

# PHYSICS ENTREPRENEURSHIP AND INNOVATION

Orville R. Butler, M. Juris, PhD and R. Joseph Anderson

*“You Can’t Depend on  
Large Companies Anymore”*



# PHYSICS ENTREPRENEURSHIP AND INNOVATION

*“You Can’t Depend on Large Companies Anymore”<sup>1</sup>*

Orville R. Butler, M. Juris, PhD and R. Joseph Anderson

December, 2013  
American Institute of Physics  
College Park, MD USA



## *Acknowledgments*

This report is based on a study conducted by the American Institute of Physics' History Programs. The study was funded by the American Institute of Physics, the Avenir Foundation, and by a grant from the National Science Foundation (#0849616). It is based on site visits, interviews, and other research.

The authors thank the 91 companies listed in the report and the physicists, other company founders, and university technology transfer officers who participated in the site visits and interviews. Without their cooperation, this report would not be possible. In addition we are indebted to Katy Newton Lawley, lecturer at the College of Information Studies, and David Kirsch, associate professor of strategy and entrepreneurship, at the Robert H. Smith School of Business, University of Maryland, as well as others who provided guidance and assistance while we conducted this study.

A number of AIP staff and consultants provided vital support, including Roman Czujko and the staff of AIP's Statistical Research Center. Stephanie Jankowski afforded valuable assistance, including arranging and initially proofing the interview transcriptions. Without Katy Lawley's advice on developing the question set and using NVivo, as well as her assistance on coding issues, we would have been unable to finish the study in a timely manner. While we could not have completed this report without the assistance of those recognized above, the authors take full responsibility for the content and conclusions of this report.

This report will also be available on the AIP History Programs website at:  
<http://www.aip.org/history-programs/niels-bohr-library/documentation-projects>

Contact us at (301) 209-3165 or [nbl@aip.org](mailto:nbl@aip.org).



## *Executive Summary*

This study is the first systematic investigation of physics-based entrepreneurship and innovation by startups in the United States. Research has included a review of the literature and online sources, but the primary focus has been onsite visits and interviews. Interviewees included about 140 Ph.D. physicists and their cofounders at 91 startups, along with academic technology transfer officers and others. Nine of the companies in the study began prior to 1990; 18 began between 1991 and 2000; and the remaining 64 began between 2001 and 2010. With the exception of one company in New York, the startups were distributed in 12 regional clusters (see map, Figure 1).

Startups have become a primary source of innovation as the large high-tech companies that once supported in-house research have turned increasingly toward product development, frequently purchasing successful startups or licensing their new intellectual property. The physics that is being done by the companies in the study offer the potential for major breakthroughs and new technologies in areas as diverse as medical devices, superfast and nano transistors, optical switching, alternative energy sources, and laser sensors and communications, along with a variety of new manufacturing tools. Depending on whether they succeed or fail in creating innovative and commercially successful products, these companies and other physics-based startups will go a long way toward determining our economic and technical future.

This four-year study is focused on investigating the structure and dynamics of physics entrepreneurship and understanding some of the factors that lead to the success or failure of new startups, including funding, technology transfer, location, business models, and marketing. We have also considered ways that the companies can work with private and public archives to preserve historically valuable records to allow future researchers to understand the ongoing technological revolution.

- A national system of entrepreneurship and innovation doesn't exist, despite efforts to create regional clusters modeled on the successes of the Silicon Valley and the greater Boston area.
- Startups in the study can be broadly divided into two business models that we called "market pull" and "technology push." Market-pull startups tend to improve upon existing technologies. The focus is on product development using existing science. Technology-push companies work to spin out new, game-changing technologies from university research for undeveloped markets. The focus is on new product creation based on fairly fundamental scientific research.
- Funding is a critical factor in the success or failure of new companies. Venture capital/angels and government funding through the Small Business Innovative Research (SBIR)/Small Business Technology Transfer (STTR) programs have both played critical roles in funding startups, but their roles have changed significantly over time.
- Regardless of their business model, participants found problems with both government funding and venture capital, even though they typically saw both as critical to success.
- Perhaps because most of the startups in the study are not yet commercially profitable, tax policies were not a major concern. Interviewees saw current immigration policies and International Traffic in Arms Regulations as hostile to American high-tech competitiveness.
- The study found potential mechanisms for preserving historically valuable records of startups.



# *Table of Contents*

Introduction . . . . .	1
Summary Findings . . . . .	2
Methodology . . . . .	4
Regional Variations in Venture Capital Availability . . . . .	9
Entrepreneurial Characteristics. . . . .	13
Entrepreneurial Self-Image. . . . .	14
Entrepreneurial Risks . . . . .	15
Employees in a Startup. . . . .	18
Location . . . . .	20
Funding the Startup . . . . .	23
The Growth of SBIR/STTR Programs . . . . .	24
State Grant Programs. . . . .	26
Phase 0 Grants . . . . .	26
Matching Grants . . . . .	26
Bridge Grants . . . . .	27
Collaboration Funds. . . . .	27
Business Funding Models . . . . .	27
Bootstrap. . . . .	27
SBIR/STTR Companies . . . . .	28
Other Federal or State Government Grants . . . . .	36
Angel Funding . . . . .	37
Combination Bootstrap/SBIR . . . . .	39
Venture-Funded Companies . . . . .	39
Evolution of Funding Models. . . . .	44
Tensions Between Venture Capital and Entrepreneurs. . . . .	46
Technological Origins . . . . .	47
Research vs. Development. . . . .	48
Transferring Technology Out of the University . . . . .	49
Communications. . . . .	53
Records . . . . .	54
Operating in a Global Competitive Environment. . . . .	57
Government Regulation . . . . .	59
Conclusion . . . . .	60
Endnotes . . . . .	65
Appendix I: Table of Companies Visited . . . . .	73
Appendix II: State Funding for High-Tech Entrepreneurship. . . . .	77



## *Introduction*

The History of Physics Entrepreneurship (HoPE) study, funded by the National Science Foundation (grant #0849616), the Avenir Foundation, and the American Institute of Physics (AIP), is an investigation of the dynamics and structure of research-based startup companies over the past two decades by groups that include Ph.D. physicists as founders. The study builds on our History of Physicists in Industry (HoPI) project, which was completed in 2007 (see final report at <http://www.aip.org/history-programs/niels-bohr-library/documentation-projects>). In the HoPI study we identified the trend for large corporate laboratories to assess technologies brought to the market by small startups for possible acquisition, as opposed to developing new technologies internally. The large corporation's role in this new knowledge economy is now relatively well understood. And Robert Black, founder of CivaTech Oncology, has pointed out that "the demise of basic research in the corporate labs has been a boon to small businesses."<sup>2</sup>

In our current study, both entrepreneurs and university technology transfer managers confirmed the importance of startups for bringing innovative new technologies to the marketplace. Lita Nelsen, Director of MIT's Technology Licensing Office, told us, "The more innovative the invention, the more likely it's going to have to go through a startup." She asserted that "established corporations are not taking on the really...early-stage technologies."<sup>3</sup> Lindsay Austin of Pavilion Integration agreed.

*Big corporations are not very nimble. They are like dinosaurs.... They can throw a lot of money at a big project that's more engineering. There's not a lot of risk associated with it, but it just takes muscle. But when it takes brain and creative thought and solutions, they tend not to be that great.... Small companies are much better, much nimbler, more motivated. They are very flexible and very fast.*<sup>4</sup>

Since R&D in the big high-tech companies has largely moved from knowledge creation to technology acquisition, it becomes important to understand the research and innovation being carried out at startups from which the large corporations are acquiring innovative technologies. This study is designed to develop an understanding of entrepreneurial physics-based startups. We believe that the study of physicist entrepreneurs' roles in innovation is particularly useful. As early as 1841 German-American economist Friedrich List argued that physics and chemistry are the sciences whose innovations transform all industrial sectors. "There is no progress, no discovery" in these fields, he asserted, "which does not improve and transform a hundred branches of industry."<sup>5</sup> Because innovations in physics continue to affect entrepreneurship across nearly all industrial sectors, we believe that this study avoids some of the peculiarities of biomedical and pharmaceutical startups that have dominated recent studies. The latter are atypical because of regulatory requirements and the need for long laboratory and clinical trials.

## Summary Findings

After interviewing about 140 physicists who had started and were either operating or had recently exited from 91 startups clustered in 12 regions across the United States covering 14 states (shown in Figure 1), we found no national culture of innovation. Rather, we found relatively unique ecosystems of innovation and entrepreneurship in each of the regions examined, shaped by a wide variety of local and regional factors. We believe that this may be the study's most important finding. It suggests that the efforts to model entrepreneurial activity on Silicon Valley or Boston's high-technology corridor are misplaced. Although these two locations are the twin birthplaces of high-tech entrepreneurship in the United States and remain the most successful areas for new startups, managers of innovation in other regions will do well to focus on the unique resources and local cultures of their particular region.



**Figure 1.** The 91 companies in the study are located in the 14 states that received 80% of venture capital funding from 1995 to 2011 and 60% of federal SBIR grants.

Other major findings include:

1. There are two dominant models of physics entrepreneurship. One, which we refer to as “market pull,” is aimed at the existing market(s) and typically focuses on incremental improvements to existing technology. The other, which we refer to as “technology push,” is aimed at creating new markets and focuses on more innovative, sometimes disruptive technology usually spun out of research activities of universities and occasionally national labs.

2. There are two major sources of funding for physics startups: federal Small Business Innovative Research (SBIR)/Small Business Technology Transfer (STTR) program grants and venture capital/angels. Many physicists, especially those who were not in either main hub of venture capital (i.e., Silicon Valley or Boston), expressed strong feelings about venture capitalists. Venture capitalists are particularly sensitive to market forces, and their practices have changed dramatically over the past 20 years in response to changes in the economy. Several entrepreneurs who had started more than one company over time noted the tightening availability and requirements for venture funding.
3. While the large number of “university spin-outs” in our study may in part result from the regions where we interviewed, overall the study shows the growing importance of the intellectual property produced by academic R&D that is moving to startups, in part replacing the investment that large corporations once devoted to research. Our interviews confirmed the importance of university knowledge creation in feeding science-based startups. At the same time we found that individual university technology transfer processes diverge sharply.
4. Startups share a variety of concerns—finding adequate funding, establishing a profitable market, worries about the timeliness of their technology, as well as more typical business concerns about government regulation and costs of doing business. Perhaps because most of the startups we studied were not yet commercially profitable, taxes remained a low priority, and the government regulations they emphasized differed greatly from those generally portrayed as causing typical business concerns. Instead, entrepreneurs opposed current immigration policies and the costs of bringing highly talented immigrants as employees in their startups. The current proposed immigration reforms only partially resolve these concerns. While they provide immigration pathways for entrepreneurs themselves, they do little to ease startups’ complaints about the difficulties in hiring and retaining foreign graduates of American universities or bringing foreign science and technology experts to the United States as employees. Second only to immigration issues, founders told us that International Traffic in Arms Regulations (ITAR) crippled many of the competitive advantages for developing technologies in the United States and made it difficult for them to compete internationally.
5. Only nine of the 91 companies in the study were founded before 1990, and 64 were founded in 2001 or later. Most had significant records documenting their business and R&D operations, and more than half had some form of records retention policy. Although interviewees typically expressed little interest in the company’s history, three volunteered to work with existing archives to preserve their records. Because of time and resource constraints, we did not volunteer to help companies partner with established archives. However, we believe that an active effort to accomplish this would result in successfully preserving significant documentation of physics entrepreneurship.

## *Methodology*

This study of physics entrepreneurs is an outgrowth of our earlier study, the History of Physicists in Industry (HoPI), which in turn grew out of a documentation study of multi-institutional collaborations that we began in the early 1990s.<sup>6</sup> In developing the methodology, work plan, and question set for this study, we relied in part on the methodology that we had used in our earlier studies. In addition, we sought advice from entrepreneurs as well as business professors and historians.

The HoPI study documents the decline of research and shift from knowledge creation to knowledge acquisition in large corporate R&D laboratories. The earlier study shows that established corporations have increasingly turned to small startups to avoid the costs and risks of conducting innovative research in-house. They acquire the technology—and often the startups themselves—that fit their corporate needs. The study also showed that the processes of entrepreneurial R&D were inadequately understood, even though many physicists spend at least part of their career working in startups. In 2011, AIP's Statistical Research Division conducted a survey of physicists who earned their Ph.D.s in the United States in 1996, 1997, 2000, and 2001 and who were working in America in 2010–2011. Almost 1,500 Ph.D. physicists responded to the survey, and nearly half of those employed in the private sector reported that they had been involved in startups since earning their doctorates.<sup>7</sup>

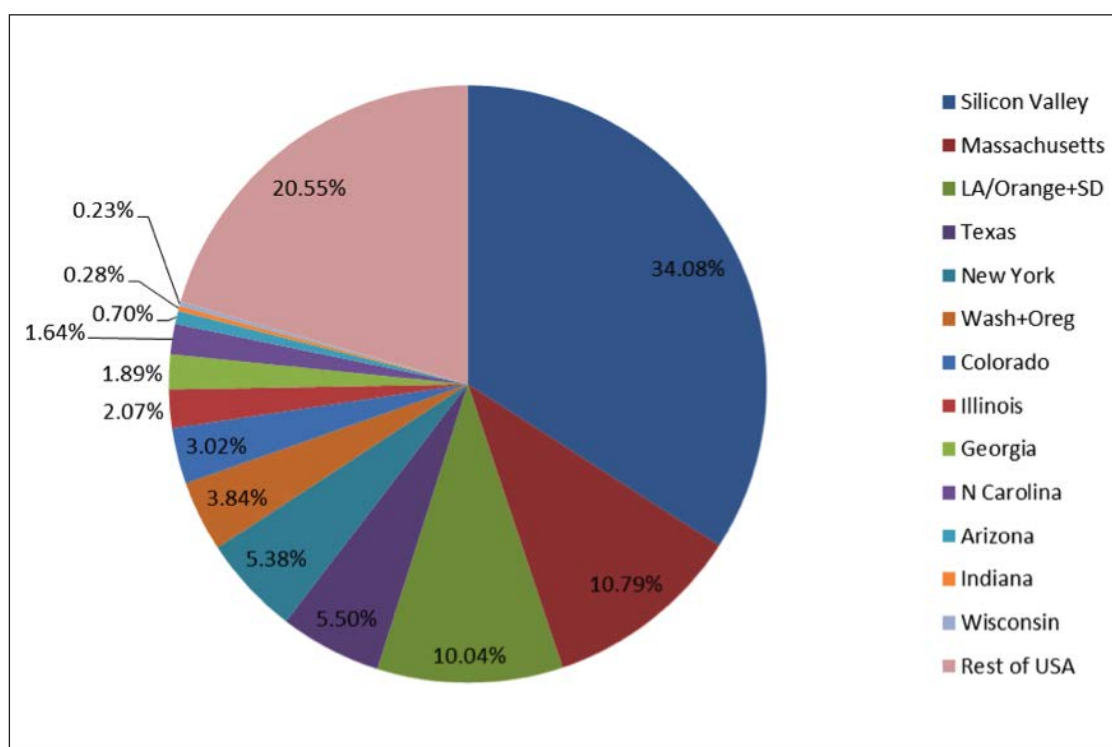
We developed the HoPE study to look closely at the processes of innovation in startups. We chose a qualitative approach—interviewing a smaller sample intensively—in order to investigate the multitude of issues that help explain the complex process by which physicist entrepreneurs bring technologies to the market and to document their efforts. We believe that qualitative methods are appropriate for this study, as they were for the earlier HoPI study, since they have allowed us to raise research questions that are open and exploratory, and supply information that is richly descriptive. This approach has allowed us to examine issues raised by the interviewees rather than measuring issues defined *a priori*.

Using standardized question sets for the interviews enabled us to compare responses of the interviewees, who had the opportunity to describe in detail complex situations. The process also enabled us to appreciate how scientists' and companies' experiences and record-keeping practices are influenced by personal backgrounds, company and regional culture, management and organizational trends, and technology. We interviewed 129 of the 192 founders and 16 other company officers at 91 startups. We also interviewed around 10 technology transfer and licensing agents at universities with established technology transfer programs. The founders we interviewed had been involved in more than 80 previous startups.

Our question set addressed startup research and business issues that included seed funding and financial resources, the nature of the business, target markets, R&D challenges, competition, and the ability to quickly respond to market demands. In addition, we asked questions about their relationship with their funding sources and the degree of freedom that they felt to pursue research and development within the constraints imposed by both their funding sources and their markets.

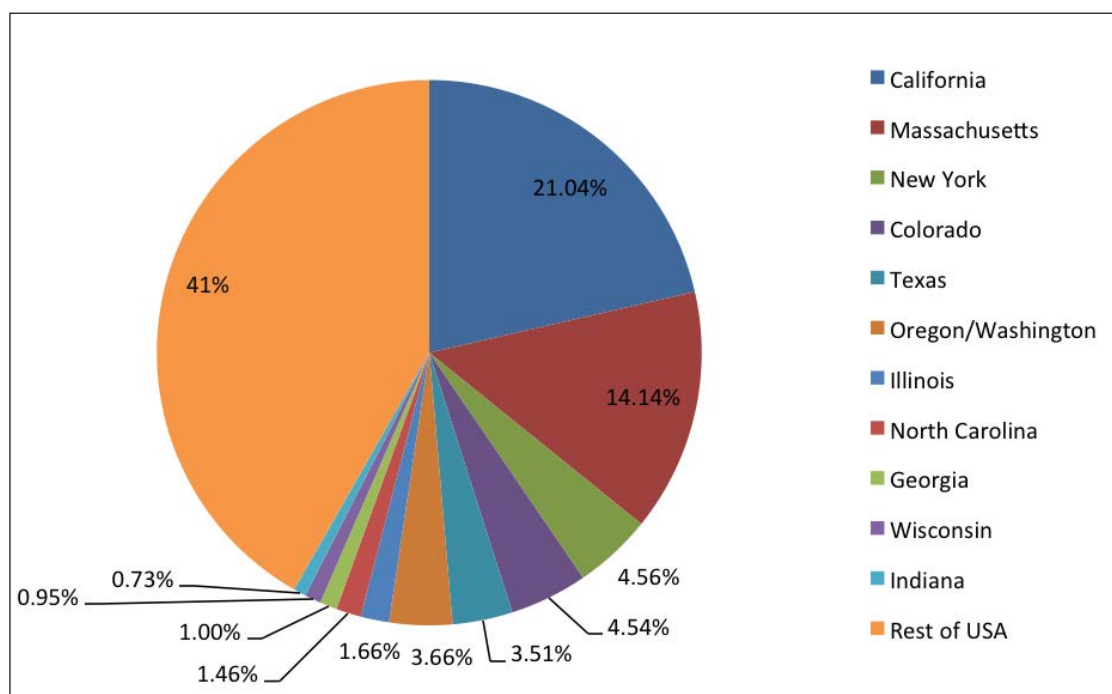
We analyzed the interviews using NVivo, a qualitative software program, and we assigned inductively created codes to flag concepts that could then be compared across companies, industry sectors, job types, and people. As in our previous HoPI study, we anticipate that an important byproduct of this quali-

tative study will be the identification of variables whose influence might be tested in future quantitative studies. The interview transcripts will be made available to researchers at the conclusion of the study, except for the small number of interviewees who requested that their responses be kept anonymous. We conducted site visits and interviews at 91 high-tech startups, ranging in size from one person to around 700 employees. Each startup we visited had at least one founder who had a Ph.D. in physics. We selected companies from diverse regions, which we identified as Silicon Valley, Massachusetts, Southern California, Washington and Oregon, Texas, Colorado, Illinois, Georgia, North Carolina, Arizona, Indiana, and Wisconsin. We also conducted one interview with a New York–based startup. We chose these regions because together they make up about 80 percent of all venture capital disbursements made from 1995 to 2011 and about 60 percent of all SBIR funds granted from the beginning of that program in 1982 through 2011 (see Figure 2 and Figure 3).



**Figure 2.** *Regional proportion of reported venture capital funds invested 1995–2011.*

Figure 1 shows the distribution of the startups we visited. We used PricewaterhouseCoopers National Venture Capital Association’s “Money Tree Report” to compare and contrast national and regional venture capital trends with information obtained from our interviewees. Our interviewees were located in 11 of the 18 regions that the Money Tree Report divides by venture capital investments. The Money Tree Report regions are Silicon Valley, New England, LA/Orange County, Texas, New York Metro, San Diego, Midwest, Northwest, DC/Metroplex, Philadelphia Metro, Colorado, Southeast, Southwest, North Central, South Central, Upstate New York, Sacramento/Northern California, and Alaska/Hawaii/Puerto Rico. For the purposes of our study, we combined San Diego with LA/Orange County into Southern California. Because we only had one interview in the New York City Metro region, we combined data from that region with New England. Figure 2 provides total regional venture capital investments since 1995, while Figure 3, drawn from data provided by [www.sbir.gov](http://www.sbir.gov), shows the regional distribution of SBIR funds since 1982.



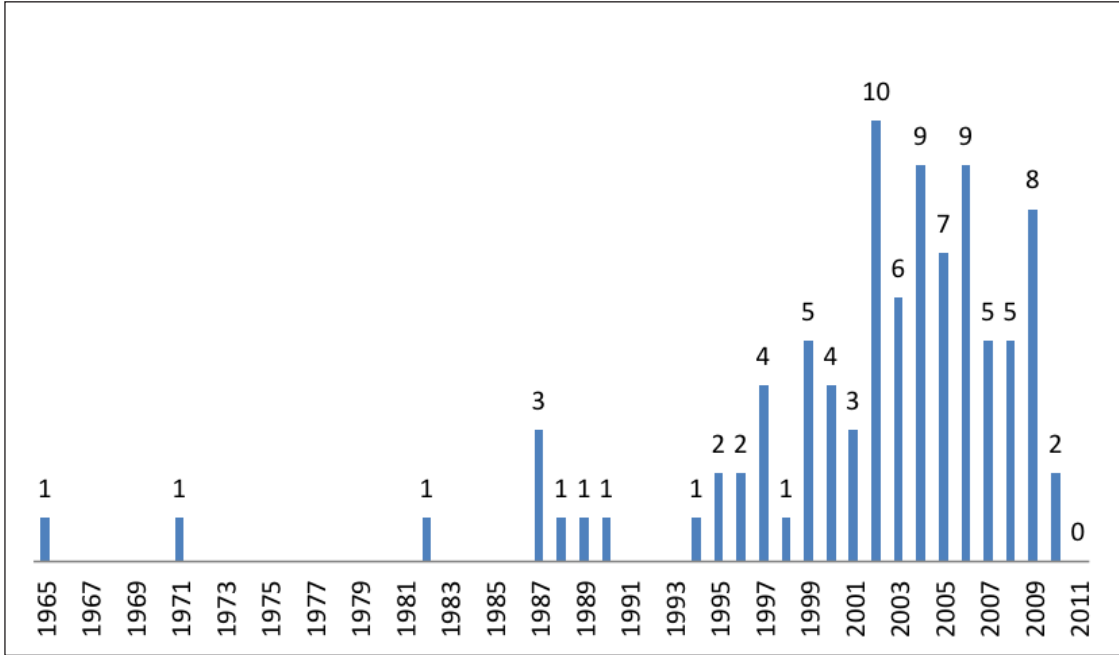
**Figure 3.** *Regional distribution of SBIR funds 1982–2011.*

We chose to interview in regions where we found a cluster of at least six startups that fit our selection criteria, with the exception of the Pacific Northwest and Arizona, where we visited four companies each. We selected the companies from a database we created of startups having at least one Ph.D. physicist among the founders (see Appendix I for a list of the companies in the study organized by state and city, including the date they were founded). We included nine startups that had been founded prior to 1990, 19 that had been founded in the 1990s, 35 companies founded between 2001 and 2005, and 28 founded since 2005 (see Figure 4 and Appendix I). We included the startups that began prior to 1990 to provide historical context to the evolution of physicist entrepreneurs in the 20 years between 1991 and 2011.

We included in our selection at least five startups that had not survived in the marketplace and at least five that had gone public or been acquired by a larger corporation. As stated above, the 91 firms selected for the study ranged in size from one person to around 700 employees, but most employed less than 30 people. We classified the startups by region, primary field of business, year founded, funding mechanisms, and the degree to which the startups were driven by the technologies they were bringing to the market or by market-defined problems to which the startups were adapting known science and technology. We described the former startups as technology-push companies, and they represent about 49 of the firms in the study. We defined the latter as market-pull companies, and they consist of approximately 35 of the startups. Another seven participants did not clearly fit either model. Instead they might be described as “service” companies. Included in this classification are those startups providing research and/or consulting services but with no intention of introducing new components or products.

We interviewed in regions where there was substantial private and public economic development. As described above, 80 percent of the venture capital invested in the United States since 1995, and almost 60 percent of SBIR and STTR grants, have been invested in the 12 regions where we interviewed. Only one of the regions—Wisconsin—fell below the median for venture capital investments since 1995, and

only Indiana fell below the median for total SBIR/STTR grant disbursements since 1982. We looked for regional variations, market variations, variations in the nature of business influenced by funding mechanisms, and issues regarding records that future researchers might turn to in order to better understand the nature of current research, innovation, development, and success in the marketplace.

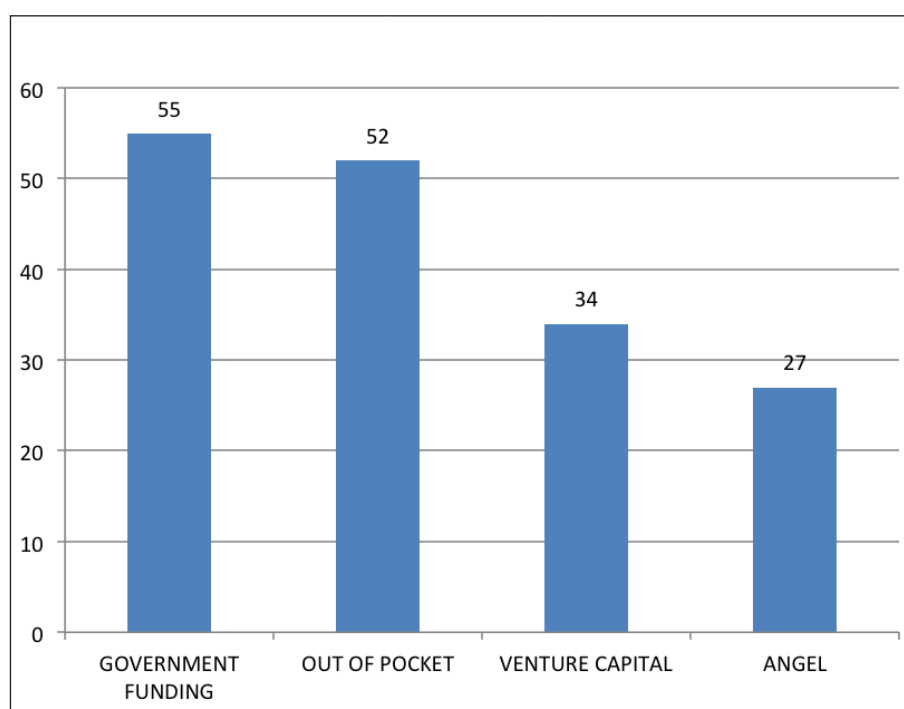


**Figure 4.** Company startups by year.

Field	Startups
Electronics/components	19
Medical devices and equipment	18
Instruments systems	13
Industrial/energy	9
Networking and equipment	9
Software	8
Other—Consult	4
Biotechnology	3
Other—R&D	3
Semiconductors	2
Computer equipment and peripherals	1
Other—Data management & analysis	1
Other—Intellectual property	1
Other—Services	1

**Table 1.** Fields of physicist entrepreneurs' endeavours.

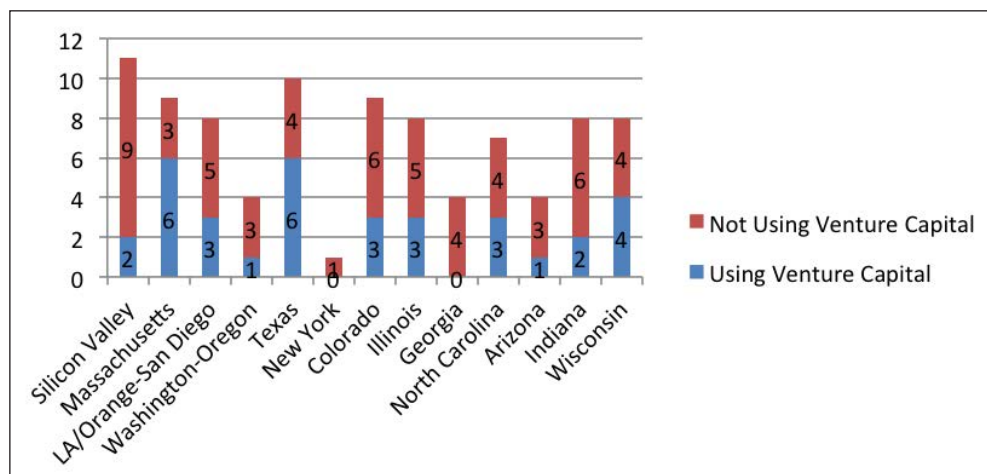
Table 1 shows the broader fields in which the startups in the study were involved. The fields were derived from the National Venture Capital Association's investment fields. However, we broke down the "other" into specific topical areas, and we changed their electronics/instrumentation into "electronics/components" that were sold to other companies, and "instruments/systems" that were finished devices to be sold to end users. Figure 5 shows the sources of funding used by the 91 startups. Most of the startups in the study relied on a mix of out-of-pocket, angel, venture capital, and government funding sources, but that mix varied greatly. Fifty-five startups drew on some form of government grant, with 52 of those receiving at least one SBIR/STTR grant. Fifty-three used some out-of-pocket and/or "friends and family" funds to help begin their businesses. Another 28 turned to angels at some point, and 34 drew funds from venture capitalists. Fifty-two used at least one SBIR/STTR grant, and 36 told us of other state or federal grants that had helped to sustain the business. The people we interviewed were generally reluctant to reveal private financial information, but a few told us that they had invested anywhere from \$10,000 to a few hundred thousand dollars of their own money in their startups. Information from public sources revealed that the startups we studied have obtained almost \$155 million in SBIR/STTR funding. While venture capital funding records are incomplete, those available make it reasonable to assume the startups have received around \$1.2 billion dollars in venture capital (VC) funding.<sup>a</sup> Three startups that did talk about angel funds reported just over \$19 million in angel-sourced funds. Assuming somewhere between \$150,000 and \$500,000 in angel funding per remaining angel-funded company suggests angel funding between \$22 and \$31 million for the companies we studied.



**Figure 5.** Sources of startup early funding.

<sup>a</sup> Public venture capital funding reports on 26 of the startups we studied showed a total of \$1,169,550,000 in funding for those firms. One of the firms, however, did not report two rounds of funding and we could not find public reports on VC funding for nine firms. Taking the median VC-funded company after removing one firm that had received \$370 million gives an average VC grant of about \$12 million. Even if the firms whose VC funds we could not find received half that amount, it would add another \$54 million in VC funding to the firms in the study, bringing the total to about \$1.23 billion.

As described above, we identified five different funding patterns that the entrepreneurs used. They personally invested and received funds from “friends and family,” angel or venture capital funding (or in some cases corporate funding), or some form of government grants, predominantly SBIR/STTR programs. Sources of funding varied widely from region to region, as did ease of access to outside funding sources. While we could not determine a quantitative measure of ease of access to venture capital, we were able to develop some general measurements by drawing on the PricewaterhouseCoopers and National Venture Capital Association data.

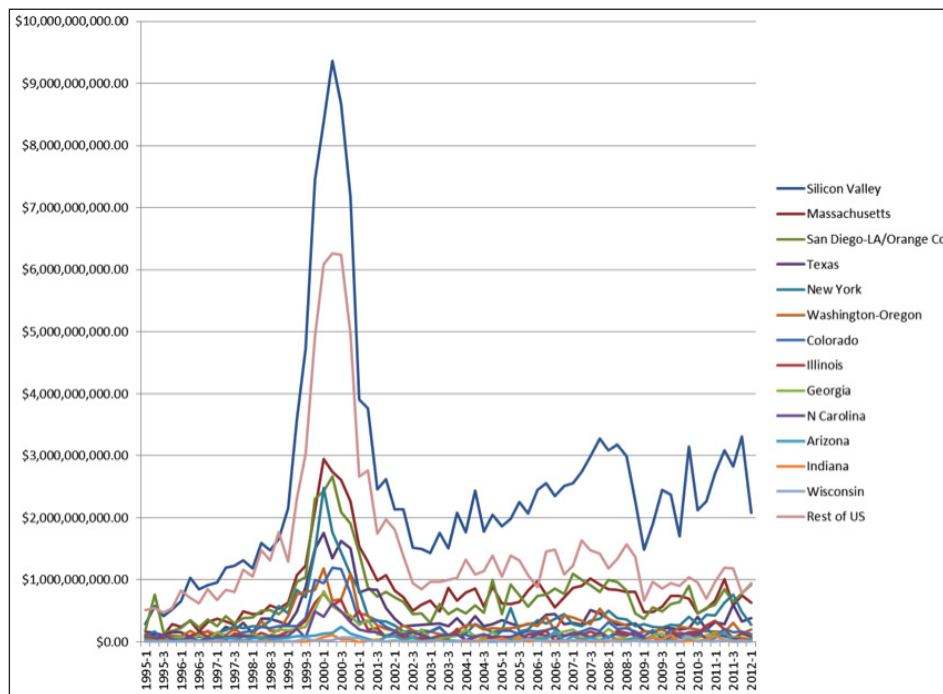


**Figure 6.** Companies interviewed by venture capital investment regions.

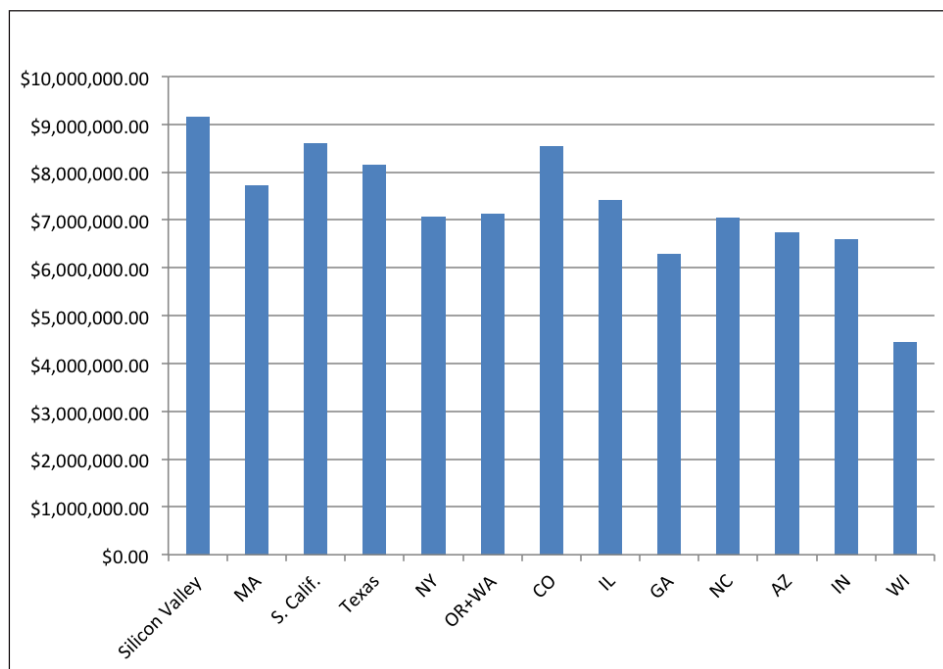
## ***Regional Variations in Venture Capital Availability***

Since 1980, when the modern notion of venture capital matured, until 2011 about \$700 billion has been raised by venture capital firms, \$489 billion of that in the last 10 years.<sup>8</sup> Figure 6 shows the number of companies we interviewed in each of these regions. Our sample size does not permit us to make assertions about the relative level of venture capital investment in each region, but that data can be derived from PricewaterhouseCoopers’ Money Tree Report. Figure 7 shows the relative quarterly venture capital investment between 1995 and 2011 in the regions we studied plus the rest of the United States, and Figure 8 shows the proportion of total reported venture capital investments by region since 1995. Figure 9 shows the relative proportion of individual venture capital investments by region.

As Figures 7, 8, and 9 show, there have been wide variations in the total amount of venture capital available in the regions we studied, and the amounts that venture capitalists were willing to invest in each deal varied significantly as well. Many entrepreneurs turned to the government SBIR program as an alternative to venture capital, and Figure 9 shows substantial regional variations in the distribution of SBIR/STTR funding, though not so wide as that of venture capital. These variations in funds available for entrepreneurial startups reflect regional variations in the attitudes toward venture capital and how it ought to be used. While we did not find so strong a regional variation in attitudes toward SBIRs and other government grants, we did find variations in how entrepreneurs approached and used those grants. Rather than a single national entrepreneurial culture, we found regional entrepreneurial cultures. All of the interviewees were enthusiastic about entrepreneurship, but their approaches to starting, funding, and bringing new technologies to market varied considerably by region.



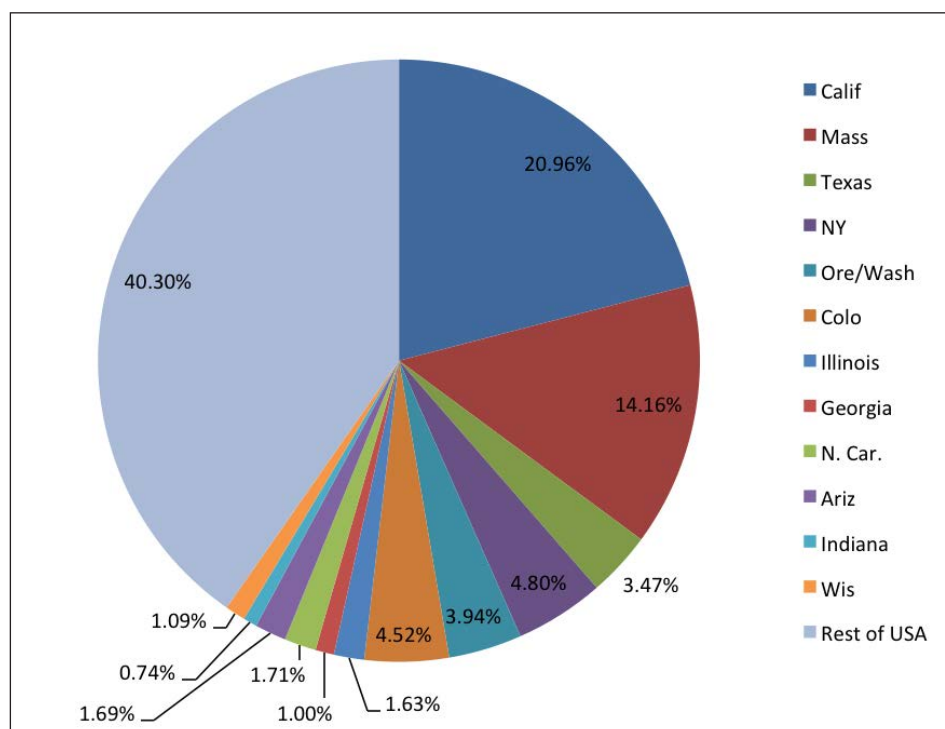
**Figure 7.** Quarterly venture capital investments by region from 1995 to 2011.



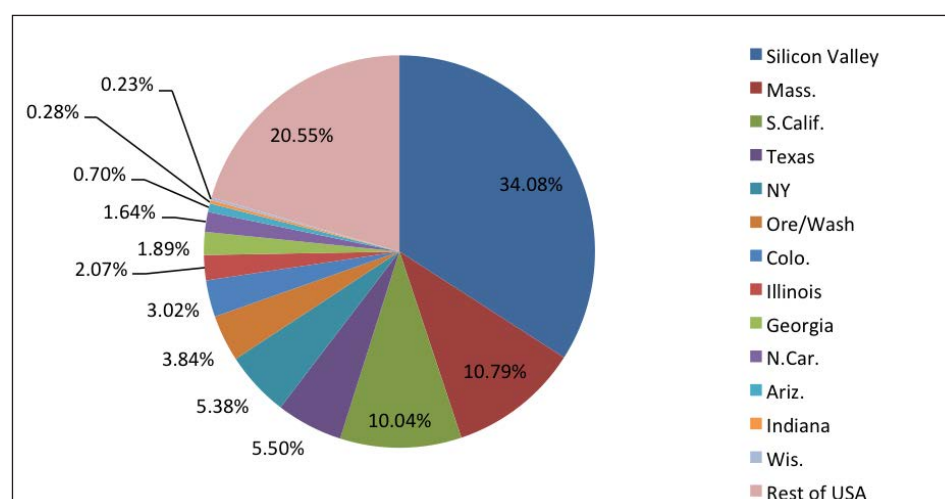
**Figure 8.** Average venture capital investment per deal 1995–2011 by region.

As Figures 9 and Figures 10 indicate, the amount of venture capital investment and SBIR/STTR grants available in the various entrepreneurial environments we studied varies greatly. Of course, these comparisons must be supplemented by the degree of state-funded investment, angel, and other forms of investment that affect the opportunities to fund entrepreneurial activities in those regions. As the resources

available for funding entrepreneurial strategies vary, so too do the strategies for business development that appear to be preferred in each region. In California, entrepreneurs clearly appreciated their relationship to venture capital institutions and understood when their business model was appropriate for venture capital investment. They turned to venture capitalists for advice even when both understood that the entrepreneur likely would not benefit from venture funding. Only a few of the physicist entrepreneurs we visited in Silicon Valley actually turned to venture capitalists for financial assistance.



**Figure 9.** Percentage SBIR/STTR grants 1983–2011 by region.



**Figure 10.** Percentage venture capital investments 1995–2011 by region.

Almost universally, the entrepreneurs who sought venture capital turned to venture firms that were located in their own regions. This means that startups outside the two major venture capital regions in the study, Silicon Valley and Massachusetts, relied on smaller, more narrowly focused venture firms. There were distinct regional differences. For example, venture capitalists in Massachusetts appeared more likely to be willing to function like angels within a closely structured entrepreneurial economy. In Texas, entrepreneurs were both less likely to turn to venture capitalists and to prefer to draw smaller amounts from multiple VCs, creating their own, sometimes global, venture capital networks that allowed them to retain greater control over their enterprise.

In Colorado, and even more explicitly in Georgia and North Carolina, entrepreneurs struggled to obtain funding, and they turned more to local venture capital and angel networks for smaller amounts of funding. VCs and angels in these areas also appeared to take a smaller percentage of equity in the firm. When VCs demanded a majority stake in the startup in these three states, the entrepreneurs typically turned down their funds, instead creating strategic alliances with larger companies and relying more heavily on SBIR/STTR and other government grants. Finally, in the Midwest, where venture capital and other forms of external funding were either less available or more likely to be rejected by entrepreneurs, we found a greater emphasis on slowly building company value by moving quickly to product sales. This is not to suggest that each of these business practices did not occur in other regions. Rather, we found a continuum of strategies with shifting emphasis in the various regions.

Entrepreneurs must address a complex set of issues in order to create and sustain new technology startups. First and foremost is how they will fund the startup until it reaches profitability and can sustain itself in the marketplace. But there are other issues inextricably tied to bringing a new business to a self-sustaining point, including the sources of their technology and the role of research and development. We also queried about the role of the workforce and where founders acquired the employees critical to the smooth functioning of their high-tech companies. While both market-pull and technology-push companies have to adjust to changing and sometimes completely new markets, technology-push companies appear to have a different strategy regarding markets, funding, and research and development. There are a variety of other issues as well, such as how taxation and government regulation affect startups. The answers we found were often surprising.

Technology-push startups offered the potential of producing more fundamental, even disruptive and game changing, innovation, and they frequently focused on finding a wide variety of applications for their technology in the hope that at least one application would take off or a group of applications would sustain the company. Technology-push entrepreneurs sometimes displayed a “build a better mousetrap, and the world will beat a path to your door” attitude. They remained less focused on markets, at least until a particular market found them. They had comparatively high research and development costs and were more likely to turn to government funding, since venture capitalists were less likely to fund their relatively heavy R&D focus and longer time to market. Technology-push companies felt that their strategy, while often resulting in slower growth, would enhance the ultimate value of their technology. Market-pull firms, on the other hand, typically focused on making incremental improvements to specific products and relied on the market to tell them what improvements were desirable. As a result they usually had a shorter time to market than technology-push companies because they were adapting known science and technology and often spent little on R&D activities.

## *Entrepreneurial Characteristics*

In the previous section we addressed the relative availability of capital in various regions and how that affected startup cultures. In this section, we will consider the nature and character of entrepreneurs, entrepreneurial attitudes about the risks associated with various funding sources, and the variety of methods they used to ameliorate other risks that startups face. Finally, we will conclude with some miscellaneous issues that consistently concerned our interviewees. Among the more intriguing questions discussed in entrepreneurial literature is who is likely to become an entrepreneur and whether entrepreneurial activity is learned or is part of the genetic makeup of the individual. Nicolaou et al. found genetic factors to be important for explaining why people engage in entrepreneurial activity in their study using quantitative genetics techniques to compare the entrepreneurial activity of monozygotic and same-sex dizygotic twins in the United Kingdom.<sup>9</sup>

In spite of occasional anecdotal suggestions of genetic influences, we found little if any evidence to support either genetic or environmental influences on the entrepreneurial activity of the physicists we interviewed. One of our interviewees told us that while his adoptive parents could not really be considered entrepreneurial, his birth father certainly had been.<sup>10</sup> Another told us that he had been drawn to entrepreneurial activity in part because of his childhood friendship with the son of one of the founders of a major insurance company, who had himself eventually turned to venture capitalist/angel activities. That friend had ultimately partnered with him in the beginning of his firm.<sup>11</sup> On the other hand, less than 25% of the founders we interviewed cited a family entrepreneurial influence, and even fewer were able to identify childhood entrepreneurial influences outside the family. Only six interviewees identified nonfamily childhood environments as encouraging entrepreneurial activity. Seventy-one interviewees identified parental careers that we defined as professional “white collar” careers. Another 32 interviewees described parental careers that we identified as “blue collar.” Twenty-four indicated that their parents had engaged in some form of business activity ranging from vice president of a corporation to proprietorship of grocery or hardware stores. Even when parents had similar careers—farmers, physicians, etc.—one interviewee would perceive his or her parent’s career as entrepreneurial, but another would not. For example, eight described their parents as “farmers,” but only two considered that to be an entrepreneurial activity. The relative absence of entrepreneurial influences during our interviewees’ formative years suggests the importance of adult work experience prior to the founding of their current company. One-third of the founders we interviewed had worked for a startup prior to founding their current company. Even more significant, nearly 40 percent had been involved as founders of previous companies. More than another 10 percent had, as faculty members, served as consultants to startups prior to initiating their own.

These numbers became even more significant when broken down by company, rather than by individual founder. One-third of the companies had at least one founder who cited family entrepreneurial influences, but more than 56 percent had at least one founder who had been involved in founding an earlier company, and 44 percent had at least one founder who had previously worked for a startup that others had created. Many, if not most, who did not have previous significant entrepreneurial influence told us they were mentored by other entrepreneurs in their community when they began their startups. Only 11 percent of our interviewees and eight percent of the companies provided no evidence suggesting previous entrepreneurial connections or experience. Our findings support the idea put forth by Nanda and Sorensen, who argue that a person is “more likely” to become an entrepreneur if his or her cowork-

ers have had entrepreneurial experience. “Peer influences,” they argue, appeared to substitute for other sources of entrepreneurial influence.<sup>12</sup> Both venture capitalists whom we interviewed and those interviewed by others in Udayan Gupta’s *Done Deals* confirmed the importance of previous entrepreneurial experience on the management team of VC-funded startups.<sup>13</sup> Our study suggests that persistence in entrepreneurial activity may be a critical factor leading to entrepreneurial success.

We were surprised by the important role that immigrants play in the high-tech startups we interviewed. Almost 29 percent of the founders we interviewed and 28 percent of all of the founders of the companies in the study were US immigrants. Many had come to the United States to study before beginning their own business here. Nearly one-third of the founders of the startups were either immigrants or children of immigrants.

### ***Entrepreneurial Self-Image***

Many if not most of our interviewees saw themselves as what we might describe as “knowledge workers” as much as entrepreneurs. Others saw themselves in some area between academics and industry. Arturo Chavez-Pirson of NP Photonics told us:

*I think the path of most of these people [entrepreneurs] is rather convoluted in a sense. They may start in academia, they may shift to industry, they may go to startup, they may leave startup, they may go back to industry or back to academia, or go back and forth.*

Rather than becoming physicists with a goal to “work at CERN or Fermilab,” or thinking “deeply about some physical phenomena and how it comes to be and how it develops from a physics point of view only,” Chavez-Pirson asserted, they now ask “how this phenomena or these interactions can be controlled and made use of for the benefit of society.”<sup>14</sup> Ron Reedy put it even more bluntly:

*You know what? I really don’t care if I make much money. There’s a minimum. I want to pay for my family and kids’ education, and then I don’t need any more. I had a very good friend who I talked to a lot about it....He said the worst entrepreneurs are the ones that start companies to make money. Entrepreneurs start companies to start companies. It’s tautological. Whether they make money or not is a measure of the success of that company, but it is not the primary role.... So my reason for starting a company myself is the experience you get, the people you meet.<sup>15</sup>*

Entrepreneurs differ from venture capitalists, with whom they are sometimes allied, in that they are concerned primarily with ensuring the success of their technology in the marketplace. As Mary Fuka, founder of TriplePoint Physics, put it, “Venture capitalists are not necessarily the helpful folks that one would want them to be.”<sup>16</sup> Venture capitalists also wish to enhance the value of the technologies in which they invest, but their goal—to achieve as high a return as possible on their investment portfolio in as short a time as possible—sometimes runs counter to the longer-term success of the technology. Stefan Murry of Applied Optoelectronics told us that venture capital “influenced our decision to move away from the military market into more commercial markets, because obviously the potential growth rate is much faster in commercial markets than in military markets.” Still, venture capital “didn’t get terribly involved in

the day-to-day operations of the company.”<sup>17</sup> When the long-term interest of the entrepreneur in the value of the technology and that of the venture capitalist in high return on investment are complementary, the feelings are generally good. When the “relationship between the entrepreneur and venture capital works, both were mutually happy,” Stefan Murry, whose company moved to venture capital funding after a couple of years surviving on SBIR grants, told us.

*The process of working with the venture capitalists has been, I mean, it's been okay. Do the owners, the original founders of the company, have as much ownership as we would like? Of course not. Nobody ever has.... Do we have as much as we thought we might when we got to this point? Probably not. But on the other hand, we're certainly well taken care of, and personally, I find more satisfaction from the opportunity to build a company that's doing great things and see our products being used out there in real applications. As long as the money is enough, we're okay.*<sup>18</sup>

## **Entrepreneurial Risks**

Many of the interviewees described themselves more as technologists than entrepreneurs. Founders of market-pull companies did not see themselves as taking great risks. Rather, they saw the importance of the technology and their confidence in understanding it as providing assurance that they would find success in the marketplace. Faculty members frequently saw little risk in their startups since they, generally tenured, had secure jobs.

Stefan Murry recalled:

*When we first started the company, there wasn't a lot of risk for us. We were still employed by the university.... But I suppose the main risk factors that we thought about at the time were really just the possibility of investing a lot of time and maybe just a little bit of money and not getting anything out of it.*<sup>19</sup>

Krzysztof Kempa agreed. There was, he asserted, “nothing personally risky, except if the idea doesn't work out, so people will not be interested in you anymore. That's essentially the risk.”<sup>20</sup> Even many who left academia remained confident that their understanding of their technology limited risk. Somesh Jha, founder of NovaShield, asserted: “I don't think there was a huge amount of risk, because I didn't invest my own money.... So the risk was mostly time, and sort of just being emotionally invested.”<sup>21</sup> Robert Fischell, who has founded several medical device companies, agreed, telling us: “You know it's funny that when we start a company, we are so confident that we'll win, I mean, that we don't think we have a risk.... We always think we'll win.”<sup>22</sup> A few did, however, note that as the business developed they discovered risks unrelated to their confidence in the technology. Even Thomas “Rock” Mackie, founder of TomoTherapy, who still maintained a faculty position at the University of Wisconsin, told us:

*Asking an entrepreneur their perception of risk is quite interesting, because their perception of risk is far different than anyone else's, right, because they understand the technology. So I didn't think there was any technical risk.... I thought it was going to be business risk.... Would we, as founders, be pushed out of the company? To me it was all of the soft issues that I thought were the risks.*

*Technical risks, we understood those. So I think if someone is honest, as a scientific entrepreneur, they will probably tell you it's personal relationships that are the biggest risk in starting a company and managing that.*<sup>23</sup>

G. Jordan Maclay, founder of Quantum Fields, asserted, "I didn't see any risks because I had this contract..."<sup>24</sup>

For Murry the notions of risk changed only after they turned to venture capital and eventually grew to a company employing 700 people. "Once you start taking other people's money that's measured in millions or tens of millions of dollars," he mused:

*Your calculus kind of changes a little bit and you start to become much more concerned with your ability to grow the company to the point where the investors get their money back and you get to make a little bit of money as well.*<sup>25</sup>

Others who turned to venture capital, and those who didn't but who addressed the risk of taking venture capital, asserted that "you go out and get venture capital and dig yourself in a hole and then you dig yourself out of it as you develop the revenues."<sup>26</sup> Even those who had not placed themselves in a venture capital "hole" addressed cash-flow risks, which was a frequent concern expressed particularly by market-pull entrepreneurs. Matt Kim, founder of QuantTera, asserted:

*When I first began the company, I knew this one rule from business: cash flow. If you don't have cash coming in, the company dies. So that's a risk that a lot of entrepreneurs don't understand.... There has to be some type of revenue stream that keeps you in business.*<sup>27</sup>

Henry Kapteyn told us, "Cash-flow issues were always something that we worried about and occasionally were something that we had a good reason to worry about."<sup>28</sup> Mikael Martinez and Todd Ditmire, cofounders of National Energetics, agreed. "One of the biggest risks from a business perspective," Martinez asserted, "the biggest challenge and risk has been cash flow—running out of money."<sup>29</sup> Ditmire recalled, "A lot of the risks we had in the initial year had to do with cash flow, and could we manage vendors so that we could get the product delivered on time and not run out of money."<sup>30</sup>

Things are different for technology push entrepreneurs. In addition to cash flow, risks for technology-push companies go through different stages. At first there is the risk of not successfully de-risking the technology. Many technology-push entrepreneurs see themselves as "the guys who take the risk, the guys who develop nascent technology."<sup>31</sup> Abdelhak Bensaoula, founder of Integrated Micro Sensors, told us:

*Most of the things we do, even though we do think about the application, most of the stuff that we either write, as in an SBIR, especially things that we get funded for, still have unknowns. High risk—it's still high risk....For me still a big chunk of it is research.*<sup>32</sup>

Once they began to address market-related issues their risks shifted. Dana Anderson, founder of ColdQuanta, told us: "We are not responding to an existing market lead. We are simultaneously cultivat-

ing the market and responding to what we've cultivated. That's a huge risk." He drew an analogy to the early laser market:

*Many of the companies that started out back then as commercial laser manufacturers were too early, and they died because they created themselves at a time when the market just wasn't there and they couldn't generate the interest fast enough. We're in a parallel circumstance, and the question is will we survive in the face of a market that can fall up and down very quickly with the economy, first of all. And second of all, everybody will agree that the applications are there, but will they mature enough for ColdQuanta to be able to keep up and survive over that time? People who are in this kind of business of seeing a new technology emerge say, "Well, we're in the valley of death." The technology is there, the promise is there, the market is not there. Are we going to cross that valley before we die of thirst? So, that's the risk.<sup>33</sup>*

Ayla Annac agreed that the time to market was a substantial risk. She came to InvivoSciences from work in Fortune 500 companies, telling us:

*I didn't know how difficult the science-based product development could be because you have to prove the literal science behind it....So what I need to figure out creatively, then, is how could I get money if this will take 10–15 years, like a drug development.<sup>34</sup>*

As products moved closer to the market, risks changed. Michael Anderson, of Vescent Photonics, asserted:

*In the early days the biggest risk was would the technical idea work, did it have merit? That continues to be a risk, but it's gone from 100% of what it was down to maybe 20% of what it was....Now risks, once you get a company established, at least to the extent that we have, you've got to keep the funding coming in. So there are a lot of risks on just do we keep getting the awards so that we can keep paying our employees and keep it moving forward....But the risks now are more associated with dealing with competition, is your product something someone wants to buy....The sales are growing, but not as fast as we'd like, so that's a risk. How do we turn that into enough revenue to base a business on.<sup>35</sup>*

John Carlisle of Advanced Diamond Technologies agreed. "It's the classic risk that every startup faces: at some point you've got to get rid of the sizzle and start to sell something."<sup>36</sup>

At that point Eric Buckland, cofounder of Biotigen, told us the risk was in whether they could "identify a market space that we could bring a product to that had sufficient pull to warrant investment?"<sup>37</sup> Arturo Chavez-Pirson of NP Photonics asserted that entrepreneurs assumed "that the market is going to grow up, and that you have a product that is going to meet that application, and that you can ramp your production up to meet that. So that's the business risk."<sup>38</sup> Once an "attractive market" was found, Chavez-Pirson noted:

*There's a competitive risk. Could we compete against other startups who may have better capitalization? Could we compete against the so-called 800-lb gorilla who already has a position in the*

*market and is going to do everything they can to protect it? Can we run fast enough with enough quality to get product out?...And then, could we raise enough money to do what we needed to do? There was also the risk of hiring the right people.*<sup>39</sup>

## ***Employees in a Startup***

Successfully hiring and managing employees was one factor that entrepreneurs told us was critical to the success of their startup. Ranier Kunz, a founder of ColdQuanta, told us: "Being so small, it's not always easy attracting the right employees because it's risky."<sup>40</sup> Sally Hatcher of Precision Photonics asserted:

*Winning and retaining the best people is critical to a small business. Getting the right team on the bus...is really important, and you have to learn how to hire. You have to learn how to hire for more than just hard skills.... We need somebody who can solve practical problems, who can work with a team, who can learn to manage several people, who can grow into a product manager. You need to be able to hire, attract, and retain all of these soft skills, which you do not learn in grad school.*<sup>41</sup>

Flip Kromer of Infochimps asserted that it was critical to find "your early employees working for peanuts, your early partners letting you try something just because you can."<sup>42</sup> Alex Murokh of RadiaBeam declared that the responsibilities of hiring employees highlighted risks: "We have a responsibility to our employees, to our customers, to funding agencies."<sup>43</sup>

Most risks remain intangible with no easy solutions. Finding funding and managing cash flow requires a variety of models that we will discuss below, but the employee risk appears to have a common solution. First hires were almost always personal acquaintances of the founding team. John Carlisle of Advanced Diamond Technologies told us that he hired his postdoc as his first employee in 2004.<sup>44</sup> Pavilion Integration's Ningyi Luo told us that his first employee had worked for him at a previous company. "He's very accountable," Luo asserted. "Accountability was very critical."<sup>45</sup> Nick Economou, founder of Alis, told us the importance of employing people you knew in the early stages was critical.

*If you get somebody you know and you know his strengths and weaknesses—everybody's got weaknesses—then you can deal with that because you know what you're getting.... When you're a startup, you have to do pretty much everything yourself.... That's why I'd rather find somebody who I know and I know their strengths and weaknesses, and I know they understand what a small company is like.*<sup>46</sup>

Integrated Micro Sensors' Abdelhak Bensaoula recalled that many of his employees were graduates of the University of Houston where he taught, but there were others who came to work for the company and "moved on to other companies that are bigger and some companies that are very successful." These former employees created a "connection" with the larger firms.<sup>47</sup> Robert Black said that his only employee was a graduate student at North Carolina State University, where he was an adjunct professor.<sup>48</sup> John Ferraris, founder of Solarno, recalled, "We initially hired former students. Then we were able to hire an employee from NASA. They were closing down a particular group down there and we knew this person was experienced in an area similar to us."<sup>49</sup> Even at later stages many startups find employees

through their networks. Scott Davis of Vescent Photonics asserted that while they had done some hires through posts on Monster.com, they had done more “just from word of mouth from professors and other companies that I’m as happy with, and that’s quicker and costs us a lot less money....So it’s really through our professional and personal networks that we’ve gotten most of our employees.”<sup>50</sup>

At later stages of development most of the startups we interviewed moved toward more traditional hiring practices. Alexei Erchak of Luminus Devices described a fairly standard, but excruciatingly careful, process. “For executive staff,” he declared, “That’s a hired search process.”

*Whenever we want to bring in a new executive into the company it’s usually a six-month process or more. And, we go through a very rigorous hired search process. For regular, everyday recruiting we don’t use the more expensive recruiting, hired-gun services....Our HR team handles that.*<sup>51</sup>

As critical as hiring the right people, keeping them and forming a startup culture with them is just as important. Several founders described their employee relations as “socialistic,” meaning in part that employees are provided an opportunity to hold equity in the company in exchange for lower-than-market salaries. Most provided some form of equity, at least as an option, to their employees. Henry Kapteyn of Kapteyn-Murnane Laboratories told us: “Our first employee, she has some actual stock in it. There’s a stock option for the employees, but most of those haven’t been exercised.”<sup>52</sup> Dhruv Bansal of Infochimps represented a substantial portion of entrepreneurs when he asserted, “We absolutely offer equity to all our employees.”<sup>53</sup> Many had unique employee benefits, such as dog-friendly offices or family-friendly policies, that would be hard to find in the corporate world. Others used a variety of devices, similar to the paternalism that early twentieth century entrepreneurs developed to create company loyalty among their employees. Philip Wyatt of Wyatt Technology recalled:

*Whenever we had a profitable quarter, we elected to give bonuses. Accordingly, every quarter that the company is profitable, we bonus our employees on the basis of their contributions to that profitability. These bonuses can be significant and may amount to up to 50% of their base quarterly salary. At this moment, we’ve been profitable for 61 uninterrupted quarters!*<sup>54</sup>

Flip Kromer of Infochimps told us that his company began by providing everyone with a “free lunch.”<sup>55</sup> While his employees were paid less than the market and, in turn, received some equity in the company, they obtained much more than that. Kromer asserted:

*In the early days, when you are bootstrapping, you just can’t afford to pay people much. At first it was pretty much like, “How much do you need to pay to make rent? Okay, that’s your starting salary.” Right? Certainly, data scientists right now go for about \$200K a year starting salary on the West Coast. So what we actually did was actually found people who were...early on the path as programmers. We would recruit as early as the sophomore and freshman year of college.*<sup>56</sup>

His cofounder, Dhruv Bansal, concurred:

*There are also sort of softer benefits that we try to offer. Like I mentioned lunch earlier—that’s incredibly motivational. I don’t care how much money you make. If somebody takes care of lunch*

*for you every day, you're just indebted to that person....It goes back to the day of not being able to afford to pay people, but being able to afford deli sandwiches, and that kind of cultural motif is still alive today. Although now at this point lunch is the cost of an employee per year for us, but it is completely worth it.*<sup>57</sup>

Many founders expressed concern about providing health coverage for their employees on a small business budget. In discussing employee benefits, Philip Wyatt recalled, "When I worked in industry, the most important benefit I had was fully paid health insurance. It will always be that in our company."<sup>58</sup> Tracy Moor of Advanced Coherent Technologies recalled, "You get employees and you have to find a health insurance broker. It's tough."<sup>59</sup> Scott Davis spoke for many when he claimed:

*One of our biggest expenses is healthcare for our employees....Since we started doing business, the rate of our healthcare costs have gone up more than 100%, and that's just nuts. If that keeps going, I don't know what we're going to do.*<sup>60</sup>

Ron Reedy recalled that in the late 1980s when he formed the company, he asked a colleague to join him. "But before we got the company started he had a congenital heart problem show up and he couldn't afford to take the risk of losing his government health insurance. So he joined and we had to un-join him."<sup>61</sup>

Overall, the startups where we interviewed saw their employees as significant assets contributing to the success of their firms. While many were not yet at a stage where they could pay competitive wages, they sought to reward their employees with benefits and opportunities that would encourage loyalty to the company and provide some measure of entrepreneurial camaraderie. As a result, many received high marks from their employees. Wyatt Technology, for example, was ranked by *The Scientist* as the fourth-best company to work for. Six of *The Scientist's* top 10 companies were small businesses employing less than 200 people.

## **Location**

Figure 1 (page 2) portrays the geographic distribution of the companies we studied. We intentionally chose a distribution of companies on the West Coast, in the Midwest, on the East Coast, and in the South. We also sought out companies that are clustered around economic and technology development centers. With two exceptions, we did not interview companies isolated from such centers. Many of these technology development centers are associated with universities such as MIT/Harvard/Boston College, Purdue, University of Indiana, University of Illinois, University of Wisconsin, University of Texas-Austin, Stanford, University of Houston, University of Arizona, and Georgia Tech. Others were in focal points or clusters of technology development—Silicon Valley, Research Triangle Park, Route 128 in Boston, and to a lesser degree Indianapolis, which is a center for developing medical technologies.

Perhaps not surprisingly, 52 of the founders we interviewed said they started the company at the location they did because that's where they lived. "Well, I live here. It's kind of that simple," Nathan Myhrvold of

Intellectual Ventures said.<sup>62</sup> “It was just kind of an accident of where we were,” concurred Stefan Murry of Houston’s Applied Optoelectronics.”<sup>63</sup> Other respondents reflected similar perspectives.

Those startups spinning technologies out of universities cited the importance of remaining close to the universities and the ability to turn to them for assistance in developing the technologies. Thirty-two founders indicated that they had other work obligations, mostly at universities; 42 cited the importance of a university nearby that they could turn to for research resources and equipment. “We’d have to rely on our own laboratories here [at the university] and the resources here to...have the company purchase time on machines and purchase access at the university,” Solasta founder and Boston College professor Michael Naughton asserted. “For a tech startup like us, it’s the equipment that matters, the micro- and nanoscale instrumentation that costs millions, and no startup can afford to just go out and buy all that stuff. You have to buy access to it at universities.”<sup>64</sup> “We use a lot of the analytical facility at Boston College,” NanoLab’s David Carnahan told us, “so it’s good to be within five miles.”<sup>65</sup> Todd Ditmire at National Energetics recalled that “leveraging our ties with the University of Texas” was the “main motivation” for establishing the company in Austin.<sup>66</sup> John Ferraris of Solarno and a professor at the University of Texas-Dallas told us the company was located nearby “to be close to some of the facilities here, which we could avail ourselves of provided we paid fair use fees....We were able to write subcontracts to the university to utilize some of their facilities and also to support some of the research in the various research groups.”<sup>67</sup> Eric Buckland of Bioptigen in North Carolina asserted that “proximity to the origin of the technology was the first objective” in determining the company’s location.<sup>68</sup> “The interaction with the University [of Arizona] was very important to me,” asserted Nasser Peyghambarian, a founder of NP Photonics.<sup>69</sup> “The University [of Wisconsin, Madison] being close, of course, was a huge resource,” said Greg Piefer of Phoenix Nuclear Labs.<sup>70</sup>

Drawing on the physical resources of the university was not the only reason for maintaining startup locations in university towns. John Pacanovsky of Triangle Polymer Technologies asserted that one reason for locating in Research Triangle Park, North Carolina, was being “around so much of the intellectual capabilities of the universities.”<sup>71</sup> “When the question comes about can you get the talent you need, Austin is pretty good in that regard and there’s a university with 50,000 to 60,000 students here,” Graphene Energy’s Dileep Agnihotri declared.<sup>72</sup> “I didn’t have to really research that part,” Dhruv Bansal of Infochimps agreed:

*Austin is cheap, and there are 50,000 undergraduates a mile from here. There are guys who work for us right now who are just brilliant and we would be totally lost without them.... We get this amazing talent for way less than it deserves.*<sup>73</sup>

Nicholas Economou, the founder of Alis in Peabody, Massachusetts, also pointed to employee resources: “There are a lot of technologists with ion beam experience that live up here on the north shore.”<sup>74</sup> Luminus Devices founder Alexei Erchak agreed: “Got to be in an area like this [Greater Boston] to be able to recruit that kind of talent. And then fundraising. We are a couple of exits away from venture capital now.... You want to be a part of that network in order to have an effective fundraising strategy.”<sup>75</sup> Anita Goel of Nanobiosym near Boston pointed to “a high density of talent, and physics, bio, nano, and because we’re crossing all those disciplines we can synergize and collaborate with a lot of people. It’s good to be in an ecosystem where others are also sharing some of those [talents].”<sup>76</sup> Eric Buckland of Bioptigen in North

Carolina pointed to “proximity to the intellectual strength of the Research Triangle Park” as one of the important factors in locating there.<sup>77</sup> Christopher Myatt of Precision Photonics in Boulder asserted that “the most beneficial thing about being in Boulder is there’s a lot of technical talent here, particularly in the laser and optical detection and imaging and so forth.”<sup>78</sup>

Sixteen interviewees told us that location of other businesses in the community that supported their work made their location decisions more positive. Matt Kim of QuantTera selected Tempe, Arizona, because he “wanted to build an infrastructure of companies around me, and so I looked at who my friends were, where they were located. I knew where the airport was and where the university was. Once I knew that, I said this is where I’m going to locate.”<sup>79</sup> Startups in the middle of the United States emphasized their environment and lower costs. David Oakley of Boulder’s WAVi asserted, “We get top talent willing to work here for less because they love the environment. It’s a nice quality of life.”<sup>80</sup> Brad Larson of Wisconsin’s SonoPlot argued that one advantage of Wisconsin was the “low cost of real estate, [and] of living overall.”<sup>81</sup> Bill O’Brien of Wisconsin’s Mad City Labs agreed that he could “get things done less expensively here. This building is a lot less expensive than it would be in Silicon Valley [and] our employees have a better lifestyle out here. It’s not as hectic.”<sup>82</sup>

Only two companies told us that they had moved from out of state because the state had recruited them. Companion Diagnostics moved from Connecticut to Indianapolis to take advantage of medical research resources there. “We need access to clinical samples, because what you think and what you know are two different animals,” Richard Selinfreund of Companion Diagnostics told us. “Having access to the Center for Translational Medicine is everything, because he’s got a facility that can run 10,000 of those tests in 24 hours to validate our products. We’ve got to have that. We did not have that in the Northeast.” In addition, \$500,000 provided by the office of the governor of Indiana enabled the move.<sup>83</sup> InvivoSciences lacked similar resources and as a result were unable to locate in St. Louis where two of the three founders were faculty at Washington University. At that time, Ayla Annac, InvivoSciences CEO, told us none of the angel investors or government entities in St. Louis were “really eager to help startups.” On the other hand, “Wisconsin was much more well equipped, I think due to the UW and WARF [Wisconsin Alumni Research Foundation]. I have to give them huge credit.” WARF put InvivoSciences in contact with people who helped them write a viable license agreement with Washington University. And Governor Doyle had put together a variety of incentives, “funding and grants at the state level for startups.”<sup>84</sup> Finally, the number of related startups in the area drew InvivoSciences as well. “Wisconsin has more than 300 small startups all supported by WARF at the UW.” Tetsuro Wakatsuki, InvivoSciences’ cofounder, concurred. “We looked around at the environment, and actually we got some state funding....I found a position at the Medical College of Wisconsin....So those are two reasons why we moved here.”<sup>85</sup>

Other entrepreneurs specifically said that they resisted financial incentives to move. SonoPlot’s Brad Larson told us that he had rejected VC inducements to move from Middleton, Wisconsin, out to California. “The things about being in the Midwest that are great,” he asserted, “are low cost of real estate, of living overall, and for a business like ours, we’re selling internationally from right here in Middleton....There’s never been a better time for a small company like us to succeed outside of either coast than there is right now.”<sup>86</sup>

While only Companion Diagnostics and InvivoSciences moved from one state to another with the help of government incentives, we found that financial inducements sometimes influenced specific locations

within a state. For example, siXis founder Dan Stevenson told us, “There are a lot of office spaces in the area [near Houston] and the current market is a bit of a buyer’s market. So, there wasn’t any consideration to relocating the company to some other part of the country.”<sup>87</sup> “We looked around several different areas in the Houston vicinity...and Sugarland was growing very fast at that time,” Applied Optoelectronics’ Stefan Murry told us. “They had an aggressive package of financial incentives that they would give us if we located the company out here. So that was specifically why we moved to Sugarland.”<sup>88</sup>

Location became an increasingly important consideration as companies shifted from R&D to production and moved toward operational phases. Moving into production is a time when many companies set up subsidiaries or move abroad. Dileep Agnihotri of Advanced Hydro and Graphene Energy told us that he was struggling over whether to put his manufacturing operations in Taiwan or keep them in the United States:

*We are living in a global economy, a flat Earth now, and as a physicist I know the mechanism of entropy. It is irreversible....There is a lot of manufacturing that is not really sustained and supported in the country. That has been really bothering me, and it is irreversible now.*<sup>89</sup>

Professor Ren of GMZ Energy told us, “You can either do production here in the United States [or]...in other countries offshore. Like, in our case we are planning to found a production facility in China.” He said that factories could be readied for operation much faster in China than in the United States.<sup>90</sup> Kathryn Atchison of UCLA’s Intellectual Property and Industrial Relations Office told us that she was on the board of the Nanosystems Institute at Zhejiang University, and “China has been investing a lot of money in trying to develop their entrepreneurial culture over there.”<sup>91</sup>

## ***Funding the Startup***

Funding is one of the two most important challenges that entrepreneurs face, both in beginning startups and sustaining them over time. Robert Black, founder of CivaTech Oncology, declared that, “Whenever you go to a meeting of entrepreneurs, funding is the first and only topic that is discussed....and there are lots of answers to that.”<sup>92</sup> A popular mantra for funding startups begins with out-of-pocket funding, then turning to financial assistance from friends and family before turning to angel funding, and finally obtaining venture capital to grow the company successfully. Our interviews indicate that this model is overgeneralized and that there are no simple formulas for funding startups. It also ignores the important role played by federal Small Business Innovation Research and Small Technology Transfer Research grants, along with the impact that an erratic economy has had on investment sources over the past 20 years. Funding patterns have changed significantly over this time period in response to the national economy, as well as to changes in the nature of research and development.

Venture capital funding has shown the most dramatic changes since 1990. The interviewees at the nine startups in the study that were founded before 1990 were reluctant to take venture funding during their first years. However, venture capital became much more popular and more available during the boom years of the 1990s. Venture firms became significantly more conservative after the dot-com bust and stock market crash in 2000–2002 and the recession of 2008. They changed course most notably by

focusing on short-term startups—companies that could bring a successful product to market in five years or so—and avoiding high-risk technologies.

Thirty-five of the companies (38%) in the study obtained venture capital funds, but only a few entrepreneurs started out by using venture capital. At least 54 of the entrepreneurs (59%) invested substantial out-of-pocket funds in their startup, and for many this was a critical component. An equal number, 54, turned to federal SBIR or STTR grants, totaling more than \$154 million dollars, either to begin their startup or to sustain it until their product revenues reached a self-sustaining level. Many of those turning to SBIR/STTR funding also obtained other government grants, though those grants were sufficiently diverse that we have not detailed them here.

Entrepreneurs turned to SBIR/STTR programs to implement a variety of strategies. Some actually began the company drawing on SBIR/STTR funds. Others used SBIR/STTR grants as their primary revenue stream, while still others used SBIR/STTR grants for higher risk product development. Thirty-five entrepreneurs told us they had obtained other government grants either as follow-on grants to their SBIR/STTR grants or independent from them. Other investors, including friends and family, angel investors, venture capitalists, and grant makers, are more likely to invest if the entrepreneur has “skin in the game.” Even those who did not put financial resources into their startup often invested their time and other resources without direct remuneration. Serial entrepreneurs would frequently invest in their next startup some of the funds from a successful exit from a previous company. Entrepreneurs also told us that they most trusted successful entrepreneurs, whether they were acting now as angel investors or venture capitalists, because they “understood the technology” and were, as a result, less likely to pull the plug on the startup prematurely. Of the 35 entrepreneurs that turned to venture capital, 21 had also successfully applied for SBIR/STTR grants.

### ***The Growth of SBIR/STTR Programs***

The federal SBIR program was created in 1982, and with its companion STTR program created 10 years later, it has become a very important source of funding for physics startups. It grew out of a prototype program begun at the National Science Foundation (NSF) and had been tested in the Department of Defense (DOD) beginning in 1978.<sup>93</sup> The 1982 Small Business Innovation Development Act set aside 0.20 percent (about \$45 million) of the external research budget for government agencies with external research programs of greater than \$100 million.<sup>94</sup> Between 1987 and 1992 the percentage set aside to fund the SBIR program increased to 1.25 percent, growing to 1.5 percent for 1993–1994 and 2.0 percent in 1995–1996.<sup>95</sup> After 1997 until the current reauthorization, the SBIR program was funded at 2.5 percent of government agencies with R&D budgets greater than \$100 million.

Currently 11 government agencies—the Departments of Agriculture, Defense, Education, Energy, Health and Human Services, Homeland Security, and Transportation, as well as the National Oceanic and Atmospheric Administration, National Institute of Standards and Technology, Environmental Protection Agency, National Aeronautics and Space Administration, and National Science Foundation—participate in the SBIR program, currently using 2.6 percent of their R&D budgets to fund small business proposals. Currently phase I SBIR awards normally do not exceed \$150,000 total costs and phase II awards normally do not exceed \$1,000,000 total costs.<sup>96</sup>

In 1992 Congress created a second pilot program, the STTR program, with the Small Business Technology Transfer Act, which required government agencies with R&D budgets of more than \$1 billion to set aside 0.15 percent of their budget for an STTR program.<sup>97</sup> STTR funds were first awarded in 1995, but not regularly until 1998, and have been continued since. The current program was reauthorized through 2017 by the 2012 Defense Authorization Act. Currently the Departments of Defense, Energy, Health and Human Services, as well as NASA and the National Science Foundation participate in the STTR program.<sup>98</sup>

Under the Small Business Technology Transfer Program Reauthorization Act of 2001, federal agencies with R&D budgets greater than \$1 billion were required to set aside 0.05 percent of their R&D budget in 1994, 0.10 percent in 1995, and 0.15 percent in 1996, and the amount has been increased incrementally since 2004 to fund technology transfer between research institutions such as universities or national laboratories and small businesses. Under the Small Business Technology Transfer Program Reauthorization Act of 2001, the five agencies participating in the program set aside 0.15 percent of the extramural R&D budget through 2003, increasing the amount to 0.3 percent from 2004 through 2009. Between 2009 and 2011 that amount was maintained by continuing resolutions. Currently they are required to set aside 0.35 percent.<sup>99</sup> STTR awards for a phase I project are about 40 percent higher than for the SBIR phase I. At least 30 percent of the STTR funding must go to the research institution, and the phase I award provides about twice the performance time of a phase I SBIR award. Phase II awards are lower than SBIR phase II. Currently phase I STTR projects receive up to \$150,000 for one year and phase II awards grant up to \$750,000 for two years.<sup>100</sup>

The SBIR and STTR programs have a few significant differences beyond the relative size of funds. The SBIR program requires the principal investigator to be primarily employed (at least 51 percent of their time) by the small business receiving the funds, while the STTR program has no employment stipulations. The SBIR program funds research at small businesses. The small business is encouraged, but not required, to collaborate with a university or other nonprofit research institution. Under the STTR program a formal collaborative relationship must exist between the small business and a research institution. At least 40 percent of the STTR research project must be conducted at the business, while at least 30 percent of it must be conducted by a single “partnering” research institution.<sup>101</sup> Finally, while 11 government agencies participate in the SBIR program, only five participate in the STTR program. Each agency runs its own program and sets separate schedules for award applications.<sup>102</sup>

Companies with no more than 500 employees, organized for profit with a place of business and operations primarily in the United States, may apply for SBIR grants. The businesses, no matter the form they take, must be at least 51 percent owned by American citizens or permanent residents. Where the company takes the form of a joint venture, no more than 49 percent of the joint venture can be held by foreign institutions.<sup>103</sup>

Until the most recent reauthorization, firms that were owned more than 50 percent by venture capital were not eligible for SBIR/STTR funding since the authorization acts specified that firms must be at least 51 percent owned by individuals. Under the National Defense Authorization Act for 2012, firms majority-owned by multiple venture capital firms became eligible for some SBIR grants. The National Institutes of Health (NIH), Department of Energy (DOE), and National Science Foundation (NSF) were authorized to award up to 25 percent of their funds to venture-capital-funded firms. The remaining participating

agencies could award no more than 15 percent of their SBIR funds to such companies. Congress also specified that a venture capital company's portfolio counts as affiliates if the VC holds majority equity and thus counts as to whether or not the firm qualifies as a "small business." The current legislation does not address whether or not VC firms with more than 500 employees qualify, nor does it address the role of foreign-funded VC firms.<sup>104</sup>

## ***State Grant Programs***

In addition to the federal SBIR/STTR funding programs, a variety of state programs are linked to SBIR funding. Most states have a variety of supplemental programs to support companies applying for or receiving SBIR/STTR funding. Some of these programs are temporary in nature and others appear to have either lost funding or been eliminated as states grappled with declining budgets. We summarize the best available current information on state grant programs in Appendix II.

### ***Phase 0 Grants***

At least 27 states provided funding, ranging from \$1,000 to around \$7,500, to help startups apply for SBIR/STTR funding when we began the study in 2009. Phase 0 programs provide funding to prepare and professionally review SBIR/STTR proposals. They are typically granted by states that claim they are not receiving their fair share of SBIR/STTR grants and hope that assistance provided to write improved grant proposals will result in increased funding. Most, but not all, describe these grants in aid as "phase 0 grants." A few also provide "phase 00" grants to support applications for phase II funding. Many of these state programs are partially funded by matching grants from the Small Business Administration's Federal and State Technology Partnership (FAST) program.

### ***Matching Grants***

In addition to phase 0 programs, 21 states had some form of matching grants that are automatically given upon application by startups that have received SBIR phase I grants when we began the study. Funding for these programs has been limited, and several states either failed to fund the programs or provided only limited funding. The current programs are documented in Appendix II. Most states have a cap on total matching grant funding that appears to be provided on a first-applied, first-granted basis, and funds often run out fairly quickly. Kentucky appears to be the most aggressive in its use of matching grants, providing them even to companies outside of the state, provided that they move to Kentucky within 90 days of receiving the award. Finally, Virginia recently passed a bill providing \$2 million for phase I award winners.<sup>105</sup>

Among the states where we interviewed, Colorado, Texas, North Carolina, Illinois, Oregon, Indiana, and Illinois had, at least for a time, some form of matching grant program. The companies we interviewed in Oregon had not turned to SBIR grants and so could not have availed themselves of matching grants. Colorado passed its matching grant program in 2007, but again, none of the companies where we interviewed mentioned it. Two companies where we interviewed in Texas told us that Texas's Emerging Technology Fund played a critical role in their startup phase.<sup>106</sup> Peter Yancey told us that North Carolina's matching program allowed him to do a lot more than he would otherwise have been able to do with the SBIR funds, thereby increasing his chances for obtaining a phase II award.

However, North Carolina did not fund its One North Carolina matching grant program in 2012.<sup>107</sup> Similarly, Indiana's 21st Century Fund has reduced support and no longer provides matching grants to SBIR-funded companies.<sup>108</sup>

### ***Bridge Grants***

Several states have "bridge grants," sometimes labeled as "matching grants," to enable companies to survive between the completion of SBIR phase I funding and the start of phase II funding. Kentucky has provided SBIR bridge grants since 1988.<sup>109</sup> Alaska has funded up to \$10,000 in grants to firms with phase I or II awards since 2002. Oklahoma has provided up to 50 percent of the phase I or \$25,000 to companies that have completed the first phase and applied for phase II. Delaware businesses that receive phase I support are eligible for a bridge grant of up to \$50,000 if they submit a phase II proposal. North Carolina provides a bridge loan to companies that have been awarded but have not yet received a phase II grant.<sup>110</sup> Again, we describe the available information on current bridge grant programs in Appendix II.

### ***Collaboration Funds***

Separate from but certainly applicable to STTR grants, a few states provide grants to companies working with the state's universities. Like the above programs, these are described in Appendix II.

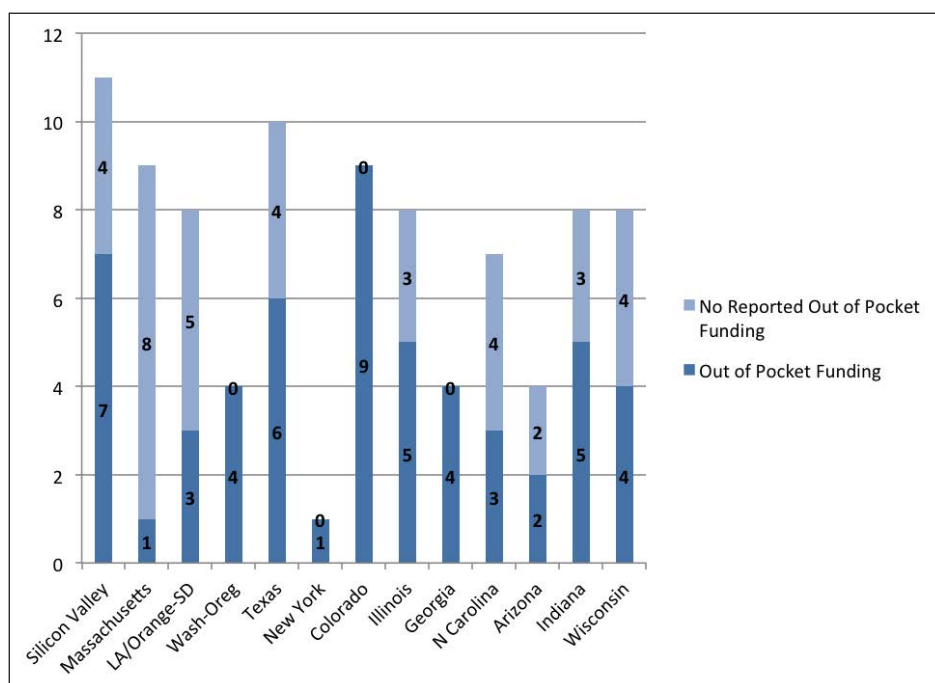
## ***Business Funding Models***

The 91 startups in our sample found answers to funding in some mix of the following five models: bootstrap, federal or state government grants, angel funding, combination bootstrap/SBIR, and venture funding. Interviewees described weaknesses and strengths in each.

### ***Bootstrap***

Only 10 startups in the study created their businesses without use of any external resources. Of those 10, seven were one- or two-person firms that were limited to consulting or contracted services. The remaining three, plus two others that had received SBIR funding only briefly, had almost immediately placed high-tech components or systems on the market to fill an existing market demand. Generally these companies did not create a new technology but felt they could build a better or cheaper product. In some cases they took components that they had been constructing in earlier academic lines of work and brought them to the commercial market. These were not all "new" technologies, and the technology that was transferred was the skill in making the products rather than intellectual property. In other cases they licensed intellectual property they created in their academic research to commercialize the instrumentation.

If any research is done in these companies, it is funded out of product sales or it is contract research paid for by a customer. Many, but certainly not all, founders who use a pure bootstrap model appear not to be truly entrepreneurial, instead creating what might be described as "lifestyle" companies—companies that provide jobs for the founders in a region or environment they find desirable. The purpose of the company is to employ the founders rather than to create a company with value beyond that employment. Not all companies relying on substantial out-of-pocket funding remained bootstrap companies.



**Figure 11.** Companies employing substantial out-of-pocket funding (by region).

As Figure 11 shows, there were significant variations by region in reliance on out-of-pocket funding. Massachusetts, more than any other region, avoided personal funds in the startup of their companies, while the startups we interviewed in the Pacific Northwest and in Colorado almost universally included a substantial out-of-pocket component in funding their companies. The surprisingly large component of out-of-pocket funding in Silicon Valley resulted in part from the slower growth model and the early-stage research many of the companies employed that meant they could not obtain venture capital funding. For some reason, venture capital appeared less reluctant to fund early-stage research in Massachusetts than in Silicon Valley, though interviews suggest that at least in one case the reliance on venture capital funds played a significant role in the demise of the company after VCs declined further funding.

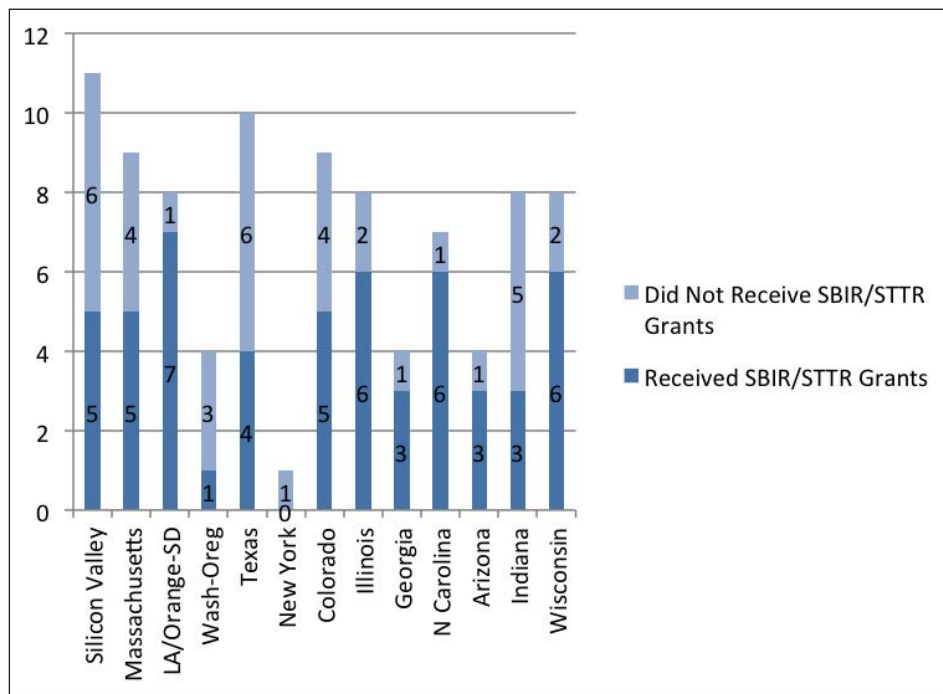
### **SBIR/STTR Companies**

Fifty-four of the startups in the study turned at some point to SBIR/STTR grants to help fund their company. While the startups had drawn funds from 10 SBIR granting agencies and all five STTR programs, Table 2 and Figure 14 show that the Department of Defense dominated the program, providing some 42 percent of the SBIR/STTR funds.

A surprising number of startups described the SBIR/STTR programs as essential to the development of their technologies, especially after venture capital began to decrease funding for research and development in the past decade. Early users of SBIR funding generally took one or two grants prior to marketing a product. More recently, even VC-funded companies have turned to SBIR/STTR grants for longer periods as they wait for their markets to grow. Companies relying on slower growth patterns also appear to be receiving larger sums for longer periods. Many, particularly those companies begun after the 2001–2002 telecom bust, described SBIR grants as the quintessential seed funding for startups today. Matt Kim of QuantTera, for example, asserted: “The seed funding, the SBIR funding that the United States government does for us, is what I consider now the startup fund for small businesses. That’s where you have to go.”<sup>111</sup>

Agency	No. of Companies	SBIR I No. of Grants	SBIR I Amount	SBIR II No. of Grants	SBIR II Amount	STTR I No. of Grants	STTR I Amount	STTR II No. of Grants	STTR II Amount	Total No. of Grants	Total
DHS	2	3	\$450,000	2	\$2,249,044	0	\$0	0	\$0	5	\$2,699,044
DOC	6	10	\$624,878	6	\$1,798,803	0	\$0	0	\$0	16	\$2,423,681
DOD	31	151	\$12,054,418	59	\$39,949,955	36	\$3,268,487	15	\$9,546,496	261	\$64,819,356
DOE	19	56	\$5,540,402	23	\$17,532,863	24	\$2,348,898	12	\$8,699,999	115	\$34,122,162
DOT	1	2	\$99,998	1	\$293,997	0	\$0	0	\$0	3	\$393,995
EPA	2	2	\$139,997	0	\$0	0	\$0	0	\$0	2	\$139,997
HHS	20	41	\$7,921,667	14	\$19,652,126	2	\$191,488	1	\$725,068	58	\$28,490,349
NASA	9	24	\$1,996,323	11	\$6,477,442	1	\$100,000	0	\$0	36	\$8,573,765
NSF	20	52	\$528,111	13	\$5,667,940	6	\$899,962	1	\$499,739	72	\$7,595,752
USDA	1	2	\$104,817	1	\$225,000	0	\$0	0	\$0	3	\$329,817

**Table 2.** SBIR/STTR grants to startups in study.



**Figure 12.** Proportion of SBIR-funded companies (by region).

SBIR grants were regionally diverse, as can be seen in Table 3, which shows cumulative grant amounts received by all companies in each region. Figure 15, however, points out the regional diversity in the proportion of firms in the study relying on SBIR grants. As Table 3 shows, the startups in our study in Southern California and North Carolina relied heavily on SBIR grants, followed closely by Georgia, Illinois, Wisconsin, and Arizona. While only slightly more than half of the companies we interviewed in Colorado and Illinois had turned to SBIR funding, they appeared to draw a higher average amount of SBIR funding per company.

Region	Total amount in grants	Companies receiving grants (total companies interviewed in the region)
Southern California	\$33.8M	7 (8)
Illinois	\$30.1M	5 (8)
Colorado	\$25.2M	5 (9)
Arizona	\$17.7M	3 (4)
Silicon Valley & SF Bay Area	\$15.6M	5 (11)
Texas	\$10.4M	4 (10)
Research Triangle, NC	\$8.8M	6 (7)
Boston Area	\$7.8M	5 (9)
Wisconsin	\$6M	6 (8)
Atlanta Area	\$4.5M	3 (4)
Indiana	\$2.4M	3 (8)
Pacific Northwest	\$300,000	1 (4)

**Table 3.** Cumulative grant amounts received by companies (in region).

The smallest grant total to a single company was \$94,000, while the recipient receiving the most SBIR/STTR funds obtained a total of just over \$15 million. The median company received \$1.15 million, while the average was \$3.124 million. Figure 16 shows how many companies are in each of seven grant-amount categories. Figure 17 shows the proportion of the total SBIR/STTR funds granted by each agency between 1983 and 2011, while Figure 18 shows the proportion of funds given to the companies in our study by each granting agency.

Companies relying on SBIR grants faced different risks than those funded by venture capital. If a company needed SBIR funding, it was often required to spread its R&D focus in directions away from the firm's primary market goal to concentrate on the priorities of the funding agency. Salime Boucher, a cofounder of RadiaBeam, asserted, "The main problem with the SBIR program is you just get pulled in so many different directions....You can't have a focus on one technology. It requires you to be spread out, maybe spread too thin."<sup>112</sup> Anita Goel, founder of Nanobiosym, agreed:

*I think you have to just be careful because different government agencies and different programs have different deliverables associated with them, they have different milestones, and as a young organization you want to make sure that your, that those agendas are aligned with yours because you don't want to be going in 10 directions. You want to be going in one. So, you have to make sure that you find those that are a good match and they share the goal that you're trying to get to.<sup>113</sup>*

Eric Buckland, cofounder of Bioptigen, recalled that while he initially was not "a fan of the SBIR approach," it turned out to be "critical to our product development. There's a reputation for becoming an SBIR mill, where you're just focused on grants, and it's kind of a way for somebody who doesn't want to be in academia to do academic research."<sup>114</sup> Richard Czerw of NanoTechLabs agreed that it was a struggle to move from SBIR grants to commercialization. "I think we did an okay job on the SBIRs," he told us, "but we had no idea how to commercialize. I came out of the university, and I pretty much ran the SBIRs as I would a university program, which is not the best way to do it. It takes a while to learn what you need to do."<sup>115</sup>

Sometimes SBIRs became an easy money source. John Cameron, who cofounded PartTec, told us, "We kept bringing in more people and getting new SBIRs, and it wasn't until this neutron one...that we moved into the manufacturing side."<sup>116</sup> John Criscione pointed out a problem with the SBIR program: "I feel like there's no money, private equity money, for the proof of concept because they expect you to go to SBIR. So it's not like it's made more companies; it's just made the private equity move" away from early-stage development.<sup>117</sup> In fact, however, other factors have played a larger role in venture capital moving away from funding proof-of-concept stage companies. Both the federal government (through SBIR/STTR programs) and venture capital invested in early-stage companies throughout the 1990s. However, venture firms moved to later-stage investments after the telecom crash around 2001, which resulted in major losses by many venture firms.

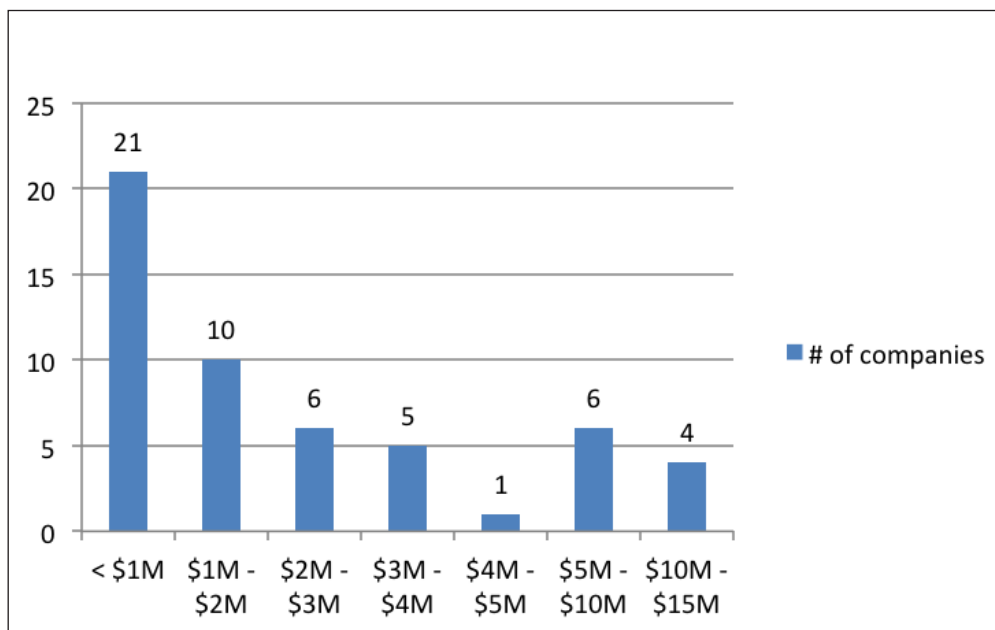
Micki Downey, head of NP Photonics, asserted "SBIR contracts from a business perspective are not strategic, but they are clearly tactical."<sup>118</sup> Scott Davis of Vescent Photonics pointed out that unlike venture-financed firms focusing on a market, "If you're writing an SBIR your customer is the program manager at this government lab, and they have a scientific or technical need, and so you're convincing them that you can solve that need."<sup>119</sup> Gang Chen, founder of GMZ Energy, chose to avoid SBIR grants and turn to

venture capital primarily because, he asserted, SBIR grants take companies away from the commercial market. “We’ve seen a lot of SBIR companies been doing SBIR their whole lifetime,” but he told us that they remain small. Instead he wanted his company to become a large, thriving business. While he would work with the government when opportunities arose, his company would focus on its own products and technology.<sup>120</sup> Jason Cleveland, cofounder of Asylum Research, agreed. “One thing we never did was chase grant revenue,” he asserted.

*Early on I actually decided that was a little dangerous because I’d seen some other scientists start companies, and I think you often do what is comfortable to you, and as a scientist coming out of academia you know about raising money from grants. . . . You can fall into the trap, I think, of being a company that’s only that. . . .*

*As soon as we started shipping our first product, there were suddenly all these aspects to the business that I realized I knew nothing about: shipping, customs in foreign countries, customer support, all this stuff. So I think it was important to us to start making a product and realize all these other things that you suddenly had to do. So yeah, very focused on making our money by making things rather than other ways.<sup>121</sup>*

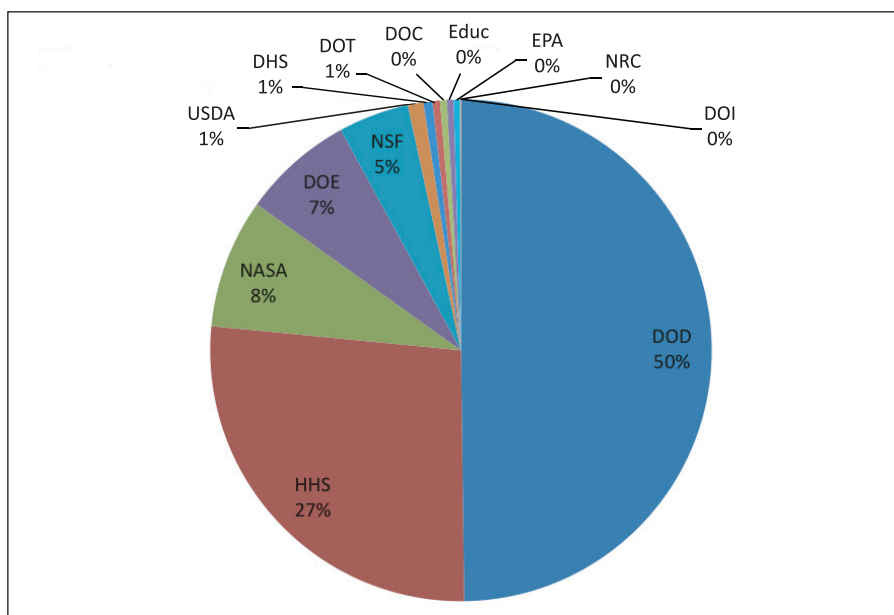
As Figure 13 shows, the vast majority of startups in our study took relatively small amounts of SBIR funding to develop and commercialize products—21 took less than \$1 million by the time we interviewed them; another 10 received between \$1 million and \$2 million; and only four firms had collected upwards of \$10 million. Even in these cases, most were developing multiple products or highly technical components of sophisticated systems, though a few may have been relying on SBIR programs to sustain their efforts until viable markets opened.



**Figure 13.** Number of companies receiving grant amount.

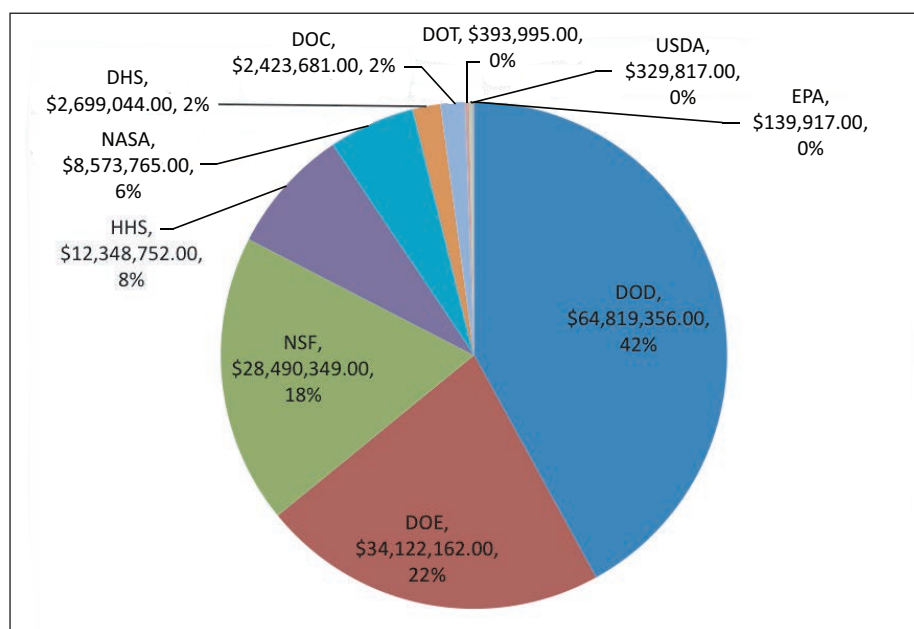
Finally, while many praised the small grants as critical to the development of their companies and permitting them to maintain control of the company that they would have lost had they turned to venture capital, at least two founders thought the SBIR programs were too risky. Richard Selinfreund, founder of Companion Diagnostics, asserted, “I can go get an SBIR for \$100,000, or I can go get a client in a week for a million.” Selinfreund maintained:

[The client would be] faster, a lot quieter, it’s easier to lock down my secrets....My worst fear with an SBIR is to build something that people won’t buy, so the nice thing about working with a client is you know, at the end of the day when you’re done building it, you get an order. Because nobody at a company these days funds million-dollar projects without their company wanting the end product.<sup>122</sup>



**Figure 14.** *Proportion of total SBIR/STTR funds distributed 1983–2011 (by agency).*

While the Department of Defense dominated both the general SBIR/STTR programs and the funding of the companies in our study in terms of numbers, it provided a proportionately smaller amount to the companies where we interviewed as did the Department of Health and Human Services. (Compare Figures 14 and 15.) On the other hand, the National Science Foundation and Department of Energy provided a proportionately larger component to the physicist entrepreneurs in our study. “The DOE SBIR managers have a somewhat different perspective than most of the other offices that have SBIRs within the government,” Thomas Roberts of Muons, Inc. asserted “The DOE is willing to issue SBIR grants to work on research projects that are parallel to their program or contribute to their overall program. Most other organizations only issue SBIRs for people who are developing hardware or equipment to do specific things...whereas the DOE was willing to do research.”<sup>123</sup> On the other hand, Rod Loewen of Lyncean Technologies told us that the NIH was “more flexible in their funding” than the Department of Energy.<sup>124</sup> While NASA’s general funding and funding to the companies in our study were comparable, the Department of Homeland Security, though still proportionately small, provided nearly twice as much to the entrepreneurs we interviewed than it did to all companies in the SBIR/STTR program. Even the amount of funding varied from agency to agency. Sally Hatcher told us that phase II grants at the Department of Commerce, were “only \$300,000, but the DOD, it can run \$750,000 to \$1 million.”<sup>125</sup>



**Figure 15.** Proportion of total SBIR/STTR funds to companies in study (by agency).

Our interviewees indicated that there was great disparity in the processes for getting SBIR/STTR funds at various government agencies. STTR funds, which require collaboration with a university or national lab, tend to be more “research” oriented, while SBIR grants varied substantially in the degree to which they funded research or development.<sup>126</sup> Abdelhak Bensaoula asserted that the success rate of STTRs is much lower and they’re more complicated to write because you have to demonstrate the innovation transfer from the university to the company. With SBIRs, on the other hand, “you’re just kind of free—the innovation can come from the university, it can come from yourself, it can come from anybody anywhere else. You write it, if it is innovative, you get it funded.”<sup>127</sup>

Scott Davis of Vescent Photonics told us that the National Science Foundation review was “similar to how an academic paper is reviewed. They have a panel that gives you a score, and the high score gets funds.” Other agencies—he mentioned the National Institute of Standards and Technology (NIST) and the Environmental Protection Agency (EPA)—had “kind of a peer review process. These were smaller grants, but they were a level playing field, I guess, in the sense that it’s open peer review.”<sup>128</sup> John Carlisle of Advanced Diamond Technologies told us that the NSF supports a lot of professor–student collaborations and that students “really are babes in the woods. They come and they have no idea what a business plan is, industrial collaboration, product development—that whole thing is completely new.”<sup>129</sup>

Davis contrasted those programs with the Department of Defense. “Their SBIR program is less of an open playing field,” he told us. “A lot of times it’s not peer review, it’s just the single program manager who gets to decide what goes and what doesn’t, and for better or worse, that program manager tends to direct funds towards companies” that he knows. He added that his company didn’t have a chance to win awards until they met the program managers and got to know them and the overall program objectives. Then they began to win some awards.<sup>130</sup> Michael Anderson of Vescent Photonics agreed. With Department of Defense grants, he told us, “it kind of came down to one person, and he liked the proposals and started funding us.”<sup>131</sup>

Others assessed the DOD SBIR program differently. Abdelhak Bensaoula of Integrated Micro Sensors asserted:

*DOD has a very focused program. They almost tell you what they want. They even give you the weight and dimensions. So they are very, very focused. We have some SBIRs from NASA, which is much more difficult to work with, and some with DOE, but by far DOD SBIRs are, I would say, the best managed.*<sup>132</sup>

Some companies focused on creating new technologies and intellectual property; the technology and/or intellectual property itself was the product. They hoped either to spin out companies to produce commercially viable technologies or to sell or license the intellectual property (IP) to existing companies capable of bringing a product to the market. Often these companies relied on SBIR/STTR funding until such a time as their portfolio of SBIR/STTR-funded technologies was sufficient to sustain the company.

Thomas Roberts, a vice president at Muons, Inc., told us that the company was created in order to get SBIR grants to fund their research. The company was supported, he told us,

*with SBIR, STTR grants from the Department of Energy, and we work with a research institutional partner on most of those.... Right from the start in 2002, Muons, Inc. has had research programs with Fermilab. This means the grant comes to Muons, Inc. and Muons, Inc. pays Fermilab to assist in the research.*<sup>133</sup>

Others who viewed their forte as research chose an endgame strategy where they hoped to be acquired by a firm capable of handling those aspects of the business they felt they lacked. They understand that they need to bring IP to the market at the end, but their interest is in the research, not transforming that IP into a product to be tested in the marketplace. Although they hadn't received many SBIR grants, Reyad Sawafta, who founded QuarTek, said, "That's money that will allow us to take some of our ideas and take them to a proof of concept or bring the product to a stage where maybe it becomes more attractive for somebody to come and sponsor it beyond the SBIR stage." QuarTek would remain a research company, either spinning out profitable technologies for other companies or licensing their intellectual property rights to client firms.<sup>134</sup>

Rory Moore, a founder and angel investor in Peregrine Semiconductor, told us that angels provided funding for about the first six years of his firm. They specifically stayed away from SBIR funding because, "We thought there would be too many strings attached to that, reporting requirements, and we needed to move, we thought, faster than that. We wanted to get a commercial status soon."<sup>135</sup> Some companies, Ron Ruth, founder of Lyncean Technologies, asserted, "have 30 or 40 SBIRs going on at the same time. I have a problem with that. I don't think that was the original intention of the program."<sup>136</sup>

Others that did turn to SBIR funding agreed that it could become a trap. "To my mind, the more SBIR work you do the more likely we'll be continuing to do SBIR work," Gil Travish, a founder of RadiaBeam told us. Falling into the SBIR trap created a different set of risks. Originally, Travish asserted, "The goal there was to pursue, to really go after a high growth market and make something pretty revolutionary, if you will, and make, hopefully, a lot of money in the process." But as product development took longer

than expected, some founders who rely on the business for their bread and butter came to see SBIRs as “a source of income, and did not want to take the kind of risks that are associated with high growth companies. That would jeopardize their livelihood. And so, there was clearly a schism that formed between those that were on the payroll, if you will, of the business, and those of us who wanted to see big profits.”<sup>137</sup>

Fear of falling into what some described as the SBIR trap led many to avoid SBIR funding. Gang Chen, a founder of GMZ Energy, said, “We do not want to go the government route, meaning particularly, SBIR type....We want to grow our company into a large-size company...[and] thrive with our own products and with our own technology.”<sup>138</sup> Startups that develop a reputation for relying on SBIRs often limit their access to other funds, particularly venture capital. Carl Gulbrandsen, managing director of the Wisconsin Alumni Research Foundation, rumored to have about \$2 billion dollars under investment,<sup>139</sup> told us:

*We have a number of companies [in Wisconsin] that we call lifestyle companies that work from one SBIR to the next, and they get federal grants, but they're never going to sell a product. I don't think that's the company we'd invest in. They pay taxes and they pay employees, but it doesn't get the product out the door.”<sup>140</sup>*

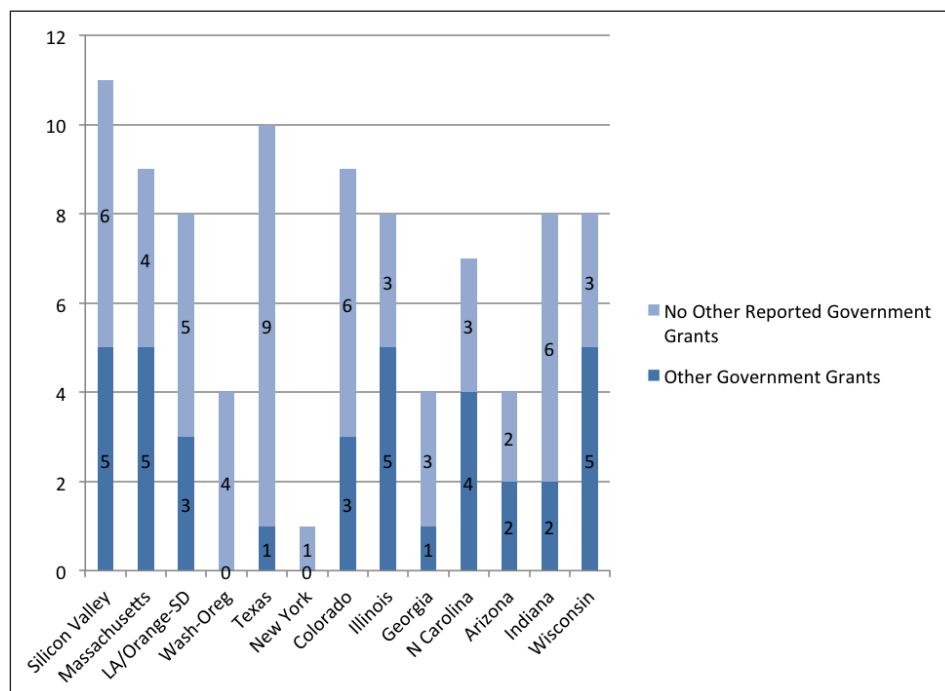
While SBIR companies focus on doing research for government agencies and see those agencies as their customers and their research as their product, other high-tech startups turn to the SBIR/STTR program for one or more of three reasons. Some startups see the SBIR program as the primary seed funding source. Often these startups are moving technology out of academic research. The founders are professors and/or their students and they are familiar with the grant writing process. Others, while they did not turn to SBIR programs to start the company, use SBIR funding to develop high-risk technologies they could not afford to develop internally. “We don't request grant funds just to do contract R&D,” asserted Neil Kane, president of Advanced Diamond Technologies, in testimony to the US House of Representatives' Subcommittee on Research and Science Education, Committee on Science and Technology Hearing: “All of the grant proposals we have written have been targeted toward doing the translational work necessary to convert great science into great products.”<sup>141</sup>

A third approach to SBIR funding uses the funds to develop intellectual property which they then market to firms that can bring the technologies to the marketplace. Quantum Magnetics appears to be one example of this approach. It operated largely as the R&D division of Quantum Design and drew nearly \$15 million in SBIR grants over a seven-year period.<sup>142</sup> Reyad Sawafta of QuarTek began with private funding but then turned to SBIR programs to develop technologies as well as to “private and public companies if they could provide you with funding for an idea,” Sawafta told us. “Our philosophy is to develop technology and find partners who are leaders in that field and team up with them.”<sup>143</sup>

### ***Other Federal or State Government Grants***

In order to help fund or maintain a revenue stream for their startups, 36 of the startups told us of federal government grants beyond the SBIR/STTR programs that they utilized. Medical device companies frequently obtain grants from the NIH. Other firms often obtain NIST or Defense Advanced Research Projects Agency (DARPA) grants, while still others receive either follow-on grants supporting develop-

ment after SBIR grants or separate from them to conduct research for various defense agencies. As Figure 16 shows, utilization of government grants beyond the SBIR program was fairly diverse and the regional variations are probably dependent upon the variations in the companies participating in our study. Some told us about Broad Agency Announcements which provide substantial funds for R&D. Other government grants range from SBIR phase I sized grants to grants bringing in millions of dollars. Richard Czerw of NanoTechLabs, for example, told us that the about \$3.8 million he had received in SBIR/STTR grants provided less than 50 percent of the government grants NanoTechLabs had received.<sup>144</sup>

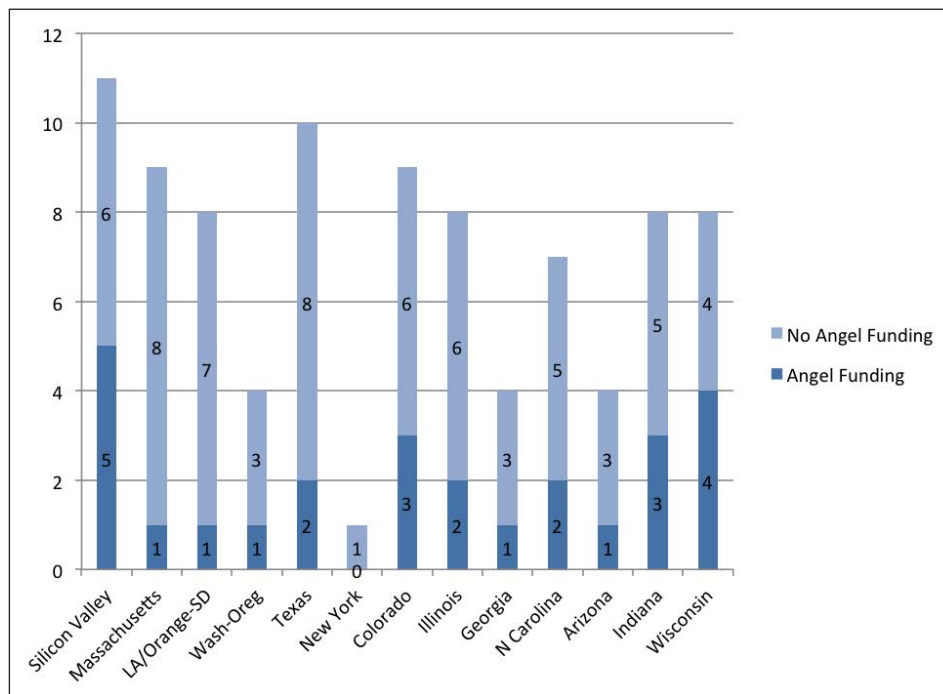


**Figure 16.** Companies receiving other government grants (by region).

While most interviewees praised the various government grants, criticism of the grant process reflected the points critics made regarding the SBIR program. Lindsay Austin of Pavilion Integration, for example, asserted, “I’ve discouraged going after government grants because there’s a lot of paperwork. If we were starving for business we might consider it, but I think it’s not necessarily a good thing.”<sup>145</sup> Overall, government grants beyond the SBIR/STTR programs serve similar purposes to those programs in the strategies of the companies we interviewed.

### **Angel Funding**

Entrepreneurs’ attitudes about angel funders varied strongly. As shown in Figure 17, at least 25 of the startups we interviewed relied on angel funding for a portion of their development. Given the high concentration of venture firms in the area, it’s surprising that companies in Silicon Valley appeared more likely to turn to angel sources of funding than did other regions in our study. Regions where founders turned heavily to SBIR/STTR funding, such as Southern California, were less likely to depend on angels. As we noted elsewhere, Massachusetts venture capitalists tended to take on angel characteristics in terms of willingness to make longer-term investments, making angels less important to startups there. But angels played roles in each region we studied.



**Figure 17.** Angel funding of companies in study (by region).

Some founders sought to avoid using angels, seeing them, as Stefan Murry of Applied Optoelectronics described them, as “a subset of venture capital.”<sup>146</sup> Maha Achour, one of the founders of Rayspan, told us, “When you bring an angel investor at the beginning of the venture when you have nothing, you have to give up a lot of equity.”<sup>147</sup> Dileep Agnihotri, a founder of Advanced Hydro, asserted that angel funders would require too much control. Since he was dealing “with the forefront of the technology,” it would take “a team and you need a long seven years of effort to really tweak it into a product. That,” he said, “will not work with angel funding.”<sup>148</sup> Tony Moretti of Vega Wave Systems told us that Vega Wave had turned its back on angels because “we do not want to give control of the company up....The reason why company control is important is that we know the technology and we don’t want to just package it to look nice and sell it and that is what most of the VC [and angel] community does.”<sup>149</sup> While not ruling out angel investors, Michael Anderson, founder of Vescent Photonics, asserted, “everything depends on the person you get connected to.”<sup>150</sup> Abdelhak Bensaoula, founder of Integrated Micro Sensors, agreed. “We’ve tried the angel and the venture [thing], and it is much harder—they want the company....We want to add a little bit to its value before we let it go.”<sup>151</sup>

On the other hand, some of the people we interviewed saw significant differences between angels and venture capitalists. David Nolte of Quadraspec told us that there was a “HUGE difference” between angels and venture capitalists. “It’s all in the dilution,” he said. Unlike venture capital firms, each angel is acting as an individual and typically contributing a smaller portion of the funding: “Each individual lacks the leverage to dilute down the originator’s share. So the angels are a really good source of money,” he asserted.<sup>152</sup> Somesh Jha, cofounder of NovaShield, told us, “We have a very strong preference for angel investing” instead of venture funding “because venture capitalists want a quick exit.” As a result, companies are under a lot of pressure to make short-term decisions that may not be the best for the company.<sup>153</sup> Katerina Moloni, CTO of nPoint, agreed that angels put less pressure on a company. Angel investors could be satisfied in “other ways,” perhaps by buying them out, that venture capital would not

permit.<sup>154</sup> William Altman, the CEO of CorInnova, asserted that if angel funding is easily available, “it might be better to go there, because we’d probably get better terms” than by going the VC route.<sup>155</sup> Gary Eden of Eden Park Illumination recalled that he and Dr. Park had been very cautious about funding issues because of “horror stories” from friends and colleagues about their interactions with investors. But he added that the angel investors that had helped to fund Eden Park were “absolutely critical to our having reached this point.” He told us that one of the top 10 venture capital firms had offered terms but they decided “to not accept that offer but to continue with smaller investors and develop at a slower rate, but in a way that we thought was more consistent with our philosophical underpinnings.”<sup>156</sup>

Others, such as John Carlisle and Orlando Auciello, who spun Advanced Diamond Technologies out of Argonne National Labs, told us that angel funding allowed them to hire their first employee. Carlisle and Auciello had previously formed Cogenesis in 2003 and attempted to draw on venture funding. “Argonne wanted the moon, the sky, the sun, and the venture people were not quite as giving. So that deal fell through,” Carlisle told us. They got a half-million-dollar check from a Chicago angel investor in March of 2004 and received their first National Science Foundation SBIR grant that summer. Auciello noted, “You get the big money from venture capitalists,” but “they tend to dilute your equity much faster than angel money.”<sup>157</sup> Angel funding similarly provided the first employee for Pavilion Integration in 2004. “When angel funding came in...we didn’t really compensate myself,” founder Ningyi Luo told us. “I compensated an employee with pretty low cash, but also equity.”<sup>158</sup> Nonetheless, only one company in the study, Eksigent, relied solely on angel funding, from its founding in 2000 until AB Sciex acquired Eksigent’s liquid chromatography business shortly after we interviewed them in 2010.<sup>159</sup>

### ***Combination Bootstrap/SBIR***

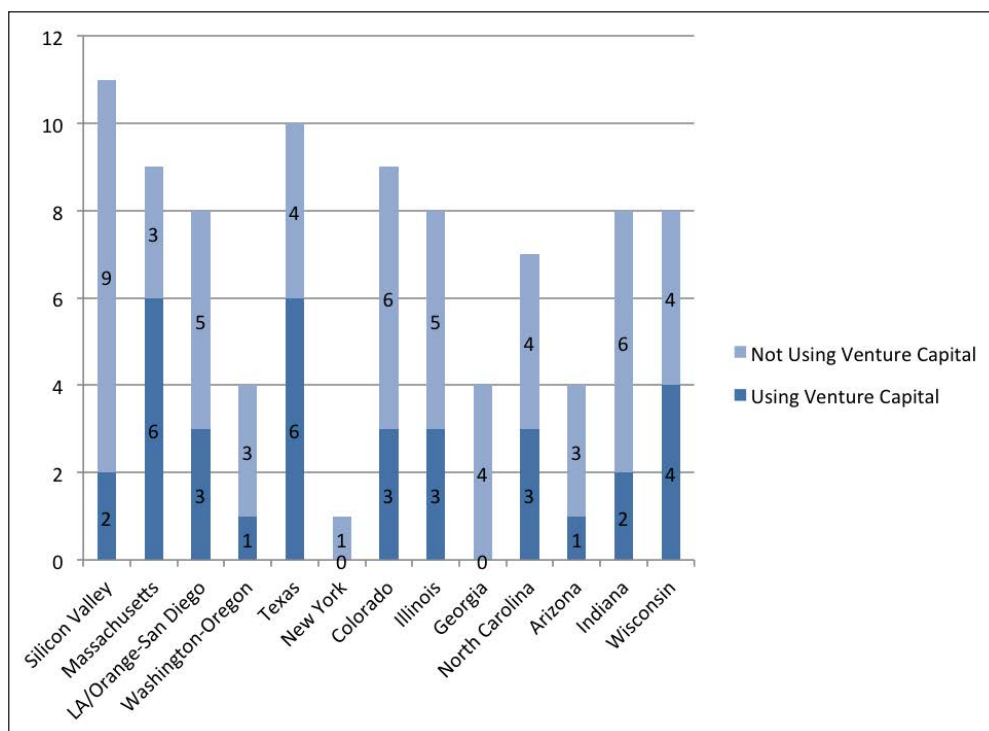
Several startups realized that their technology lacked the growth potential to attract venture capital or feared that venture capital would manage the commercialization in a way that would not maintain their firm. They turned to a combination of SBIR/STTR programs and bootstrapping to fund the longer-term development of their technologies, waiting until their technology was ready for a quick ramp-up to mass production to turn to venture capital. Others pointed out that the market for their business would permit growth to perhaps no more than a \$20 to \$50 million company and utilized SBIR/STTR funding to help slowly bootstrap the company to a point where the market could sustain it. This model appears to have become increasingly favored as venture capital has become more conservative and refused to fund slow-stage technology development.

### ***Venture-Funded Companies***

Thirty-five of the companies we interviewed turned to venture capital funding totaling about \$1.2 billion. As Figure 18 shows, relatively few of the companies where we interviewed in Silicon Valley relied on venture capital, although most had a relatively positive view of venture capitalists. As noted above, this is surprising given the high level of venture capital in Silicon Valley.

Only two of the 11 companies where we interviewed in Silicon Valley had relied on venture capital; a third firm accepted venture funding in preparation for going public. At least two more had been unsuccessful in seeking venture capital funds. Of the two firms that had turned to venture capital, one had avoided venture funding in Silicon Valley, turning instead to a venture fund in China to support its development of a manufacturing plant there. Another five had turned to angel investors, and five more of the Silicon

Valley startups had used between \$100 thousand and \$10 million in SBIR/STTR grants. All had invested “substantial” amounts of their own money. However, one of the firms receiving venture funding, Pacific Biosciences, has been described as the most capitalized venture company in the United States, receiving some \$370 million from venture capitalists prior to going public shortly after we interviewed there.<sup>160</sup>



**Figure 18.** Companies in study turning to venture capital (by region).

Several companies told us that while they worked informally with venture capitalists, they did not fit the VC market. James Vickers, cofounder of tau-Metrix that he initially funded from the sale of an earlier company, told us:

*We occasionally are approached by people that want to know what we’re doing. Usually they’re some kind of investor or venture capitalist, or something. And when we meet with them I think the general feeling is a lot of these people are looking for something huge. They’re not looking for something that might only be, you now, a \$50 million market.*<sup>161</sup>

Philip Mauger and Alex Shimkunas agreed that their startup, Nanostructures, Inc., was too small to be of interest to venture capitalists. “We’re not really set up with that scale of an organization,” Mauger asserted.<sup>162</sup>

The physicist entrepreneurs we interviewed in Silicon Valley had extensive informal relationships with the VC community, and they were highly sophisticated in their understanding of the needs of venture capitalists. As Katharine Ku, director of Stanford’s Office of Technology Licensing, told us, “Stanford is so entrepreneurial, there’s a view that if you’re really going to be entrepreneurial you can figure out your own funding or you can try to get your own funding or you can be connected by other entrepreneurs.” Silicon Valley lacked many of the formal structures to help entrepreneurs find VC funding that we found

elsewhere. Ku suggested this was a “Darwinian thing, which says if you want to start a company then you need to figure out the funding and you’ve got to figure out how to do this. Otherwise maybe you shouldn’t start a company...”<sup>163</sup>

A substantially higher number of startups in Massachusetts turned to venture capital at earlier stages, but the venture capital firms funding most of the companies we interviewed in Boston frequently took on characteristics often associated with angels, especially in their willingness to provide longer-term support for startups. MIT and the Boston area appeared to have a more structured relationship between startups and venture capital—with meetings and other formal opportunities for entrepreneurs and venture capitalists to interact—than in the Silicon Valley, but it still viewed itself as largely informal. Lita Nelsen, director of the MIT Technology Licensing Office, asserted: “MIT’s a very networky kind of place....If something very interesting is going on, I don’t have to have a business plan written. I can just call a few of my venture capital friends and tell them they ought to go talk to the professor.”<sup>164</sup> Nelsen added that most venture capitalists, like most of the corporate world, would not likely be interested in university-stage technologies.

All five of the startups we interviewed that were spun out of MIT were venture funded, but as noted above, many of the early “venture capital” investors exhibited characteristics more typically associated with angels than with venture capital organizations. Yoel Fink, founder of OmniGuide and a faculty member at MIT, told us that when they first sought funding for OmniGuide, “There was just a lot of, the way I’d put it now, cultural differences with the venture groups that suggested that we were not going to be able to work very well together.” He eventually found a VC willing to work with him who agreed to the founders’ request that the VC be the initial figurehead CEO.<sup>165</sup>

With rare exceptions venture capitalists in Southern California made between 10 and 20 fewer investments per quarter than those in Massachusetts. However, the average value of those investments was about \$1.23 million more for Southern California than for Massachusetts, perhaps reflecting the former’s proximity to Silicon Valley VC resources. More likely the difference reflects the willingness in Massachusetts for the smaller venture capital firms located there to invest in and guide earlier stage companies through a longer R&D phase as they bring their technologies to the market.

Only three of the eight companies we interviewed in Southern California received venture capital funding. None of the remaining five had sought venture capital funding, and like Massachusetts, one of the three that had originally relied on VC funding had been shut down by their investors. Startups in Southern California seemed particularly cognizant of the risks of venture funding. Several had used venture funding in previous startups and intentionally avoided it this time around.

After the initial venture capital investment, Ron Reedy of Peregrine Semiconductor explained, if you need money again, the only source is VCs. But the VCs would either close the company or raise money such that the VC’s investment would not be substantially diluted. “So the stock price stays the same, which means the dilution just keeps going up and up and up with every round.”<sup>166</sup> Reedy told us that they had been through four rounds of venture capital funding and that all the rounds—angel, private equity, and venture—had raised somewhere between \$200 and \$250 million. They were in the process of preparing to go public when we interviewed them. Rory Moore, a cofounder, asserted:

*You run out of angel money eventually; friends and families run out of money. A semiconductor company is a capital-intensive venture.... So without the venture capitalists, ... they would be out of business.*<sup>167</sup>

Southern California startups, while they turned to VCs more frequently than had the companies where we interviewed in Silicon Valley, were far less positive about their interaction. As Philip Wyatt pointed out, venture capitalists must have an exit strategy: "They have the exit strategy. How much can I make and what's the exit strategy? The exit strategy is very important. And that will decimate an entrepreneurial venture very quickly."<sup>168</sup>

Venture capital funding in Texas was only about 55 percent of that in either Massachusetts or Southern California and less than one-sixth that of Silicon Valley. Most of that difference in total venture capital funding was defined by the smaller number of venture capital investments, but a slightly smaller average size of each investment also contributed. Five of the 10 firms we interviewed in Texas had turned to venture funding. Several of these five startups did so by creating venture consortiums that, like the venture capitalists in Massachusetts, sometimes took on angel characteristics.

Applied Optoelectronics, Inc. (AOI) stumbled into their initial funding by a consortium of small venture capitalists. In many respects the VCs acted much like angels, in the same sense that the smaller VCs supporting some of the companies spun out of MIT have acted. But AOI stayed with that pattern of venture funding, looking to groups of small venture capital firms rather than one major VC firm for additional support. Typically venture capital rounds are arranged by a "lead investor" that puts up the most money for the round. Often one of their people is installed on the company's board of directors. Other venture funds are often brought to the round by the lead investor and provide smaller amounts. Murry told us:

*We didn't really take that approach. We've never really had a specific lead investor. We've always sort of negotiated a deal with a consortium of investment groups, which I think is good. It's good and it's bad. It takes a little more management bandwidth to do it that way because you've got a bunch of different people you have to talk to.*<sup>169</sup>

Even so, members of their initial consortium continued to invest in subsequent rounds, and other small venture funds from California, New York, and Taiwan joined in. Lin told us it was "very important to choose the right investor." Their current consortium included one firm in Dallas, which had provided the initial investment, some firms in New York, some in California, and some in Taiwan.<sup>170</sup> "Flip" Kromer, the founder of Infochimps, which is located in Austin, asserted venture funding "was not totally dissimilar" to angel funding; rather it was "a more formal version of that."

Ingrain, a third Texas startup that turned to venture funding, similarly worked through developing its own, in this case, international consortium. After they wrote up the business plan, they showed it to "three or four" venture capital firms. Founder Henrique Tono recalled:

*We had a friend that we knew in the oil and gas business in Houston who has worked in Norway and knew some of these people. So when I mentioned to him that I was putting together this business plan, he said, "Hey, let me send it to some of my friends in Norway, see what they have to say."*

Two Norwegian firms out of three or four firms that they sent the business plan to responded positively. “Within a couple of weeks I was on a plane with Amos Nur to Norway, and we signed an agreement right there and then and got started immediately.”<sup>171</sup> Energy Ventures, a Norwegian-based venture capital firm specializing in funding oil and gas technologies, provided the initial investment of \$5 million, which the company used to cover its licensing of patents and other expenses.<sup>172</sup> Tono told us that the Stanford University license included an equity share in the company.<sup>173</sup> The second and third rounds of funding in September 2008 and September 2009 focused on expanding Ingrain’s laboratories to Canada, the Middle East, North Africa, and Latin America. Both rounds, like those of Applied Optoelectronics, were “collaborative,”<sup>174</sup> meaning they did not have a lead investor. The second round included investments from Energy Ventures, Klaveness Invest AS and Kommunal Landspenjonskasse, Stanford University, and the Shoaibi Group in Saudi Arabia. The Shoaibi Group subsequently formed Ingrain’s Abu Dhabi laboratory as a joint venture with Ingrain.

Almost as surprising as the near absence of venture-funded companies in our study in Silicon Valley was the high degree of venture funding in Wisconsin. Even during the height of the dot-com boom, venture capital in Wisconsin rarely provided more than eight VC deals during any quarter. Even so, a full 50 percent of the eight firms we interviewed in Wisconsin told us they had received venture funds ranging from \$1.75 million to around \$30 million. Part of this comes from the influence of the Wisconsin Alumni Research Foundation, but the startups that took venture capital there noted not only WARF’s assistance but also the fact that they focused on venture capital firms based in the Midwest. Thomas “Rock” Mackie of TomoTherapy asserted that WARF was “extremely helpful” in obtaining venture funding. He also told us that relying on Midwest VC firms was critical to his success. “I still rely much more on the Midwest people than I do the Coasts. They don’t understand the Midwest.”<sup>175</sup> John Carlisle of Advanced Diamond Technologies in Illinois recalled, “We visited Sand Hill Road guys. We went to Kleiner Perkins and a couple of other firms in that region. They liked us, but we’re not the Segway, we’re not Google, we’re not Facebook.” Most of the venture funds, as a result, came from Midwest VCs.<sup>176</sup> Similarly, Eden Park founders first turned to Illinois Ventures, a venture fund established by the Illinois legislature to fund their startup. Their entire venture funding, when we interviewed them, had come out of firms headquartered in Chicago and Ann Arbor, Michigan.<sup>177</sup> With rare exceptions, startups we interviewed in the Midwest—Illinois, Indiana, and Wisconsin—intentionally limited their VC funding to venture capitalists who were themselves Midwesterners.

Venture-funded companies appear to have differing strategies depending on when they were founded, which in turn reflects the more conservative policies of venture firms after the dot-com bust. The startups begun prior to around 2005 frequently reported that the first year or two after founding was devoted almost completely to research, after which research declined as they moved to product. Some indicated that they expected to return to research at a lower level in order to develop new products after they reached profitability. Those companies founded after 2005 predominantly told us that they did little or no research, only development, and moved as quickly as possible to providing a product or service.

While entrepreneurs and venture capitalists alike told us that venture firms typically had a timeline of four to five years to an exit, more than 20 of the VC-funded firms in the study that had been founded before 2005 had remained under VC funding substantially longer than that. One company that went public shortly after we interviewed had been under VC management for 20 years. Another six firms remained under venture management after 10 years. Two factors at least partially explain the anomaly of start-

ups remaining under VC financing longer than current VC funding models allow. Many of these startups were first funded in the 1990s when venture capital was easy to obtain. They remained at the margin of success, not earning high returns on the investment, although showing they had eventual potential. Secondly, the collapse of the telecom market at the turn of the century also collapsed the initial public offering market. Many venture capitalists held on to these marginally successful firms in the hopes that the initial public offering (IPO) market would revive and they could obtain greater returns on their investment during a public offering.

These companies reflect the more tolerant, less rushed philosophies of venture capital prior to the economic crises of the first decade of the 21st century. Almost all our interviewees told us that IPOs were not a viable exit strategy at the time of our interview and that they expected any exit to come through acquisition. Three firms where we interviewed went public in 2010–2011, suggesting that the IPO market may have recently eased.

The regional differences in the use and approaches to venture capital reveal the importance of regional entrepreneurial cultures in entrepreneurial activity. No region built its entrepreneurial activity on a “Silicon Valley” model. The variety of approaches to funding from venture capital reflected local entrepreneurial attitudes and experiences as much as they reflected the availability of venture funds in the region.

### ***Evolution of Funding Models***

The funding models that the companies in the study have used show distinct changes over time. Most of the companies begun in the 1980s used relatively small SBIR grants to develop their technology, and six of the nine founders identified early SBIR grants as critical to their success. None of them relied heavily on venture capital or angel investors, although at least two did turn to venture capital in the 1990s. Several founders of the pre-1990 companies had used venture capital to fund earlier, unsuccessful startups and held the venture firms at least partly responsible for those failures.

Philip Wyatt had just overseen the bankruptcy of his venture-funded firm, Science Spectrum, when he started Wyatt Technology Corporation in 1982. He told us that “no venture capital firm would get near to us after our earlier failure. Both the VCs and we had learned our lesson. Thank goodness for the DOD!”<sup>178</sup> Instead, he obtained one of the last DSAT (Defense Small Business Advanced Technology) awards, which was the prototype for the SBIR program that started the following year. The around \$600,000 Wyatt obtained in four or five SBIR awards in the 1980s established his business. Frank Levinson founded Netek in 1984 using venture capital. The financiers subsequently fired him. When he created Finisar in 1988 venture firms offered funding, but Levinson did not accept it until about a year and a half before his Finisar went public in 1999.<sup>179</sup>

Nor did Stephen Wolfram turn to outside funding to begin Wolfram Research in 1987. “I had no outside funding,” he told us. “I made a bunch of deals fairly early on which were prepaid license deals with computer manufacturers, and that provided some of the earlier working capital....Other than that, I put in I don’t remember how much money, but not a huge amount by today’s standards.” He had previously started another company using venture capital. However, “It was extremely distracting to have a company that had venture capital investors calling up every week and saying, ‘Hey, did you see this piece of news? Maybe the company should be going in that direction.’ ” So when he started Wolfram Research, he recalled, “I basically said, ‘If I don’t need their money, why get it?’ ”<sup>180</sup>

Philip Mauger, one of the founders of Nanostructures in 1987, told us, "It was basically a bootstrap operation; we had no outside funding. We had no investors....We just had contracts." He added, "We did some SBIRs."<sup>181</sup> Lowell Burnett, who founded Quantum Magnetics in 1987 to be the research arm for Quantum Design, similarly drew most of his funding from SBIR grants in addition to Department of Defense research contracts and development funding from Quantum Design.<sup>182</sup>

Use of venture investment by startups increased significantly during the 1990s through 2005. Seven of the 19 companies in the study (37 percent) founded in the 1990s drew on venture capital for at least some of their funding, ranging from about \$1 million to over \$88 million. Twelve of the 35 startups (34 percent) beginning between 2000 and the end of 2005 relied on upwards of \$770 million in venture capital investment, 55 percent of that going to Procure and Pacific Biosciences. (Some have called the latter firm the most capitalized startup in the United States.) Thirteen of the 28 startups (46 percent) founded after 2006 received upwards of \$126 million in venture capital, with \$110 million going to four companies: Rayspan and GMZ Energies, founded in 2006; and Ingrain and WiTricity, founded in 2007. Venture capitalists pulled the funding on Rayspan, which disbanded shortly before we interviewed the founder. Solasta, founded in 2006, received another \$6 million in venture capital funds and was disbanded shortly after we interviewed there in 2011.

While the percentage of startups funded by venture firms has increased over time, many of the interviewees told us that attitudes and practices of venture capitalists changed dramatically after the telecom bust in 2001. Matt Kim, who started a venture-funded firm in the late 1990s and QuantTera in 2004, drawing on out-of-pocket funds and government grants, told us, "After the crash, things really changed a lot with the venture capital mindset. They wanted..." a very fast return on investment.<sup>183</sup> R.C. "Merc" Mercure agreed, telling us that "the world of venture capitalism has totally changed in the last five years." After the telecom bust venture firms had difficulty raising money. Many went out of business, and the ones that survived became "much more risk averse than they have historically been." As a result, venture firms shifted toward later-stage investments. "People have to realize today," Mercure noted, "that they can't count on venture capital as they perhaps could a while back." When venture capital would agree to invest they would not invest small amounts. Mercure asserted, they "need to put together packages of \$2, \$3, or \$4 million before they're [VCs] really interested." Mercure suggested that for startups that work in today's economic environment, you "don't need to take more money than you can get from angels" before "you start generating your own money."<sup>184</sup>

A careful qualitative analysis of the firms that provided venture funding to the companies we interviewed, particularly after 2005, suggests that many of them do not quite fit the traditional definition of venture capital. Many of the funders were themselves entrepreneurs who appeared to include substantial amounts of their own money in their venture capital investments. Because of their inclusion of at least some of their own funds, they appeared to have adopted many of the characteristics of angels who had moved into the venture capital market as venture capital firms declined. Furthermore, while we were unable to obtain the financial inputs of those entrepreneurs described as angels, their numbers increased in startup investments after 2000. Only two angels invested in our pre-1990 startups. Six of the startups in the 1990s relied at least partially on angel funds, while nine startups between 2000 and 2005 and 10 startups between 2006 and 2010 depended at least partially on angel funding. Those numbers would increase dramatically if the venture funds that had at least some angel characteristics were counted as angels in post-2000 investments.

### *Tensions Between Venture Capital and Entrepreneurs*

Many of the companies in Silicon Valley talked about how helpful venture capitalists were, even when they had not turned to VCs for funding. “What surprised us completely,” Ron Ruth of Lyncean Technologies in Palo Alto recalled, “was how helpful and how open that [VC] community is....They’re in the market for ideas. And so they actually are very helpful.”<sup>185</sup> However, a surprising number of entrepreneurs in other parts of the country appeared openly hostile to venture capital playing a role in their company. Only 35, or a little more than a third of the companies we interviewed, had used venture capital funds. Many insisted that they would never turn to VCs, and more indicated that they would only do so if they were ready to ramp-up to manufacture a high-volume product. Acknowledging the many stories of venture capital deals gone bad, Ruth’s cofounder, Stefan Murry, asserted:

When you first start the company, you hear all these horror stories about, “They stole my company and stole my idea and kicked me out on the street.” I’m not saying it doesn’t happen, but I think it’s probably less common than most people think. They do have a stake in the company and you have to deal with them to a certain extent.”<sup>186</sup>

In contrast, Richard Selinfreund of Indianapolis, in talking about a previous startup, said, “We did everything wrong. We went to venture capital. They put tons of money into the company [but they had] absolute control. You’re dead—they own you. Overnight, I owned 35 percent of the company when I started, and, at the end, they were beating me up over 1.3 percent.”<sup>187</sup> Herschel Workman, the CEO of PartTec in Bloomington, Indiana, raised similar concerns about VC control and its danger for the business. “When the venture capitalist talks about an endgame, they’re talking about how they turn their money into more money—that’s what they’re wanting to know. They don’t want to know what is my end-game for turning the business into a more solid member of the business community.” If they are looking to make more money, the endgame “would be for this business to sell itself to a larger competitor....Their job isn’t creating business. It’s acquiring more money.”<sup>188</sup> Another company in Indiana told us, “We were so stupid....So you thought okay, they [venture capital] have as much to lose as you do, so if they don’t work for the good of the company, they’re going to lose. What I didn’t realize is a big bull is worth more dead than alive.”<sup>189</sup> Nick Nolte of Quadraspec in West Lafayette, Indiana, asserted, “The problem with VC is they tend to have a lot of clout, a lot of leverage, they always have somebody on the board, and so they... bring pressure to bear in the running of the actual company.”<sup>190</sup>

Others who had used VC money in the 1990s told us the times had changed. Matt Kim said that when he cofounded MicroLink Devices in Niles, Illinois, “in 1999, they were giving away venture money on napkins, so it wasn’t hard for us to get money.” Today, however, he said that venture firms wanted to invest only in companies that had revenue streams.<sup>191</sup> And Dileep Agnihotri, founder of Graphene Energy in Austin, Texas, asserted that the 2008 recession affected access to capital as well: “It was different three years ago....Everybody wanted to put money in and get into some exciting stuff. Since the recession happened, it changed it quite a bit....You have to take their terms. So it can be drastic in the current market.” He added that “if you look at VCs, people jokingly use the term vulture capitalists; their interest is to protect their investment and get the best ROI [return on investment].”<sup>192</sup>

The tensions between venture capitalists and entrepreneurs seem to be endemic in the current economy. Venture capitalists focus on maximizing their return on investment quickly, while entrepreneurs focus on the stability of the companies they are creating and maximizing the success of their technology in the

marketplace. A major point of contention is control. Dileep Agnihotri told us a lot of venture capitalists will put their own people on the board of directors, and it's "driven by who they know and who they work with, and not much driven by what expertise they bring to the board."<sup>193</sup> Kal Ramnarayan went further. He described his venture capital experience as good in the beginning, "But towards the end, when the number of venture capitalists on the board became quite a lot, ...then a lot of noise starts to happen where different venture capital people want to pull us in different directions." He added that because VCs aren't concerned about human problems, he couldn't promise employees permanent jobs.<sup>194</sup> Angel investor Rory Moore agreed, but did not see this as a problem. He told us that one of the controls he asserted as an investor was to, "just make it clear to the company that there is no job security....Very few executives in the first stage can scale to be that executive as the company grows and expands."<sup>195</sup>

Max Lagally agreed: "Most companies are successful only after they get their founder out of the way because he's constantly going to keep doing what he did all the time, and in order to be successful you've got to move the founder sideways."<sup>196</sup> Many of the entrepreneurs, like Dr. Ramnarayan, on the other hand, not only wanted to ensure their own job and the direction of their company, but also the job security of their employees. "If you were to do the company on your own," Ramnarayan declared, "which we are doing in this Sapient Discovery here, then we are not pushed around by anybody else. We make the decision how we are going to grow."<sup>197</sup>

Thompson Lin of Applied Optoelectronics in Sugarland and other Texas entrepreneurs typically reduced the control that venture firms exerted by relying on consortia of small VC firms rather than a large lead investor. However, Lin also noted that venture capital was changing and bemoaned the trend toward shorter and shorter investment time frames. He told us, "That has got to change."<sup>198</sup> And Stefan Murry, his cofounder, acknowledged that there were potential issues in dealing with venture capitalists. But his company had found common ground with their venture capital funders where their goal of return on investment merged fairly harmoniously with the founders' goal of enhancing their technology's value. "Every round you obviously give away a little more of the company," but, he told us, "at this point, overall I would say that the process of working with the venture capitalists has been—I mean it's been okay." For Murry, the issue was not one of venture capitalists per se, but rather one of choosing the right investors. "If you do it right," he said, "their interests are fairly well aligned with that of the company and everybody wants to grow the company and make it a success."<sup>199</sup>

## *Technological Origins*

Of the 91 companies we interviewed, 41 did not have university-related research as a critical component of their startup. Most of these "market-pull" startups were created by physicists to provide services or technological solutions to the marketplace. Some of these firms had developed technologies based on expertise the founders had developed during graduate school or work at another company, but the technology itself was not being drawn from the university. Some of these startups provided consulting services or skilled technological resources to other firms or government agencies. Others had developed solutions to market problems—cheaper components or specialized equipment that did not derive from research. The intellectual property appeared to result from the application of established science to product components or systems demanded by an existing market. Little or no research was required. Rather

the focus had been on development based on established scientific principles. Lindsay Austin, head of Pavilion Integration, describes his company as a marketing company. “It was a convergence of a couple of ideas targeted to a whole different problem....There was no research ever done.”<sup>200</sup>

Thirty-nine of the companies we interviewed were “technology-push” operations, bringing new technologies out of university research. Of those, 20 were founded by professors who had developed the technologies in their labs. Another eight were founded and run by both the professor and one or more of his students, all of whom actively participated in the running of the company.<sup>b</sup> Another eight firms were created by students to bring to the market technologies that they developed during graduate school. Three startups were based on university research and included professors’ names among the founders, but no one tied to the university appeared to participate in the operation of the firm. Another six startups transferred their basic technologies from national labs or another government agency, and two had brought their technologies from previous companies started by the same founder. These two companies continued to license the technology for a new application after the previous company had been acquired.

Market-pull companies serve well-defined markets and had typically been created to serve those markets by applying existing science and technology to market problems. On the other hand, technology-push companies, which were developing potentially innovative technology, frequently had to find their markets. And many technology-push organizations had to shift to new markets as they found attempts to serve a given market rebuffed or inadequate to sustain the company. A third group might best be described as skilled service companies.

### ***Research vs. Development***

Most of the companies we interviewed told us that their basic focus in R&D was on development rather than research. Graphene Energy and Advanced Hydro founder Dileep Agnihotri asserted, “I think in my company the focus would be mostly on development: taking the research and developing it into a product. On the research side, I would still leverage university collaborations.”<sup>201</sup> Peregrine cofounder Ron Reedy told us, “I would say that officially, we spend 20 percent of our revenues approximately on R&D....So I would say it’s more likely 19 of our 20 percent is development and maybe 1 percent is the R.” Companies could not afford to do more, he continued:

*We really don’t explore the basic properties of nature. Companies in general are paid to do development—they’re paid to create products that do something. So one of the reasons that you’ve seen the decline in basic research in corporate laboratories is because in the end, companies don’t get paid for understanding nature. Companies get paid for making products.*<sup>202</sup>

Jason Cleveland at Asylum Research agreed. “I would say there is no R here without D involved,” he told us. “Most of the things we’re playing with are almost exclusively things that are done with the goal of it landing it in a product.” He did make one exception. He asserted that they do basic research for marketing purposes. The “basic research” done in collaboration with customers serves two purposes: it provides

---

<sup>b</sup> We do not include in these numbers professors who founded and have equity in the startup but do not appear to actively participate in the operation of the firm.

a market awareness of their capabilities and it adds value to their customer service. Cleveland told us, "The same guy that's doing some of the basic R&D on the instrument might be the same guy interacting with a customer a few years later."<sup>203</sup> His cofounder, Roger Proksch, concurred: "We have way too many Ph.D.s here." But he added that customers loved communicating with them.<sup>204</sup>

That does not mean that research doesn't play any role in companies, but it's "little r and big D." Ron Reedy told us that in the United States it is relatively easy to get government funding for research and difficult to get funding for development. He said that government agencies and philanthropists don't want to build manufacturing companies. On the other hand, he added that companies that do basic research often don't profit from it:

*So much of what the Department of Defense funds in basic research never goes anywhere because...you can't go raise that kind of money these days to build a manufacturing company. Frankly, nobody wants to build manufacturing companies these days.*<sup>205</sup>

While agreeing that fundamental research is critical for the development of industries, Reedy told us that it is detrimental to the profitability of the business that carries it out. As a result, while his company put one to two percent of its budget in research, he told us that "At Peregrine, most of the current true research activity is done collaboratively with universities."<sup>206</sup>

While some interviewees suggested their startups continued to do research, none of them even hinted that their research was the same as the "blue sky research" that Bell Labs once made famous. Of course, Bell Labs and other earlier industrial R&D laboratories had also carried on applied research and development. What our interviewees made clear was that blue sky research has been largely relegated to universities and national laboratories, both of which are under pressure to bring even their blue sky research to the brink of commercial activity. Once near the proof-of-concept stage, startups could continue applied research to bring the technology to a commercially viable stage, ready to be accepted or rejected by the marketplace.

## ***Transferring Technology Out of the University***

The Bayh-Dole Act of 1982, which was an effort to respond to the economic malaise of the 1970s, permits the transfer of intellectual property generated by federally funded research from the government to the university, small business, or non-profit institution sponsoring it. It is one of many factors increasing the role of technology transfer out of the universities. We interviewed managers in technology transfer programs at Harvard, MIT, Boston College, Stanford, UCLA, UC Berkeley, Wisconsin Alumni Research Foundation, Indiana, Purdue, and Georgia Tech. In addition, one entrepreneur we interviewed had been closely connected with developing technology transfer policies at the University of Colorado, and we asked the entrepreneurs we interviewed about their technology transfer experiences. The results are a mixed bag of procedures and programs. We did not find unified operating procedures for any of the technology transfer offices in the study. Not even Stanford and MIT, generally conceded to be the best technology transfer operations in the country, agreed on policies. Stuart Hall, one of the founders at Passport Systems, put it succinctly: "Every university is different, so every university has its own policies."<sup>207</sup>

Some universities, including MIT and the University of Colorado,<sup>208</sup> took at least a partial equity share in startups as a part of the technology transfer process. Yoel Fink, founder of OmniGuide, told us that while MIT funded the patent process and owned the patents, “they ask in return for about five percent of the company in the first round of financing” in the licensing process.<sup>209</sup> Others, including the University of Houston, preferred cash up front plus royalties. Abdelhak Bensaoula, whose Integrated Micro Sensors was spun out of the University of Houston, told us the university was willing to lower the royalty rate in exchange for “some cash injection into the research.... There are examples on campus where they would say a 3.5 percent royalty, we’re willing to take 2 percent, but we want you to fund half a million dollars for five years” for research by faculty involved in the company.<sup>210</sup>

Among the entrepreneurs who had transferred technology out of a university, many had very strong opinions. Most of them suggested that the people handling technology transfer at the universities were more important than the policies they were implementing. Sally Hatcher, one of the founders of mBio Diagnostics, had recently worked with the University of Utah on a licensing agreement. “We found them very reasonable to work with,” she told us. “They like the idea of being a part of what happens to their technology, so the licensing agreement included a very minor equity component.”<sup>211</sup> Jerry Cuomo, who is a professor at North Carolina State University and was a founder of AP Solutions, told us that while relations with the NC State technology transfer office were great when we interviewed, that had not always been the case. “We have a wonderful relationship now with certain people within the tech transfer office,” he told us, but “it was horrible for the five years” when another director ran the operation. “They have the same rules, the same laws, but how people enact those rules and laws make a total difference.... It’s a different world when you’re dealing with people who are reasonable and people who are ridiculous.”<sup>212</sup>

Robert Black found technology transfer offices to be a mixed bag.

*At some institutions, some academic institutions the tech transfer offices are not very good, you know. Stanford and MIT are exceptions.... At Duke, to be quite honest, when I was there, anyway, it was very difficult to get any sort of buy into an entrepreneurial startup.... The best places, again like Stanford and MIT, help but then they get out of the way.*<sup>213</sup>

Dileep Agnihotri of Graphene Energy had worked with technology commercialization offices at the University of Texas at Austin, Rice University, Northwestern University, and a “couple of other places,” and he told us that some of the university technology transfer offices focused “on short-term strategies where they... just want quick bucks on it for the inventors and the university. They will sell it very quickly, very cheap.” While this strategy is frequent, other universities “want some big winners... want to take it to market on a big scale.” He added that he thought the latter programs had obtained more licensing revenue.<sup>214</sup>

Some entrepreneurs found the particular strategy at their university helpful. Eric Buckland, founder of Bioptigen, has licensed technology from several universities but brought his initial technology out of Duke University. He told us: “Bioptigen has licensed from multiple universities, but the amount of energy that goes into negotiating the licenses is extraordinary.” Their license from Duke came as part of a master license agreement negotiated by the incubator they were in. “But, with other universities the energy that

goes into taking out licenses is quite hard, and I think there's a general sense that universities, through their licensing policies, get in the way of innovation."<sup>215</sup>

Others found the strategy at their university to be disruptive. Clayton Kerce recalled his interaction with an earlier Georgia Tech transfer officer. "The interaction that I had with the guy—he's now gone—but basically he was looking for something that was a sure \$100 million [project]....So personally, I didn't get any value out of my discussions with them."<sup>216</sup> Edward Conrad, cofounder of Graphene Works, told us that the Office of Technology Transfer at Georgia Tech, as opposed to the Enterprise Innovation Institute there, was "not easy" to work with "at all."<sup>217</sup> Another entrepreneur there, who declined to be formally interviewed, told us that Georgia Tech was still working with conflict of interest issues and had not resolved them, at least to his satisfaction.<sup>218</sup> Again, entrepreneurs focused on whether or not the person managing conflict of interest issues was the right person for the job. Henry Kapteyn, a founder of Kapteyn-Murnane Laboratories and a professor at the University of Colorado, told us that both the conflict of interest compliance officer and the people in the technology transfer were new when he arrived in 1999, and they were all very good. However, their predecessors had been dysfunctional, and the university had disbanded the offices and started over again. He added, "They did a much better job the second time around."<sup>219</sup>

The Wisconsin Alumni Research Foundation (WARF) is unique among the technology transfer programs that we visited in having a substantial endowment that it uses to invest in startups created by University of Wisconsin faculty. It's estimated that it has approximately \$2 billion under investment, and interviewees praised it both for its own investments and the staff's skills generally and especially for connecting them with other Midwestern venture capital firms. Ayla Annac, founder of InvivoSciences, told us that when they took their technology out of Washington University, St. Louis, the university was helpful, but their incubator didn't have the equipment of a fully commercial incubation center. In addition, the university had an outside consultant do the negotiating, and his interest was in getting the maximum amount of money from them and blocked their efforts. After she moved the company to Wisconsin, things got better she told us: "Wisconsin was much more well equipped, I think due to the UW [University of Wisconsin-Madison] and WARF. I have to give them huge credit." She added that the director of WARF didn't know them, but he helped a great deal in negotiating with Washington University.<sup>220</sup>

Texas A&M, like some of the other technology transfer offices in the study, was reluctant to fund patenting of faculty ideas, turning instead to potential licensees to pay for the patent. John Criscione, founder of CorInnova, who was bringing the technology out of the university, told us, "CorInnova pays for them, and that's part of our licensing agreement....CorInnova can go ahead for any new disclosures or any related inventions, they can go ahead and file." He added, "We have a very young technology licensing office, Office of Technology and Commercialization."<sup>221</sup> They had not yet obtained sufficient licensing revenue to bear the cost of covering patenting.

John Ferraris, founder of Solarno at the University of Texas-Dallas, also focused on the person running the tech transfer who was himself a multiple entrepreneur. So while the program didn't have an extensive network, the director was a good resource in problem solving. Ferraris told us that since both he and his cofounder were "full-time employees of the University of Texas-Dallas, [so] anything that we do belongs to the University of Texas system." But they had "agreements with the university wherein we can get

right of first refusal or exclusive licenses and the like.” The university did bear the cost of patenting. He added: “Stuff that we invent on our own off-site, the university doesn’t have anything to do with. So we have to bear the cost of that. Stuff that’s done...jointly with the university can have a couple of options.”<sup>222</sup>

Georgia state agencies had to address further legal issues that complicated the process of technology transfer out of the universities. Stephen Fleming, vice provost of Georgia Tech’s Enterprise Innovation Institute, told us that under the Georgia state constitution no state agency could have multiyear contracts. This created a variety of bureaucratic issues, including the inability of state agencies to hold patents, since patents were, at their core, multiyear contracts. “You could argue,” Fleming told us, “that it’s actually illegal for the State of Georgia to directly own a patent. So all of the state universities have research corporations....They are all 501(c)3s. And those 501(c)3s are the entities that do enter into multiyear contracts that survive the fiscal year boundary.”<sup>223</sup> The 501(c)3s were modeled after the University of Wisconsin’s Wisconsin Alumni Research Foundation but apparently, because of the ambiguities of Georgia law, were not as closely integrated into the technology transfer process. Even so, Fleming told us that about one startup a month, or “12 to 15 a year,” are created based on Georgia Tech intellectual property:

*I think that our [technology transfer] terms are some of the friendliest out there, to the entrepreneurs....I think that most of the [departments]...do include commercialization and startup activity in their promotion process. The way we split that baby is it does not count towards tenure. Once you’ve got tenure, it does count towards promotion and other advancement.*<sup>224</sup>

Fleming argued that Georgia Tech’s technology transfer system was more complex and designed to encourage entrepreneurial activities than Stanford’s or MIT’s. He added:

*We’re doing a lot of stuff to kind of artificially greenhouse an ecosystem here that they don’t need to do at Stanford, that MIT doesn’t need to do at Boston, because you cross the street [in those places to venture capital and other entrepreneurial institutions]...But all the stuff I do with the handholding and the coaching and the building connections and all of that, I think Kathy [Katharine Ku, Stanford University] would say, “Well hell, if a VC doesn’t come into their lab and get excited about it on their own, why should I help them?”*<sup>225</sup>

All four of the startups we interviewed in the Atlanta area had some connection with Georgia Tech, though only one of them was bringing new technology out of the university. While they typically praised Fleming’s office, some told us that legal issues in other offices of the university complicated things. Edward Conrad, founder of Graphene Works, for example, complained that “there were a lot of communication errors that go through.” Part of the problem, Conrad asserted, derived from the divisions within the university that appeared to separate the legal department from the Advanced Technology Development Corporation. “They’re two different things,” Conrad told us.<sup>226</sup>

Like the differing regional cultures in the mechanisms for funding startups, the different university attitudes toward and policies regarding technology transfer profoundly reflect and influence the needs and cultures of the startup communities. To give but a few examples, universities in the Midwest placed a strong influence on the development of research parks, while such parks played relatively minor roles

on either coast. Some universities focused on licensing to major corporations or viewed the licensing process as a revenue generator for the university, while others played a much more influential role in economic development programs and in generating indirect revenues by enhancing the value of the industrial communities that surrounded the university and employed students and graduates. These differences profoundly affected the entrepreneurial cultures in the regions the universities influenced.

## *Communications*

The small size of most startups would suggest, and our interviews confirm, the importance of verbal communication within the enterprise. At the same time, 45 percent of the companies in the study said that they have some kind of formal records retention policy. In addition, scientists at 24 percent of the companies that don't have formal policies said that they "keep everything," and another 16 percent without formal policies said that they had large amounts of extant records. So in addition to the reliance on face-to-face interaction, a total of 85 percent of the startups in the study reported that they have at least some paper or electronic records that document their operations.

A number of interviewees described the kinds of formal records that they created. The sources might be sparse, but some included lab notebooks, traditionally one of the most important records for documenting science, and others consisted of contracts and reports, another important documentary source. For example, Philip Paul, one of the founders of Eksigent, told us that their communication is "almost all face-to-face":

*There is no time for written records and there's not a lot of time for meetings where you brainstorm. They don't work anyway. So, they're kind of a waste. Written records here will be lab notebooks and manufacturing documents, and that's pretty much all you can afford to waste your time on.*<sup>227</sup>

Nicholas Economou, founder of Alis and head of the American arm of Carl Zeiss Jena GmbH at the time of the interview, said that communication at his current company was "a lot of nice productive hallway conversations. That's the best kind. When we communicate with Germany, by necessity it's more formal....It's either a visit or we put together a structured presentation."<sup>228</sup> Thompson Lin, cofounder of Applied Optoelectronics, told us, "In Houston we're used to face-to-face meetings, more convenient. But since we have a lot of people in Taiwan and China, we use videoconference, email, every day. But right now that's all we do, internationally."<sup>229</sup> Christopher Myatt of Precision Photonics and mBio Diagnostics asserted, "The communication is mostly verbal, and everyone has a lab notebook that they keep track of specific stuff that they're doing."<sup>230</sup>

Others reported a higher proportion of communication that was a combination of written reports and emails. John Parker recalled that communication at Nanophase Technologies had been "probably a good even split."<sup>231</sup> Alex Shimkunas of Nanostructures said:

*A lot of email traffic and verbal on top of that. We have a combination of both written and verbal communication. We try to go more towards written communication, particularly with our customers we have to. We don't do anything with a customer until we have something in writing.*<sup>232</sup>

Todd Ditmire of National Energetics said that communication within the company was mostly “by emails, but we’re a small enough group that we meet pretty regularly. So it’s by emails and verbally.”<sup>233</sup> Others focused on email or even intranet wikis. Eric Buckland of Bioptigen asserted:

*Well, researchers these days tend to want email, tend to abhor the telephone, and we like to encourage as much voice conversation as possible. And we make a point of sending our team to go visit; we want to have as much face-to-face as we can but it’s kind of limited. I think that everyone wants to go to email.*<sup>234</sup>

Tetsuro Wakatsuki asserted that while they did monthly reports, much of their communication was by email: “We mostly communicate through the email so we have a track record of what we have done.”<sup>235</sup> Henry Kapteyn of Kapteyn-Murnane Laboratories told us that communication was a mix of oral and written but, “I think there’s more written now. I think the written process is extremely important to get these complicated laser systems put together.”<sup>236</sup> Those who focused on written reports pointed out the importance of those reports for SBIR and customer contracts. An exception was Bill O’Brien, founder of Mad City Labs, who told us, “We have a financial meeting that meets once a week, and we have sales meetings probably about once or twice a month, loosely scheduled.” So communication, he asserted, was mostly verbal.<sup>237</sup>

## ***Records***

Record keeping by startups is an important element in our study and over time will determine the extent to which historians and other researchers can investigate and understand today’s high-technology culture. Our findings in this area represent something of a paradox. While entrepreneurs emphasized the importance of verbal communication, they frequently described relatively large amounts of extant records, including lab notebooks, reports, and email. Forty-one of the 91 startups (45 percent) had some form of formal records retention policy. One additional startup was in the process of establishing a formal policy in preparation for seeking venture funding. Most of these policies were very limited but represented a rough effort at identifying and preserving potentially valuable records.

Many that had formal policies told us that they had developed them in response to requirements by the FDA, other government agencies, or businesses with whom they held substantial contracts. And among the 50 without a formal policy, 22 told us they kept “everything,” which was also true for several that did have a retention policy. Another 15 told us of substantial records that, while they had no formal policy, they expected they would keep. Eric Buckland, for example, said:

*We don’t have a specific written policy. Everyone in the company uses lab notebooks that are numbered and tracked, and in that sense our retention policy is twofold. Everyone does all of their writing in these things and they are all company property and kept, and we’ve done that since almost day one.*<sup>238</sup>

Several factors played into the absence of records retention policies. Dan Stevenson, a founder of siXis, asserted, “There’s not much in the way of formal published policies with small companies, in my experience.”<sup>239</sup> Several, both among those who had and those who did not have a formal policy,

told us that all their records were digitized and that the low cost of keeping records on a computer, frequently backed up off-site, made the development of a records retention policy unlikely. Others asserted that the cost of focusing on formulating administrative policies would divert them from business that provided needed cash flow. As Dana Anderson of ColdQuanta put it, "A company's mission is not to preserve data, and so there would not be directly a policy for preserving data. There would be a policy to do something else that would require data preservation as part of it." In short, the only records a company should preserve, he asserted, are data that the company finds useful and they should preserve it only for as long as it has utility.<sup>240</sup>

Anderson agreed that a company might not always know in advance the future value of records, a point argued by Stephen Wolfram toward an opposite conclusion. Wolfram told us:

*I'm an informational pack rat, so I have everything. I've got my email for 24 years. I've got my paper records forever. In fact, we're almost finished after a three-year project of scanning all of my paper documents, and I have nice searching technology for that....So every so often, I go through and try and do a little bit of analysis of what can I learn about things that I should be doing differently.*<sup>241</sup>

In Wolfram's case the commercial programs he has developed to analyze disparate data, including Wolfram Alpha, have been highly profitable. Most of the entrepreneurs we interviewed were somewhat more selective in the records they kept and the length of time they expected to keep them.

Many entrepreneurs told us that the success of their startup depended upon informal voice communication that could not easily be preserved. However, 52 of the startups in the study told us that they either required or kept lab notebooks. A few more told us that lab notebooks were not required because all of the data was recorded on a computer which was backed up. Many preferred to transfer all records to an electronic format. At least four startups provided some form of electronic notebook to their employees. Several others were considering the use of electronic notebooks but had not yet found one that fit their needs. Peter Yancey, cofounder of AP Solutions, told us, "We are definitely interested in a robust, inexpensive, and easy-to-use electronic version. We've looked at that a number of times."<sup>242</sup> Others told us that audit requirements limited their use of electronic notebooks. Jim Costales of Passport Systems explained: "We're in the paper age still here and, you know, I think part of that is that we're doing government projects and a lot of times if you get audited, I think, the most accepted standard is still a paper logbook."<sup>243</sup> Robert Ledoux, president of Passport Systems, added another concern about electronic notebooks: "I think everybody's a little suspicious of the electronic versions of them."<sup>244</sup> Because of the possibility of computer hacking, people think that traditional lab notes are more secure.

Others had equally practical reasons for not shifting to electronic notebooks. Dana Anderson of ColdQuanta told us, "Nothing against electronics—there are some aspects that are very nice and very modern. But all of my students, first of all, are already trained to use paper lab notebooks....It's a little old fashioned, but that's the way we're doing it right now."<sup>245</sup> John Carlisle of Advanced Diamond Technologies asserted, "I'm completely electronic; I don't file anything. It's all digital on my hard drive." However, he added that he required paper lab notebooks and had one himself. "If you get an inventible idea," he told us, "you have to write it down and get it witnessed. But....I don't write much in my paper notebook. I do all of my notes and everything electronically, and of course lawyers hate that."<sup>246</sup>

While most of the interviewees continue to use traditional notebooks, many talked about shifting their research documentation to electronic formats. For the most part these electronic notebooks were very basic systems put together using Microsoft products. Michael Anderson of Vescent Photonics asserted, “I am personally experimenting with an electronic notebook, and I’m not even aware if there’s software out there. I just use Word, and that works really well for me....So I have both a paper notebook and an electronic notebook.”<sup>247</sup> Yoel Fink of OmniGuide told us that while most of those who come from science disciplines use traditional paper lab notebooks, others create “an electronic notebook in which they document their findings in electronic format. They use Word. Primarily Word, Excel, stuff like that.”<sup>248</sup>

Nathan Myhrvold at Intellectual Ventures asserted, “We don’t require the use of a physical lab notebook because some people want to do it on computer, and that’s fine, as long as we back it up.” Someone in his lab, he told us, had created “some wiki software” that was available as an option, though he did not personally use it.<sup>249</sup> Dileep Agnihotri told us that Graphene Energy did not require lab notebooks but instead used electronic documentation based on Excel. He said, “In it we document every change we are making and things like that. Other documentation we have in the emails. So those are the two forms. And then I have my own notebooks where I take notes for every meeting I have.”<sup>250</sup> Eric Buckland told us that they used off-the-shelf electronic notebooks such as National Instruments LabVIEW or MATLAB.<sup>251</sup>

Stefan Murry of Applied Optoelectronics represents the view of those who told us that keeping a notebook had once been required but no longer was: “The end of the R&D process is a big stack of information, whether it’s electronic or literally a stack of paper that defines how we make that product,” he remarked. “If we lose that data on how to make the product, then we’re in trouble because we can’t make it anymore....How do we retain that? Well, we make multiple copies of it. It’s on different servers around the world and password protected.” Applied Optoelectronics had a records management software program that implemented their computer records policies.<sup>252</sup>

Many saw changes in government patenting policies as diminishing the value of the lab notebook. While some companies expected lab notebooks, or their electronic equivalent, to be kept permanently, others said that they would have no value after the life of the patent.

While most companies had some form of backup policy for their electronic records, the quality of those backups varied greatly. One company opined that the only permanent records were those kept live on the electronic network. Those not kept live would eventually disappear as recording technologies changed.<sup>253</sup>

Given the fact that 82 of the companies in the study were founded after 1990, the relative volume of the records that we saw during site visits was typically small, but some provided fairly extensive documentation of the company’s history. Although it wasn’t part of the question set, we occasionally talked with interviewees about preserving records by placing them in academic or public archives, and three asked for help in contacting repositories that would take them in. All three are now working with appropriate archives, two of which are academic and one government. Based on the small volume of most of the records and the wide distribution of the companies across the country, we believe that there is an opportunity to create a distributed collecting program to document the companies in the study and other startups.

AIP has begun initial efforts to link companies with regional or national archives that will work with them to preserve records. We have applied for funding for a pilot project to work actively with repositories in the Northeast Corridor to preserve the records of Boston area startups. As noted above, the Silicon Valley and Boston's Route 128 corridor are the twin birthplaces of high-tech entrepreneurship in the United States, and the greater Boston area remains the second most successful location for new startups. However, unlike the Silicon Valley there has been no systematic effort to preserve the records of high-tech entrepreneurship in Boston. If funded, we will hire a full-time historian/archivist to do career-length oral histories with entrepreneurs and to develop and coordinate relations between the startups and repositories throughout the corridor. About 10 archives have agreed to participate in the project, and we will expand the network if we obtain funding. If successful, the pilot project may offer a national model for documenting the history of innovation and entrepreneurship.

## *Operating in a Global Competitive Environment*

While many of the startups we interviewed, particularly those relying on the SBIR program, initially had American government customers for their products and services, they ultimately operated in a global marketplace. In order to grow and thrive they would sooner or later compete with companies in Europe and Asia to provide products and services. And many, if not most of the startups we interviewed already faced global markets. Henry Kapteyn of Kapteyn-Murnane Laboratories told us, "We do less than half of our business in the US. The rest is Europe and Asia."<sup>254</sup> Bud Magera of Applied Physics Technologies said, "One of my customers is in Europe and one project is in Japan."<sup>255</sup> Even the smallest startups were faced with global issues.

While American academic technology transfer programs took off after the 1982 passage of the Bayh-Dole Act, Isaac Kohlberg, head of Harvard's Office of Technology Development, told us:

*Israel technology transfer programs started in 1958...1959 and they have become very successful. In Europe...[it is] not as advanced. But, if you look in Japan, major Japanese universities are moving very fast in this area. Even some Chinese universities are moving very fast.*<sup>256</sup>

Katharine Ku, head of Stanford's Office of Technology Licensing, agreed:

*I would say many, many of the foreign countries...are developing these kinds of university technology licensing offices. I don't know the order of things, but Japan has been doing this for a really long time....And then throughout Europe they're trying to do this. [The] UK has actually set up offices. Cambridge has been around doing this for a while, so, they're fairly sophisticated. Germany, all of them. Taiwan is just having their tenth-year celebration of a similar law [to Bayh-Dole].*<sup>257</sup>

So American startups are facing global competition for pioneering ideas, and big business has moved globally in their search for innovative startups to acquire.

Many issues affect the global markets and global competition faced by the startups in the study. American companies have to protect their intellectual property and find ways to compete and overcome constraints

on competition often imposed by both the United States and foreign governments. These constraints affect where and how they may grow the company once their markets take off and will affect their ability to compete in those markets. Lindsay Austin, a founder of Pavilion Integration, said that the market drives innovation, so visiting and understanding global markets is critical to solving the problems those markets face. He said, “You always come back with new ideas. That’s where most products come from, to a large extent. It’s not just technology, which is research in a lab trying to understand fundamental physics questions. It’s really dedicated to trying to solve [market] problems.”<sup>258</sup>

Our interviewees praised the role of the SBIR/STTR program in giving them an early advantage. Michael Anderson of Vescent Photonics told us, “It’s one thing the United States does really well, and it really helps with innovation because people we work with in Europe just don’t have as many opportunities as we do to get this kind of funding.”<sup>259</sup> In order to grow and thrive they would have to sell their technology globally. Not everyone saw that as a benefit, however. Salime Boucher, whose company, RadiaBeam, has received significant SBIR funding, told us:

*I’ve found that industrial physics is much more alive and healthy in Europe than it is in the United States.... The companies here, I’m sorry to say it, but we all seem to be dependent on the SBIR program and not being very ambitious in attacking markets.... I think SBIR can be a curse if anything—it makes you dependent on the government.*<sup>260</sup>

More of our interviewees appear to be sympathetic with the position asserted by Anita Goel of Nanobiosym. She told us that the government is a good partner for fundamental research work and added that “there are agencies in the US government who have fundamentally been the chief investors into fueling innovation.” However, after “you have technologies past a certain level of feasibility and prototyping, and you’re looking at commercializing that and bringing it into a market and scaling it up, that’s when private investors make sense.”<sup>261</sup> If the SBIR program provides advantages compared to Europe, at least one entrepreneur complained that the relationship between the American national labs and small business made it difficult for American small businesses to compete. The national labs, Alex Murokh of RadiaBeam asserted, “are not pro-business. They view us as a threat, not as somebody who wants to work with them. They buy from us but...even when we can uniquely provide the product they need, there are all kinds of hurdles in making the business go forward.”<sup>262</sup> One result of the hostility toward small business on the part of the national labs, Murokh argued, was a shift in technology innovation away from America. He maintained that the national labs receive most federal research money, but they don’t encourage small businesses to commercialize the labs’ high-tech intellectual property. He added that his company had to compete “with Chinese companies that have very low manufacturing costs” and with “European companies which are technologically 10 years ahead.”<sup>263</sup>

Protecting Intellectual property in the global market is also a significant cost for startups. Herschel Workman told us that it cost \$25,000 to file a European patent, adding, “That does not protect us. Once we’ve filed the patent, then we have to defend it. That’s not the defense; that’s just the filing.”<sup>264</sup>

## Government Regulation

It should come as no surprise that commercial companies would worry about government regulation. We were surprised, however, at the regulations that most gnawed at startup founders. Few, if any, founders mentioned taxation, but it certainly was not absent. Ron Reedy, founder of Peregrine Semiconductor, told us:

*When we started the company, we had all these permits and taxes. We were paying inventory taxes. You wouldn't believe the things that we had. . . . For such a capitalist country, you see all sorts of public policy, and California is among the worst because of the regulations, that just literally the combined message is, "We really don't want you to start a company."*<sup>265</sup>

Reedy noted, "I saw recently that 30 percent of all US venture capital is now starting companies in China, and you know the number one reason? It's easier. And they want companies. They want jobs. They'll do everything they can to get those companies."<sup>266</sup> Though several mentioned the complexity of taxation as an issue in passing, few saw it as a major problem compared to issues like immigration and International Traffic in Arms Regulations (ITAR).

Several included the difficulties of providing health care among policies with which they struggled. More frequently, government restrictions on immigration and regulations on technologies offended the sensibilities of our founders. Ron Reedy called American immigration policies "the most self-inflicted, worthless, damaging policy the United States has." He added, "If Congress could do one thing to stem the flow of venture capital leaving this country, it would be to simply say, 'There is no limit on the number of H-1B visas.' Any smart person who can get a job here can get a visa."<sup>267</sup>

Thompson Lin, founder of Applied Optoelectronics and himself an immigrant from Taiwan, agreed: "The thing about it, I'm an immigrant, too. If I started AOI in Taiwan or China, the whole story would be changed," he told us. "In the past 50 years, the US has been very successful in recruiting the best people in the world. . . . [but] the change of immigration law of the US in the past few years really, really did not allow the good students to stay in the US."

Noting that in many graduate programs up to 50 percent of the students were foreign, Lin asserted, "That means you are kicking out 50 percent of your innovation now." Admitting that these issues are not likely to be noticed now, he continued:

*You can see a big effect in 10, 20, or 30 years. And don't forget right now China, India, other countries are growing very fast. They are offering very good opportunities to these people. They are so hungry to get this high tier of people. And the US is doing the opposite. They are pushing these people out. Not good at all.*<sup>268</sup>

While not all founders brought up the topic, which we did not include in our question set, more than one cited ITAR along with current immigration policy as factors that made them uncompetitive with startups in other countries. When asked about government regulations, Mikael Martinez of National Energetics asserted, "We have had to deal with export controls and ITAR issues for sure."<sup>269</sup> Dana

Anderson told us, “ITAR restrictions are very dangerous for a startup company....So you have to be careful what you say your system is good for in an email.”<sup>270</sup> Scott Davis of Vescent Photonics told us that “for all of our products,...we had to get them ITAR certified.” This put him at a sharp disadvantage with foreign competitors.<sup>271</sup>

The founder of Thinking Systems, Darrell Conway, told us that ITAR regulations prevented him from putting some of his programs on SourceForge, a web-based source code repository that permits global software developers to manage open-source software development so it can then be seen internationally. As a result, his access to collaboration that would enhance his programs and apply them more broadly was limited. Because of ITAR, “certain things that could be used militarily you have to follow a different set of rules.”<sup>272</sup> Richard Czerw of NanoTechLabs pointed out that ITAR rules limited his ability to license his technologies: “Most of the stuff we work on is ITAR restricted, so it can’t be exported easily....If you want to have a worldwide market, you can’t really.”<sup>273</sup> Companies circumvented ITAR regulations by moving jobs overseas. Ron Reedy of Peregrine Semiconductor told us that, “If a company is at risk that there’s any military or space application to a product,” they would often “design those products outside the US because we’re not allowed to export them....We can’t export the products but we can export the jobs.”<sup>274</sup>

An area that at least one startup noted was the difficulty in transitioning from a privately held company to a public company. Ron Reedy told us, “Your customers want you to be public. They can see if you’re healthy. It’s harder for their competitors to buy you....And of course you raise a lot of capital, which allows you to grow the company faster.” However, the process is very expensive: “Being prepared to go public means meeting Sarbanes-Oxley, which [alone] costs about \$2 million a year that ultimately is coming out of our R&D. So it’s incredibly expensive....So there are all sorts of positives, but there are some pretty-good-size negatives.”<sup>275</sup>

## *Conclusion*

The HoPE study has validated our original premise that the sources of technical innovation have shifted dramatically over the past 50 years. R&D laboratories at large high-tech companies, some once famous for blue sky research, have come to concentrate on product development at the expense of longer-term research. The gap in industrial research is being filled by physicists and other scientists who are producing a wide variety of innovative technology through entrepreneurial startups. As Lita Nelsen, Director of MIT’s Technology Licensing Office, told us, “The more innovative the invention, the more likely it’s going to have to go through a startup.” She added that “established corporations are not taking on the really... early-stage technologies.”<sup>276</sup> At the same time, high-tech startups are complex and diverse organizations, and there is no formula that insures technological and commercial success.

Each of the companies in the study was founded or cofounded by a Ph.D. physicist, often in partnership with individuals in other professions. About 35 of the 91 startups participating in the study focus on incremental improvements to existing products, and we described these as market-pull operations. We classed approximately 56 of the companies as technology-push enterprises that are focusing on research that offers the potential for providing fundamental innovations in a wide variety of fields. In examining

the structure and dynamics of the 91 startups across the United States through site visits, interviews, and a literature review, we have identified a variety of factors that are critical to developing innovative and commercially successful new technology.

Two of the geographical clusters that we studied, Silicon Valley and perhaps to a lesser extent Boston's Route 128 high-technology corridor, are international symbols of innovative and commercially successful high-tech startups. A number of commentators have suggested that other areas both in the U.S. and abroad should use them as models in creating policies and programs to spur technological development and economic growth. However, in addition to these two areas, there are many other geographical clusters of successful high-tech entrepreneurship in the United States. In the ten of these that we visited, we found highly individualized startup ecosystems that have grown out of regional economic, intellectual, and technological resources and mindsets. For example, many of the Midwestern entrepreneurs expressed strong distrust of venture capitalists, and startups in Arizona centered around new optical technology, reflecting the Tucson area's history as "optical valley."

Successful funding is critical for high-tech startups, and it remains a complex process with about as many solutions as there are startups. As noted above, Robert Black of CivaTech Oncology said "Whenever you go to a meeting of entrepreneurs, funding is the first and only topic that is discussed...and there are lots of answers to that."<sup>277</sup> And each of the funding methods bring unique risks. The peculiar circumstances of the startup, as much as the technologies it is bringing to market, determine the methods the founders we interviewed took.

Tensions between enhancing the value of the technology and enhancing return on investment played a particularly important role in founder decisions to avoid venture capital funding and conflicts between founders who chose VC funding and the VC organizations that invested in them. Entrepreneurs similarly took widely divergent approaches to their uses of SBIR funding. Some limited their application for SBIR funding to proposals directly related to product development. Others used the SBIR grants as research funding, and a few saw SBIR programs as the primary revenue source for their company. The latter typically intended to sell the intellectual property they developed to others who would bring the products they had researched to the marketplace.

Entrepreneurs who worked with venture capital clearly understood the different motivations driving their work as an entrepreneur and the venture capitalists' desire to obtain a high, rapid return on investment. When those two goals fit together, they worked happily with venture capitalists. When they did not, the entrepreneurs' goal to maximize the value of their technology meant that they either sought to avoid venture capital investment or to limit the control that venture capitalists might have over the company. Those entrepreneurs who were further away from centers of venture capital markets were more likely to misunderstand the role of venture capital or to see venture capital as much as a threat as a benefit to the company. The more closely they were associated with a venture-capital-based culture, the more positive were their attitudes toward venture capital, even when they did not use it. However, even then most seemed to feel that venture capital, especially venture capital that did not understand the technology, could not be trusted to fund the company all the way to the marketplace. Only a few argued that the venture capitalist did not need to understand the technology, arguing instead that they should understand the markets into which they would place that technology.

We conducted interviews with directors or managers at 10 university technology transfer programs and one regional program, and we found that their policies were all different, including those of the three—Stanford, MIT, and the Wisconsin Alumni Research Foundation (WARF)—with the strongest reputations. In general, the programs that took equity in new startups in return for covering the costs of patenting and licensing were most effective in generating income for the organization and received the most positive reviews from entrepreneurs. Those programs that tried to achieve a quick payoff by charging fees for licensing were described as less successful in both generating income and meeting the needs of entrepreneurs.

We found a close connection between most entrepreneurial founders and their workforce. There existed a tendency, though not universal, to grant employees some equity share in the company. Often this was done to motivate company loyalty to highly skilled employees working below their market value, offsetting lower-than-average salaries. We also found highly liberal policies toward creating a positive workplace environment.

Even American-born founders of startups complained that immigration restrictions inhibited the growth of their companies. More than one of the startups we interviewed had developed international offices, both to serve the global market and to employ technologists where it was too difficult and too costly to keep them in the United States. Second only to the problems with immigration policy, founders complained about International Traffic in Arms Regulations forcing them to move research abroad. There were little or no restrictions on bringing technology into the United States, but the ITAR restrictions often forced them to develop technologies abroad in order to compete effectively in the global marketplace.

Most market-pull entrepreneurs did not view themselves as taking high technological risks. Though some acknowledged the risks of the marketplace, most saw their understanding of the technology as reducing risk to minimal levels. On the other hand, technology-push entrepreneurs typically avoided acknowledging market risks, focusing almost solely on technological issues. Where the company had not survived, most blamed it on inequities in the market environment or what they viewed as unfairness—and occasionally corruption—in the funding environment or business associates.

Finally, the extent to which startups preserve their historically valuable records will determine the ability of current and future researchers to understand the sources of innovation in today's economy. We found that records keeping among startups represents a paradox. Most of the entrepreneurs stressed that their companies depended on informal, face-to-face communication. However, 45 percent of the companies had formal records retention schedules, and a total of 85 percent described significant collections of digital and analog records, although our impression is that the total volume of records at each company is relatively small, largely because most are fairly young operations. We believe that it may be possible to link startups with regional or national archives that will work with them to preserve their records, and we hope to be able to start a pilot distributed collecting project focusing on startups in the Boston area. However, it's too early to tell if the approach will be successful in preserving significant bodies of records.

Unlike many examinations of entrepreneurship, the HoPE study focuses on operations instead of policy. Physics has always been a vital driver of new and innovative technology, and we believe that the findings contained in this report represent significant new information on the current dynamics of physics-based

entrepreneurship and the evolution of technological innovation over the past 30 years. We expect our findings will provide a basis for further research on entrepreneurship and innovation, and all the oral histories that we conducted as part of the research have been transcribed and are available to researchers at AIP's Niels Bohr Library & Archives (<http://www.aip.org/history-programs/niels-bohr-library>), except for those of a small number of individuals who requested that their interviews be closed.



## *Endnotes*

- <sup>1</sup> Richard Czerw interview by Orville R. Butler, Yadkinville, NC, Jan. 18, 2010.
- <sup>2</sup> Robert Black interview by Orville R. Butler, Research Triangle Park, NC, Jan. 20, 2010.
- <sup>3</sup> Lita Nelsen interview by Orville R. Butler, Cambridge, MA, Sept. 29, 2010.
- <sup>4</sup> Ibid.
- <sup>5</sup> Friedrich List, *National System of Political Economy*, 1840.
- <sup>6</sup> Cf. Joel Genuth et al., "The Organization of Scientific Collaboration," *Research Policy* (2002) 31, 5:749–767 (with Ivan Chompalov and Wesley Shrum); Joan Warnow-Blewett, Joel Genuth, and Spencer R. Weart, *AIP Study of Multi-Institutional Collaborations: Final Report. Highlights and Project Documentation* (Melville, NY: American Institute of Physics, 2001), <http://www.aip.org/history-programs/niels-bohr-library/documentation-projects> (under "Study of Multi-Institutional Collaborations," click on "Highlights"); Joan Warnow-Blewett, Joel Genuth, and Spencer R. Weart, *AIP Study of Multi-Institutional Collaborations: Final Report. Documenting Multi-Institutional Collaborations* (Melville, NY: American Institute of Physics, 2001), <http://www.aip.org/history-programs/niels-bohr-library/documentation-projects> (under "Study of Multi-Institutional Collaborations," click on "Main Report"); R. Joseph Anderson and Orville R. Butler, *History of Physicists in Industry: Final Report* (Melville, NY: American Institute of Physics, 2008), <http://www.aip.org/history-programs/niels-bohr-library/documentation-projects> (under "History of Physicists in Industry").
- <sup>7</sup> Correspondence with Roman Czujko, Director, AIP Statistical Research Division, July 19, 2013.
- <sup>8</sup> Harry Cendrowski and Adam A. Wadecki, "Introduction to Private Equity," in *Private Equity: History, Governance, and Operation* (New York: Wiley, 2012), 3.
- <sup>9</sup> Nicos Nicolaou, Scott Shane, Lynn Cherkas, Janic Hunkin, and Tim D. Spector, "Is the Tendency to Engage in Entrepreneurship Genetic?" *Management Science*, 54, no. 1 (Jan. 2008): 167–179.
- <sup>10</sup> Christopher J. Myatt interview by Orville R. Butler, Boulder, CO, Apr. 28, 2011.
- <sup>11</sup> Ron Reedy telephone interview by Orville R. Butler, Mar. 30–31, 2011.
- <sup>12</sup> Ramana Nanda and Jesper B. Sorensen, "Workplace Peers and Entrepreneurship," *Management Science*, 56, no. 7 (July 2010): 1116–1126.
- <sup>13</sup> Udayan Gupta, ed., *Done Deals: Venture Capitalists Tell Their Stories* (Boston, MA: Harvard Business School Press, 2000).
- <sup>14</sup> Arturo Chavez-Pirson interview, Tucson, AZ, Jan. 12, 2010.
- <sup>15</sup> Ron Reedy telephone interview by Orville R. Butler, Mar. 30–31, 2011.
- <sup>16</sup> Mary Fuka interview by Orville R. Butler, Boulder, CO, Apr. 25, 2011.
- <sup>17</sup> Stefan Murry interview by Orville R. Butler, Sugarland, TX, Mar. 24, 2011.
- <sup>18</sup> Stefan Murry interview, op. cit.
- <sup>19</sup> Stefan Murry interview, op. cit.
- <sup>20</sup> Krzysztof Kempa interview by R. Joseph Anderson, Newton, MA, July 28, 2009.
- <sup>21</sup> Somesh Jha interview by R. Joseph Anderson, Middleton, WI, Dec. 14, 2010.
- <sup>22</sup> Robert Fischell interview by Orville R. Butler, Dayton, MD, Dec. 21, 2009.
- <sup>23</sup> Thomas "Rock" Mackie interview by Orville R. Butler, Madison, WI, Dec. 13, 2010.
- <sup>24</sup> G. Jordan Maclay interview by Orville R. Butler, Richland Center, WI, Dec. 15, 2010.
- <sup>25</sup> Stefan Murry interview, op. cit.
- <sup>26</sup> Lynwood Swanson interview by Orville R. Butler, McMinnville, OR, Dec. 1, 2009.
- <sup>27</sup> Matt Kim interview by Orville R. Butler, Tempe, AZ, Jan. 13, 2010.

- <sup>28</sup> Henry Kapteyn interview by Orville R. Butler, Boulder, CO, Apr. 25, 2010.
- <sup>29</sup> Mikael Martinez interview by Orville R. Butler, Austin, TX, Mar. 22, 2011.
- <sup>30</sup> Todd Ditmire interview by Orville R. Butler, Austin, TX, Mar. 23, 2011.
- <sup>31</sup> Robert Black interview, op. cit.
- <sup>32</sup> Abdelhak Bensaoula interview by Orville R. Butler, Houston, TX, Mar. 24, 2011.
- <sup>33</sup> Dana Anderson interview by Orville R. Butler, Boulder, CO, Apr. 25, 2011.
- <sup>34</sup> Ayla Annac interview by R. Joseph Anderson, Madison, WI, Dec. 14, 2010.
- <sup>35</sup> Michael Anderson interview by Orville R. Butler, Denver, CO, Apr. 27, 2010.
- <sup>36</sup> Orlando Auciello and John Carlisle interview by R. Joseph Anderson and Orville R. Butler, Romeoville, IL, Jan. 10, 2011.
- <sup>37</sup> Eric Buckland and Joe Izatt interview by Orville R. Butler, Research Triangle Park, NC, Jan. 19, 2010.
- <sup>38</sup> Arturo Chavez-Pirson interview by Orville R. Butler, Tucson, AZ, Jan. 12, 2010.
- <sup>39</sup> Eric Buckland and Joe Izatt interview, op. cit.
- <sup>40</sup> Ranier Kunz interview by Orville R. Butler, Boulder, CO, Apr. 25, 2011.
- <sup>41</sup> Sally Hatcher interview by Orville R. Butler, Boulder, CO, Apr. 27, 2011.
- <sup>42</sup> Philip (Flip) Kromer interview by Orville R. Butler, Austin, TX, Apr. 8, 2011.
- <sup>43</sup> Alex Murokh interview by Orville R. Butler, Santa Monica, CA, Feb. 9, 2011.
- <sup>44</sup> John Carlisle and Orlando Auciello interview, op. cit.
- <sup>45</sup> Lindsay Austin and Ningyi Luo interview by Orville R. Butler, San Jose, CA, Feb. 2, 2010.
- <sup>46</sup> Nicholas Economou interview by R. Joseph Anderson and Orville R. Butler, Peabody, MA, July 27, 2009.
- <sup>47</sup> Abdelhak Bensaoula interview, op. cit.
- <sup>48</sup> Robert Black interview, op. cit.
- <sup>49</sup> John Ferraris interview by Orville R. Butler, Dallas, TX, Mar. 21, 2011.
- <sup>50</sup> Scott Davis interview by Orville R. Butler, Denver, CO, Apr. 27, 2011.
- <sup>51</sup> Alexei Erchak interview by Orville R. Butler, Billerica, MA, Aug. 5, 2009.
- <sup>52</sup> Henry Kapteyn interview, op. cit.
- <sup>53</sup> Dhruv Bansal interview by Orville R. Butler, Austin, TX, Mar. 22, 2011.
- <sup>54</sup> Philip Wyatt interview by R. Joseph Anderson and Orville R. Butler, Santa Barbara, CA, Mar. 10, 2011.
- <sup>55</sup> Philip (Flip) Kromer interview, op. cit.; "Infochimps: All The Bananas You Can Eat for Hires," Texas TechPulse, Oct. 21, 2011, [http://www.texastechpulse.com/infochimps\\_all\\_the\\_bananas\\_you\\_can\\_eat\\_for\\_hires/s-0038899.html](http://www.texastechpulse.com/infochimps_all_the_bananas_you_can_eat_for_hires/s-0038899.html).
- <sup>56</sup> Philip (Flip) Kromer interview, op. cit.
- <sup>57</sup> Dhruv Bansal interview, op. cit.
- <sup>58</sup> Philip Wyatt interview, op. cit.
- <sup>59</sup> Tracy Moor interview by R. Joseph Anderson, San Diego, CA, Mar. 7, 2011.
- <sup>60</sup> Scott Davis interview, op. cit.
- <sup>61</sup> Ron Reedy interview, op. cit.
- <sup>62</sup> Nathan Myhrvold interview by Orville R. Butler, Bellevue, WA, Dec. 2, 2009.
- <sup>63</sup> Stefan Murry interview, op. cit.
- <sup>64</sup> Michael Naughton interview by Orville R. Butler, Newton, MA, Aug. 5, 2009.
- <sup>65</sup> David Carnahan interview by R. Joseph Anderson and Orville R. Butler, Newton, MA, July 29, 2009.
- <sup>66</sup> Todd Ditmire, op. cit.
- <sup>67</sup> John Ferraris interview, op. cit.

- <sup>68</sup> Joseph Izatt and Eric Buckland interview by Orville R. Butler, Research Triangle Park, NC, Jan. 19, 2010.
- <sup>69</sup> Nasser Peyghambarian interview by Orville R. Butler, Tucson, AZ, Jan. 12, 2010.
- <sup>70</sup> Greg Piefer interview by Orville R. Butler, Middleton, WI, Dec. 21, 2010.
- <sup>71</sup> John Pacanovsky interview by Orville R. Butler, Triangle Research Park, NC, Jan. 21, 2010.
- <sup>72</sup> Dileep Agnihotri interview, op. cit.
- <sup>73</sup> Dhruv Bansal interview, op. cit.
- <sup>74</sup> Nicholas Economou interview by R. Joseph Anderson and Orville R. Butler, Peabody, MA, July 27, 2009.
- <sup>75</sup> Alexei Erchak interview, op. cit.
- <sup>76</sup> Anita Goel interview by Orville R. Butler, Medford, MA, Aug. 1, 2009.
- <sup>77</sup> Joseph Izatt and Eric Buckland interview, op. cit.
- <sup>78</sup> Christopher J. Myatt interview, op. cit.
- <sup>79</sup> Matt Kim interview by Orville R. Butler, Tempe, AZ, Jan. 13, 2010.
- <sup>80</sup> David Oakley interview by Orville R. Butler, Boulder, CO, Apr. 26, 2011.
- <sup>81</sup> Brad Larson interview by R. Joseph Anderson, Madison, WI, Dec. 14, 2010.
- <sup>82</sup> Bill O'Brien interview by Orville R. Butler, Madison, WI, Dec. 15, 2010.
- <sup>83</sup> Richard Selinfreund and Dick P. Gill interview by R. Joseph Anderson, Bloomington, IN, Nov. 9, 2010.
- <sup>84</sup> Ayla Annac interview by R. Joseph Anderson, Madison, WI, Dec. 14, 2010.
- <sup>85</sup> Tetsuro Wakatsuki interview by Orville R. Butler, Madison, WI, Dec. 14, 2010.
- <sup>86</sup> Brad Larson interview, op. cit.
- <sup>87</sup> Dan Stevenson interview by Orville R. Butler, Research Triangle Park, NC, Jan. 18, 2010.
- <sup>88</sup> Stefan Murry interview, op. cit.
- <sup>89</sup> Dileep Agnihotri interview by Orville R. Butler, Austin, TX, Mar. 23, 2011.
- <sup>90</sup> Zhifeng Ren interview by Orville R. Butler, Newton, MA, July 27, 2009.
- <sup>91</sup> Kathryn Atchison interview by Orville R. Butler, UCLA, Los Angeles, CA, Mar. 9, 2011.
- <sup>92</sup> Robert Black interview, op. cit.
- <sup>93</sup> Ellen Kim, Jeff Finkelman, and Ahson Wardak, "Small Business Administration SBIC and SBIR Programs," Jan. 2011, <http://www.ieeeusa.org/careers/webinars/2011/files/SBA-OI-Webinar-Presentation-18-Jan2011.pdf>; Philip Wyatt interview by R. Joseph Anderson and Orville R. Butler, Santa Barbara, CA, Mar. 10, 2011.
- <sup>94</sup> Albert N. Link, Testimony before the US House of Representatives Committee on Small Business, Apr. 7, 2011, [http://smbiz.house.gov/UploadedFiles/Al\\_Link\\_SBIR\\_Testimony\\_for\\_4.7.11.pdf](http://smbiz.house.gov/UploadedFiles/Al_Link_SBIR_Testimony_for_4.7.11.pdf).
- <sup>95</sup> Small Business Research and Development Enhancement Act of 1992, S. 2941, <http://thomas.loc.gov/cgi-bin/query/F?c102:1:./temp/~c102psprSU:e18151>.
- <sup>96</sup> "SBIR," <http://www.sbir.gov/about/about-sbir>; Small Business Reauthorization Act of 2000, <http://www.gpo.gov/fdsys/pkg/BILLS-106hr2392es2/pdf/BILLS-106hr2392es2.pdf>; SBIR/STTR Reauthorization Act of 2011, <http://www.gpo.gov/fdsys/pkg/PLAW-112publ81/html/PLAW-112publ81.htm>.
- <sup>97</sup> Small Business Technology Transfer Act of 1992, <http://thomas.loc.gov/cgi-bin/query/C?c102:./temp/~c102DXsL3V>.
- <sup>98</sup> "STTR," <http://www.sbir.gov/about/about-sttr>; SBIR/STTR Reauthorization Act of 2011, op. cit.
- <sup>99</sup> Office of Extramural Research, National Institutes of Health, "Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs," [http://grants.nih.gov/grants/funding/sbirsttr\\_programs.htm](http://grants.nih.gov/grants/funding/sbirsttr_programs.htm).

- <sup>100</sup> <http://www.nasa.gov/centers/dryden/about/Organizations/Technology/SBIR/history.html>.
- <sup>101</sup> Office of Extramural Research, National Institutes of Health, "Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs," [http://grants.nih.gov/grants/funding/sbirsttr\\_programs.htm](http://grants.nih.gov/grants/funding/sbirsttr_programs.htm).
- <sup>102</sup> "STTR," <http://www.sbir.gov/about/about-sttr>.
- <sup>103</sup> "SBIR," <http://www.sbir.gov/about/about-sbir>.
- <sup>104</sup> "New SBA Regulations Expand Eligibility for SBIR/STTR Funding," Cooley Alert, [http://www.cooley.com/files/93411\\_ALERT\\_NewSBAreulations.pdf](http://www.cooley.com/files/93411_ALERT_NewSBAreulations.pdf); Michael H. Bison, "New SBA Rule Enabling VC-Backed Small Businesses to Qualify for SBIR Grants, Now Effective," Goodwin Procter Alert, Jan. 29, 2013, [http://www.goodwinprocter.com/Publications/Newsletters/Client-Alert/2013/0129\\_New-SBA-Rule-Enabling-Venture-Capital-backed-Small-Business-to-Qualify-for-SBIR-Grants.aspx](http://www.goodwinprocter.com/Publications/Newsletters/Client-Alert/2013/0129_New-SBA-Rule-Enabling-Venture-Capital-backed-Small-Business-to-Qualify-for-SBIR-Grants.aspx).
- <sup>105</sup> Charity Pennock, "Data Commentary—Small Business Innovation Research (SBIR) Program in the South," Southern Growth Policies Board, Apr. 12, 2011, <http://www.southerngrowth.com/communityresources/downloads/SBIRData.pdf>;  
"Kentucky SBIR/STTR Matching Funds Program," Iowa SBIR/STTR Newsletter, 2, no. 12, (Dec. 2006): 2, [http://www.techtransfer.iastate.edu/documents/news/u\\_sbir\\_newsletter\\_v2\\_iss12.pdf](http://www.techtransfer.iastate.edu/documents/news/u_sbir_newsletter_v2_iss12.pdf).
- <sup>106</sup> John Criscione and William Altman interview by Orville R. Butler, Houston, TX, Jan. 7, 2011; John Ferraris interview by Orville R. Butler, Dallas, TX, Mar. 21, 2011.
- <sup>107</sup> Peter Yancey and Jerry Cuomo interview by Orville R. Butler, Carey, NC, Jan. 19, 2010.
- <sup>108</sup> <http://www.nccommerce.com/scitech/grant-programs/one-nc-small-business-program>; Jim Jay, "Disappointment over 21 Fund Cuts Doesn't Cloud Bright Tech Future," Inside Indiana Business, <http://www.insideindianabusiness.com/contributors.asp?id=1498>.
- <sup>109</sup> Robert S. Frey, *Successful Proposal Strategies for Small Businesses: Using Knowledge Management to Win Government, Private Sector, and International Contacts* (Norwood, MA: Artech House, 2008), 16; [http://books.google.com/books?id=jwYgWcZJF\\_0C&vq=bridge&dq=Delaware+bridge+grants+sbir&source=gbs\\_navlinks\\_s](http://books.google.com/books?id=jwYgWcZJF_0C&vq=bridge&dq=Delaware+bridge+grants+sbir&source=gbs_navlinks_s).
- <sup>110</sup> [http://dedo.delaware.gov/BusinessServices/BusinessFinancing/BusinessFinancing\\_SBIR.shtml?businessfinancing](http://dedo.delaware.gov/BusinessServices/BusinessFinancing/BusinessFinancing_SBIR.shtml?businessfinancing).
- <sup>111</sup> Matt Kim interview, op. cit.
- <sup>112</sup> Salime Boucher interview by R. Joseph Anderson, Santa Monica, CA, Mar. 9, 2011.
- <sup>113</sup> Anita Goel interview by Orville R. Butler, Medford, MA, Aug. 1, 2009.
- <sup>114</sup> Eric Buckland and Joe Izatt interview by Orville R. Butler, Research Triangle Park, NC, Jan. 19, 2010.
- <sup>115</sup> Richard Czerw interview by Orville R. Butler, Yadkinville, NC, Jan. 18, 2010.
- <sup>116</sup> John Cameron interview by Orville R. Butler, Bloomington, IN, Oct. 21, 2010.
- <sup>117</sup> John Criscione and William Altman interview, op. cit.
- <sup>118</sup> Micki Downey interview by R. Joseph Anderson, Tucson, AZ, Jan. 12, 2010.
- <sup>119</sup> Scott Davis interview, op. cit.
- <sup>120</sup> Gang Chen interview by Orville R. Butler, Cambridge, MA, Aug. 5, 2009.
- <sup>121</sup> Jason Cleveland interview by Orville R. Butler, Santa Barbara, CA, Mar. 10, 2011.
- <sup>122</sup> Richard Selinfreund interview by R. Joseph Anderson, Indianapolis, IN, Nov. 9, 2010.
- <sup>123</sup> Thomas Roberts interview by R. Joseph Anderson, Batavia, IL, Jan. 10, 2011.
- <sup>124</sup> Rod Loewen interview by Orville R. Butler, Palo Alto, CA, Feb. 3, 2010.
- <sup>125</sup> Sally Hatcher interview, op. cit.
- <sup>126</sup> Dana Anderson interview, op. cit.

- <sup>127</sup> Abdelhak Bensaoula interview, op. cit.
- <sup>128</sup> Scott Davis interview, op. cit.
- <sup>129</sup> John Carlisle and Orlando Auciello interview, op. cit.
- <sup>130</sup> Scott Davis interview, op. cit.
- <sup>131</sup> Michael Anderson interview, op. cit.
- <sup>132</sup> Abdelhak Bensaoula interview, op. cit.
- <sup>133</sup> Thomas Roberts interview, op. cit.
- <sup>134</sup> Reyad Sawafta interview by Orville R. Butler, Greensboro, NC, Jan. 18, 2010.
- <sup>135</sup> Rory Moore interview by R. Joseph Anderson and Orville R. Butler, San Diego, CA, Mar. 8, 2010.
- <sup>136</sup> Ron Ruth interview by R. Joseph Anderson and Orville R. Butler, Palo Alto, CA, Feb. 3, 2010.
- <sup>137</sup> Gil Travish interview by Orville R. Butler, Los Angeles, CA, Mar. 9, 2011.
- <sup>138</sup> Thomas Roberts interview, op. cit.
- <sup>139</sup> Thomas “Rock” Mackie interview by Orville R. Butler, Madison, WI, Dec. 13, 2010.
- <sup>140</sup> Carl Gulbrandsen, Stephanie Whitehorse, and Michael Falk interview by Orville R. Butler and R. Joseph Anderson, Madison, WI, Dec. 14, 2010.
- <sup>141</sup> Testimony from Neil D. Kane, president and cofounder, Advanced Diamond Technologies, Inc., to the US House of Representatives’ Subcommittee on Research and Science Education, Committee on Science and Technology Hearing: “From the Lab Bench to the Marketplace: Improving Technology Transfer,” Delivered June 10, 2010, p. 3.
- <sup>142</sup> Lowell Burnett interview by R. Joseph Anderson and Orville R. Butler, San Diego, CA, Mar. 7, 2011.
- <sup>143</sup> Reyad Sawafta interview, op. cit.
- <sup>144</sup> Richard Czerw interview by Orville R. Butler, Yadkinville, NC, Jan. 18, 2010.
- <sup>145</sup> Ningyi Luo and Lindsay Austin interview by Orville R. Butler, San Jose, CA, Feb. 2, 2010.
- <sup>146</sup> Stefan Murry interview by Orville R. Butler, Sugarland, TX, Mar. 24, 2011.
- <sup>147</sup> Maha Achour interview by R. Joseph Anderson and Orville R. Butler, San Diego, CA, Mar. 8, 2011.
- <sup>148</sup> Dileep Agnihotri interview by Orville R. Butler, Austin, TX, Mar. 23, 2011.
- <sup>149</sup> Tony Moretti interview by Orville R. Butler, Chicago, IL, Jan. 12, 2011.
- <sup>150</sup> Michael Anderson interview, op. cit.
- <sup>151</sup> Abdelhak Bensaoula interview, op. cit.
- <sup>152</sup> David Nolte interview by R. Joseph Anderson, West Lafayette, IN, Nov. 8, 2010.
- <sup>153</sup> Somesh Jha interview, op. cit.
- <sup>154</sup> Katerina Moloni, Skype interview by Orville R. Butler, Madison, WI, and College Park, MD, Dec. 10, 2010.
- <sup>155</sup> John Criscione and William Altman interview, op. cit.
- <sup>156</sup> Sung-Jin Park interview by Orville R. Butler, Champaign, IL, Jan. 11, 2011.
- <sup>157</sup> John Carlisle and Orlando Auciello interview, op. cit.
- <sup>158</sup> Ningyi Luo and Lindsay Austin interview, op. cit.
- <sup>159</sup> Philip Paul interview by R. Joseph Anderson and Orville R. Butler, Dublin, CA, Feb. 3, 2010; “AB SCIEX Acquires Eksigent Liquid Chromatography Business,” Reuters, Feb. 16, 2010, <http://www.reuters.com/article/2010/02/16/idUS166319+16-Feb-2010+BW20100216>.
- <sup>160</sup> Colleen Debaise and Scott Austin, “Sizing Up Promising Young Firms,” The Wall Street Journal, Mar. 9, 2010, <http://online.wsj.com/article/SB10001424052748703915204575104222702359984.html>.
- <sup>161</sup> James Vickers interview by R. Joseph Anderson and Orville R. Butler, Santa Clara, CA, Feb. 2, 2010.
- <sup>162</sup> Philip Mauger interview by Orville R. Butler, Santa Clara, CA, Feb. 2, 2010; Alex Shimkunas interview by R. Joseph Anderson, Santa Clara, CA, Feb. 2, 2010.

- <sup>163</sup> Katharine Ku interview by R. Joseph Anderson, Stanford University, Stanford, CA, Sept. 15, 2010.
- <sup>164</sup> Lita Nelsen interview, op. cit.
- <sup>165</sup> Yoel Fink interview by R. Joseph Anderson, Cambridge, MA, July 28, 2009.
- <sup>166</sup> Ron Reedy interview, op. cit.
- <sup>167</sup> Rory Moore interview, op. cit.
- <sup>168</sup> Philip Wyatt interview, op. cit.
- <sup>169</sup> Stefan Murry interview, op. cit.
- <sup>170</sup> Thompson Lin interview, op. cit.
- <sup>171</sup> Henrique Tono interview, op. cit.
- <sup>172</sup> "Energy Ventures Invests in Ingrain," Ingrain Press Release, Sept. 16, 2007, <http://www.ingrainrocks.com/files/212/>; "Ingrain Heads Toward Profitability After Rock-Solid Funding Round," Houston Business Journal, Oct. 19, 2008, <http://www.bizjournals.com/houston/stories/2008/10/20/story13.html?page=all>.
- <sup>173</sup> Henrique Tono interview, op. cit.
- <sup>174</sup> "Ingrain Closes Third Round of Funding, Ingrain News, Sept. 23, 2009, <http://www.ingrainrocks.com/news/ingrain-closes-third-round-of-funding/>.
- <sup>175</sup> Thomas "Rock" Mackie interview, op. cit.
- <sup>176</sup> John Carlisle and Orlando Auciello interview, op. cit.
- <sup>177</sup> John Eden telephone interview by Orville R. Butler, Jan. 14, 2011.
- <sup>178</sup> Philip Wyatt interview, op. cit.
- <sup>179</sup> Frank Levinson interview by R. Joseph Anderson and Orville R. Butler, Tiburon, CA, Feb. 1, 2010.
- <sup>180</sup> Stephen Wolfram telephone interview by Orville R. Butler, Cambridge, MA, and College Park, MD, Feb. 3, 2011.
- <sup>181</sup> Philip Mauger interview, op. cit.
- <sup>182</sup> Lowell Burnett interview, op. cit.; Newspaper reports at the time asserted that Quantum Magnetics employed about 85 people in San Diego; Catherine MacCrae Hockmuth, "GE acquires Quantum Magnetics," The Daily Transcript, Dec. 13, 2004, <http://www.sddt.com/News/article.cfm?SourceCode=20041213tbb>.
- <sup>183</sup> Matt Kim interview, op. cit.
- <sup>184</sup> Raul C. "Merc" Mercure interview by Orville R. Butler, Boulder, CO, Apr. 26, 2011.
- <sup>185</sup> Ron Ruth interview, op. cit.
- <sup>186</sup> Stefan Murry interview, op. cit.
- <sup>187</sup> Richard Selinfreund and Richard Gill interview, op. cit.
- <sup>188</sup> Herschel Workman, Dennis Friezel, and John Collins interview by Orville R. Butler, Bloomington, IN, Oct. 20, 2010.
- <sup>189</sup> David Kotlick interview by Orville R. Butler, West Lafayette, IN, Oct. 18, 2010.
- <sup>190</sup> Nick Nolte interview by R. Joseph Anderson, West Lafayette, IN, Nov. 8, 2010.
- <sup>191</sup> Matt Kim interview, op. cit.
- <sup>192</sup> Dileep Agnihotri interview, op. cit.
- <sup>193</sup> Dileep Agnihotri interview, op. cit.
- <sup>194</sup> Kal Ramnarayan interview, op. cit.
- <sup>195</sup> Rory Moore interview, op. cit.
- <sup>196</sup> Max Lagally interview by R. Joseph Anderson, Madison, WI, Dec. 13, 2010.
- <sup>197</sup> Kal Ramnarayan interview, op. cit.
- <sup>198</sup> Thompson Lin interview, op. cit.

- <sup>199</sup> Stefan Murry interview, op. cit.
- <sup>200</sup> Ningyi Luo and Lindsay Austin interview, op. cit.
- <sup>201</sup> Dileep Agnihotri interview, op. cit.
- <sup>202</sup> Ron Reedy interview, op. cit.
- <sup>203</sup> Jason Cleveland interview, op. cit.
- <sup>204</sup> Roger Proksch interview by R. Joseph Anderson, Santa Barbara, CA, Mar. 10, 2011.
- <sup>205</sup> Ron Reedy interview, op. cit.
- <sup>206</sup> Ibid.
- <sup>207</sup> Stuart Hall interview by R. Joseph Anderson, Billerica, MA, July 27, 2009.
- <sup>208</sup> Henry Kapteyn interview, op. cit.; Raul C. "Merc" Mercure interview, op. cit.
- <sup>209</sup> Yoel Fink interview, op. cit.
- <sup>210</sup> Abdelhak Bensaoula interview, op. cit.
- <sup>211</sup> Sally Hatcher interview, op. cit.
- <sup>212</sup> Peter Yancey and Jerry Cuomo interview by Orville R. Butler, Cary, NC, Jan. 19, 2010.
- <sup>213</sup> Robert Black interview, op. cit.
- <sup>214</sup> Dileep Agnihotri interview, op. cit.
- <sup>215</sup> Eric Buckland and Joe Izatt interview, op. cit.
- <sup>216</sup> Robert Bock, Clayton Kerce, and Steve Conover interview by R. Joseph Anderson, Atlanta, GA, Apr. 25, 2011.
- <sup>217</sup> Edward Conrad interview, op. cit.
- <sup>218</sup> Anonymous discussion with Orville R. Butler, Rochester, NY, Oct. 25, 2010.
- <sup>219</sup> Henry Kapteyn interview by Orville R. Butler, Boulder, CO, Apr. 25, 2011.
- <sup>220</sup> Ayla Annac interview, op. cit.
- <sup>221</sup> John Criscione and William Altman interview, op. cit.
- <sup>222</sup> John Ferraris interview, op. cit.
- <sup>223</sup> Stephen Fleming interview by R. Joseph Anderson, Atlanta, GA, Apr. 27, 2011.
- <sup>224</sup> Ibid.
- <sup>225</sup> Ibid.
- <sup>226</sup> Edward Conrad interview by R. Joseph Anderson, Atlanta, GA, Apr. 27, 2011.
- <sup>227</sup> Philip Paul interview by R. Joseph Anderson and Orville R. Butler, Dublin, CA, Feb. 3, 2010.
- <sup>228</sup> Nicholas Economou interview, op. cit.
- <sup>229</sup> Thompson Lin interview, op. cit.
- <sup>230</sup> Christopher Myatt interview, op. cit.
- <sup>231</sup> John Parker telephone interview by Orville R. Butler, Jan. 17, 2011.
- <sup>232</sup> Alex Shimkunas interview, op. cit.
- <sup>233</sup> Todd Ditmire interview, op. cit.
- <sup>234</sup> Eric Buckland interview, op. cit.
- <sup>235</sup> Tetsuro Wakatsuki interview, op. cit.
- <sup>236</sup> Henry Kapteyn interview, op. cit.
- <sup>237</sup> Bill O'Brien interview, op. cit.
- <sup>238</sup> Eric Buckland interview, op. cit.
- <sup>239</sup> Dan Stevenson interview, op. cit.
- <sup>240</sup> Dana Anderson interview, op. cit.
- <sup>241</sup> Stephen Wolfram interview, op. cit.

- <sup>242</sup> Peter Yancey and Jerry Cuomo interview, op. cit.
- <sup>243</sup> Jim Costales interview by Orville R. Butler, Billerica, MA, July 28, 2009.
- <sup>244</sup> Robert Ledoux interview, op. cit.
- <sup>245</sup> Dana Anderson interview, op. cit.
- <sup>246</sup> John Carlisle and Orlando Auciello interview, op. cit.
- <sup>247</sup> Michael Anderson interview, op. cit.
- <sup>248</sup> Yoel Fink interview, op. cit.
- <sup>249</sup> Nathan Myhrvold interview, op. cit.
- <sup>250</sup> Dileep Agnihotri interview, op. cit.
- <sup>251</sup> Eric Buckland interview, op. cit.
- <sup>252</sup> Stefan Murry interview, op. cit.
- <sup>253</sup> Stephen Wolfram interview, op. cit.
- <sup>254</sup> Henry Kapteyn interview, op. cit.
- <sup>255</sup> Bud Magera interview by Orville R. Butler, McMinnville, OR, Nov. 30, 2009.
- <sup>256</sup> Isaac Kohlberg interview by Orville R. Butler, Cambridge, MA, Sept. 30, 2010.
- <sup>257</sup> Katharine Ku interview, op. cit.
- <sup>258</sup> Ningyi Luo and Lindsay Austin interview, op. cit.
- <sup>259</sup> Michael Anderson interview, op. cit.
- <sup>260</sup> Salime Boucher interview, op. cit.
- <sup>261</sup> Anita Goel interview, op. cit.
- <sup>262</sup> Alex Murokh interview, op. cit.
- <sup>263</sup> Ibid.
- <sup>264</sup> Herschel Workman, Dennis Friezel, and John Collins interview, op. cit.
- <sup>265</sup> Ron Reedy interview, op. cit.
- <sup>266</sup> Ibid.
- <sup>267</sup> Ibid.
- <sup>268</sup> Thompson Lin interview, op. cit.
- <sup>269</sup> Mikael Martinez interview by Orville R. Butler, Austin, TX, Mar. 22, 2011.
- <sup>270</sup> Dana Anderson interview, op. cit.
- <sup>271</sup> Scott Davis interview, op. cit.
- <sup>272</sup> Darrell Conway interview by R. Joseph Anderson and Orville R. Butler, Tucson, AZ, Jan. 11, 2010.
- <sup>273</sup> Richard Czerw interview, op. cit.
- <sup>274</sup> Ron Reedy interview, op. cit.
- <sup>275</sup> Ibid.
- <sup>276</sup> Lita Nelsen interview, op. cit.
- <sup>277</sup> Robert Black interview, op. cit.

## *Appendix I: Table of Companies Visited*

Arizona		
Company	Year Founded	City
AdValue Photonics, Inc.	2006	Tucson
NP Photonics, Inc.	1998	Tucson
QuantTera, LLC	2004	Tempe
Thinking Systems, Inc.	2001	Tucson

Northern California		
Company	Year Founded	City
Eksigent	2000	Dublin
Evolved Machines, Inc.	2005	Palo Alto
Finisar Corporation	1988	Tiburon
Gemio Technologies, Inc.	2005	Palo Alto
IC Scope Research, Inc.	2002	San Jose
Lyncean Technologies, Inc.	2001	Palo Alto
Nanostructures, Inc.	1987	Santa Clara
Pacesetter Systems, Inc.	1965	Santa Clarita
Pacific Biosciences of California, Inc.	2004	Menlo Park
Pavilion Integration Corporation	2003	San Jose
tau-Metrix, Inc.	2002	Santa Clara

Southern California		
Company	Year Founded	City
Advanced Coherent Technologies, LLC	2006	San Diego
Asylum Research	1999	Santa Barbara
Peregrine Semiconductor Corporation	1990	San Diego
Quantum Magnetix	1987	San Diego
RadiaBeam Technologies, LLC	2003	Santa Monica
Rayspan Corporation	2006	San Diego
Sapient Discovery	2003	San Diego
Wyatt Technology Corporation	1982	Santa Barbara

Colorado		
Company	Year Founded	City
CDM Optics	1996	Boulder
ColdQuanta, Inc.	2007	Boulder
Kapteyn-Murnane Laboratories	1994	Boulder
mBio Diagnostics, Inc.	2009	Boulder
picoSpin	2010	Boulder
Precision Photonics Corporation	2000	Boulder
TriplePoint Physics	2009	Boulder
Vescent Photonics, Inc.	2002	Denver
WAVi Co.	2006	Boulder

Georgia		
Company	Year Founded	City
Advanced Technology & Research Corporation	1995	Marietta
Argos Intelligence, LLC	2009	Marietta
Graphene Works, Inc.	2008	Atlanta
United States Energetics, LLC	2009	Atlanta

Illinois		
Company	Year Founded	City
Advanced Diamond Technologies, Inc.	2003	Romeoville
Eden Park Illumination	2007	Champagne
Green Light Industries, Inc.	2007	West Chicago
Muons, Inc.	2002	Batavia
Nanophase Technologies Corporation	1989	Chicago
SA Ignite	2009	Chicago
Vega Wave Systems, Inc.	2001	West Chicago
Wolfram Research	1987	Champagne

Indiana		
Company	Year Founded	City
2k Corporation	1999	West Lafayette
Companion Diagnostics, Inc.	2002	Indianapolis
PartTec, Ltd.	2002	Bloomington
PathoChip, Inc.	2002	West Lafayette

Indiana (continued)		
Company	Year Founded	City
ProCure	2005	Bloomington
Quadraspec, Inc.	2004	West Lafayette
Snare2	2008	West Lafayette
Spherosense Technologies, Inc.	2006	Bloomington

Massachusetts		
Company	Year Founded	City
Alis Corporation	2005	Peabody
GMZ Energy	2006	Cambridge
Luminus Devices, Inc.	2002	Billerica
Nanobiosym	2004	Medford
NanoLab, Inc.	2000	Newton
OmniGuide, Inc.	2000	Cambridge
Passport Systems, Inc.	2002	Billerica
Solasta, Inc.	2006	Newton
WiTricity Corp.	2007	Watertown

North Carolina		
Company	Year Founded	City
AP Solutions, Inc.	2005	Carey
Bioptigen, Inc.	2004	Research Triangle Park
CivaTech Oncology	2006	Research Triangle Park
NanoTechLabs, Inc.	2004	Yadkinville
QuarTek Corporation	2004	Greensboro
siXis, Inc.	2008	Research Triangle Park
Triangle Polymer Technologies, Inc.	2004	Research Triangle Park

New York		
Company	Year Founded	City
Graphene Laboratories, Inc.	2009	Ronkonkoma

Oregon and Washington		
Company	Year Founded	City
Acclivity Photonics, Inc.	1996	Portland
Applied Physics Technologies, Inc.	1995	McMinnville

Oregon and Washington (continued)		
Company	Year Founded	City
FEI Company	1971	McMinnville
Intellectual Ventures	1999	Bellevue

Texas		
Company	Year Founded	City
Advanced Hydro, Inc.	2008	Austin
Applied Optoelectronics, Inc.	1997	Sugarland
CorInnova, Inc.	2004	Dallas
Graphene Energy, Inc.	2008	Austin
Infochimps	2009	Austin
Ingrain, Inc.	2007	Houston
Integrated Micro Sensors, Inc.	2003	Houston
National Energetics	2010	Austin
Paragon Science, Inc.	2002	Austin
Solarno, Inc.	2005	Richardson

Wisconsin		
Company	Year Founded	City
InvivoSciences, Inc.	2001	Madison
Mad City Labs, Inc.	1999	Madison
NovaShield, Inc.	2006	Middleton
nPoint, Inc.	1997	Madison
Phoenix Nuclear Labs	2005	Madison
Quantum Fields, LLC	1997	Richland Center
SonoPlot, Inc.	2003	Madison
TomoTherapy, Inc.	1997	Madison

## Appendix II: State Funding for High-Tech Entrepreneurship

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
Alabama	None identified.	None identified.	None identified.	None identified.	
Alaska	Grants up to \$5000 to assist SBIR/STTR Phase I proposal preparation.	None identified.	\$15,000 to firms with Phase I to prepare Phase II proposal	None identified.	
Arizona	None identified.	None identified.	None identified.	None identified	The Arizona Angel Investment Tax Credits program provides tax credits to investors who make capital investment in small businesses certified by the Arizona Commerce Authority (ACA). Set to expire June 30, 2016. Enhancement of the R&D Tax credit Program now offers up to a 34 percent income tax credit for R&D made in conjunction with an Arizona public University.
Arkansas	Some sources say there are some funds available, but we did not find a state phase 0 source	None identified.	None identified.	None identified.	An eligible business that contracts with one or more Arkansas colleges or universities in performing research may qualify for a 33 percent income tax credit for qualified research expenditures. In-house R&D credits 20% of R&D expenditures exceeding the base year, for a period of three years and incremental increase in qualified research for the succeeding two years. Can offset 100 percent of businesses state income tax liability. R&D in an area of "strategic value, can obtain an income tax credit equal to 33 percent of qualified research expenditures up to \$50,000/year. Arkansas also has an equity investment tax credit equal to 33.33 percent of the amount invested in an eligible business. Credit can offset up to 50 percent of investor's Arkansas income tax liability and unused credit may be carried forward for nine years
California	None identified.	None identified.	None identified	None identified	California has a variety of regional Small Business Development Loan Funds. See for example <a href="http://sdelta.toolsforbusiness.info/california/2b/funding/toolkit/">http://sdelta.toolsforbusiness.info/california/2b/funding/toolkit/</a> 15 percent R&D tax credit against corporate tax liability for qualified in-house research and 24% credit for basic research payments to outside organizations where the research is conducted in California.

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
Colorado	None identified but a 2013 Brookings Institution Report recommended the establishment of a Phase 0 program in Colorado	Colorado HB1060, signed into law in 2007, provides \$2 million in state funds to be awarded to bioscience and biofuels companies that license or option university bioscience IP. Companies must have received a Phase I SBIR/STTR award. Funding to each company must not exceed \$100,000.	None identified.	None identified.	Colorado Enterprise Fund provides loans from \$1,000 to \$250,000 to startups not able to receive bank financing
Connecticut	None identified.	SBIR Phase I Matching Grant initiative, managed by Connecticut Innovations, is designed to help recent Connecticut SBIR Phase I winners advance their federal Phase I feasibility studies to million-dollar Phase II research awards.	Grants are designed to help bridge the funding gap between Phase I and subsequent awards and enhance companies' chances of winning a Phase II. Subcontracting with a Connecticut research university may increase the state funding by \$10,000 above the base award, in order to fund the direct costs of the university effort.	COMMERCIALIZATION LOANS Initiative, also managed by Connecticut Innovations, offers commercialization loans to winners of SBIR Phase II or Other Significant Federal R&D Funding. These loans are meant to accelerate commercialization of new technologies and innovations developed by companies that have recently won Phase II SBIR/STTR OR other significant federal R&D funding and to remove roadblocks to revenue generation.	Connecticut Pre-Seed Fund provides loans of up to \$150,000 that must have a 50 percent match from private sources. Eli Whitney Fund invests up to \$1 million in early stage funding. Connecticut R&D tax credits equal to 20 percent of R&D expenditures in Connecticut exceeding those of prior taxable year. Credits can be carried forward and for companies with income less than \$70 million can be sold to the state for 65 percent of their value. Connecticut-based businesses with less than 100 employees are eligible for loans and lines of credit of up to \$500,000.
Delaware	\$10,000 seed grants to research and develop SBIR/STTR Proposals	None identified.	Delaware provides SBIR Bridge grants and loans as part of its Delaware Strategic Fund program.	None identified	

Florida	Professional Assessment and potential Award up to \$3,000 to improve proposal.	Florida's Commercialization Matching Grant Program competitively funds companies receive both Phase I and Phase II SBIR/STTR grants.	None identified	Florida High Tech Corridor Council provides some matching grants to companies in its high tech corridor.	Florida's Seed Capital Accelerator program provides loans from \$50,000 to \$300,000 to qualified Florida companies using technology developed by a university, college or research institution in the State of Florida.
Georgia	SBIR Georgia, an ATDC program, assists Georgia's technology companies in applying for SBIR/STTR awards. No direct funding appears to be a part of the program.	None identified.	None identified	None identified	Georgia companies may claim a 10 percent R&D tax credit on increased R&D expenses over a calculated base. credit is applied to 50 percent of the company's net GA income tax liability after all other credits have been applied. Unused credits can be carried forward 10 years. Georgia has an Angel Investor Tax Credit but the investor must get approval before claiming the credit. Through One Georgia Authority, Georgia provides loan guarantees in specified communities for loans between \$35,000 and \$250,000 but require a 10 percent cash equity injection by the borrower.
Hawaii	Up to \$3,000 to Hawaiian companies submitting Phase I SBIR applications	Hawaii-based companies that receive Phase I SBIR awards can apply for funds from High Technology Development Corporation Matching Grant program. The matching grants provide up to 50% of the Phase I award, though awards of more than \$25,000 are not likely.	None identified.	None identified.	

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
Idaho	Phase 0 Matching Grant Program assists Idaho small businesses by providing funds for SBIR/STTR proposal preparation. Upon successful review and award, timelines and deliverables will be negotiated for each specific Phase 0 award and a grant contract prepared with Idaho Commerce.	None identified.	None identified.	None identified.	Businesses conducting qualified research may earn a 5 percent income tax credit that may be carried forward up to 14 years.
Illinois	Illinois had a phase 0 type program, funded through 2010, managed through the University of Illinois. The program does not appear to be currently funded	The Illinois Department of Commerce and Economic Opportunity (DCEO) will match up to fifty-percent of the grant funds awarded through the federal SBIR or STTR Phase I grant or contract. The DCEO will issue a letter of support for eligible Illinois businesses that submit grant applications.	None identified	None identified.	An Angel Investment Credit Program offers a tax credit of 25 percent of up to a \$2 million investment made by an angel.

Indiana	Indiana implemented a phase 0 program through its Indiana University Research & Technology Corporation in 2005. However we found no web discussion of their program recently.	As of May 2012 Indiana's 21st Century Fund has less than half as much funding now as it did in 2008—and no longer offered matching grants for firms that win SBIR/STTR grants.	None Identified.	As of May, 2012 Indiana's 21st Century Fund has less than half as much funding now as it did in 2008—and no longer offered matching grants for firms that win SBIR/STTR grants.	Indiana's \$200 filing fee for venture capital eliminated until June 30, 2013. The VCI tax credit cap raised from \$500,000 to \$1 million for VC investments in Indiana firms. administered by the Indiana Department of Revenue, it provides a credit against state tax liability for qualified company research expenses and is based on the increase in Indiana R&D over the prior three-year base. In the base year, research expenses must have been at least half of the research expenses in the current year. The credit equals 15 percent of qualified research expenses on the first \$1 million of investment. Applied against income tax liability the credit may be carried forward 10 years. Sales tax exemption ineligible R&D equipment purchased after June 30, 2007.
---------	---	--	------------------	---	---

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
Iowa	<p>The Iowa Innovation Corporation has a contract with Solix Grant Management Solutions to provide pre-proposal reviews for Phase I/II. The cost for this service ranges from \$1,450 - \$1,700 with no cash match required (100% grant). Professional grant writing services from a third party vendor for SBIR/STTR Phase I and II applications. \$1 cash match required for every \$2 of requested program funds. The Innovation Corporation also has a contract with Solix Grant Management Solutions to provide professional grant administration coaching for Phase I awards. The cost for this service is \$10,000 with \$1 cash match required for every \$3 of program funds (\$2,500 applicant/\$7,500 program funds).</p>	None identified.	None identified.	None identified.	<p>Iowa PROPEL provides seed capital of up to \$500,000 or 50 percent of a projects cost in the form of low interest loans or royalty agreements . Iowa Launch program provides up to \$100,000 or 50% of total costs to startups able to match funding dollar for dollar using private sources. Iowa Demonstration Fund provides awards up to \$150,000 to encourage commercialization activities to small and medium sized Iowa companies in advanced manufacturing, biosciences and information technology. Iowa Research Activities Tax Credit: Iowa's research credit is an incremental credit, which means only research expenditures that exceed a base amount are eligible. In addition to the Research Activities Tax Credit, companies can also be awarded the Supplemental Research Activities Tax credit by the Iowa Economic Development authority. Although Research Activities Tax Credits are only applicable to qualifying business research expenditures, individuals with ownership interests in pass-through entities such as limited liability companies, S corporations, and partnerships may qualify to claim a portion of the credits earned by one or more businesses. Both the Research Activities Tax Credit and the Supplemental Research Activities Tax Credit are refundable, which means the taxpayer can claim the entire credit even if the claim exceeds current year tax liability.</p>

Kansas	Any existing programs appear to have been eliminated by Governor Brownback's elimination of the Kansas Technology Enterprise Corp. in 2011.	Funding was available to match SBIR awards up to 50 percent proportionate to the amount of work performed in Kansas. Program was dismantled in 2011.	Kansas had some form of Bridge grants until 2011 when the program was dismantled.	Funding was available to match SBIR awards up to 50 percent proportionate to the amount of work performed in Kansas. Program was dismantled in 2011.	A Kansas income tax credit equal to 6.5 percent of a company's investment in R&D above the average expenditure of the previous three year period. 25 percent of the allowable annual credit may be claimed in any one year. Until 2011 Kansas had an angel tax credit and a direct investment program that was dismantled as a part of Governor Brownback's program to eliminate Kansas Technology Enterprise Corp.
Kentucky	A maximum of \$4,000 may be awarded for the first Phase I proposal and up to \$2,000 for each additional Phase I proposal in one calendar year. Phase II proposals can be awarded the same amounts but \$1,000 of the phase II award is designated to pay an external service provider to review the final draft.	The Kentucky SBIR/STTR Matching Funds Program provides matching funds up to \$150,000 for Phase I to Kentucky startups or startups willing to relocate to Kentucky within 90 days	Kentucky sees its matching grant program as, in part, a mechanism to bridge the funding gap between Phase I and Phase II awards. However it administers no separate bridge grant program	The Kentucky SBIR/STTR Matching Funds Program provides matching funds up to \$500,000 for Kentucky companies receiving Phase II SBIR grants or Phase II recipients willing to relocate to Kentucky within 90 days.	Kentucky has a variety of seed capital funds for investment in companies including the Kentucky New Energy Ventures Fund, the Incentives for Energy Independence Act, Commonwealth Seed Capital, LLC and Kentucky Enterprise fund and rural Innovation Fund.
Louisiana	Up to \$2,500 to Louisiana business submitting a Phase I/II proposal	Louisiana's R&D tax credit provides a refundable credit of up to 40 percent to businesses that conduct R&D activities in the state or secure federal SBIR/STTR grants.	None Identified	Louisiana's R&D Tax credit provides a refundable credit of up to 40 percent to businesses that conduct R&D activities in the state or secure federal SBIR/STTR grants.	Companies whose credits exceed tax liabilities receive a refund. Louisiana's Angel Investor Tax Credit provides up to a 35 percent tax credit for individual investors who invest in early stage businesses. Louisiana's Technology Commercialization Credit provides a 40 percent refundable tax credit for companies investing in the commercialization of Louisiana Technology and a 6 percent payroll rebate for the creation of new jobs.

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
Maine	Up to \$5,000 in "TechStart" grants per proposal available to a Maine firm submitting a Phase I/II proposal. Each grant requires a 1:1 match consisting of actual cash, salaries, staff time, or equipment directly attributable to the proposed project.	None identified.	None identified.	None identified.	Maine Technology Institute Seed Grants of up to \$25,000 to support early-stage research and development activities for new products and services that lead to the market. Funded activities may include activities such as proof of concept work, prototype development, field trials, prototype testing, pilot studies, or technology transfer activities. SMALL ENTERPRISE GROWTH FUND is a \$9 million fund providing venture capital exclusively to Maine companies. Maine's Seed Capital tax Credit Program may authorize State income tax credits for up to 60 percent of the cash equity investors provide to eligible Maine businesses. Investments may fund fixed assets, research or working capital. Maine's Economic Development Venture Capital Revolving Investment Program allows the state to invest as an equal partner in eligible private VC funds that are investing in emerging and early-growth businesses in Maine. There is a maximum of \$1 million state investment per fund.
Maryland	None identified.	None identified.	Maryland efforts to establish a Maryland Biotech SBIR/STTR bridge fund failed in both the 2011 and 2012 legislatures.	None identified	Maryland Technology Development Corporation (TedCo) offers a variety of funding and loan programs including up to \$15,000 to license IP from a qualified Maryland University. Maryland also has a Maryland Technology Transfer and Commercialization Fund for up to \$75,000 seed funding for Maryland startups. <a href="http://tedco.md/">http://tedco.md/</a> Maryland also provides grants to private enterprises in the state working with universities in the state. Maryland also has a variety of investment funds including Invest Maryland, Maryland Venture Fund and Maryland Challenge Investment Program. Businesses that incur qualified research and development expenses for cellulosic ethanol technology in Maryland are entitled to a tax credit. The total credits for all businesses may not exceed \$250,000 per year. This credit is available for tax years between December 31, 2007 and January 1, 2017. The credit may be taken against corporate or personal income tax. Businesses that incur qualified R&D expenses in Maryland are entitled to a tax credit but the total credits for all businesses may not exceed \$5 million per year.

Massachusetts	None identified.	MassVentures SBIR Targeted Technologies "START" Program provides funding to up to 10 Massachusetts firms each year who have received phase II grants. It grants #100,000 each to 10 applicants in the first year. Five of those receive up to \$200,000 in the second year and two of the companies receive a \$500,000 grant in the third year of the START Program.	None identified	Massachusetts provides "matching" support capped at \$500,000 per company to Phase II or Post Phase II SBIR/STTR grants which applicant companies have already received. MassVentures SBIR Targeted Technologies "START" Program provides funding to up to 10 Massachusetts firms each year who have received phase II grants. It grants \$100,000 each to 10 applicants in the first year. Five of those receive up to \$200,000 in the second year and two of the companies receive a \$500,000 grant in the third year of the START Program.	Massachusetts offers a 3 percent investment tax credit for qualifying businesses against their Massachusetts corporate excise tax. Massachusetts offers an R&D tax credit similar to the federal credit program but offering qualifying Massachusetts companies advantages for doing business in the state. Massachusetts Emerging Technology Fund offers loans or loan participations up to \$2.5 million and loan guarantees up to \$1 million to high-tech firms starting or expanding manufacturing in Massachusetts. Massachusetts Cooperative Research Grants of up to \$250,000 per year for up to three years at universities working on scientific discoveries with medical applications. The industry partner must provide a dollar for dollar match. Massachusetts has a Life Sciences Accelerator providing up to \$750,000 to early-stage life science companies to leverage additional sources of capital.
Michigan	None identified.	Up to \$25,000 for matching 25% of SBIR/STTR Phase I grant.	None identified.	Up to \$25,000 for matching 25% of SBIR/STTR Phase II grant.	In conjunction with Michigan law firms and the Small Business Technology Development Center, the Michigan Economic Development Commission makes available pro bono services on patents, trademark and copyright law.
Minnesota	None Identified	None identified.	None identified.	None identified.	Minnesota Angel Tax Credit offers incentives to angels and investment funds that put money into emerging Minnesota companies focused on high technology or new proprietary technology. Individuals, partnerships, S-corporations and LLCs may claim an R&D tax credit of 10 percent, up to the first \$2 million in eligible expenses and 2.5 percent for greater eligible R&D expenses.

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
Mississippi	Phase 0 projects are awarded up to the following amounts: Research to acquire preliminary data \$2,500, Phase I SBIR/STTR proposal preparation assistance \$1,500. Maximum total grant (using a combination of the two categories) \$3,000	None identified.	None identified.	None identified.	Mississippi R&D Skills Tax Credit of \$1,000 per R&D employee per year for a five year period. Mississippi R&D Loan Program provides loans to qualified companies. Companies must have at least 10 percent of the workers be scientists, engineers or computer specialists and the average wages at the facility must be at least 150 percent of state average wage.
Missouri	Missouri Technology Incentive Program (MOTIP) grants up to \$5000 to Missouri companies to help prepare a Phase I SBIR proposal.	None identified.	None identified.	Missouri Small Business Technology Development Centers provide assistance in preparing SBIR/STTR applications and in managing the commercialization process to SBIR/STTR awarded companies. No monetary grants were identified.	Missouri Technology Corporation provides a variety of investment funds and loans drawing on their Innovation Development and Entrepreneurship Advancement (IDEA) Fund. Awards include the maximum \$100,000 TechLaunch grants, the maximum \$500,000 Seed Capital Co-Investment awards made in the form of equity or convertible debt, the maximum \$2.5 Million Venture Capital Co-Investment awards given in the form of equity or convertible debt, the maximum \$3 Million High-Tech Industrial Expansion awards in the form of secured low-interest loans and the maximum \$500,000 Missouri Building Entrepreneurial Capacity awards.
Montana	Up to \$5,000 for a Montana company submitting a Phase I Proposal	Montana's SBIR/STTR matching grants appear to serve the purpose of Bridge grants.	Montana SBIR/STTR Matching Funds Program (MSMFP) grants funds to Montana Companies awarded SBIR/STTR Phase I awards and intend to apply for Phase II awards. Grants are limited to a maximum of \$30,000.	None identified but it may be possible to apply for an MSMFP grant to further commercialization of a Phase II grant.	Montana has a variety of grant programs including the Montana Technology Innovation Partnership grants, Research and Commercialization Grants and the Big Sky Trust Fund.

Nebraska	Up to \$5,000 for a Nebraska company submitting a Phase I Proposal. No firm may receive more than one such grant every two years.	Competitive program approved under Nebraska LB 387 in 2011 which potentially matches up to 65 percent of federal Phase I grants.	If a large manufacturing company wants to work with an SBIR company and will pay them \$50k for that relationship, then the State of Nebraska will match the \$50k.	Competitive option to provide up to \$400,000 to successful recipients of SBIR phase II grants approved under Nebraska LB 387 in 2011	Nebraska's Business Innovation Act, recently passed intends to provide competitive grants for research at Nebraska institutions, new product development and testing as well as expand small business outreach efforts. It will provide targeted industries with matching funds for prototype development, commercialization and applied research in Nebraska. Nebraska Angel Investment Tax Credit provides refundable income tax credits to investors in qualified early stage companies. Capped at \$2 million, it requires at least \$25,000 investment for individuals and \$50,000 for investment funds investing in businesses with less than 25 employees. Nebraska has a variety of loans and grants including the Nebraska Progress Loan Fund (NPLF), Nebraska Progress Seed Fund (NPSF), and the Nebraska Microenterprise Partnership Fund.
Nevada	None identified. Nevada failed to raise funds for a proposed Phase 0 prior to 2008. Nevada Small Business Development Center provides no monetary assistance in the development of SBIR/STTR proposals.	None identified.	None identified.	None identified.	Partial abatement of sales tax, modified business tax and personal property tax is available to intellectual property development companies who locate or expand their business in Nevada. Applicant must apply not more than one year before the business begins to develop for expansion or operation. Investment must exceed \$500,000
New Hampshire	None identified.	None identified.	None identified.	None identified.	New Hampshire R&D tax credit of up to \$50,000 for qualified businesses for new R&D costs. Credit may be carried forward up to 5 years. New Hampshire's Granite State Technology Innovation Grant provides matching funds designed to expand research activities involving industry/academia collaboration.

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
New Jersey	None identified.	None identified.	Bridge Grant Program awards \$50,000 grants to entrepreneurs who have both applied for Phase II funding and been identified as potential Phase II SBIR/STTR awardees.	None identified.	New Jersey's Edison Innovation Angel Growth Fund leverages private angel investors supporting emerging technology businesses. An angel supported NJ technology company with 12 month commercial revenues of \$500,000 in its core business activities can apply for growth capital of up to \$250,000. The Edison Innovation R&D Fund awards funds for proof-of-concept research to New Jersey technology companies. Supplemental financing is available for non-project specific costs not covered by the grant. The Commission on Science and Technology will award grants to New Jersey Companies in the amounts of \$100,000 to \$500,000. Companies awarded the Edison Innovation R&D fund can apply for and receive up to 20% of the approved NJCST grant (No more than \$100,000 in equity-like funding for non-R&D related costs. Other New Jersey funds include the Edison Innovation Clean Energy Fund, Edison Innovation Centers of Excellence Federal Matching Program and the University Intellectual Property Program
New Mexico	None identified.	None identified.	None identified.	None identified.	New Mexico extended its R&D tax credit from 2011 to 2015. Technology Ventures Corporation, a 501c3 nonprofit created by Lockheed Martin, provides SBIR training programs for New Mexico firms.

New York	No statewide programs identified but at least two regional programs providing grants up to \$2,000 for energy proposals in Western NY and up to \$2,500 for companies in the Finger Lakes region submitting Phase I proposals.	CUNY offers \$1,000 summer salary reimbursement to faculty involved as PI on SBIR Phase I applications. A second \$1,000 is available if the award is granted. Sponsored Research Agreement funded from the award to small NY businesses will be eligible for consideration for matching funding from the CUNY CAT ("CAT Match") that may be above and beyond the standard matching level. CUNY CAT provides matching funds for qualified projects	None identified.	CUNY offers \$1000 summer salary reimbursement to faculty involved as PI on SBIR Phase I applications. A second \$1000 is available if the award is granted. Sponsored Research Agreement funded from the award to small NY businesses will be eligible for consideration for matching funding from the CUNY CAT ("CAT Match") that may be above and beyond the standard matching level. CUNY CAT provides matching funds for qualified projects	New York Science, Technology & Academic Research provides a wide variety of specialized research and development centers including regional SBIR proposal assistance centers throughout the state.
North Carolina	One North Carolina Phase 1 Incentive Funds Program reimburses qualified NC businesses for a portion of costs incurred in preparing and submitting Phase I SBIR proposals	The One North Carolina SBIR/STTR Phase I Matching Funds Program: between 2006 and 2010 North Carolina's SBIR matching grant program provided up to \$100,000 to North Carolina companies that received Phase I SBIR awards from the federal government. In 2010-2011 the award provided a maximum of 50% of the Federal SBIR/STTR award, not exceeding \$30,000.	None Identified	At least one state web page suggests the state matches Phase II grants. Cf: <a href="http://www.thrivenc.com/incen-tives/financial/discretionary-programs/small-business-technology-funding">http://www.thrivenc.com/incen-tives/financial/discretionary-programs/small-business-technology-funding</a>	North Carolina administers a Green Business Fund and an Energy R&D Cost-Sharing Program both of which are frequently over subscribed. Businesses with qualified North Carolina research expenses are allowed a tax credit equal to a percentage of those expenses. Small business with annual receipts less than \$1 million are allowed a 3.25 percent credit. Research performed in a "tier 1 county" gets a 3.25 percent credit. Other research with qualified expenses less than \$50 million gets a credit of 1.25 percent, between \$50 and \$200 million, 2.25 percent and more than \$200 million 3.25 percent. Businesses with North Carolina university research expenses get a credit equal to 20 percent of those expenses.

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
North Dakota	Up to \$1,500 for North Dakota Companies submitting proposals.	None identified.	None identified.	None identified.	North Dakota permits a credit equal to 45 percent of an angel investment or investment in an angel fund up to \$45,000 per year. Unused credit may be carried forward up to 7 years. Credits based on investments after January 1, 2011 cannot exceed \$150,000. A research expense credit of 25 percent for the first \$100,000 of excess expenses over the base for a year. If qualified research begins in 2007 through 2010 the rate is 20 percent for over \$100,000 and 18 percent for 2010 through 2016. After 2016 the rate for R&D exceeding \$100,000 is 8 percent.
Ohio	None statewide but University of Toledo has a \$8,000 Phase 0 grant for faculty collaborating with small businesses in submitting proposals.	None identified.	None identified.	None identified.	Ohio provides a nonrefundable tax credit against the corporate franchise tax equal to 7 percent of qualified research expenses above the base. Some relevant funds include Innovation Ohio Loan Fund, and Invest Ohio. Ohio also has an R&D investment loan fund providing below market loans of between \$1 million and \$5 million for projects engaging in R&D activity. Companies receive a dollar-for-dollar non-refundable commercial activity tax credit for principal and interest payment during the year. Ohio sales taxes are exempted for purchases of R&D equipment. Ohio offers a tax credit of 25 percent of an investment of up to \$250,000 in Ohio-based technology companies. Credit may be claimed against income tax, corporate franchise tax, public utility excise tax or intangibles tax. Ohio also has a few innovation investment funds. Ohio has a wide variety of investment funds that it seems to change frequently. Cf. <a href="http://development.ohio.gov/">http://development.ohio.gov/</a>

Oklahoma	As of December 5, 2011, funding was no longer available for OCAST's SBIR/STTR incentive funding program. OCAST previously offered 50% of the proposal costs up to \$3,000 for an Oklahoma company submitting a SBIR Phase I proposal and \$5,000 for an STTR Phase I proposal.	None identified.	As of December 5, 2011, funding was no longer available for OCAST's SBIR/STTR incentive funding program eliminating its previous bridge funding program. Previously it provided 50 percent of the SBIR/STTR award up to a maximum of \$25,000.	None identified.	
Oregon	Match the applicant's contribution (1:1) for one of three eligible expenditures: (1) a proposal writing consultant (up to \$3,000 of matching funds); (2) a proposal review consultant (up to \$500 matching funds); or (3) attendance at a qualified SBIR/STTR conference (up to \$500)	None identified.	No SBIR bridge grants but Oregon Signature Research Centers provide "valley of death" grants."	None identified.	Oregon has a corporate tax credit for qualified research conducted in Oregon that is a state-level extension of federal R&D tax credits. Oregon's Entrepreneurial Development Loan Fund provides up to \$50,000 at 2 percent APR amortized over 5 years. Corporate tax credit for qualified research and basic research conducted in Oregon, as a state-level extension of federal R&D tax credits. Oregon Inc. has created three Signature Research Centers that provide gap grants of up to \$250,000 to help start-ups through the "valley of death" stage and provide matching grants and expertise in application for SBIR grants and private foundation funds.

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
Pennsylvania	A maximum of \$4,000 may be awarded for the first Phase I proposal and up to \$2,000 for each additional Phase I proposal in one calendar year. Phase II proposals can be awarded the same amounts but \$1,000 of the phase 0 award is designated to pay for an external review.	The Pittsburgh Technology Council has been advocating a SBIR Phase I matching grant program since 2001, but legislation does not appear to have passed.	None identified.	None identified.	Programs include the Ben Franklin Technology Development Authority (BFTDA) Venture Investment Program, Technology Development Grant and Alternative Energy Development Program. Pennsylvania's Innovation Grant of up to \$100,000 to encourage tech transfer and commercialization of intellectual property requires a dollar-for-dollar match from private funds.
Rhode Island	A Phase 0 program was proposed to the state legislature in 2013 but apparently not passed.	State Sen. James Sheehan proposed a matching grant program last year, but the proposal was held for further study.	None identified.	None identified.	Rhode Island Innovation Tax Credit of up to 50 percent with a maximum credit of \$100,000. Credit may be carried forward for up to three years and companies must apply for the credit prior to making investment. A 22.5 percent R&D tax credit for increases in qualified research above base period. If expenditures above base exceed 111,111 credit is 16.9 percent of excess. Credit can be carried forward up to 7 years. An R&D property credit of 10 percent for cost of construction or acquisition of property used for R&D Unused credit may be carried forward up to 7 years. A one year write-off for R&D property is allowed in lieu of depreciation or investment tax credit. R&D costs are exempted from RI sales tax.

South Carolina	Seed grants (up to \$6,000 per proposal) to small businesses seeking SBIR and STTR support.	In 2007 South Carolina began its SBIR/STTR Phase I matching grant program maximum grant amount: 50 percent of the Federal SBIR/STTR Program Phase I award, not to exceed \$50,000. Total annual expenditure for program limited to \$750,000.	South Carolina describes its Phase I matching grant as a bridge grant between the Phase I and Phase II awards.	None identified	A credit equal to 5 percent of the taxpayer's qualified research expenses in the state. The credit taken in any one taxable year may not exceed 50 percent of the company's remaining tax liability after all other credits have been applied. Unused credit can be carried forward for 10 years. South Carolina Launch provides Grant Funding, University Start-up Assistance as well as loan and equity investments.
South Dakota	None identified	None identified.	None identified	None identified	
Tennessee	Launch Tennessee contracts with Grow Emerging Companies for grant support consultation at no cost to the SBIR applicants as a part of its Phase 0/Phase 00 programs for SBIR/STTR Phase I and Phase II applications. Previously the Tennessee Technology Development Corporation provided grants of \$4,000 to provide assistance in SBIR/STTR Phase I and Phase II applications	None identified.	None identified	None identified	Tennessee INCITE Co-Investment Fund invests along with private sector in Tennessee-based startups.
Texas	None identified	Texas Emerging Technology fund is apparently preparing a matching grant program that may include SBIR/STTR matching grants	None identified	Texas Emerging Technology fund is apparently preparing a matching grant program that may include SBIR/STTR matching grants	Created in 2005 Texas Emerging Technology fund provides Commercialization Awards, Matching Awards from university, government grant and industry programs .

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
Utah	USTAR provides fee based proposal writing assistance through its SBIR-STTR Assistance Center.	None identified.	None identified	None identified	Utah Life Science and Technology Tax Credits provide investors in a Utah life science company a non-refundable capital gains tax credit of 5 percent of capital gains after holding the investment for at least two years. Life science and technology companies generating new state revenues are eligible for a post-performance refundable tax credit of up to the amount of new state revenues generated over three years.
Vermont	Vermont provides up to \$15,000 to Vermont companies to help them apply for SBIR/STTR Phase I/Phase II grants	None identified.	None identified.	None identified.	Vermont Technology Loan Program provides up to \$250,000 in loans to companies whose major activity is technology based goods and services. Vermont Science, Technology and Mathematics (STEM) Incentive pays new hires at Vermont companies \$1500 cash for each year they are employed up to five years at a STEM company. The money is taxable income.
Virginia	Unidentified funding through the Center for Innovative Technology for Virginia-based tech firms. Also has low cost proposal training as part of CIT's Federal Funding Assistance Program.	Beginning in 2011 Virginia established an SBIR matching grant program for Phase I grants	None identified.	None identified.	CIT's GAP Fund provides up to \$100,000 in convertible debt and bridge loans to technology companies needing assistance between "family and friends" and "angel investment". Virginia's R&D tax credit provides a 15 percent refundable credit for qualified research and 20 percent for research conducted in collaboration with a Virginia university

Washington	Washington phase 0 pilot program initiated in 2010. In December 2012 Innovate Washington Launched a modified phase 0 program. Also the Washington Biotechnology & Biomedical Association (WBBA)'s SBIR/STTR Match Program matches each selected company with an intern paid by the WBBA- a current graduate student or postdoctoral fellow - who will assist the company with the preparation and writing of an SBIR/STTR grant to be submitted in 2013.	None identified.	None identified but some studies recommended the state implement a bridge grant program.	None identified.	Innovate Washington provides "Investing in Innovation Grants" to help startups with projects that show strong potential for long-term economic impact in the state. It's Washington Bridge Fund invests in emerging technology companies during transition from seed stage and early stage. Washington provides a High Technology B&O tax credit for R&D spending.
West Virginia	The West Virginia Small Business Development Center offers a WVSBDC Research and Commercialization Assistance grant of \$5,000 to help offset costs associated with SBIR/STTR proposals. In special situations consideration may be given to Phase II proposals	None identified.	None identified.	None identified.	West Virginia's Commercial Patent Incentives Tax Credit can offset up to 100 percent of the business franchise tax, corporation net income tax or personal income tax. Credit is based on a percentage of royalties, license fees and other considerations. West Virginia also has a High-Tech manufacturing credit, a High-Technology Business Property Valuation act and a Strategic R&D credit that can offset up to 100 percent of corporate net income tax and business franchise tax. An R&D sales tax exemption for property and services used in R&D

State	Phase 0 SBIR Grants	Phase I SBIR Matching Grants	Phase I/II SBIR Bridge Grants	Phase II SBIR Matching Grants	Other
Wisconsin	Wisconsin Center for Technology Commercialization offers micro-grants of up to \$4,000 per SBIR/STTR proposal, up to \$8,000 per company for Phase I and Phase II proposals	None identified.	None identified.	None identified.	Wisconsin's Technology Development Fund helps business finance early phase product development research. Firms completing research phase can receive product-commercialization funding. Angel investors can claim up to 25 percent of the investment as an income tax credit. Wisconsin also has an early stage seed investment credit.
Wyoming	Up to \$5,000 for a Wyoming firm submitting a Phase I proposal. A similar Phase 00 grant is available for Phase II proposals.	None identified.	None identified.	None identified.	



