# Early Stage Technology Development: the Transition from Invention to Innovation in the US Economy

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# US S&T-based industrial policy

- A residue of confidence in 'social contract' for science (Vannevar Bush)
- Technology Pull policies: Bayh-Dole Act
- Technology Push policies: CRADAs
- Partnerships to reduce risk in radical, technology-based commercial innovations. (ATP and SBIR programs)

# Radical Innovation vs Incremental Growth

- Virtually all economic growth comes from incremental improvements in productivity, products and markets
  - Markets will drive it
  - Private investment and profits finance it
- But the sources of new industries offering competitive (Schumpeterian) advantage come from radical innovations. This must be a source of attention in public policy.
  - Government research is a primary instigator of radical innovations in firms large, small and new.

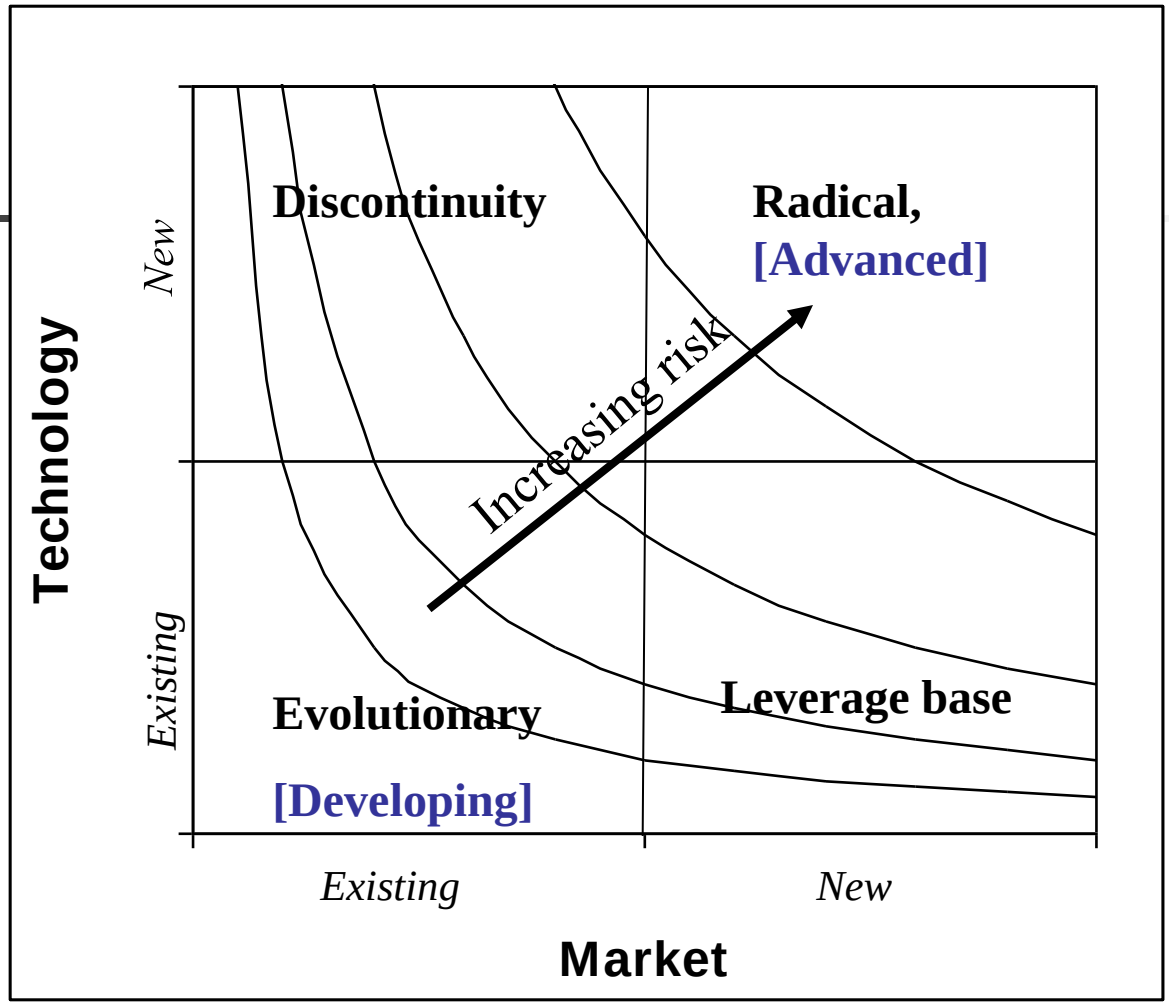

Technology
New
Existing
Discontinuity
Radical,
[Advanced]
Increasing risk
Evolutionary
[Developing]
Leverage base
Existing
New
Market

**Figure 3**

# The Chaotic, Creative path from Invention to (Radical) Innovation

- We think we understand the US research and invention enterprise, much of it publicly funded.
- We think we understand business case management and new firm creation, mostly privately funded.
- Do we understand what goes in between?

# Large vs small firms

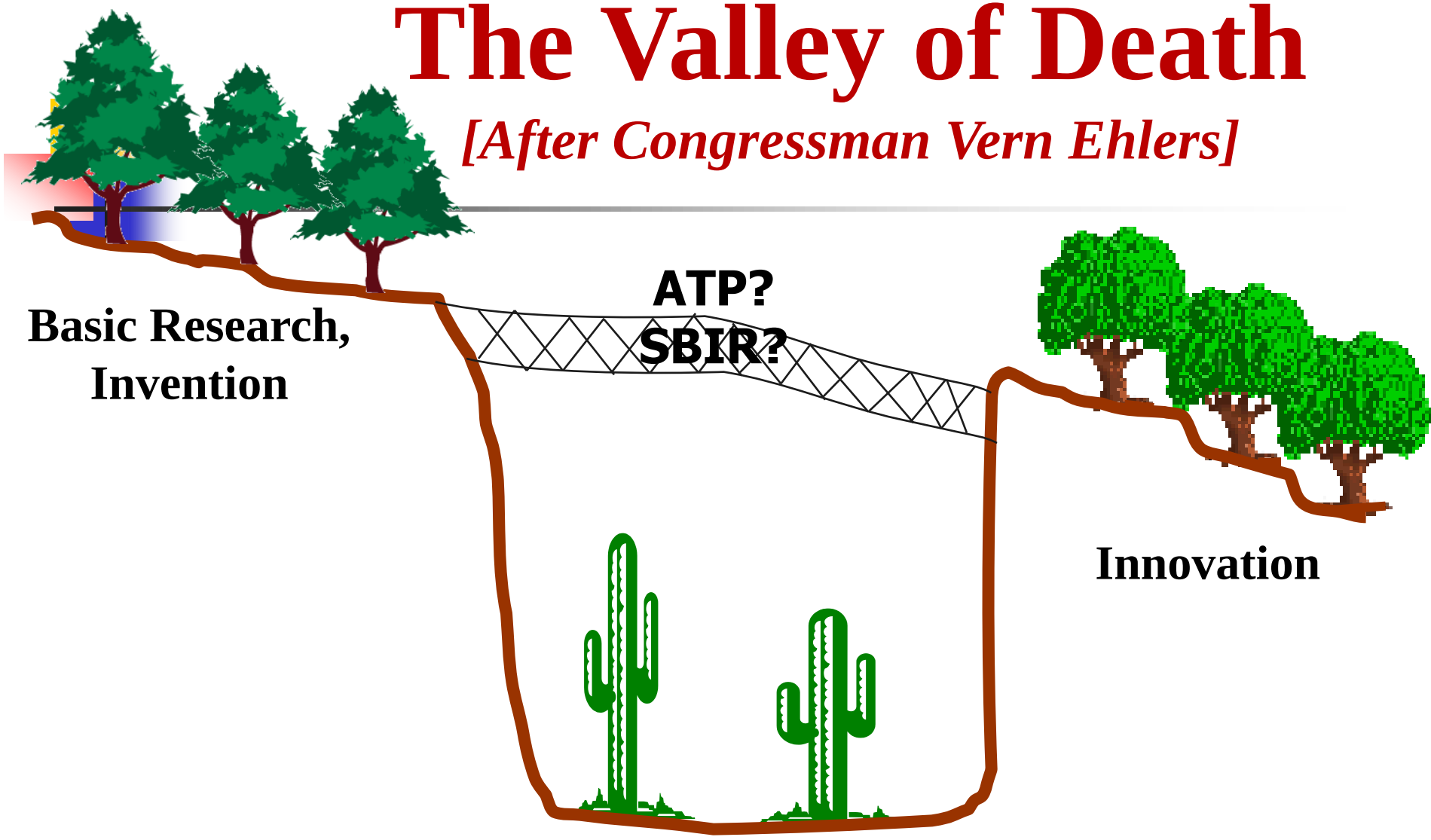
- Invention to Innovation Transition most easily understood in new firm creation.
  - Scott Shane shows new firms most successful when radical science based.
- Big firms outnumber and outsize small ones.
  - 1997: One firm (IBM) $4.3B in R&D
  - 1997: All early stage VC: $3.4B
  - 1997: All seed VC: $0.4B
- Case studies show decade required for transition to be complete as firms mature
  - Caliper, GE amorphous Si, PPL Therapeutics

# The invention-to-innovation transition

| | | |
|---|---|---|
| Corp research<br>Gov't research<br>Bootstrap | Seed (angel)<br>Early Stage VC<br>Bootstrap<br>Advanced Tech. | Second Round Venture Cap.;<br>Revenue in the business plan |
| Basic research,<br>Applied res. | Basic technology and applied res. | Development |
| Invention, new concept research | Conversion of invention to business plan | Revenue committed in plan |

# The Valley of Death

*[After Congressman Vern Ehlers]*



# Early Stage Technology Development

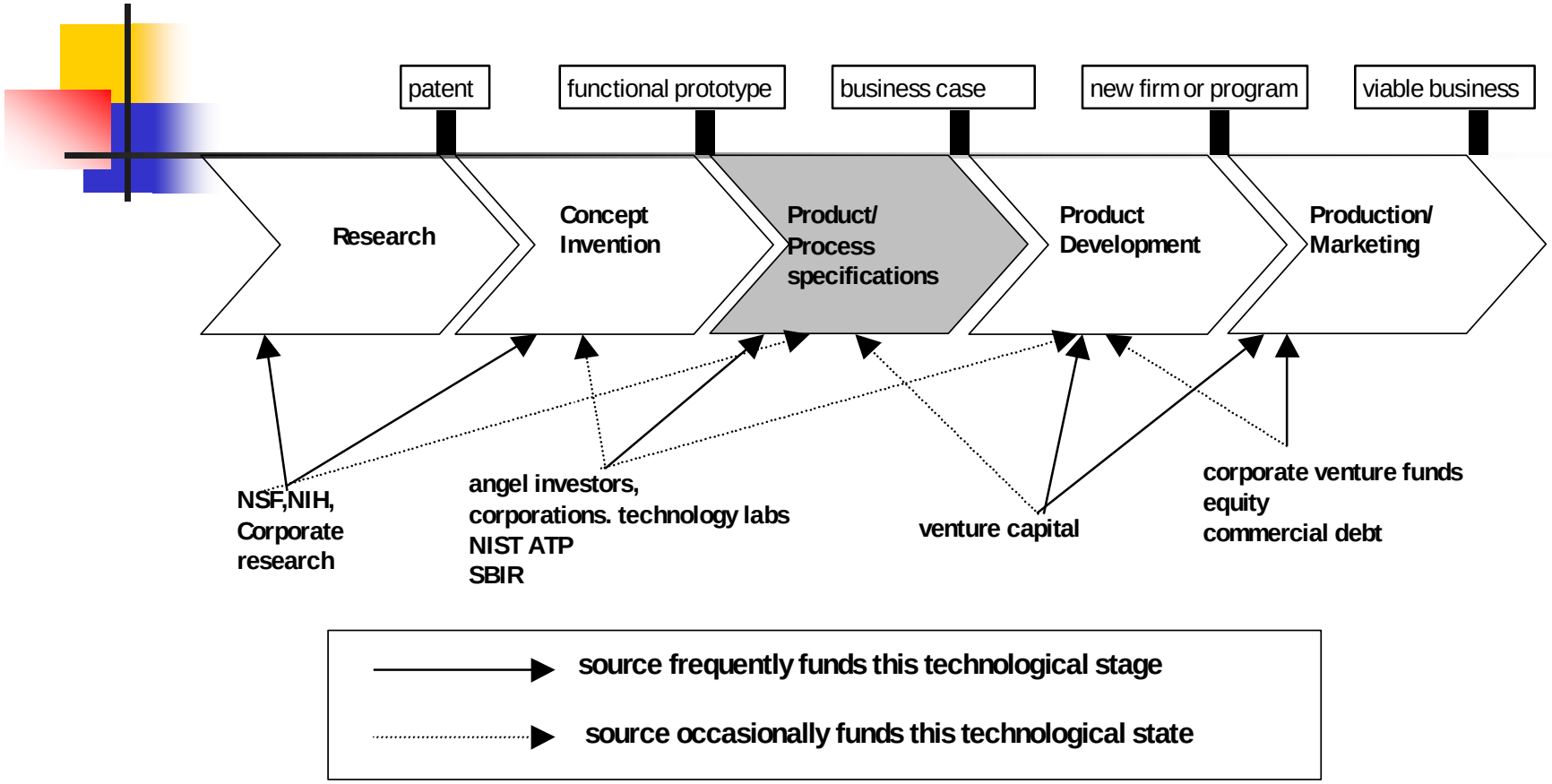



**Figure 1. Sequential model of development and funding**
The region corresponding to the "Funding Gap" is shaded in grey.
The boxes at top indicate milestones in the development of a science-based innovation.

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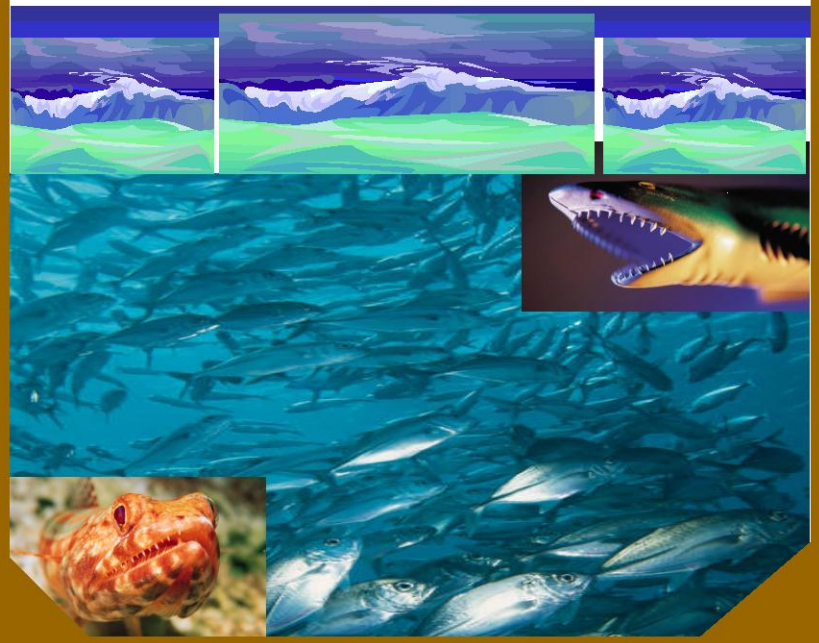
# The Darwinian Sea

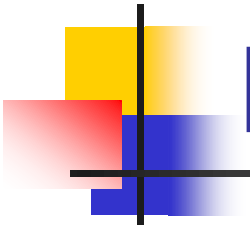
## The Struggle of Inventions to Become Innovations

Research & Invention



Innovation & new business

"Struggle for Life"in a Sea of Technical and Entrepreneurship Risk



# Defining and quantifying Risk

- Risk and uncertainty - definitions
- Competence, information and trust:
  - Risk is not inherent in technical realities
- Defining failure
  - Abandonment
  - “If you can’t fix it, feature it.”
  - Technical learning through failure
  - “Burying projects in a shallow grave”

# Innovation Risk Elements - Xerox

| Technical risk | Skills & complementary assets | Product Spec. achievability | Probability of success |
|---|---|---|---|
| Incrementing technology now in house | Tech competence in hand; complementary assets available | Modest extension of existing specs & market needs | 0.9 |
| New technology; Feasibility not demonstrated | Techn available outside Complementary assets Not available | Specs uncertain, depend on market and research | 0.3 |
| New invention, not reduced to practice | New competences and complementary assets must be created | Specifications dependent on new market; unknown | 0.1 |

# Barriers to bridging invention-to-innovation

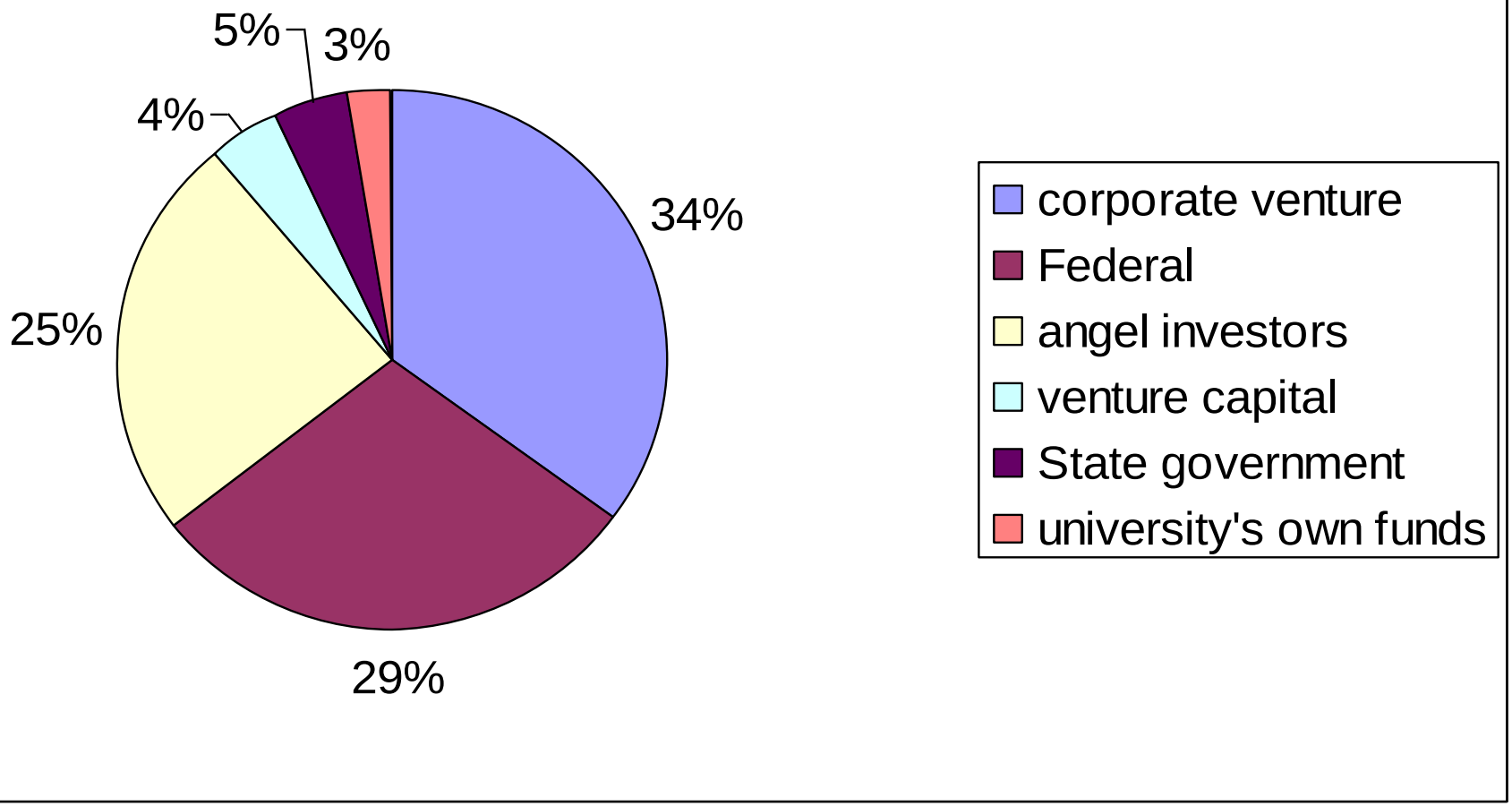
- Lack of knowledge to evaluate technical, managerial and market risks concurrently.
- Skew of private investments to IT, retail, medical & biotech (76 % of total in ‘99)
- Skew of private investment to CA, MA, NY, TX (67 % of total in ’99)
- Cyclical changes in available private capital for early stage investment.
- Lack of public resources to bring radical inventions closer to reduction to practice.

# Sources of funding for transition

- Historic sources
  - Corporate diversification investments
  - Venture Capital seed investments
  - Individual Angel investors
  - Bootstrap (use of own and FFF funds)
  - Incubators and state government programs
- New, growing sources
  - Angel networks "seed mutual funds"
  - Corporate venture funds
  - University venture funds
  - Banks, coupled to VC and Angel investments

| | | | Low Estimate ⟷ | | High Estimate | |
|---|---|---|---|---|---|---|
| | $B | Data source | $B | Data source | $B | Data source |
| Industry | 149.7 | Total Industry funded R&D, National Science Board (2000) table 2-5. | 1.7 | Early stage innovation research in central research laboratories | 16.8 | Half of all basic research and a third of all applied research funded by industry |
| VCs | 16.8 | Total VC disbursements, National Science Board (2000) table 7-14, based on data from Venture Economics. | 0.4 | Seed stage disbursements to product-based technology firms | 0.8 | Fractional components of all VC disbursement to product-based technology firms |
| Angels | 20.0 | Total angel disbursements, as reported by Sohl (1999). | 1.5 | Angel disbursements based on extrapolations from Silicon Valley data | 8.5 | Angel disbursements to new technology startups based on Reynolds and Sohl |
| Universities | 5.0 | Total university funded R&D, National Science Board (2000) table 2-5. | 0.2 | University support for faculty spin-offs | 1.8 | All university funding for applied research and development |
| Federal Government | 72.1 | Total federal obligations for R&D, National Science Board (2000) table 2-25. | 1.4 | Total funding for ATP, SBIR, and STTR programs | 7.3 | Portions of federal obligations for non-defense R&D |
| State Government | 2.3 | Total state funded R&D in 1995, State Science and Technology Institute (1998) table 13 | 0.2 | Fractional portion of state-funded applied research in 1995 | 0.8 | All state funding for applied research in 1995 |
| **Totals** | **$265.9** | **Total support** | **$5.4** | **Lower estimate** | **$36.0** | **Upper estimate** |
| | | | 2.0% | of total support | 13.5% | of total support |

# Average percentage distribution of sources of finance for the invention – innovation transition drawn from high and low estimate models



# Communications and Trust: Social Capital

- Technical innovator confident of success but risks failure if nature is not compliant.
- Business executive acts only when assured that risks are manageable.
- Venture capitalists rely on networks of trust and actively manage new firms.
- Success depends on networks of trust

# Social Capital: trusted networks for innovation

- Capturing benefits locally
  - Examples of Si Valley & Boston vs. Cleveland
  - Building on, vs. displacing existing economy
  - 80% of university based startups in same state.
- Using the tools of innovation policy with local government to increase social capital.
- Partnerships and consortia may enhance social capital.

# Universities and high-tech innovations

- $1.26B in royalties to US universities from 4,346 licenses in FY2000.
- 454 spin-off companies from universities
- 8,500 patents filed by US universities
- US universities took equity interest in 56% of the 454 deals up 46% from 1999.
  - Data from Association of University Technology Managers (AUTM) www.autm.net

# Conclusions for policy

- Largest funding sources for early stage technology development are:
  - Federal commercial R&D (ATP, SBIR + other)
  - Angels and angel networks
  - Corporate technology partnerships
- Venture capital is a very small contributor to the "funding gap," will not replace ATP/SBIR
- Proximity to investment is critical: social capital matters.

# The Public Policy Issues

- Do we understand how research is converted to successful commercial innovations?
  - Is there a financial or institutional gap?
- What is the role of governments (federal and state) in promoting the transition from invention to innovation?
- Does ATP -- the one government program specifically intended to easing the transition – work as it should?
- How does the Administration propose to improve it?

# References


- *Investing in Innovation: Creating a Research and Innovation Policy that Works*, LMB & James Keller, eds (MIT Press 1998) ksgwww.harvard.edu/iip/techproj/home.html
- *Industrializing Knowledge: University-Industry Links in Japan and the USA*, LMB, Fumio Kodama & Richard Florida eds (MIT Press, 1999) ksgwww.harvard.edu/iip/usbid/usbid.html
- *Taking Technical Risks: How Innovators, Executives & Investors Manage High-tech Risks* LMB & Philip Auerswald (MIT Press 2001).