Resource Allocation in Applications Research:

Challenges and Strategies of Small Technology Developing Companies

by

Jacob v.R. Pretorius

B.S. Mechanical Engineering (1993)
University of Stellenbosch

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Signature of Author_____

Jacob V.R. Pretorius
System Design and Management Program
February 2003

Certified by _____

Professor Chris Magee
Thesis Supervisor
Center for Innovation and Product Development

Accepted by_____

Tomas J. Allen
Co-Director, LFM/SDM
Howard W. Johnson Professor of Management

Accepted by_____

David Simchi-Levi
Co-Director, LFM/SDM
Professor of Engineering Systems

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Abstract

This is a study into the allocation of resources in the early stages of research in a small commercial entity that develops innovative technologies. The premise is that resource allocation must focus on the implementation of the technology from a broad, end-to-end, systems viewpoint rather than purely on the inventive or scientific research. Only by understanding and addressing issues early in a development process can technology be efficiently developed.

This thesis examines in depth the approach to the development of technologies taken by eight small innovative research companies in the New England Area. These companies all received funding through the government's Small Business Innovative Research program. Half of the companies received additional funding from external entities and qualified for Fast Track funding from the Department of Defense.

The study was conducted by means of a questionnaire and in person interviews to identify how companies identify, evaluate and allocate resources to challenges. The strategies that were followed, problems encountered, collaborations with other entities and the outcomes of their programs were examined. This process set up a natural experiment between companies that received Fast Track and thus external funding on the basis of augmented external communication.

The main conclusions of the research are that the Fast Track program, for the small sample studied here, did not influence the processes followed by the companies. Rather the long-term strategies of the companies dictated how they dealt with adversity. Moreover, in contradiction to previous studies that examined these same companies immediately after the SBIR work was completed, the fast-track companies showed no greater commercialization success than the comparison companies. The diminished differentiator of the Fast Track program can be attributed to a) the great deal of uncertainty that is inherent with applications research and b) the short time and limited funding of the SBIR program, which in itself limits the probability of success independent of the Fast-Track mechanism.

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I would like to thank my mother and father, Tarisa and Pieter Pretorius who have been without a family for such a long time. Their education and upbringing has left me no option but to strive for the best. This has come at a price to their happiness and I will hold their sacrifice dear forever.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Introduction

Economic growth depends strongly on the formation of small companies and their success in developing new technologies. This thesis focuses on a key issue that all such companies must address. The viewpoint we adopt is to examine how these companies manage uncertainty. Uncertainty is required in order to have an opportunity for success. How that uncertainty is managed will influence the outcome of the development process.

In order to increase the chance of success, sources of uncertainty that will have a substantial influence on the outcome of a research effort should be identified and resources devoted to them. How is this three-step process accomplished: Identification, evaluation and allocation? An attempt to address this very complex and difficult problem was made by studying a number of small application research companies.

Application research is possibly the most risky of all development efforts. The pure scientific research field accepts a very low percentage of success, hence the funding for universities and large corporate research is often viewed as a portfolio that diminishes the risk of any single project. Product development should and most often is built on well developed, well understood and predictable technologies in order to limit technical risk. Small Company applications research on the other hand has simultaneously the difficulties associated with both of these fields in the sense that the technology is often not well understood or modeled for the applications and the price of failure is often the end of a company.

Allocation of resources is governed by the highest perceived risk and uncertainty in the development. In many technology development cases this lies within the technical concept and the underlying science itself. It is therefore natural to focus purely on the "proof of the concept",

ignoring other influences. This often results in a program that ends with a viable technology without a market, manufacturability, sustainability or profitability. The end result can be another shelved invention.

A much-used method is to avoid issues that are highly uncertain. For instance, how is one supposed to know how the market will react to something that they have not seen or experienced? The most common reaction is: "We will deal with this issue when it comes up". What is actually implied is that once the issue becomes important enough, resources will be allocated to it. Unfortunately, by the time the perceived importance becomes high, it might be too late and or costly to change what has been done. The end result being that requirements are not met or that the research programs end with only a working prototype and without a plan to take the concept further. Only by considering these problems early in the development process, can it be cost effectively influenced (Figure 1).

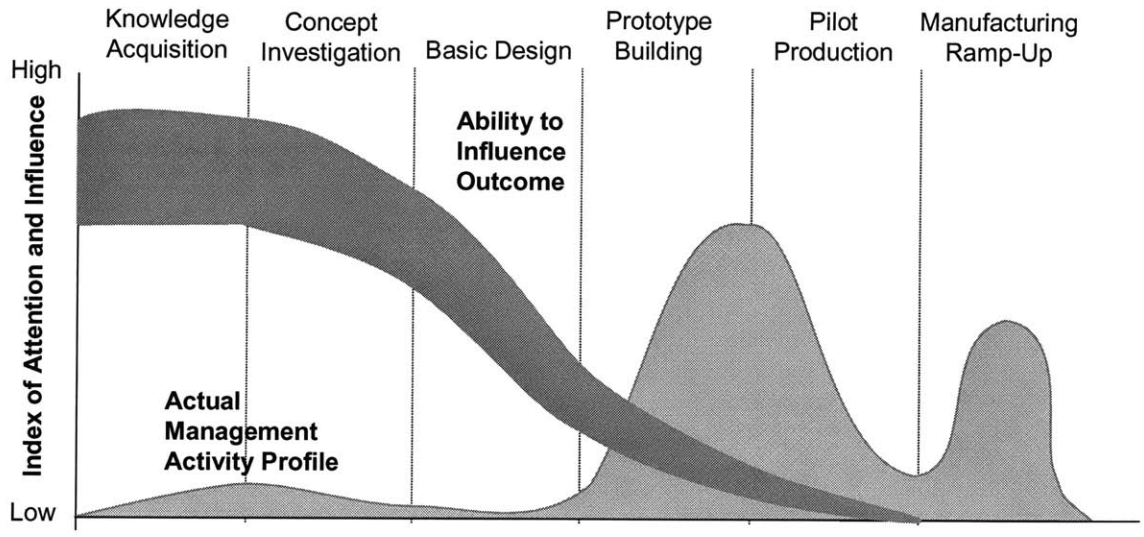


Figure 1: **The ability to influence the outcome diminishes as the program matures. Also, the cost of change increases with program stages. [Reference XX]**

The first step in planning action against uncertainty is to define what is uncertain. This requires some knowledge of the obstacles and hurdles that lies in the way of success. The more holistic the set of characteristics that are evaluated, the higher the probability of identification.

The most relied on method for determining the set of factors that need to be evaluated is experience. Experience is obtained by experimentation, in the sense that success and failure of projects we pursue is a basis for important learning. Experience is also obtained from others. We consult literature on product development, science and engineering to enable us to identify our attributes. We attend conferences, go to workshops and are involved in active discussion with others, all in an attempt to identify what problems others have faced, so that we add those to our set of concerns and plan for them.

It is a common practice in today's development firms to implement multi functional teams [Reference XXVIII, XV, X, VIII]. The premise here is that a mix of experienced individual with an open mind to each other's fields will consider more factors than a homogenous group. In essence the collective experience of the diverse team is broader and more and therefore the probability for overlooking important issues less.

A small business does not have the means to employ and utilize a multifunctional team. This does not preclude it from having to obtain different viewpoints and multi background views on the application that it wants to develop. The basic premise of this thesis is that interaction with clients, partners and other entities will increase the number of downstream issues that are considered, thereby increasing the possibility of successfully developing a technology.

1.1 Resource allocation

The topic of resource allocation has been extensively covered in the literature for larger entities [Reference III, XII], but very little has been done on small, technology application developing firms. This study concentrated on the process followed at small companies that were developing new technologies and applications to new technologies.

All small businesses face the problem of lack of resources complicated by cash flow problems and the fact that all personnel are responsible for all tasks of the firm. These challenges make it often hard for the leadership. Most managers in technology developing firms are scientists and engineers themselves and do not always have the formal training or experience to cope with the significant personnel and other business related issues that arise. Even in the cases where the management has formal training in business, their experience and education are with larger or less technology application intensive organizations. These factors create the opportunity for this thesis to contribute to deeper understanding for such managers of the challenges they face.

1.2 Significance of Small, Technology Developing Businesses

Small, technology based companies were chosen as the topic of research because of their ever-growing influence on the economy. Schumpeter in his 1936 classic [Reference XXVII] glorifies the entrepreneur as the driving force behind technological change and economic development. "... the function of the entrepreneur is to reform or revolutionize the pattern of production by exploiting an invention or, more generally, an untried technological possibility for producing a new commodity or producing an old one in a new way, by opening up a new source of supply of materials or a new outlet for products, by reorganizing an industry and so on".

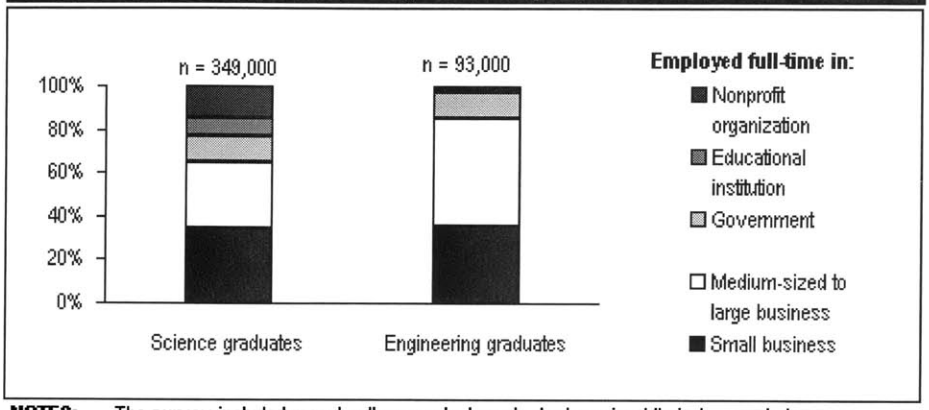
Acs, Carlsson and Karlsson emphasizes the importance of small businesses in "Entrepreneurship, small and medium-sized enterprises, and the macroeconomy" [Reference II].

They argue that some of the main differences experienced between Europe and the US economies are attributed to the emphasis that was placed on small businesses in the US. From 1960 to 1984, Europe and the US economies followed each other closely: GNP grew at identical rates during this period (3.3% EC, 3.1 % US). From 1960 to 1975, the unemployment rate in US was 5 % and in the EC below 3%. This rate increased to 10% for both in 1982, where it stayed in Europe, but dropped to 5% in the US. To explain this divergent behavior, these authors argue that the main influence was the number of businesses formed during the period: The number of US corporations and partnerships doubled from 1960 to 1983, while it stagnated in Europe. They articulate that the formation and support of small businesses had a significant influence on the positive economic signs in the US.

Other authors like Christensen [Reference VII], Utterback [Reference XXIX] and Henderson [Reference XVI] note that many/most breakthrough technology developments are created by small firms. This is in part because they are able to take the risk and partly because larger, well-established enterprises see too clearly the strengths of the existing approach and have difficulty seeing the need to change their flourishing businesses. The end result is the disruption of the stable business by the technology of the smaller entity.

Small businesses remain a driving force for the technical employment market. Lynch and Rothchild, also in Reference II, mention that 25 companies, some of which did not exists in 1975, created 1.4 million jobs between 1975 and 1995. Figure 2 illustrates that the percentage of recently graduated engineers and scientists that were employed by small companies in 1995 approached 40% These facts underline the importance of performing meaningful research on the practices followed by small businesses. However, as noted below this is a challenging task for several reasons.

Figure 1. Employment sector of recent S&E bachelor's degree recipients in full-time jobs as of April 1995



NOTES: The survey included recent college graduates who had received their degrees between July 1, 1992 and June 30, 1994. The graduates were asked questions regarding their employment status on April 15,1995. Full-time employment is defined as 35 hours per week or more; full-time students are excluded. Medium-sized to large businesses are defined as for-profit firms with 500 or more employees. Small businesses are for-profit firms with less than 500 employees and self-employed individuals.

SOURCE: National Science Foundation/Division of Science Resources Studies, National Survey of Recent College Graduates: 1995, special tabulations.

Figure 2: Distribution of technical graduates' employment by business size in 1995.

1.3 Sources of Information

Little information on the nature of business in small technology programs is available. This is partly because of the fact that few studies have been performed on small technology based firms and partly because small firms do not easily reveal data about their business practices. It also results because there is a great diversity of small businesses and it is not easy to identify those who are trying to be technically innovative. However, the basic approach of this thesis was to utilize the Small Business Innovative Research (SBIR) program sponsored by the federal government as a resource of information focused on the type of companies we want to study. The SBIR program is described in detail in Section 1.4

A 1996 study conducted by the National Research Counsel entitled "An assessment of the Department of Defense Fast Track Initiative" [Reference VI] discusses the benefits of the Fast

Track program. A part of this study was an in depth look at the performance of fourteen companies in New England [Reference XIX]. The study is a direct antecedent of the research conducted here. Eight of the original companies described in Reference XIX were located and examined further by questionnaire and interviews into the strategies, processes and ultimate successes of the projects and companies..

The original study is summarized in Section 1.5 and its main conclusion is that Fast Track funded companies had higher expected profit to the innovator. The research was done at the outset of the Phase II in 1996 and the expected rate of return and profits were projected estimates. This thesis was able to gauge the profits and rates of returns that were achieved eight years after the initial Phase I funding and thus decreases uncertainty of the earlier conclusions due to prediction of future events.

Before these studies are discussed in further detail, it is appropriate to describe the SBIR program in more detail.

1.4 Description of the SBIR Program

In 1982, Congress established the Small Business Innovation Research (SBIR) program to strengthen the research and development role of small companies in the US. Ten federal agencies, including the Departments of Agriculture, Commerce, Defense, Energy, Education, Health and Human Services, Transportation, the EPA, NASA and National Science Foundation participate in the program and are required to set aside a certain proportion (2 to 3 %) of their research budget for it. The largest of these agencies, the DOD, spends over $500 million a year on the SBIR program.

Each year the agencies put out at least one solicitation in which they identify topics that require new innovative, high-risk research. Small companies, defined as having less than 500 employees, are invited to propose new approaches to the problems that the agencies face. The agencies then receive on the average twenty proposals per solicitation. Usually only one of the proposals is selected for funding. The average success rate is one funded proposal per every ten written.

Each of the agencies has a separate process for selecting the topics for solicitation. Most have a round where different scientists inside the agency propose solicitations for areas in which they would like to see research performed. As the SBIR program is funded up by the agency, scientists and engineers in the individual laboratories do not have to part with their own research funding. The SBIR is thus an opportunity to fund independent work in the area that the agency employees are involved in. The different branches of the agency have a down selecting process where they choose the best solicitations for publication.

The SBIR program has a three stage funding process. These are a Phase I feasibility study, a Phase II prototype development and Phase III procurement.

1.4.1 Phase I

The phase I feasibility study receives funding between $60 k and $100k and lasts 6 to 9 months. The purpose is to determine the technical feasibility of the approach to solve the problem. The company performs this by developing a model or a prototype or a combination of both. This early research is primarily focused on the technology and science and very little emphasis is placed on downstream effects. One can argue that the entire Phase I effort is concerned with upstream process and technology.

The company's goal during the Phase I is to generate enough evidence of the feasibility of the approach as well as interest inside the funding agency so that it will be a) invited to submit a Phase II proposal and b) the Phase II proposal will receive beneficial reviews. The Phase I effort is thus focused on the goal of obtaining Phase II funding.

An outline of a Phase I proposal is given in Appendix B.

1.4.2 Phase II

The Phase II funding consists of $750k spread over two years. This is a firm fixed price contract. Only Phase I winners are allowed to submit a proposal for Phase II funding. Phase II's are funded based on the technical merit and the *potential for commercial success* of the approach.

The company is thus required to consider the commercialization of the innovation during the Phase II proposal. An entire section of the proposal is dedicated to the potential markets, the benefit for both the private and government sector and the approach that the company will follow to ensure that the venture is a success. However, most of the research efforts are in such new fields (Innovative Research) that existing markets and trends are inconsequential and any attempt to define the commercial potential of the approach is extremely uncertain at best.

Phase II efforts can be divided into two types of research efforts: those that focus on the commercial market and those that pursue fundamental science. The success of a Phase II SBIR is evaluated on either of these two metrics by the government: Those that made a commercial success or those that have fundamental scientific benefits to the sponsoring agency.

The focus of the Phase II is to develop a working prototype of the approach. The proposal thus concentrates on mitigating the technical risk and tackling all the issues surrounding

the feasibility of the approach. There is an implicit condition that the Phase II needs to end with a clear, defined and implementable commercial plan.

To encourage more research into approaches with commercial potential, the DoD founded the Fast Track program in 1996. .

1.4.2.1 Phase II Fast Track

In 1996 the DoD instituted the Fast Track policy under which proposals with matching funds have a significantly larger probability to obtain Phase II funding. These matching funds can be obtained from any qualified third party investor. Proposals with this independent funding also have an opportunity to receive funds earlier, reducing the lag and subsequent cash flow shortage that plague traditional two phase programs. A program that obtains third party investments will receive:

- Interim funding of up to $50,000 between Phases I and II.
- Evaluation under a separate, expedited process.
- A Phase II contract, subjected to certain technical criteria.

A reasonable assumption behind the Fast Track process is that third party investors serve as an extra filter to find programs with significant commercial potential. This approach has been deemed successful by the DoD and is now a permanent part of the SBIR process.

1.4.3 Phase III

Phase III involves private sector or federal agency funding (outside of the SBIR program) to commercialize the technology.

During this phase, the funding agency can sponsor the development of a production facility with the exclusive goal of producing the technology application that was developed in the

previous two phases. The sponsoring agency may also go into procurement of the product that is manufactured.

While the small business entity is ultimately responsible for the commercial marketing and sale of the technology or product developed under SBIR, the government encourages commercialization efforts. In this role, the government makes every reasonable effort to ensure that any government follow up actions to research, develop or produce technology developed under SBIR is accomplished. This is often through sole-source contracts with the same SBIR small business that originally worked on developing the technology.

1.5 National Research Counsel (NRC) Fast Track Review

In 1996, the NRC conducted an assessment of the Department of Defense's Fast Track program. The results of this study were published in 2000 [Reference VI]. The main objective of the study was to evaluate the effectiveness of the SBIR Fast Track program. Three key papers from the NRC study have direct bearing on this thesis. The first, Reference XIX was a detailed study into fourteen New England companies. The second was an assessment of whether the Fast Track program was speeding commercialization of SBIR projects [Reference XXI]. The last was a statistical analysis on the influence of the Fast Track program [Reference XI]. A short summary of the results of these three papers is presented as background to the research.

1.5.1 New England Company Survey [Reference XIX]

This study took an in depth look at the expected results of fourteen New England based Phase II projects that were distributed among thirteen companies. The most significant findings of the study to this thesis were as follow:

- Taken as a group the Fast Track projects show higher prospective expected lower-bound social returns – a measure that is based on upon he expected profits to the innovator and other producers benefiting from the innovation.
- The average projected duration of additional development beyond Phase II and before commercialization is somewhat less for the Fast Track projects, suggesting that they are somewhat closer to commercialization at the end of Phase II than the non-Fast Track projects.
- In summary, the SBIR Program has funded innovative projects with high social rates of return that would not have been undertaken in the absence of the Program; further, the non-Fast Track as well as the Fast Track projects appear to be quite valuable, although they typically do not exhibit private commercial potential as quickly as the Fast Track projects.

These results indicate that the Fast Track companies had a higher expected rate of return, were faster to market and had higher commercial potential. Table 15 in the study, listed as Table 1 illustrates some of the results.

Table 1: Fast Track and NFT projects: Averages for time line of cost and benefits.

Variable	Fast Track	Non-Fast Track
Total SBIR Project Cost	$ 1.7 million	$ 1.0 million
SBIR Funding	$ 0.9 million	$ 0.7 million
Additional Period of Development	1.2 years	1.8 years
Costs for Additional Development	$ 0.5 million	$1.5 million
Lower Bound Rate of Return to Society (including benefits to SBIR firm and its investors and also to other firms)	68%	55%

The next list, taken from Table 16 in the study, illustrates further differences between the FT and NFT companies:

- A smaller proportion of Fast Track companies have had previous SBIR awards (3 of 6 vs. 6 of 7).
- A smaller proportion of Fast Track companies expressed difficulties bridging a gap in time between Phase I and Phase II (0 of 6 vs. 4 of 7).
- A larger proportion of Fast Track companies said that the SBIR award facilitated attracting outside investors (4 of 6 vs. 1 of 7).
- Fast Track projects show commercial potential earlier, and by the end of Phase I outside third-party investors are found.
- Fast Track projects have a higher lower bound for the social rate of return (based on the benefits for the collection of firms using the technology created by the SBIR project).

These results illustrate a clear advantage to the Fast Track sponsored companies. Especially in the metric of commercialization potential, the study indicated that Fast Track companies have a better change and are expected to produce a commercially viable product.

1.5.2 Is Fast Track Speeding Commercialization? [Reference XXI]

The paper by Cahill [Reference XXI] based its results on a survey of 379 companies that received Phase II awards in the period 1992 to 1996. The questionnaire aimed to compare the commercialization potential of and performance outcomes of SBIR's sponsored by the DoD. The conclusions of included the following:

- "Past studies of SBIR commercialization has used three primary measurements of success: sales, additional developmental funding, and expected sales. By each of these measures, the Fast Track projects are clearly outperforming those in the control group."

- "Fast Track has been successful in nearly eliminating the funding gap between Phases I and II.
- "Firms that apply for Fast Track tend to be much younger than average SBIR firms. They have had far fewer Phase II awards than the overall population. Sixty percent have had no prior Phase II awards. The average annual revenue for Fast Track applicants is less. These characteristics may have little to do with success and may change if the cost-matching arrangement is changed."
- "The predominance of firms in Fast Track whose founders have business backgrounds and firms whose founders have started other firms may indicate that such firms have an easier time acquiring third-party funding."
- "Additional developmental funding is a leading indicator of commercial success. High expectations of sales are probably better than low expectations, but the bottom line is sales achieved, and *it is several years too early to measure that bottom line*. Given the inherent risk associated with research-driven business, today's high expectations for future sales may not be realized."
- "Whether it is the validation by a third party to the commercial potential, the timing and magnitude of the additional funding, or merely the reduction in funding gap that contributes most to Fast Track, the program is working. By each primary measurement of commercialization success used in past SBIR studies (sales, additional developmental funding, and expected sales), Fast Track projects are clearly outperforming those in the control group."

These conclusions reiterate the findings of the Reference [XIX] that the Fast Track initiative was beneficial to the commercialization of SBIR projects. Of note is the second to last bullet point that indicates that the results are based on expectations and not achieved results.

1.5.3 Statistical Analysis of the Influence of the Fast Track Program [Reference XI]

The study by Audretsch [Reference XI] summarized the findings of the collection of regional studies such as Reference XIX and the data collected in Reference XXI. It took the results of all these studies and compiled a statistical analysis comparing Fast Track and Non-Fast Track projects. Their main conclusions are as follow:

- Fast Track projects have greater expected sales (commercialization) than do non-Fast Track projects,
- Fast Track projects experience a shorter funding gap between Phase I and Phase II awards than do non-Fast Track projects, and
- Fast Track projects have greater employment growth than do non-Fast Track projects.

1.6 Focus of the Thesis

The description of Phase II in the previous section highlights a few facts: The process followed during Phase II does not require that downstream processes will be considered during the development. Again, as stated earlier, upstream processes that have a direct influence on the technical success of a once off prototype tend to dominate. It is only after the prototype is in a working condition that most companies start to give serious consideration to the downstream processes and functions like manufacturing and marketing.

Technology strategies, namely mapping to market, competing against incumbents, capturing value, determining the diffusion of the technology and so forth do not receive a lot of

consideration. The focus is entirely on developing the technology into a working prototype. Downstream processes and considerations are lower in urgency compared to upstream considerations that are essential for working prototypes and models required in Phase I. This "environmental constraint" leads to the situation where most companies find themselves at the end of the Phase II: A working prototype and technology demonstrator but no market.

At the outset of the study it was hypothesized that small companies, given the scarceness of resources would benefit from interacting with other entities. It was proposed that communication with downstream players would increase the company's awareness of what the market and clients would perceive as the value proposition. This would then enable the researchers to develop their technologies to fit these needs, increasing the probability of commercial success.

If a further assumption is made that there was more significant interaction between the FT companies and another entity to enable them to receive the matching research funds, this identifies a possible explanation for the relative success of FT companies. For Fast Track firms, this interaction had to occur very early in the research process, often in the beginning of the Phase I. In order to obtain funding form another commercial entity, the company will be forced to address downstream issues and set up plans of how to deal with perceived problems and hurdles. The company must be able to convince the sponsoring entity that it had performed a significant intelligence gathering process to obtain information about downstream issues. It was thus implied that the companies with FT sponsorship had gone further in addressing possible hurdles other than the technical feasibility by the onset of the Phase II.

These assumptions set up a natural experiment between FT and NFT companies on the basis that the FT companies had more communication, interaction and information gathering with

others on a technical, business and strategic level. This instinctive split was pursued in this research by studying an equal number of FT and NFT companies.

As the focus of this thesis is the allocation of resources, comparing the practices followed at Fast Track and Non-Fast Track would highlight the differences between the entities that had a high level of collaboration with others and those that did not. The NRC study, summarized in the previous section, provided a welcome source of data for this experiment.

A further value of Reference XIX was that it provided the names of the companies that it studied. Ten of the original thirteen companies that participated in the initial study were willing to participate in this follow up study. Of these, four Fast Track and four Non-Fast Track were selected for participation in the thesis.

The original study into the New England companies was performed shortly after they received their Phase II funding. Most of the results are based on expected yields and growth that were provided to the researchers by the companies themselves. It is clear that the overall findings of the papers were that the expected successes of the fast track projects were much higher than those of the NFT projects. A small number of the companies that participated in this research were revisited to evaluate what the outcomes of the projects were and why they ended up the way they did.

2 Premise

The premise of this thesis is: A wider search for uncertainty sources and tackling these sources early by allocating resources to them will have a significantly positive influence on the outcome of an applications research project.

Since the allocation of resources depends largely on the magnitude and urgency of the problem, identifying origins of uncertainty is the main task. In a small business, the lack of multifunctional backgrounds increases the probability that important factors are overlooked. One way to overcome this deficiency is to collaborate with other entities that might have access to crucial information. This interaction will not only increase the awareness of the small company but also its absorptive capacity if such information is discovered through other sources. [Reference IX]

Applying this methodology to the SBIR program, the logical conclusion is that the Fast Track companies had to have more interaction with another entity than the FT companies in order to obtain external funding. This in itself might be the reason why the NRC study found that Fast Track companies had a significantly greater probability of successful commercialization of technologies. Therefore, the research path leads us to revisit eight of the companies that participated in the original NRC study to actually examine how uncertainties were identified, evaluated and how resources were allocated.

3 Research

The research focused on eight small companies that are developing innovative technology. Of particular interest were the processes that these companies followed to identify challenges and problems, how they evaluate these different metrics and how they allocated resources to solving them. The aim was to identify differences in this process between companies and establish reasons for why these differences exist. It was further attempted to ascertain and quantify similarities between the companies and their strategies.

In order to access this information, a number of companies needed to be identified and their strategies investigated. In the 1996 study conducted by the National Research Counsel [Reference XIX], thirteen New England companies were identified that received Phase II Small Business Innovative Research (SBIR) grants from the Department of Defense (DOD). The study was helpful in that it not only revealed possible research subjects, but also provided the opportunity to expand on the research that was done seven years ago. This situation presented the opportunity to establish what the outcome of the research projects were and thus have a reasonable evaluation of the strategies that were followed.

3.1 Researched Company Background

In the original study of Reference ???2, thirteen companies participated. Only ten of those were traceable, indicating that the remaining three had either gone out of business or had been acquired by another entity. Of these, eight were selected in order to keep equal numbers for the natural experimental of Fast Track versus Non Fast Track.

Table 2 lists the letters used to reference the eight companies that were studied. The notation FT is reserved for the four companies that received Fast Track sponsorship and the NFT is for the four companies that received their funding through the normal channels.

Table 2: Reference letter and classification of companies by type of Phase II funding.

Company	Award
A	FT
B	FT
C	FT
D	FT
E	NFT
F	NFT
G	NFT
H	NFT

As the nature of the business of each of these companies is relevant to their responses, a short description is appropriate.

3.1.1 Company A: Fast Track

Company A is a leader in the development and commercialization of small scale manufactured materials. The company spends significant resources on continuous improvement of its manufacturing techniques.

The company is the developer of a core technology. It's SBIR was in the application of this core technology to electronic equipment and the manufacturing thereof. Its Phase II Fast Track sponsor was interested in using the technology in the mobile communications industry where it is a leader.

3.1.2 Company B: Fast Track

Company B is a materials and systems corporation that specializes in a number of patented platform technologies. These technologies are concentrated in the marking, sensing, tracking and authentication fields. Products of the company are found in the document process and security, the marking and tracking in challenging environments and industrial sensing industries. The company has eleven corporate and institutional partners, a solid technology advisory board and affiliations with more than six entities.

The SBIR combined three of the company's core technologies. The goal was to develop an application of these baseline technologies to mass marketed products. The promise of the application was better performance and lower overall cost. Its Fast Track sponsor was an Angel investor.

3.1.3 Company C: Fast Track

This company developed a revolutionary approach to a very basic and widely used mechanical concept. They are in the business of improving the performance and manufacturing this core technology.

The Phase II SBIR was for the application of the technology to guidance systems. Longer life, less maintenance and lower installation costs are some of the benefits. Its Phase II Fast Track sponsor was a Venture Capitalist that supplied market definition.

3.1.4 Company D: Fast Track

In recent events, this company spun off the group that developed the technology under the Phase II effort. This move was done with the anticipation that each entity can focus their marketing and development efforts. The company has seen an increase of 80% in revenue in the last year, mainly because of the capturing the success in producing and marketing of its two main

technologies. The company recently signed contracts to be the supplier of its technologies to two large Navy programs.

The Phase II effort focused on driving the cost out the manufacturing of its core technology. Lower cost with comparable performance would open new markets. The Phase II Fast Track sponsor was a client that anticipated using the technology in its products once it was cost effective to do so.

3.1.5 Company E: Non-Fast Track

This company focuses on development of new polymers. The manufacturing and composition control of the materials are the core business of the company.

The Phase II of the company was in the application of materials in a reconfigured manner to supply superior qualities to the electronics industry. These qualities included higher power pulses, reliability and operation at higher temperatures. This was both a development of an application of the core technology as well as refinement of the technology itself.

3.1.6 Company F: Non-Fast Track

This company specializes in developing SBIR's into commercial products. The company is what is referred to as a "medium small" firm since it maintains a staff of just under the maximum of 500 required to be eligible for an SBIR. The company's strategy is to spin off commercially viable products into separate entities so that the core of the company remains small enough. This strategy has proved to be successful and they have spun off over six companies.

The company organizes itself into groups and each group is responsible to bring in their own research money. One of these research group's Non Fast Track programs was studied. This

was an application that combined off-the-shelf technologies. The company is not the developer and manufacturer of the core technologies.

3.1.7 Company G: Non-Fast Track

This company specializes in energy storage devices for the aerospace industry. The company uses established science and applies it in novel ways to produce new products. It is an applications developer.

The Phase II under study promised to deliver a new storage device that would have better performance under severe environmental conditions. The applications for these devices are in the aircraft as well as space industries.

3.1.8 Company H: Non-Fast Track

This company combines proven technologies in one field with applications in another. They concentrate on the telecommunications sector and specifically in manufacturing the applications of the technologies that they combine.

The Phase II was aimed at improving performance of communication devices by utilizing techniques developed for the directed energy market.

3.2 Research Process

The research was conducted in two phases. The initial phase was a written questionnaire that was sent to each of the companies. Half of the companies did not employ the original Principal Investigator (PI) anymore. In these cases the questionnaire was completed by either the president of the company or by a senior member of the original research team.

The research programs that were the subject of the questionnaire were completed in 1997. It was therefore necessary to compile the questions in such a manner as to help the respondents

recall the specifics of the program. The generality of the questions were intentional, provocative and sometimes met with criticism from the respondents. The full list of questions is attached in Appendix A.

The questionnaire phase was followed by an interview. After the respondents had jogged their memory of the specifics of the research programs under assessment, an in person interview was conducted. The interview was aimed at revealing the details of the companies' methodology towards identifying and evaluating obstacles and how they allocated resources towards driving down the uncertainties in the key characteristics that they identified. These questions were open ended. This allowed the respondents to go beyond the specifics of the Phase II SBIR's that they were involved in. Generally a broader, more philosophical answer was encouraged and received.

The respondents were encouraged to reveal the details of the technology and program selection process, the funds application process and the application research process. Follow up questions dealt with the obstacles that were apparent in programs and how the firms deal with them.

3.2.1 Questionnaire

As apparent from Appendix A, the first few questions were basic yes/no or multiple-choice type. These were deliberately closed ended questions as to encourage the respondent to continue. At the end of the multiple-choice question, there would be an open ended probe that encouraged more detail to be revealed. As the questionnaire progressed, the suggested answers became more vague and the respondent was encouraged to reveal more detail.

The questionnaire was divided into four logical sections. Each of these sections contained a number of questions that probed into the methods and strategies that were followed. The four sections are:

1. The benefits of the SBIR project to the company.
2. The points of resistance or hurdles that the company experienced during the project.
3. The collaboration of the company with other entities.
4. The final outcome of the SBIR effort.

Not all of the answers in the results section came directly from the questionnaire. If there was some uncertainty or gap in the answer received, the interview was expanded to include more detail on the subject.

3.2.2 Interview

Apart from clearing up some of the uncertainties of the survey, the interview had the following basic four open ended questions:

- How do you identify the issues, or parameters that you determine to learn more about?
- How do evaluate which ones are the most important?
- How do you decide what kind of resources to use and when to allocate them?
- Elaborate on the collaboration between you and other companies.

The answers from their response to the questionnaire were used to introduce these questions. The interview followed the flow of the conversation. It was found that after an initial explanation of the research and the goal of the interview, the interviewer only needed to steer the direction of the conversation. The respondents provided more than enough data.

In the beginning it was considered desirable to record the interviews. The interviewees were asked if they would mind in a manner that it was very easy for them to decline. It soon became clear that recording would be obtained at the cost of honest, direct and frank answers.

The decision to abandon recording meant that the interviewer had to manually register the conversation. As speech is about ten times as fast as the typing of the specific researcher, the exact wording of the responses were not captured. In the results section the responses are in quotation marks, but because of the above-mentioned reason, these quotes are an approximation.

4 Results

The results of the growth of the companies since their receipt of the Phase I SBIR and the answers to the questionnaire and survey form the essence of this chapter. Before these results can be presented, a major finding must be explained as it has interpretation value to all of the other results.

4.1 Core versus Application Developers

One of the unanticipated findings in the research was that there was a company-specific characteristic just as dominant as the Fast Track (FT) versus Non-Fast Track (NFT) that seems to determine the process of research and resource allocation in the small companies under study. A short explanation of how small companies approach risk will introduce us to this new concept.

Small application research companies tend to have one of two approaches to risk. The first is to spend every ounce of the company's resources on one technological innovation. Companies going down this avenue usually have a well defined, although changeable, plan on how to capture value from the innovation. This approach, if successful, will bring in multiple sources of income and provide the company with a good marketable product and considerable sales. The downside of this approach is that if the opportunity does not take off, in a relatively short time, the company may be forced to close shop. The second approach to mitigating the risk associated with application research is to have a portfolio of applications that span over many different fields. In this case, multiple innovations for a wide variety of applications are pursued. The benefit of this approach is that a number of applications can fail, but this will not mean the end of the company. The downside is that when an opportunity for one of these multiple applications present itself, the company is usually not in a position to take full advantage of it or perhaps even

to recognize it. This is because its minimal resources are already spread very thin across all the company's other interests.

Both approaches seem to work and there are numerous examples of companies having long and successful existences utilizing either approach. It is therefore not surprising to see that companies are trying combinations of these two basic methods. One of the fist results of the thesis was to identify one of these "crossed strategy" approaches and refer to it as core technology developers or "Core".

The Core firms have a technology that is the basic product of the company. They sell the basic product to any entity that will use it in an application. The company's main intellectual property (IP) rests with this technology and they are also the manufacturers of the technology. They do however independently develop applications to their technologies. As they are the ones that understand the physical limitations of the technology best, they are in a prime position to develop applications for it. In these applications they are more open and compromising on the IP. It is here that they invite partners and other entities to share in the information of downstream processes and implementation issues that they might face. Therefore, according to the premise of this thesis they should have a better chance of creating a successful application than others.

A category of distinction beyond the Fast Track and Non-Fast Track companies was developed to accommodate these findings. This category distinguishes between a core technology developer (Core) or an applications developer (App). This distinction was made on the basis of the underlying business of the entity. If the company sold the technology that they were applying in the SBIR separately, they were labeled "Core". In the case that the company manufactured their own underlying technology, they were also denoted as "Core". If the company

relied on a supplier for the underlying technology of the application, they were labeled as "App" developers.

A short hypothetical example will serve as a further explanation: A company is the producer of piezoelectric material. They have a number of in house applications, primarily in sonar, which is funded by the Navy. If current materials do not have the desired performance for the application, these application programs pay for the development of new materials such as single crystal piezo materials. Another company on the other hand is in the aerospace business and are structural vibration experts. For a particular application, piezo electric materials have the energy density and other performance characteristics to make it a viable solution. The aerospace firm will then acquire the material from the piezo company, although it will be applying it to a totally different field. The piezo company is exploring new applications to find new markets for its underlying technology and at the same time they are developing other core technologies. The aerospace company is a system integrator and only uses the piezo company's technology for a particular application. Therefore, the piezo company is a core developer while the aerospace company is an application developer.

This category was added to the results as it gives a clearer understanding of the trends. Table 3 lists the companies that were identified through their respective business practices to be either Core or Application developers. It was found that all FT companies were also core developers. Only one entity, company E were both a Core and a NFT. All the other NFT 's were Application developers.

Table 3: Distinction of the companies on the metrics of FT/NFT funding and Core/Application developers

Company	Award	Core / App
A	FT	Core
B	FT	Core
C	FT	Core
D	FT	Core
E	NFT	Core
F	NFT	App
G	NFT	App
H	NFT	App

The first result of the study was to determine what happened to the companies since receiving their respective SBIRs, i.e. to extend the expected returns to actual results

4.2 Company performance since receiving SBIR

Publicly available data was used to compare the companies. All of the companies are privately owned and therefore do not have to publish yearly financials in the public domain. This made it quite difficult to get a year-by-year update on the performance of the companies. It was decided to use two basic metrics for the comparison: number of employees and sales.

The distributions of these metrics among the companies are shown in Figure 3 and Figure 4 respectively. The median is ten to twenty employees, although there are two companies that have 160 and 240 workers respectively. Most companies had sales around $2M per year in 2002 although the larger corporations also had significantly higher sales.

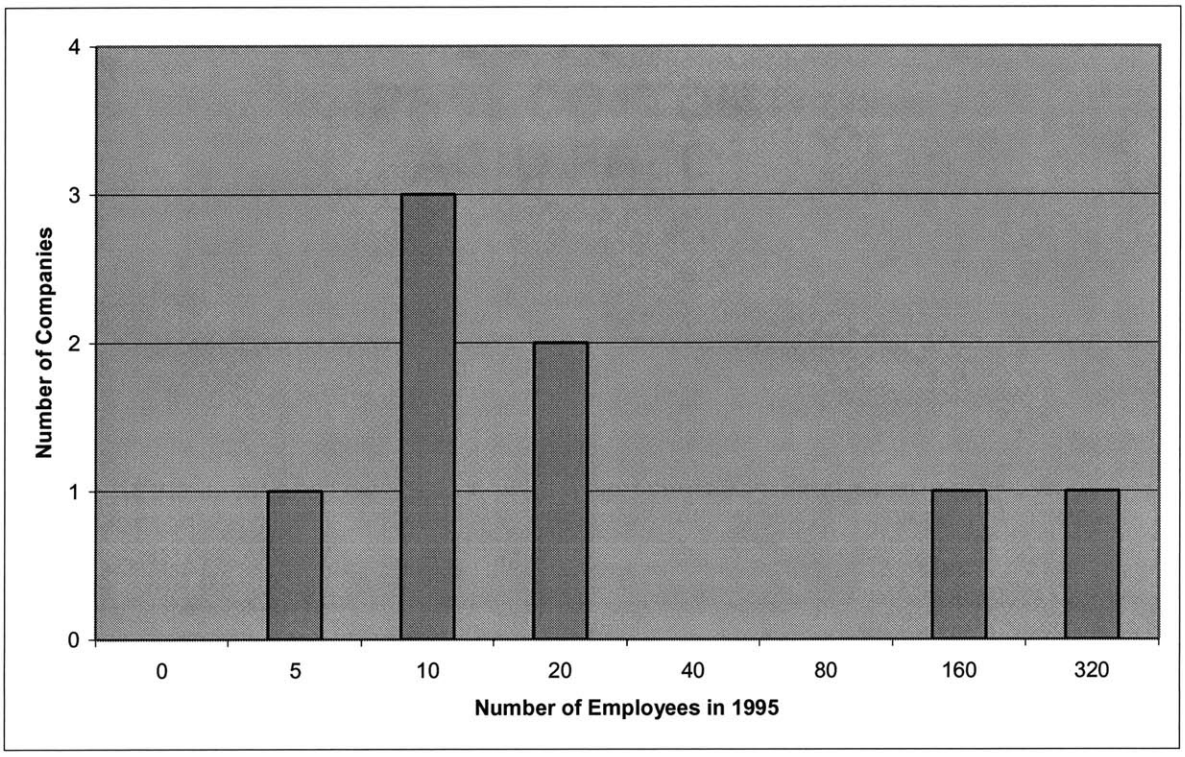


Figure 3: **Distribution of number of employees at the start of Phase I of the companies studied.**

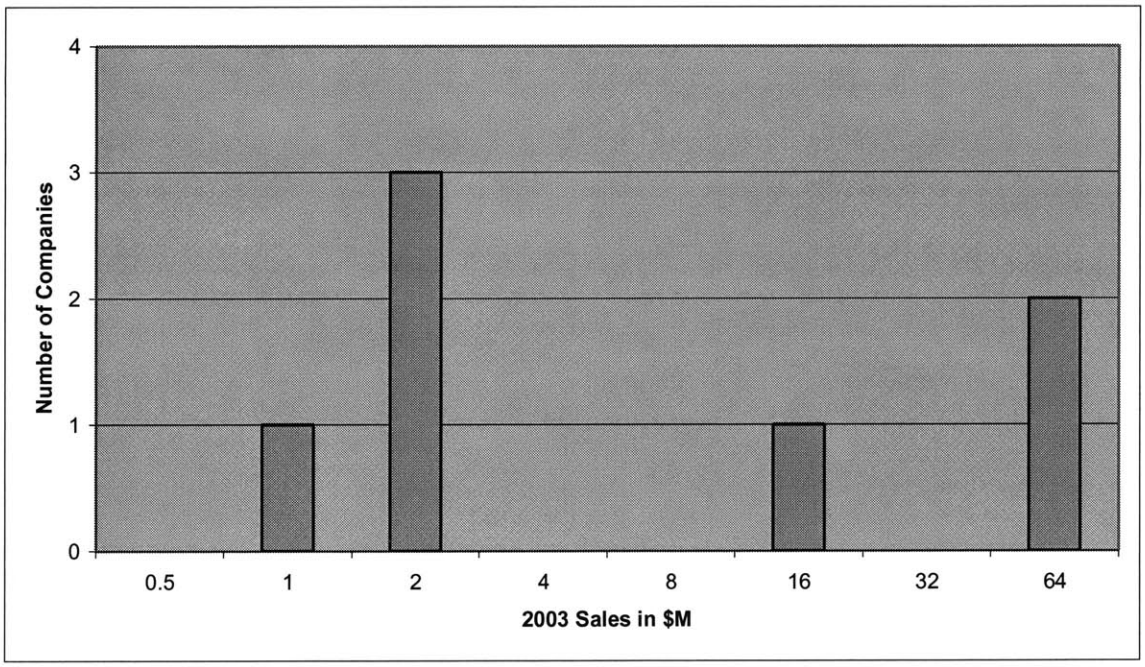


Figure 4: **Distribution of 2003 sales of companies interviewed.**

Also of interest were the overall ages of the companies. At the time of receiving the Phase I SBIR, two companies were more than 40 years old, and four were less than ten years old. It is clear that the companies were well established by the time they received the SBIR that was studied. From Table 4 it can be seen that company B was established in 1997. This is because the parent company had a re-organization and decided to re-establish the research arm. After deliberation it was decided to use this date as the start of the organization since it maintained the same business strategy of the original entity.

Table 4: Age and employee growth of companies researched.

Company	Award	Core / App	Year Established	# Employees 1995	2002	Employee Growth Ratio
A	FT	Core	1982	20	35	1.75
B	FT	Core	1997	7	6	0.86
C	FT	Core	1994	8	8	1.00
D	FT	Core	1940	155	110	0.71
E	NFT	Core	1982	18	12	0.67
F	NFT	App	1956	260	300	1.15
G	NFT	App	1989	3	4	1.33
H	NFT	App	1991	8	70	8.75

Table 4 and Figure 5 indicates the growth rate in number of employees from 1995, the year of receiving the Phase I SBIR, to 2002. Three companies, all core developers, showed a decline in the number of employees. Only one core developer showed growth, while all application developers had an increase in the number of employees. On this metric, company H seems to be the most successful with a growth ratio of six times that of the second most successful grower. There is no indication that the FT companies grew faster than their NFT counterparts. As a matter of fact, for this limited data, the opposite seems to be true

The amount of sales in 2002, the sales per employee, the sales per year in business and the combination of the two of the companies are compared in Table 5. Company F had the most sales followed y company H and A. This can be correlated to number of employees as the next metric shows.

It is interesting to note that although company H was the fastest grower, it still had the third highest revenue per employee. Company F has the most sales per employee, followed by company A. These also the have the highest revenue, suggesting that these companies are selling products in the market. Six years after the award of the Phase II SBIR, there is no indication that the Fast Track Companies had more sales per employee or greater sales growth than the NFT's.

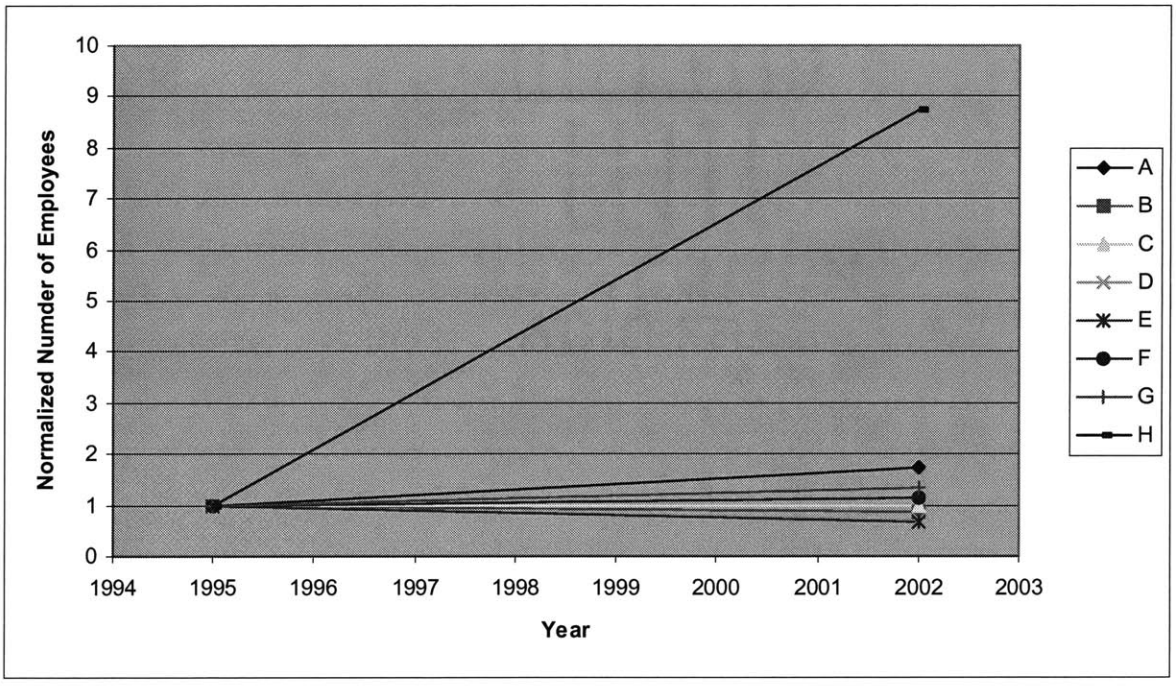


Figure 5: **Growth of umber of employees since the receipt of the Phase I SBIR. The number of employees are normalized by the initial size.**

Table 5: Sales and growth ratios of companies.

Company	Award	Core / App	2002 Sales in $M	Sales / Employee	Size / Years in Business	Sales/Empl / Years in Business
A	FT	Core	35	1	1.75	5.00
B	FT	Core	1.75	0.291667	1.20	5.83
C	FT	Core	1.75	0.21875	1.00	2.73
D	FT	Core	15	0.136364	1.77	0.22
E	NFT	Core	1.75	0.145833	0.60	0.73
F	NFT	App	400	1.333333	6.52	2.90
G	NFT	App	0.75	0.1875	0.31	1.44
H	NFT	App	35	0.5	6.36	4.55

4.3 Questionnaire Results

Table 6 below summarized the responses of the companies. A full list of all the questions and discussion of the results of each individual question is listed in Appendix A. The table has a short summary of the question and an abbreviation of the answers. A short discussion of the results is given below the table.

The questionnaire was divided into four subsections namely:

1. Questions about the benefits of the program (Questions 1-3),
2. Points of resistance or hurdles that were experienced (4-10),
3. Collaboration with others (11-14) and
4. The outcome of the program.

Table 6: Summary of questions and answers from the survey questionnaire.

Company	A	B	C	D	E	F	G	H
FT/NFT	**FT**	**FT**	**FT**	**FT**	**NFT**	**NFT**	**NFT**	**NFT**
Core / App	**Core**	**Core**	**Core**	**Core**	**Core**	**App**	**App**	**App**
Q1: Benefit of technology	Cost	Perform	Perform	Cost	Perform	Capability	Perform	Perfrom
Q2: Did benefit Change?	Modify	Modify	Stayed	Stayed	Modify	Stayed	Stayed	Stayed
Q3: Type	Modular	Modular	Product	Modular	Arch	Product	Product	Product
Q4: Sources of Obstacles	External	Other	Internal	Internal	External	External	External	External
Details of Obstacles	Market Vanish	Resource Starvation	Personnel Strife	Resource Available	Colla - boration	Competition	Market DMU	Resouce Available
Q5: Were these Expected?	Y	Y	Y	Y	Y	Y	Y	Y
Q6:Could these be Anticipated?	Did	Did	Not Level	Did	Did	Not Level	Level	Did
Q7: Were they Present Elsewhere?	Y	Y	Y	Y	Y	Y	Y	Y
Q8: Why were they Present	Other pressing	Other pressing	Not Consider	Other pressing	Other pressing	Other pressing	Other pressing	Other pressing
Q9: When did they Appear	End Ph II	End Ph II	St Ph I	Mid Ph II	End Ph II	End Ph II	End Ph II	Mid Ph II
Q10: Result of Obstacles	Killed	Killed	Modify	Modify	Modify	Modify	Killed	Allocate
Q11: Was there External Interaction	Y	Y	Y	Y	Y	N	Y	N
Q12: With Who	Client	Angel	Active Investor	Client	Partner	None	Partner	Client
Q13: What did External Conribute	Passive	Broad	Mark Def	Mark Def	Mark Def	Nothing	Nothing	Mark Def
Q14: Level of Customer Interaction	All fields	All fields	All fields	All fields	All fields	All fields	All fields	All fields
Q15: What was Ph II Outcome	No Product	Used technologies elsewhere	No Product	Learned and apllied lessons to another successful program.	Commercial sales and added external funding	In Process od Selling Rights to Manufacturing	No Product	Used technologie s elsewhere

A few short observations on the results of the questionnaire will be made here. In general, there are no questions to which the answer shows correlation to the Fast Track differentiator. This result was surprising and will be further discussed in Section 5 after we present the results of the interviews.

4.3.1 Expected Benefits of Project

The expected advantages of FT and NFT projects were similar.

- The only differentiator on question 1 is that one NFT, Application company indicated that they were developing a new capability, while none of the FT or Core companies did.
- In answering question 2, all Application developers believed that the benefits did not change during the program. The only NFT Core company's answer was connected to the other Core companies.
- Of possible significance is the fact that company E is the only one that viewed their invention as architectural.
- All the Application developers answered to question 3 that their innovation was a product. All the NFT companies describe the innovation as more than just a module to another system.
- Company C's product is in essence a module to a larger system, although they are selling it independently of the more complex system.

4.3.2 Points of Resistance or Hurdles

A few of the problems experienced by the companies can be categorized, but in general the FT and NFT entities were faced with the same dilemmas.

- All the Application developers experienced resistance from outside of the organization.

- None of the NFT companies experienced internal conflicts.
- It is interesting to note that everyone expected some type of obstacles. This is because all the companies had experienced these obstacles before as answered in question 7.
- Half of the NFT companies did not expect the obstacles to be at the level that they experienced it.
- Only one FT company found them selves being surprised by the intensity of the obstacle.
- Most of the companies, except C, acknowledged that other considerations were more important than the factors that eventually proved to be crucial to the program. This is not surprising when it is noted that all SBIR programs are high-risk innovative research. The technical issues of the program must take precedence over anything, especially in the beginning of the program. Only after the technical issues have been sorted out will the technology be facing other issues. Without technical feasibility, there will be no manufacturing, marketing and collaborations to consider.
- The timing of the appearance of the critical obstacle is of interest and answered by question 9. Except for companies C, D and H, all the companies found themselves in a familiar position: at the end of the funding period, they had some sort of a working prototype, but there was a source of resistance that kept the program from moving forward.
- The Application companies seem to experience problems that could have been anticipated and dealt with earlier in the programs. To identify what the competition is developing or attempting to develop, to satisfy the needs of the decision making unit (DMU) of your customer and to team up with someone that can manufacture your critical component are issues that should come up early in a program can be dealt with. These are all upstream

processes. The Core developers on the other hand experienced the problems that one expects from these high-risk programs. Having a market collapse, running out of funding because of technical difficulties, experiencing internal conflict because of design issues and realizing that the problem is larger that initially anticipated is all part of the gamble in high-risk research. It thus seems like the core developers had gone a bit further in the process before they experienced their ultimate problem.

- The obstacles, compounded by when they were discovered had a meaningful outcome on the projects.
  - Half of the FT companies and only one of the NFT had the projects killed because of the problems.
  - Half of the companies modified their projects to overcome hurdles.
  - All the FT companies that modified the project, did so earlier in the project as shown by the answers to question 9.

4.3.3 Collaboration

All the companies, regardless of their category, except company F, had significant collaboration and exchange of information with other entities.

- This might be because company F is significantly larger than any of the other organizations. It is therefore possible fore them to have expertise in-house that the others needed to obtain form outside.
- Question 12 pertains to the collaboration of question 11 and that is the reason why some of the NFT companies answered that they did have interaction with a "Sponsor".
- Only two of the FT companies had clients as sponsors.

- It is important to note that three of the NFT companies had interactions with clients and partners. This might be one of the reasons why there is such little difference between the FT vs. NFT and Application vs. Core technology developers.

4.3.4 Outcome

The most important result of the questionnaire is that there is no distinction in the outcome of the programs based on the Fast Track differentiator. This is significantly different from conclusions reported in the earlier work of References VI, XI and XIX.

- The only company that had actual commercial sales and made money was company E, also the only Core developer among the Non-Fast Tracks.
- Company F is negotiating the sale of the right of manufacturing and a host of others used the SBIR technology in other programs.
- Two of the four Non-Fast track companies had commercial sales or are negotiating commercial sales.
- None of the Fast Track programs had any sales.
- Company H, also a Non-Fast Track company, developed and marketed another SBIR successfully with significant commercial sales.
- Company E, the only company with tangible sales from the Phase II project had a number of differences with the rest of the companies:
  - Only company to have commercial sales.
  - Only company to report an architectural innovation.
  - Only developer of a core competency that did not have Fast Track sponsorship.
  - One of two companies that interacted with a partner.

- Partner was another small business concern.

4.4 Interview Results

The results of the interview can be divided into three major "trend" categories. These are collaboration, problems and strategy. It was found that collaboration consisted of three major categories namely collaboration with customers, partners and universities. The problems that the companies faced can be separated into anticipated and unanticipated; the interviews also revealed how companies typically dealt with these problems. Lastly, the strategies that the companies followed to obtain funding, to decide which technology to pursue and how that impacted the company in the long and short terms was revealed.

In the next sections, these trends will be discussed in more detail as the responses of the companies are listed under each section. The response of the interviewee is in quotation marks. Although every effort was made to accurately document the response, it must be noted that it was only possible to record the meaning of the actual conversation.

Each answers is identified if it came from a Fast Track (FT) sponsored company or from a non-Fast Track (NFT) company. The responses are also numbered so that they can be referred to in the interpretation section. A further distinction is made between application developers (App) and companies who manufacture and develop the core technology (Core). The Companies are also identified so that they can be linked to the answers of the questionnaire in the previous section. These directions are in parenthesis after each quotation.

4.4.1 Strategy

In a small technology based firm it is often difficult to steer the company and the allocation of its resources down a well-defined path. Survival sometimes dictates that projects that are not

in the long-term goals of the company must be completed. Vast amounts of applications for new technologies are generated each day and it is difficult to decide in the early stage where to focus. How do companies deal with this? It was found that the strategies of the companies addressed two major issues. The one was how to decide which applications to pursue and the other was how to fund the research and in particular, how they decided on applying for SBIR grants. The following are direct quotes from the interviews with the different companies.

4.4.1.1 Deciding which applications to pursue

1. "We pursue high risk / high reward programs only. This means that we are not interested in incremental change. Our technology applications must be break through and radical." **(E, NFT, Core)**
2. "The development team must inquire from the market what is needed. They must communicate with the potential customer because the chances of them randomly coming up with a break through is very small" **(E, NFT, Core)**
3. "We tackle obstacles through redundancy i.e. we try a lot of ideas so that statistically at least one should work" **(A, FT, Core)**
4. "If you build on previous work you can be successful. You have to find a few holes in the current technology and try to fill it" **(A, FT, Core)**
5. "We made a decision a few years ago to not only develop the technology, but also applications to the technology" **(A, FT, Core)**
6. "The secret is to balance the research between something that can be sold soon and the Holy Grail that eventually hit the big time. While perusing this long-term goal you will stumble onto some applications that has a short (1 year) time frame. You need to apply at the obvious solutions and if that does not work get out." **(A, FT, Core)**
7. "There is a delicate balance between satisfying the government's needs in the SBIR and keeping commercial customer focus. You need to satisfy the sponsor first and then you can go after broader markets". **(D, FT, Core)**
8. "We invest money to look for other interested parties, not only commercial, but also in the government." **(D, FT, Core)**
9. "Every week we sit down with our scientists that run our different technology programs. We evaluate the programs on commercial potential and decide to allocate funds accordingly". **(D, FT, Core)**
10. "We have a matrix of metrics that we use to evaluate all our programs. The main parts of that metrics are the fundamental potential, the commercial potential and the fit with the current expertise of the personnel. Every business should have this set of metrics and it will be different for each one. Once you have figured out

what these metrics are for your field, it becomes an easy job to allocate resources". **(D, FT, Core)**

11. "We have a pragmatic metric that evaluates every program according to the goals we set for the company. Once we synchronized all our research programs with this metric, things started to fall in place. This metric needs to evolve because what is working now might not work in the future". **(D, FT, Core)**
12. "For us, the patent is the number one goal. This is the only way that you can bring value to customers and eventually capture value". **(D, FT, Core)**
13. "Survival is the primary objective in the beginning. Once you have a stable business, you have the luxury to focus on specific programs that you want to pursue". **(D, FT, Core)**
14. "During Phase II we found a better technology that had a higher probability to be accepted into the market and started to pursue it". **(D, FT, Core)**
15. "Our goal during Phase II was to build a technology demonstrator so that we could sell the manufacturing rights to a large corporation". **(D, FT, Core)**
16. "We have stopped proposing for SBIR funding. We learned that submitting out of the blue was very risky and getting funded was a random occurrence". **(D, FT, Core)**
17. "We are privately funded and successful. Unlike other firms, we do not need the SBIR program to survive". **(D, FT, Core)**
18. "We are still working with materials and technologies that we developed during our Phase II SBIR". **(D, FT, Core)**
19. "We look at the expertise we have at hand and then read the solicitations to try and find a good match". **(H, NFT, App)**
20. "We used to do a lot of SBIR's until one of them led to a full scale manufacturing of a product. We de-emphasized our focus on government contracts until the market disappeared under us". **(H, NFT, App)**
21. "When we identify technologies to pursue, we look at different metrics. We keep focus on our specific market segment and try to identify how new technologies can be applied there". **(H, NFT, App)**
22. "We supply modules to system suppliers. We need to identify them, their needs and their customer's needs". **(H, NFT, App)**
23. "We are interested in making a final product, not only in developing the technology and then selling the manufacturing rights. We are a component supplier". **(H, NFT, App)**
24. "We focus on the fundamentals to make the technology for this application work. We do not worry about the supporting technologies that are required to make the rest of the application work. We know that that might pose a problem later on, but we also know that without the fundamental technology working, there will be no application". **(H, NFT, App)**
25. "We do not need any sophisticated program management tools or strategies. Our programs are small enough that we can keep all the metrics and timing issues at hand". **(H, NFT, App)**

26. "The longer you are in the SBIR business, the more you know to do your homework upfront. You need to answer the questions who, where, what, when and what is your marketing plan. The more experience you have, the better you get at it". **(F, NFT, App)**
27. "Experience teaches you to look at the larger picture". **(F, NFT, App)**
28. "For a small business, the easiest way to capture value is to partner with a larger company and license the technology. We are looking and doing more of it in the future". **(F, NFT, App)**
29. "Although we believe in partnering, some programs are small enough so that we can do the production ourselves". **(F, NFT, App)**
30. "The original concept that we worked on was perfected by another company. We simply shifted gears and came up with a great application for the original concept, using their technology". **(F, NFT, App)**
31. "We are large enough that we can share resources. This allows us to have experts on board. This is a tremendous help when looking at the bigger picture. Their costs are distributed between the programs". **(F, NFT, App)**
32. "When we discover a core technology, we always have to make and vindicate it in our labs first. Need a lot of resources to fund this and keep going and the SBIR program is a wonderful opportunity to do that". **(C, FT, Core)**
33. "We look at applications that will make us successful and self sustained in the near future". **(C, FT, Core)**
34. "You have to look at the overall picture and preserve the balance between the objective and the "bookkeepers" in order to make something that will get accepted". **(C, FT, Core)**

4.4.1.2 Proposing for SBIR and funding strategy

35. "We will not sell out to out to the SBIR process. In other words we will not propose for funding in our core technology area. We will propose for funding in applications of our core technology" **(A, FT, Core)**
36. "There is a lot of uncertainty in the business and we would not have pursued this application if it was not for the SBIR funding. The application was just to risky" **(A, FT, Core)**
37. "This SBIR taught us how to apply out technology. We ended up opening a whole division because of the results of the SBIR program" **(A, FT, Core)**
38. "We knew the funding agency did not have a direct need for the technology themselves. This was fine with us because we could pursue the commercial application". **(D, FT, Core)**
39. "Programs that are sponsored by the government have no financial risk to the company. You can make your basic profit by doing research for the government". **(D, FT, Core)**
40. "Phase I is not a profitable study. We loose money on Phase I's. We only use Phase I's to get enough data so that we can have a successful Phase II proposal. Our primary focus is to get the Phase II money". **(D, FT, Core)**

41. "We have found that funding agencies tend to have s specific goal. It is however possible to move that goal". **(D, FT, Core)**
42. "It is very easy to have a shotgun approach when proposing for government funds. Your owners want to see the money coming in and this encourages shotgun approaches. To avoid the shotgun, you need a vision and you have to be very rigorous and stay focused." **(D, FT, Core)**
43. "You can get away without any commercialization. As long as you perform valuable research for your contract monitor, you will not need commercialization". **(D, FT, Core)**
44. "We identify a technology that will be basic R&D and then identify a Phase I topic that will fund it" **(B, FT, Core)**
45. "We only do Phase I's because it is an entrance for Phase II funding". **(D, FT, Core)**
46. "Our Phase II fast tract funding came from a current investor. The investment was independent from the technology". **(D, FT, Core)**
47. "We had no conflicts between the Fast Track sponsor's requirements and the funding agency. The funding agency did not have a use for the technology and was supporting the commercialization entirely". **(D, FT, Core)**
48. "We were bought out in 2000 and our new owners did not want to do any government work". **(H, NFT, App)**
49. "The company is split up into groups and each group decides what solicitations to pursue. Will look at the background of the individuals as well as the history of the group in deciding which ideas to propose". **(F, NFT, App)**
50. "You need a lot of interaction with the funding agency, especially before proposing, to find out what they really need. Some of the customers are very specific and are aware of the capabilities of the technology. Others have an idea of what they want, but no idea how to get there. You need to know who your audience is". **(F, NFT, App)**
51. "Part of our Phase I proposed work is to identify who the customer is. We develop what is known as notional requirements. We take trips with demo's and show and tell. Prototypes, videos and even simulation is great for conveying the technology and selling it. What people see is what they are going to buy". **(F, NFT, App)**
52. "You demos must be of such a quality that you gain the "WOW" factor. If you undershoot, you just discredit yourself". **(F, NFT, App)**
53. "SBIR's are a wonderful avenue because they are wide open for what they are looking for. They need an order of magnitude improvement or an empathy in a certain area and this provides the opportunity for you to align your technology with their need". **(C, FT, Core)**
54. "We look for angel investors. Our technology is not as sexy as nano or bio, but we are very successful in attracting the right kind of investor, the kind we want". **(C, FT, Core)**

55. "We look at all the SBIR solicitations that come out and see where we can align ourselves even if we have to adapt a little. To meet the requirements. We also look where it would be appropriate for us to extend our technology". **(C, FT, Core)**
56. "We were lucky in the timing of our external funding. There were a lot of wealthy people with extra money that did well in the market and needed to invest in something more conservative". **(C, FT, Core)**
57. "The SBIR program helped us enormously financially in developing the new technology and trying to develop a product". **(C, FT, Core)**

4.4.2 Problems

In the questionnaire, the companies were asked to identify if the problems encountered could or were anticipated and if these problems were internal or external. During the interview, the respondents were asked to elaborate on the problems that they faced. Again, the interviewer encouraged and received answers that were applicable to programs other than the Phase II.

Below, the problems are split into anticipated and unanticipated problems. Comments about how the companies dealt with the problems are also reported. Again the responses of the different companies are quoted and the company identities are in parenthesis.

4.4.2.1 Anticipated problems

58. "To balance the needs of the government and the commercial customer can be a delicate act. They often do not coincide". **(D, FT, Core)**
59. "Collaboration with universities are very difficult because they have different objectives". **(D, FT, Core)**
60. "Large companies in our industry are only interested in preventive research and therefore it is very difficult to write research agreements with them". **(D, FT, Core)**
61. "Larger firms do not "collaborate with smaller firms. To do so is an insult to their technical staff. They actively take what technology they need from a smaller firm and get very upset when this is suggested". **(E, NFT, Core)**
62. "Foreign companies, especially the Japanese, have carefully defined their future technology needs and have highly trained personnel who visit small companies and ask questions about the novel technology. This is translated, sent back to the main office and generates more questions. "Good" technology must have a patent position and must make a fundamental difference to the dynamics of an industry. Years of fruitless negotiations wear out the resources of the small firm, reduce the

value of the technology and allow time for the foreign firm to understand the improvements and to develop their own intellectual property". **(E, NFT, App)**

63. "Possibly the most common and dangerous form of "collaboration" in the SBIR program comes from university professors with consulting arrangements with SBIR program managers. It is not unusual for these professors to actively review the proposals and then write their own grant requests for their own university programs. This practice makes it very difficult and expensive for anyone to obtain a clean title to the intellectual property and have "good" technology". **(E, NFT, App)**
64. "Small businesses have limited resources to get market information. The more information you are able to get of the market, the more information your competitors are able to get." **(E, NFT, App)**
65. "Most small companies do not have the machines and facilities to do some of the essential development themselves". **(G, NFT, App)**
66. "Most large companies like to buy technology off the shelf. They are not interested in spending R&D dollars on small companies". **(G, NFT, App)**
67. "Our industry has a very long clock speed. Takes up to 15 years to test a new technology. Thus is not just a matter of changing something to see if it works. Have to be very rigorous when setting up a new experiment". **(G, NFT, App)**
68. "The two phase SBIR program m is just too short and has too little money to really produce a production ready solution". **(B, FT, Core)**
69. "We knew that the funding that we would receive was not going to be enough to develop the application to a marketable product. We knew we had a very low probability of success". **(D, FT, Core)**
70. "You need to develop a way to make the technology self sustaining after the funding is complete. This is the biggest hurdle, since the two phase money is not enough to make a product". **(F, NFT, App)**
71. "Your biggest challenge is always technical, but in the end you need something that you can sell. Even if the technology works, you are never sure if the product will be a hit". **(F, NFT, App)**
72. "Survival is the key early on. The finances will kill you and you need to adapt all the time just to stay alive. This means it is very difficult to focus". **(C, FT, Core)**
73. "Our large customers have a very tough time to decide between technologies because they have to listen to the financial and technical people. You need to make both happy before you can sell". **(C, FT, Core)**
74. "Our technology was entirely new, there were no textbooks or handbook to fall back on when it was not working, so it was very difficult to start". **(C, FT, Core)**
75. "Finances were our biggest obstacles." **(C, FT, Core)**
76. "There are always differences of opinion, and to sort this out internally is a sensitive issue, especially if you are creating the standard for the technology". **(C, FT, Core)**

4.4.2.2 Unanticipated problems

77. "It became clear to us that our customers had performance goals that were beyond the thermodynamic limits of the technology". **(E, NFT, Core)**
78. "While lower level employees of large companies maintain the fiction of being very willing to visit, listen and learn about technology developments, agreements with their bosses are very elusive. Most of these mission are information gathering events and serve as market insurance". **(E, NFT, Core)**
79. "Collaboration has the disadvantage that a larger competitor might steal your edge". **(E, NFT, Core)**
80. "We were part of a novel energy program. Had the technology built, but we were unable to get the raw materials because politicians were not lobbied". **(E, NFT, Core)**
81. "It has happened to us that the government engineers decided to use our technology. But then the procurement officer when ahead and bought the older technology". **(G, NFT, App)**
82. "Foreign competitors are state sponsored for not only the research, but also the development and first round procurement". (NFT)
83. "The market collapsed under us towards the end of the Phase II. The government was never going to be a client and therefore we had no customer base when we finished the program". **(A, FT, Core)**
84. "Our customer realized that the market was disappearing, but did not inform us. We ended up spending 6 months to try and find another application for our technology". **(A, FT, Core)**
85. "At the end of Phase II we had a wonderful technology demonstrator model but no market. Other things became more pressing and we eventually aborted the application". **(D, FT, Core)**
86. "We focused on one technology and one market. If we had diversified more, we would have been in a better position to deal with the market crash'. **(H, NFT, App)**
87. "At the end of Phase II we had a great technology, but we found it very difficult to market it". **(H, NFT, App)**
88. "The technology that we manufacture was initially funded by an SBIR in 1991. We sold the first product in 2000. This is an indication of the time frame that is required to make a technology work". **(H, NFT, App)**
89. "The community moved to a different technology than the one we were working on. This was worrisome for a while, but they shifted back when that technology could not deliver the promised functionality". **(F, NFT, App)**
90. "We are still working on the concept". **(F, NFT, App)**
91. "Another company was able to make the technology better and cheaper and bring it to market earlier than we could". **(F, NFT, App)**
92. "When you are very small, everyone needs to do everything. You need to be sensitive to everyone's reputations and feelings. In a small company this can be

very disconcerting and it makes reaching the design goals very difficult". **(C, FT, Core)**

93. "The only areas of real conflict were in the design. What attributes do we include, which ones go into another model, how will it look and so on. Once the technology works, these start biting you". **(C, FT, Core)**
94. "We had the obstacle of investors that would read some thing in a magazine and then ring you up and say: Hey why are we not doing this, you should be considering that". **(C, FT, Core)**

4.4.2.3 Dealing with problems

95. "You need constant feedback from your customers otherwise you will eventually solve a problem just find out that the market for it has disappeared". **(E, NFT, Core)**
96. "To publish is very dangerous, your competition will review publications and might find an edge". **(E, NFT, Core)**
97. "Once you have explained the technology to a potential customer, someone will bad mouth the invention. You need to be prepared for that. Anticipate what a potential customer might use to shoot down your technology". **(G, NFT, App)**
98. "We were able to change the focus of the program when we saw the market disappearing. We had to develop a lot of technologies in order to make the first application work. We were able to use some of those technologies in other areas. We ended up going way over the Phase II budget in order to set up the manufacturing facility". **(A, FT, Core)**
99. "If there is a paradigm shift, you need to protect yourself, you need a contingency plan that will keep the program alive". **(F, NFT, App)**
100. "There are the customer requirements that can be met, and then there are the customer wishes, the unobtainium that is beyond thermodynamic limits. It is very difficult to keep the expectations real, especially if you are developing a new "breakthrough" technology". **(F, NFT, App)**
101. "We had a professor in Mechanical Engineering that decided he wanted to be part of a commercial entity. He became a guru on our technology and this was indispensable because there was no standard. He created the standard for the technology". **(C, FT, Core)**
102. "In the early stages of a small company trying to make an entirely new technology work, you need a strong leader that can make decisions very quickly so that you do not waste resources arguing yourselves". **(C, FT, Core)**

4.4.3 Collaboration

The collaboration between companies and other entities was of particular interest for this research since the premise was that the potentially higher level of interaction of FT companies would result in a better outcomes. The help that companies receive from others have many

benefits and pitfalls. These were touched on in the questionnaire and the companies were asked to elaborate on their responses. The interviews showed that there were three major types of collaborations: those with partners, universities and customers.

4.4.3.1 Partners

103. "The whole industry that works in our field comes together at a conferee once a year. Here we get the opportunity to make contacts and do marketing. We can get a very good handle on what the community thinks of our products and what they a re willing to pay". **(A, FT, Core)**
104. "Our partners are essential in creating new opportunities. We combine expertise to deliver break though products". **(A, FT, Core)**
105. "No small company has the broad range of resources needed to successfully bring a new product to market. Thus without some form of collaboration, the SBIR project will be commercially unsuccessful. Our US small business partner contributed 1) a definition of system attributes and interface definitions for power systems useful in the oil patch 2) manufacturing expertise and 3) marketing contacts." **(G, NFT, App)**
106. "While it is needed, most forms of collaboration are extremely dangerous to the health of a small company. For this reason, few small companies survive collaboration. We only work with smaller US firms and does not to propose ideas for SBIR review without first establishing intellectual property rights. This seems to work but it does require anticipating the SBIR topic areas before they are announced." **(E, NFT, Core)**
107. "We identified potential investors during Phase I". **(B, FT, Core)**
108. "Our partner supplied sophisticated testing equipment that they were the sole source of". **(B, FT, Core)**
109. "When defining interfaces, we have a two way relationship. If the functionality benefit is great enough, our customer will be willing to change their architecture. Else we tend to design to fir with their system". **(H, NFT, App)**
110. "We never entertained venture capitalists. In three years they want five times their money back and all the trimmings that go with that. They are in the driver seat then because you do not own your company anymore and they force you to sell. They will write clauses into their agreements that, if you are not careful, will take it all. **(C, FT, Core)**

4.4.3.2 Universities

111. "Universities tend to chase atoms and not dollars. You can expect great research for the next generation." **(D, FT, Core)**
112. "It is dangerous to work with universities as they need to publish. This will reveal to your competition what is the latest techniques and will reduce your competitive edge". **(E, NFT, Core)**

113. "We have a very close relationship with the university that the company stated out from. We hire employees and interns form there". **(D, FT, Core)**

4.4.3.3 Customers

114. "We closely worked with a potential customer with whom we already had a licensing agreement with and who could benefit tremendously from the work." **(A, FT, Core)**
115. "We have very close ties with our Phase II fast track sponsor. Their application was different from the one that we were developing for the SBIR, but they used the technology". **(A, FT, Core)**
116. "We have inquiries from time to time from our Phase II customer to see if we have novel ideas and or technologies for problems that they have". **(A, FT, Core)**
117. "We carefully consider the sponsoring agency and make sure that we do a very good job for them. This leads to later funding opportunities". **(D, FT, Core)**
118. "The government agency that we were doing the SBIR for introduced us to potential customers". **(G, NFT, App)**
119. "Some larger companies have active partnering programs for later stage technologies". **(E, NFT, Core)**
120. "You have to be very careful when collaborating with foreign trading companies, they tend to gather information about your technology without giving you any reward for the information". **(E, NFT, Core)**
121. "To collaborate with potential customers you need to have a number of things in place. Firstly, they need to be fairly wealthy so that you can pursue a lot of options and thereby mitigate the risk. For instance if the government is your potential customer (SBIR), they can afford to look at lot of alternatives". **(E, NFT, App)**
122. "You can get a good idea what the customer wants when you collaborate with them". (NFT)
123. "Constant feedback from customers is the only way to make sure that your research is relevant" **(H, NFT, App)**
124. "Once our customers are interested in our technology, they will write letters of support for us". **(H, NFT, App)**
125. "We found that the customer does not know what they need when it comes to revolutionary products. They need to be educated with regards to the benefits". **(H, NFT, App)**
126. "You need to get a feel for what the customer wants and what the are prepared to tolerate". **(F, NFT, App)**
127. "You must be able to show the value if there is to an increase in cost". **(F, NFT, App)**

5 Interpretation

The data of the previous section is quite substantial and in many cases self-explanatory. An effort is made in this section to draw together some of the statements and questions in order to make observations of trends relative to the companies practices. In order to support the claims that will be made here, reference to the actual quote in the previous section will be made in parenthesis.

The major finding was that Fast Track was a) not a differentiator for interaction with other entities nor b) was a differentiator relative to the eventual success of the innovation. Although this result obviates the natural experiment, it neither discards nor proves the premise of the thesis. This finding is an important fact in relation to the SBIR program and particularly to assessing the value of the fast-track approach. In addition, it is useful to engage in discussion of the practices followed by the companies.

5.1 Fast Track (FT) versus Non-Fast Track (NFT)

For the small group that was observed in this study, a remarkably small difference in the strategy, collaboration, problems and outcomes of the Phase II SBIR's were found. The only difference between the two types was that of the nature of the innovations. The FT companies all reported that their inventions were modular where the NFT companies believed that theirs were either product or architectural.

This difference might be attributed to the fact that the FT companies believe that their products will be used in a larger system and will thus be an integral module to that system, which might stem from more interaction with potential clients. The NFT companies might think of their

products as stand alone, off the shelf type products that can be used in a variety of similar systems.

As for the outcomes of the projects, two companies stand out. Company E, a NFT, Core developer was the only company to realize commercial sales from the specific SBIR project. Company H, realizing the benefits of another SBIR program was the only company that showed significant employee growth and increase in sales.

These findings differ significantly from the predictions made in Reference XIX. Here the FT companies were given a much higher probability of success and commercial sales than their counterparts. The reasons for the difference in the findings are two fold:

1. Firstly, the study in Reference XIX was conducted in 1996, one year after the Fast Track funds were released. At this stage none of the companies had any hard data to validate their predictions of sales and market share. The FT companies, because they had to prepare business plans in order to receive external funding, had already put significant effort into projections of sales and market forecasting. The NFT companies were probably still battling with the technology during Phase I and had barely thought of the processes that need to be followed once the technology was proven.
2. The funding received by the FT companies was not always focused on the specific Phase II program. Some of the FT's acknowledged that they had an investor already lined up to make a generally investment in the company. By timing the investment with the Phase II proposal, they were eligible for FT funding and thus increased their chances of doubling the funding. Some respondents perceived this as a common occurrence. (46, 56)

Further investigation revealed that all the FT companies were developers of the underlying technology for the application of the SBIR where all except one of the NFT companies were application integrators. This will be discussed next.

5.2 Application developers versus technology developers

As was stated earlier, the discovery was made that all the FT companies and one NFT company were primarily core technology developers. The interviews further substantiated this finding. The Core companies made the decision to also develop applications for their technologies and found the SBIR process a welcome vehicle for funding of those applications. (5, 33, 35, 44).

These core technology companies have an established business in developing the underlying technology. At some point they realize there is an alternative market for their technologies that are not developed and that they might benefit from an application in this market. While keeping their focus on developing the technology, they also pursued applications opportunities. (6, 9) In essence, they are widening the use of their technology by creating new markets for it. In the process of developing the application, some found their initial technology lacking and expanded its functionality or created other related technologies to fill the gap. (18, 49).

Thus the core companies only wander into the application to expand their possible markets. This might be the reason why they feel that they are always module developers and hence the response to question 1 in the survey.

The application developing companies on the other hand tend to be users and implementers of technology. They seem to use novel technologies that are available from elsewhere and integrate it into useful applications. (21, 65)

These companies are in essence technology system integrators. Although they have a fundamental understanding of the technology, they do not produce the technology itself. They rather focus entirely on the application of the technology to a specific solution. (24). Although the novel application of a new technology to a problem is a "technology" development project in itself, the distinction between Core and Application approaches is clear.

5.3 Interaction with other entities

All of the companies, except for company F had significant interactions with other entities. Company F is significantly larger than the others and might have had the expertise required in house. The interaction between entities would have helped all these organizations in defining their problems that they would face. As stated earlier, interaction occurred regardless of the transfer of funds. As a matter of fact one of the FT company's investors contributed nothing to the project and was a passive client. (Question 13, Company A)

The separation between Core and Application companies that was discussed in the previous section might be the reason why FT companies received external funding. The core business of the FT companies is the underlying technology. They are therefore in business selling the technology, not the application. If someone else develops the application, but still use their technology, they will nevertheless profit. The FT / Core companies' trade secrets and subsequent intellectual property (IP) lies within the technology. They are thus more willing to discuss possible applications with numerous people and entities and will have a larger probability of finding a potential investor. (54)

The application developing companies on the other hand are dependent on the application and will not so easily discuss it. Their entire IP is contained in the application. It is possible for someone to approach the holder of the underlying technology, a supplier to the application-developing firm, and create a competing application. These companies are therefore less likely to interact with numerous entities at a level that might inspire investors.

Some of the small companies are wary of larger corporations although others acknowledge the potential benefit of interacting with them (60, 61, 66, 28). Only three companies interacted with larger organizations that were customers on a technical level (108, 109, 114).

A number of the companies collaborated extensively with other small entities. This was done because the mix of the expertise and resources of the two firms drives some risk from the development process (105). Partners, aware of the abilities of one another, run across potential applications for each other's technologies and are able to identify other potential markets and opportunities for one another (104). Other small companies also pose less of a risk to the company because they do not have the resources to take the opportunity away from the firm and develop it independently (106, 79).

One of the best opportunities for interaction and collaboration are at conferences. Here the companies can trade information on opportunities, technology and other essentials with other members of their technical community (103).

Of interest was the view on interacting with universities. Some of the companies have their founding roots inside a university lab. This is where the underlying technology was developed. Research institutes like MIT encourage graduates to pursue commercial application to the technologies that they developed because of the licensing possibilities that it offers the university. There is however a mixed feeling from the SBIR companies on working with

universities. Some companies still have close ties with specific departments inside the universities and see these as good areas for scouting possible employees (113). Others see working with universities as dangerous because they differ in emphasis form the small company (59). Universities have to publish their results while commercial entities must protect their IP at all cost (112, 63). Universities tend to delve deeper into the science while commercial entities have to decide on the technology and build a product around that (111).

All the companies, regardless of their position as a FT or NFT, Core or App, acknowledged the value of interacting with customers on a constant basis. Therefore it is not surprising that most companies had some sort of a strategy to enquire from the market on what is needed, how their technology was fulfilling a requirement and what they can offer to potential clients. Again, the fact that all of the companies had extensive interaction with clients might be why there is such little difference in their strategies and outcomes (115 - 126).

5.4 Strategy

Most of the companies surveyed, regardless of their category, agreed that survival is the key in the early stages of the company's life (13, 72). The delicate balance between developing the technology and maintaining funding streams was experienced by most (34).

Most start-up companies that go out of business do so because of a cash flow problem. It is here that the SBIR process is so valuable because it provides sustaining resources. The availability of the SBIR resources can be both a blessing and a curse. In order to survive early on, there is a need for cash flow, but starvation tempts the company to go after applications that is not part of an overall plan. It is very difficult to keep the focus when the owners want to see a return on their investment or when times are tough (42).

The companies surveyed had a definite distinction in the strategy toward deciding on their applications. On the one spectrum were the companies that had very stringent rules and selection processes (9, 11, 10) to those that have a very loose selection process and will go after any idea that they think they can get funding for (49). To both these their strategy is viewed as a way to mitigate risk.

This split is evident in the approach taken when the companies decide which solicitations to pursue. Some of the focused core technology companies believe in expanding previous work (4), finding a Phase I topic that will fit their previously identified technology (44), or adapt their underlying technology slightly to align with a solicitation (53, 55). This is in contrast with the application developing companies that will adapt their approach or idea to fit the needs of the soliciting agency. Some look at the expertise on hand they have on hand and try to find a match with a solicitation (19). Others will interact extensively with the soliciting agency in order to understand hat they really need and then provide it for them (26, 50, 51). The focused core developers only explore opportunities that are aligned with their technology development plans (1, 5, 16, 17) while the application developers will take on any idea that they think they have enough experience or a good idea in (20).

These core technology companies believe in seeking balance between being focused on the ultimate goal of developing the technology to where it will dominate the market and creating opportunities in the interim (6).

All the companies accepted that change was part of the research effort. In the questionnaire, four of the companies indicated that problems experienced during the development forced them to modify the project. It is thus not surprising to see that the companies implemented

change when they were faced with better technologies (14) or when the competition had a solution sooner (30).

5.5 Problems

One of the major problems that the companies had was that the SBIR funding was not enough to develop a marketable application (68) Most seem to have anticipated it and look for other avenues of funding early on in the process (69, 70, 75).

Technical problems are at the heart of the applications development process. This is not surprising since the reason for getting SBIR funding is that it is innovative research. So, to find the companies struggling to make the technology work was expected. As a matter of fact, the premise of the thesis is that companies spend too much time on the technical aspect and too little on the actions that are required once the technology is proven (71). Some companies had severe technical challenges such as a customer with expectations that were beyond the thermodynamic limits (77), technologies that were so new that the scientific theory had to be invented (74).

Marketing was a major obstacle. Some companies had a perfect market opportunity, a working technology and then found that the market disappeared just as they were ready to launch (83, 84). Others had a great working prototype, but no market (85, 87). Some focused on one technology and one market, only to be left to deal with a changing market (86). Limited resources made it tough to obtain market information. In the rare case that obtaining market information was trivial, the companies found that their competitors had access to the same data (64). Probably the worst marketing obstacle came from marketing to the wrong decision making unit (DMU). The technical personnel of the customer wanted the technology, but the procurement officer decided on something else (81, 73).

Internal strife between employees in a small firm is common. Because everyone needs to do everything, there is often an overlap on tasks that no one in the company has training on how to do and this can cause conflict (92). Sometimes there are conflict over technical issues, often because the technology is so novel that the basic science is not understood or developed (93, 76).

Dealing with customers and investors that have high expectations is not trivial. Some customers will have expectations that are beyond the thermodynamic limits of the technology and in order to keep their business, it is very tough to manage their expectations (100). Some investors or customers will have enough knowledge of the technology so that they make assumptions of its worth in other applications. Companies found it tough to manage individuals that were eager to suggest applying their technology to unrealistic problems (94).

5.6 Timing

The time it takes to develop a technology, or the clock speed of the industry is an often-underrated obstacle. Some companies find themselves still working on the technology, almost eight years after the initial Phase I funding (90). It took some nine years to develop other SBIR funded technologies before it reached the market (88). Others found that the competition was able to make a better product and bring it to market faster than they could (91). In another case, by the time the company develops the technology, the community moved to a different technology. Luckily the new technology did not live up to expectations and they were able to recapture some of the market (89).

All these examples point to the fact that a two-and-a-half year development contract is not enough to take a novel technology to market. The time and funding of a Phase II SBIR cannot provide the resources required to make a product technically robust, introduce it to the market and capture value from it. Even with the added benefit of shorter funding gap between Phase I

and Phase II, higher probability of funding and added external resources, companies find that a Fast Track Phase II runs into the same problems and have identical difficulties because of the short development time.

It is therefore interesting to note that companies with linked strategies, such as Core developers, were successful in developing their underlying technologies regardless of the SBIR funding. This points to the fact that profitable companies have a strategy of pursuing only SBIR's that are aligned with their core business or use the SBIR to create a new line of business. In either case, they have a follow up plan and exit strategy from the SBIR program in order to supplement the limited resources of time and funding. This is key for the survival of the company under the great uncertainty that is associated with the development of new technology applications.

6 Concluding Remarks

In contrast to earlier work, the limited sample of companies that were studied indicates that there was no significant difference in the outcome of the projects on the differentiator of Fast Track and Non Fast Track sponsorship. This is contrast to prior work and one can speculate that it is because the data in Reference XIX was based on expected results. Further work is required in order to obtain a statistically significant sample to substantiate this claim. However, it is telling that the results of the detailed study performed on the New England companies in 1996 is completely changed by the research reported in this thesis. It is suggested that the companies that participated in the 1996 study be revisited so that the outcomes of their projects can be determined exactly in order to substantiate the favorable reviews of the Fast Track program.

The detailed results also indicate that the time and funding of a two-phased SBIR is not sufficient to bring technologies to market. Thus it appears that even though the Fast Track program does improve the funding gap and increases the total investment in the application, it is still not enough to increase the probability of success. It is therefore advisable for companies to have a linked strategy when starting a SBIR program where, from the onset, the goal is to obtain further government or external funding by the time the SBIR runs out. All the Core development companies that identified in this study had a linked strategy, while only one of the Application developers did.

Application research is an enormously difficult and risky undertaking. All the companies that participated in this research had processes in place to mitigate risk and drive ambiguity out of the development process. Not one of these methods could be condemned nor are any of them

prototypical. This is because each program faces so many different and unique problems that it will be impossible to define a coherent framework that can work across the board.

Every principal investigator or manager of an application research project should evaluate his / her situation on a daily basis in order to decide where to spend resources. Interaction with other entities may identify hurdles and help in making plans to overcome them. Constant review of the technology against the competition, the market and customers is needed. A willingness to change direction, reallocate resources or stop work on a project is a requirement for continual success and survival.

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APPENDIX

APPENDIX A: QUESTIONNAIRE AND ANSWERS

Benefits

1. What were the perceived benefits of the program when it was started?
    - Cost
    - Performance
    - Other

Table 7: Answers to Question 1.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
1	Cost	Performance	Performance	Cost	Performance	New Capability	Performance	Performance

The only differentiator is that one NFT, App company indicated that they were developing a new capability, while none of the FT or Core companies did.

2. How did these benefits change as the program developed?
    - Modified
    - Stayed the same
    - Why?

Table 8: Answers to Question 2.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
2	Modified	Modified	Stayed	Stayed	Modified	Stayed	Stayed	Stayed

All Application developers believed that the benefits did not change during the program. The only NFT Core's answer was connected to the FT companies.

3. Would you describe the innovation as:
    - Architectural
    - Modular
    - Product
    - Process
    - Why?

Table 9: Answers to Question 3.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
3	Modular	Modular	Product	Modular	Architectual	Product	Product	Product

All the Application developers answered that their innovation was a product. All the NFT companies describes the innovation as more than just a module to another system. Company C's product is in essence a module to a larger system, although they are selling it independently of the larger system.

Points of Resistance or Hurdles

4. What were the sources of resistance that you experienced in this project?
    - Internal
    - External
    - Other

Table 10: Answers to Question 4.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
4	External	Other	Internal	Internal	External	External	External	External
Details	Market collapse	Funding / timie shortage	Perosnnel design and interpretation	Scope beyond internal expertize	Callboration	Competition Superior Technology	Market to the wrong DMU	Critical component manufacturing

All the Application developers experienced resistance from outside of the organization. None of the NFT companies experienced internal conflicts.

The App companies seem to experience problems that could have been anticipated and dealt with earlier in the programs. What the competition is up to, the correct DMU and finding the right person to produce your critical component is technology strategy 101. The Core developers on the other hand experienced the problems that one expects from these high-risk programs. Having a market collapse, running out of funding because of technical difficulties, experiencing internal conflict because of design issues and realizing that the problem is larger that initially anticipated is all part of the gamble in high-risk research.

5. Did you expect these obstacles?

   - Y/N

Table 11: Answers to Question 5.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
5	Y	Y	Y	Y	Y	Y	Y	Y

Everyone expected some type of obstacles. The next questions dives a little deeper into the nature of the obstacles

6. Did / Could you have anticipated them?

Table 12: Answers to Question 6.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
6	Did	Did	Not at Level	Did	Did	Not at Level	Not at Level	Did

Once again there is no differentiation between the FT and NFT responses.

7. Have they been present in any other programs?

Table 13: Answers to Question 7.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
7	Y	Y	Y	Y	Y	Y	Y	Y

All the companies experienced similar problems in other programs and that is probably why they did anticipate them.

8. Why do you think these resistance factors were present?
    - They appeared as the program progressed.
    - We did not consider them to be a factor early on.
    - We did not perceive them as resistance/risk factors.

- There were other risks that we perceived to be of more importance.

Table 14: Answers to Question 8.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
8	Other	Other	Not Consider	Other	Other	Other	Other	Other

All the respondents, except company C believed that other considerations were more important than the factors that eventually proved to be crucial to the program. This is not surprising when it is considered that all SBIR programs are high-risk innovative research. The technical issues of the program must take precedence over anything, especially in the beginning of the program. Only after the technical issues have been sorted out will the technology be facing other issues. Without technical feasibility, there will be no manufacturing, marketing and collaborations to consider.

9. When did these points of resistance first appear?
   - At the start of the program (Phase I)
   - Middle (Phase I)
   - Change over (Phase II proposal)
   - During Phase II
   - End of Phase II
   - As we entered possible Phase III

Table 15: Answers to Question 9.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App

9	End Ph II	End Ph II	Start Phase I	During Ph II	End Ph II	End Ph II	End Ph II	During Ph II

Except for companies C and H, all the entities found themselves in a familiar position: at the end of the funding period, they had some sort of a working prototype, but there was a source of resistance that kept the program from moving forward. Anticipating these problems earlier might have produced a different outcome.

10. What was the result of the resistance

- Modified project
- Killed project
- Ignored and carried on.
- Allocated significant resources to it.

Table 16: Answers to Question 10.

Company	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
10	Killed	Killed	Modified	Modified	Modified	Modified	Killed	Allocate

These answers are meaningful. Half of the FT companies and only one of the FT had the projects killed because of the problems. This contrasts earlier work that suggested that FT companies have a better chance at success than NFT's. Half of the companies modified their projects to overcome hurdles. All the FT companies that modified the project, did so earlier in the project as shown by answer 9.

Collaboration

11. Was there significant trading of information with another entity or individual?

Table 17: Answers to Question 11.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
11	Y	Y	Y	Y	Y	N	Y	Y

Everyone except company F had significant collaboration and exchange of information with other entities. This might be because company F is significantly larger than any of the other organizations. It is therefore possible fore them to have expertise in-house that the others needed to obtain form outside.

12. Was your Phase II Fast Track sponsor?

- A potential client.
- An active investor (Venture Capitalist)
- A passive investor (Angel)

Table 18: Answers to Question 12.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
12	Client	Angel	Active Investor	Client	Partner	None	Partner	Client

This question pertains more to the collaboration of the previous question and that is the reason why some of the NFT companies answered that they did have interaction with a "Sponsor". Only two of the FT companies had clients as sponsors. It is important to note that

three of the NFT companies had interactions with clients and partners. This might be one of the reasons why there is such little difference between the FT vs. NFT and Application vs. Core technology developers.

13. What did the partners contribute to the program?
    - Market definition
    - Broader spectrum of attributes.
    - Identified possible hurdles.
    - Helped negotiate hurdles.
    - Did the collaboration increase/ decrease the effective use of project resources?
        - Forced to look at non-essential attributes.

Table 19: Answers to Question 13.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
13	Passive	Broad	Market Def	Market Def	Market Def	Nothing	Nothing	Market Def

Although company G indicated that they had interaction with a partner, they believe that the partner contributed nothing to the program. It is interesting to note that the partner of company A was passive during the development, although it was a client.

14. How much contact was there with potential customers during the program?
    - Technical + Marketing
        - Interface definitions

- Cost estimates and projections
- Compatibility issues
- Other?

- Timing
  - Launch
  - Investments

Table 20: Answers to Question 14.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
14	All	All	All	All	All	All	All	All

All the companies had some sort of a strategy to obtain information from the market and customers about what is needed and required. The fact that the sponsoring agency is the client in some cases may have influenced the answers.

Outcome

15. What was the outcome of the Phase II effort?

- Lead to Phase III
- Lead to commercial sales (Amount?).
  - Company manufacturing product.
  - Sold rights for manufacturing
- Additional funding from external sources.
- Form integral part of DOD research effort.

- Technical progress
    - Increased technology base of firm.
    - Instrumental in obtaining additional funding.

Table 21: Answers to Question 15.

Company	A	B	C	D	E	F	G	H
Award	FT	FT	FT	FT	NFT	NFT	NFT	NFT
Core / App	Core	Core	Core	Core	Core	App	App	App
16	No Product	Used technologies elsewhere	No Product	Learned and apllied lessons to another successful program.	Commercial sales and added external funding	In Process od Selling Rights to Manufacturing	No Product	Used technologies elsewhere

APPENDIX B: EXAMPLE PHASE I SBIR PROPOSAL OUTLINE

FROM: HTTP://WWW.ACQ.OSD.MIL/SADBU/SBIR/SOLICITATIONS/SBIR032/

3.5 Phase I Proposal Format

a. **Proposal Cover Sheets.** On the DoD Electronic Submission Web Site (www.dodsbir.net/submission), prepare Proposal Cover Sheets, including a brief technical abstract of the proposed R&D project and a discussion of anticipated benefits and potential commercial applications. Your cover sheets will count as the first two pages of your proposal no matter how they print out. If your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released on the Internet; therefore, do not include proprietary or classified information in these sections.

For Components requiring proposal submission by mail (see Section 8.0), print out a hard copy of the Proposal Cover Sheet from the Web Site and include it, with the appropriate signatures, as the first two pages of your proposal. Also include a copy of the signed Proposal Cover Sheet in the additional copies of the proposal that you submit per Section 6.0 of this solicitation.

b. **Technical Proposal.** Covers the following items in the order given below. Begin your technical proposal on Page 3 (since the cover sheets are pages 1 and 2). If electronic submission of your technical proposal is required by the DoD Component (see Component instructions, Section 8.0), first create the cover sheet and then upload the technical proposal file in Portable Document Format (PDF) onto the DoD Electronic Submission website. Perform a virus check before uploading the technical proposal file. If a virus is detected, it may cause rejection of the proposal. The technical proposal should be a single file, including graphics and attachments (and cost proposal if not using the Web Site's on-line cost proposal form).

(1) **Identification and Significance of the Problem or Opportunity.** Define the specific technical problem or opportunity addressed and its importance. (Begin on Page 3 of your proposal.)

(2) **Phase I Technical Objectives.** Enumerate the specific objectives of the Phase I work, including the questions it will try to answer to determine the feasibility of the proposed approach.

(3) **Phase I Work Plan.** Provide an explicit, detailed description of the Phase I approach. If a Phase I option is required or allowed by the Component to which you are submitting, it should describe appropriate research activities which would commence at the end of the Phase I should the Component elect to exercise the option. The plan should indicate what is planned, how and where the work will be carried out, a schedule of major events, and the final product to be delivered. The Phase I effort should attempt to determine the technical feasibility of the proposed concept. The methods planned to achieve each objective or task should be discussed explicitly and in detail. This section should be a substantial portion of the total proposal.

(4) **Related Work.** Describe significant activities directly related to the proposed effort, including any conducted by the principal investigator, the proposing firm, consultants, or others. Describe how these activities interface with the proposed project and discuss any planned coordination with outside sources. The proposal must persuade reviewers of the proposer's awareness of the state-of-the-art in the specific topic.

Describe previous work not directly related to the proposed effort but similar. Provide the following: (1) short description, (2) client for which work was performed (including individual to be contacted and phone number), and (3) date of completion.

(5) **Relationship with Future Research or Research and Development.**
   (1) State the anticipated results of the proposed approach if the project is successful.
   (2) Discuss the significance of the Phase I effort in providing a foundation for Phase II research or research and development effort.

(6) **Commercialization Strategy.** Describe in approximately one page your company's strategy for commercializing this technology in DoD and/or private sector markets. Provide specific information on the market need the technology will address and the size of the market. Also include a schedule showing the quantitative commercialization results from this SBIR project that your company expects to achieve and when (i.e., amount of additional investment, sales revenue, etc. - see Section 5.4).

(7) **Key Personnel.** Identify key personnel who will be involved in the Phase I effort including information on directly related education and experience. A concise resume of the principal investigator, including a list of relevant publications (if any), must be included. All resumes will count toward the 25-page limitation. Identify any foreign nationals you expect to be involved on this project, country of origin and level of involvement.

(8) **Facilities/Equipment**. Describe available instrumentation and physical facilities necessary to carry out the Phase I effort. Items of equipment to be purchased (as detailed in the cost proposal) shall be justified under this section. Also state whether or not the facilities where the proposed work will be performed meet environmental laws and regulations of federal, state (name), and local Governments for, but not limited to, the following groupings: airborne emissions, waterborne effluents, external radiation levels, outdoor noise, solid and bulk waste disposal practices, and handling and storage of toxic and hazardous materials.

(9) **Subcontactors/Consultants**. Involvement of a university or other subcontractors or consultants in the project may be appropriate. (See Section 2.6) If such involvement is intended, it should be described in detail and identified in the cost proposal. A minimum of two-thirds of the research and/or analytical work in Phase I, as measured by direct and indirect costs, must be carried out by the proposing firm, unless otherwise approved in writing by the contracting officer.

(10) **Prior, Current, or Pending Support of Similar Proposals or Awards**. *Warning* -- While it is permissible, with proposal notification, to submit identical proposals or proposals containing a significant amount of essentially equivalent work (see section 2.8) for consideration under numerous federal program solicitations, it is unlawful to enter into contracts or grants requiring essentially equivalent effort. If there is any question concerning this, it must be disclosed to the soliciting agency or agencies before award.

If a proposal submitted in response to this solicitation is substantially the same as another proposal that has been funded, is now being funded, or is pending with another Federal Agency or DoD Component or the same DoD Component, the proposer must so indicate on the Proposal Cover Sheet and provide the following information:

(a) Name and address of the Federal Agency(s) or DoD Component to which a proposal was submitted, will be submitted, or from which an award is expected or has been received.
(b) Date of proposal submission or date of award.
(c) Title of proposal.
(d) Name and title of principal investigator for each proposal submitted or award received.
(e) Title, number, and date of solicitation(s) under which the proposal was submitted, will be submitted, or under which award is expected or has been received.
(f) If award was received, state contract number.
(g) Specify the applicable topics for each SBIR proposal submitted or award received.

Note: If Section 3.4.b(10) does not apply, state in the proposal "No prior, current, or pending support for proposed work."

c. **Cost Proposal**. Complete the cost proposal in the format shown in the Cost Breakdown Guidance, either using the on-line cost proposal form on the DoD Electronic Submission Web Site or as the last page(s) of your technical proposal. Some items in the Cost Breakdown Guidance may not apply to the proposed project. If such is the case, there is no need to provide information on each and every item. What matters is that enough information be provided to allow the DoD Component to understand how the proposer plans to use the requested funds if the contract is awarded.

(1) List all key personnel by name as well as by number on hours dedicated to the project as direct labor.
(2) Special tooling and test equipment and material cost may be included under Phases I and II. The inclusion of equipment and material will be carefully reviewed relative to need and appropriateness for the work proposed. The purchase of special tooling and test equipment must, in the opinion of the Contracting Officer, be advantageous to the Government and should be related directly to the specific topic. These may include such items as innovative instrumentation and/or automatic test equipment. Title to property furnished by the Government or acquired with Government funds will be vested with the DoD Component, unless it is determined that transfer of title to the contractor would be more cost effective than recovery of the equipment by the DoD Component.
(3) Cost for travel funds must be justified and related to the needs of the project.
(4) Cost sharing is permitted for proposals under this solicitation; however, cost sharing is not required nor will it be an evaluation factor in the consideration of a Phase I proposal.
(5) A Phase I Option (if applicable) should be fully costed separately from the Phase I (base) approach. For Phase I, the on-line cost proposal form (if applicable) will count as one page no matter how it prints out. Additional cost proposal information may be required at the end of your technical proposal (See Component Instructions, Section 8.0).

When a proposal is selected for award, the proposer should be prepared to submit further documentation to its DoD contracting officer to substantiate costs (e.g., a brief explanation of cost estimates for equipment, materials, and consultants or subcontractors).

d. **Company Commercialization Report**. If your firm is submitting a Phase I or Phase II proposal, it is required to prepare a Company Commercialization Report through the password-protected DoD Electronic Submission Web Site (www.dodsbir.net/submission). If you submit a proposal, you must submit a company commercialization report whether or not you have previously received SBIR or STTR awards. As instructed on the Web Site, list in the Report the quantitative commercialization results of your firm's prior Phase II projects, including the items listed in section 5.4 of this solicitation (sales revenue, additional investment, etc.). The Web Site will then compare these results to the historical averages for the DoD SBIR Program to calculate a Commercialization Achievement Index (CAI) value. Only firms with five or more completed Phase II projects will receive a CAI score; otherwise the CAI is N/A. Firms with a CAI at the 5th percentile or below may receive no more than half of the evaluation points available for commercial potential criteria (see Section 4.4). For Components requiring proposal submission by mail (see Section 8.0) print out a hard copy of the Report, and attach it to the back of your proposal. This report need only be prepared once and submitted with all your proposals for this solicitation.

As noted on the Web Site, your firm may also, at its option, include at the end of the Report additional, explanatory material (no more than five pages) relating to the firm's record of commercializing its prior SBIR or STTR projects, such as: commercialization successes (in government and/or private sector markets) that are not fully captured in the quantitative results (e.g. commercialization resulting from your firm's prior Phase I projects); any mitigating factors that could account for low commercialization; and recent changes in the firm's organization or personnel designed to increase the firm's commercialization success. The Company Commercialization Report and additional explanatory material (if any) will not be counted toward the 25-page limit for Phase I proposals. A Report showing that a firm has received no prior Phase II awards will not affect the firm's ability to obtain an SBIR award.