WHERE DO HIGH TECH COMMERCIAL INNOVATIONS COME FROM?

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ABSTRACT

On February 19, 2004, Dr. Lewis Branscomb gave the Meredith and Kip Frey Lecture in Intellectual Property at Duke Law School. In his speech, Dr. Branscomb discussed various models for turning basic scientific inventions into high-tech innovations and highlighted the roles that universities, private investors, and intellectual property law play in each model. Dr. Branscomb concluded that this intermediary process is the most important step in getting high-tech innovations to market.

INTRODUCTION

¶1 On February 19, 2004, Dr. Lewis Branscomb gave the Meredith and Kip Frey Lecture in Intellectual Property[2] at Duke University School of Law. During his lecture, Dr. Branscomb expounded upon the process by which basic scientific inventions are turned into high-tech innovations. He outlined the various roles of universities, corporations, and government agencies in this process, as well as the role of so-called "angel investors" who provide seed venture capital for high-tech start-ups. Dr. Branscomb further discussed the role that social capital plays in the innovation process, emphasizing the geographical concentration of high-tech innovation and

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[2] "The Meredith and Kip Frey Lecture in Intellectual Property is a lecture series that was established in 2000 by Duke Law alumnus Kip Frey '85 and his wife, Meredith, to increase discussion about emerging issues in the areas of intellectual property, cyberspace, and science and technology law." Duke University School of Law, *Lecture Series: Meredith and Kip Frey Lecture in Intellectual Property, at* http://www.law.duke.edu/conference/namedlectures.html (last visited Mar. 25, 2004).

high-tech companies that has occurred in the United States. In conclusion, Dr. Branscomb asserted that the intermediate process between research and development is vital to the successful introduction of high-tech innovations into the marketplace. This iBrief is an edited transcript of Dr. Branscomb's lecture.[3]

I. WHERE DO INNOVATIONS COME FROM?

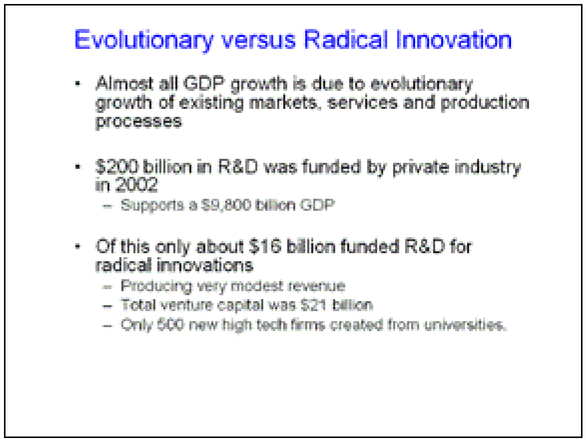
¶2 I'm going to talk about the demand source for technical knowledge. It is commonplace for people to discuss the commercialization of science and technology from a supply side perspective. That's because we think about the engines of investment that make the science and technology possible. But what's really more interesting is to ask is: What are the forces that determine what kind of science and technology (S&T) gets done, particularly in response to the needs of society? And how does S&T contribute to those needs? We're going to be talking today about commercial opportunities and economic growth, but some of these same ideas would apply to more public goods kinds of uses of S&T.

¶3 There is general agreement that high-tech innovation does create new conditions for growth in the economy. (See Slide 1). Some people do confuse innovations and inventions, however. It's important to recognize that an innovation hasn't happened until there is a product successfully introduced into the market. By successfully, I mean that someone is actually selling it, whether profitably or not.

Slide 1: High-Tech Innovations

[3] A complete recording of Dr. Branscomb's lecture is available at http://law.duke.edu/webcast/?match=Lewis+Branscomb (last visited Mar. 25, 2004).

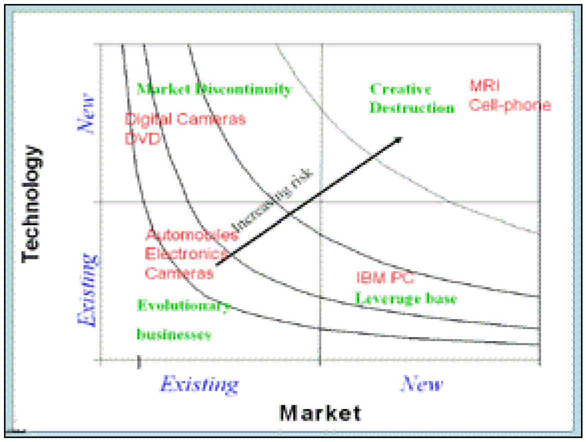
¶4 Where do innovations come from and how is the research world linked to the world of innovation? The high-tech innovation sector of the economy is totally negligible and meaningless in the larger scale of a ten trillion dollar economy. In fact, just look at the numbers. These are a couple years old, but private industry was spending a couple of hundred billion on research and development (R&D), but only sixteen billion of that, according to a survey done for us by Booze, Allen, Hamilton, was R&D leading to radical innovation. (See Slide 2).



Slide 2: Evolutionary Versus Radical Innovation

¶5 And so, the revenue produced from high-tech innovations is very small. The amount of money actually required to drive that sector is also relatively small. In 2000 the universities, spinning off a large part of the high-tech start-ups, only spun off 454 firms, and a lot of those firms didn't survive. So it's a small activity. The real activity that creates employment and creates that ten trillion dollars of GDP is evolutionary growth by marginal extensions in technology or in markets or businesses that already exist.

¶6 Slide 3 is a conventional diagram that allows you to think about how you would distinguish high-tech innovations from others. The lower left quadrant is existing markets for established high-tech products such as electronics, photographic cameras, and automobiles. In the upper left quadrant we find new technologies for existing markets, such as digital cameras, and DVDs replacing tapes. Down in the lower right-hand side we have new markets for an existing technology—the IBM PC would be an example. And up in the upper-right, we have magnetic resonance imaging systems, which was a brand new capability for the medical world when it was introduced twenty years ago.



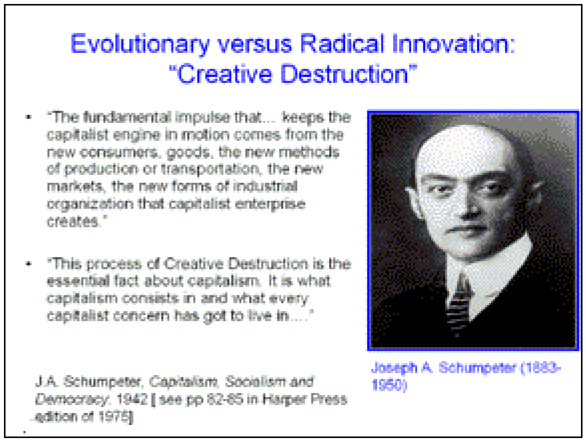
Slide 3: Distinguishing High-Tech Innovations

II. THE EFFECT OF INDUSTRIAL CHANGE IN THE ECONOMY

¶7 Joseph Schumpeter drew attention to the important role that radical change, especially technological change, makes in the economy. (See Slide 4). An Austrian economist, he spent a number of years at Harvard. And let me just read for you quickly these two quotes. First, "the fundamental impulse that . . . keeps the capitalist engine in motion comes from the new consumers, goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates." Interesting sentence, because every one of those new nouns is a part of the innovation world. Note that one can have market innovations or business model innovations that need not involve new technology.[4]

¶8 Second, "this process of Creative Destruction is the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in."[5] And it is "Creative Destruction" that high-tech innovations produce that allow another growth curve to start with incremental market and technological development.

[4] *See* J.A. SCHUMPETER, CAPITALISM, SOCIALISM AND DEMOCRACY 82-85 (Harper Press ed., 1975) (1942).
[5] *Id.*

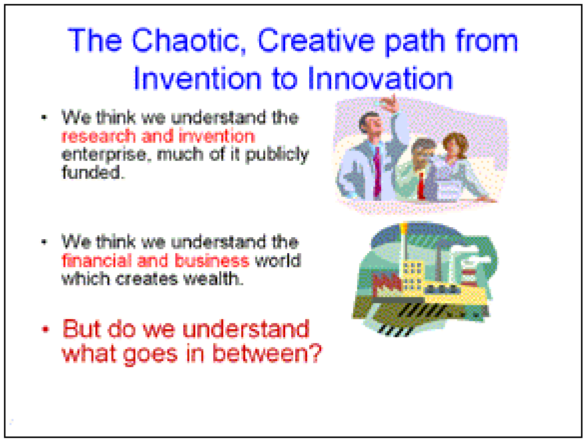


Slide 4: "Creative Destruction"

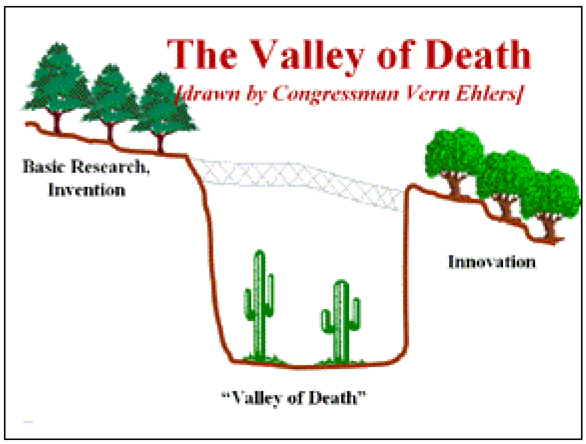
III. The Path From Invention to Innovation: Models and Metaphors

¶9 Let's think a little bit about this chaotic, creative path that starts with an invention or a concept, or a new commercial idea that has some new technology in it. We think we understand that world of research. We understand the sociology of how scientists and engineers get their jollies; we know where they get their money. They usually get it from the company in which they're employed or they get it from an institution funded largely by government—state, local, or federal. So that's a pretty well-understood piece of the national enterprise. Similarly, we know we have not only graduate school to make Physics Ph.D's, but we have business schools and law schools to teach people about the financial and business world that creates the wealth, and we think we understand that system pretty well too. (See Slide 5).

¶10 But do we understand what goes on in between? That's the central issue I want to address, because I think the answer is "no, we don't." One reason we don't understand it is that there really isn't very much structured processes or institutions there. In fact, that whole transition is so mysterious that in the professional literature it's called the "Valley of Death." And this particular drawing was made by Congressman Vernon Ehlers, a PhD physicist. (See Slide 6). I think the metaphor here is poor, because the "Valley of Death" (to Americans at least) signifies Death Valley, and Death Valley we think of as a sterile place. When we're talking about the transition from research to innovation, it's not a sterile world at all.

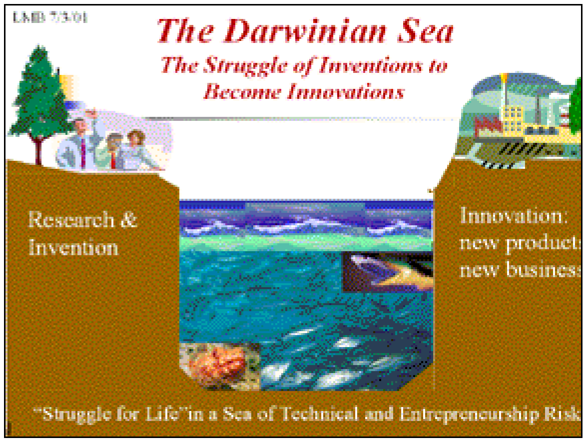


Slide 5: Path from Invention to Innovation



Slide 6: The Valley of Death

¶11 And so, I rather like better the metaphor in Slide 7. It's a sea full of sharks, and it's full of little fishes. There's all kinds of stuff happening. If you think about how you get from the research world to the innovation world, it turns out there are lots of pathways. And they're complicated. They begin and end at many kinds of intervals. The fact that there are multiple ways of financing this transition and that there are multiple institutional ways of accomplishing it, suggests to me that this transition is ridden with market failure—markets do not describe that process. And if we really understood how to get from one shore of the Darwinian Sea to the other, we might try to invent a set of institutions and a set of policies that would facilitate the trip. If it were possible to link one shore to the other in a kind of rigid and institutionally continuous way, and what you would get is the Soviet Union economy. In other words, it is the vibrancy of this connection that is necessary to make it possible to go from one culture to a radically different culture successfully, and have the feedback of rewards which keep that system going.

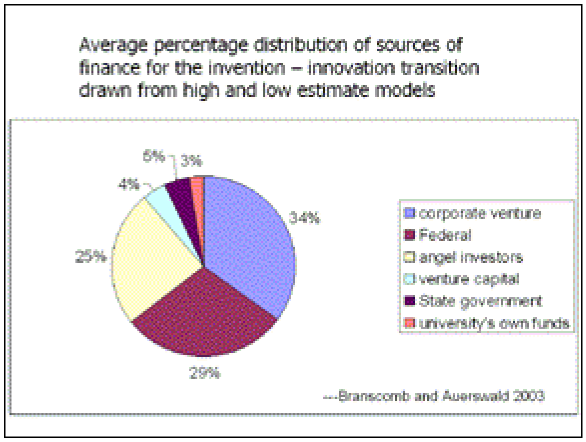


Slide 7: The Darwinian Sea

IV. FINANCING OF THE HIGH-TECH ECONOMY: EFFECTIVE BUSINESS MODELS

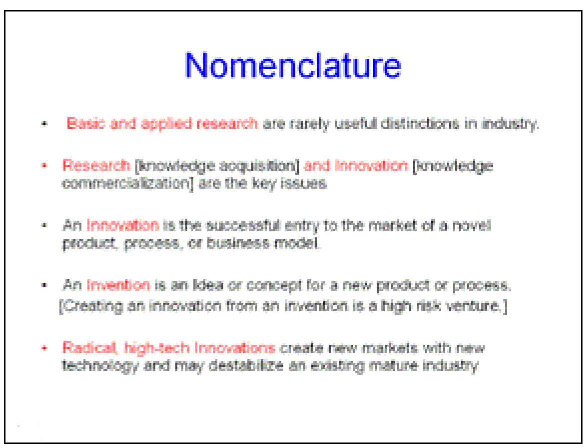
¶12 Let us think about how the transition gets financed. Philip Auerswald and I did a study, which has been published by the National Institute of Standards and Technology (NIST).[6] We made estimates of the sources of money for this drastic transition. There are three major sources. (See Slide 8). The first is corporate seed ventures—that's a relatively new phenomenon, but a surprisingly big one, and I'll come back to that later. The other is the federal government—that's 29% of the total. Surprisingly, one of the criticisms of the Advanced Technology Program (ATP) at NIST in the Department of Commerce is that the ATP program is too small and couldn't possibly matter. How could a $100 million program investing in early-stage technology development with high-tech companies possibly have an influence in a three trillion dollar manufacturing economy? It turns out that the ATP program, plus the Small Business Innovation Research (SBIR) grant program—the only two programs in government that are intended to invest in high technology to stimulate the economy—those two programs are as big as each of the other two major contributors. The really interesting source of funding, the most effective part of that triangle, is our angel investor community. I'll come back to that too.

[6] National Institute of Standards and Technology, http://www.nist.gov (last visited Mar. 25, 2004).



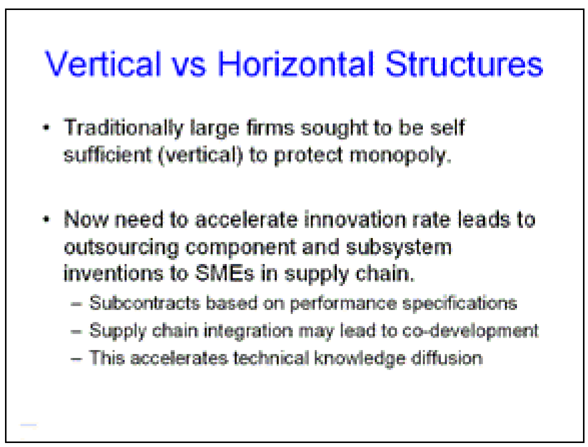
Slide 8: Sources of Finance

¶13 Let me clarify the nomenclature I'm going to use here. (See Slide 9). Basic and applied research are distinctions that have no meaning when used in industry—just call them "research." Research is, of course, knowledge acquisition, whereas innovation is knowledge commercialization. And innovation, as I've already said, is successful entry into the market. Invention is an idea or a concept for a new product or process. And the way I'll use the word "invention" doesn't necessarily mean that it's patented. It probably does mean that it is somehow protected, but it could be protected as a trade secret, or it could just be protected by somebody moving faster than anybody else. And when I refer to "radical high-tech innovations," I'm talking about innovations that create new markets with new technology that, in the best case, have the potential to destabilize an existing mature industry, and offer huge opportunities for investment in a new line of work.



Slide 9: Nomenclature

¶14 It's important to appreciate that there has been a huge change in the business and technical worlds since World War II—in the last 50 years. There was a time when companies like IBM, where I worked for 15 years, sought very hard to be vertically integrated—to have within the company all the skills and capabilities they needed to invent the products, to make the products, to sell the products, and capture the money. And indeed, they focused their attention on account control and trying to make sure that their customers never bought anything from anybody else in the industry, and so on. They don't do that anymore, and the reason they don't do that anymore is because technology has changed in such a fashion that the speed required for innovation can't be done within a vertically integrated institution. And so these firms have figured out where their comparative advantage lies. In a big company like IBM, its comparative advantages are deep pockets, efficient manufacturing, and the ability to do distribution around the world and understand the market. They now outsource most of the needed technical innovations to small to medium enterprises (SMEs). In some cases they enter into co-development with their supply chain. (See Slide 10).

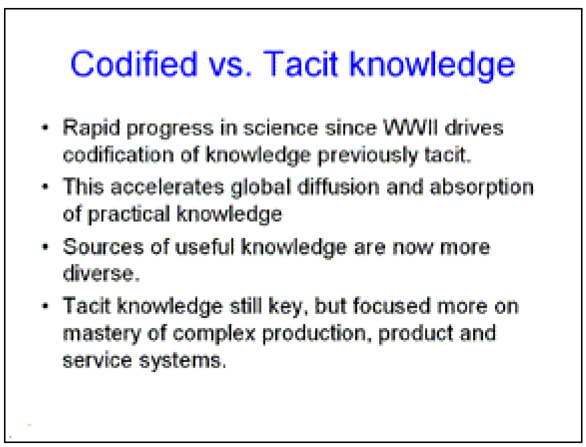


Slide 10: Vertical vs. Horizontal Structures

¶15 So there is a whole new way of doing innovation in the big company world. It borrows from the small company world and partnerships that are a very important part of the small company story. And all that happens because of this enormous shift from a technical world where most of the knowledge was what we'll call tacit or informal. I remember in the '50s, I talked to engineers, and engineers would say, "We're not scientists, and we're proud of it. Most of what we engineers can do, you scientists can't do. Because we learned it the hard way by trying stuff. We learned that this works, and that doesn't work. We engineers can do stuff, and the scientists have to agree." That was true, because when I was in graduate school in the late '40s, physicists could compute the energy structure of an atom with one charge on the nucleus, a hydrogen atom, and one electron. We couldn't even compute a two-electron atom. That was what my doctoral dissertation was about.

¶16 Chemists knew about valence theory, but that was about it. They knew in a chemical reaction that atoms were conserved. That's about all they knew. And biologists were doing taxonomy. That has enormously changed. Now if you want to do something, there's so much technical knowledge out there, that almost anything is possible. You can design the materials you want to work with, design the architecture of the system you want to put together, and actually go to the factory and start making it without ever doing bread-boarding. That world has now made it possible for innovation to be divided up into pieces and reassembled by those who are architecting the end product.

¶17 So tacit knowledge is still important, but now the important tacit knowledge is understanding that mixture of the technology and the market, and the financial world, and the distribution system, and all the software and the hardware that make the product useful, all of that collection of systems-level stuff that's required to satisfy customers. (See Slide 11).



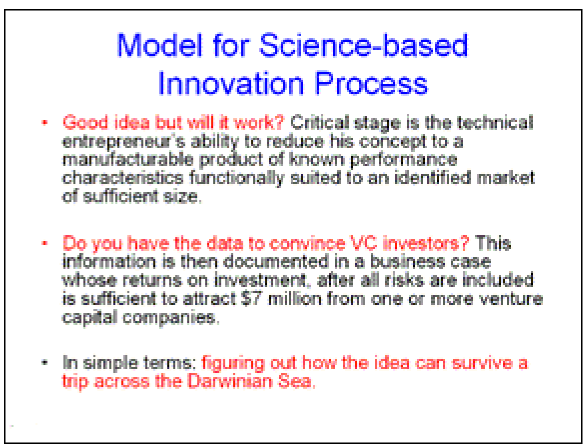
Slide 11: Codified vs. Tacit Knowledge

¶18 So here's a simple idea of a model for this transition from the technical idea to the initial innovation. It starts with the technical innovator, usually an innovator with a technical background, not always, and the problem is to figure out: "Is this idea good enough to work? What do you have to do to find out if it will work?" You have to go into the laboratory and you have to reduce this technical idea to practice. You have an idea of what the manufacturing process is going to be, and figure out what the window is for that production process. It's got to be a process that is fairly forgiving in a real world manufacturing environment.

¶19 And all of that drives the details of the technology. And as you do that work, and the technology gets more and more perfected in this pilot manufacturing environment, the function of the product begins to change. And when the function of the product begins to change, of course, the market you've had in mind for it is also going to change. And when that changes, and you must reoptimize the product around a different market, all of a sudden, the manufacturing technology changes. So it's very important to appreciate that there's a technical task here, which is very difficult and is not done in universities in most cases. It involves trying to transform a technical idea into the information that you can take to a venture capitalist firm with some hope of success.

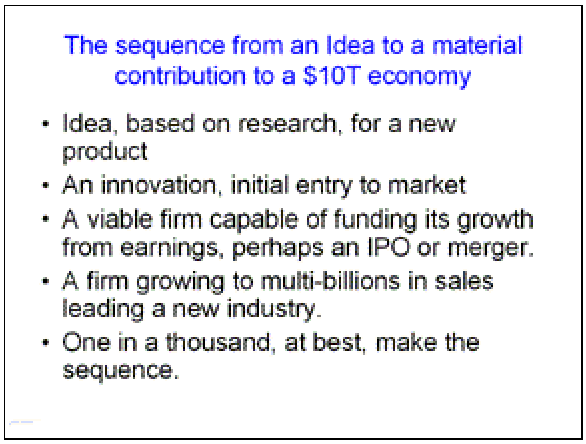
V. THE ROLE OF VENTURE CAPITAL

¶20 Venture capitalists do not invest in early stage technology development. Only about 4% of venture capital firms invest in seed venture capital. What the venture capitalist wants is a solid business case. He is not interested in taking chances in technology. Venture capitalists buy companies cheap and sell companies dear, and do it in seven years. A venture capitalist needs to have this business case pretty solid in order to start putting the real money in, which allows this enterprise to grow. So the problem is how can an idea swim across that Darwinian Sea? (See Slide 12).



Slide 12: Model for Science-based Innovation Process

¶21 Consider the uncertainty involved in the transition from an idea to an industry that is a material addition to the GNP. The sequence from an idea to a material contribution begins with an idea based on research. That idea has to be turned into the initial innovations—with a chance of success, maybe one in ten—then that little company has to cover its initial opportunities well enough that it can fund its own growth. It then hopes to reach the point of an initial public offering, perhaps, or a merger into a larger company. And there's maybe a one in ten chance of that being done successfully. At that point, you have an enterprise, probably a public company, and maybe it's got several hundred million dollars of business, but its still small potatoes compared to a ten trillion dollar GNP. But one in ten of those firms reach the Fortune 500. The rarity of this success is called "skew," and has been extensively studied by economists—once again, a one in ten likelihood. (See Slide 13).



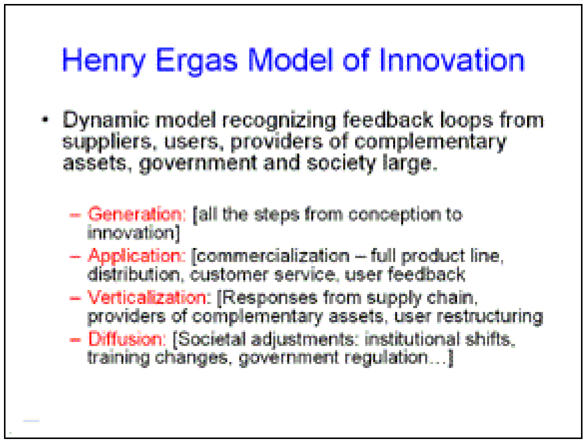
Slide 13: Sequence from Idea to Economic Contribution

¶22 So I just want to emphasize the fact that while there are no really good numbers on any of those risk factors, we're talking about an activity that has a one in a thousand chance of actually making a big difference in the economy, truly destabilizing some large existing industry. Nevertheless, that destabilization doesn't happen, and doesn't keep the economy alive at the ten trillion dollar level unless that first step works.

¶23 Henry Ergas, an economist from Australia came up with an interesting model for the innovation process, and I put it up here because his is the only model that is dynamic.[7] (See Slide 14). Almost all the others are static. The static models say you start with a research idea, and somebody's got to reduce it to practice, and somebody's got to put money in it, and somebody's got to make a company. Things happen in a time sequence, but they all kind of happen in a vacuum. In Ergas' model, the first step, Generation, is everything a scientist thinks is innovation—all the steps from

[7] LEWIS M. BRANSCOMB & YOUNG HWAN CHOI, KOREA AT THE TURNING POINT: AN INNOVATION-BASED STRATEGY FOR DEVELOPMENT 202 (1997).

conception to innovation. The second stage is Application, which I had in the last slide. Namely, you've got to get out a full product line, you've got to get your manufacturing yield up, you've got to get a distribution system, you've got to provide customer service, and you're beginning to get feedback from users, and changing the product.



Slide 14: Henry Ergas Model of Innovation

¶24 The Verticalization step is terribly important. If this is a successful innovation, the firms in this line of work are buying stuff from their supply chain, and the supply chain says, "Well look, there's a whole new market out here and I'm going to go back and generate better components or better materials that are appropriate for this new application." Firms in the supply chain begin to innovate in response to this opportunity. Similarly, the users begin to change the way they do business using this product. They will re-optimize their operations, seeking to improve their productivity, in light of this new product. So that's a dynamic response of the economy to the innovation. And then the final step in Ergas' model is Diffusion: if the innovation survives as a significant area of the economy, there are social adjustments; there might be some regulatory requirements; there are changes in the education system, and so forth. And of course all of this is a continuous loop.

VI. The Demand For Technical Knowledge

¶25 Now, an interesting question is: Where does the demand come from for technical knowledge? Who decides what kind of technical knowledge gets invested in? And here is a list that starts from the most compelling sources, not how much money is involved. (See Slide 15). Knowledge to permit incremental improvement is fully justified; the market system works fine for creating that kind of knowledge. The second source of demand comes from customer or user expectations in some rapidly developing, newer, more science-based industry, the kind of one I'm talking about. Markets do help drive this source. But you also will find government research investments, which amounts to a subsidy, going in there, and driven by a competitive expectation, rather than the immediate market.

Slide 15: Demand Function for Commercial Knowledge

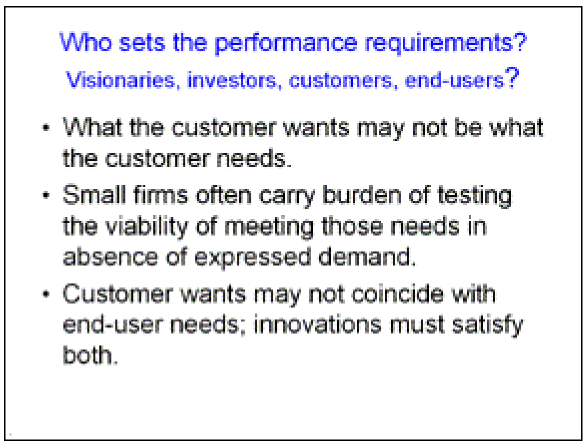
¶26 The third is the radical, out-of-core, new firm or product opportunities, which either come as spin-offs from a research institution, typically a university, maybe a national lab, or the out-of-core spin-out from a large enterprise. In one little book that we did,[8] we have a guest chapter by Jim McGroddy, who used to be president of the research labs at IBM. The title of this chapter is: "Raising Mice in the Elephant's Cage," and it is about the virtual impossibility of doing an out-of-core—meaning not in the computer business—innovation in a place like IBM, which spends all of its time trying to do in-core innovations. The forces to keep innovations within the incremental scope are very strong. And finally, of course, there is the general investment in knowledge, which is what the professors wish all of the demand function was about.

¶27 Let me now talk about corporate seed venture capital and angel investors. Corporate seed venture capital has flowered in the last 10 to 15 years. If you go to Intel's home page,[9] they feature what amounts to three-quarters of a billion dollars of equity investment in small high-tech firms, exploring technologies that Intel thinks might be interesting, either because they can use the technology or because that technology will create demand in their customers. Intel has figured out that they can get more return per

[8] LEWIS M. BRANSCOMB & PHILIP AUERSWALD, TAKING TECHNICAL RISKS: HOW INNOVATORS, EXECUTIVES, AND INVESTORS MANAGE HIGH TECH RISKS 87-95 (2001).
[9] Intel Corporation, http://www.intel.com (last visited Mar. 25, 2004).

dollar of R&D expense by taking equity positions in small high-tech firms than by doing this kind of work in their own corporate lab. The angel investor story, of course—well, let me come back to angel investors a little later.

¶28 So who sets the performance requirements? (See Slide 16). What the customer wants may not be what the customer needs, so the customer may not be a good one to tell you what that knowledge ought to be. Small firms carry a burden of testing the viability of meeting those needs in the absence of an expressed demand. If you're doing a radical innovation, of course, there is no market. You can't go out to focus groups and ask them: "Would you like to buy this?" And they say, "This what?" So there's more risk involved in market definition. So what the customer wants may not coincide with their customers' needs, and innovations have to satisfy both.

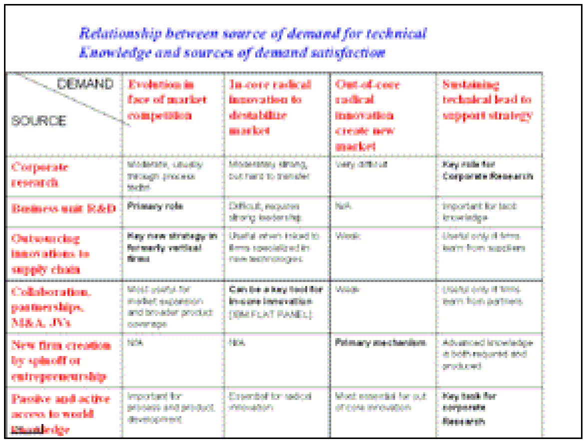


Slide 16: Who Sets the Performance Requirements?

¶29 Slide 17 is an attempt to put down on the vertical row, the various sources of technical knowledge, and across the top, the sources of demand. The key sources are in bold-face and they go down the diagonal in this chart. It is intended to show that people who are thinking about the relationship between the business opportunity and the source of technical knowledge are working in a multi-dimensional space; there are many institutional avenues for accomplishing this. It's a very complex picture, and the people who make public policy and determine where the government is going to invest its money don't think very deeply about how complex this problem is.

¶30 What are the institutional sources of commercial ideas? (See Slide 18). We have the individual entrepreneurs; we have the universities spinning out firms; we have government research that's commercialized through licenses; joint ventures and the like or government funded research;

angel investors or others with a novel business model or market opportunity, looking for technology; and spinouts from corporate research, those "mice in the elephant's cage."



Relationship between source of demand for technical Knowledge and sources of demand satisfaction

SOURCE \ DEMAND	Evolution in face of market competition	In-core radical innovation to destabilize market	Out-of-core radical innovation create new market	Sustaining technical lead to support strategy
Corporate research	Moderate, usually through process techn	Moderately strong, but hard to transfer	Very difficult	Key role for Corporate Research
Business unit R&D	Primary role	Difficult, requires strong leadership	N/A	Important for tacit knowledge
Outsourcing innovations to supply chain	Key new strategy in formerly vertical firms	Useful when linked to firms specialized in new technologies	Weak	Useful only if firms learn from suppliers
Collaboration, partnerships, M&A, JVs	Most useful for market expansion and broader product coverage	Can be a key tool for in-core innovation (IBM FLAT PANEL)	Weak	Useful only if firms learn from partners
New firm creation by spinoff or entrepreneurship	N/A	N/A	Primary mechanism	Advanced knowledge is both required and produced
Passive and active access to world knowledge	Important for process and product development	Essential for radical innovation	Most essential for out of core innovation	Key task for corporate Research

Slide 17: Relationship Between Source of Demand for Technical Knowledge and Sources of Demand and Satisfaction

Slide 18: Sources of Commercial Ideas

VII. THE ROLE OF THE UNIVERSITY

¶31 Universities do play a very important role, and in some sense it's bigger than you might have thought, and in another sense, maybe not. Now this data is three years old, going on four.[10] (See Slide 19). In that year of 2000, there were 8,500 patents filed by universities, one and a quarter

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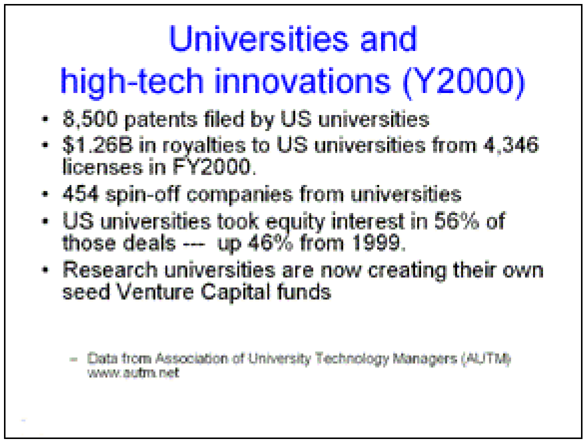
[10] Data from Association of University Technology Managers (AUTM), http://www.autm.net (last visited Mar. 25, 2004).

billion dollars in royalties, and around 500 spin-out companies. Even in the year 2000—and this has been going up rapidly—universities are beginning to experiment with taking an equity interest in deals that spin out of the university rather than just trying to collect royalties off of patent licensing. They've finally gotten smart and realized where the money is—it's in the equity growth in the enterprises, not in the royalties, in most cases.



Slide 19: Universities and High-Tech Innovations

¶32 There are at least a dozen universities, probably more now who set up their own seed venture capital companies with endowment money. They usually work in collaboration with a commercial venture capital company that knows how these small enterprises have to be managed and financed in order to get the money to help their faculty bridge that evolution from the science idea to the S&T reduced to practice. Then they find a way to commercialize it, usually in a new enterprise, sometimes not.

¶33 Studies clearly show that somewhere around 80 to 90% of all the revenue universities receive from their inventions comes from 10 to 20% of their licenses. The 80% of the university licenses that don't make any money are all those clever faculty inventions that are exclusively licensed. Because the patent is such a small fraction of the resources required for a company to build a new product, most companies are not very interested. There's very little commercialization of the huge number of university patents of that sort.

¶34 The money comes from the university patents where they have invented a new process or a new way of doing things. The Cohen-Boyer patent at Stanford, for example, in molecular biology,[11] this is a tool that every biotech company must have. Stanford got smart. They licensed it to

[11] U.S. Patent No. 4,237,224 (issued Dec. 2, 1990).

the whole world, and they set the license fee at a moderate level. When the big pharmaceutical houses asked their lawyers: "Can you break this Stanford patent so we don't have to pay the license?" The lawyers said, "Yes, I think we could probably break it, but at the fee that Stanford has set, it's cheaper for you to pay the license fee than it is for you to pay us to try to do it." It's very smart by Stanford.

¶35 But the reason I go through this is because I want you to appreciate that the facts are counter to one of the big faculty concerns in universities. Faculties worry that this commercialization of university patents drives people away from real science and makes them into widget inventors. But the low return from the widget businesses, exclusively licensed, is dwarfed by the money from advances in fundamental science. So universities should stick to their knitting, and pay attention to the intellectual property that's inherent in the university research outcomes.

VIII. PRIVATE INVESTMENT AND "ANGEL" INVESTORS

¶36 So, I promised you that I was going to say something about angel investors. The name comes from the Broadway theatre. Rich people thought, "I've got money to waste, I'm going to invest in this Broadway show, and I'll probably never see my money again, but I will get to go to a lot of nice parties with all those actresses and actors and producers, and that will be great fun." Some of them made a pile of money; most of them didn't. But now the phrase "angel investor" is used to refer to a large population of private individuals who make equity investments in new ventures—a couple hundred thousand of them. This whole phenomenon is extensively studied by Prof. Jeffery Sohn at the University of New Hampshire.

¶37 A tiny fraction of the 200,000 are high-tech angels, who invest in new companies that are based on new research or new markets. Who are these technical entrepreneurs who now have the money to invest? They're the people who've been there and done that. They're the technical entrepreneurs who did start a company; they got across the Valley of Death, they started a company that was enormously successful. At the age of 45 or 50, these entrepreneurs have $300 million in the bank; they never want to work that hard again in their lives, but boy, it was exciting.

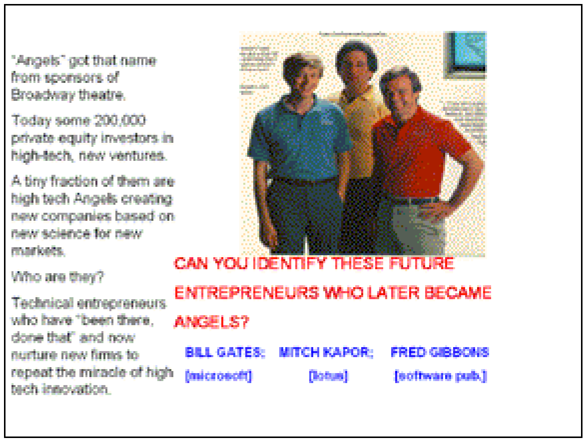
¶38 So how do you capture that excitement? How do you put your $300 million to work and feel like you're doing something good, and not work too hard? And the answer is you find some younger entrepreneur who looks like you when you were that age, who's got a great idea. You go to him and you say, "Look, I'll give you half a million dollars max. I want you to mortgage your house—if you don't mortgage your house, I'm not going to give you the money—and I want you to go ahead and start your company. I'm going to be your advisor, and I'll give you advice and the money in return for the following share of equity in your enterprise."

¶39 This angel investor is inside the network that's required to allow an enterprise to flourish. He knows which bankers understand high-tech and which ones don't. He knows the government people in the regulatory world, and he knows all of the service organizations, the lawyers, and all the other folks that you need to help create a business. He understands how to build a business model for this particular innovation, and helps them present their case to the venture firms and investment bankers.

¶40 So this combination of mentoring and pre-venture capital investing is absolutely crucial, and now this process has gone quite far. About 10 or 15 years ago Heinz Severans in San Francisco, Silicon Valley, had a good idea and created the Band of Angels. The Band of Angels consists of a hundred or so angel investors in the Palo Alto area. They're not a company—all they do is meet for dinner once a month in a very nice restaurant with a super wine cellar in Palo Alto. But they do put up enough money to have two or three staff people, who interview would-be entrepreneurs who are looking for angel money. The entrepreneur will get thirty minutes after the dinner to talk to all these angel investors. If any of the angel investors holds up his hand and says, "Well, I'm interested in that," then it's up to them to go talk to the entrepreneur offline and the Band of Angels is no longer involved.

¶41 This is a surprisingly effective way to do things, because the broad spectrum of experience that those angel investors have in different technologies, different markets, different business models, allows some combination of two or three of them who might want to invest together. They take their experience and map it against this new business with this new idea and figure out how to get comfortable with the risks. So it is the very diversity in the Band of Angels that makes it effective. If you talk to the academics in the business schools, they will tell you that the key to economic growth in high technology is not diversity, its specialization. It's not accidental that the machine tool companies are clustered in Dayton, Ohio, and the textile companies are in Charlotte, and so on. But clustering of like companies is not the secret of community success in early stage high-tech innovation; there, diversity pays.

¶42 So who are these angels? I'm going to show you a picture of three of them. (See Slide 20). Can anybody identify any of those folks? They happened to be together many years ago. I'm sure you can identify Bill Gates on the left. In the middle is Mitch Kapor, who started Lotus. On the right is my good friend Fred Gibbons, who started Software Publishing years ago.



Slide 20: Famous Angel Investors

IX. THE GEOGRAPHICAL CONCENTRATION OF HIGH-TECH INDUSTRY

¶43 Let me now call attention to a rather remarkable, different kind of skew in the return on investments in high-tech innovations. It's not too surprising that investors both at the pre-stage I'm talking about, but also at the IPO level—the investment bankers in New York—they tend to invest in only a few technical areas, where they can get some comfort with experience. So if you're trying to innovate outside one of those areas, you've got an uphill climb, because it's hard to find bankers and others who have any comfort in that new technical area.

¶44 But even more interesting is the skew by geography. There are four states that in 1999 got two-thirds of all the venture capital money. (See Slide 21). Where all the venture capital money is found is surely also where the angel money is, because both angels and venture capitalists like to invest in companies that are no more than an hour's automobile drive from their offices because this is an intimate business.

¶45 Let me show you some interesting data, and this data is kind of old, from 1982.[12] (See Slide 22). The percentage of patents that actually turned into innovations, that is, the ratio of innovations to patents, in that year in San Jose (Silicon Valley) was 57%. In Albany/Schenectady it was 0.3%. That means there were 192 innovations per patent difference between Albany and San Jose. The data's old and it will have changed by now, but what this says is: The capacity to convert commercially promising technical ideas into innovations is not something that is found all over the country.

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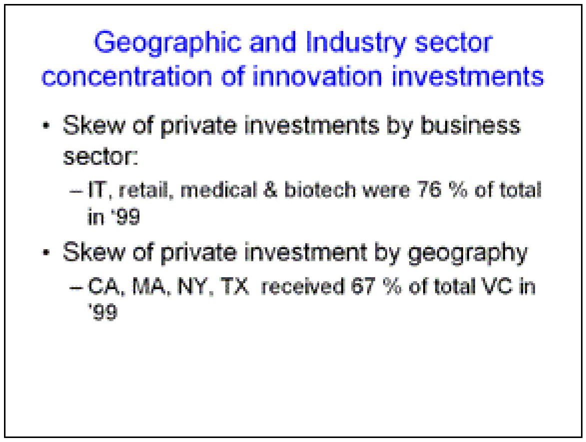
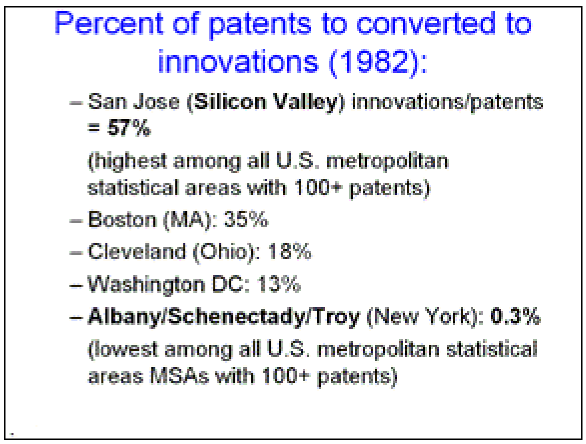
[12] *See* BRANSCOMB & AUERSWALD, *supra* note 8, at 177-80.



Slide 21: Geographic and Industry Sector Concentrations



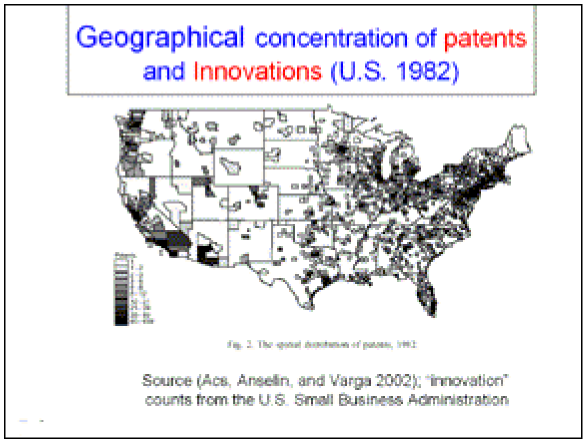
Slide 22: Percentage of Patents Converted to Innovations

¶46 Here are two maps to show it. Slide 23 shows the spatial distribution of patents in 1982. You can see there's a bunch of activity in California, and there's a bunch in the Northeast, but they are scattered all over the place.[13] There's a fair number in North Carolina, Florida, and even in Colorado and Utah and Arizona.

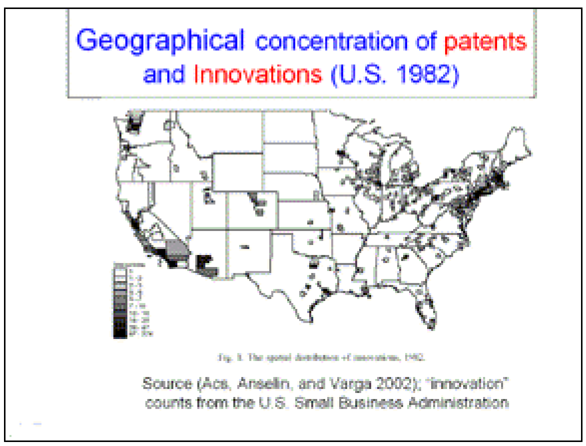
¶47 Now, Slide 24 shows the distribution of innovations.[14] Now, it's no longer nearly as widespread. It's very heavily concentrated in a narrow sector in the Northeast and in California. I think if we did this now, 20 years later, you'd find a big bunch in Virginia, around the Washington area, you'd find a much bigger bunch around Dallas and Austin, Texas, and some

[13] *See* Zoltan J. Acs, Luc Anselin, & Attila Varga, *Patents and Innovation Counts as Measures of Regional Production of New Knowledge*, RESEARCH POLICY 31:1069-85 (2002).
[14] *Id*.

other places that are beginning to bloom. But it's very concentrated. And so, I'm going to come back to the question: What causes this concentration of propensity to innovate?



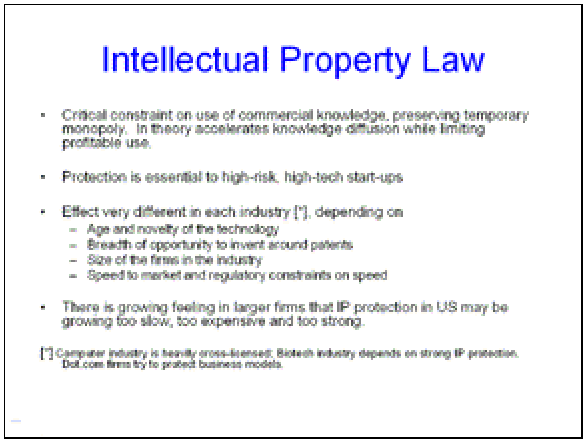
Slide 23: Geographic Concentrations of Patents



Slide 24: Geographic Concentrations of Innovations

X. Finding an Optimal Level of Intellectual Property Protection

¶48 Let me say a little bit about intellectual property law. (See Slide 25). Obviously, we know what patents do—they provide a constraint on the uses of commercial knowledge, while, nevertheless, providing knowledge diffusion. That's the reason it's in the Constitution. It was intended to promote innovation, not to stop it, by making sure that if people have access to patent protection they would indeed file the patent, and through the patent disclose the invention. And from that disclosure, ultimately inventors could get other ideas and move ahead. So there's no doubt that high risk high-tech start-ups need protection—need to be able to protect the essential idea.



Slide 25: Intellectual Property Law

¶49 But the situation is very different in different industries. In the biotech industry, if firms didn't have rigorous legal protection of ideas, they could not risk development, because the government imposes such a long delay between the time you have the idea and the time you're allowed to go to market. On the other hand, in the computer industry, large firms like IBM were cross-licensed with every big computer company in the world. IBM could use all of their patents, and they could use all of IBM's patents. Many inventions were published in the disclosure bulletin, because it was much cheaper than filing a patent. IBM patented for freedom of action protection, not for exclusivity. But the firm needed a big patent portfolio, of course, to make sure that when IBM cross-licensed, it didn't have to pay anybody anything. For small companies, it is a very different story. You can't expect to be cross-licensed to all your competition, nor would that be desirable.

¶50 Advanced industrial nations such as the United States, generally seek stronger intellectual property protection, a trend that concerns the developing countries which are trying to catch up technologically. But there is increasing concern that the trend may go too far. In June 2002 at a small invitation-only conference outside of Zurich, we discussed intellectual property in the Information, Computers and Telecommunications (ICT) industry. To the astonishment of everyone, almost everybody there—the judges, the industry executives, the academics, and the international regulators—thought the global economy was moving down a path of too-strong of protection.

¶51 And so, there may well be at least the beginnings of some sense that maximum protection is not necessarily optimal, that there is some kind of balance. And I've talked to my economics professor friends at Harvard and elsewhere, and asked them: "What do microeconomists really know about what is the optimum intellectual property system if your only interest was maximizing innovation and growth of the economy for the benefit of society?" The answer I got was that nobody has really done that study. There were a few studies many years ago—they're very incomplete and they're very old. It would be very hard to do and nobody's doing it. So I think that's a very interesting and important challenge to the research groups interested in innovation policy.

XI. Social Capital and Trusted Networks for Innovation

¶52 Why does the innovation process that flourishes in Massachusetts and California have trouble elsewhere? (See Slide 26). The answer has something to do with trusted networks for innovation. That's an area in which my research is now focusing. If you want to capture benefits from new ideas for science-based innovations, you have to capture them locally. All of the empirical evidence shows that spin-outs from universities create companies that are within 50 miles of the university, and not further. There are a whole lot of good social reasons why that's the case. And so this tends to be a local phenomenon, first of all.

Slide 26: Social Capital: Trusted Networks for Innovation

¶53 Secondly, if in that locality, the tools of innovation policy are understood by the local government, governments may well take actions to try to increase the social capital available there. Partnerships and consortia may enhance it, or at least be evidence of strong social capital. Most interesting is Richard Florida's book called *The Rise of the Creative*

Class,[15] stealing a pun on Thorstein Veblin's Theory of the Leisure Class. He took existing statistical data on all of the social attributes of a metropolitan area and correlated them statistically with a set of data that he took as surrogates for innovation rate. I will give you one result he found that might cause you to want to read this book. The strongest correlation he found between a social attribute of a community and its propensity to innovate was how many gays and lesbians there are in the metropolitan area. He did not conclude that gays and lesbians are more creative than straights, only that a society that can tolerate gays and lesbians can probably tolerate entrepreneurs. High-tech entrepreneurs aren't that easy to tolerate. If you go to a bank in a town that is not accustomed to financing these kind of people, they will not be understanding.

¶54 A flourishing environment for high-tech innovation demands a high level of communications and trust. (See Slide 27). The technical innovators speak a language that the business people don't understand, and *vice versa*. Venture capitalists rely upon networks of their own making; so too do angel investors.

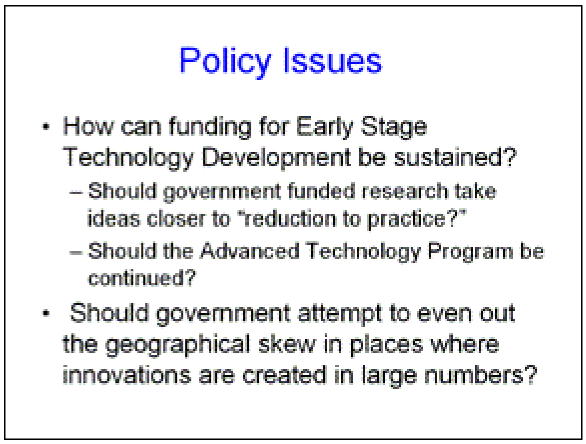
Slide 27: Communications and Trust

XII. CONCLUSION

¶55 Let me close with some questions. (See Slide 28). How can we fund early stage technology development and sustain it? Should the government attempt to even out the geographical skew in the places where innovations happen? This question is a puzzling one. One might say that fairness requires that every community should be able innovate with equal likelihood. But it's not obvious that this is the right public policy. First of

[15] RICHARD FLORIDA, RISE OF THE CREATIVE CLASS AND HOW IT IS TRANSFORMING WORK, LEISURE, COMMUNITY AND EVERYDAY LIFE *(*2002).

all, I'm not sure what fraction of the economy needs to be devoted to radical innovations. Maybe the level we have now, or a bit more, is the right balance between creative destruction and incremental growth. And if that's the case, then there may be a requirement for a critical mass of angel investors, and banks, and companies, and university ideas, and all the other ingredients that go into this network of trust. That doesn't suggest to me that any community should stop trying to beat out Silicon Valley, California or Route 128 in Boston, but it may be that the combination of critical mass requirements and the right balance of economic investment suggests that concentrating innovation capability in a small number of regions is economically optimal.



Slide 28: Policy Issues

¶56 So finally, let me say: everybody talks about R&D, but it really isn't about "R," and it really isn't about "D," it's about the "&."

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