

Turning Community Inventions into Sustainable Technology Clusters

Finding the Right Strategy

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Abstract

Although tech companies accounted for just 4 percent of the nation's job base in the 1990's, they generated two-thirds of national growth. Much of this growth occurred in a few communities with existing concentrations of technology companies. This article discusses how developers, outside the tech mainstream, can stimulate the formation of technology clusters: Who generates the ideas for launching new technology companies? What role do universities play as a technology platform? Does technology development raise a community's standard of living? The article concludes with a discussion of 10 strategic issues that improve the effectiveness of technology programs?

*Why do you rob banks, Willy?
"Cause that's where the money is"*
Willy Sutton
Bank Robber

Willy Sutton had life easy compared to the economic developer of today. When he needed money, he knew where to look. Money, for economic developers, is now in the high-tech sector (About two-thirds of US economic growth since 1990 has been in high-tech industry, based on a conversation with Ross DeVol of the Milken Institute in July 2000). When we look for technology opportunities, however, our job is much more illusive than Willy's: We can't look on the nearest corner for the tallest building to find our stash; in fact, we're not even sure where to look. If we are going to harness the technological revolution, developers need to understand how to look for new technology.

This article discusses a range of topics that help the economic development practitioner understand how technology clusters form. It discusses the role that universities and the private sector play in the process. And finally, it concludes with recommendations of how to improve technology development programs.

Innovation Cascades

As Peter Hall observed in his pioneering work on technology clusters, tech industries in Silicon Valley and Boston didn't spring from a single invention but from a "*cascade of innovations*" (See Manuel Castells and Peter Hall, "Technopoles of the World"). A chain of inventions must be linked together in a community before a technology cluster forms. The links in the chain consist, not of a single university or company, but of a variety of institutions. Linkages between public institutions and science-based companies are critical infrastructure in this chain. Figure 1 is a model of the four major links in the chain.

Basic Research

Basic research builds the nation's long-term growth. Only a sixth of the nation's R&D is leading edge enough to be classified as basic research. The principal product of basic research consists of published scientific articles. An example of a basic research project is the Laser Interferometer Gravitational-Wave Observatory in Livingston Parish, Louisiana. This project measures gravitational waves on earth formed by the collision of neutron stars in distant solar systems. A less "Buck-Rogers" example of basic research is the mapping of the human genome, finished in early 2000. Basic research pushes the frontiers of scientific knowledge and commercialization of its discoveries often takes generations.

Universities and Federally Funded Research and Development Centers (FFRDC's) perform about 60 percent of the nation's basic research. Basic research is a huge business with \$34 billion of expenditures in 1998 and employing 66,000 Ph.D. scientists and engineers. The ratio of expenditures per job compiled by the Bureau of the Census suggests that basic research generates a total of 272,000 jobs in the national economy. Although every state has a backbone in basic research, the majority of basic research is concentrated in eight states (See Figure 2).

Applied Research

Applied Research is a larger component of the R&D infrastructure than basic science, exceeding \$51 billion of expenditures, employing 95,000 scientists and engineers, and about 408,000 total workers. The composition of the workforce is different in applied research. Approximately a fourth consists of engineers versus just six percent in basic research. Applied science is different too in that it produces work that warrants patent protection. Universities perform a puny portion of applied research, however, about an eighth of the total (See Figure 3). Applied research is the domain of the private sector, which performs \$35 billion of the total (nearly 70 percent).

Development

A patent isn't a commercial product, merely an idea for one. Before patents can be turned into businesses, someone must develop a prototype, must create a production

method and plan, and importantly, must develop a market assessment and determine the production cost and potential profitability of the patented idea. This process, the Development component of R&D, is the largest portion of the process and accounts for two-thirds of the total expenditures for national R&D. The development process involves an estimated 1.0 million jobs of the US R&D workforce.

Development is nearly the exclusive domain of the private sector, which performs almost 90 percent of the total. The knowledge base used in development is far different from the earlier stages of R&D. The workforce in a development project consists of an equal number of engineers and scientists and a smaller number of Ph.D.'s (See Figure 4).

Commercialization

Once an invention has become a salable product, entrepreneurs are needed to turn the invention into a business. This step in the cascade requires another set of skills. Entrepreneurs need a business plan to launch their ideas commercially. The base of the business plan is an understanding of the market opportunity, of the costs and risks involved, and an operations plan that identifies key executives that will launch the business. As the innovation cascade enters commercialization, the requisite skills get farther and farther from the lab and more into mainstream business.

Where Do Inventions Originate?

Do commercial ideas originate in the universities that generated the basic research that spawned them or do they originate elsewhere? The Census Bureau and the National Science Foundation undertook a landmark study in 1993 to ask entrepreneurs in technology where they found their product ideas (responses shown below):

Very Significant or Crucial

- Internal sources
- Clients and customers
- Suppliers of materials and components

Slightly Significant or Insignificant

- Government labs
- Technical institutes
- Consulting firms

Technology companies rely on their network of customers and vendors for product ideas far more than they rely on research organizations like universities and government labs. Technology programs built on attempts to commercialize university research, if not grounded in private sector collaborations, are likely to fail.

Niche and Mass Market Technologies

The commercialization step is really two distinct sub-steps: niche markets and mass markets. Not all technologies make the transition from the first step to the second, yet it is important for developers to understand the difference since the vast majority of jobs stem from mass-market technologies. A couple of examples, discussed next, explain the distinction.

The transistor was pioneered by a research team at Bell Labs because it offered the company a means to miniaturize communication devices. The first commercial applications of the technology by Fairchild Semiconductor in the mid-1950's created devices for use in high-end missile guidance and aircraft electronics systems, true niche markets that employed few workers. A young Dallas-based company, Texas Instruments (TI), discovered that these devices could be used to make radio truly portable, provided transistors could be produced cheaply. The transistor radio was launched by TI in the mid-1950's and the price of transistors plunged with the growing worldwide market for portable radios, which in turn created a huge increase in semiconductor employment.

The saga of the microprocessor is similar. Originally used in defense electronics, the devices spawned a huge growth in jobs in the 1980's when Apple Computer and IBM harnessed this technology as the brains of the personal computer. The blockbuster technologies, in terms of economic development potential, are those that bridge from the niche market to the mass market.

The Role of Venture Capital in Commercialization

In established businesses, the commercialization phase is financed through internal earnings, debt or a new equity issue. Startup companies rely on seed capital for commercialization, the most difficult form of capital to acquire. Even the majority of venture capitalists don't provide startup capital-- and for good reason (the NSF reports that less than 10 percent of venture capital in 1998 went into seed or startup stage projects). Startup companies based on a single product or idea often fail. Just one in every 10 drug discoveries reaches market, for example. University technology transfer offices only patent about a third of the invention disclosures they receive from professors (Association of University Technology Managers (AUTM) licensing survey in 1999). The private sector, by contrast, sees about 10 percent of their invention disclosures granted patents.

A high churn rate in technology fields is a characteristic of the sector. While the national economy added 695,000 new businesses in 1994-95, the net effect was much lower because 587,000 of these startups died during the period (See www.neweconomyindex.org). These statistics suggest that communities need to fund six ventures if they want a survivor. Commercialization is indeed a high-risk and high-

reward game that few but the largest and wealthiest can play. The pros don't call this "seed capital" for nothing.

Communities have been experimenting with venture capital as a means of stimulating their technology development, particularly with the commercialization of university patents. Considering the parameters under which venture capital funds become self-sustaining, we wonder if more thought shouldn't be given to creating markets for venture capital, rather than merely raising venture capital.

Innovation, as measured by patents, is not normally distributed among US metro areas (see Chart 1). Half of America's metro areas produce under 16.6 patents per 100,000 population. The top 10 have rates that are 500 percent of median; the top 20 350 percent of median; the top third just slightly above the median. The intellectual activity that draws venture capital, therefore, is concentrated in about two dozen regions around the US.

Venture capital, it appears, is much of a "chicken or egg" dilemma in technology development. Can a supply of venture capital create its own market or does venture capital need a market of sufficient volume and depth to survive? The evidence favors the latter conclusion. Perhaps communities should probe this issue in some depth before rushing to clone successful programs from other communities.

Resource Requirements Grow During the Innovation Cascade

The development stage of the innovation cascade is far more capital intensive than the earlier stages of the process. While basic or applied research requires \$500-550,000/year to support each scientist and engineer, the budget jumps at the development stage to \$3.36 million/Ph.D., six times the resource level of the earlier stages! Access to capital becomes a far more important ingredient in the later stages of the cascade than access to inventions.

The mix of technical talent is different as well. Development requires far more non-scientists and engineers than the earlier stages of the process (See Table 1) implying that academic collaboration or recruitment of academics as private R&D workforce are not strong location factors at this stage of the process. The strength of a company's management team, a function of work experience, is far more important in attracting venture capital for commercialization than the academic credentials or scientific ideas on which the business is based.

Case studies of technology clusters formed in the last 50 years all identify a large science-based company as a critical element in the formation of the cluster (See "Technopoles of the World" by Manuel Castells and Peter Hall). Collaboration between university researchers and scientists employed in the private sector seems to be of far more importance to the process of forming technology clusters than the activities of a research university. We've coined a term for companies that serves as a platform for launching technology startups: *Spin-Gens* (short for *spinoff generators*).

Top quality academic science is not sufficient for launching sustainable technology clusters except in the few instances discussed later in this article. A private sector science-based company that can act as a training ground for technology entrepreneurs, however, seems a prerequisite.

Spatial Distribution of R&D Activities

Research and Development is highly concentrated in a few states. The Top-10 states account for over half of the nation's academic research and almost three-fourths of industrial R&D (See Figure 5). The spatial concentration of industrial R&D activity stems from the economic structures of the states. States with a large pharmaceutical sector, such as New Jersey, have concentrations of industrial R&D facilities while states lacking science-based industries, like Louisiana, lack a private sector base. Science-based companies find it convenient to perform R&D near their headquarters location or near concentrations of the requisite technical talent, therefore tech clusters form near concentrations of science-based companies.

Industrial R&D is concentrated too by industry group. Eight industry groups account for 85 percent of industrial R&D (See Table 2). The venture capital that seeds technology companies is concentrated in these same sectors. Eight-five percent of seed capital in 1998 went into just four technologies (the largest venture capital sectors in 1998 were software, communications, medicine and biotech).

In terms of labor force, the majority of the nation's Ph.D. engineers and scientists work in the private sector, not in universities and governments. In 1998 the ratio was 6.7 Ph.D.'s in industry for every one employed in government or academia. Communities with a base of technical industry have much larger labor pools for technology startups and expansions than those with a research university.

Although developers have overlooked the importance of industrial structure as an asset, this aspect of technology development is probably the most important community characteristic that determines the success of technology programs.

Positioning the University as a Technology Platform

University research in the US is a vital element of our national infrastructure. Over half of the nation's basic research, which creates commercial opportunities several decades in the future, is performed by universities. Over 100 universities now have technology transfer programs to license discoveries by their faculty, and universities now collect over \$655 million annually in license fees (See AUTM licensing survey for 1999). The university total, however, is just 0.75 percent of the \$78+ billion of license fees received by the private sector in the same period (a figure compiled by Tamerica Management Company from IRS studies of corporate tax returns). IBM and Texas Instruments each

received in excess of \$1 billion/year for patent royalties in the early 1990's. The evidence suggests that universities play a minor role as a platform for startup of technology companies compared to the private sector.

Much of the economic development thrust in the technology arena over the last 20 years has centered on creating startup companies through technology transfer from universities. This approach certainly was important in developing the semiconductor industry in California and the mini-computer industry in Boston. The National Business Incubator Association estimates that over 100 technology incubators were operating in 1997, most associated with a university. Technology incubators have sprung up at university-based technology parks over the last two decades in an attempt to clone the success witnessed in Silicon Valley. But how viable an approach is this in the 21st century?

University Patent Activity is Small. University researchers are rewarded for discoveries at the leading edge of science while commercial products fall at the opposite end of the innovation spectrum. University patents, which averaged around 2,500/year over the last three years, comprise just three percent of the 203,000 awards issued by the US Patent and Trademark Office to US inventors during that period (See Figure 6). IBM alone received 2658 patents in 1998, more than all US universities combined .

Three US companies, IBM, Microsoft and Intel, performed more R&D in 1998 than America's top 40 research universities. (See Figure 7 for comparison of R&D budgets of the three with those of leading universities). Each of the three exceeded the R&D spending of all universities in California combined! Intel's portion of R&D for contract research exceeds the R&D budget of the nation's largest engineering school--MIT. While university research is important, it is paltry compared to R&D flows in the private sector.

University Patent Activity Diverges From Areas of Commercial Interest. University patent activity contrasts with the areas where venture capitalists invest their money (See Table 3). In two areas, biotechnology and medicine, the interests of universities and entrepreneurs converge yet the VC investment sectors which currently attract half the nation's venture capital (communications and software) have attracted minor university interest. University programs do have active research in breakthrough technologies in image analysis (2.3 x the level of private sector) and in artificial intelligence (3.3 x the level of private sector) but overall universities are not prolific spinout machines in the software and communications fields.

Universities Are Effective at Spinoffs in Breakthrough Technologies Like Biotech. The spin-out of US universities, measured as the number of startup companies, averaged about 350 companies/year nationwide over the last three years. Most startups are appearing around medical schools and major engineering schools because of the role that biotech is playing in university-connected ventures.

MIT, arguably America’s premier engineering school, reported that half of its active startups were in biotechnology. MIT generated 73 startups during the 1990’s from its exclusive patent licenses and these startups collectively generated 2,300 total jobs over that period.

We surmise that the amount of spinout potential from smaller universities depends on the amount of applied research they perform and on the absolute size of their R&D efforts. An institution like MIT, with an intense interest in applied research and an annual R&D budget exceeding \$400 million certainly generates more spinoff jobs than institutions without its orientation, its size, or its network of industry contacts.

A patent must offer a “blockbuster” opportunity to warrant the formation of a new company and most university patents don’t fall in the “blockbuster” category. The following five patents granted to universities over the last 30 years fit the blockbuster category and demonstrate that the university can occasionally serve the role of a *Spin-Gen*:

System	Discovery	Cumulative Royalties
U Wisconsin System	Vitamin D Production	\$99 million
UC & Stanford	Cohen-Boyer Gene Splicing	\$97 million
Michigan State	Cisplatin	\$86 million
U Florida	Gatorade	\$33 million
Iowa State	Fax Technology	\$27 million

Universities Serve as Better Technology Platforms for Established Companies.

The Association of University Technology Managers reports that just 12 percent of the patents licensed from universities in 1999 went to startup companies. Universities are much more adept at licensing to established companies, particularly in the fields of chemistry and chemical engineering. The NSF estimates that around 17 percent of the nation’s R&D in chemistry and chemical engineering occur in universities. University research is often cited in chemical patents by private companies (from analysis of tables in Science and Engineering Indicators 2000). Patents in chemicals offer companies a significant flow of intellectual property to mine, as chemical patents comprise over 16 percent of overall university patents and encompass around 400 annual discoveries in recent years.

Commercializing University Patents Requires Significant Time and Money. MIT pioneered an economic analysis of its exclusive patent licenses that has since been replicated by the University of Pennsylvania, Ohio State and the University of Wisconsin. All of these studies reported the following parameters:

- 60 percent of university patent licenses are in the areas of biotech and medicine while 40 percent fall in the areas of chemistry, physics, software and medical devices.

- 44 percent of MIT's licenses are commercialized within Massachusetts, the majority commercialized elsewhere. The proportion averages around 85 percent for other institutions.
- the average startup company acquired licenses to Four patents.
- The average startup invested \$ 4 million over four years to develop a commercial application for the MIT patents(about the same as at other schools).
- Startup companies based on MIT licenses rarely generate revenues until their fourth or fifth year and generate significant revenues eight to nine years after signing the license agreement.

The evidence suggests that many developers need to redefine the role of the university in their technology development programs. Don't look to universities as a source of startup companies but rather as a tool for growing established science-based companies in the areas of chemistry, plastics and drugs. The evidence also suggests that building technology incubator programs with three or four year exit requirements might not be a sound policy.

Look to the Private Sector for Startups. Don't Ignore University Spinoffs in Breakthrough Technology

The research suggests that universities, except in the area of drugs, are a small share of the annual technology startups in the US. Extrapolations of figures produced by MIT and by the AUTM suggest that universities are generating a substantial proportion of the new companies in drugs and biotech, however.

Universities have generated about 200 biotech startups per year over the last three years and our research suggests that the drug arena has added 310 net new companies during that period (See Table 4). The implication is that virtually all of the startups in biotech can be traced to a university connection yet the pattern is far different in other areas of technology.

University startups are a mere two percent of the total net new companies formed during the period and perhaps one percent of the balance of startups (excluding biotech and medicine) have a university connection. Unless a university offers opportunities for significant commercial break-throughs, like biotech, developers should look to the private sector for their technology starts.

Improving the Performance of Technology Programs

Developing technology is not a simple process for practitioners of economic development. An analysis of the process allow us to draw conclusions about how the process of technology development can be improved. Following are nine suggestions.

Pathfinders in Basic Research Don't Always Commercialize the Technology.

Strategists posit that communities that invest in basic research are most likely to commercialize the work. Three examples from the twentieth century suggest that doesn't always happen. Boston became the hub of postwar activity in the commercialization of radar technology, an invention discovered in Britain. The semiconductor was developed at Bell Labs in New Jersey yet was first commercialized by defense contractors in Silicon Valley and Dallas. The electronic computer was created at the University of Pennsylvania during World War II yet was commercialized by IBM, which needed it to control the network of radar stations on the Defense Early Warning Line. Basic research, particularly if it is world class, might not be commercialized in the same location. MIT reports that only 44 percent of its exclusive patent licenses are granted to Massachusetts firms, far lower than the 85 percent average for all members of the AUTM.

The lesson for economic developers is that commercialization and basic research are distant in time and can be just as distant in geography. To create jobs, investment and tax revenues, programs to seed basic research also need to seed the applied research and the development and commercialization that must follow. A break in the innovation cascade might allow another community to reap the rewards of your basic research portfolio. The economic payoff to the community and state don't come until commercialization.

Think in Decades, Not in Years. Volunteers especially hate to hear this news. Technology projects don't develop quickly. Tech companies based on MIT research, for example, begin to create significant jobs and revenues for eight years from the date that licenses are signed. Tech startups in particular require lots of R&D before production begins. Lots of communities over-promise their leadership on the costs and rewards of technology efforts. Why, for instance, would one create an incubator based on graduating technology companies in two years when the average startup at MIT doesn't see significant revenue until their eighth year of operation?

High Risk and High-Reward. Technology businesses offer communities great opportunities for building high-growth companies with high paying salaries. Many communities therefore are experimenting with venture capital funds as a method of building a technology base. Yet the process of *investing* in high-tech companies is definitely a high-risk and high-reward payoff for communities. The only effective way to manage the risks are: (1) have a large pool of funds spread over a large number of projects; and (2) have a diverse portfolio of projects underway. A piecemeal program will likely give a token return.

Gauging the value of a particular technology is not a job for amateurs, either. Anyone who has ever looked at the business plan for a technology startup knows how difficult it is to gauge the commercial potential of an abstract scientific idea. Venture capitalists themselves limit their exposure by focusing on technological niches they understand. Venture capital funds are not a panacea for technology development and the skills and knowledge required to succeed in the VC arena are far beyond the experience of most developers.

No Smoke and Mirrors. Large scale is an important component in technology clusters. Because of the inherent volatility of startup companies, the clusters don't see sustained growth until they generate a large stable of startups. Getting there requires tons of money, far in excess

of what most states & communities have historically invested in their economic development efforts. After all, it's taken \$4-5 million, on average, to seed each company spun out of MIT's laboratories. Extrapolating this total to all US universities suggests that university spinoff ventures require \$5 billion of investment at the current pace, roughly 2.5 times what all 50 state governments combined currently spend on university research.

Cloning the Past Might Not Work in the Future. University sponsored research at the Lincoln Labs of MIT was crucial in the development of the mini-computer, a machine needed to deploy the Defense Early Warning Radar line in the 1950's. Likewise, the semiconductor was a breakthrough technology pioneered with the help of Stanford University for use in DOD missile and aerospace electronics applications. These breakthrough technologies were spawned during a cold war era where the federal government commanded two-thirds of R&D resources and spent much more of the total in universities. The federal share of the nation's R&D has dropped to 26 percent today. Development strategies that worked in earlier times might not work in an era where three-fourths of the total R&D budget resides in the private sector.

Biotech and Breakthrough Technologies. Universities are a platform for commercializing breakthrough technologies like biotech. Even though the basic techniques of gene splicing have now been fully transferred from the academic lab to industry, the frequency of academic-industry collaboration in the biotech field continues to grow since biotech is a radical departure from the traditional methods of drug discovery. Building on a university's excellence in a breakthrough technology is a valid economic development strategy provided the community is willing to wait for 10-20 years for significant results.

Software and IT Offer Quicker Returns to Communities Than Breakthrough Technologies. It's nice to think that your community has the potential of becoming the next Silicon Valley but it's a high risk strategy and a long-term process. As Figure 7 shows, the money in technology right now is in computer software, R&D labs and business services. These activities lend themselves to startups and the vast majority of jobs created in the technology arena over the last three years are in these categories. Developers that can't wait a decade to show results might target data centers and IT companies for relocations as an alternative.

A Culture of Collaboration and Cooperation Are Essential for Success. If a research university or federal lab is the community's keystone for technology development, it is vital that the institution have its means of networking with the private sector. Universities like MIT that have a dense network of industry contacts and research sponsored by industry groups have much better track records at commercializing their

inventions. University technology parks and incubators that omit collaboration with the private sector are probably not going to grow.

The University's Critical Role Is Providing a Technical Talent Pool. The evidence is conclusive that the private sector is the driver that turns research into useful products and services. The university's role in the process is largely one of supplying technically trained workers for product development and commercialization by private sector companies. Good engineering schools and computer science departments are an excellent resource for attracting technology companies that have entered the mass-market step in the innovation cascade. Developers should look first at the talent pool provided by universities, then, if the university has world class research in a breakthrough technology, at the potential for technology startups.

If forced to Choose, Engineering Is More Important Than Science. The resource that attracts technology business to the community tends to be an abundance of engineers and applied researchers, not an abundance of Ph.D.'s undertaking basic research. A large pool of computer programmers, systems analysts, and computer engineers is much better bait for technology companies than Ph.D. scientists.

Conclusion

Finding the right strategy for technology development is complicated because it involves restructuring the community to fit the needs of technology companies, rather than the traditional approach of matching the community's strengths and weaknesses to the requirements of target industries. The job is even more complicated because developers must try and gauge the needs of entrepreneurs, as well as the needs of companies large to small. Economic developers haven't had the best success at defining the needs of entrepreneurs. *The Wall Street Journal* made the point succinctly in 2000 when it reported "MORE TALK THAN ACTION: States vow to help entrepreneurs but do little." (See Eleena De Lisser's Small Business Suite Column, January 4, 2000). The analysis suggests that a major part of the problem with technology efforts has been that developers make assumptions about technology that are not supported by the realities of the marketplace.

The most revealing part of the analysis is the role that universities play in the success of technology development. The university's role in seeding technology businesses is, in the author's opinion, much more complex than the role presented here simply because of the lack of data needed to measure the university's impact in several key areas. Anecdotal evidence suggests that universities play a much larger role in seeding startups, for instance, when they attract a large pool of technical Ph.D. students with industry contacts, experience, and entrepreneurial interests. Many technology companies have been formed around the owner's Ph.D. dissertation. Anecdote also suggests that college professors can be valuable technical consultants to industry if the university has an intellectual property policy that allows companies to own interests in technologies developed through their collaborations.

Too much of our past efforts in the technology arena have been “me-too” strategies that clone the latest technological fad without attempting to understand the community dynamics behind the faddish tool or technique. Real efforts in technology development revolve around long-term strategies based on critical assessments of a community’s strengths and weaknesses for particular types of technology development. This article has attempted to help practitioners formulate realistic technology strategies. Rather than cloning each other, clone Willy Sutton’s simple idea: look for money in the places where it’s stockpiled.

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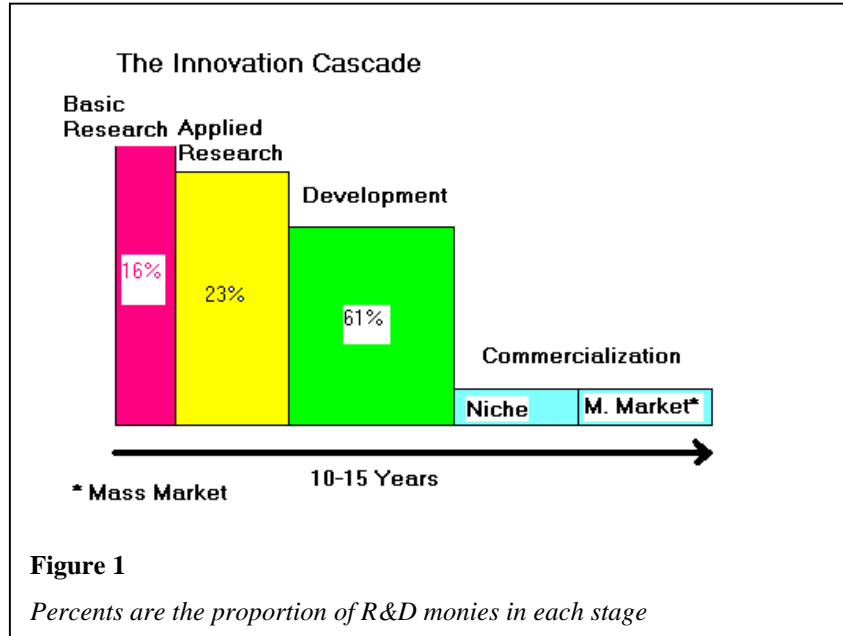


Figure 2

University Research by State 1998

State	(\$Millions)	Cumulative Percentage
California	2979	12.6%
New York	1784	20.1%
Texas	1581	26.8%
Massachusetts	1268	32.2%
Maryland	1242	37.4%
Pennsylvania	1241	42.7%
Illinois	930	46.6%
Michigan	842	50.1%
North Carolina	786	53.5%
Georgia	766	56.7%

Figure 3
R&D by Source in 1998

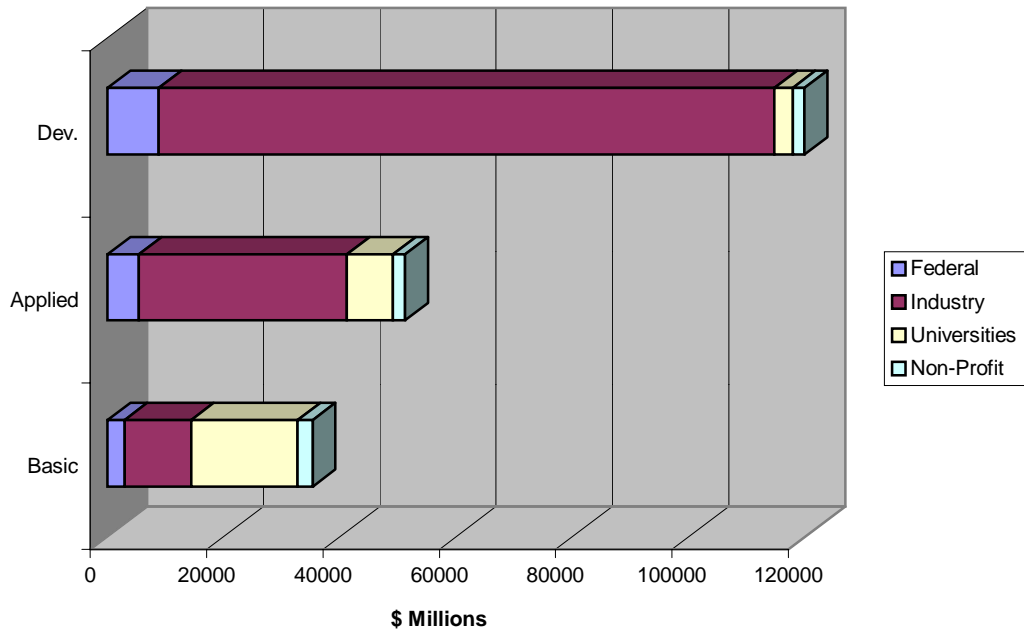
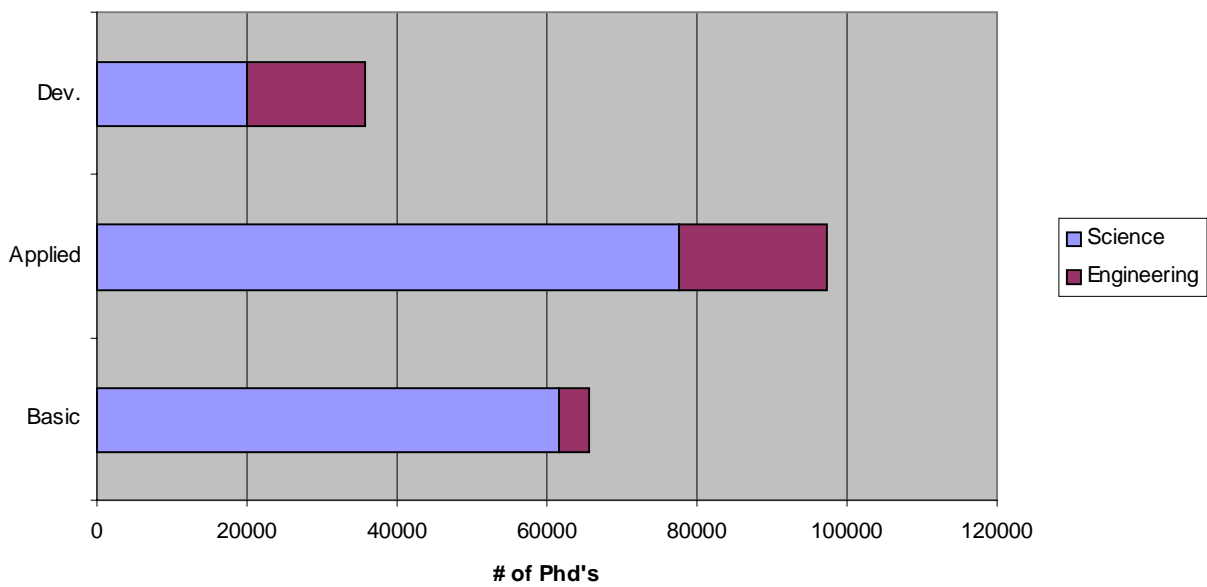
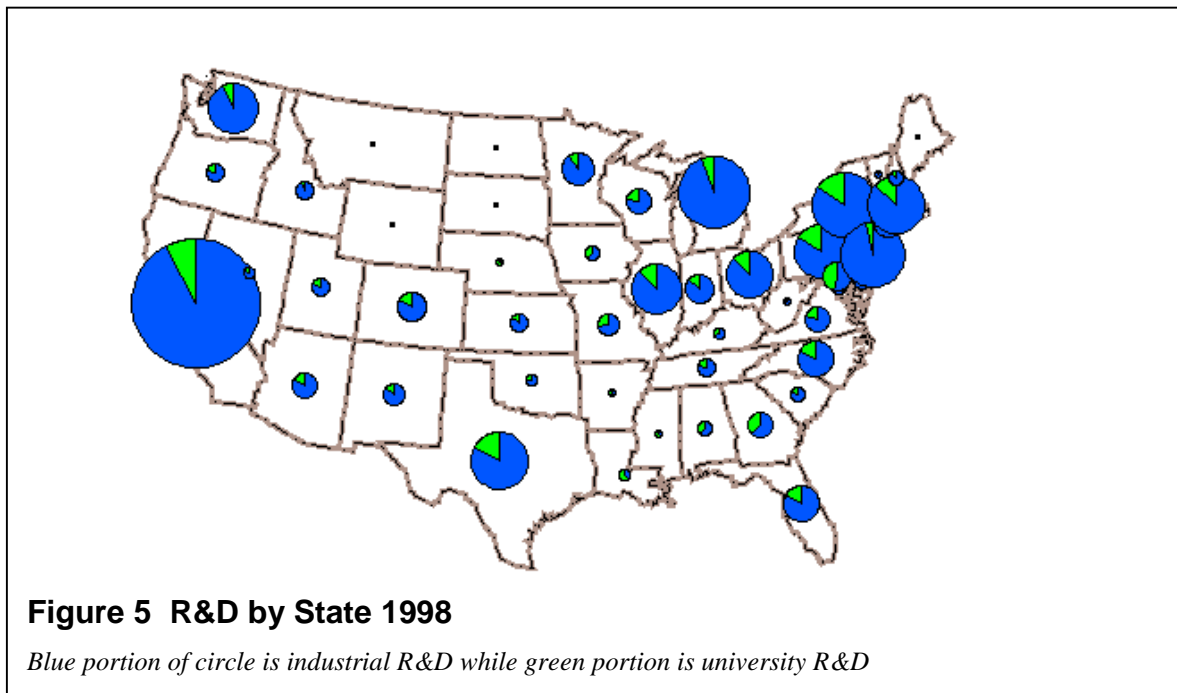


Figure 4
Breakdown of R&D Workforce by Tech Stage



Stage	Basic	Applied	Dev
Phd Level			
Scientists	61,628	77,532	19,880
Engineers	3,976	19,880	15,904
Other Workers	216,924	312,364	923,120
Percent(%)	76.8%	76.2%	96.3%



Sector	\$ Millions	Percent	Cumulative
1 Services	28149	19.5%	19.5%
2 Electronic equipment	19138	13.2%	32.7%
3 Aerospace	16224	11.2%	43.9%
4 Motor vehicles	16022	11.1%	55.0%
5 Computers	12786	8.8%	63.8%
6 Instruments	12149	8.4%	72.2%
7 Pharmaceuticals	9773	6.8%	79.0%
8 Ind Chemicals	9094	6.3%	85.3%
9 Nonelect machinery	6108	4.2%	89.5%
10 Electrical Machinery	3360	2.3%	91.8%

SOURCE: IISF Appendix Tables 7-9

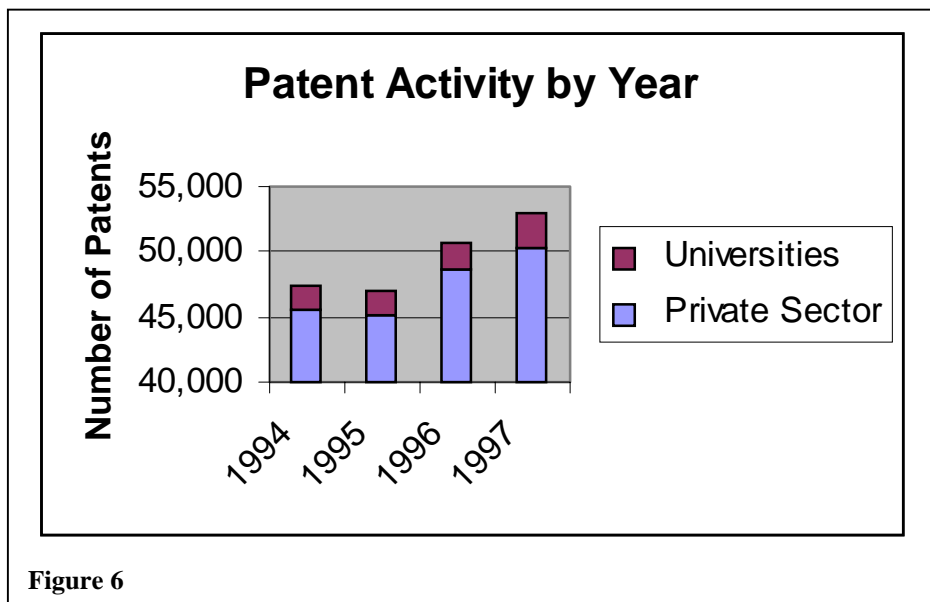


Table 3 Areas of Overlapping Interest Venture Capital and Academic Research

	VC Share 1998(%)	University Patents(96-98)	University Patents(%)	Activity Index Range
Software	34.1	364	4.8	0.7-3.3
Communications	17.1	38	0.5	1.1
Medicine/Health	13.6	323	5.4	1.7-4.6
Other Products	10.9			
Biotech	6.1	3152	40.7	4.0-14.0
Semiconductors	5.2	101	1.3	1.1-1.8

Source: NSF Compiled from Appendix Tables 7-14 and 6-68

Table 4 Technology Growth in the USA 1997-1999

SIC	Name	Establishments		Jobs		Growth	
		1997	1999	1997	1999	Est.	Jobs
283	Drugs	2,153	2,463	269,786	297,820	310	28,034
357	Computers	2,807	2,892	371,192	366,414	85	-4,778
366	Communications Equip	2,632	2,815	276,610	265,862	183	-10,748
367	Electronic Components	7,074	7,268	648,263	637,524	194	-10,739
372	Aircraft & Parts	2,915	3,012	496,141	498,917	97	2,776
376	Guided Missiles, space v	292	308	91,313	86,842	16	-4,471
381	Search, Detection, Instr.	834	849	159,602	162,705	15	3,103
382	Lab Apparatus	5,777	6,188	300,173	293,038	411	-7,135
384	Surgical-Med Instruments	4,890	4,987	275,094	283,339	97	8,245
481	Telephone Comm.	28,437	31,546	968,788	1,069,033	3,109	100,245
737	Computer Programming	113,864	155,790	1,410,076	1,843,515	41,926	433,439
781	Motion Pictures	18,485	20,654	236,152	271,660	2,169	35,508
871	Engineering Serv.	75,497	82,851	871,767	954,173	7,354	82,406
873	R&D & Testing Labs	27,412	29,907	587,260	609,775	2,495	22,515
		293,069	351,530	6,962,217	7,640,617	58,461	678,400

Source: Compiled by Tamerica from ES-202 reports

CHART 1

Relation Between Patent Activity and Per Capita Income

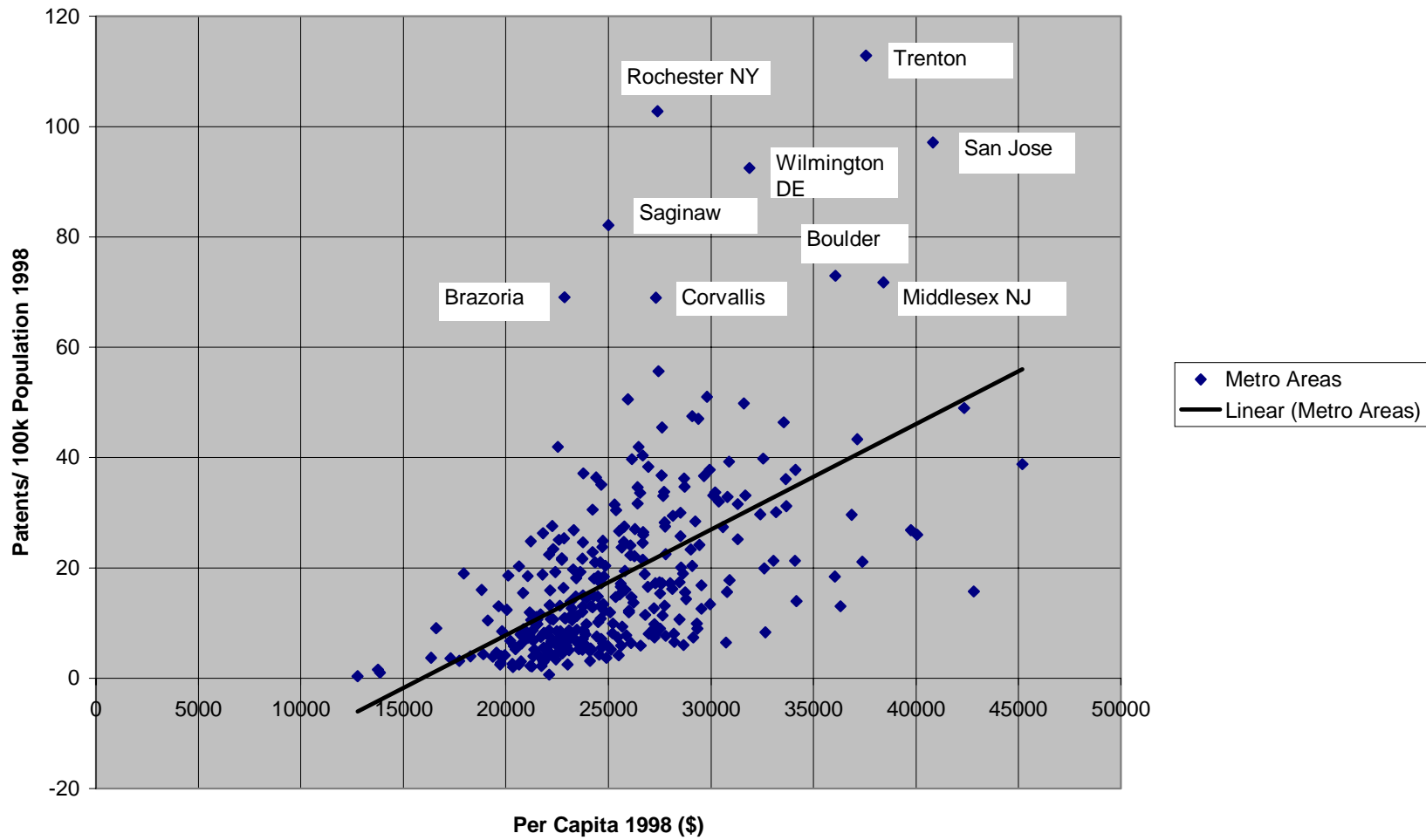


Figure 7
Comparison of Research Budgets at 3 Major Tech Companies and at the 7 Largest Academic Programs

