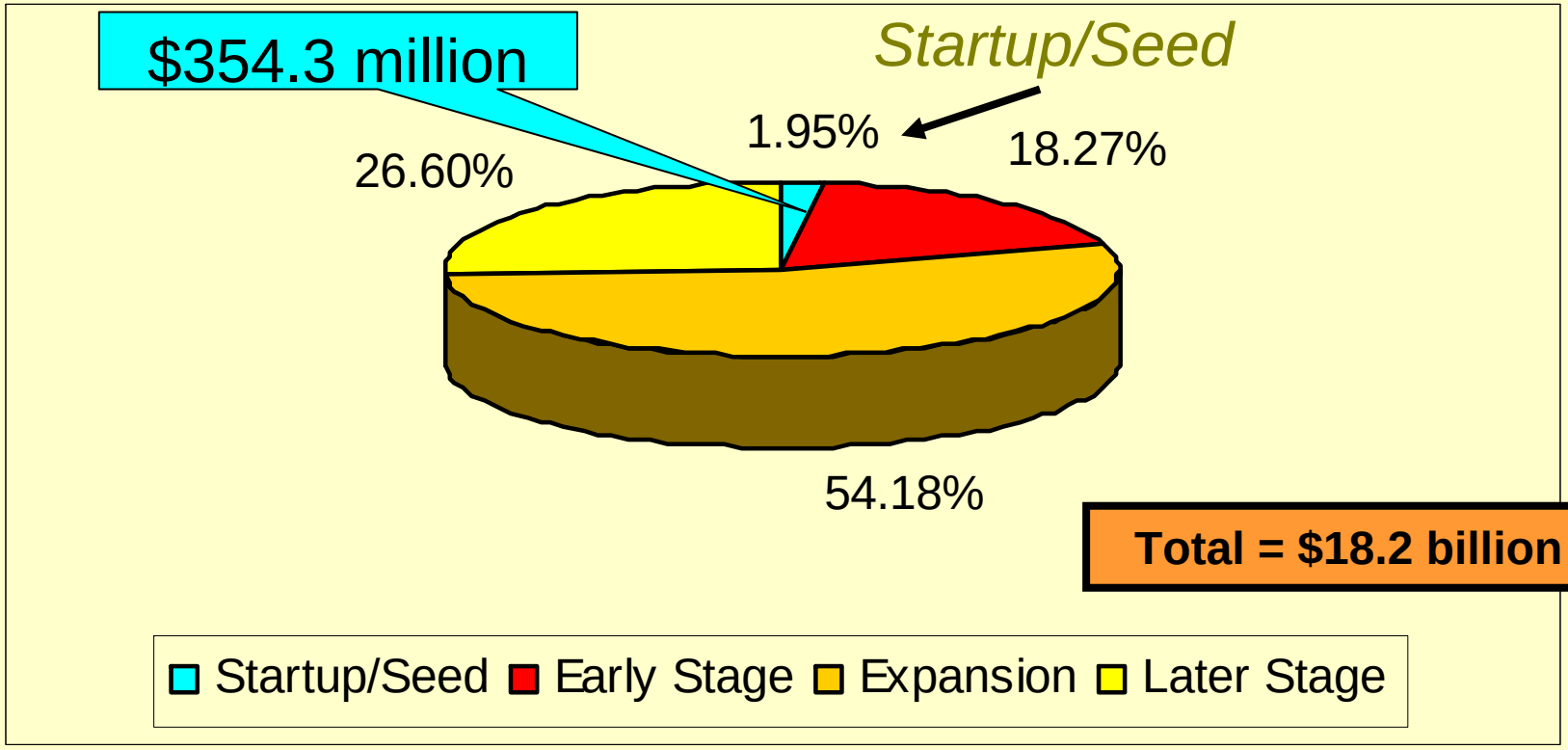
Source: PriceWaterhouseCoopers/Venture Economics/National Venture Capital Association Money Tree Survey, 2004

Breakdown of U.S. Venture Capital by Stage of Development-2001



Source: PricewaterCoopers, Venture Economics, National Venture Capital Association, 2003

Breakdown of U.S. Venture Capital by Stage of Development-2003



US Innovation Ecosystem—Strengths

Powerful Contribution of Small Businesses

Importance of Small Businesses to the U.S. Economy

- Small Businesses are a Key Driver of the U.S. Knowledge-Based Economy
  - Generating 60% to 80% of Net New Jobs Annually
    - 2.5 million of the 3.4 million Total Jobs—1999-2000
    - Employs 39% of High-Tech Workers—Scientists, Engineers, Computer Workers
  - Producing 14 times more Patents per Employee than Large Patenting Firms
    - Patents are of High Quality
    - Twice as Likely to be Cited

Small Businesses…

- Grow Jobs
- Generate Taxable Wealth
- Create Welfare-Enhancing Technologies
- Transform the Composition of the Economy, Developing Products to Ensure our Well-Being and Productivity in the Future

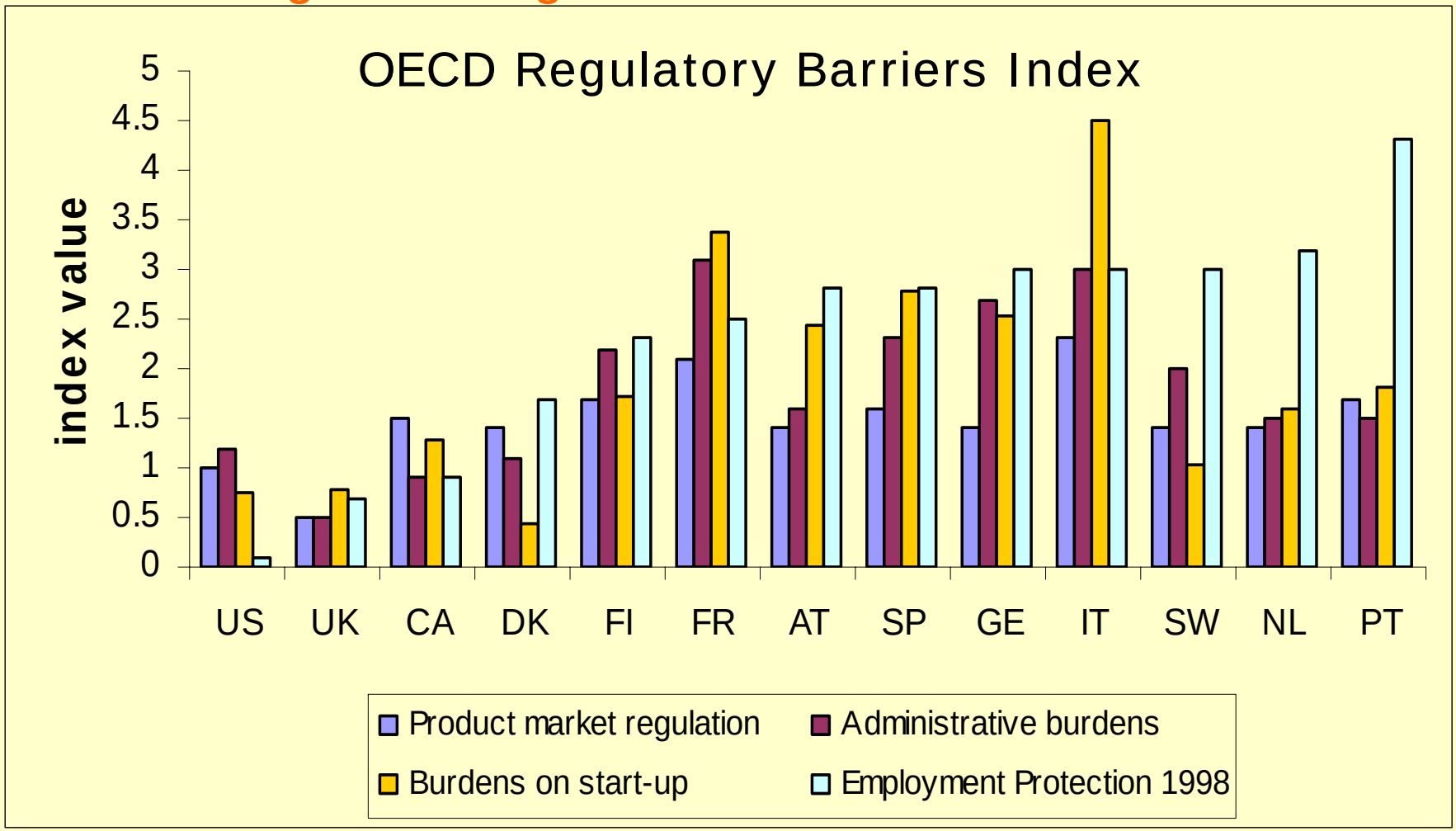
This is Why we Punish Them!

Challenges Facing Small Firms in the United States: Regulation & Finance

- SME's Face High Regulatory Burdens
  - Very small firms (less than 20 employees) spend 60% more per employee than large firms to comply with federal regulations
- New Firms Struggle for Adequate Financing
  - Start-Up funds from "Friends, Family, and Fools"
  - Over 80% of small firms in U.S. rely on credit but banks hesitate to lend

Where the UK Does Well:

Challenges Facing Small Firms across the OECD



US Innovation Ecosystem—Strengths

Positive Entrepreneurial Environment

U.S. Entrepreneurial Environment:
A Key to Knowledge-Based Growth

- Drive for Ownership: High Rates of Business Formation
  - High Social Value placed on business success
  - Low penalties for failure: Gentle Bankruptcy Laws
- Low Regulatory barriers for entry
  - Ease of company formation
  - Access to early-stage financing—very important
  - Pace of activity increases the effective value of capital

Positive Policy Framework:
Microeconomic Incentives

- Positive Incentives for Entrepreneurs
  - Strong Intellectual Property Regime:
    - Personal Incentive for Invention
  - Tax Policy: Potential High Returns are the Best Incentive for High Risks
  - Regulatory Policy: Low Regulation for New Entrants = Lower Cost, Faster to Market
  - Labor Flexibility: Hire and Fire as Needed
    - Firms that Can't Fire, Will not Hire (or Invest)
- Good Goals do not Guarantee Good Policy

US Innovation Ecosystem—Strengths

Diversity of Funding Sources

Recent Research: U.S. Funding Sources for Early-Stage Technology Development

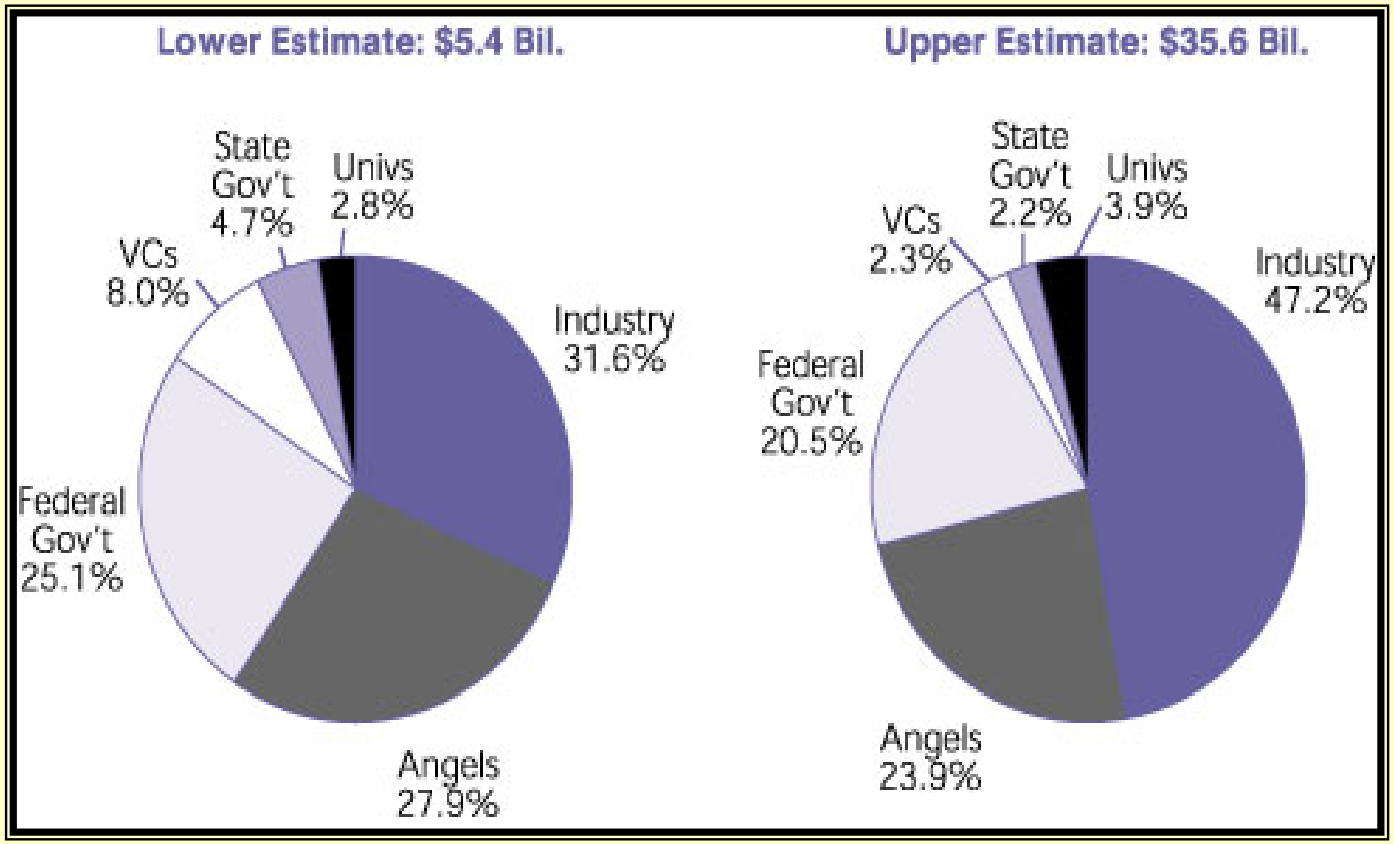
Multiple Actors

*

Multiple Sources of Finance Focused on Different Stages

*

Government Role is Significant



Branscomb & Auerswald, *Between Invention and Innovation An Analysis of Funding for Early-Stage Technology Development*, NIST, 2002

Figures based on 1998 data

Multiple Actors

- Friends, Family, and Fools
  - Often a source of Start-up funding
- Angel Investors
  - Successful Entrepreneurs ready to reinvest in new Companies
- State and Federal Governments
  - Key role in helping new firms cross the Valley of Death
- Venture Capital
- Industry Funding

Angel Investors: A Key Source of Early Stage Funding in the US

- Angels are "Cashed Out" Entrepreneurs who provide seed capital and advice for companies that exhibit high-growth prospects
  - Often contribute to companies that have a synergy with their own business or compete in an industry in which they have succeeded
- America's angel investors numbered 350,000 in 2001. They invested between $30billion to $35 billion in early stage finance in close to 50,000 ventures
  - Jeffrey Sohl, director of the Center for Venture Research at the University of New Hampshire

Some States Have Early-Stage Funding

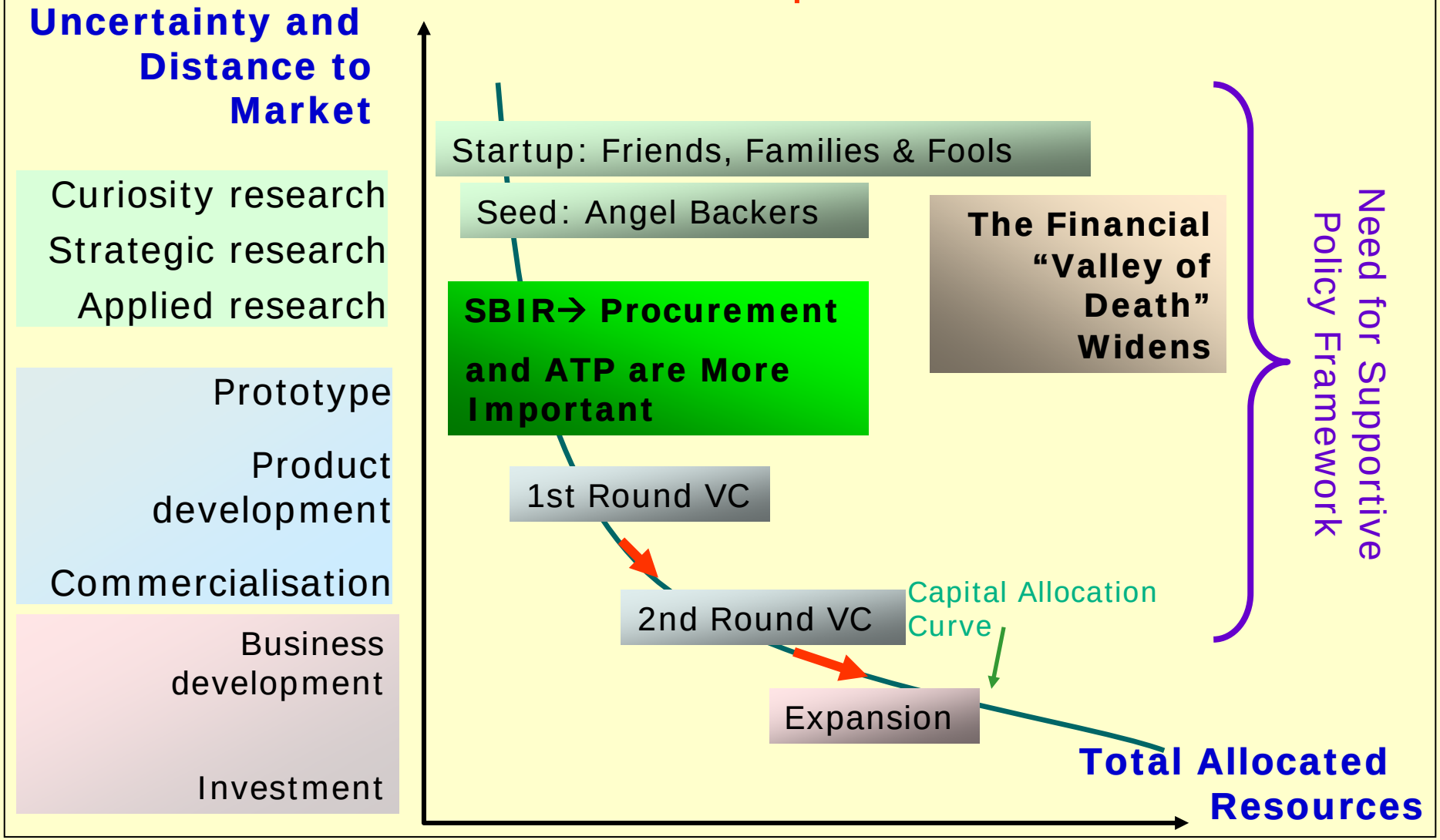
- Example: The Ben Franklin Technology Partnerships
  - Pennsylvania Program founded in 1983
  - Pennsylvania population=12,335,000 (2000 census)
  - Gross State Product = $408,373 billion (2001)
- Mechanisms: provides low cost loans to regional high-technology firms
  - $26 million a year program
  - Seeks synergy with Federal SBIR Applications
- Focus on High-tech firms
  - Biotechnology, IT, Materials, etc.
- Active Assessment Program: Does it work?
  - Measured by Firm Creation and Employment

Surprising Role of U.S. Government in Early-Stage Technology Development

- Markets for Allocating Risk Capital to Early-Stage Technology Ventures are not Efficient
- Most Early-Stage Funding comes not from Venture Capitalists but from
  - Individual "Angel" investors,
  - Corporations, and
  - The Federal Government
- Federal Technology Development funds Complement Private Funds
  - More important than we thought

U.S. Innovation Curve

Innovation Awards More Important in a Recession



Federal Programs to Help Bridge the Valley of Death

The Small Business Innovation Research Program
The Advanced Technology Program

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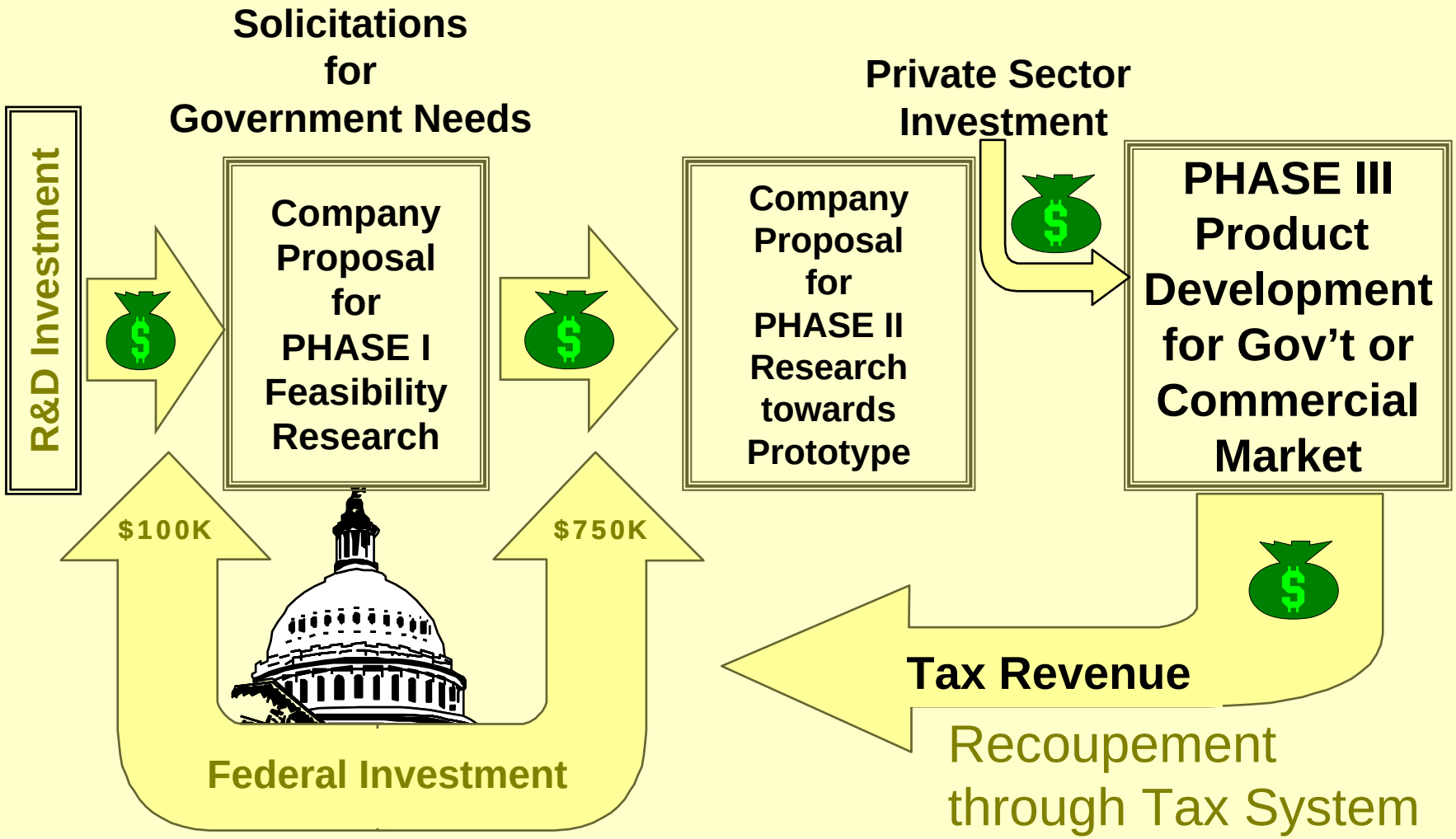
The Small Business Innovation Research (SBIR) Program

- Created in 1982, Renewed in 1992 & 2001
- Participation by all federal agencies with an annual extramural R&D budget of greater than $100 million is mandatory
  - Agencies must set aside 2.5% of their R&D budgets for small business awards
- To be a $2 billion per year program in 2004
  - Largest U.S. Partnership Program

SBIR Model


Solicitations for Government Needs
Private Sector Investment
R&D Investment
Company Proposal for PHASE I Feasibility Research
Company Proposal for PHASE II Research towards Prototype
PHASE III Product Development for Gov't or Commercial Market
$100K
$750K
Federal Investment
Tax Revenue
Recoupement through Tax System

SBIR Differs Among Agencies

- Multiple Administrative Systems
  - Each agency typically has its own manner of choosing awardees and screening applications
  - Different metrics reflecting unique agency missions and needs
  - Different Metrics by industrial sector, e.g., software vs. drug development vs. weapon components

- Commendable Flexibility & Diversity in Goals, Processes, and Achievements in a Common Framework

SBIR Success Stories

QUALCOMM	Internet & Intranet tools Key software for cell-phones	Founded in 1985 $4 billion in revenues (2003)
ATMI	Semiconductor Device Manufacture products; Safer, "green" solution for handling toxic gas	Founded in 1986 $172 million in revenues (2003)
Martek	Nutritional Fatty acids for Infant Formula; Improves IQ and visual acuity	Founded in 1985 $115 million in revenues (2003)

The Advanced Technology Program (ATP)

Focuses on developing the economic benefit for early-stage, high-risk, enabling innovative civilian technologies

Key ATP Characteristics

- Industry-initiated Proposals: Bottom-up Approach
- Highly Competitive: 12.5% Receive Awards
  - Rigorous Independent selection process, includes
    - evaluation of the project's technical merit
    - Commercial worthiness and broad-based benefits
- Cost Share: $200 Million
  - All Awards are cost shared with industry—Acts as a Reality Check
- Partnering Encouraged:
  - Dissemination of enabling technologies is key to public benefits and rationale for public support
- Careful Assessment

ATP Assessment

- Rigorous selection process
  - Companies must prove need for Government Support
  - Demonstrate Technical & Commercial Merit
- Real Time Project Monitoring
  - ATP stops projects that are failing
  - Willingness & Ability to Stop, Drop, & Recommit is rare in public program
- Follow-up Evaluation
  - Achieved Technical Goals, Commercial Goals, Social Goals ?

ATP Achievements

- Next Generation Lithography: EUV Program launched by ATP award
  - Now a major consortium
- Digitalized Breast Cancer Detection
  - Fewer false positives: less fear, less cost
  - Second opinions easier
- First US Fuel Cell Technology supported by ATP—e.g., Plug Power
- Biological Assay for Accurate “Blood fingerprinting” to match blood correctly

ATP Achievements: Better Medical Outcomes

- Automated care givers to maintain privacy and prolong independence
  - Honeywell Inc.
- New virtual reality software to allow surgeons to rehearse operations
  - Immersion Medical Inc.
- Founded DNA diagnostic tool industry
  - Nucleic acid microarray
  - Amersham Biosciences

SBIR & ATP

Characteristics of U.S. Innovation Awards

- ✓ Highly Competitive: Many Apply; Few Win
- ✓ Industry Initiation and Leadership
- ✓ Public Funding is limited in Time
- ✓ Public Funding is limited in Amount
- ✓ Clear Objectives
- ✓ Regular Assessments & Learning (ATP, and now SBIR)

Key Findings: The Programs Achieve Government Goals through Leveraging the Private Sector

The Enabling Role of Universities

A Major U.S. Asset

University-Industry Cooperation is Key

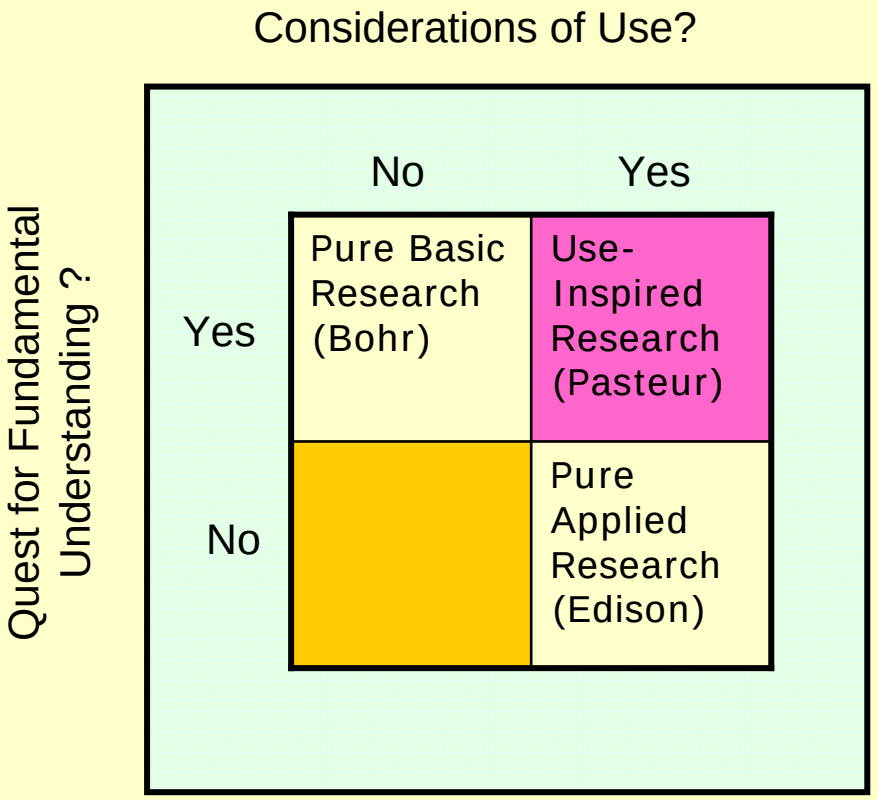
- Cooperative Research
  - University research draws ideas from commercial trends more than ever before
  - Feedback loops from industry to universities are important
  - Major contribution to training for real jobs
- Regional Growth
  - Regional economies need their research universities more than ever before
- Firm Formation
  - University innovation + early government funding have been key to the growth of many successful technology companies
- Supportive University Culture & Incentives are crucial

Pasteur's Quadrant: Research can be Applied, Practical, *and* Basic at the Same Time

- Use-inspired research
  - increases existing understanding *and* creates improved technology.
  - can take existing technology to new levels but it
- can also improve understanding of fundamental principles

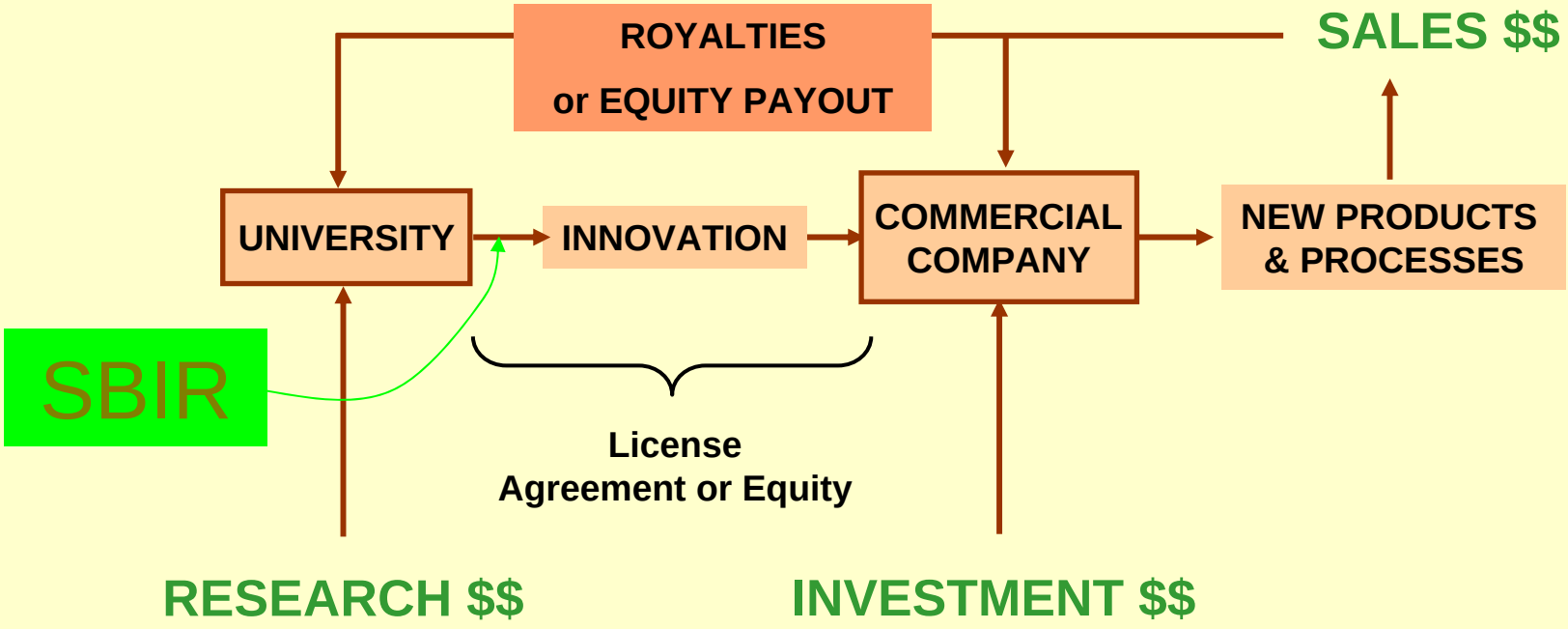
From Donald Stokes, *Pasteur's Quadrant, 1997*

Quadrant Model of Scientific Research



How Ideas are Commercialized

Transferring University Technology to Firms



- Licensing to existing companies – brings royalty $
- New company formation – brings royalties and/or equity
- Other, less direct, contributions to regional economic activity – **5,000 Good New Jobs in Pittsburgh Area**

Adapted from C. Gabriel, Carnegie Mellon University

The Benefits of University-Industry Cooperation: SBIR Role

- SBIR Innovation Awards Directly Cause Researchers to create New Firms
  - Jobs and Regional Growth
  - Cooperation creates High-Tech Jobs
- Universities help diversify and grow the job base
  - Increasingly universities are the largest regional employer for all types of employment
- Cooperation validates Research Funding
  - Returns to Society in Health, Wealth, & Taxes
  - SBIR is a proven mechanism in an uncertain game

UK's Challenge

Transforming Strengths into Opportunities

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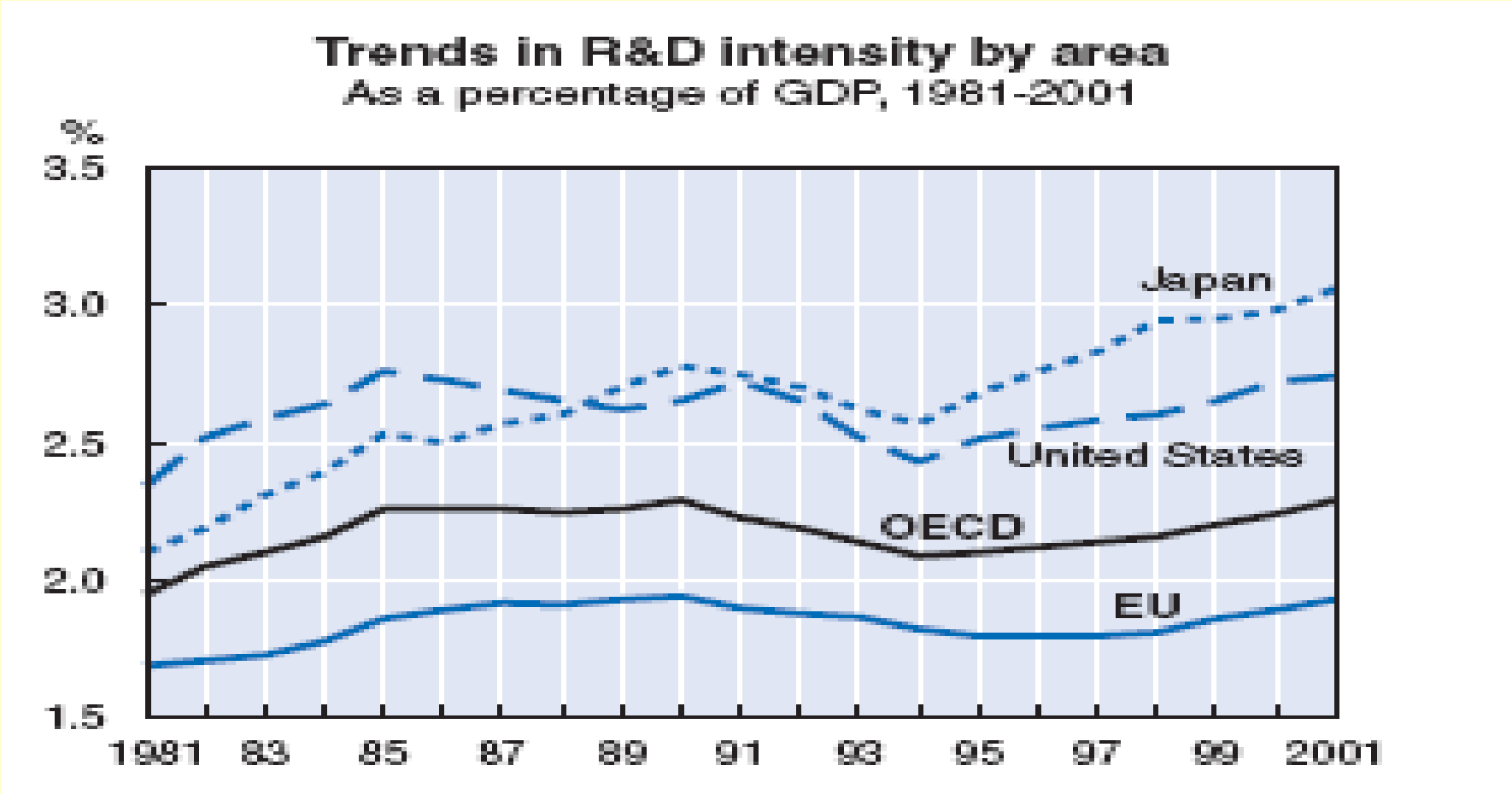
Strong Commitment to Scientific Research

- UK is a global leader in biotechnology, nano-science, and other cutting edge science-based industries
- New budget commitments set to renew science infrastructure for the 21st Century*
  - Increased by 15% following 1998 spending review
  - Now increasing by 7% a year in real terms
- Institutional Innovations include
  - Wellcome Trust Partnerships
  - Cambridge Science Park
  - Cambridge-MIT Institute

* "Science Matters," Speech by Rt. Hon. Tony Blair, PM, 10 April 2002

Is the 3% Target the Solution?



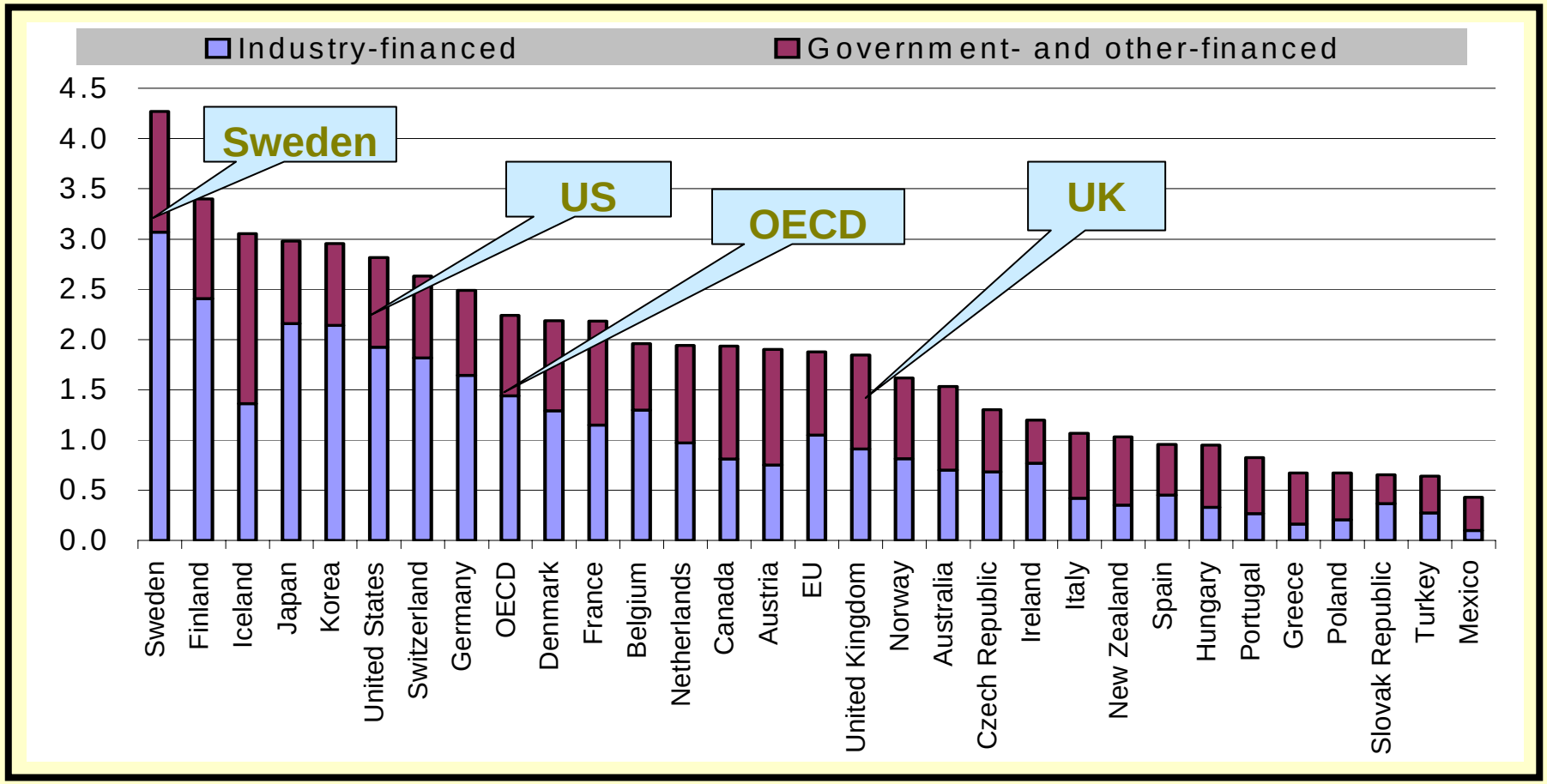
OECD S&T Statistical Compendium 2004

Capitalizing on R&D Investments: Is 3% the Key?

- Useful Focus on Innovation & Need for R&D, but only one input measure
  - Sweden spends 4.27% of GDP on R&D –but has low Levels of Entrepreneurial Activity in High-Tech Company formation
- It is less how much is spent but
  - How well
  - In what context
  - With what incentives (or disincentives)?

➢ Charles W. Wessner & Sujai J. Shivakumar, "The Role of Macro Targets & Micro Incentives in Europe's R&D Policy," The IPTS Report, Vol. 69, 2002.

Is 3% of GDP for R&D the Key?
R&D Intensities across OECD, 2001



Source: OECD, DSTI/DOC (2003)8

Challenges for UK Policymakers

- Lambert's Review
  - UK science base is strong but Business R&D/ Innovation is relatively weak
  - Globalization of business R&D & Open Innovation Model presents growing threat to UK prosperity and growth
- Robert's Review
  - UK faces skills shortages in science and engineering
- How to meet these challenges?
- Public-Private Partnerships

Meeting the Challenge of Early Stage Finance

- DTI's many new products
  - New grants for investigating an innovative idea
  - Smart grants for R&D
  - Faraday Partnerships
  - Small Firm Loan Guarantees
  - Networks for knowledge transfer
  - Small Business Investment Companies
  - Regional Capital Investment Programmes

Danger: Need to Avoid 'Tyranny of Small Scale'

- Many Good Ideas, but
- Good Ideas require Critical Mass of Funding and Activity
- Volume required for Program to have Impact
- Single, Multi-Stage, Distributed Program may Prove More Effective
  - or at least help

Conclusions

Understanding Innovation Ecosystems

- National Innovation Ecosystems approach highlights importance of:
  - Linkages: Connecting university research with business opportunities; Bridging the Valley of Death with government awards
  - Bio-diversity to be encouraged:
    - A bio-diverse ecosystem is a healthy ecosystem
    - Multiple sources of innovation & Multiple sources of Funding
    - Coordination but not Harmonization

Understanding Innovation Ecosystems

- All Innovation Systems face Common Challenges
  - Performance: Need to justify R&D expenditures by creating new jobs & new wealth
  - Adaptability: Need to reform institutions (or craft new ones) to meet new challenges
  - Assessment: Failure to Assess Blocks Needed Corrections and Obscures Accomplishments

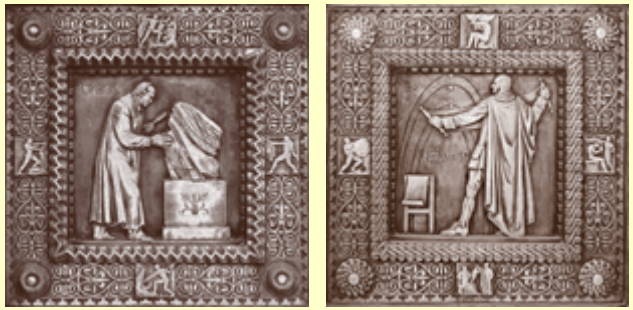
Addressing Lambert's Challenge: Capitalizing on R&D Investments

- Programs like SBIR and ATP can help Small Businesses cross the Valley of Death
  - National Academies finding: These programs work
  - SBIR Concept is being emulated abroad
- Regular and rigorous assessment helps keep these programs real
  - Assessment →Adaptation →Relevance
  - Maintains health of Innovation Ecosystem

Common Challenges

- National Innovation Systems are Different in Scale and Flexibility
  - Flexibility is a differentiator
  - It is less how much is spent but *how well*
- All Systems Have Common Challenges
  - Need to justify R&D expenditures by creating new jobs & new wealth
  - Need to reform institutions (or invent new ones)
  - Need to try new mechanisms that shift innovation incentives in a positive way
- Learning from each other is a Pathway to Progress

THANK YOU



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