THE PROCESS OF TECHNOLOGY TRANSFER: A CASE STUDY OF THE NATIONAL AERO-SPACE PLANE PROGRAM

THESIS

Brett T. Smith, Capt, USAF

AFIT/GSM/LAS/95S-8

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GSM/LAS/95S-8

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The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

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Brett T. Smith, Capt, USAF

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Table of Contents

Page

Page

List of Figures

List of Tables

Abstract

Due to reduced funding levels and increased pressure towards cooperation with industry, government research and development (R&D) organizations are becoming increasingly involved in the transfer of technology to the commercial sector. However, the process of technology transfer is complex, and transfer activities are being applied inconsistently across the Department of Defense.

This research explores the approaches, processes and mechanisms to accomplish technology transfer. A comprehensive literature review documents many of the transfer concepts that have been proposed or are currently in use. A detailed case study then examines the technology transfer efforts of an advanced government research organization: the National Aero-Space Plane (NASP) Program. Using personal interviews with key NASP personnel as primary data, unique examples of NASP technology transfer are examined to determine whether specific transfer activities support the overall transfer goals of the organization. The analysis further investigates the similarities between the NASP program and the elements documented in the literature, and highlights recurring elements and underlying themes.

The key findings of this research suggest recommendations that can be applied to enhance the transfer activities of any organization involved in technology transfer. Opportunities for additional research in this area are also offered.

THE PROCESS OF TECHNOLOGY TRANSFER:

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I. Introduction

Research Objectives

The definition of technology transfer is commonly given as "the process by which technology, knowledge and/or information developed in one organization, in one area, or for one purpose is applied and used in another organization, in another area, or for another purpose" (Deonigi et al., 1990:327). More succinctly, technology transfer is "simply putting something which is known into use or a new use or application" (Creighton et al., 1985:65).

This research explores this concept by examining the approaches, processes and mechanisms for accomplishing the transfer of technology from government organizations to industry. Specifically, the case study method is used to examine technology transfer from the National Aero-Space Plane (NASP) program, an advanced government research and development effort. Utilizing program documentation and personal interviews, the study describes general transfer components of the NASP organization, as well as specific aspects of selected technology projects. The analysis examines how well these specific transfer activities support the approach and transfer goals of the program.

Analysis will further determine whether NASP transfers followed any formal process, or whether transfers have occurred simply through a happenstance combination of events or situations. Examination of the transfer projects also highlights the use of any of the established strategies or mechanisms for technology transfer that have been documented in the literature. Success of the transfers is assessed, and contributing factors and lessons learned are noted.

Through this synthesis of the data, and identification of recurring transfer themes and elements, conclusions are drawn to facilitate applying the specific findings of this study to general technology transfer applications. These conclusions will also suggest areas for further study.

The following investigative questions guide the research:

1. What are the prevalent documented approaches, mechanisms, and processes for technology transfer from government research organizations?

2. What is the NASP program's organizational approach to technology transfer?

3. How were specific transfers of NASP-developed technology accomplished?
   a) How were the transfers initiated and motivated?
   b) Was a strategy or process used, or did the transfer occur due to circumstance?
   c) What specific elements and mechanisms were used?

4. Do the specific examples of NASP technology transfer support the organizational transfer goals of the NASP program?

5. Does the overall approach and the specific transfer cases found in the NASP program support the technology transfer concepts documented in the literature?

6. What conclusions can be drawn from the analysis of the technology transfer efforts of the NASP program? What specific aspects can be applied in general to other organizations involved in technology transfer?

Background

Technology transfer is becoming increasingly important within the government. President Clinton has encouraged the nation's 726 federal laboratories to cooperate with industry in sharing innovative technology (Roessner, 1993:36). The administration has recommended a review of all Department of Defense (DOD), Department of Energy (DOE), and National Aeronautics and Space Administration (NASA) labs, and that ten to twenty percent of their research and development (R & D) funding be redirected towards joint research with industry. Many recent reports, studies and congressional activities have suggested that the new mission of the labs should be technology transfer to U.S. industry (Roessner, 1993:37). Shrinking resources have forced the labs to justify their existence, and technology transfer has become a significant factor in demonstrating the importance of government research organizations.

The NASP program was initiated as a result of a conceptual study conducted in the mid-1980's. The objective of the program was:

> To develop, with a research airplane (X-30), the technologies of a single stage to orbit aircraft which can take-off from a runway, fly into orbit utilizing air breathing propulsion, and return to land on a runway. (Sefic, 1993:1)

In 1986, the program became a Presidential Initiative. In President Reagan's State of the Union message, the President proposed the NASP as "The Orient Express", an airliner capable of crossing the oceans and continents in a matter of hours (Staten, 1986:1). Although the President's message was misleading (the NASP was never intended as an airliner), it increased public awareness of an orbital vehicle that could take off and land like a conventional airplane. Support for the program grew, enabling a continuation of hypersonic technology research that had been relatively dormant since the 1960's. A consortium of major aerospace firms was created for the program, enabling an unprecedented level of technical progress. This cooperative approach, combined with favorable federal funding levels, led to significant technological advances, primarily in the areas of materials development and computational fluid dynamics (CFD).

A dedicated organization within the NASP program office was chartered with the specific purpose of transferring these technologies into other applications. Unfortunately, technical, programmatic and financial difficulties have plagued the NASP in recent years, leading to the ultimate cancellation of the program in January 1995. However, the significant contributions of the NASP technology transfer program are still evident, and an analysis of their technology transfer process is appropriate.

Thesis Overview

Archival data from the NASP program office, as well as interviews with NASP personnel, is used as a primary source of information to determine what processes and techniques the NASP program has used to transfer technology. The analysis will determine whether this approach supports the organizational transfer goals. The analysis will determine if a high-technology government program such as the NASP has utilized any of the prevalent transfer mechanisms found in the literature. This will serve as a basis for discussion of the lessons learned from the NASP program technology transfer efforts.

The thesis is organized in a logical manner to describe the research process. Following this introduction, Chapter II focuses on outlining the prevalent approaches and methods for technology transfer that have been documented in the literature. A brief discussion of documented case studies identifies these components in actual transfer situations. The literature review provides a framework for analysis of the NASP organization.

The research methodology will be described in Chapter III. This discussion will outline the approach and motivation of the exploratory case study method used for this research, and will identify the specifics of the data collection and analysis plan. The personal interview process is described, and a discussion of the interview questions shows how the interview data supports the research objectives.

The research data is presented and analyzed in Chapter IV. A comprehensive overview of the NASP program is provided, followed by a detailed analysis of four specific technology transfer projects. The discussion of the data addresses the research objectives, and provides the basis for the development of conclusions and recommendations.

Chapter V summarizes the research and presents the key findings of the analysis. The discussion describes how the specific results of the analysis can be generally applied to other technology transfer organizations. This chapter will also recommend areas for additional research based on the conclusions found in this thesis.

II. Literature Review

Overview

Technology transfer has become a primary goal of many government research organizations. Technology transfer was a major focus of the 1993 federal research and development (R & D) budget (Goodwin, 1992:75). The National Science Foundation (NSF) cites increased cooperation with other federal research agencies as one of the highest priorities of its strategic plan (Palca, 1992:671). A trend towards increased commercial competition with foreign firms has forced policy-makers to focus on restoring cooperative technological efforts between domestic organizations (Harrison, 1993:72). Dwindling military budgets and increased taxpayer awareness have placed more emphasis on diversifying the benefits of government research. As this level of government and industry cooperation continues to increase, organizations seek an efficient method of transferring technology. The objective of this thesis is to determine to what extent a high-technology government program, the National Aero-Space Plane (NASP), has used any of the documented approaches for technology transfer. This literature review forms a background of these established approaches by presenting prevalent concepts and processes for transferring technology.

This chapter first establishes a broad framework for analysis of the technology transfer process. A list of basic steps is presented, followed by a discussion of several approaches, described variously as elements or mechanisms, that support the most important of these general steps. These will be compared to identify similarities and establish underlying themes. Case studies will then be analyzed to determine if these common elements have been applied successfully to accomplish technology transfer. Finally, a conclusion will summarize the results of the literature search and form a foundation for analysis of the NASP program.

The Technology Transfer Process

A survey of 172 technology transfer cases within the Department of Energy (DOE) revealed that no two technology transfer strategies were identical (Deonigi and others, 1990:328). This shows that there is great inconsistency in the establishment and enforcement of government transfer policies. In fact, the recently released AFMC Technology Transfer Handbook describes the "what" of technology transfer, but not the "how"; the handbook dictates that each organization is to choose the method that best suits its needs. As an indication of the evolving process of technology transfer, the handbook also states that the document will be updated to reflect how the transfer process actually occurs. (AFMC Technology Transfer Handbook, 1990:C-1). While the research shows that many different methods for technology transfer have been developed, the general process is generally recognized.

The research of Souder and others provides a framework of the technology transfer process in the broadest sense. The process is defined as a sequence of four stages: prospecting, developing, trial, and adoption (Souder and others, 1990:5). Prospecting involves the preliminary identification and screening of technologies that may potentially satisfy the needs of an established user. Developing involves the further refining and enhancing of these technologies. The trial stage performs field testing on the developed technology. After success in the first three stages, the technology then undergoes final development and is then implemented or adopted by the user (Souder and others, 1990:6). This process is dynamic; stages may overlap, and there are often activities from each stage occurring in parallel. Some stages, or the entire process, may be repeated before the technology can be successfully transferred (Souder and others, 1990:7). This general process provides a basis for more detailed analysis.

The Department of Defense, specifically the Air Force Materiel Command (AFMC) has developed a somewhat more specific approach to technology transfer that also focuses primarily on general stages, or steps in the process. These steps are outlined as follows:

1. Develop Strategy
2. Identify Assets
3. Market Assets
4. Identify Mechanism
5. Transfer Technology
6. Post Transfer Administration (Sharp, 1993:6)

The transfer strategy and the mechanisms for transfer are of the greatest significance to this research. Consequently, elements and activities that contribute to these specific steps will be discussed in detail.

Transfer Strategies

As with any complex process, development of a well-defined strategy can be a key factor for success. The strategy is used as a roadmap to guide the project, track progress, and identify problem areas. This step is essential to overcome the challenges of technology transfer.

Shama reveals four distinct strategies that have been used by the national laboratories: Passive, Active, Entrepreneurial, and National Competitiveness. Each successive strategy requires increasing levels of involvement and commitment from the organization (Shama, 1992:23). The specifics of these approaches will be examined in detail.

The passive technology transfer strategy focuses on information dissemination (Shama, 1992:19). Specifically, it entails providing information or responding to a specific inquiry. It may involve such activities as distributing documents, attending meetings, or answering phone inquiries. Shama notes that this passive strategy is generally risk-aversive, and represents a highly conservative approach to technology transfer (Shama, 1992:19). In today's increasingly pro-active technology transfer environment, the passive strategy is typically not considered adequate in the national laboratories.

A more comprehensive strategy identified by Shama is the active approach. In addition to providing information like the passive strategy, this approach takes the process a step further by making specific efforts to move technology into the marketplace (Shama, 1992:19). This strategy seeks to actively improve the national economy and improve U.S. industry by sharing laboratory-developed technology. Candidate technologies are typically identified by the labs, and are then marketed to potential users through licensing agreements (Shama, 1992:19). This strategy reflects the more prevalent approach found in today's technology transfer environment.

The entrepreneurial strategy takes the approach one step further. In addition to the information dissemination and licensing activities done by the passive and active approaches, the entrepreneurial strategy encourages the formation of new business ventures to use the technologies the lab develops (Shama, 1992:20). Not only does this strategy promote the technological well-being of industry, it can also create jobs and benefit the national economy.

The final strategic approach identified by Shama is the national-competitiveness strategy. Building on the functions of the passive, active, and entrepreneurial approaches, the national-competitiveness strategy focuses on increasing the social and economic position of the U.S. relative to other countries (Shama, 1992:21). This strategy is based on the belief that competition with other countries is essentially economically based; therefore, technology that stimulates domestic economic growth should be aggressively pursued (Shama, 1992:19). This strategy has the highest risk, and requires the most commitment and involvement from the organization.

After a technology transfer strategy is developed, the subsequent steps of the AFMC model can be addressed. However, before analyzing specific transfer methods, several factors are examined that can affect the success of transfer efforts.

Technology Transfer Elements

The research of Creighton and others reveals a set of broad, recurring elements that have been present in most successful technology transfer efforts. These can be categorized as formal or informal, as shown in Table 1. The formal elements form a framework that helps facilitate accomplishing the basic steps of technology transfer. The informal elements represent more subtle, yet still significant factors that affect the technology transfer process. Analysis of the case studies shows the importance of each of these elements.

TABLE 1

FORMAL AND INFORMAL TECHNOLOGY TRANSFER ELEMENTS

Formal Elements	Informal Elements
Organization to lead effort	Linking between source of technology and user
Project established to identify technology effort	Capacity to transmit and receive information
Documentation of information	Credibility of parties involved
Distribution of information	Willingness of parties to communicate ideas
	Reward (Creighton et al, 1985:68)

Transfer Mechanisms

In addition to outlining the broad technology transfer process, describing strategic approaches, and identifying key elements, the literature reveals many detailed, well-defined mechanisms that represent the specific "act" of technology transfer. Analysis of the Department of Energy (DOE) and the Department of Commerce (DOC) will provide insight into these documented mechanisms.

The DOE has been a government leader in establishing an effective technology transfer program in the U.S. A Department-level strategy has been defined, and increased partnerships with the private sector are noted as one of the DOE's five main organizational objectives (Lewis, 1994:109). To characterize the important factors in the DOE technology transfer process, eight broad categories are defined. These are summarized in Table 2.

Contrasting the DOE methods is a set of transfer mechanisms developed within the Department of Commerce (DOC). While developed from the perspective of increasing industrial productivity, these mechanisms share many similarities with those found within the Department of Energy. The DOC methods are listed in Table 3.

TABLE 2

DEPARTMENT OF ENERGY TRANSFER METHODS

Advisory groups
Research collaborations
Exchanges of personnel
Technical assistance
Licensing
Spin-off companies
Dissemination of information
Education
(Deonigi, 1990:328)

TABLE 3

DEPARTMENT OF COMMERCE TRANSFER METHODS

Colloquia/Published Reports
Consensus Development Efforts
Demonstration Projects
Comprehensive Centers
Information Clearinghouses
Personnel Exchanges/Field Agents
Computerized Information Systems
Library Services
Collaborative R & D Projects
(O'Brien and Franks, 1981:73)

Comparison between Table 2 and Table 3 shows several important similarities between the DOE and DOC approaches to technology transfer. Foremost of these is the use of advisory groups and published research reports as a means to disseminate technology. In fact, the DOE survey revealed that technical reports, workshops and journals/magazines were the most successful transfer mechanisms (Deonigi and others, 1990:328). The research of Chapman also shows the distribution of publications as one of the most universal technology transfer activities (Chapman, 1989:6). Collaborative research efforts and exchanges of technical personnel between organizations are also methods common between the two Departments. Winebrake notes a distinction between these approaches and classifies them as active, such as consulting or two-way interaction, or passive, such as reading a technical journal (Winebrake, 1992:54).

Although both the DOE and DOC methods share some similarities, the DOE survey found that each transfer situation was unique, and used a different combination of mechanisms. This supports the AFMC Technology Transfer Handbook's approach to modifying the process to suit each particular organization. The DOE researchers discovered the need for earlier participation from the users to foster more efficient development of the technology. Personal contact was also shown to be a crucial element for effective technology transfer in any situation (Deonigi, 1990:334). The research of Wilson and Norris supports this by noting that lack of communication between the users and producers of information as a common problem when transferring technical information (Wilson and Norris, 1993:684).

While the activities outlined in Table 2 and Table 3 enhance technology transfer, they do not in themselves constitute a process that an organization could follow. More appropriately, they represent vehicles an organization could use to support their technology transfer program. Creighton notes that, regardless of the formal process that may be in place, much of the evolution of technology can be due to the natural diffusion of information rather than as a result of the dedicated efforts of the organization (Creighton and others, 1985:79).

Conceptual Transfer Models

As a comparison to the tangible mechanisms documented by federal organizations, Climent proposes a group of highly conceptual technology transfer models from a non-government viewpoint. Since the models provide a significant contrast to the previously discussed concepts, they are described here in detail.

According to Climent, a set of complementary models are required for success rather than a single approach. Among nine models discussed in the literature, four are of interest: Linear/Multilinear, Cybernetic, Holistic and Inter-independent (Climent, 1993:76).

The linear/multilinear model implies a direct, one-way course of events. In the context of technology transfer, this implies a rigid arrangement of one-way events or procedures, accomplished in defined stages. Multilinear models imply the same constraints, but address multiple channels of action. The concept of this model could be demonstrated in the form of a briefing or dissemination of a technical report. The lack of feedback in these models is significant, since there is no means for communication from the user back to the source of the technology.

The Cybernetic model addresses this with a more circular structure that includes a feedback mechanism. It is noted, however, that this feedback is used as a control function rather than a path for exchange. This means that the inputs from the receiver is only used to affect the one-way actions of the source of the technology.

The Holistic model begins to resemble the behavior of actual processes. The concept of linearity or circularity is replaced by the idea of complex interactions between all the relevant parties. However, the Holistic model does not include the factor of time as an input to the model. Consequently, this Holistic model can be used to analyze specific transfer events at a specific moment, but cannot be applied to examine the chronological characteristics of the transfer process (Climent, 1993:79-81).

The Inter-independent model incorporates the time element, and approximates the complex communication processes that take place among people. A relationship of exchange and dialog is implied rather than that of sender and receiver (Climent, 1993:79-81). All individuals and organizations are active participants, and the entire transfer effort becomes more of a "team effort," with contributions being received by all parties.

The conceptual nature of the models, along with the lack of defined objectives, makes it difficult to apply these models to the specific task of guiding the process of technology transfer in an organization. However, Climent uses his models to support the view that technology transfer is a participatory process, and that technological change is achieved through a shared interaction. It is these concepts that are critical elements of a technology transfer framework.

Case Studies

Analysis of case studies within the literature shows the presence of many of the documented components of technology transfer in real-world situations. In addition, several significant new transfer elements are highlighted. Analysis of these cases will facilitate an effective approach for the case study of the NASP program.

The first case examines the Microelectronics and Computer Technology Corporation (MCC), a large research and development consortium. The analysis of this organization provides insight into four key elements of the MCC transfer efforts: communication, distance, motivation and technological equivocality (Smilor and Gibson, 1991:3). Once again, communication is identified as a crucial factor in successful technology transfer. As with Winebrake's analysis, Smilor and Gibson also make the distinction between the passive and active aspects of communication. Active links consist of direct, person-to-person interactions. A noted advantage of this form of communication is that it facilitates immediate, focused feedback between personnel (Smilor and Gibson, 1991:6). This serves to minimize misunderstanding or misinterpretation of the information. Passive communication, as described by Smilor and Gibson, is typically media-based, taking the form of journal articles or technical reports (Smilor and Gibson, 1991:7). It is an effective technique for disseminating detailed information to a wide audience, and reading an article or report typically demands less time and effort than a face-to-face, personal exchange of similar information. However, the potential for rapid feedback is greatly diminished. The analysis of MCC notes that the higher the percentage of active communication, the more likelihood there is of a successful transfer (Smilor and Gibson, 1991:9).

The element of distance implies both geographical and cultural differences between the source of the technology and the user. Diversity of culture within the company, or between the groups trying to transfer the technology, is shown to be a strong influence affecting the success of the transfer. Physical distances between personnel, such as between floors, in different buildings, or across the country, was shown to have a lesser, but still significant effect (Smilor and Gibson, 1991:9).

Motivation involves the reward or incentives involved in technology transfer. It can apply to either the receiver or the originator of the technology being transferred. Obviously, the greater the perceived benefit of the transfer, the more motivation there will be to accomplish it.

Lastly, technological equivocality deals with the level of complexity or ambiguity of the technology being transferred. Simple, easy to understand concepts have low equivocality, and will typically experience a high level of successful transfer. Complex technology is harder to understand, demonstrate, and apply; consequently the transfer will likely be more difficult to accomplish (Smilor and Gibson, 1991:9).

Smilor and Gibson combine these four elements in what they describe as the "Technology Transfer Grid", which shows the relative importance of each factor in determining successful transfers. This grid is illustrated in Figure 1.

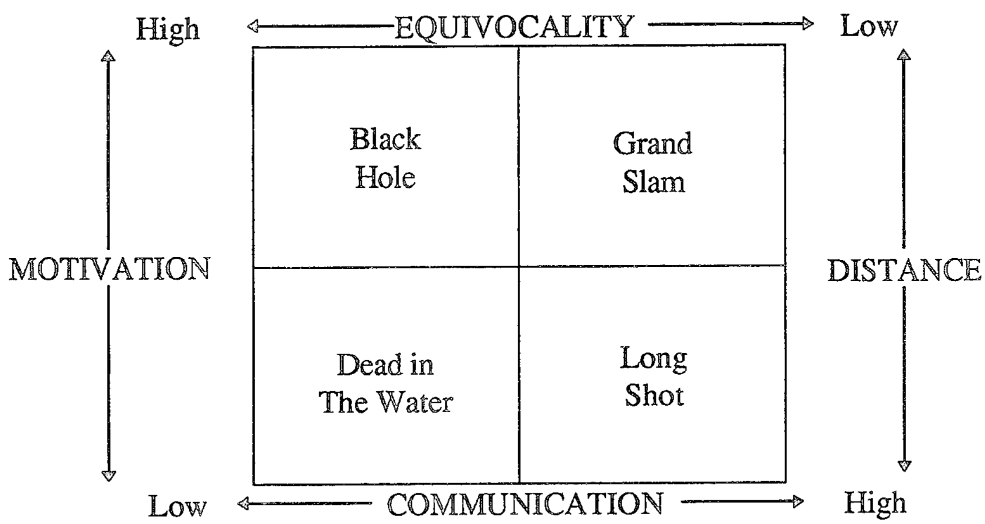

Figure 1. Technology Transfer Grid (Smilor and Gibson, 1991:10)

At one extreme, which Smilor and Gibson describe as "Dead in the Water", motivation and communication are low, while distance and equivocality are high. All factors are working against the transfer, and success is unlikely in this situation. At the other extreme, the "Grand Slam" represents a situation where all elements are present for a successful transfer. Communication and motivation are high, and distance and equivocality are low. Personnel are enthusiastic and there is a high degree of interaction to transfer an applicable technology. The two other situations on the grid represent other combinations of the four primary elements. For the "Long Shot", communication and distance are high, but motivation and equivocality are low. In this case, a well-defined technology is being communicated successfully, but there are large distances, and participants are not well motivated. For the "Black Hole", great benefits may exist between close transferring organizations, but the technology may not lend itself to clear application, and communication is not being done effectively. In both these cases, successful transfer may be difficult (Smilor and Gibson, 1991:10).

The four factors identified in the MCC case nearly duplicate Creighton's informal elements as outlined in Table 1. Linking between the source of the technology and the user, as well as the capacity to transmit and receive information, obviously support the communication requirement. Establishing credibility and demonstrating a willingness to communicate are dependent on both the physical and cultural distance that exist between the participants. And as with Creighton, Smilor and Gibson also relate motivation directly to the potential for reward (Creighton and others, 1985:68).

In contrast to the MCC analysis, another case study reveals a set of elements more closely related to Creighton's formal elements. This case involves incorporating artificial intelligence into the programming of computers in a small Air Force communications directorate. This study demonstrates the use of a technology transfer framework that emphasized orientation and awareness, preparation, pilot use of the technology, adoption of the technology, and refinement (Romo and Roecks, 1988:55).

Consistent with Creighton's steps, a project team was brought together and a specific, dedicated project established to facilitate transfer of the technology. Personnel were then introduced to artificial intelligence concepts and made aware of the capabilities of the technology and how it would fit into the organization. Potential applications were identified, and preliminary evaluations were made to determine suitable uses within the unit.

The last two stages of Souder's model, trial and adoption, were realized as prototypes and pilot projects were established and monitored before the technology was finally implemented into the unit's way of doing business. The documentation function was accomplished as the progress of the transfer was being tracked through the process. The last element used in this case, refinement, falls into line with the final step in the AFMC model described by Sharp, namely, the post transfer administration of the technology.

The importance of developing an overall transfer strategy, the first step in the AFMC model, is noted by Romo and Roecks as being of prime importance to the success of the transfer (Romo and Roecks, 1988:55).

A case of technology transfer in a non-DoD environment provides a comparison to the previous cases, while still illustrating key elements of the documented transfer processes. The effort involved the commercialization of a shock absorbing system for bicycle seats. The researchers noted the significance of focusing on a single application for the technology, and emphasized that a formal process had been established within the company to efficiently transfer the technology. Important aspects of the process included developing a strategic technology transfer plan, and marketing the technology to potential investors (Dakin, 1994:48). These steps were identified as crucial factors in the AFMC approach to technology transfer. Utilizing the appropriate elements of technology transfer, the commercialization of the bicycle shock system was deemed a success.

Also noted in this technology transfer case were factors that emphasized advertising, investments, profit-making, and other concepts applicable to the corporate environment. While these elements are not directly significant to transfers in the government environment, the notions of promoting the technology, obtaining support, and demonstrating the potential for a return on investment are elements of technology transfer that must still be considered for transfers within DoD.

Technology transfer is not confined to government organizations, defense contractors, or other corporations. Innovation and examples of shared technology are also evident in the academic environment. A case study by von Rosen reveals that these transfers can also share common elements with the documented processes.

Von Rosen's study examines the commercialization process of a high-speed data transceiver developed at the School of Engineering Science at Simon Fraser University (von Rosen, 1994:8). Transfer of the technology was facilitated though the use of a university-industry liaison office (UILO), created specifically to address technology transfer issues. Identification of a specific organization to coordinate the transfer was identified by Creighton as a key element for successful transfers.

Cooperation with industry was established early in the project. The study notes the importance of an effective working relationship between the university faculty leading the project and the industry recipients of the technology (von Rosen, 1994:15). A successful working relationship is a direct reflection of efficient communication, as well as minimization of the cultural differences between transferring organizations, as discussed in the MCC case.

Also contributing to the success of the transfer was the potential for tangible rewards. In addition to patents and licensing agreements obtained by the university, benefits were also received in terms of conference presentations, published articles, and dissemination of the information within the university (von Rosen, 1994:14). Rewards from successful transfers are identified by Creighton as a significant factor for motivating the technology transfer process.

Insight into the technology transfer process can also be obtained through analysis of an industry that has shown little success in implementing new technologies. Despite the advances of DOE in the technology transfer arena, Knight identifies the petroleum industry as an area that has historically been reluctant to accept change or innovation (Knight, 1984:27).

Knight attributes this reluctance to the structure and underlying nature of the petroleum business. His analysis reveals the industry as being highly fragmented, with little interaction or integration between the many different services that are required during the exploration, drilling, refining, and distribution processes. This lack of cooperation results in hundreds of different firms being required to bring the product to the consumers (Knight, 1984:28). Consequently, widespread, efficient implementation of new technologies is difficult, even if the use of these technologies will save money.

Compounding the problem is that the petroleum industry has traditionally been labeled an "old boys network", which also tends to stifle creativity and the acceptance of new technology (Knight, 1984:27). Firms are set in their ways, and current practices have been deemed "good enough", despite many problem areas and opportunities for process improvement. As a result, companies are frequently unwilling to investigate the potential benefits that could be realized with new technology.

Both these barriers to successful technology transfer in the petroleum industry can be linked to the failure of the business to satisfy several of the identified elements for successful transfer. The cultural differences between the firms involved, as discussed in the MCC case, are great, which in turn hampers the communication process that has been shown to be such a highly significant factor for successful transfer. Creighton's formal elements were shown by Knight to be essentially non-existent in the industry, and most of the informal factors such as linking and willingness to exchange ideas are clearly absent. The lack of technology transfer in the petroleum industry, attributed to the absence of most of the established elements, helps to build a case for the significance of these factors in successful transfer.

The case studies also show that the type of transfer, and the motivating force behind it, can have a great impact on the success of the transfer effort. This motivating force, which usually initiates the transfer process, typically has two primary sources. The first can be described as technology or market "pull", in which a specific need is identified and the appropriate technology is developed and implemented as a direct transfer (von Rosen, 1994:9). In contrast is the idea of technology "push", where a developed technology leads to a search for suitable applications (Knight, 1984:29).

The literature reveals that the most successful transfers are influenced by market pull, involving a defined need that is specifically addressed by transferred technology (Edwards, 1994:46, Knight, 1984:29). In fact, too much emphasis on technology "push" was identified as a major fault in the technology transfer efforts of the national labs (Scott, 1993:65). Clearly, the success of a technology transfer effort is greatly dependent on the underlying motivation behind it.

Chapter Summary

The literature review identified steps in the process of technology transfer, and several methods and elements were found that facilitated accomplishment of the key steps. Similarities were noted between organizations with different technology transfer approaches. The case studies provided insight into actual technology transfer programs, and gave an indication of which methods contributed to successful transfer. Unfortunately, identifying these elements and techniques is only part of the problem. The more significant task is determining if an organization can successfully use the documented approaches to successfully transfer technology (Winebrake, 1992:60).

Through a case study of the NASP program, the research that follows examines this problem by determining the presence or absence of the documented processes and elements that have been described in this chapter. The analysis will attempt to determine if a formal process has facilitated transfer within the NASP program, or if transfers occurred simply due to favorable conditions and chance events. The research seeks to highlight the key elements that were present in transfer projects, and identifies the formal and informal factors that contributed to transfer success.

Based on the foundation of information obtained from this literature review, an appropriate research methodology, supported by a comprehensive data collection and analysis plan, ensured that the information required by this research was obtained efficiently and accurately. The next chapter presents this research approach, and describes the methods used to collect the necessary data.

III. Methodology

Overview

This chapter discusses the methodology used to obtain data for this study. Presented first is the overall research approach, followed by a detailed description of the data collection plan. Concluding this chapter is a discussion of how the data will be analyzed, and how it will be used to support the research objectives described in Chapter I.

Research Design

The approach used is a combination of exploratory research and case study. As the first step of the exploratory process, the literature review established a framework of the technology transfer process, and highlighted many of the prevalent documented mechanisms and techniques for accomplishing it. Discussion of several transfer situations shows the application of many of these methods in real-world situations. This thesis carries this concept a step further, by examining technology transfer activities of the NASP program.

Several factors led to selecting the NASP organization as the subject for this study. Because of its high-technology mission, and the fact that the organization had specific teams dedicated to technology transfer activities, the NASP program presents an exceptional opportunity for analysis of the technology transfer process. In addition, the progressive nature of the NASP organization, combined with the personalities of the individuals assigned to the Technology Applications Branch, results in a unique transfer environment that sets it apart from most of the local research organizations within the Air Force Material Command (AFMC). Lastly, the NASP program office is also the last duty assignment of the researcher. It is believed that this familiarity with the NASP organization facilitates effective interaction with key personnel and collection of data.

Since this research focuses on the transfer efforts of a single organization, the case study approach was used to obtain the primary data. The case study method is appropriate for use in an exploratory manner to develop theories and provide insight into an uncharted area of study (Bryman, 1989:174). This research design, as noted by Kervin, involves the intense examination of a single case using a variety of data gathering techniques including available documents and interviews (Kervin, 1992:48). The research can be further categorized as descriptive, defined by Cooper and Emory as "finding out who, what, where, when, and how much" (Cooper and Emory, 1195:16).

Although typically not used to make generalizations to a larger population, the case study method is useful to provide and understanding of organizational functioning, and determine patterns and establish theoretical linkages among the components being examined. Additionally, the qualitative data obtained in most case studies has been shown to be more attractive to the manager than the abstract variables and relationships that often characterize qualitative research (Bryman, 1989:173,178).

A final advantage of the case study method is that it is used to develop hypotheses for analysis in later studies (Dane, 1990:114). This point is fundamental to this thesis, since the analysis highlights other areas of interest in the technology transfer process. As discussed in Chapter V, areas for further research are suggested based on the findings of this study.

To support the case study, data is first obtained describing the overall organizational policies and goals of the NASP technology transfer program. This information was complemented by data describing specific cases of NASP technology transfer. To obtain a manageable database of information for analysis, a representative sample of four selected transfer cases within the NASP program are examined in detail. For each of these cases, data is obtained to describe the background of the technology, provide an overview of significant transfer events, identify a transfer strategy, describe the transfer process used, and to explore the elements and factors that contributed to the success or failure of the transfer. This information is then used for analysis in comparison to the NASP program goals as well as information collected in the literature review.

Data Collection

To facilitate analysis of the NASP transfer efforts, data is obtained from two main sources within the NASP Joint Program Office (JPO). First, program documentation was reviewed to establish the top-level strategy and organizational objectives of the NASP technology transfer effort, and to provide an overview of the documented NASP technology transfer plan. Most of this organizational information is obtained from the *NASP Domestic Technology Transfer Integrated Plan,* which is a comprehensive formal document outlining the entire NASP transfer program.

Additional program documentation is used for analysis of the specific cases to describe the background of the transfer, to trace its history, and to identify the more formal steps and methods used during the process. This documentation includes official briefings, policy letters, executive summaries, white papers, and historical and archival reports.

To reinforce the data obtained from the documentation, formal interviews with key personnel are conducted. This process consists of interviews with the technology transfer facilitators assigned to manage each of the four technology projects. In addition to supporting the program data, these interviews obtain more subtle, informal information, and determined some of the more passive aspects of the technology transfer process not readily found in the program documentation.

Interview Question Development

Using the findings of the literature review as a guide, a series of formal questions are asked to address specific details to support the thesis research objectives. The questions explore:

- Characteristics/Chronology of the Transfer
- Transfer Strategy/Process
- Transfer Mechanisms/Elements
- Inputs to the Technology Transfer Grid
- Transfer Success
- Lessons Learned

Miles and Huberman stress the importance of structure during qualitative data collection (Miles and Huberman, 1984:60). Consequently, the interview questions were listed on formal interview sheets, which were then used for note-taking during the meeting. The list of interview questions is provided in Appendix A.

The rationale for each question was traced directly to a specific research objective. This serves to limit the scope of the interview and ensure that all information obtained was pertinent to the goals of the research. As a complement to the interview questionnaires, the rationale for each question provided in Appendix B.

Interview Development

The interview follows a formal structure, although the funneling technique is used to gain more specific information in selected areas. The questions are provided in advance to facilitate any required preparation. Following the completion of the formal survey questions, an unstructured discussion is used to address any other issues the interviewee may deem appropriate to this study.

Cooper and Emory define three conditions that must be met for successful personal interviews. They are: the availability of the needed information from the respondent, an understanding by the respondent of his or her role, and adequate motivation by the respondent to cooperate (Cooper and Emory, 1995:271). The individual in the NASP program office that managed each technology area is chosen to ensure the first condition was met. As technology project managers, each individual interviewed is well-versed in all areas addressed, and, as such, is an appropriate source of data. The goal of the interview, the objectives of the research, and the role of the respondent as an expert are defined prior to the interview. Finally, the respondent was motivated to cooperate by the possibilities for improvements to the technology transfer process that could result from this research.

As noted by Schmitt and Klimosky, a key advantage of the qualitative interview is the use of follow-up questions and probes (Schmitt and Klimosky, 1991:142). This enables the interviewer to obtain additional information to short or incomplete answers to interview questions. This technique is used extensively during the data collection process. In addition to probing questions during the meeting, later analysis of the data often revealed the need for more information, so several follow-up telephone calls were made to the respondents to clarify issues or obtain additional detail.

Data Analysis and Interpretation

A significant limitation of qualitative data is that the methods of analysis are frequently unclear (Schmitt and Klimosky, 1991:152). To overcome this disadvantage, specific efforts are made to accurately organize, integrate, and summarize the data so that the analysis directly supported the thesis research objectives.

The analysis consists of several comparative components. First, the NASP transfer program approaches and objectives defined by the *NASP Domestic Technology Transfer Integrated Plan* are compared to the organizational transfer aspects identified in the literature review. This is done to provide a macro-level investigation of the NASP transfer efforts of the organization as a whole. The focus of the analysis is then narrowed by examining the qualitative data obtained for each of the four technology projects. The discussion of the data provides a detailed exploration of the processes and mechanisms used, and identifies the similarities, differences, contributing factors and underlying trends among the specific transfer cases. These results are then compared to the organizational objectives defined in the *NASP Domestic Technology Transfer Integrated Plan*. This allows a general assessment of whether the actual transfer activities support the intent of the *Integrated Plan*. Finally, the data obtained for each technology is compared directly to the transfer components described in the literature. This allows a determination of differences and similarities of the NASP transfer efforts with established and documented aspects of technology transfer. As recommended by Miles and Huberman, a data accounting sheet was used to provide a visual representation of the data obtained from the four technology transfer cases (Miles and Huberman, 1984:77). This data sheet will complement the narrative analysis found in Chapter IV.

The data collected and analyzed using these methods is used to present a comprehensive narrative of the NASP technology transfer program. Through analysis of the *NASP Technology Transfer Integrated Plan*, the organizational approach of the NASP program is presented. Exploration of the specific transfer cases determine the specifics of transfer initiation, the process used, and the existence of key elements and techniques. The analysis will determine how well these transfer cases support the Integrated Plan, as well as the concepts identified in the literature.

Following these detailed comparisons, conclusions are described and the specific research questions answered. Results from the analysis of NASP technology projects are used to make general recommendations for use by other organizations involved in technology transfer. The general findings of the study will suggest areas for further research.

The next chapter presents the detailed application of the data collection and analysis methodology described in the preceding sections.

IV. Results and Analysis

Introduction

The data that follows was collected using the approach and techniques described in Chapter III. The data was obtained in direct support of the research objectives, which are restated here for convenience:

1. What are the prevalent documented approaches, mechanisms and processes for technology transfer from government research organizations?

2. What is the NASP program's organizational approach to technology transfer?

3. How were specific transfers of NASP-developed technology accomplished?
   a) How were the transfers initiated and motivated?
   b) Was a strategy or process used, or did the transfer occur due to circumstance?
   c) What specific elements and mechanisms were present?

4. Do the specific examples of NASP technology transfer support the organizational transfer goals of the NASP program?

5. Does the overall approach and the specific transfer cases found in the NASP program support the technology transfer concepts documented in the literature?

6. What conclusions can be drawn from the analysis of the technology transfer efforts of the NASP program? What specific aspects can be applied in general to other organizations involved in technology transfer?

Using the information collected from NASP documentation and personal interviews, this chapter presents a detailed description of the NASP technology transfer program. The first section reviews the underlying approach and philosophy, the stated objectives, and the documented processes and components that have been established as part of the overall NASP technology transfer strategy.

Following this top-level organizational review, a comprehensive narrative describes the specifics of the four selected transfer projects. For each technology, a short introduction and background section precedes a detailed overview of each project. A discussion of the data obtained from the personal interviews is then presented. Analysis of the data determines how well the transfer process and elements used for each transfer project support the organizational objectives described in the NASP program overview. Discussion of the data also compares the important aspects of each transfer project to the transfer components documented in Chapter 2.

After the presentation and discussion of the data for the transfer projects, a chapter summary highlights the key findings of the NASP technology transfer case study. Similarities and differences between the projects are noted to establish recurring themes and identify the most significant transfer elements. This summary section will describe general conclusions from the data, forming a basis for addressing the research objectives. Based on findings of this study, areas for future research are also presented.

NASP Technology Transfer Program Overview

The NASP program is unique in the sense that technology transfer was identified as a program goal, and a specific organization within the program office was formed to support this objective ("NASP JPO Vision Statement," 1992:2). Designated the

"Technology Applications Branch", one of the primary functions of this group was to aid the dissemination of NASP-developed technologies to U.S. industry. To facilitate this activity, the *NASP Domestic Technology Transfer Integrated Plan* was developed. Although other sources are utilized to some extent, this document forms the basis for the overview of the NASP technology transfer program.

The *NASP Domestic Technology Transfer Integrated Plan* describes not only the approach and objectives of the NASP efforts, but also identifies specific components to be used to facilitate the transfer efforts. Each of these major components are broken down into subelements and discussed in detail. Additional emphasis is placed on those areas most significant to this research.

<u>NASP Technology Transfer Objectives.</u> Two major motivations support the underlying philosophy behind the NASP technology transfer program. First, the erosion of the U.S. industrial base, combined with increased foreign competition, offers an opportunity for the infusion of high technology to foster domestic research and development. Secondly, several legislative actions have mandated technology transfer as an active component of most federal research organizations (DeNardo, 1994:2). Consistent with these philosophies, the *NASP Domestic Technology Transfer Integrated Plan* specifies the NASP Technology Transfer Objectives as follows:

1. <u>Maximize the return on the investment</u> for the NASP Research and Development (R&D) budget through proactive technology transfer.

2. <u>Enhance the United States international competitiveness</u> through rapid and direct transfer of NASP technologies to the U.S. commercial, civil, and Federal sectors.

3. <u>Develop, exercise, refine, and rigorize the technology transfer process</u> to provide the most efficient means of transfer.

In fulfilling these objectives, it is the intent of the NASP program office to utilize, to the greatest extent possible, existing technology transfer organizations to maximize existing resources and processes and to minimize duplication of effort.

Documented within the *NASP Technology Transfer Integrated Plan* are seven broad components that facilitate accomplishment of the defined objectives. Although each component implies a distinct purpose and unique activities, all are interrelated and work together as part of the comprehensive technology transfer program. These seven components are presented in detail in the following sections.

NASP Domestic Technology Transfer Integrated Plan. This document was developed to form a single source of guidance for the NASP technology transfer efforts. The plan outlines all general activities, defines organizational responsibilities, and identifies relationships between all technology transfer program components. The integrated plan serves as a roadmap and a reference document for accomplishing the NASP technology transfer objectives.

Technology Description Document (TDD). The purpose of this formal document is to identify all current NASP technologies in a single source so they may be reviewed by potential users. The TDD describes the application of the technology, not only in terms of its intended purpose, but also suggest possible alternate uses. This document assists potential users by describing the technical, organizational, and administrative procedures for establishing a NASP technology transfer project. Available in both classified and unclassified versions, it is made readily available to all organizations interested in receiving NASP technologies.

Technology Transfer Infrastructure. This crucial activity describes establishing and maintaining three components necessary for technology transfer: The technological base (represented by organizations and individuals actively working on NASP technology projects), the potential user base, and the architecture that connects them together. Key elements required to establish the technological base include identifying and publishing the appropriate points of contact for each technological area, establishing effective communication links such as interactive computer or voice networks, and incentivizing personnel and organizations involved in technology transfer. After the technology base is established, potential users can be identified. This can consist of any domestic government or commercial organization qualified to receive the technology. Once the two bases are put into place, an efficient means of communication must be created between them. This includes not only direct communication methods such as phones or computers, but also any intermediate government or commercial organizations that may be required to facilitate exchange of technical information between the technology base and the user. Establishing and maintaining these three elements is a key activity of the NASP technology transfer program.

Data Access and Control. Many of the technologies developed by the NASP are sensitive, militarily critical, or classified. Consequently, this component is a key element in the technology transfer program to ensure that only authorized individuals or organizations have access to this type of information. The data access and control function outlines the steps necessary for organizations to obtain the certification required to receive NASP technologies.

Technology Exposition/Public Outreach. As will be discussed in later sections, the Technology Exposition/Public Outreach function is one of the first key steps in the technology transfer process. This activity serves to advertise the available NASP technologies to potential users, with the intent of stimulating interest in possible transfer opportunities. The widest dissemination of information is typically obtained by specific efforts to expose NASP technologies to the media. This is accomplished through several methods, ranging from interviews with editors of technical publications to invited tours of NASP technology development centers. A somewhat more general technique includes exhibiting NASP technologies at air shows, trade conventions, technical expositions, and professional society symposia. To obtain an even more diverse audience of potential users, this exhibition method can be extended to include schools and universities, entrepreneurial groups, local and state government offices, and other diverse organizations that typically may not otherwise be exposed to NASP technologies. The primary goal of this component of the NASP transfer program is to reach as many interested groups or individuals as possible, to maximize the potential opportunities for transfer of NASP technologies.

NASP Technology Transfer Case Development. This activity forms the core component of the NASP transfer program. It generally represents the subsequent step of the transfer process after the initial contact is made with a potential user. DeNardo notes that the case development efforts can also include tracking examples of transfer that have occurred through passive methods or through natural transfer avenues (DeNardo, 1994:5). However, this discussion will focus on case development as a proactive effort to establish and advance opportunistic relationships with organizations that have shown interest in NASP technologies for possible commercial applications. The specific activities that support this component are the basis for the case studies of each of the four NASP technologies that will be analyzed in this chapter. Since these activities represent a significant portion of the research, they will be examined in detail in later sections.

The Case Development section of the *NASP Domestic Technology Transfer Integrated Plan* also describes a set of "Qualifying Conditions" that are used to gauge the success of NASP transfer efforts. Should any of these conditions be satisfied as a result of NASP transfer activities, the transfer is deemed a success. These conditions are listed below:

- A qualitative improvement of an existing product or product line
- The efficiency/effectiveness of a process is improved
- An existing product becomes less expensive to manufacture
- An existing product gains additional applications or different customers
- The instance of production defects is reduced
- An entirely new product line or industry is enabled
- A new research methodology is enabled
- Improvements in industrial/technological management are created/enabled
- Any instance where new jobs are created or saved
- Improvement of technological awareness and skills in a work force
- Any instance of industry requests to enter into Cooperative R & D Agreements (CRDAs) or other agreement with another non-NASP commercial agency
- Any instance where NASP transfer initiatives encouraged patent application or awards (*"NASP Domestic Technology Transfer Integrated Plan,"* 1991:8)

These conditions are used during the interview process to determine transfer success, as defined by the *Integrated Plan*, for each of the four technologies analyzed. Success or failure of the transfers will be examined for each of the case studies.

NASP Technology Transfer Process Development. The activity of defining and improving a specific process for accomplishing technology transfer is identified as a primary objective of the NASP transfer program. This component also represents a significant aspect of this research. Consequently, this activity will be examined in detail.

Stages of Technology Transfer. As a starting point in developing a transfer process, the *NASP Domestic Technology Transfer Integrated Plan* outlines the familiar four stages of technology transfer:

Prospecting Stage. This marks the initial step of the technology transfer effort, consisting primarily of disseminating information and subsequent activities intended to match potential users with NASP technologies.

Developing Stage. At this point in the process, a potential user has been identified, and efforts have been initiated to modify, develop, or enhance the NASP technology from the current developmental stage to its new application. Activities during this stage consist primarily of preliminary studies and laboratory work.

Trial Stage. At this point, the NASP technology has been suitably adapted and applied to its new use. Field testing is conducted to assess and refine the performance of the technology in this new application.

Adoption Stage. During this final stage in the transfer process, the final technology development, modification, and implementation activities are accomplished.

Although these stages represent a roughly chronological order, it should be noted that many activities performed during the process may overlap, and that the length or scope of each particular stage is highly dependent on the nature or maturity of the technology itself. In addition, a vigorous feedback cycle is exercised throughout the process to ensure a smooth transition between each of these stages.

Transfer Roles of Participants. To implement the NASP technology transfer program, the *Integrated Plan* also describes the roles of the participants that must be involved throughout all stages of the process. These roles are summarized below.

Disseminator. The primary goal of the disseminator is to make information available to potential users of NASP technology. Although the disseminator is a key element during the prospecting stage, the involvement in this role continues throughout the process as the disseminator functions as a broker between the technology developers and the users. Accordingly, participants in this role are typically personnel either assigned to the NASP Technology Applications Branch, or operating under its authority.

Sponsorship. Once a link is established between technology developer and user, a dedicated sponsor is required. This generally involves some level of financial commitment, but sponsorship can also be expressed in terms of political support. Organizations involved in the sponsorship role can consist of professional or civic groups, as well as local, state, or federal government agencies. Depending on available funding levels, the NASP Applications Branch often functions as a sponsor to a certain extent in most technology transfer cases. Sponsorship becomes an important element during the development and adoption stages.

Developer. It is in this role that the user becomes increasingly involved in the transfer process. In this capacity, actual hands-on laboratory and trial work are accomplished. While the new user is typically an active participant in the development function, continued support from the original developing organization is usually maintained through some form of agreement. This support agreement can be a formal contract, an informal memorandum, or a Federal Laboratories Cooperative Research and Development Agreement (CRDA), which is expressly intended for technology transfer applications. (Although in the personal interview, Kasten notes that most NASP technology transfer agreements were not accomplished through CRDAs). The developer's work is focused primarily in the trial stage.

Implementor. After the technology has been adapted and proven in its new application, it can be transferred to full operational status. This final activity is the responsibility of the implementor. Performed primarily by the recipient organization, this role consists of establishing and maintaining customers for the product, selling, and trouble shooting.

It is appropriate here to highlight the use of U.S. Air Force and Navy reservists to complement the full-time personnel assigned to the NASP Technology Applications Branch. This unique method adds another dimension to the NASP transfer program by utilizing the services of many reserve officers across the country. As part of their reserve duty, these individuals are tasked as part of the NASP organization, and are able to contribute as formal members of the NASP technology transfer team. The transfer process is significantly enhanced by taking advantage of the diverse backgrounds, interests, and skills of these individuals. In the disseminator role, the increased government and industrial contacts of these personnel allow the involvement of a more comprehensive range of organizations in the technology transfer process. In addition, the reservists may also act in the developing and implementing role as they assist in adopting NASP technologies for their civilian employers. As a fringe benefit, the services of the reservists are funded from the military reserve budget, and not through NASP program funds (DeNardo, 1994:3). The contributions of the reserve officers will be described during the analysis of case studies.

Figure 2 shows the relationship between the stages of the transfer process and the roles of the participants.

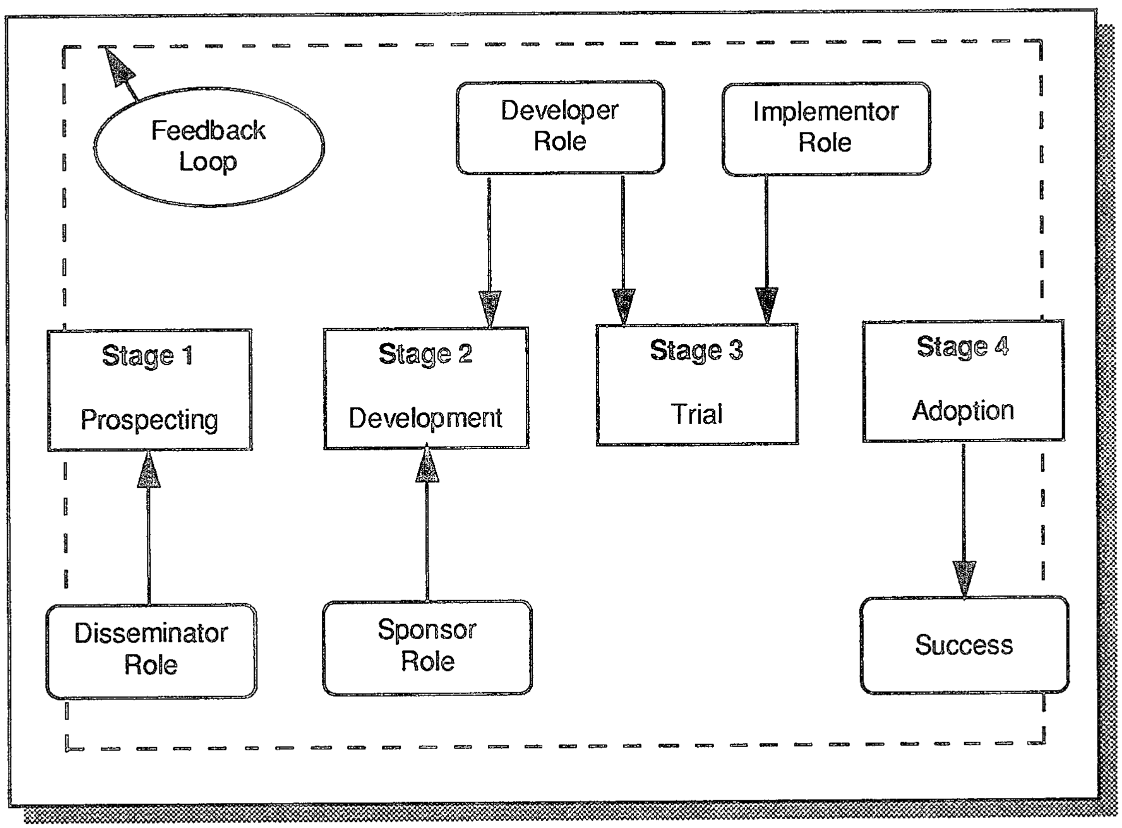

Figure 2. Technology Transfer Process and Roles
(*"NASP Domestic Technology Transfer Integrated Plan,"* 1991:10)

Technology Transfer Practices. With a process defined and the roles of the participants specified, the *NASP Domestic Technology Transfer Integrated Plan* outlines specific activities to accomplish the actual transfer of NASP-developed technologies for commercial applications. These activities encompass functions performed not only by individuals within the NASP Technology Applications Branch, but also collectively by the branch as a whole. The use of these practices represent a key element of the case studies; consequently, their definitions and intent are discussed in detail.

Analysis. This practice is used to identify the most promising technologies, to match technologies to suitable recipients, to assess the impact of this technology on a potential user's operations, and to measure the benefits or user's satisfaction once the transfer has been accomplished. This activity can make use of decision checklists, surveys and audits, cost benefit analysis, or other analytical methods. Analysis is performed as appropriate through all stages of the technology transfer process.

Facilitization. This practice involves providing physical and organizational support to the receiving organization during the transfer. The NASP Applications Branch performs a range of activities in this capacity, which can include providing laboratory facilities, assisting in joint demonstration and evaluation projects, and obtaining sponsorship for a technology transfer project.

Pro-action. These pro-active efforts represent perhaps the most definitive and tangible functions that occur during the technology transfer process. They represent all levels of specific techniques that are used in direct support of transfer projects. The case studies examine whether these functions were actually accomplished in the four cases analyzed. For convenience, the activities are summarized in Table 4.

TABLE 4

PRO-ACTIVE NASP TECHNOLOGY TRANSFER TECHNIQUES

Passive Outreach
Cooperative Agreements
Joint Funding Actions
Joint Transfer Teams
Personnel Exchanges and Loans
Cooperatively Funded Training
One-on-One Consulting to Users
Open Interactions
Training By Developer to User
(*"NASP Technology Transfer Integrated Plan,"* 1991:13)

Establishing Credibility. This task is a somewhat less tangible than the pro-active techniques outlined above. In general, this activity seeks to establish the transfer project as a credible effort in the eyes of other individuals or groups outside the developing or using organizations. This can include technical authorities in the field, university-based research groups, or other organizations involved in similar technical development. Enhancing the credibility of the transfer can improve the reputations of both the developers and the users, as well as casting a positive light on the technology transfer process itself. The goal of this activity is to promote the goodwill from successful transfers, which in turn can generate the potential for additional transfer opportunities.

Establishing the Value of the Technology. Technology transfer efforts will only be undertaken if there is a reasonable chance for success. The probability of success is highly dependent on the characteristics of the technology being transferred. The *Integrated Plan* specifies several attributes that can be used to gauge the quality of the technology in terms of how well it can be transferred. The transfer of a given technology must first provide a *measurable* benefit or improvement to the user. This could include explicit cost savings, a process improvement, or the demonstrated potential for future benefits. The technology must also be "divisible", in the sense that it can be adopted on an incremental, low risk basis if necessary. This requirement is especially critical when funding profiles do not allow complete funding of a technology project at its inception. Another consideration is how familiar the technology is to the adopting organization. Most successful transfers are those that *extend* some form of a technology that is already being employed by the user in some capacity. The final characteristic used to establish the quality of the technology is its adaptability. This measures how well the technology actually lends itself to spin-off applications. For example, a technology with a very specific or unique function may not be suitable to other uses, and attempts to transfer it to another application may be impractical. It should be noted that investigations into the characteristics of the technology as described above may constitute a significant portion of the *Analysis* activity previously described.

Organizational Development. The final transfer practice defined by the *NASP Domestic Technology Transfer Integrated Plan* encompasses approaches at the organizational level that will contribute to successful transfers. Several of these are applicable to general organizational effectiveness. In the spirit of the systems engineering concept, the first of these approaches is assigning and maintaining an interdisciplinary team that will remain with the transfer project throughout its life cycle, from inception through the successful implementation of the technology. Although frequently difficult when military members are involved, the benefits received from the continuity and "corporate knowledge" of a consistent project team cannot be overstated. Assigning responsibility of the project to a single team leader is also identified as a key factor in gearing the organization towards transfer success. As previously discussed, establishing technology transfer as a specific program office goal will serve as a motivating force for individuals involved in the transfer process. Lastly, the *Integrated Plan* specifies that the developer-user partnerships should be established early to foster successful transfer projects.

Analysis of the *NASP Domestic Technology Transfer Integrated Plan*

The NASP *Integrated Plan* defines, at the organizational level, the objectives, intended process, and methods for transferring NASP-developed technologies. As a formal policy document of the program, it is appropriate to examine whether it supports the key organization-level elements described in the literature review.

The mere existence of the *Integrated Plan* supports Shama's belief that a defined strategy is an important contributor to transfer success. By defining the organizational goals, highlighting components of the transfer program, identifying the proposed transfer mechanisms, and specifying conditions for success, the *NASP Integrated Plan* essentially documents the NASP organization's strategy for accomplishing technology transfer. While the activities described in the *Integrated Plan* suggest primarily Shama's active strategy, characteristics of the entrepreneurial and national competitive strategies are also evident. Analysis of the specific case studies will investigate the actual strategies used, and determine how well they reflect the approach described in the *Integrated Plan*..

At a more detailed level, the next obvious similarity between the *NASP Integrated Plan* and the literature is the plan's use of Souder's four stages of the technology transfer. Defining these stages at the organization level suggests that breaking down the transfer process into distinct phases, each with its own primary goal and supporting activities, can be an efficient way of plotting the course of the project and effectively managing it. Government technology projects and schedules are often driven by milestones and accomplishment of specific events. While Souder's four stages are broadly defined and overlap greatly, defining these phases may still be an efficient organizational tool for the upper-level planning of technology transfer projects.

Another significant transfer component described in the *NASP Integrated Plan* is the development of specific transfer cases. This activity highlights a defined technology, establishes a unique project and team leader, and tracks the transfer case as a dedicated effort throughout the life cycle of the project. This approach support two of Creighton's key formal elements: establishing a transfer project and specifying an organization or individual to lead the effort. The data from the case analyses also demonstrates the significance of these two components.

Of Creighton's informal elements, establishing the credibility of the parties involved in the transfer is noted as a specific transfer practice in the *NASP Integrated Plan*. This activity seeks to establish the transfer project as a credible effort worthy of participation from interested organizations. The analysis of the specific transfer cases will show how this element of credibility can generate interest in the project and contribute to the success of the transfer.

Specific transfer projects are used primarily as a management tool to organize and track the technological interactions among the participants in the transfer effort. The case development approach supports several of the general transfer methods found in the literature. As shown in Table 2, the Department of Energy (DOE) uses research collaborations as a transfer method. Similarly, the Department of Commerce (DOC) identifies demonstration projects as one of its key transfer techniques. Collaborative R&D projects, which could also involve technology demonstration, is another transfer method used by the DOC. These similar organization-level techniques all support the use of technology demonstration projects as described by the *NASP Integrated Plan*.

Several of the pro-active transfer techniques outlined in the Integrated Plan, shown in Table 4, share similarities with those described by other organizations in the literature. The NASP techniques of passive outreach, one-on-one consulting, and open interaction all correspond roughly with the DOE's use of technical assistance and dissemination of information. Cooperative agreements and joint transfer teams, as described by the NASP plan, are analogous to the DOE's advisory groups and research collaborations. The similarities and overlap among these transfer methods suggest that they are well-accepted methods of transferring technology.

Case Studies of NASP Technology Transfer

Introduction. In pursuit of the ultimate NASP program goal of designing, building and flying the X-30 demonstration vehicle, several advanced technological developments have been achieved. Due to the unique and severe operating environment of the NASP, high-strength, high-temperature materials are required to ensure the vehicle can withstand the enormous heat and structural loads encountered in transatmospheric flight. Additionally, the complexities of hypersonic flow behavior and propulsion/airframe integration require advanced computational fluid dynamics (CFD) analysis methods for validation of flight characteristics and vehicle design. (NASP Domestic Technology Transfer Program Technology Description Document, 1991:18) These two areas, materials development and CFD analysis, form the focus for the case studies of specific NASP transfer projects.

Overview. As described in Chapter 3, four examples of technology transfer within the NASP program are analyzed. The cases examined are:

- The Timetal® 21SRx Orthopedic Implant
- The Timetal® 21S Navy Tomahawk Missile Launcher
- The CFD Design Aid for Optical Surgery Instruments
- The NASP Technology Demonstrator Automobile Engine

A brief background is presented for each technology, followed by a comprehensive overview to trace the sequence of events that took place during the life cycle of the transfer project. After this introductory information, the data collected during the personal interviews is presented and discussed. The final analysis section for each technology compares the approach and methods used for each transfer to those outlined in the NASP Technology Transfer Integrated Plan and to those identified in the literature.

The discussion of the four technology projects serves as a foundation for the final analysis section, which will synthesize the key findings of the research.

The Timetal® 21SRx Orthopedic Implant

Background. This section and the overview discussion presents information documented by Donofrio and Mitchell in the Timetal® 21SRx Orthopedic Implant Technology Commercialization Project Executive Summary (Donofrio and Mitchell, 1992). Unless referenced otherwise, material in these sections was obtained from this source.

The design requirements of the X-30 necessitated a lightweight, high-strength, high-temperature alloy for use in the aircraft skin. Targeted as the matrix material for a metal-matrix composite skin, a candidate titanium-based alloy, designated Timetal® 21S, was developed by the Titanium Metals (TIMET) Corporation in Henderson, NV. Because of the high corrosion resistance and unique mechanical properties of the 21S alloy, the potential for alternative applications of this material was recognized early in the development process. It was discovered that titanium alloys, originally developed for jet engine components, had already been in widespread use in joint implant prosthetics (Donofrio and Mitchell, 1995:2). Consequently, the biomedical community seemed a logical area to investigate for possible application of Timetal® 21S.

Based on the past use of titanium in joint prosthetics, the Orthopedic Implant project was originally conceived by members of the NASP Technology Applications Branch to further explore the potential uses of Timetal® 21S in this area. The ultimate goal of the project was proposed to establish what is referred to by the Food and Drug Administration (FDA) as a "master file," or MAF. This comprehensive report, which documents test data on the various mechanical properties and biocompatibility qualities of a proposed biomedical material, must be written and approved prior to any further development of a the material for commercial use. However, this approval process is a costly and lengthy effort; the testing required to establish an MAF could amount to over a million dollars to a single prosthetic manufacturer. By soliciting free or low cost testing from interested biomedical companies and Air Force test facilities, the cost of establishing a master file on the Timetal® 21S material was estimated at $75 K. As a NASP technology demonstration project, $55 K of this funding would be provided by the NASP program office. In addition, the risk of the project could be reduced by involving several different manufacturing companies during the development of the MAF.

After approval by the FDA, the master file is made available to all prosthetic manufacturers to improve their own devices. From the development of the master file, several specific benefits are anticipated:

- Unexclusive use of non-proprietary, high performance alloy data
- Enabling smaller manufacturing companies to establish themselves among larger implant manufacturers
- Providing the U.S. orthopedic industry an advantage over foreign manufacturers by providing an implant material with superior biocompatibility and modulus, as compared to those already in use (Contributing to the domestic implant market is a significant benefit, given the fact that many biomedical companies are moving overseas to avoid the lengthy approval process for new prosthetic devices in the U.S. In 1994, the average time for device approval was 823 days in the U.S., compared to 250 days in Europe (Friend, 1995:2).)
- Demonstrating the impact of NASP-developed technologies for commercial use (Donofrio and Mitchell, 1995:2).

With a candidate technology and a potential recipient identified, a NASP technology demonstration project was established. Supported by a defined overall goal and specific project objectives, an individual within the NASP Applications Branch was designated as the project leader, and the formal technology transfer process was initiated.

Transfer Overview. After initial contact with the prospective participants in the project, the first preliminary meeting was held at TIMET in January 1993. Attendees included Timetal® 21S material production personnel, as well as representatives from several biomedical implant manufacturers. During this early planning phase, it was determined that a variant of the original Timetal® 21S material should be developed to eliminate concerns of the biocompatibility of aluminum within the body. This new aluminum-free alloy, designated Timetal® 21SRx, would be used for the remainder of the implant project. Early in 1993, a 300 lb ingot of 21SRx material was produced and designated for NASP testing.

The second planning meeting was held in May 1993. At this point, the services of reserve officers assigned to NASP were first put to use. Stationed in Boston, MA, the two reservists added their expertise to the project not only as project managers, but also in the areas of biomedical and metallurgical engineering. They turned out to be key contributors in the development of the Timetal® 21SRx master file.

Several other significant action items resulted from the May 1993 meeting. Among these was the agreement to document a formal action plan for the Timetal® 21SRx implant project. This document would highlight the goals of the program, identify the roles of the participants, and provide a roadmap for accomplishing action items to support the project objectives. The formal strategic plan, written with significant contributions by the reservists, was submitted to the NASP program office in June 1993.

During this phase of the program, outreach to implant manufacturers was still being performed to obtain endorsement and added support for the project. Several trips to the primary companies were made to identify issues and obtain feedback. Close contact with these manufacturers was maintained throughout the summer of 1993 to ensure an end product that would best suit their needs.

In October, contact was established with Dr. Anna Fraker of the National Institute of Standards and Technology (NIST). It was hoped, in addition to obtaining assistance from this organization during the MAF approval process, that the notoriety of Dr.

Fraker with the National Institute of Health (NIH) and the FDA would add an element of high visibility and credibility to the implant project.

After nearly a year of preliminary planning, the first formal project kickoff meeting was held at TIMET in January 1994. This forum addressed several key issues regarding the implant project, resulting in several significant activities. The first of these was the decision to allow licensing of Timetal® 21SRx to other titanium manufacturers. The objective of this decision was to build confidence of the implant manufacturers and testers by allowing them to purchase the material directly from companies with whom they already had working relationships.

The January meeting also resulted in the detailed development of the extensive test program required to develop the MAF. Using inputs from Dr. Fraker and the proposed test organizations, the test matrix was developed in two phases. The first phase would address primarily the material specifications of the Timetal® 21SRx alloy, and demonstrate the viability of NASP materials in the medical community. Phase II of the test program would focus more on the longer-term biocompatibility tests needed to establish the MAF with the FDA. With an approved test matrix, details were arranged among all participants to obtain the test samples, conduct testing, and document and exchange the data.

The biocompatibility testing required the involvement of the Wilford Hall Medical Center (WHMC), the primary medical facility for the U.S. Air Force. The test plan specified implanting eight dogs with Timetal® 21SRx alloy samples, which would then be removed and observed at specified time intervals to determine the effect of the material on the internal systems of the body. A detailed meeting at WHMC was held to determine the protocols needed for this procedure. The required proposals were written and submitted to the Surgeon General for final approval. It should also be noted that coordination of the test plans was also obtained by the Animal Use and Care Committee.

The first surgical implantations of the Timetal® 21SRx material were conducted in August 1994 by a clinical orthopedic research team at WHMC. Samples of the alloy were placed in the hip bones of the dogs as well as in soft tissue areas. The procedures were observed by NASP personnel and other project participants, allowing them the first opportunity to view the transferred technology in its anticipated environment.

Outreach activities continued during the summer of 1994. The project was briefed to several new organizations, including research centers, material test facilities, and additional orthopedic implant manufacturers. A paper discussing the implant project was submitted to the American Society for Testing and Materials (ASTM) Committee on Medical and Surgical Materials and Devices, for presentation at the ASTM symposium in November. Preliminary data from the test programs was becoming available, and was being used to complement these informational briefings made to interested organizations. The Timetal® 21SRx implant project had now involved over a dozen different companies and organizations, involving manufacturing, development, testing, and evaluation. The project was becoming well known in the biomedical community.

By November, the first scheduled retrieval of Timetal® 21SRx samples implanted in the dogs had been completed by WHMC. Another set of samples were removed in

February 1995, with the final retrievals scheduled for August 1995. Several organizations are participating in the analysis, including pathologists at the University of Texas and the U.S. Army's Watertown Laboratory.

As of this writing, the first phase of the Timetal® 21SRx test program, to document the mechanical properties of the material, has been completed. The project so far has been considered a dramatic success, as evidenced by the participation of so many organizations and the sincere interest shown by the biomedical community. The completion of the first test phase clears the way for comprehensive biocompatibility testing, which is the next key step in establishing the material as a master file with the FDA.

Once the second stage of testing is completed, all data will be compiled by Wilford Hall medical personnel. After gathering the data, a final report will be written and submitted to the FDA for approval as a master file. The FDA will evaluate the material in terms of mechanical strength, as well as the material's internal effects on the body. Once the MAF is approved and made available to interested manufacturers, the first three objectives of the Timetal® 21SRx project will be satisfied. The fourth goal, demonstrating the potential for commercial use of NASP-developed technologies, has certainly been attained already, as evidenced by the interest, involvement, and accomplishments of the participants.

It should be noted that even though the FDA approves the master file, the actual 21SRx implants themselves must be evaluated for use in humans. This final phase involves continued clinical testing, approval, and ultimately using the material on an experimental basis in a prosthetic application, such as a hip replacement. Although the NASP program is no longer actively involved in the project, interest has already been expressed by other organizations in building a prototype hip prosthetic and pursuing its approval for human use. A prototype prosthetic hip implant is shown in Figure 3. This final stage would represent complete technology transfer success of the Timetal® 21SRx Prosthetic Implant project.

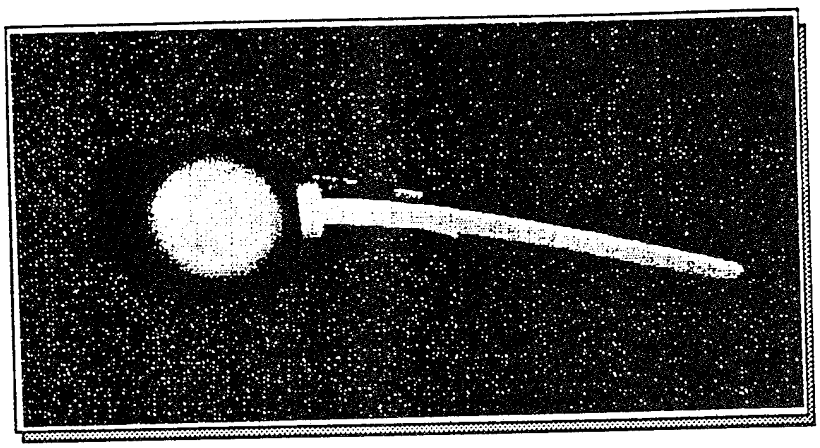

Figure 3. Prototype Hip Prosthetic
(NASP Technology Transfer Project Overview, 1993:4)

Discussion of Data.

Initiation of the Transfer. The interview revealed that the implant project was conceived and initiated by the personnel within the NASP Technology Applications Branch. The idea of applying Timetal® 21S in the medical field came as a direct result of its similarity with the prominent titanium alloy already being used for prosthetics. NASP reservists realized that Timetal® 21SRx resembled existing alloys being used in that application, and they reasoned that it may actually be a superior material for prosthetic use. The preliminary analysis supported this, so the project was pursued.

Potential users were identified easily, since the project had a unique target application and the technology appealed to a relatively small and specific constituent of biomedical manufacturers. The interface with these potential users was established through active, direct outreach from the NASP technology transfer team. Other interested organizations joined the transfer effort after learning about the project through conventions and symposia.

This active approach implies the technology was initially pushed into a prospective new application. However, after the project established credibility and the material demonstrated the potential for improvements over existing prosthetics, the activities of the implant manufacturers and the biomedical community as a whole contributed to pulling the technology into its new application. Thus, the motivation behind the transfer changed as the project matured and gained support. The market merely needed to be informed as to the existence of this new material, in which case the "push" was only slight. Once the medical community gained confidence in the 21SRx project, the more powerful effects of market pull began contributing to the transfer.

Transfer Strategy. The development of a strategic action plan was highlighted as a significant accomplishment during the early stages of the implant project. The strategy outlined the specific objectives of the effort, assigned responsibilities, and established detailed action items that supported the project goals. It is significant that this strategy was developed with input from all participants, not just the NASP personnel that were managing the project. These included the reservists, the FDA, the manufacturers and suppliers, and other organizations involved in the development of the material or the approval of the master file. The contributions from all participants assured the formulation of an accurate and efficient strategy early in the process.

The strategy documented in the action plan falls under Shama's definition as an active strategy. Passive outreach activities were complemented by pro-active efforts to convert and implement the technology into a new application. Since no real new business ventures were created or anticipated as a result of the implant project, the strategy did not qualify as an entrepreneurial strategy as defined by Shama.

Transfer Process. Although the four transfer stages of prospecting, developing, trial and adoption, as described by Souder and the *NASP Integrated Plan* were not specifically labeled as such during the Timetal® 21SRx project, examination of the interview data shows that characteristics of each stage were still present. Prospecting initially took the form of direct contact with potential users, namely, the prominent implant manufacturers. Additional prospecting efforts took place as the implant project was briefed at various meetings and symposia. The primary activity that occurred during the development stage was the modification of the original Timetal® 21S alloy into the aluminum-free 21SRx variant. This action was directly intended to make the technology more suitable for its new application in the biomedical environment. The most obvious activity that initiated the trial stage was the implantation of titanium samples into the dogs. This phase of the test program was essentially "field testing" the product, although not exactly in its intended environment. Although the final stage of adoption has not yet been reached, progress is still being made to complete the technology transfer process and get the master file approved and Timetal® 21SRx certified as a prosthetic implant.

The chronology of the transfer shows that several steps in the AFMC transfer model were also present. A strategy was developed, as documented by the project's formal action plan. Identifying Timetal® 21SRx as a transferable asset came as a result of the preliminary analysis. Marketing the material as a potential transfer technology was accomplished during the outreach activities. Suitable transfer mechanisms were identified, and the transfer process was initiated.

Transfer Elements/Mechanisms. Several of the technology transfer practices described by the *NASP Technology Transfer Integrated Plan* were significant in the implant project. Analysis was performed early in the preliminary stages of the process to investigate 21S as a viable transfer candidate and identify potential users. This was a key step in motivating the implant project.

Pro-active transfer efforts were obviously demonstrated during all phases of the transfer. Most prominent of these was the prevalence of outreach activities that took place to advertise the project to interested parties.

The value of the technology and its suitability for transfer was investigated early in the project, and the analysis showed the Timetal®21S alloy as a promising candidate for transfer to the biomedical community. The presence of the required attributes, of showing measurable benefits and having incremental, divisible characteristics suggested the alloy as a prime candidate for transfer as described in the *Integrated Plan*. Demonstrating the value of the technology was an instrumental step in the early stages of the project.

The interview noted that identifying a specific individual to lead the transfer project was the most significant of Creighton's formal technology transfer elements. A single project leader provided consistency and continuity to the effort, and helped to avoid the miscommunications and misunderstandings that can occur from involving too many managers in a project. Most importantly, a single NASP point of contact was found to be indispensable when interacting with the dozens of personnel involved in this project.

The concept of a unique project, led by a single manager, also supports the NASP transfer practice of organizational development, as described in the *NASP Technology Transfer Integrated Plan*. This approach is facilitated by the Technology Applications Branch, whose primary organizational purpose was to support these technology projects.

The frequent references to a primary integrator for this project also highlights the significance of a dedicated sponsor for technology transfer efforts. This responsibility was noted as the most important of the key roles as described in the *Integrated Plan*.

Distribution of information was also noted as a significant component in this transfer. Letters were sent frequently to all participants, updating them on the status of the project. A current list of points of contact was maintained at all times, and information pertaining to test results, new personnel, or other project changes was distributed on a regular basis. Letters of intent were frequently used to document the responsibilities of the participants, so that miscommunication and duplication of effort were minimized. The use of these letters supports Kasten's observation that formal CRDA's were not often used for NASP technology transfer efforts.

Several of Creighton's informal elements were also present during the course of the implant project. In addition to the formal letters already discussed, electronic mail, FAX, and commercial and DSN phone lines served as an effective link between the technology developers and the potential users.

Credibility of the parties involved was found to be a highly significant element in the implant case. In the relatively close-knit biomedical community, associating well-known names with the project helped to give it credibility, as was the case with Dr. Fraker from the National Institute of Standards and Technology. Potential new participants were found to be more confident and willing to contribute to the project if it were endorsed or supported by prominent names in the field. This component is also noted as a key transfer practice identified in the *NASP Technology Transfer Integrated Plan.*

Willingness to communicate was also noted as an informal element that affected this case. The interview revealed that most parties were somewhat reluctant to communicate ideas initially. Lack of funding made many companies unwilling to participate at first, although this effect was reduced somewhat as the project gained momentum. Divulging trade secrets was also a concern, but was likewise alleviated as test data became available and licensing agreements were reached. Willingness to communicate improved as the project progressed.

Creighton's informal element of reward was also noted during the interview as a contributing factor. Despite some reluctance early on, companies soon realized the value of being able to associate their name and reputation with a successful project that had high visibility in the biomedical community. Although these initial rewards were intangible, the companies remained motivated throughout the project by the possibility for financial rewards later.

A final informal element revealed during the interview was the effect of how "visionary" the participating organizations were. Many firms were fairly conservative, and seemed content not to change the materials and processes in the prosthetic field. But as in any new technological endeavor, those personnel or organizations that could look ahead to a possibly better product were ones that could contribute the most during the process, and stood to gain the most if the project was successful.

The interview revealed several of the transfer mechanisms defined by the DOC and DOE, as shown in Tables 2 and 3. The project in general was a collaborative R & D effort, and required the technical assistance of many organizations and individuals. Information was disseminated in the form of published reports, journal articles, and presentations at meetings and symposia. Finally, the implantation of the Timetal® 21SRx samples into the dogs was a technology demonstration project to examine the interaction of the material with living bone and tissue.

Climent's Conceptual Model. While the data collection did not specifically address Climent's conceptual models, the process observed in this case does show similarities with his theories. The complex interactions between the diverse participants in the project suggest that the Inter-independent model is applicable in this case. Two-way communication was occurring throughout the process, and constant feedback ensured that all organizations involved in the project could actively contribute. In this case, the similarity with Climent's model is a *result* of the working environment of the project, rather than Climent's model being used as an approach that guides the process.

Technology Transfer Grid. Data from the interviews allows an assessment of the project in terms of Smilor and Gibson's Technology Transfer Grid. Although the production methods for Timetal® 21S are complex and proprietary, the technology of applying it to prosthetic implants is not inherently complicated. As an alloy, Timetal® 21S is relatively mature in terms of its development for use in the outer skin of the X-30. However, the process of certifying a new material for biomedical use is reasonably complex, due the comprehensive testing and FDA and clinical certification approval required.

Communication between the participants in this project was relatively efficient. A constructive working relationship was formed between the key players, although the somewhat low initial priority of the project resulted in slow communication early in the project. The personalities of the individuals involved was also found to affect the communication process, both positively and negatively.

Although organizations were dispersed throughout the country, this geographical barrier was overcome to some extent by a substantial travel budget within the NASP organization. Meetings, symposia and plant visits could usually be attended as needed. Communication between geographically separated organizations was also complemented by an efficient voice and electronic mail system, as well as FAX machines and written mail. No significant cultural differences were noted, despite the involvement of many different organizations. This is especially surprising, given that the project required cooperation between individuals accustomed to working the diverse environments of the aerospace or medical fields.

Motivation for successful transfer in the implant project was not particularly high initially, but did improve slightly as the program progressed. As stated earlier, the anticipated rewards were mostly non-monetary, although that is also changing as the development of the MAF comes closer to completion. Moderate motivation for the project stemmed primarily from generating publicity, improving corporate reputation, and from curiosity about participating in this unique development effort.

Referring to Figure 1, the inputs of low equivocality, high communication, low but increasing motivation and generally low distance combine to indicate a likelihood of a "grand slam," suggesting the probable success of this transfer. The interest generated in the implant project and accomplishments so far support this conclusion.

Transfer Success. Success in the Timetal® 21SRx implant project will ultimately be achieved when a 21SRx implant is certified for human use. Even though that goal has not yet been achieved, success can also be measured in terms satisfying several of the Qualifying Conditions described in the *NASP Domestic Technology Transfer Integrated Plan.* Foremost of these is the identification of a new application and a new set of users for the NASP technology. The implant case satisfies this condition dramatically, since the technology is being transferred to an application far removed from the aerospace environment. Another condition for success according to the *Integrated Plan* are the licensing agreements that have been established to allow other titanium suppliers to manufacture the 21SRx alloy. As discussed in the transfer chronology, these agreements help establish a feeling of confidence and cooperation among the project participants. The final Qualifying Condition that was satisfied was the increased technological awareness in the biomedical field resulting from the 21SRx development project and the entire MAF approval process. Hopefully this awareness will foster additional cooperative efforts between the aerospace and medical communities.

Lessons Learned. The interview noted several barriers that were present during the transfer process. The first of these was the limited funding available for this project among the project participants. Although the NASP program supplied a significant portion of the funding required, it is believed that additional cooperation would have been obtained if more financial support had been available. This factor was compounded by the relatively stagnant state of the U.S. titanium market, partly due to significant reductions in defense production. This has resulted in somewhat low interest in titanium development, and the subsequent reluctance of materials processing companies to obligate resources towards research and development in this area. As a final barrier, it was noted that some companies were reluctant to share test data with competitors, even though the data did not represent a compromise of proprietary information. In future projects of this nature, additional measures should be taken to foster a more cooperative working environment these cases.

Case Summary. It was noted during the interview that the *NASP Domestic Technology Transfer Integrated Plan* was not used extensively as a planning or reference document during the Timetal® 21SRx implant project. This begs the question of whether the implant project supports the NASP program's organizational approach to technology transfer.

Analysis of the project shows the existence of many of the elements described in the *Integrated Plan.* The four stages of transfer were clearly evident, and several of the methods for transfer described in the plan were used. The implant project was a model example of a technology case development project, which is the key component of the NASP transfer program.

Using the approach and methods discussed in the analysis, the Timetal® 21SRx implant project satisfied many of the Qualifying Conditions for success as described in the Integrated Plan. Since the plan states that satisfying *any* of the conditions makes the project successful, it can be said that, by definition, the implant project supported the perceived benefits of technology transfer defined by the organization.

At the broader level, it can also be seen that the implant project generally supported the three major technology transfer objectives of the NASP program. The project attempted to <u>maximize the return on investment of R&D resources</u> by actively pursuing a new application for the Timetal®21S alloy. Although this does not imply direct compensation back to the government, the return on investment takes the form of increasing the industrial base, and enhancing the potential for government use of this developed material. The concept of applying government developed technologies to other *government* programs is called "spin-back," and will not be addressed extensively here (Mitchell, 1994:51).

By establishing the master file on the material, the project sought to enhance the United States international competitiveness by encouraging domestic manufacture of orthopedic implants. Finally, the dedicated activities of the Technology Applications Branch served to develop, exercise, refine, and rigorize the transfer process.

So even though the formal technology transfer document of the NASP program was not implicitly used as a planning or reference document, the accomplishments of the Timetal® 21SRx implant project nevertheless shows that it supported the organizational approach and objectives of the NASP program.

The analysis revealed many similarities between the implant project and the methods described in the literature. The importance of a defined strategy was highlighted, and most of the key steps in the transfer process defined by Souder and AFMC could be identified. Key transfer elements were evident, foremost among them being the importance of a unique transfer project managed by a single team leader, and the value of establishing the credibility of the transfer effort. The Technology Transfer Grid predicted a successful transfer, which supported the accomplishments of the project so far. The combined effects of both technology push and market pull were demonstrated.

These similarities show that the activities of the implant project correspond well with the concepts defined in the literature. This suggests that the prevalent documented transfer approaches and methods are readily applicable to actual transfers of government technology.

The CFD Design Aid for Optical Surgical Instruments

Background. Although this project also involves the medical field, this case examines the unique application of a technology that is significantly different from the other examples. Because of the unique nature of this transfer, a fundamental understanding of computational fluid dynamics (CFD) will support the discussion. Appropriately, a brief overview of CFD concepts is provided.

The design of any aircraft requires a detailed understanding of the airflows that the vehicle will experience in flight. This knowledge can generally obtained by testing aircraft components and scale models in wind tunnels on the ground. Models are placed in the tunnel and are subject to airflow conditions that are representative of what the vehicle will experience in flight. The behavior of the airflow is observed, and the resultant aerodynamic forces acting on the model can be measured. This data is then used to refine the design of the aircraft. However, the performance of these wind tunnels is limited; the high velocities and complex dynamics involved in hypersonic flight simply cannot be simulated accurately and consistently on the ground.

As a result, the vast capabilities of modern computers are used to predict these complex aerodynamic flows that cannot be simulated in a test facility. Complicated mathematical expressions, known as the Navier-Stokes equations, are used to develop computer codes to analyze high-speed fluid flow (NASP Domestic Technology Transfer Program Technology Description Document, 1991:28). These equations must be manipulated to suit the geometry of the body being analyzed and the parameters of interest. The complex interactions between airflow, heat transfer phenomena, propulsion effects, and chemical reactions must all be considered. The CFD programs are validated by comparison to data obtained by precise laboratory tests. Once the codes have been validated for a specific class of applications, they can be used to accurately predict the flight behavior of the vehicle in question. The development of these analytical codes is a significant technology in itself, requiring the skills of not only the aerodynamicist, but also the computer programmer. As one of the primary activities within the NASP program, CFD code development was highlighted as a likely candidate for other potential applications.

As in the Timetal® 21SRx project, the medical field was identified as a potential user of the CFD code technology developed for the NASP. It was suggested that CFD could be used to design surgical tools that are used in a fluid operating environment; specifically for retinal surgery within the vitreous fluid in the interior of the eyeball. The delicate nature of this procedure is obvious, as are the unique performance characteristics of the necessary instruments. Given the precision and miniaturization required, the design of the required apparatus has been difficult. In the past, the instruments used for these procedures have been designed primarily through trial and error. This approach was generally unsuitable given the complex and sensitive operating environment. A technology transfer project was proposed as a systematic method of improving the design of these delicate surgical tools through the application of advanced fluid analysis techniques.

Two primary types of probes are used during these retinal surgery procedures: the infusion cannulae and the reciprocating cutter tool. These tools must perform the basic functions of infusing, aspirating and cutting during retinal surgery within the vitreous fluid of the eye (Kirkpatrick and others, 1995:13). The cannulae are simply tubes that are inserted into the eyeball, through which fluids can be added or removed from the interior. The cutting instrument is another internal surgical probe consisting of a tube oscillating within an outer tube, with the cutting action being performed through a port in the outer tube. Suction is provided through the inner tube to remove fluid and waste tissue during the cutting process (Kirkpatrick and others, 1995:15). The relative size of the probes and their positioning within the eye during the surgical procedures are shown in Figure 4. Schematic views of the cannulae and the cutting tool are shown in Figure 5.

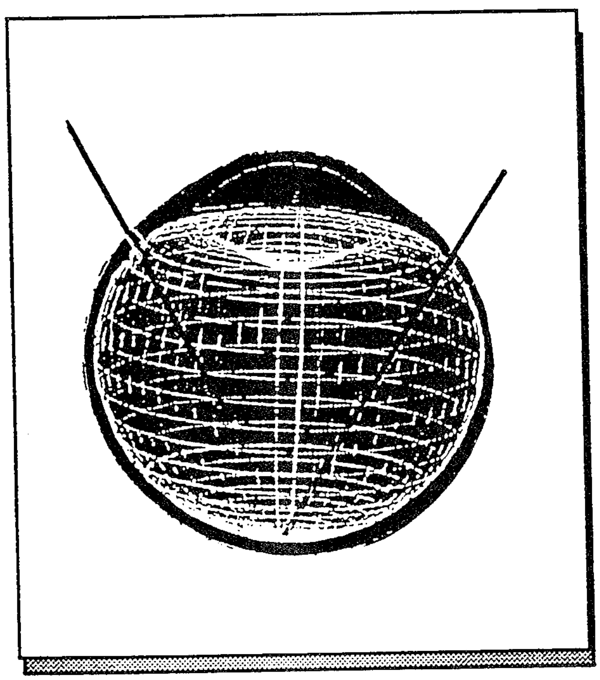

Figure 4. Computer-Generated 3-Dimensional Grid of Human Eye Pierced with Vitreoretinal Surgical Instruments (Kirkpatrick and others, 1995:14)

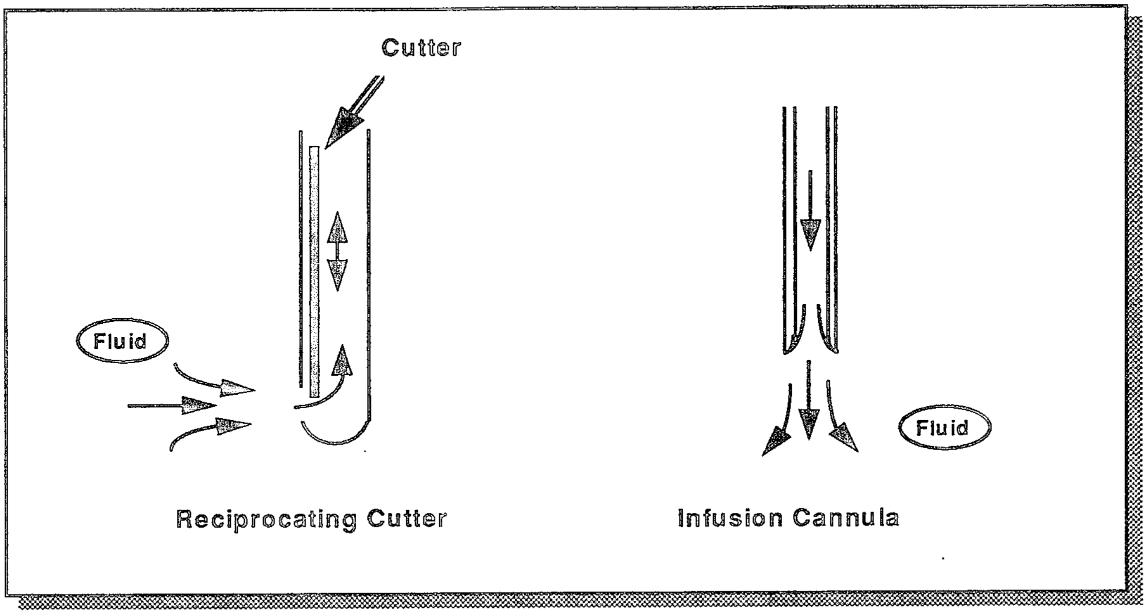

Figure 5. Schematic of Vitreoretinal Surgical Instruments
(Kirkpatrick and others, 1995:14)

The development of these tools presents a clear opportunity for the application of computer fluid analysis methods. For example, the performance of the cannulae is directly influenced by the design of the nozzle and the fluid interaction at the tip of the instrument. Similarly, the efficient operation of the reciprocating cutter is affected by the stability of the flow around the cutting port opening. Both of these effects are compounded by the fact that the vitreous within the eye is gelatinous, and does not behave like ordinary fluids such as air or water.

The CFD Design Aid for Optical Surgical Instruments project was initiated to address these issues and demonstrate the feasibility of applying advanced CFD codes to improve the design of the vitreoretinal surgical instruments.

Transfer Overview. The CFD Design Aid project differs from the Orthopedic Implant project due to the increased management role of Rockwell International, a prime NASP contractor. Because of their significant CFD efforts supporting the NASP, Rockwell was designated as the primary integrator for the CFD Design Aid project. This was only one of several demonstration projects included in Rockwell's overall program to commercialize NASP CFD technologies. Another project within this program was the NASP Technology Demonstrator Engine project, which will be discussed in later sections. Because of the increased role of the contractor in managing this transfer project, a brief discussion will outline Rockwell's organizational methods employed in this case.

The Integrated Product Development (IPD) management approach was used for this project. Key personnel were formed into an Integrated Product Team (IPT) that acted as a central core for managing transfer activities. This strategy allowed integration of the project under a common program management "umbrella" with shared contracting, subcontracting and administrative support (Kirkpatrick and others, 1995:15). The Rockwell IPT, with guidance from the NASP program, would lead the project through the following general stages:

- Verification of the feasibility of the application
- Identification of the benefits of the application and its potential users
- Identification of participants and approaches for establishing a development consortium for the product
- Outreach activities to build the consortium and the general support necessary to make the project self-sustaining (Kirkpatrick and others, 1995:5)

The IPT was also responsible for establishing an integrated master plan. This document described major tasks, task durations, completion dates, and workload and cost estimates. A master schedule was defined that was divided into quarterly segments, with specific accomplishments required for each 3- to 4-month segment. These accomplishments were designed so that the results could be presented to potential consortium members to generate interest and show progress in the project. The integrated master plan for the engine project was provided to the NASP program as a contractual requirement (Kirkpatrick and others, 1995:7).

After the initial feasibility studies and the demonstrated potential for applying CFD technology to the retinal surgical tools, the IPT continued its efforts to solicit participation in the project. Through a NASP Navy reservist, who was also a medical physician, a key relationship was established with Dr. Steve Charles of the Center for Retinal Vitreous Surgery (CRVS) in Memphis, TN. Dr. Charles provided overall technical guidance, medical requirements, and verification of results to the CFD Design Aid IPT (Kirkpatrick and others, 1995:7). As one of the nation's leading ophthalmic surgeons and inventors of surgical equipment, Dr. Charles was an indispensable asset to the project.

The first step in the development process was to define the specific medical requirements for the surgical instruments. As inventor of the vitreous cutter, Dr. Charles was instrumental in providing these requirements. As extensions of the early feasibility projects, the expected benefits, risks and issues were identified before the actual CFD code development and modeling could begin. The computer programs used for application to medical projects were adaptations of the Rockwell's proprietary NASP codes. Clinical data, provided by Dr. Charles, was used to verify modeling results.

Modifications to the CFD codes resulted in successful trial analyses on eyeball fluid dynamics. Further refinements to the codes advanced the project through the development phase, and the technology was deemed ready for possible application in the medical industry. Through the use of Dr. Charles' extensive medical connections, outreach activities were initiated to attract potential consortium members to continue the commercialization project. The medical supply industry consists of a relatively small group of large manufacturers. Consequently, outreach efforts were directed towards two major firms: Alcon Surgical and Baxter Healthcare. Inputs from these firms were solicited to improve the CFD technology for surgical instrument design. The participation by these firms in the project would be motivated by the opportunity to influence the product's requirements, and also by having first access to the capabilities of the CFD technology.

Although NASP support has been lost, the CFD Design Aid project is continuing, and further development of the medical CFD codes is underway. Based significantly on the successes of this project, Rockwell has established a Computational Center of Excellence to foster continued development in CFD technologies. Alcon and Baxter have shown interest in continuing the development of the program into the next phase. A joint program between Baxter, Alcon, Dr. Charles and Rockwell's new computer center is being initiated to continue the maturation of the medical CFD technology for design of vitreoretinal surgical instruments.

The University of Memphis has also established a computational center for biomedical research. The CFD Design Tools IPT leader, Dr. Sukumar Chakravarthy, who has left Rockwell to form his own CFD company, also plans to join the center. Support for the research center is also being provided by the National Institute of Health and the National Science Foundation. As of this writing, the center will be operational by January 1996.

Discussion of Data.

Initiation of the Transfer. The first initial link to the medical community was made through Dr. P. McCormack, a NASP Navy reservist. In addition to his reserve duties, Dr. McCormack was a medical physician with many contacts in the medical field. Among these contacts was Dr. Charles, with whom preliminary discussions were held regarding the application of NASP CFD technologies to surgical instrument design.

Additional interest in the project was generated by Dr. McCormack at the annual NASP Symposium held in Monterey, CA. This meeting was the first outreach activity proposing the application of NASP CFD technology to the medical field. Presentations described the potential for predicting fluid flow for medical applications using the computational methods developed for NASP.

The interview data showed that the CFD Design Aid project was initially a case of technology push, since the medical community was actively solicited for possible uses of computational analysis techniques. But now that the potential for this technology in medical applications has been demonstrated, the effects of market pull may have become more evident. The involvement of large manufacturing firms may have accelerated the market pull, since they have the resources necessary to support further development of the technology for other medical applications.

Transfer Strategy. After being assigned primary management responsibility for the project, Rockwell defined its strategy as part of their statement of work in response to the government's Request for Proposal (RFP). This document, a formal contractual submittal, defined the IPD/IPT approach, identified potential project participants, and established project schedules and objectives.

This project is the first case that extends Shama's strategy theories to the entrepreneurial stage. All the components of the active strategy are present, including proposed licensing agreements between Rockwell and Dr. Charles. But the project takes the strategy a step further through the formation of the University of Memphis computational center for biomedical research and Dr. Chakravarthy's CFD spin-off company. Both these new organizations came as a direct result of the successes of the CFD Design Aid project and Rockwell's other CFD commercialization efforts. In addition, both these cases show the characteristics of being the implementors of the technology, which is defined as a key role in the *NASP Integrated Plan.*

The involvement of Rockwell in this case shows the contractor functioning in an increased sponsorship role, as described in the *Integrated Plan.* This is even more apparent now, since their sponsorship of the project is continuing after losing NASP program support.

Transfer Process. The first two of the four phases of the technology transfer process are readily identifiable. Prospecting activities began at the Monterey Symposium. These initial efforts were intended to introduce the technology to the medical industry. Later prospecting activities targeted specific medical firms to gain their participation in the project. Development consisted of modifying the aerospace-based CFD codes so they could be used for medical applications. In this case, this application was the analysis of fluid behavior within the human eye. Code modeling was verified by comparing analysis results to the clinical data provided by Dr. Charles. The suitability of the CFD codes for application in this area has essentially been proven. If the project continues, the technology will progress to the trial stage where the codes will be used for surgical tool design.

In addition to identifying Souder's transfer phases, several steps in the AFMC model are also apparent in the CFD design aid project. A strategy was developed and documented in Rockwell's integrated master plan. CFD codes were identified for possible medical applications. The technology was then actively marketed, initially to the medical community in general, and later to specific medical equipment manufacturers. Specific mechanisms were identified to facilitate the transfer. The technology has been transferred, to the extent that CFD analyses have been performed to determine the behavior of optical surgical tools within the fluid of the eye. Even though the project has lost NASP support, the post-transfer administration function is still evident as interaction continues between the technology developers and the medical community.

Transfer Elements/Mechanisms. The interview showed the use of several of the technology transfer practices described in the *NASP Integrated Plan*. Analysis was performed to determine the suitability of the CFD codes for vitreous fluid dynamics prediction. Several pro-active transfer techniques, as described in Table 4, were used. These included outreach activities (briefings, symposia, journal articles), cooperative agreements (such as the relationships established between Rockwell and the University of Memphis), consulting (demonstrated by the inputs from Dr. Charles), and open interactions (which encompasses all exchange of information between the project participants).

Given the extremely diverse technological requirements of the aerospace and medical communities, the unique application of CFD technology outside of the aerospace industry demonstrates the importance of proving the quality of the technology for transfer. The importance of this practice is noted in the *NASP Integrated Plan*. In this case, the task involved demonstrating the adaptability of CFD analysis methods for use within the fluid of the eye. Since this was a totally new use for this technology, proving the adaptability of the CFD methods was a key activity for this project.

Rockwell's management of the CFD Design Tools project is also a clear example of the organizational development technology transfer practice as described in the *NASP Integrated Plan.* The IPT approach specifically requires a life cycle team, with responsibility assigned to the team leader. Commercialization of the CFD technology is defined as the goal of the IPT, with the "product" being a CFD design tools package. Finally, the early involvement between the developers and users contributed to an effective working organization.

The interview data also shows that all of Creighton's formal and informal elements were present in this transfer example. As in the previous case, the most important of the formal elements was the management of the project by a dedicated organization lead by specific individual. Distribution of information, in the form of briefings and symposia, was also noted as a key element in generating support for the project. The submittal of a final report is an additional formal activity that occurred during the transfer.

The credibility of the parties involved, specifically Dr. Charles, was stressed during the interview as the most critical of the informal elements. As the nation's leading vitreoretinal surgeon, with over 16,000 operations, his involvement in the project brought indispensable recognition and prestige to the project (Kirkpatrick and others, 1995:9). The importance of establishing the credibility of the effort is also noted as one of the key transfer practices described by the *NASP Integrated Plan.*

The contributions of Dr. Charles in the disseminator role highlights this key function as described in the *Integrated Plan.* The efforts of Dr. Charles in "advertising" this technology to the medical community shows that crucial dissemination efforts were not always accomplished by NASP personnel.

The potential for reward was also noted as a key informal element. The developer of the CFD technology was motivated by the possibility for increased sales of computational packages, and the adopter was motivated by the potential for improved procedures and reduction in health care costs.

Several of the DOE and DOC mechanisms were also present during this project. Among these were: Advisory groups (such as the University of Memphis), research collaborations, licensing (of technology between Rockwell and Dr. Charles), spin-off companies (Dr. Sukumar Chakravarthy left Rockwell to form his own CFD company) , dissemination of information, colloquia/published reports, demonstration projects, comprehensive centers (the University of Memphis computational center), and collaborative R&D projects. Since the entire project was essentially a research collaboration, it is noted as one of the most important transfer mechanisms.

Climent's Conceptual Model. Analysis of the transfer shows the behavior of Climent's Inter-independent transfer model. Complex interactions between all participants were occurring throughout the transfer process. The constant feedback between Dr. Charles, the medical community and the CFD development team shows a strong relationship of exchange rather than sending and receiving. This project supports Climent's concept that technological change is best achieved through shared interaction between the participants.

Technology Transfer Grid. The NASP CFD codes used as a basis for this project were highly complex, yet relatively mature for use in aerospace applications. However, the technology was very immature for any other use, including medical applications.

The communication between the participants was highly effective, despite the varying backgrounds of the medical and aerospace personnel involved. Frequent personal meetings enhanced the communication process.

The geographical and cultural differences between personnel were high. Organizations were widely dispersed throughout the country. Several of the individuals involved in the

CFD effort were from India, which also introduced some cultural differences during the project.

Motivation for the CFD Design Aid Project was high. Anticipated rewards included prestige and financial benefits for Dr. Charles, as well as the potential for improved medical procedures. Rockwell was also motivated by the possibility of sales of CFD packages for medical applications.

Based on these factors, analysis of the CFD Design Aid project using Smilor and Gibson's Technology Transfer Grid initially proved to be inconclusive. Using Figure 1, it can be seen that the high technical equivocality for this project is offset on the horizontal axis by the high communication level that was present. Similarly, the high motivation of the project participants is countered on the vertical axis by the relatively high geographical and cultural distance between them. With this *general* combination of the four inputs, the potential for success cannot be predicted since transfer cannot be placed in any specific quadrant on the grid.

However, the relative success of the project suggests the likelihood of a "Grand Slam" in this case. A more refined examination of the inputs shows how this apparent inconsistency may occur. For example, the level of communication may have been high enough to *more than* offset the high technical complexity of the project. This would tend to draw the transfer more towards the right side of the grid. Similarly, very high motivation would push the transfer towards the upper quadrants. This "massaging" of the inputs results in a successful transfer prediction output from the grid, which more closely resembles the actual behavior of this transfer project.

This suggests that, even though this type of general model is not always a viable method of obtaining accurate predictions based on qualitative data, a more detailed refinement of the inputs may result in a more accurate prediction of transfer success.

Transfer Success. Many of the Qualifying Conditions described in the *NASP Domestic Technology Transfer Integrated Plan* were met by this project. These included: application of an existing product to different customers, enabling of a new product line (CFD tools for medical use), and several instances of working agreements between NASP technology developers and other agencies. Should the medical CFD technology mature and be used for design of tools, then the following additional conditions would be satisfied: improvement in existing products (medical tools), improved efficiency/effectiveness of a process (vitreoretinal surgery), and reduction of production defects (during surgery). Licensing and patent agreements between Rockwell and Dr. Charles are also likely.

Lessons Learned. Barriers that hindered the transfer process in this case were: the high technical complexities and immaturity in applying CFD to medical applications, the shortage of funding to complete the effort through the end of the demonstration project, the geographical distances between organizations, and the slight language barrier that existed between several of the individuals involved in the project.

According to the interviewee, greater success could have been achieved if more funding were committed by participants involved in the CFD tools development. In addition to more financial contributions, more personnel were also needed to adequately address the problem. Earlier involvement in the project by the large medical supply companies was noted as a possible way that these resource issues could have been addressed.

A final issue discussed during the interview was the difficulty in maintaining the balance between the strict success-driven requirements of government project management with the relaxed "inventor" mentality that exists in new technology projects. There was a tendency for some participants to want to simply "play" with the technology, which conflicted with the government's motivation to accomplish milestones and show results. Some of this conflict may be reduced by the discontinued involvement of the NASP program.

Case Summary. The interview for the CFD Design Tools project also revealed that the *NASP Integrated Plan* was not used to facilitate the transfer process. But, as was noted in the previous case, many similarities with the plan suggest that this transfer still supported the intent of the NASP technology transfer program as documented in the *Integrated Plan.*

Rockwell's IPD approach to the management of the project was shown as a unique application of the sponsorship role as discussed in the *Integrated Plan.* The use Integrated Process Teams also demonstrated the concept of organizational development, a primary component of the defined NASP transfer program.

This case was also a clear demonstration of the value of the NASP military reservists. Without the medical connections of Dr. McCormack, a naval reserve officer, the potential for application of the CFD technology to the medical field may have never been realized.

The NASP elements of analysis and proving the quality of the transfer were shown as key activities to prove that the CFD methods, used primarily in aerospace applications, could be applied to the altogether different medical environment. The project likely would not have continued if the potential for transfer could not have been demonstrated using these methods.

Several of the NASP Qualifying Conditions were met, and it was noted that several more would be satisfied if the CFD Design Tools project continues to mature.

As in the implant project, this case generally accomplished the organizational objectives defined in the *NASP Integrated Plan.* The return on investment of R&D funds was addressed by the specific effort to find new applications for the CFD technologies. Meeting this objective was even more evident in this case, since the commercialization of the technology was also a specific goal of Rockwell. It should be noted that this return on investment does not take the form of direct compensation to the government. As in the previous case, the return is characterized by improved national capability, and the potential for spin-back technologies. National competitiveness was enhanced by the potential for improved surgical tools and techniques in this country. Finally, the creation of the CFD Design Tools IPT sought to improve the technology transfer process.

The analysis demonstrates that this transfer project was successful in terms of the organizational approach and objectives of the NASP program, even if the Integrated Plan was not specifically used to facilitate the process.

The data from this case also supports many of the transfer concepts found in the literature. The formation of the IPT once again demonstrated the importance of a specific organization to manage each unique transfer project. The contributions of Dr. Charles shows how the involvement of a prominent figure in the field can contribute to information dissemination and greatly enhance the credibility of the process.

This project shows increased focus on the actual commercialization of the technology. The analysis shows the first example of Shama's entrepreneurial strategy. This is supported by the creation of the University of Memphis computational center, as well as the CFD company formed by Dr. Chakravarthy of Rockwell. The commercialization aspects of this project are further evidenced by the fact that the development efforts are continuing without the participation of the NASP program.

The analysis of the CFD Design Tools project also showed how the limitations of Smilor and Gibson's Technology Transfer Grid could be overcome. The combination of initial inputs to the grid yielded an inconclusive result, even though the project shows significant past accomplishments and shows continued promise for the future. Despite the drawback of using a simple model to analyze complex qualitative interactions, the analysis shows that a more refined input to the model can give a more accurate assessment of transfer success.

In addition to sharing many similarities with the concepts in the literature, this effort also demonstrates some of the differences that can exist between technology transfer cases. This is apparent even though the CFD Design Tools project and the Orthopedic Implant project both addressed the application of technology in the medical community. But the peculiarities of the projects examined so far tend to support Deonigi's claim that all transfer cases are different.

The Timetal® 21S Navy Tomahawk Missile Launcher

Background. This project is the second significant transfer effort involving the Timetal® 21S alloy. It differs from the Implant project in that the NASP technology was transferred for military application to another government service, namely, the U.S. Navy. In this respect, this project also differs from the other cases, where the technology was applied to commercial uses.

As described in previous sections, Timetal® 21S is an advanced titanium alloy developed for the outer skin of the X-30 aircraft. The material is light weight, highly corrosion resistant, and shows superior structural performance under extreme temperature conditions. With these desirable properties, it was suggested that the Timetal® 21S alloy could be applied in the harsh conditions of Navy ships at sea.

Several variants of current naval vessels are configured with the Tomahawk cruise missile. The missiles are launched from a stainless steel, concentric launcher, which has the general configuration as shown in the breakout view in Figure 6.

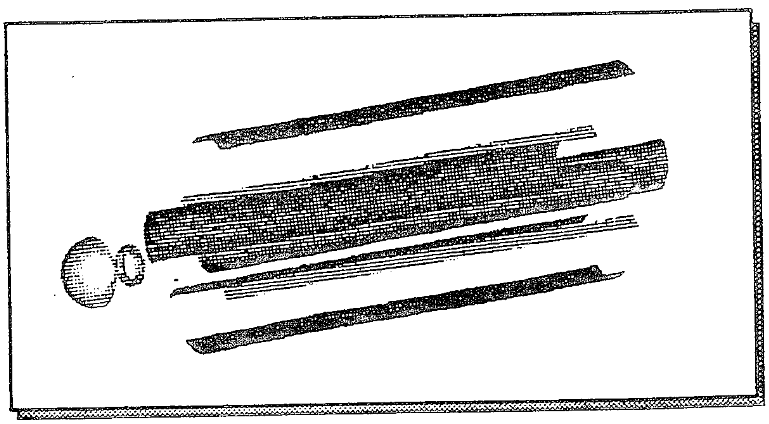

Figure 6. Tomahawk Missile Launcher
(NASP Technology Transfer Project Overview, 1993:12)

Batteries of Tomahawk missiles, consisting of several of these launchers nested together, are normally associated with ships displacing 10,000 tons or more. However, the current trend in Navy surface combatant vessels is toward lighter, faster ships with firepower comparable to those currently in use (DeNardo, 1991:4).

Consequently, a new class of ships has been proposed that would utilize Tomahawk batteries, but would only displace 5,000 tons. While operationally feasible, the heavy weight of the current steel Tomahawk missile launchers limits the practical use of these batteries on lighter classes of vessels. The Navy sought a material for a new launcher that would not only withstand the required number of missile launches and the corrosive sea environment, but would also save weight.

Specifically, the new launchers had to satisfy the following requirements:

- It must be fabricated using state-of-the-art techniques.
- When loaded with a missile, the entire assembly must weigh less than 7,500 pounds.
- The new structure must be capable of supporting the same number of launches as the current system.
- The structure must be sound enough to withstand the vibration and impact associated with rough water traverse (DeNardo, 1991:4).

After initial contact with Navy personnel, Timetal® 21S was identified as a material that could potentially meet these criteria. A technology demonstration project was proposed, and the following additional general guidelines were defined:

- As a primary project goal, the NASP program office would provide the Navy with a quarter scale, proof-of-concept missile launcher made primarily with Timetal® 21S.
- The cost to the NASP program should be minimal, and resources would be provided in-kind before dollars.
- The fabrication of the quarter-scale launcher, if deemed feasible, should be accomplished using a cooperative agreement between government and industry (DeNardo, 1991:5).

With these broad objectives, the Timetal® 21S Navy Tomahawk Missile Launcher project was established, and the technology transfer process was formally set into motion.

Transfer Overview. This project was a clear demonstration of the value of military reservists to the NASP technology transfer program. It was the Navy reserve officers, in performing duties to support NASP, that first generated program interest in Navy requirements and the potential for NASP technology to satisfy those requirements (DeNardo, 1991:3). This key relationship was not only crucial in initiating the missile launcher project, but also resulted in the creation of an entirely new market of potential NASP transfer opportunities.

After the key link to the Navy was established by the reservists, preliminary meetings between NASP and Navy personnel were held in the fall of 1993. The initial project requirements were defined in September. The next step was to begin forming a core of expertise required to address the various aspects of the problem (DeNardo, 1991:6). Forming this consortium was the primary activity in the early stages of the project. Telephone calls and organizational visits were made to generate interest in the project and attract potential members. Soliciting participation, establishing points of contact, and defining responsibilities lasted until June 1994.

The consortium consisted of several diverse organizations, each with a specific function to accomplish in support of the project. The titanium alloy required would be furnished by TIMET Corporation, along with associated material characteristics data. The Rocketdyne Division of Rockwell International, already a prime NASP contractor, would perform the fabrication of the model in conjunction with Exotic Metals Forming

Corporation and Astec-MCI. Laser welding and assistance would be provided by the Ohio Edison Welding Institute and the Applied Physics Laboratory of Pennsylvania State University. The Developmental Modification and Manufacturing Facility (DMMF) at Wright-Patterson, AFB was tasked to provide design optimization and prepare for full-scale fabrication of the launchers if required. The Naval Surface Warfare Center (NSWC) at Dahlgren, Virginia was the primary focal point for administering Naval requirements. The Science Applications International Corporation (SAIC) would control consortium building, facilitate technology transfer efforts, and provide documentation for the project. Finally, the NASP Technology Applications Branch acted as the overall program sponsor and integrator, and would provide some financial resources.

Once all the project participants were in place, the actual fabrication development efforts could begin. It should be noted that the launcher project did not address redesigning the launcher, but merely fabricating it from a different material. However, the unique requirements of the launcher, combined with the characteristics of Timetal® 21S, required specialized fabrication techniques to produce an acceptable product.

These fabrication methods were developed during the summer of 1994. Once the methods were perfected, the launcher model components were produced from Timetal® 21S material supplied by TIMET. The scale missile launcher was assembled, heat treated and delivered to NSWC in January 1995. As of this writing, the quarter scale missile launcher is undergoing testing to determine its suitability in comparison to the current stainless steel design. At the conclusion of testing, a corrosion resistance analysis and a life-cycle cost study will be performed. If the Navy is satisfied with the results of these efforts, they will proceed with a Advanced Technology Demonstration (ATD) Program, where full-scale prototypes will be built and tested ("NASP Advanced Technology Impacts, SAIC Final Report," 1995:12).

Discussion of Data.

Initiation of the Transfer. The naval reservists working for the NASP program were the first to suggest the use of NASP materials for naval applications. On their recommendation, preliminary meetings were held at NSWC to investigate the possible uses of NASP technology. After reviewing the properties of the Timetal® 21S alloy, naval personnel were convinced that it would be the optimum material for the missile launcher.

The initiation of this transfer was unique in that it shows the characteristics of both technology push and market pull. Technology push was demonstrated by the ambitious efforts by the NASP program to find alternative applications of the Timetal® 21S alloy. On the other hand, the Navy was actively seeking an alternative material to improve the weight characteristics of the existing stainless steel launchers. Establishing the link between these two organizations would satisfy the needs of each.

Transfer Strategy. The key personnel involved in this project met early in the process to identify possible participants, define program goals, and to address approaches to the problem. Assisting in the development of this strategy were representatives from the Navy, TIMET, Pennsylvania State University, SAIC and the NASP program office.

As with the implant case, the approach used for this project qualifies it as an active strategy, as defined by Shama. Passive outreach activities to generate interest in

Timetal® 21S were ultimately complemented by active solicitation of the Navy to use the material for its launcher. No new business ventures were created, so the strategy did not advance to the entrepreneurial stage.

Transfer Process. The first two transfer phases were brief and well defined in this case, with the primary focus of the project being on the third stage. The early prospecting activities were relatively short-lived, since NASP outreach efforts to find new application for the Timetal® 21S alloy were met quickly by the Navy's requirement for a new material for the launchers. Development activities mainly addressed the relatively straight-forward welding techniques required to fabricate the quarter-scale model. The primary activity of the launcher project, the demonstration of the scale launcher, is the key component of the trial phase of the process. This stage is underway, since the scale launcher is undergoing field testing to determine the suitability of the alloy in its new application. Should the tests be successful and the material approved by the Navy, the project would progress to the adoption stage.

The most significant step of the AFMC process in this case was the identification of the Timetal® 21S as a potential technology suitable for application to the Navy launcher. It was fortuitous that this identification was made with the assistance of the Navy reservists. This key step resulted in the formation of the crucial link between the marketing of the alloy and the Navy's search for a new launcher material.

Transfer Elements/Mechanisms. Several of the transfer practices described in the *NASP Integrated Plan* were significant during the launcher project. The analysis function, to determine the suitability of the Timetal® 21S alloy in marine applications, was instrumental in complementing the technology identification step described above. The matching of the material to the Navy requirements for the launcher was accomplished by this activity. Complementing the Navy's search for a material were the pro-active efforts of the NASP program to find suitable applications for Timetal® 21S. These efforts were best demonstrated by the outreach activities of the reservists in soliciting the Navy for possible uses of the 21S alloy. This led to cooperative development agreements, which are identified in the *Integrated Plan* as a key pro-active mechanism. Open interactions were occurring constantly throughout the transfer process. Involving organizations such as Penn State and the Ohio Welding Institute helped to establish the credibility of the launcher project.

Establishing the quality of the technology for transfer was a significant, yet easily performed activity for this project. The tangible value of the technology was readily measurable in terms of reduced weight and improved material performance. The characteristics of Timetal® 21S make it highly adaptable to many other applications. Both these attributes suggest that the material was a likely candidate for transfer, as described by the *NASP Integrated Plan*.

Once again, the interviews showed that nearly all of Creighton's formal and informal transfer elements were present in this case. Similar to the other transfers, the definition of a specific project and a single project leader was noted as the key element in this example. But the missile launcher project demonstrated a unique variation of the management and sponsorship concept. This case differed from the others in that significant project management responsibility was assigned to the support contractor, SAIC, rather than managing it from within the NASP Technology Applications Branch. The SAIC project leader, under a formal contract funded by NASP, was given total responsibility for the effort. The interviewee noted that the management of the project by a civilian organization also seemed to eliminate some of the subtle barriers that can exist by the government's involvement in this type of project.

The involvement of SAIC also enhanced the formal elements of documentation and distribution of information, since project reports were required as part of the contractual agreement with the NASP program. These project reports were used extensively in this research.

The data suggests that the informal link between the source of the technology and the user was demonstrated here by the naval reservists. This link formed the basis for the initiation of the project. Both parties were willing to communicate ideas, since both organizations were motivated by unique requirements: the NASP program by its technology transfer motives, and the Navy by its desire for a lighter missile launcher. The potential for reward, in the sense of reduced weight for the launcher, was another informal element that contributed to success of the project. The interviewee stressed the importance of these informal factors.

The analysis of the launcher project also showed several of the DOE and DOC transfer methods at work. The fabrication of the quarter scale launcher was essentially a demonstration project that supported the overall objectives of the broader transfer effort. The formation of the consortium to develop, fabricate and assemble the launcher could be considered a collaborative R&D project. As noted earlier, dissemination of information, in the form of published reports, was also a significant transfer mechanism used in this case.

Climent's Conceptual Model. As with the other cases, the data for the launcher project suggests similarity with Climent's Inter-independent transfer model. The exchange of information between all participants shows a relationship beyond that of simply sending and receiving. Feedback and discussion of issues occurred between all organizations throughout the transfer process. As in previous cases, this application of Climent's model describes the behavior of the participants during the project rather than being used as an approach to facilitate the process.

Technology Transfer Grid. Based on the input factors described by Smilor and Gibson, the Technology Transfer Grid predicts a successful transfer in the launcher case. The technical equivocality was low, since the material had been proven and was simply being applied to an existing design. Motivation for the Navy was high, given the potential weight savings and increased performance of the Timetal® 21S material. Distance was generally low, despite the potential for cultural differences stemming from the involvement of two different services, the Air Force and the Navy. The personalities and the working relationships fostered a high level of communication. Referring to Figure 1, these factors indicate the likelihood of a "Grand Slam" on the Technology Transfer Grid. Given the relative success of the project so far, this appears to be an accurate assessment.

Transfer Success. If the testing of the quarter scale launcher is successful and the Navy implements Timetal® 21S for production, several of the Qualifying Conditions for success, as described by the *NASP Integrated Plan*, would be satisfied. These include improvement of an existing product (the missile launcher), and additional applications and customers for the product (the 21S alloy). But even if the Navy does not approve the use of Timetal® 21S for the launchers, the project has already satisfied the requirement of forming agreements between NASP technology developers and a non-NASP agency.

Lessons Learned. The interviewee iterated again in this section the importance of a single facilitator to manage the project. It was also noted that most organizations were reluctant to take risks and go outside their established routines. This was evident even in the relatively straightforward Tomahawk missile project.

The interviewee also reflected that greater success could have been achieved if a more aggressive funding profile was pursued, with more money spent early in the program.

Open discussion of the project also revealed an underlying motivation for this project that was not noted in the other interviews. This was the potential contribution of the launcher project in maintaining the U.S. industrial base, specifically the dwindling titanium infrastructure. Decreasing defense requirements and increased competition from the Soviet titanium industry has resulted in a drastic loss of titanium production capability in this country. The large-scale adoption of Timetal® 21S would bring a needed boost to the sagging U.S. titanium industry. This was the first direct reference in this research that suggested the potential of technology transfer in supporting the national industrial base.

Case Summary. Interestingly, the SAIC project lead that was interviewed for this case was the primary author of the *NASP Technology Transfer Integrated Plan.* It was surprising, then, that the interviewee notes that aside from limited referral to the success metrics, the *Integrated Plan* was not used as a specific reference document in this case. Nonetheless, the analysis suggests that the intent of the plan was still supported by the approach and methods used in this case.

This case again showed the benefits of using military reservists to support NASP transfer efforts. Navy reserve personnel were instrumental in making the connection between the outreach efforts for the Timetal®21S alloy and the Navy's search for a new material for the launchers. Without the naval reservists, this match may not have never been made. This key step cannot be overemphasized.

The analysis function, combined with proving the quality of the technology for transfer, complemented the reservists efforts to demonstrate that the Timetal®21S alloy was a prime candidate for naval applications.

The project has so far satisfied only a limited number of the Qualifying Conditions for success as described in the *Integrated Plan.* Does this imply that the missile launcher project has been unsuccessful? The fact that the project has progressed to the early trial stage is an indication that the project has been successful. This, then, suggests that the Qualifying Conditions do not represent universal metrics for transfer success. For the launcher project, the true measure of success will be demonstrated if the material is accepted for use by the Navy. Success in that case will be significantly more measurable.

Despite the fact that few Qualifying Conditions were met, this case still clearly satisfied the broad transfer objectives outlined in the *Integrated Plan.* The return on investment on research funds will be great, especially since the investment of NASP funding in the project was relatively small. The military application of the new technology shows how the government benefits from R&D funding through the spin-back concept. As discussed in the Lessons Learned section, the international competitiveness of the U.S. is enhanced by the potential for stimulating the stagnant titanium industry in this country. Finally, the technology transfer process was improved, shown in this case by the activities of the support contractor, SAIC.

So even though the author of the NASP Technology Transfer Integrated Plan concedes that the plan wasn't used to facilitate this transfer, the objectives of the NASP organization were still addressed by this project.

Several of the now-familiar concepts found in the literature were present in this case. A variation of the formal management element was demonstrated by the involvement of SAIC in leading the project. The informal link between the technology developer and the user has been shown to be a crucial element of this transfer. The fabrication of the quarter-scale launcher is a noteworthy example of a technology demonstration project.

In direct contrast to the number of Qualifying Conditions satisfied, the Technology Transfer Grid predicted success for the launcher project. This again raises the question of how to accurately measure transfer success.

The NASP Technology Demonstrator Automobile Engine

Background. In addition to Timetal® 21S, many other strong, lightweight and high-temperature materials have been developed to meet NASP requirements. Among these are other variations of titanium alloys, aluminum-beryllium alloys, and carbon-carbon composite materials (Ashley, 1994:20). These unique materials presented significant opportunities for alternative applications.

As a result of several feasibility studies conducted during the late 1980's, the automotive industry was identified early in the program as a potential recipient of NASP-developed technologies. The studies cite a variety of reasons to support this link: automotive applications require different levels of material technologies, the volume potential of the automotive industry, and the challenging requirements of automotive development (West and Mitchell, 1994:5). These conditions gave compelling support to the potential for technology transfer from NASP to the automotive industry.

The automobile engine itself was proposed as potential area for improvement using advanced materials technology. Preliminary estimates showed that a midsize engine made of NASP materials could weigh 50% less than a conventional engine of comparable power. The reduced weight of components, combined with the elevated operating temperatures allowed by NASP materials, could result in an estimated 20% increase in engine efficiency with less polluting emissions (Teresco and Stevens, 1994:53). The promising potential shown by these early studies convinced the NASP program that a dedicated automotive technology demonstration project should be pursued.

The NASP Technology Demonstrator Automobile Engine project was initiated as an ambitious effort to disseminate aerospace technology into the automotive industry. The plan was not to compete with the current engine manufacturers, but to join with them to demonstrate the capabilities of alternate applications of technology in their industry. The project was intended as a high-visibility activity involving NASP technology developers, automobile companies and engine designers.

The broad goal of the project would be supported by the specific objective of designing and fabricating a revolutionary, lightweight, and efficient automobile engine using NASP-developed materials (West and Mitchell, 1994:5). The proposed engine would represent a straightforward, conventional V-8 design, shown in conceptual, cross section view in Figure 7. Displacing 1.5 to 2 liters, weighing 70-90 pounds, and generating around 200 horsepower, the engine would produce 80% of the power at about 50% of the weight of the current Ford 5-liter V-8 (Kirkpatrick and others, 1995:32). Although the engine block and heads will use non-NASP high-temperature aluminum, NASP materials would be utilized for the other engine components as follows:

- Timetal® 21S connecting rods and crankshaft
- Titanium camshaft
- Carbon-carbon composite intake manifolds and valve covers
- AlBeMet™ aluminum beryllium pistons
- Beta Titanium-aluminide valves
- Nickel Aluminide catalytic converter (Kirkpatrick and others, 1995:32, "The NASP: A Unique R&D Program Benefiting AFMC, DOD, and the United States," undated:18)

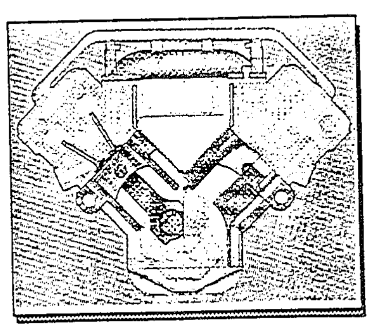

Figure 7. The NASP Technology Demonstrator Automobile Engine (NASP Technology Transfer Project Overview, 1993:2)

After identifying the project objectives and defining the preliminary requirements for the engine, the formal technology transfer process could begin.

Transfer Overview. Given the ambitious goal, the diversity of participants and the potential for significant market benefits, the NASP Technology Demonstrator Automobile Engine project was intended as a showcase for the NASP technology transfer program. The engine was a readily identifiable, highly visible product that, if successful, could have great implications in the automobile industry. The various materials and engineering expertise required implied the involvement of a consortium of many different organizations.

The consortium members would be involved in the following activities:

- Verification of the feasibility of the application
- Identification of the benefits of the application and its potential users
- Identification of participants and approaches for establishing a development consortium for the product
- Outreach activities to build the consortium and the general support necessary to make the project self-sustaining (Kirkpatrick and others, 1995:5)

The project was further organized into four distinct phases:

- Requirements, design criteria definition and preliminary modeling
- Trade studies and advanced modeling
- Component Design and fabrication
- Assembly and system testing (Kirkpatrick and others, 1995:33)

During the preliminary planning efforts, an integrated master plan was established. This plan described major tasks, task durations, completion dates, and workload and cost estimates. A master schedule was defined that was divided into 3- to 4-month segments, with specific accomplishments required for each segment. These accomplishments were designed so that the results could be presented to potential consortium members to generate interest and show progress in the project. The integrated master plan for the engine project was provided to the NASP program as a contractual requirement (Kirkpatrick and others, 1995:7).

Through a contract with Rockwell International, Texas Instruments Metallurgical Materials Division was tasked with integrating the engine project ("Auto Engine Modeled Materials Developed for NASP," 1994:3). This project was the second effort led by Rockwell as part of their program to commercialize NASP CFD technology. As with the CFD Design Tools project, the demonstrator engine program utilized the Integrated Product Development (IPD) management approach, utilizing an Integrated Product Team (IPT) to centralize transfer activities. This strategy allowed integration of the project under a common program management "umbrella" with shared contracting, subcontracting and administrative support.

Through existing industrial contacts, the Texas Instruments project leader tasked Callaway Advanced Technology for assistance with the requirements definition, primary design and development of the engineering database for the NASP demonstrator engine.

The involvement of Callaway was a key element to the early successes of the project. The reputation and expertise of Reeves Callaway, namesake and owner of Callaway Advanced Technologies, is well known throughout the automotive industry for his advanced designs and modifications of high performance street and race car engines.

Callaway's recent project, a heavily modified Corvette C7, recently competed against the likes of Ferrari and Porsche in the prestigious 24 hour race at Le Mans (Cooper, 1995:32). The association with Callaway contributed significantly to generating interest and support for the NASP Demonstrator Engine project.

Once the primary integrator and design organization were defined, the remainder of the consortium could be formed. The suppliers of the various materials selected for the engine were, of course, key players in the project. In addition to TIMET Corporation, other materials manufacturing firms included Brush Wellman, Textron Specialty Materials, Howmet Corporation, McDonnell Douglas and Allied Signal Corporation. Since these firms were already involved in NASP materials development, support for the engine project was readily obtained. General Motors, Chrysler, and the National Institute for Standards and Technology (NIST) also contributed to the project in an advisory capacity ("The NASP: A Unique R&D Program Benefiting AFMC, DoD, and the United States, undated:18). In addition to providing materials and resources, all consortium members also had significant outreach activities to promote the project and attract additional contributors to the effort.

Callaway initiated preliminary design and computer modeling work in September, 1994 ("Computer Modeling Starts on NASP Engine, 1994:1). Other activities performed during this phase included development of the engineering database of the NASP materials, risk analysis, definition of engine system requirements, and predictions of engine performance. Exhaust system and cylinder gas analysis was also being performed by the Rockwell Science Center using advanced CFD modeling techniques (Kirkpatrick and others, 1995:35). This early development phase of the effort was anticipated to last six months (West and Mitchell, 1994:6).

Although interest and momentum in the project was high during the fall of 1994, the discouraging state of the NASP program began to affect its technology transfer efforts. Despite the high visibility and potential of the engine project, the dwindling NASP budget could not support the anticipated cost of nearly $2 million. The final cancellation of the NASP program was imminent, and the sponsorship role of the NASP could no longer be maintained.

In an effort to keep the demonstrator engine project alive, a funding arrangement was pursued between NASA Marshall Space Flight Center (MSFC) and the remaining consortium members. However, difficulties were encountered during the negotiations for this agreement, and the project was dropped by MSFC personnel in December, 1995.

NASA Langley Research Center then became interested in the project and proposed sponsoring it using a mechanism called the Aerospace Industry Technical Program (AITP). A proposal was submitted that would enable NASA to provide $3 million for the project, to be matched by funds provided by the industry participants ("NASP to the Highway," 1994:3, Kirkpatrick and others, 1995:52). Although the proposal was selected first out of all 56 projects submitted, the AITP funding program was terminated before any additional progress was made.

Perhaps most significant was the loss of sponsorship from the NASP program. The project had benefited greatly from the aggressive, pro-active efforts of the NASP

Technology Applications Branch. But without the support of this group, the engine project quickly lost momentum.

As of this writing, the NASP Technology Demonstrator Automobile Engine project is on hold. Texas Instruments is soliciting assistance from the automotive and petroleum industries to continue the project using corporate funding.

Discussion of Data.

Initiation of the Transfer. As described in earlier sections, the unique characteristics of Timetal®21S and the other advanced NASP materials made them attractive candidates for other applications. Several of the NASP reserve officers worked in the automotive industry, and suggested it as an prime area for prospecting efforts. The Texas Instruments project lead, Mr. Richard Delagi, was instrumental in initiating the demonstration engine project and soliciting needed support. His experience and industry contacts helped contribute to the success of the prospecting stage for this project.

The specific materials identified for use in the NASP engine were identified primarily by the feasibility studies and in the early stages of NASP as part of the Materials and Structures Augmentation Program (MASAP). Candidate materials were matched to the appropriate engine components based on the requirements of weight, strength, corrosion resistance, and elevated temperature performance. Texas Instruments was a key player in this activity.

Callaway Advanced Technology was chosen as an appropriate link between the technology developers and the technology users. Callaway was a technology developer himself, although he still maintained firm ties to the general automotive industry.

Callaway's notes that "technology is first proven in advanced vehicles such as race cars, but it must also apply to general automotive applications."

As with the other cases, the advanced materials technology was pushed into use in the demonstrator engine project. Given the relatively low use of advanced materials in current automobile engine design, there seems little motivation by the industry to "pull" high technology into use. However, this position would likely change if the engine project demonstrates the potential for financial benefits from the use of advanced materials in automotive applications. For the commercial firms involved, this could translate into increased business should the application of the technology succeed. It was also noted that the interviewee contradicts the finding of Edwards by stating that technology transfer is rarely motivated by market pull.

Transfer Strategy. The strategy for the project was initially defined in Rockwell's integrated master plan, and restated again in their Aerospace Industry Technical Program (AITP) proposal.. The strategy defined the IPD approach, identified potential participants, and established activities and schedules to guide the effort through the general phases of preliminary design, advanced design, fabrication, and test. Rockwell also defined this strategy in their Aerospace Industry Technical Program (AITP) proposal.

While not defined as such, the demonstrator project is a clear case of Shama's active transfer strategy. Distinct, pro-active efforts were accomplished to implement the NASP technology into a new application in the automotive industry. Had the project progressed to the successful demonstration of advanced aerospace materials for engine design, a more entrepreneurial strategy would have been implemented. This would result in the creation of many new automotive business ventures.

Transfer Process. The usual four stages of technology transfer were replaced here by four different phases as described in Rockwell's strategy: Requirements, design criteria definition and preliminary modeling, trade studies and advanced modeling, component design and fabrication, and assembly and system testing. It is noted that these stages occur primarily as development and trial activities, and that the prospecting stage has been bypassed. However, in actuality the accomplishments of the project so far dealt primarily with the prospecting and early development activities. Even though the primary integrator (Texas Instruments) and the primary designer (Callaway) were identified in the early stages, the prospecting function was still evident in the form of outreach activities performed by the primary consortium members to attract participants for other roles.

Transfer Elements/Mechanisms. Several of the transfer practices identified in the *NASP Integrated Plan* are again present in this case. The engine project was defined early on as a "demonstration project," and the development function would be the primary activity of the effort. The readily identifiable product of an automobile engine would have made a spectacular demonstration of NASP materials technology.

The pro-active transfer efforts of the transfer team was another key element in this case. From the summary of NASP techniques shown in Table 4, it is noted that passive outreach, cooperative agreements, joint funding actions and the all-encompassing open interactions were all evident during the engine project.

A recurring theme in the NASP demonstrator engine project is the significance of consistent, integrated team to facilitate the transfer process throughout the entire process. The presence of this team contributed to the early success of the project, and supports the NASP practice of organizational development as a key element of success. However, the lack of this integrated team contributed equally to the project failure in later stages.

As described in the overview section, a single project leader within the NASP Technology Applications Branch was noted as the most important of Creighton's formal transfer elements. The NASP project manager, in conjunction with the IPT leader, acted as a catalyst for accomplishing the key program activities, and served as an indispensable "go-between" for establishing and maintaining the relationships between the participants.

The transfer process was also complemented by the fact that the demonstrator engine effort was a specific, recognizable project on its own. This gave the project an "identity," which aided in the tracking process and helped it to gain support.

The transfer project was supported by the roles of the participants, as outlined in the *NASP Integrated Plan*. The NASP program office served in the usual sponsorship capacity, which has been shown to be crucial to success. The NASP reservists once again functioned successfully as information disseminators, and helped to form the key links between the NASP technology and the automotive industry. However, the engine project also showed the contractor participating more prominently in dissemination, sponsorship and development. The integrating function performed by Mr. Delagi and Texas Instruments spanned across nearly all of the defined roles, and contributed significantly to the accomplishments of the project so far. Unfortunately, the engine effort has not yet progressed to the point where a dedicated implementor is required.

Since Texas Instruments was serving as the primary project integrator, they were responsible for most of the project documentation. Information on the engine project was distributed regularly by program briefings, symposia, or journal articles.

All of Creighton's informal elements were also present. Foremost among them was the credibility of the parties involved. Delagi was a prominent figure in the materials field, and Callaway's reputation was highly regarded in the automotive industry. The involvement of both these individuals brought considerable credibility and prestige to the project. The significance of this activity is also highlighted in the *NASP Integrated Plan*. Similarly, the endorsement of Texas Instruments and Callaway Advanced Technology by a high-profile government program was also a motivating factor for Callaway and Delagi.

The interview showed that advisory groups, dissemination of information, and colloquia/published reports were the DOE methods most commonly used during the engine project. The advisory groups were very informal. The simple task of getting key participants together in the same room was noted as an important activity. Contractual agreements were generally not used to define responsibilities; they were used merely as a mechanism to transfer funds. And since the engine project was being used to generate publicity in the NASP program, briefings, speeches, reports and articles were used extensively.

Since the primary objective of this transfer case was the cooperative development of the automobile engine itself, the demonstration project as a collaborative R & D project was the most significant similarity with the DOC methods of technology transfer.

Climent's Conceptual Model. The complex nature of the engine project, along with the diverse participants involved, suggests the behavior of Climent's Inter-independent model transfer model. The forming of the consortium and the open interaction between the participants shows a relationship of information exchange rather than that of sender and receiver.

Technology Transfer Grid. Analysis of the Demonstrator Engine project shows how the assessment of project behavior using Smilor and Gibson's Technology Transfer Grid can change over the course of the effort. This effect is noted as a result of changes in the input factors over time.

The complexity of the technology in this case was moderately high, especially considering the limited use of titanium in the automotive industry. Producing the required quantities of advanced materials to support the high production rates of automobile manufacturers was also identified as a significant technical hurdle facing adoption of the technology. Communication was initially very effective among the project participants, and a very efficient working relationship evolved as the project progressed.

Some geographical differences hampered the transfer process, but no real cultural differences were initially present. This is surprising given that the project attempted to bridge the gap between the aerospace and automotive industries. This may have been due in part to the fact that Mr. Delagi was versed in both environments, and consequently was an appropriate integrator.

The project participants were initially highly motivated by the high potential for reward. Significant economic benefits to the commercial firms involved were possible if the demonstrator engine was a success. In addition, a successful project could also be used as a key selling point by the NASP sponsors to obtain support for the NASP program.

Referring to Figure 1, the combination of high technological equivocality, motivation and communication and moderate distance initially suggests an encouraging result on the Technology Transfer Grid. The moderate equivocality is opposed by the high level of communication that was present, which pushes the transfer towards the right of the grid. The high motivation and low distance combined so that the potential for success tended toward the upper quadrants. These initial inputs seemed to predict a "Grand Slam" for the Engine Demonstrator project.

However, the elimination of NASP sponsorship, and the resulting loss of the key integration function, significantly reduced the effectiveness of the communication among the participants. The lack of a clear project leader seemed to reduce the level of motivation for the project, especially on the side of the government. In addition, the later stages of the project showed indications of cultural differences between the contractors and the new NASA sponsors. All these later factors suggest that the transfer may end up being "Dead in the Water," which seems to be an accurate assessment of the current project status.

Transfer Success. Success of the NASP Technology Demonstrator Automobile Engine project will ultimately be achieved by the widespread adoption by the automotive industry of the advanced NASP materials. This final goal is directly dependent on fabricating and testing the actual engine. Even though this is not likely to occur in the near future, some benefits were still realized.

The point was proven that advanced technologies developed for the aerospace industry could be transferred to automotive applications. Specifically, automobile companies were made aware of the possible advantages of using titanium in engine manufacturing. An entirely new market of potential titanium users was created.

The relationship established between Texas Instruments and Callaway Advance Technology satisfied the Qualifying Condition of forming agreements between commercial non-NASP organizations. The working arrangement between these companies may benefit the automobile industry even without the involvement of NASP.

It should be noted that if the engine demonstrator project is completed, many more of the Qualifying Conditions defined in the *NASP Domestic Technology Transfer Integrated Plan* will be satisfied.

Lessons Learned. Several barriers to transfer were noted during this case. As described in the overview, the lack of a clear contractual mechanism frequently made it difficult to fund certain aspects of the project. This effect became even more evident as the project struggled to stay alive after the loss of NASP sponsorship. As with many projects of this nature, the lack of adequate funding was also a barrier to success.

Despite the potential benefits from the project and the enthusiasm from most of the participants, more commitment was needed from some members of the consortium. There was also an apparent lack of vision in the automotive industry, as there seemed to be a reluctance to consider potential benefits that may not be realized for several years. This was the case even if these benefits were shown to be significant.

Perhaps the greatest lesson learned from this technology transfer case was the need for government involvement throughout the entire transfer process. Without the dedicated resources and support from the NASP program office, the project lost momentum and has essentially stagnated. This example showed that the key activities of integration and sponsorship by a dedicated government organization are paramount to a successful technology transfer project.

Case Summary. The interview data from the NASP Technology Engine Demonstrator project revealed that this final case, like the others, did not specifically use the *NASP Technology Transfer Integrated Plan*. But as in the other examples, many activities that were accomplished through the course of this project supported the concepts outlined within the plan.

Once again, the core of the NASP transfer program was demonstrated through the use of a technology case development project. The completion of the engine would have been a clear example of a technology demonstration project.

The need for clear, consistent management of the transfer project was perhaps the most obvious in this case. The benefits of a defined project led by a specific team manager were demonstrated throughout the analysis. Even more evident were the disruptive effects of losing the consistent management team when the NASP support was lost.

The importance of project credibility was again demonstrated in this case. Without the influence of Callaway and Delagi, it seems likely that the engine project would not have enjoyed the successes that it did.

Despite the fact that the project did not advance to completion, the transfer was considered a success even though few of the NASP Qualifying Conditions were met. The significant point was that the project opened a new and potentially vast market for the application of aerospace technology in the automotive industry. Adoption of these new technologies by automotive corporations would obviously satisfy many more of the Qualifying Conditions as described in the Integrated Plan.

Should this occur, this project has the potential for satisfying the organizational transfer objectives of the NASP program in the most spectacular manner. Although the cost of the project so far has been relatively high, the return on investment from widespread adoption of the NASP technologies would be staggering in terms of the economic benefits to the auto industry and the nation as a whole. Assuming dramatic improvements in automotive engine weight and performance through the use of these materials, international competitiveness in automotive manufacture would surely be enhanced. Finally, the management of this large and complex project has resulted in dramatic improvements in the technology transfer process.

This case again shows that project success cannot necessarily be measured implicitly by the Qualifying Conditions described in the *Integrated Plan*. Bridging the gap between the aerospace and automotive industry can be considered an accomplished measure of success that supports the key organizational goals of the NASP program.

This final case also shows several similarities to the transfer concepts described in the literature. Nearly all of Creighton's formal and informal elements were present, and the analysis showed the use of several of the DOC and DOD transfer mechanisms.

The inconclusive result from the Transfer Grid once again demonstrates the limitations of using these types of models for prediction the behavior of qualitative interactions.

Nevertheless, the similarities to the literature noted during this transfer suggest that these documented components can be applied successfully in actual transfer situations.

Chapter Summary

By presenting a comprehensive analysis of the technology transfer efforts of the NASP program, this chapter addresses the primary objectives of this research. Through discussion of the *NASP Domestic Technology Transfer Integrated Plan*, the organizational approach and specific NASP transfer methods are described. Using data collected as outlined in Chapter III, a detailed analysis of four technology transfer examples show how transfer was accomplished, and examine how well the transfer supported the objectives of the NASP organization. In addition, the analysis of the data explores how well the transfer examples compared to the transfer concepts that were identified in the literature review found in Chapter 2. A summary of the key findings is presented here.

It is noted that the *NASP Technology Transfer Integrated Plan* was not used as a planning or reference document in any of the four cases analyzed. This included the project that was managed by the primary author of the plan. Follow-up interview questions showed that the plan was developed simply to prove that the NASP program *had* a plan, and was not necessarily intended as a formal guidance document. Despite this apparent inconsistency, it is found that each of the four transfer cases generally supported the transfer approach, methods, and objectives defined at the organizational level in the *Integrated Plan*. Each project attained varying levels of success in terms of accomplishing the defined success metrics or the specified overall objectives of the program.

This suggests that the *NASP Domestic Technology Transfer Integrated Plan* was not just a document, but was actually a reflection of the transfer culture within the NASP program. Even though the plan wasn't explicitly used, knowledge of its intent motivated the activities of the NASP personnel involved in technology transfer. This favorable transfer culture is supported not only by the similarities between the cases and the *Integrated Plan*, but also by the existence and dedicated transfer activities of the Technology Applications Branch as a whole.

When the transfer cases were analyzed in comparison to the literature and each other, several recurring themes and significant differences were noted.

First, it is noted that each of the transfers cases were initiated primarily by technology push. It is interesting to note, however, that once the project started, several of the projects showed the effects of market pull. This indicates that once a technology is initially pushed and its potential is demonstrated, then potential recipients frequently assisted in further transfer efforts.

This is supported by noting the negative effects resulting from the lack of market pull, as shown by the Demonstrator Engine project. Despite the potential for future benefits, the automobile industry seems resistant to change, and reluctant to incorporate new materials on a large scale. Driven by the need for immediate financial returns on investment, the industry was slow to accept the relatively long development cycle of the engine project. Because of this relative lack of support from the major automobile manufacturers, the engine project did not enjoy the significant benefits from market pull that were seen in the other cases.

This highlights a key point of the technology transfer process: that transfers are ultimately driven by the needs of the market. The analysis shows that government transfer efforts can only be effective to a point, beyond which the technology will be pulled if a genuine market need is identified. The cases demonstrate that making the industry aware of the new technology, and clearly demonstrating the potential of applying the technology in a new application, is then the fundamental purpose any government transfer program.

The cases also show the importance of a specific approach, supported by a formal planning tool, to manage the transfer. Although not always identified as a strategy, a detailed overview of the project goals and supporting activities was always evident. In three of the four cases, this was demonstrated as Shama's active strategy, where dedicated efforts are planned to disseminate technology into the marketplace, with the specific objectives of improving industry and enhancing the national economy.

Of the four cases, only the CFD Design Aid project showed the entrepreneurial strategy, characterized by new business ventures to market the CFD technologies. This is not surprising given the explicit commercialization goals of Rockwell. This strategy was also complemented by the increased management role of Rockwell in this project. In general, technology transfer programs managed solely by the government would not be overly concerned with new business ventures and the entrepreneurial strategy.

Although the NASP program office had overall control of the transfer projects, other individuals and organizations also had lead roles. It is interesting to note the different "character" that each project took on based on the varying management approaches of each. For example, the increased management role of Rockwell, and their use of IPT's, in the CFD and engine projects led to an increased emphasis on the commercialization and profit-making aspects of these transfers. Another example is the management of the launcher project by the support contractor, SAIC. As revealed in the interview, the non-government involvement of this entity tended to soften the restrictive environment that is often present in most government-managed projects.

A recurring theme found throughout the analysis is the significance of Creighton's formal element of managing transfer efforts through a specific transfer project, led by a single team leader. This concept was highlighted as one of the most significant factors in each of the four transfer cases. A single project governing the transfer of a specific technology gave the effort an "identity," and enabled the unique marketing of the project's potential. A single manager brought continuity to the program, and improved the efficiency of the process by providing a single management point of contact for all the participants. The structure and methods of the NASP Technology Applications Branch directly complement this key concept, and highlight the importance of developing a specific organization to accomplish technology transfer.

Of Creighton's informal elements, the linking of the technology source to the potential user was of utmost importance. The initiation of each of the projects was dependent, to some extent, on a fortuitous connection to a specific industry afforded through personnel involved in the NASP transfer program. While the NASP outreach activities were a direct effort to reach new markets, it was the unique link of individual contacts, demonstrated so dramatically by the military reservists, that actually precipitated the transfer projects.

This point highlights the need for a dedicated method to make connections to potential commercial users of government-developed technologies. The brilliant use of the reservists is shown by the case study as one method of ensuring diverse contacts to different industries. The significance of establishing these key relationships to the commercial sector cannot be overstated.

Establishing the credibility of the project and the participants was another of Creighton's informal elements that was noted as a significant contributor to the transfer process. The involvement of Dr. Charles and Reeves Callaway were indispensable in promoting the projects, and demonstrating that the efforts had the support of the industry. This contributed to the key function of proving the technology in the new application.

The case study shows the use of several of the DOC and DOE transfer mechanisms, the most significant of which overlap significantly. Research collaborations, technical assistance, demonstration projects, and collaborative R&D efforts are all phrases that can be interchangeably applied to characterize the NASP transfer projects. As described in detail in the preceding sections, each transfer example used a unique combination of the available mechanisms to support the transfer objectives of each project. The analysis shows that each situation dictates which methods will be most effective.

The complex interactions involved in the transfer process are demonstrated by the recurrence of Climent's Inter-Independent transfer model. The many participants in the projects, and the participatory relationships between them, support Climent's theory of an environment of exchange during the transfer process, rather than a situation of sender and receiver. Although Climent's models are complex and hard to quantify, their intent of explaining the complexities of technology transfer is recognized, and their applicability to the transfer process is demonstrated by the analysis of the cases.

While Smilor and Gibson's Technology Transfer Grid was noted as a somewhat simplistic method to quantify complex qualitative interactions, the analysis using the grid does show a relationship between the four factors of technical complexity, communication, distance and motivation. Based on varying levels of these inputs, a rough assessment of success for each transfer was made and found to compare relatively well to the actual behavior of each project. The analysis of the Demonstrator Engine effort also shows that the grid can be used to get varying results if applied at different times during the transfer process.

Analysis of these organizational components revealed a final recurring component that hampered the eventual success of all the transfer examples. As a direct result of the reduction and ultimate cancellation of the NASP program, focused management of the transfer projects by the Technology Applications Branch could not be provided through completion of the transfer effort. Without the consistent sponsorship of the NASP program throughout the life-cycle of the transfer, the true potential of the applied technologies could not be realized. While each project had significant accomplishments and was deemed a general success, none achieved the ultimate goal of full adoption in its new application. Regardless of Qualifying Conditions and organizational objectives, universal acceptance of the technology in its transferred environment is the only complete measure of transfer success.

The data collected, analyzed and discussed in this chapter forms the foundation for the conclusions and recommendations presented in Chapter V.

V. Conclusions and Recommendations

Introduction

This chapter presents the key findings of the case study of the transfer efforts of the NASP program. The conclusions not only summarize answers to the research objectives described in Chapter I, but also suggests how these specific results can be applied to technology transfer organizations as a whole. Additional questions resulting from the analysis serve as a basis for recommending areas for additional research. Finally, an overall summary of this research effort is provided.

Conclusions

The goal of this research was to provide answers to the specific investigative questions defined in Chapter I. To that end, the following discussion summarizes the conclusions that directly support the research objectives.

The literature review presented in Chapter II describes the prevalent approaches, mechanisms and processes for accomplishing technology transfer. Many similarities and recurring themes are noted, and many of the documented transfer elements supported, complemented, or served as a subset of other transfer components. Underlying themes are identified, suggesting that commonalties exist even among diverse transfer cases. The case studies described in the literature reveal many of these transfer elements at work in actual transfer examples, while also demonstrating unique characteristics of their own. The analysis of the NASP program was accomplished using this information as a guide.

The comprehensive discussion of the *NASP Domestic Technology Transfer Integrated Plan* provides a detailed overview of the NASP program's approach to technology transfer. In addition to defining the transfer objectives of the organization, the *Integrated Plan* describes the familiar four stages of the transfer process, and highlights the key components and practices that the organization has determined are best suited for effective technology transfer. Finally, several Qualifying Conditions provide a basis for assessing the success of the program's transfer efforts.

The *Integrated Plan* shows it has many similarities with the elements found in the literature. This suggests that the plan was well formulated, using many of the established and proven concepts that have been documented by other organizations.

Supported by the information from the literature and the Integrated Plan, the analysis of the specific transfer projects presents a detailed study of how the NASP program actually accomplished technology transfer.

Contrary to the findings of Edwards, and perhaps intuition, it is noted that all the transfer cases were initiated by technology push. This is undoubtedly due to the aggressive, pro-active transfer efforts of the NASP Technology Applications Branch. It is also interesting to note, however, that after the project had begun and the technology became known, that the market began to pull the technology through the process. This implies that many potential applications for transfer exist, but lack only the initial step to link the technology developer and user together.

The program documentation for the transfer cases usually revealed at least an attempt at defining a project strategy. General objectives were defined, and activities and milestones were planned to support them. Key players were identified, contacts were made, and responsibilities were generally assigned before the project progressed.

The process of transfer, while usually not specifically defined, generally followed the broad steps of prospecting, development, trial and adoption. Again, the dedicated efforts of the NASP transfer personnel suggest that transfer activities were specifically planned to support the objectives of the project. However, planned outreach activities, such as symposia and briefings, frequently resulted in unplanned, yet fortuitous contacts with personnel who ultimately proved valuable to the project. The specific background of many of the participants, particularly the reservists, also led to key relationships. This implies that, while the efforts of the NASP transfer team were specific and well thought out, serendipity frequently contributed to enhancing the technology transfer process.

The analysis of the technology projects shows the existence of many elements and mechanisms, as described in detail in Chapter IV. The recurring themes are highlighted again here. The significance of defining a unique transfer project managed by a single team leader is reinforced throughout the analysis. Establishing the credibility of the project, typically though the involvement of a well-known expert in the technology field, was also noted as a key component.

It is disappointing to note that none of the transfer projects used the NASP Integrated Plan as a planning document or reference source. This included the project that was managed by the primary author of the plan. It was apparent that the Integrated Plan was intended to satisfy a policy requirement for a formal document, not because a plan was actually needed to facilitate actual transfers.

Nevertheless, the analysis shows that most transfer activities support the intent of the *Integrated Plan*. Several key components were consistently identified throughout the transfer projects, and the several of the Qualifying Conditions described in the plan were met. This, in turn, resulted in the satisfaction of most of the general organizational transfer goals of the NASP program. This suggests that, even if the *Integrated Plan* isn't specifically used, the documentation of the concepts in the plan demonstrates that a favorable culture for technology transfer exists within the NASP program.

The detailed discussion presented in Chapter IV shows that each transfer case shared many similarities with the concepts described in the literature. In general, the analysis suggests that nearly all the documented components of technology transfer are applicable in actual transfer situations. Recurring themes and commonalties among the projects imply that current transfer examples generally support the prevalent approaches, mechanisms and processes that have been described by other organizations in the literature.

Supported by the *NASP Technology Transfer Integrated Plan* and the literature review, the results of the analysis described in Chapter IV suggest that the following specific findings can be generally applied to other technology transfer organizations:

1. Establish a top-level organizational strategy for technology transfer. Write a formal technology transfer document and use it to facilitate planning, and to establish a favorable culture for technology transfer within the organization.

2. Establish a single project to facilitate the transfer of each specified technology. This management approach will allow the specific definition of project objectives, and enhance the planning and tracking of the unique activities and accomplishments necessary to support the project goals.

3. Identify a single individual to manage each transfer project. This will lend continuity and efficiency to the effort by identifying a single point-of-contact to coordinate transfer activities and interface with external project participants.

4. Aggressive outreach efforts should emphasize pushing a technology into new applications. Seek out diverse industries. Once potential users are made aware of the technology, their pulling efforts will help the project through the transfer process. Transfer efforts should focus on demonstrating the technology in its new application.

5. Make the best use of personnel with backgrounds or experience that will enhance the transfer process. Encourage diversity of project participants. Recruit and utilize individuals with contacts in industries that could benefit from transferred technologies.

6. Project participants should be chosen to enhance the credibility of the transfer effort. Solicit well-known individuals or organizations that could hold a potential stake in a successful transfer.

7. Do not underestimate the informal elements of technology transfer. Effective communication is paramount to successful transfers. Participants, both the technology transferors and receivers, should be motivated by the potential for reward. Employ organizational techniques to enhance the complex interactions between individuals and organizations.

8. Make the most appropriate use of the transfer mechanisms available. Some methods work better than others in different situations.

9. Identify measures of transfer success. Without them, no one will know if the project has been successfully transferred or not.

10. If at all possible, plan technology projects with the intent of sustained, consistent management throughout the life cycle of the transfer. Address funding contingencies to maintain transfer projects even if resources are reduced.

Recommendations for Future Research

Despite the consistent findings decribed above, the case study of the NASP program has identified many additional questions regarding the technoogy transfer process. Thses issues suggest potential areas for futer research, as described below.

Measures of Transfer Success. This research raises the question of how to accurately measure elements of successful transfer. Although none of the four transfer projects reached the ultimate success of full adoption, each was still judged a success, to some extent, when compared to a set of "Qualifying Conditions" defined by the NASP program. A follow-on study could further examine this measurement aspect by exploring additional "conditions" that could be satisfied, or elements that could be quantified to assess the success of technology transfer projects.

Identifying Technology Recipients. This study has shown vaying methods of identifying potential recipients of govenment technology, and has highlighted the importance of establishing the credibility of transfer efforts by forming relationships with key participants. But the analysis also shows that these contacts were often made by chance and circumstance. Research should be conducted to determine more systematic methods of identifying potential recipients and establishing relationships with individuals and organizations that will enhance the transfer process.

The analysis of the NASP has shown the contributions made in this area by the NASP military reservists. Consequently, a particular aspect of this area of research could focus on the role of specific individuals within the transfer organizations tasked with the responsibility of making industrial contacts and establishing these key relationships with potential technology recipients. A dedicated study would further highlight this function, and allow a refinement of the techniques to enhance this process.

Explore Management Approaches for Technology Transfer Projects. The analysis also shows the use of several managerial arrangements for administrating and controlling technology transfer efforts. These include direct management by the program office, contracted management to a support organization, and the IPD technique as used by Rockwell. Additional reseach could further examine and compare each of these approaches, or identify and analyze other technology transfer management strategies that have been used for other programs.

Update Status of NASP Technology Transfers. As described in previous sections, each of the technology projects examined in this study were left in a questionable state after the loss of NASP sponsorship. Management of the projects has continued, to a lesser extent, through the industry organizations that were members of the original transfer team. A follow-on study would examine the status of the four NASP technologies, and would determine which, if any, projects have advanced to the adoption stage. A format similar to this thesis would trace the post-NASP chronology, and explore the approaches and mechanisms used by the commercial firms once government interaction ceases.

This general concept of government sponsorship could further be explored by examining the chronology and characteristics of other transfer projects that have continued after losing government support or sponsorship.

Thesis Summary

This research identified technology transfer as a significant activity of most government research and development organizations. Dissemination of technology from these organizations to commercial industry has been mandated through legislation and governmental policy.

It is appropriate, then, to examine the technology transfer efforts of a unique R&D organization within the government. The case study of the NASP program allowed a detailed investigation into how technology transfer is actually accomplished. Guided by the foundation of information from the literature review, the analysis highlighted the significant transfer elements and techniques of the NASP program, and demonstrated how these factors supported, and were supported by, the documented concepts. Based on the analysis, key findings were presented, and a list of recommendations was offered for use by other technology transfer organizations.

The results of this study also suggested areas for additional research. Possible follow-on studies would update the status of NASP technologies, examine the transfer program of another organization, and explore the concepts of transfer success and establishing relationships with potential recipients of government technology. These continued research efforts would in turn stimulate additional studies, which would further enhance the current understanding of the technology transfer process.

Appendix A - INTERVIEW QUESTIONS

Initiation of the Transfer

1. How was transfer initiated, and by whom?

2. a) How was the candidate technology identified, and by whom?

   b) What made the technology transferable, and who determined it as such?

3. a) How was the potential user identified?

   b) Who identified the potential user?

   c) How was the interface established?

4. What was the motivating force behind the transfer? Was the developed technology "pushed" into an suitable application, or was the technology developed and "pulled" into an application as a result of an existing need?

Transfer Strategy/Process

5. Was an overall transfer strategy developed for the transfer prior to its initiation?

6. Can you explain the strategy that was developed, if any?

7. a) Can you explain the process that was used?

   b) What specific actions were accomplished?

   c) What chronological events occurred?

Transfer Mechanisms/Elements

8. To what extent were the following formal elements present? Which of these elements contributed to the success of the transfer? Which was the most important?

   a) Specific individual identified to lead the transfer effort

   b) Specific project established to track the effort

   c) Documentation of the project

   d) Distribution of information

   e) Other elements that could be considered "formal"?

9. To what extent were the following elements present? Which of these elements contributed to the success of the transfer? Which was the most important?

   a) Link between the source of the technology and the user

   b) Capacity to transmit information

   c) Credibility of parties involved

   d) Willingness of the parties to communicate ideas

   e) Reward

   f) Other elements that could be considered "informal"?

10. To what extent were the following mechanisms used during the transfer?

a) Advisory groups

b) Research collaborations

c) Exchanges of personnel

d) Technical assistance

e) Licensing

f) Spin-off companies

g) Dissemination of information

h) Education

i) Colloquia/Published Reports

j) Consensus Development Efforts

k) Demonstration Projects

l) Comprehensive Centers

m) Information Clearinghouses

n) Personnel Exchanges/Field Agents

o) Computerized Information Systems

p) Library Services

q) Collaborative R & D Projects

r) Other mechanisms?

11. Which of these mechanisms contributed to the success or failure of the transfer? Which were the most important?

Technology Transfer Grid

12. How complex was the technology being transferred? How mature was the technology? How close was it to being an actual product?

13. How effective was the communication between the NASP transferring personnel and the organization receiving the technology? Was a constructive working relationship established? How did the relationship evolve?

14. What was the level of geographical or cultural differences between the NASP and the organization receiving the technology?

15. What were the anticipated rewards or incentives for successful transfer?

Transfer Success

15. Did any of the following "Qualifying Conditions" come as a result of the transfer? Where there others?

a) A qualitative improvement of an existing product or product line

b) The efficiency/effectiveness of a process is improved

c) An existing product becomes less expensive to manufacture

d) An existing product gains additional applications or different customers

e) The instance of production defects is reduced

f) An entirely new product line is enabled

g) A new industry is enabled

h) A new research methodology is enabled

i) Improvements in industrial/technological management are created/enabled

j) Any instance where new jobs are created

k) Any instance where existing jobs are saved

l) Any instance where technological awareness and skills in a workforce is upgraded or improved

m) Any instance of industry requests to enter into Cooperative R & D Agreements (CRDA's)

n) Any instance where NASP technology transfer initiatives encouraged patent application/awards

o) Any instance where a commercial NASP technology developer enters into an agreement with another non-NASP commercial agency

Lessons Learned

16. In this example, what barriers hindered the technology transfer process?

17. What could've been done differently to ensure greater success?

18. What lessons can be learned from this transfer?

Appendix B - RATIONALE FOR INTERVIEW QUESTIONS

Initiation of the Transfer. This section establishes the starting point for the transfer, and identifies why and by whom the transfer was conceived. Data collected will define the significance of the prospecting stage, and to what extent it was used.

1. This determines to what extent the prospecting function was accomplished, as described by Souder, and identifies how did the initiator fit into the personnel roles defined in the *NASP Tech Transfer Integrated Plan.*

2 and 3. This establishes the extent of the steps of "Identifying/Marketing Assets", as described by the AFMC Technology Transfer Handbook.

4. This question explores the concept of push versus pull, and identifies the underlying force behind the transfer, as discussed by Knight and von Rosen.

Transfer Strategy/Process. This section examines whether a dedicated plan was formulated in advance to facilitate the transfer, and compare this plan to established strategies. It will investigate the specific steps that were accomplished during the entire transfer process, and will again attempt to compare them to the processes identified in the literature. Although not directly supported by specific questioning, the analysis will include a discussion of how the transfer process for each NASP technology compares to Climent's conceptual models.

5 and 6. This question will determine whether the first step of the AFMC process (Develop Strategy) was accomplished, and to what extent. It will attempt to fit the strategy or approach into the four categories defined by Shama (Passive, Active, Entrepreneurial, and National Competitiveness). The analysis will examine how the development and implementation (or lack) of a comprehensive strategy can effect the success or failure of the transfer.

7. The data from this question will serve to develop a detailed chronology of the transfer, and examines what actions were taken that satisfied the other steps described by Souder and the *NASP Tech Transfer Integrated Plan* (Developing, Trial, Adoption). It also

determines to what extent the remaining steps in the AFMC approach (Identify Mechanism, Transfer Technology, Post-Transfer Administration) were accomplished.

Transfer Mechanisms/Elements. This section will identify the elements or factors that were present during the transfer, and examine which of these contributed to transfer success. Data obtained from the questions will enable the development of a detailed narrative of the specific methods that were utilized during the transfer process.

8. This series of questions examines the presence and significance of Creighton's formal elements during the transfer process.

9. This set of questions looks at the informal transfer elements. Great detail will be sought in this section, since it is the informal elements that often contribute greatly to the success of the transfer.

10. These questions will identify the use of any mechanisms documented by the Dept of Energy or the Dept of Commerce. Specific details will be obtained that describe what each mechanism entailed, to what extent it was used, and how it contributed to the transfer process. (Clarification of any elements or mechanisms will be made by the interviewer as required.)

Technology Transfer Grid. This section will collect information so that each NASP technology can be placed on Smilor and Gibson's Technology Transfer Grid. (pg. 12) Data will be obtained for each of the four factors, and the success of the actual transfer will be compared to the level of success predicted by the model. This section will also examine the details of the technology itself, which may be of use in other areas of the analysis.

11. These questions establish the level of technical equivocality of the technology.

12. Data obtained from this question will gauge the level of communication during the transfer.

13. This question identifies the distance between source and user of the technology.

14. This question determines the motivation of the parties involved.
(The above three questions will complement the data regarding Creighton's informal elements.)

Transfer Success. This section will examine how transfer success was measured. Transfer success will be judged if any of the "qualifications" listed in the *NASP Tech Transfer Integrated Plan* are satisfied. "Success" of the transfer, defined in these terms, will be analyzed in relation to the information obtained in the previous sections of the interview.

Lessons Learned. This section will be a guided, but somewhat "open ended" discussion to allow the interviewee to identify any barriers that were noted, to reflect on the overall success or failure of the transfer, or to provide any additional information that could be used to enhance the technology transfer process.

Bibliography

Air Force Materiel Command. "AFMC Technology Transfer Handbook." Unpublished report. Wright-Patterson AFB OH, 1991.

ASC/NA. "The NASP: A Unique R&D Program Benefiting AFMC, DOD, and the United States - A Background Book for Brigadier General Richard R. Paul." Unpublished briefing charts. Wright-Patterson AFB OH, undated.

ASC/NA. "The National Aero-Space Plane (NASP) Domestic Technology Transfer *Integrated Plan*." Unpublished report. Wright-Patterson AFB OH, May 1991.

ASC/NA. "The National Aero-Space Plane (NASP) Domestic Technology Transfer Program Technology Description Document." Unpublished report. Contract with Science Applications International Corporation (SAIC). Wright-Patterson AFB OH, October 1991.

ASC/NA. "NASP JPO Vision Statement." Unpublished memo. Wright-Patterson AFB OH, 15 January 1992.

ASC/NA. "NASP Technology Transfer Project Overview." Unpublished briefing charts. Wright-Patterson AFB OH, 1993.

ASC/NA. "National Aero-Space Plane (NASP) Advanced Technology Impacts: Final Report." Unpublished Report. Contract F33657-90-2195/DO 0009 with Science Applications International Corporation (SAIC). Wright-Patterson AFB OH, 31 March 1995.

Ashley, Steven. "Auto Engine to Use NASP Materials," Mechanical Engineering, 116/10: 18-20 (October 1994)

"Auto Engine Modeled Using Materials Developed for NASP," Advanced Materials and Processes, 146/5: 13 (November 1992).

Bryman, Alan. Research Methods and Organizational Studies. Winchester MA: Unwin Hyman Inc., 1989.

Chapman, Richard L. "The Federal Government and Technology Transfer - Implementing the 1986 Act: Signs of Progress," Technology Transfer: 5-13 (Winter 1989).

Climent, Juan B. "From Linearity to Holism in Technology Transfer Models," Technology Transfer: 75-85 (Summer-Fall 1993).

"Computer Modeling Starts on NASP Engine," Ward's Engine and Vehicle Technology Update, 20/18: 1-4 (15 September 1994)

Cooper, Adam. "Near Miss," Racer: 28-32 (August 1995).

Cooper, Donald R. and C. William Emory. Business Research Methods. Chicago: Richard D. Irwin Inc., 1995.

Creighton, J.W., J.A. Jolly, and T.A. Buckles. "The Manager's Role in Technology Transfer," Technology Transfer, 10: 65-81 (1981).

Dakin, Karl. "BodyShock: A Technology Transfer Case Study," Technology Transfer: 47-50 (August 1994).

Dane, Francis C. Research Methods. Pacific Grove CA: Brooks/Cole Publishing Company, 1990.

DeNardo, Adrian. "The National Aero-Space Plane Tech Transfer Triad: The Tomahawk Missile Case," 1991 SAE Aerospace Atlantic Conference and Exposition. Paper 911202. Dayton OH: SAE Technical Papers Series, 1991.

-----------. "Technology Transfer Mechanisms for the National Aero-Space Plane," 1994 SAE Aerospace Atlantic Conference and Exposition. Paper 941169. Dayton OH: SAE Technical Papers Series, 1994.

Deonigi, D.E. and others. "The Technology Transfer Process - Background for the National Energy Strategy," Proceedings Technology Transfer Society 15th Annual Meeting: 327-334 (June 1990).

Donofrio, Mark and Jennifer Mitchell. "Timetal®21SRx Orthopedic Implant Technology Commercialization Project Executive Summary." Unpublished Report. Wright-Patterson AFB OH, February 1995.

Edwards, Robert L. The Industrial Revitalization Forum Program: Successful Industry/University Cooperation," Technology Transfer: 43-46 (August 1994).

Friend, Tim. "Clinical Trials in U.S. Called 'Endangered,'" USA Today, 10 May 1995, sec. A:1.

Goodwin, Irwin. "In Its Rush to the Elections, Congress Skimps on Research," Physics Today: 75-78 (November 1992).

Harrison, Bennett. "Why Government Consortia?," Technology Review: 72-79 (January 1993).

Kasten, Terry D. Chief of Systems Applications, NASP JPO, Aeronautical Systems Center, Wright-Patterson AFB OH. Personal interview, 10 February 1995.

Kervin, John B. Methods for Business Research. New York: HarperCollins Publishers Inc., 1992.

Kirkpatrick, James R., and others. "Commercialization of NASP Computational Fluid Dynamics." Unpublished final report NA 95-02. Contract F33657-86-C2127 with Rockwell Aerospace, North American Aircraft (NAA). Wright-Patterson AFB OH, 1 May 1995.

Knight, Kenneth E. "Technology Transfer in the Petroleum Industry," Technology Transfer, 8: 27-34 (1984).

Lewis, Roger A. "U.S. Department of Energy Technology Transfer: Strategic Vision and Mission," Technology Transfer Society Proceedings, 19th: 109-117 (June 1994).

Miles, Matthew B. and A. Michael Huberman. Qualitative Data Analysis. Beverly Hills: Sage Publications, 1984.

Mitchell, Jennifer. "NASP Program Technology: An Example of Transfer Benefit for the Medical Industry and Spinback for the Government," Technology Transfer: 51-53 (December 1994).

"NASP to the Highway: Consortium Would Apply Spaceplane Materials to Making a Lightweight V-8 Automobile Engine," Performance Materials 10/5: 1-2 (28 November 1994).

O'Brien, Thomas C. and Lawrence M. Franks. "Evaluation Framework for Federal Technology Transfer Initiatives," Technology Transfer, 6: 73-85 (1981).

Palca, Joseph. "Increases in Federal Technological Cooperation," Science, 253: 872-879 (14 August 1992).

Roessner, J. David. "What Companies Want From the Federal Labs," Issues in Science and Technology: 36-42 (Fall 1993).

Romo, John G. and Alan Roecks. "Transferring Technology Into an Air Force Unit," Technology Transfer: 54-57 (Fall 1988).

Schmitt, N.W. and R.J. Klimoski. Understanding the Organization Through Qualitative Research. Cincinnati: Southwestern Publishing, 1991.

Scott, William B. "U.S. Labs Embrace Technology Transfer," Aviation Week and Space Technology, 139(8): 64-66 (23 August 1993).

Sefic, Walter J. "National Orbital Research Aircraft." Unpublished report. Wright-Patterson AFB OH, 1993.

Shama, Avraham. "Guns to Butter: Technology Transfer Strategies in the National Laboratories," Technology Transfer: 18-24 (Winter 1992).

Sharp, Timothy J. "Implementing Technology Transfer in the Air Force Materiel Command." Unpublished report. Wright-Patterson AFB OH, 1993.

Smilor, R.W. and D.V. Gibson. "Technology Transfer in Multi-Organizational Environments: The Case of R&D Consortia," IEEE Transactions on Engineering Management, 10: 3-13 (February 1991).

Souder, Wm. E., Ahmed S. Nashar, and Venkatesh Padmanabhan. "A Guide to the Best Technology Transfer Processes," Technology Transfer: 5-14 (Winter-Spring 1990).

Staten, Kenneth E., Program Manager for the National Aero-Space Plane Program. "Potential of National Aero-Space Plane," Address to the 39th Annual Airport Operators International Convention. Denver CO, 24 September 1986.

Teresco, John, and Tim Stevens. "NASP Could Change Auto Engines," Industry Week. 53 (7 November 1994)

von Rosen, Earnest. "University Technology Transfer: The 64 Kilobit Transceiver Case Study," Technology Transfer: 8-16 (April 1994).

West, William K. and Jennifer L. Mitchell. "National Aero-Space Plane Contributions to the Automobile Industry," 1994 SAE Aerospace Atlantic Conference and Exposition. Paper 941196. Dayton OH: SAE Technical Papers Series, 1994.

Wilson, John R. and Beverly J. Norris. "Knowledge Transfer: Scattered Sources to Skeptical Clients," Ergonomics, 36: 677-686 (June 1993).

Winebrake, James J. "A Study of Technology Transfer Mechanisms for Federally Funded R&D," Technology Transfer: 54-61 (Fall 1992).

Vita

Captain Brett Smith was born on June 19, 1962 in Minneapolis, Minnesota. After graduating from Jefferson High School in Bloomington, MN in 1980, he attended the Institute of Technology at the University of Minnesota. After joining active duty in 1984 in the Air Force College Senior Engineering (CSEP) program, Capt Smith graduated with a Bachelor of Aerospace Engineering and Mechanics degree in 1985. He was subsequently commissioned through the Air Force Officer Training School (OTS) at Lackland AFB, TX. His first tour of duty was as an aircraft structural engineer at the Ogden Air Logistics Center, Hill AFB, UT. After leaving Hill AFB in 1989, Capt Smith was assigned as a research engineer in the Flight Dynamics Laboratory at the Wright Research and Development Center (WRDC), Wright-Patterson AFB, OH. After serving a year in the labs, Capt Smith then moved to the National Aero-Space Plane (NASP) Joint Program Office (JPO) where he served as a test program manager. He then left the NASP JPO in May 1994 to pursue a degree in Systems Management at the AFIT School of Logistics and Acquisition Management. Following graduation in September 1995, Capt Smith will be assigned to the Space and Missile Center, Los Angeles AFB, California.

Permanent Address:
7300 Portland Ave S.
Richfield, MN 55423

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Due to reduced funding levels and increased pressure towards cooperation with industry, government research and development (R&D) organizations are becoming increasingly involved in the transfer of technology to the commercial sector. However, the process of technology transfer is complex, and transfer activities are being applied inconsistently across the Department of Defense.

This research explores the approaches, processes and mechanisms to accomplish technology transfer. A comprehensive literature review documents many of the transfer concepts that have been proposed or are currently in use. A detailed case study then examines the technology transfer efforts of an advanced government research organization: the National Aero-Space Plane (NASP) Program. Using personal interviews with key NASP personnel as primary data, unique examples of NASP technology transfer are examined to determine whether specific transfer activities support the overall transfer goals of the organization. The analysis further investigates the similarities between the NASP program and the elements documented in the literature, and highlights recurring elements and underlying themes.

The key findings of this research suggest recommendations that can be applied to enhance the transfer activities of any organization involved in technology transfer. Opportunities for additional research in this area are also offered.

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