Economic Rationales and Metrics for an Advanced Manufacturing Sector

Gregory Tassey

Economic Analysis Office

National Institute of Standards and Technology

tassey@nist.gov

http://www.nist.gov/director/planning/

March 2012

Policy initiatives and metrics evolve from economic rationales:

1) Does a modern economy need an advanced manufacturing sector, including nanotechnology?

2) If yes, what are the economic (underinvestment) metrics and hence rationales for government support roles?

3) What are the policy response mechanisms for each type of underinvestment?

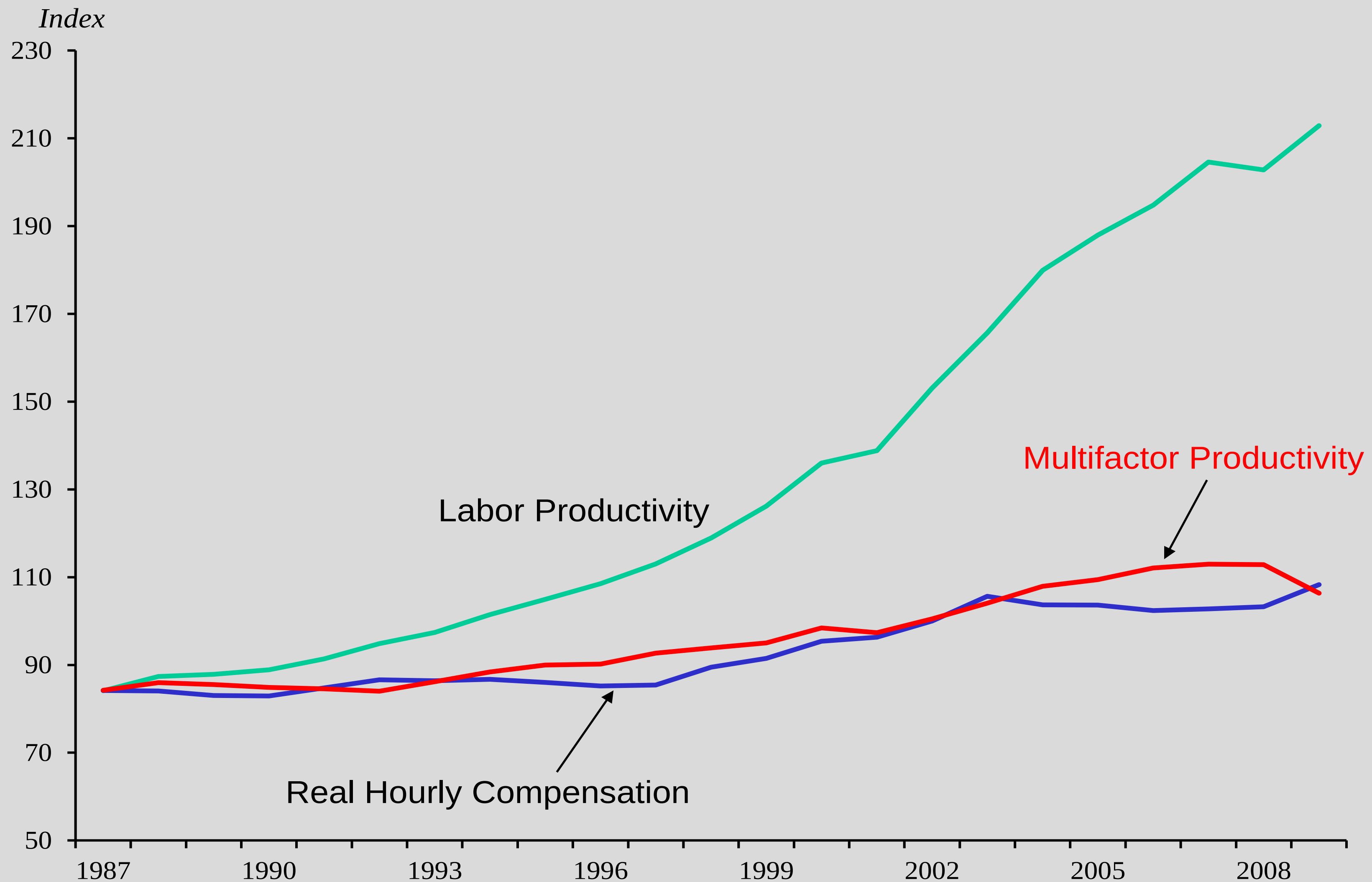
    a) The nature of the underinvestment phenomenon determines the most efficient policy mechanism

    b) The policy response determines impact assessment metrics

Causes of Underinvestment – Inaccurate Productivity Measurement

Policy Focus: Multifactor Productivity

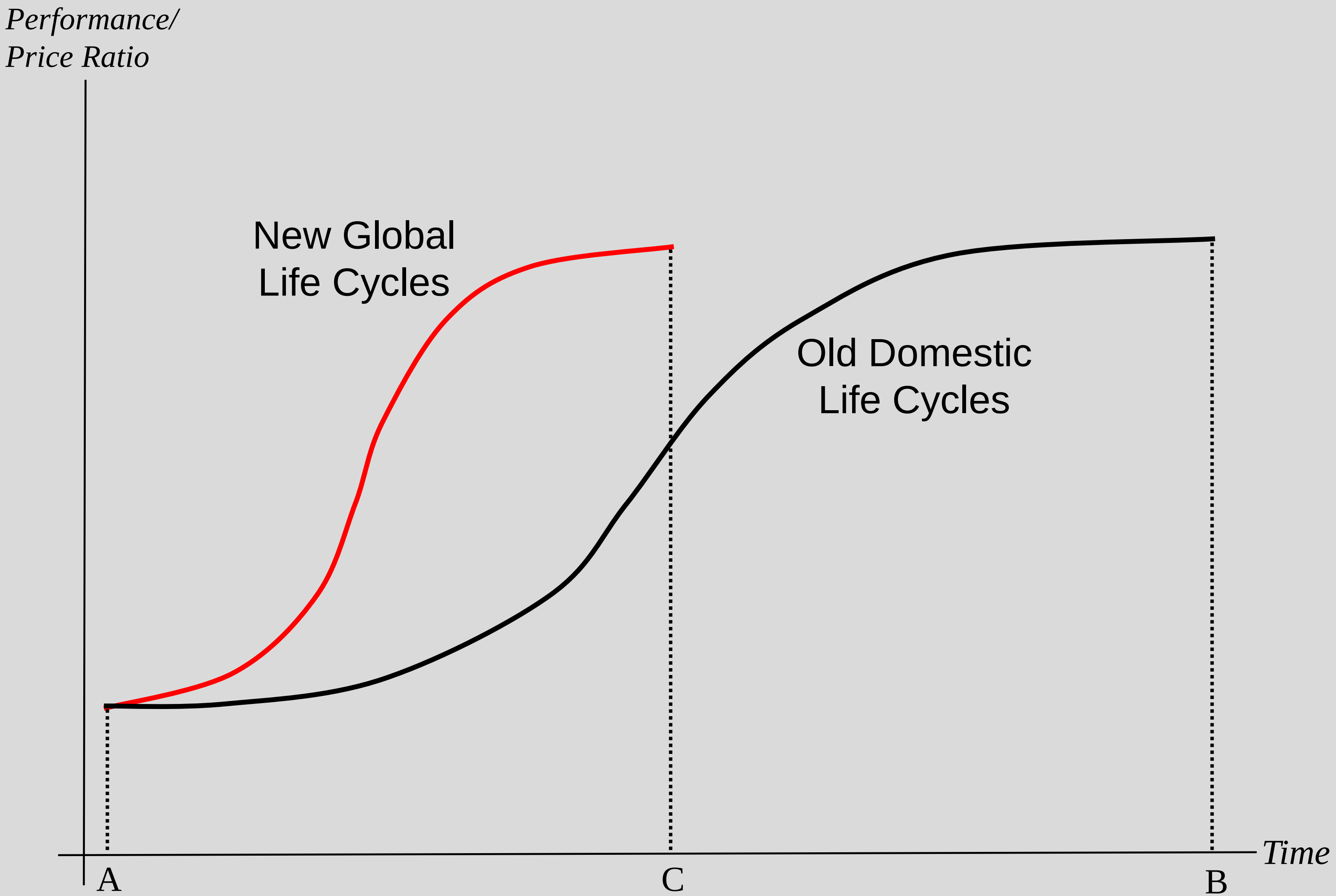
Trends in Productivity and Income: U.S. Manufacturing Sector, 1987-2009



Source: Bureau of Labor Statistics

Causes of Underinvestment – Life Cycle Management

Compression of Technology Life Cycles



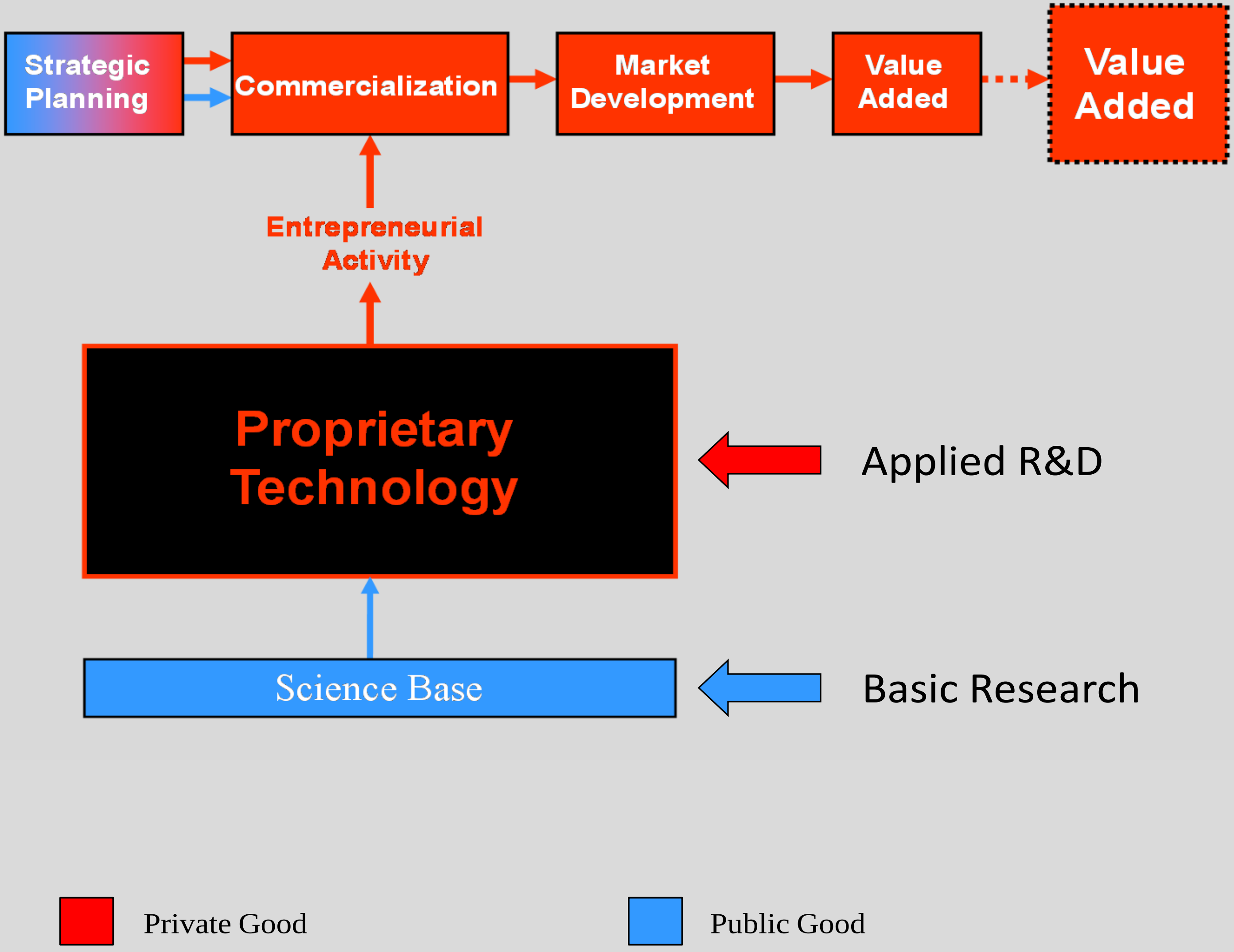
G. Tassey, *The Technology Imperative*, Edward Elgar, 2007

Common rationales for government support of advanced manufacturing R&D:

- Excessive risk (increase costs)
  - The “Valley of Death”
- Spillovers (reduce benefits)
- Long development time (reduce benefits)

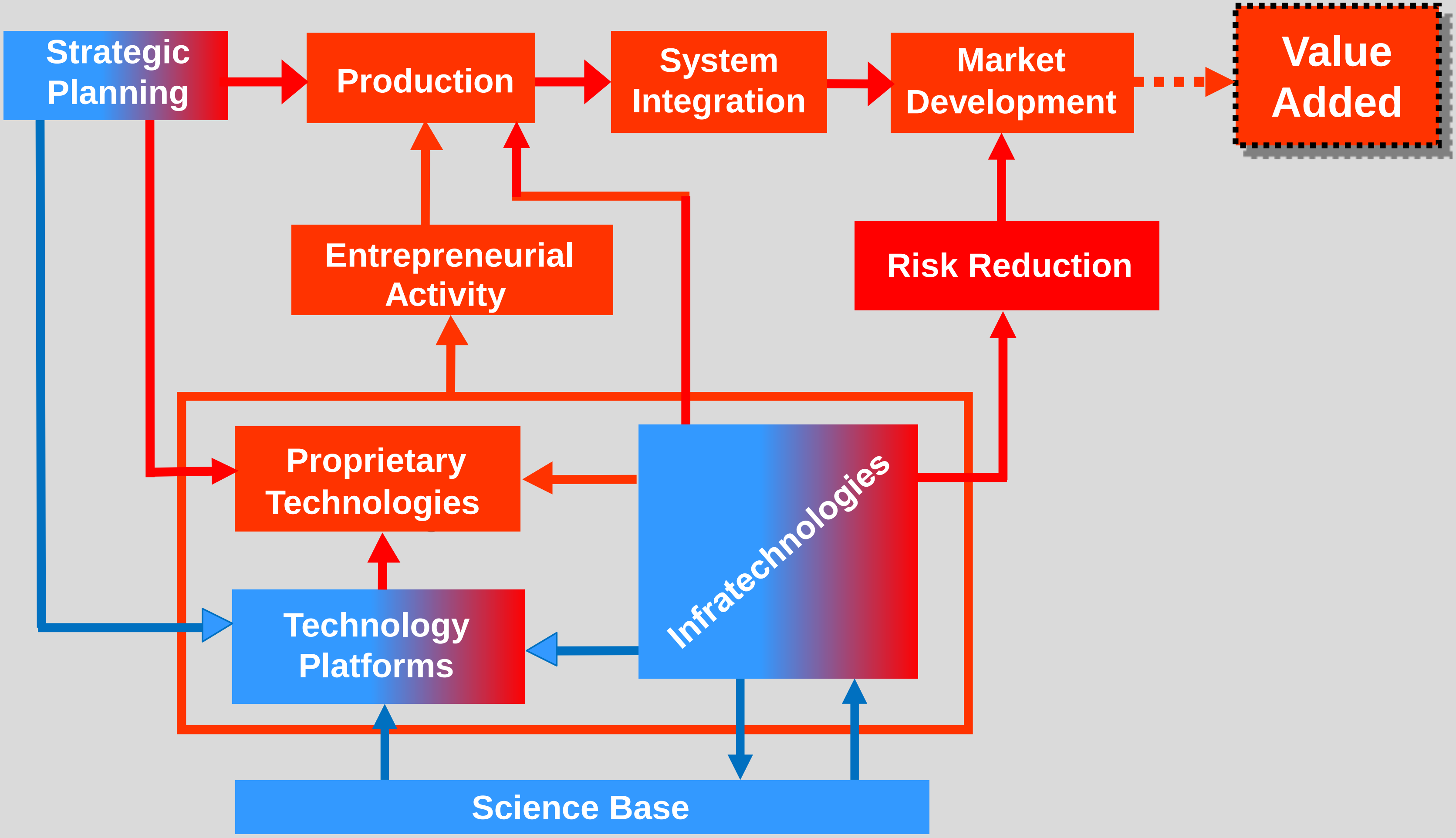
Identifying Underinvestment – Technology-Element Growth Model

"Black Box" 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.

Technology-Element Model



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

Identifying Underinvestment – Technology-Element Growth Model

Application of the Technology-Element Model: Nanotechnology

Science Base

- carbon-based nanomaterials
- cellulosic nanomaterials
- magnetic nanostructures
- molecular nanoelectronic materials
- quantum dots
- optical metamaterials
- solid-state quantum-effect nanostructures
- functionalized fluorescent nanocrystals
- quantum-confined structures

Infratechnologies

- biological detection and analysis tools
- in silico modeling & simulation tools
- in-line measurement techniques to enable closed-loop process control
- sub-nanometer microscopy
- high-resolution nanoparticle detection
- thermally stable nanocatalysts for high-temperature reactions

Technology Platforms

Product

- carbon nanotubes
- dendrimers
- hybrid nanoelectronic devices
- ultra-low-power devices
- self-powered nanowire devices
- nanoparticle fluorescent labels for cell cultures and diagnostics
- metal nanoparticles & conductive polymers for soldering/bonding
- nanoparticle sensors

Process

- epitaxy
- nanoimprint lithography
- nanoparticle manufacture
- rapid curing techniques
- self-assembling & self-organizing processes
- scalable deposition method for polymer-fullerene photovoltaics
- inkjet processes for printable electronics
- purification of fluids with nanomaterials
- roll-to-roll processing

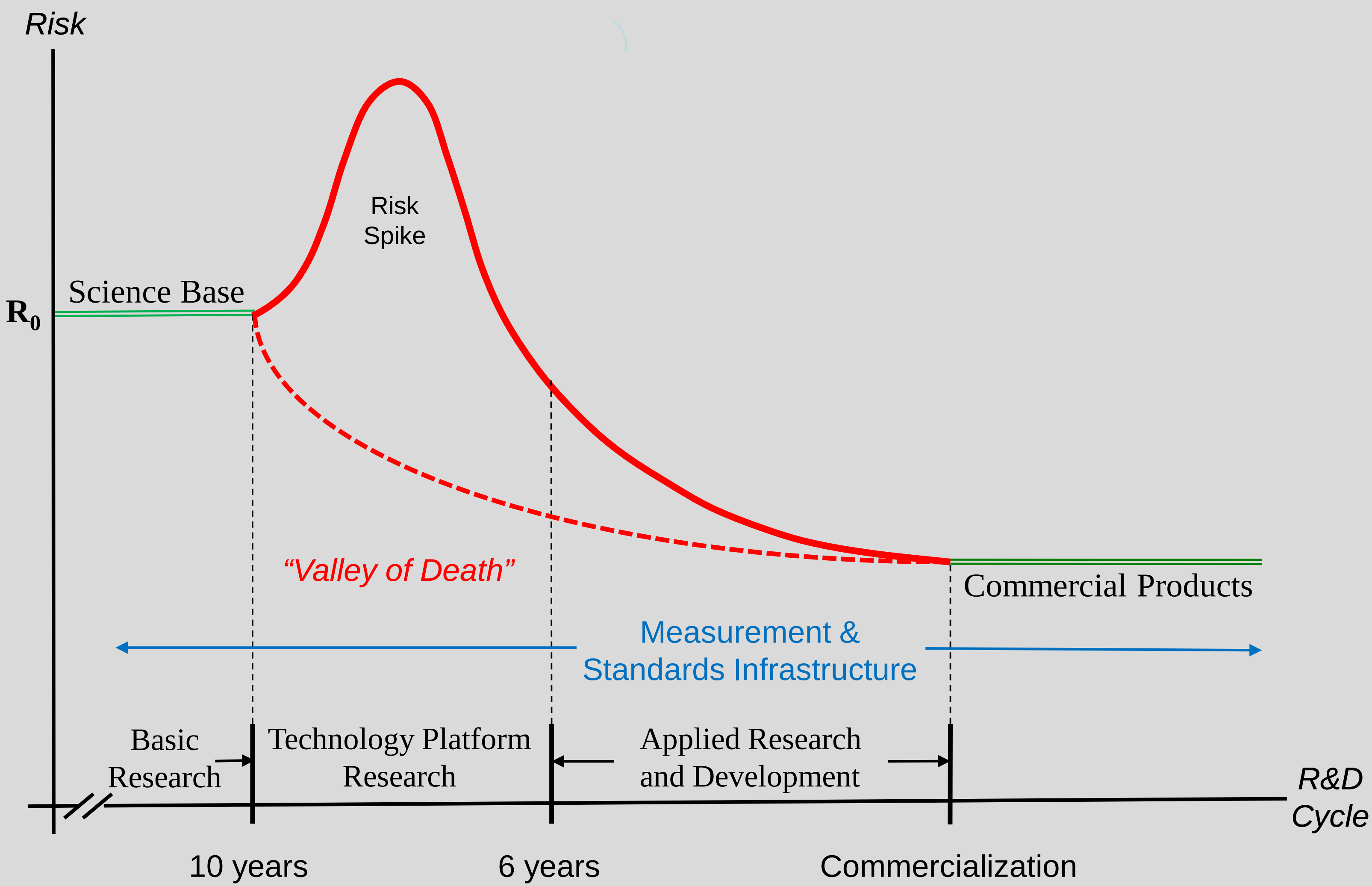
Commercial Products

- hardened nanomaterials for machining/drilling
- flame-retardant nanocoatings
- sporting goods
- solar cells
- sunscreen/cosmetics
- targeted delivery of anticancer therapies
- biodegradable and lipid-based drug delivery systems
- self-repairing & long-life wood composites
- anti-microbial coatings for medical devices

Public Technology Goods ← **Mixed Technology Goods** → **Private Technology Goods**

Causes of Underinvestment – Composition of R&D

R&D Efficiency: Overcoming the Innovation Risk Spike (Valley of Death)

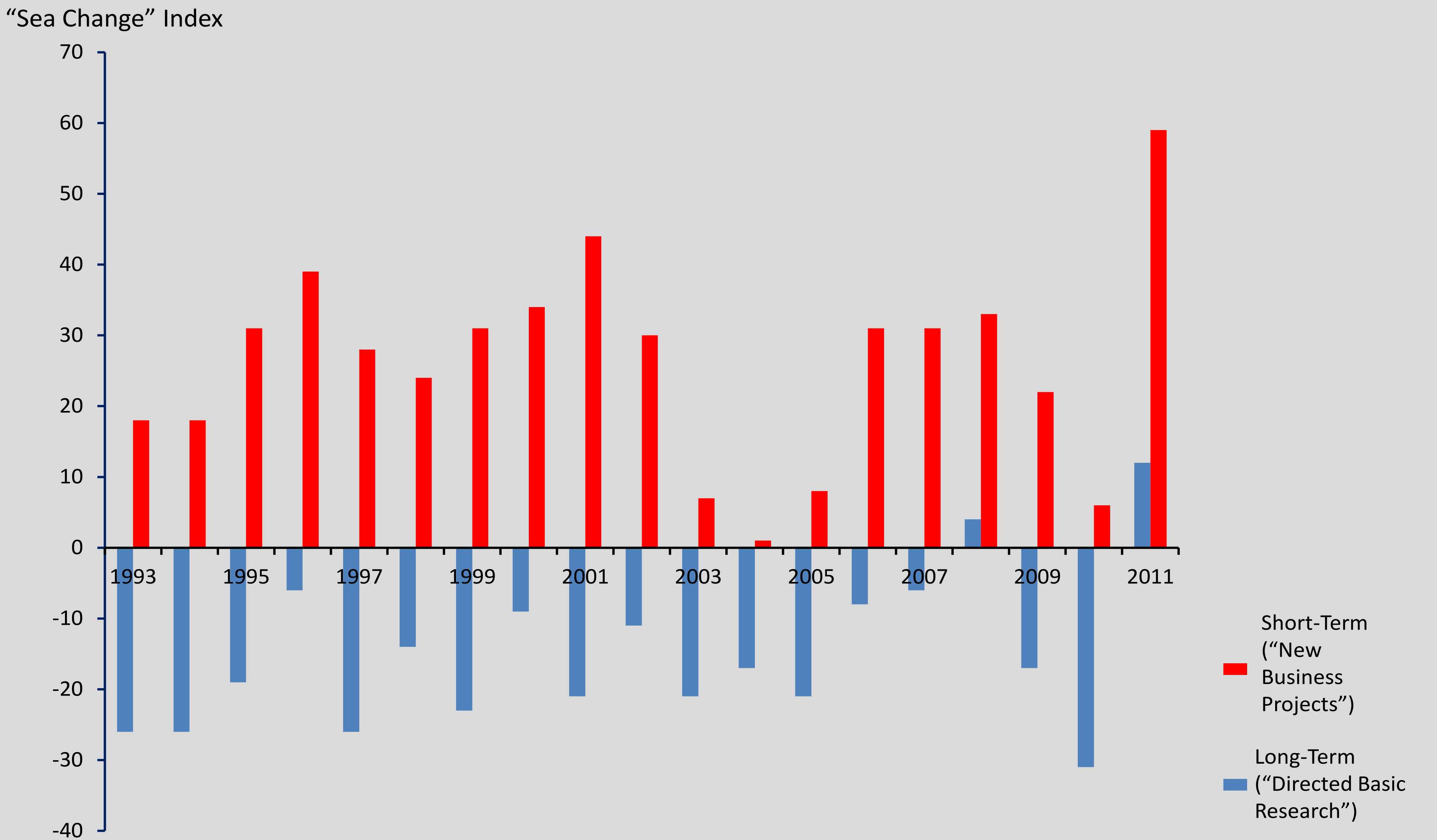


Source: Gregory Tassey, "Underinvestment in Public Good Technologies", *Journal of Technology Transfer 30: 1/2* (January, 2005); and, "Modeling and Measuring the Economic Roles of Technology Infrastructure," *Economics of Innovation and New Technology 17* (October, 2008)

Causes of Underinvestment – Composition of R&D

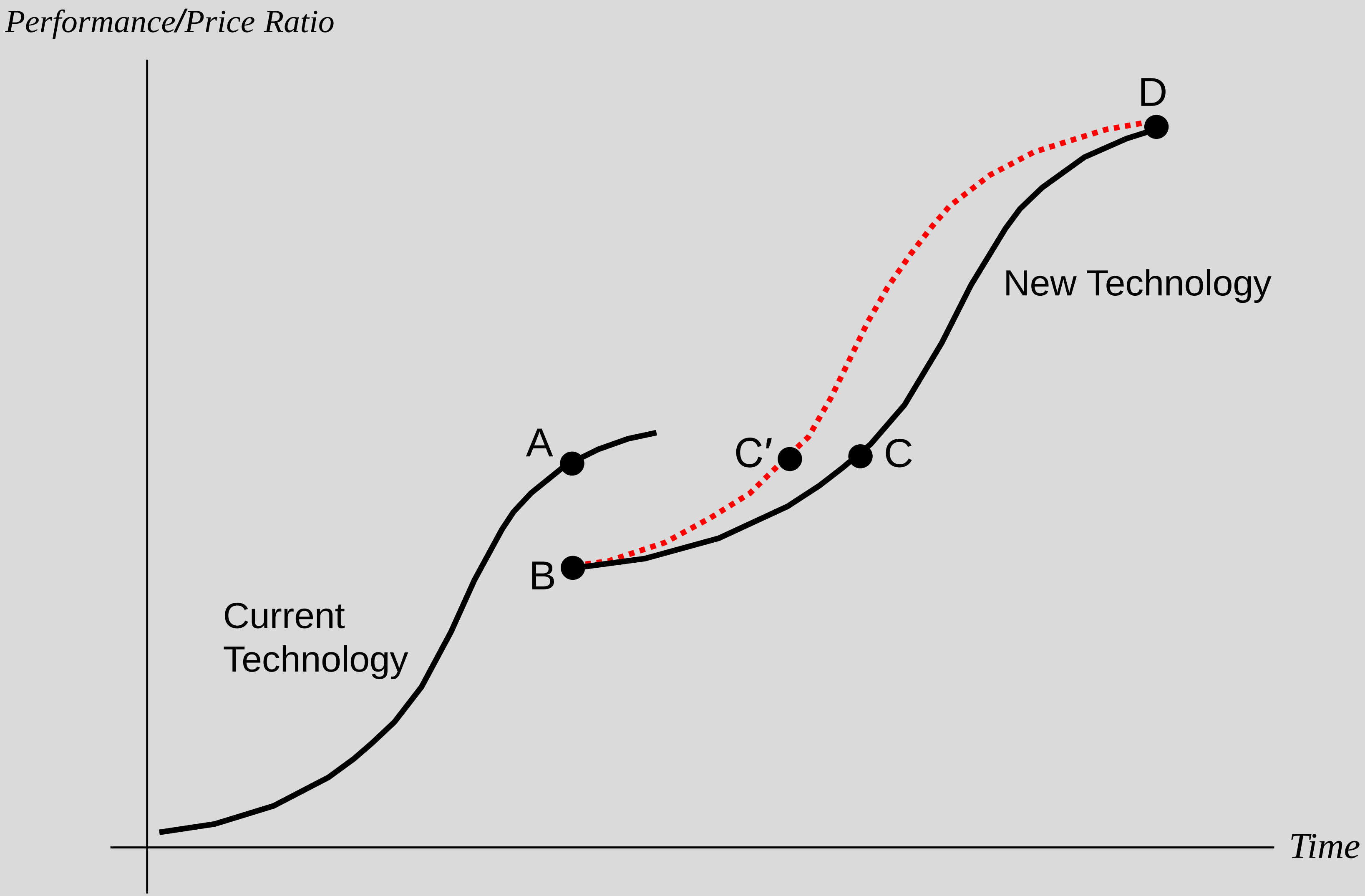
The "Valley of Death" is Getting Wider

Trends in Short-Term vs. Long-Term US Industry R&D, 1993-2011



Gregory Tassey, "Beyond the Business Cycle: The Need for a Technology-Based Growth Strategy," NIST Economics Staff paper, December 2011. Compiled from the Industrial Research Institute's annual surveys of member companies.

Life-Cycle Market Failure: Technology Platform Development



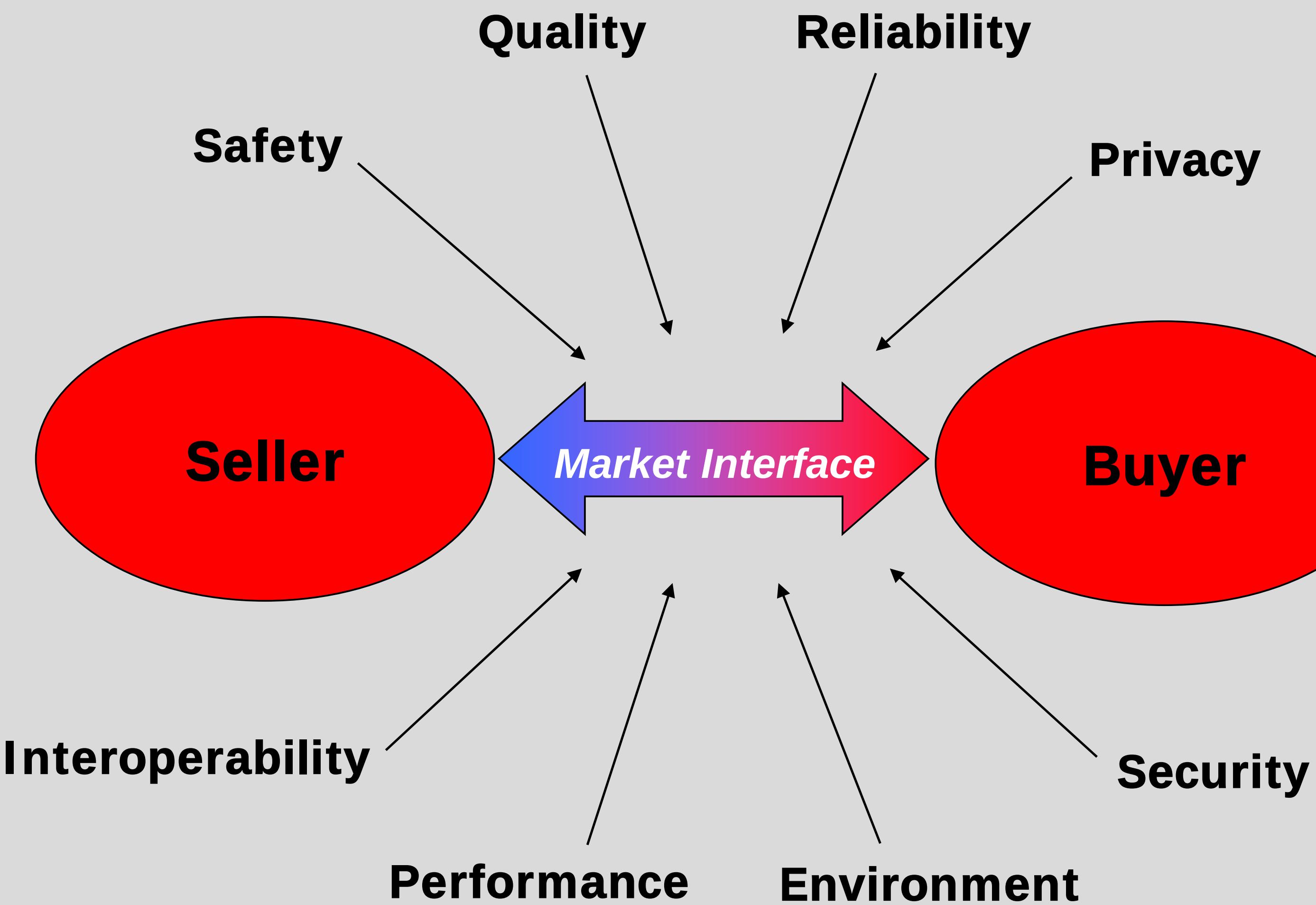
Gregory Tassey, "Rationales and Mechanisms for Revitalizing U.S. Manufacturing R&D Strategies," *Journal of Technology Transfer 35* (2010): 283-333.

Potential R&D Cost Reductions in Biopharmaceutical Development with Improved Infratechnologies

Technology Focus Area	Expected *Actual* Cost per Approved Drug (millions)	Percentage Change from Baseline	Expected *Present-Value* Cost per Approved Drug (millions)	Percentage Change from Baseline	Development Time (months)
Baseline	*$559.6*	—	*$1,240.9*	—	*133.7*
Individual Scenarios					
Bioimaging	—	—	—	—	—
Biomarkers	$347.9	–38%	$676.9	–45%	108.2
Bioinformatics	$375.0	–33%	$746.3	–40%	116.6
Gene expression	$345.8	–38%	$676.0	–45%	111.9
Combined Scenarios					
Conservative	$421.2	–25	$869.6	**–30**	**122.4**
Optimistic	$289.2	–48	$533.1	**–57**	**98.1**

Causes of Underinvestment – Composition of R&D

Complex Infrastructure for Efficient Transactions in High-Tech Markets



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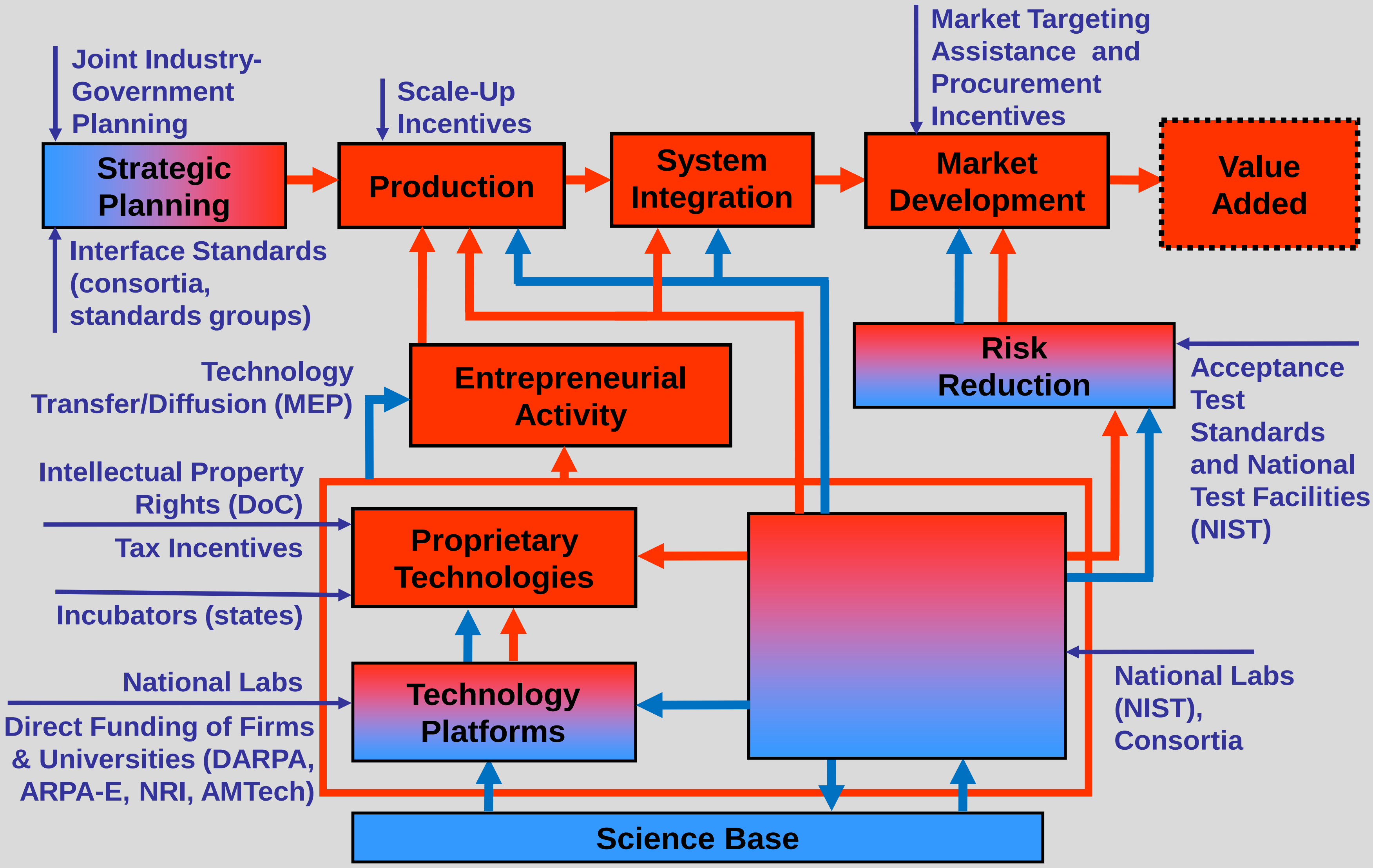
Managing the Entire Technology Life Cycle: Science, Technology, Innovation, Diffusion (STID) Policy Roles



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Need a Total-Technology-Life-Cycle Growth Strategy

- Germany has a trade surplus in manufacturing, even though, compared to the United States, it has a
  - Approximately the same R&D intensity (2.82 percent vs. 2.90 percent for U.S.)
  - 26 percent higher average hourly manufacturing labor compensation

- Reason: Germany has a more comprehensive and intensively managed STID policy
  - Coordinated government R&D programs
  - Strongly integrated R&D and manufacturing
  - Highly skilled labor force across all technology occupations
  - Optimized industry structure (support for both large firms and SMEs)
  - Highest % of manufacturing value added from R&D-intensive industries

Policy Response – A National Strategic Plan for Advanced Manufacturing

Target #1: Enable vigorous ***development and commercialization*** of transformative manufacturing technologies

- Increase efficiency of technology platform development through
  - coordinated public and private research in precompetitive advanced manufacturing technology
  - Implement government-wide funding and portfolio management
- Expand R&E tax credit to lower industry's cost of R&D

IMPACT: **Higher Rates of Innovation**

Target #2: Promote ***domestic deployment*** of advanced manufacturing technologies to increase productivity and economic growth across all manufacturing industries

- Maintain competitive industry structures including opportunities for small and medium firms (SMEs)
- Provide the skilled workforce needed for deployment of new technologies
- Facilitate scale-up (capital formation) to enable rapid market penetration
- Use government procurement to leverage new market development

IMPACT: **Market Share Growth**

Impact Metrics for a Nanotechnology Innovation Cluster Model

Short-Term	Medium-Term	Long-Term
• Partnership structures & strategic alliances organized • New research facilities and instrumentation in place • New firm formation • Initial research objectives met/increased stock of technical knowledge	• Supply-chain structure established • New-skilled graduates produced • Compression of R&D cycle • New technology platforms & infratechnologies produced • Commercialization ➢ New products ➢ New processes ➢ Licensing	• Broad industry and national economic benefits ➢ Return on investment ➢ GDP impacts