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An Analysis of NASA Technology Transfer

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ABSTRACT

This study had two thrusts aimed at identifying areas of improvement for the federal laboratory technology transfer efforts.

One purpose of this study was to determine if federal laboratory researchers were prepared and/or interested in performing technology transfer to the private sector. Researchers at federal laboratories are typically promoted on the basis of publications. Recently federal legislation and federal agencies have called for a more active technology transfer role for federal laboratories. Most of the directives have established funding levels and policies have consequently resulted in the creation of organizational structures specifically established for the purpose of transferring federal laboratory's technologies to the private sector. Yet there has been little change in the role of the researchers. The aim of this study was to identify if a cultural barrier existed between the researchers and this new directive. Specifically, the researchers were surveyed to determine their attitude, awareness and perception toward technology transfer.

One hundred researchers at NASA Langley Research Center were surveyed to determine their attitude, awareness, and perceptions toward performing technology transfer. Prior to the survey, the survey instrument was refined through a focus group, a pilot study and a review by the Director

of the Technology Applications Group. The survey consisted of 19 questions aimed at assessing the researchers' awareness of the current technology transfer mechanisms and policies, their attitude toward the policies and their personal involvement, and their perception of the policies.

The second thrust of this research was to find appropriate metrics for technology transfer from federal laboratories to the private sector. Although many recommendations have been made regarding metrics, there have been few studies to verify those metrics. In this study, a new approach to identifying metrics was undertaken. Successful technology transfer cases were identified as those that satisfied previously defined successful outcome metrics (commercial sales, production savings, etc.). These cases were tracked backward through their history to identify the key critical elements that lead to success. The cases studies were constructed from interviews with principals and historical documents. The three cases represented a spectrum of economic impacts ($100M/Yr., $10M/Yr., $1M/Yr.).

The results of the survey showed that researchers were not prepared/educated to perform technology transfer and personally did not want to be responsible for it. The researchers were uninformed on the mechanisms for technology transfer. A negative relationship was found between researcher's attitudes toward performing technology transfer and increasing accountability and responsibility for technology transfer.

In the three case studies, four key critical elements were identified that contributed to success: champions (internal and external), early government funding of research, equivalent technology, and licensing. Of the four key elements, licensing is the only quantitative metric that can be used by the federal laboratory for intermediate measures. The other three key elements indicate areas in which future policies should be directed. Federal laboratories should concentrate on identifying external champions, developing and identifying internal champions, working with their technology transfer partners to bring technology to an appropriate level for transfer, and investing research funds in market-failure situations. Additionally, the concern is raised that there exists a chasm between the results of the survey and the case studies. The case studies indicate the need for internal championing while the survey results show a lack of interest in participation.

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CHAPTER I

INTRODUCTION

Background

The issue of technology transfer between federal laboratories and the private sector has become a focus for public and congressional debate. In times of increased global economic competition, there is increased legislative and public interest to better utilize the US taxpayer investment in government research. In support of the surrounding debates, many studies have been performed to evaluate the economic impact of technology transfer from the government to the private sector and often commissions and reports have put forward recommendations for improved technology transfer implementation. Within the few quantitative studies performed (Bozeman and Papadakis 1995; Roessner 1993; Chapman et al. 1986; Mathematica 1976) there is indication that the benefits of technology transfer make it worthwhile. Yet there remain ample opportunities for improvement in the cooperative efforts between federal laboratories and the private sector.

One of the most prominent Federal agencies involved in technology transfer is the National Aeronautics and Space Administration (NASA). This agency includes 10 field centers located throughout the United States. NASA, long viewed as a leader in technology transfer, fared only average in terms of royalties when compared with US universities' technology transfer efforts (See Chapter II, analysis of NASA data). A startling finding is that the entire NASA system received $162,000 in royalties based on 27 licenses in 1993, while in that same year, 81 universities had more in royalties and 32 universities had more licenses than NASA (AUTM 1994). More revealing is that NASA's average revenue per licenses generating revenue in that same year was one order of magnitude *less than universities and Canadian institutes* and two orders of magnitudes *less than US hospitals & research institutes and patent management firms*, as surveyed. These comparisons may be unfair, since most universities and patent management firms are multi-disciplinary and, along with hospitals and research institutes see licensing as an important part of their mission. NASA has a narrower focus, with a primary mission toward the aerospace community that limits the scope of commercialization. In addition, revenue generation is not a thrust of Federal agencies like NASA. Still, there appears to be adequate opportunity to create a culture at federal laboratories, or more specifically NASA, more responsive to technology transfer issues.

This dissertation study does not attempt to add to the wealth of preexisting economic impact or policy studies linking the government with the private sector or add to the already extensive debate on the benefits of technology transfer. Rather, it addresses the *role of the federal laboratory researcher* as a key component in the process, and attempts to find *useful* *metrics to help guide federal laboratories policies* toward technology transfer. In order to find useful metrics, a proposal is made to find those practices that are common to successful transfers through a reverse engineering process. The process is to select an economically successful technology transfer and backtrack the procedures through the adopting company, the technology transfer agent, and the researcher to find the key elements that contribute to the economic success. In addition, federal laboratory researchers are surveyed to identify the awareness and attitudes that compose the culture of technology transfer in federal laboratories. The results of the culture survey and the metrics study will be compared to search for overlaps and disconnects.

Most existing studies addressing the improvement of the technology transfer process from federal government to the private sector focus on the needs of the end customer, private industry. It is natural and necessary to focus on the customer. Yet there has been little attention or recognition given to measuring the culture internal to the federal laboratories to support technology transfer (Technology Transfer, Barriers Limit Royalty Sharing's Effectiveness 1992). There have been many studies performed to identify the appropriate organization and procedures for technology transfer, but these refer to those professionals working in support of technology transfer and not the researchers (Bagur and Guissinger 1988; Brockman 1986; Greenberg 1995; Horsham 1992; Lionberger and Guin 1991; Mock et al. 1993; Mogavero and

Shane 1982; Palmintera 1993; Reck 1994; Rose 1990; Shama 1992; Souder et al. 1990).

US federal laboratories and the scientific and technical community have, since the end of WW II, been operating under a reward system based almost entirely on the peer-reviewed publication (Shapley and Roy 1985; Raymond 1966). However, it is commonly recognized that technology transfer occurs best through *active* communication methods and not the passive approaches characteristic of publications and their uses. As a measure of technology transfer, publications are weak and inefficient (Schulte-Hillen et al. 1976). Even as a measure of scientific work, bibliometrics have many pitfalls and shortcomings (Melkers 1990). Now there is a call by both private industry (Industry as a Customer of the Federal Laboratories 1992) and the Congress for federal laboratories to become more active in technology transfer. Researchers operating under the existing paradigm of "publish or no promotion" have little to no reason to support technology transfer efforts. Although recent legislation (e.g., Stevenson-Wydler Act 1980; Federal Technology Transfer and Commercialization Act 1986) has allowed for improved monetary rewards through royalties and performance evaluations, little has changed in the system. A recent Government Accounting Office (GAO) study found that the monetary rewards attached with royalties are usually not significant enough to change behavior (Technology Transfer, Barriers Limit Royalty Sharing's Effectiveness 1992). The study found that there was no improvement in the invention rate at 14 of 21 federal agencies after the introduction of the Federal Technology Transfer Act's revenue sharing legislation. Real improvement of six of the remaining seven of the other agencies was not necessarily due to the legislation, but was attributed to the effects of scientific, legal, or other legislation on patenting activity that preceded or coincided with the Federal Technology Transfer Act rather than to the implementation of royalty sharing.

Within this same GAO study, comments from a focus group of federal scientists were collected to help define their culture. The scientists believed in obtaining patents for reasons other than obtaining financial results, valued peer recognition of research achievements, and were wary of any restriction or delay in publishing or discussing research results with peers such as reporting inventions. Scientists also believed that collaboration on research between federal and private-sector scientists is difficult because of incompatibilities in the two groups' research objectives and time frames to achieve results. Another GAO report (Diffusing Innovations: Implementing the Technology Transfer Act of 1986 1991) found that less than 40% of the Laboratory Directors were aware of the legislation that supports the use of performance evaluations for researchers. Another survey of federal technology managers shows that 44% believe the current reward and incentive system needs to be changed, while 9% disagree and 47% are neutral (Lesko & Irish 1995). Improved communications between government laboratories and the private sector will require that a technology transfer culture be instilled into the laboratory researchers.

A number of studies have identified metrics for technology transfer (Spann, Adams and Souder 1993; Creedon et al. 1992). Most metrics studies categorize the metrics according to phases of the transfer process (Figure 1.1).

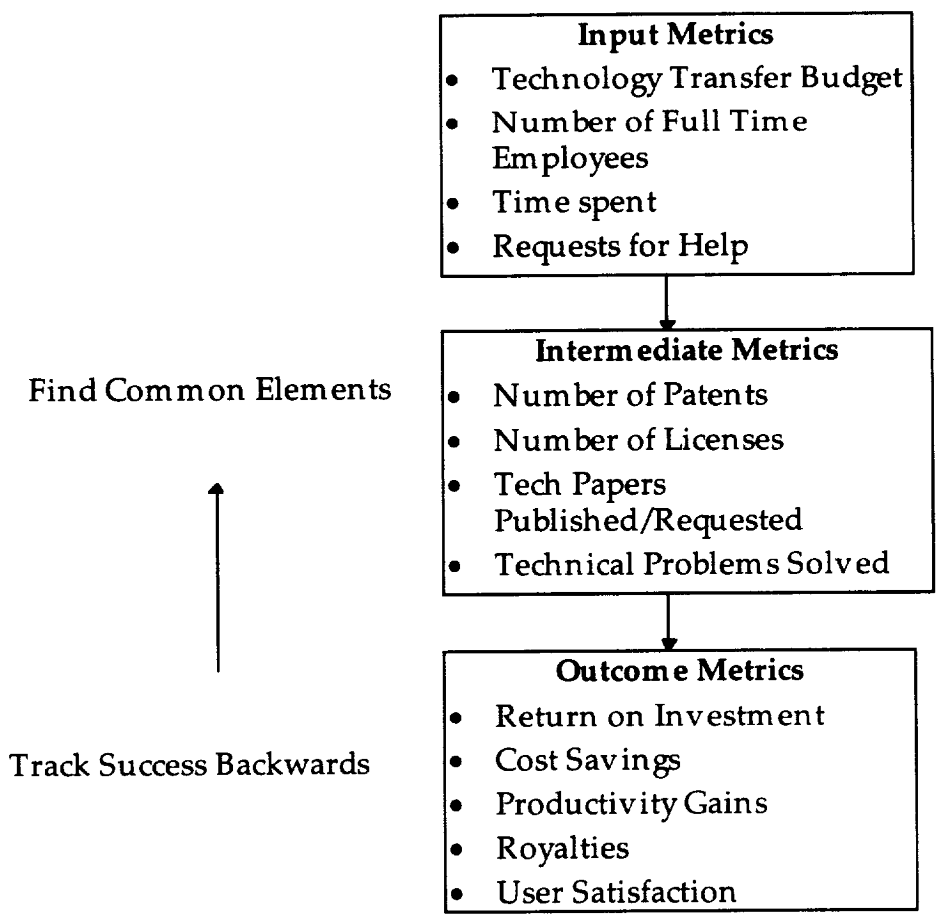


Figure 1.1: Categories of Technology Transfer Metrics

These studies, in general, divide metrics into three categories including: *input*, *intermediate*, and *outcome*. The input and intermediate metrics may be easily obtained but do not necessarily correlate with the outcome metrics, which are the true measures of success (economic impacts). However, the outcome metrics are difficult to obtain and nearly impossible to utilize as a guiding measure, since the temporal attributes are out of proportion to the actions occurring within the input and intermediate frames. As a result of these issues, federal agencies have had difficulty in measuring the level of achievement of their investment in technology transfer.

Descriptive Title of Project

Analysis of Technology Transfer at NASA.

Statement of the Problem

This research sets out to identify metrics for effective technology transfer and to measure the contemporary attitude, awareness, and perceptions of federal laboratory researchers with respect to technology transfer. Specifically, the research:

(a) identifies the common, key critical elements that contribute to an economically successful technology transfer from a federal laboratory to the commercial sector.

(b) investigates the current culture (attitudes, awareness, and perceptions) of the researchers of one Federal laboratory (NASA Langley Research Center) with respect to technology transfer, to determine if its culture is consistent with current legislation and management expectations.

One of the two primary purposes of this research is to determine those activities that contribute to successful technology transfer and to identify appropriate metrics for evaluating technology transfer activities. The other primary purpose is to determine the attitude, awareness, and perceptions of federal laboratory researchers toward the technology transfer process.

Hypotheses

This research combines both quantitative and qualitative approaches. The qualitative approach will be used in studying and analyzing successful technology transfer metrics case studies and in assessing open-ended questions contained in the researcher culture survey questions. Open ended questions and cultural issues are expected to lead to other, as yet undefined hypotheses or conclusions. As a starting point, the basic hypotheses are posed below.

$H(1)_{null.}$ Technology transfer as a component of the performance plan and performance appraisal was widespread at NASA Langley Research Center. H(1) Technology transfer as a component of the performance plan and performance appraisal was minimal at NASA Langley Research Center.

$H(2)_{null}$ Researchers at NASA Langley Research Center are aware of the technology transfer policies of the agency and the Center. H(2) Researchers at NASA Langley Research Center are not aware of technology transfer policies of the agency and the Center.

$H(3)_{null}$ Researchers at NASA Langley Research Center are aware of the technology transfer points of contact and technology transfer mechanisms. H(3) Researchers at NASA Langley Research Center are minimally aware of the technology transfer points of contact and technology transfer mechanisms.

$H(4)_{null}$ Researchers at NASA Langley Research Center want to be responsible or accountable for technology transfer.

H(4) Researchers at NASA Langley Research Center do not want to be responsible or accountable for technology transfer.

$H(5)_{null}$ Researcher awareness of technology transfer is not linked to educational level.

H(5) Researcher awareness of technology transfer is linked to educational level.

$H(6)_{null}$ Researcher perceptions about technology transfer is not linked to their educational level.

H(6) Researcher perceptions about technology transfer is linked to their educational level.

$H(7)_{null}$ Researcher attitudes about technology transfer are not linked to their educational level.

H(7) Researcher attitudes about technology transfer are linked to their educational level.

$H(8)_{null}$ Researcher awareness about technology transfer is not linked to age.

H(8) Researcher awareness about technology transfer is linked to age.

$H(9)_{null}$ Researcher attitudes about technology transfer is not linked to age.

H(9) Researcher attitudes about technology transfer is linked to age.

$H(10)_{null}$ Researcher perceptions about technology transfer is not linked to age.

H(10) Researcher perceptions about technology transfer is linked to age.

$H(11)_{null}$ Success in technology transfer activities is not dependent upon individuals who take responsibility for the process and act as champions. (The presence of a "champion" in the technology transfer process does not supersede other quantitative elements in terms of success.)

H(11) Success in technology transfer activities is dependent upon individuals who take responsibility for the process and act as champions. (The presence of a "champion" in the technology transfer process supersedes other quantitative elements in terms of success.)

H(12)$_{null}$ Successful technology transfer activities (i.e., positive economic impacts) are not linked with input metrics ($ spent, etc.) and intermediate metrics (activities).

H(12) Successful technology transfer activities (i.e., positive economic impacts) are linked with input metrics ($ spent, etc.) and intermediate metrics (activities) through some as yet unidentified common elements.

Definition of Terms

AUTM: Association of University Technology Managers

Champion: An individual who takes a leadership role in commandeering a project to fruition in spite of the bureaucratic, organizational, technical, financial, and other hurdles.

Culture: Awareness, attitudes, and perceptions of researchers toward technology transfer.

Division: Second highest organizational structure at NASA Langley Research Center

FTE: Full time employees

GAO: Government Accounting Office

Group: Highest organizational structure at NASA Langley Research Center

LGR: Licenses generating revenue

Metrics: Measures of technology transfer success

- Input Metrics: Elements that represent inputs into the technology transfer process such as budgets, expenditures, and expended time.
- Intermediate Metrics: Elements that represent activities such as technical papers published and licenses granted.
- Outcome Metrics: Sometimes referred to as long-term metrics, these represent the true goals of technology transfer such as, productivity gains, cost savings and competitive advantage gains.

NASA: National Aeronautics and Space Administration

NASA Langley Research Center: A NASA research center located in Hampton, Virginia with approximately 2,300 civil servants with a focus on aeronautics, atmospherics, materials, sensor, space and systems research.

R&D: research and development

Researcher: Individual classified as performing research (science, engineering) by the Human Resources Division at NASA Langley Research Center.

Royalties: Funds collected by the holder of a patent from the licensee of the patent for the exclusive or non-exclusive use of the patent.

Technology Transfer: The active participation by NASA to transfer research results to private industry and universities via formal or informal cooperative partnerships with the intention of improving (the) economy and quality of life. Although we practice technology transfer with our traditional customers in aerospace, for this study we are interested only in non-aerospace technology transfer.

CHAPTER II

REVIEW OF LITERATURE

The study of technology transfer from federal laboratories to the private sector is a broad subject comprising a massive amount of information. The review of literature is divided into four sections in an effort to simplify and organize the relevant studies of information. Some of the studies are mentioned more than once since it may address different sections. The four sections are: (1) technology transfer culture, (2) measures of technology transfer, (3) analysis of NASA technology transfer data, and (4) analysis of AUTM technology transfer data. In addition, there is an addendum to the review of literature entitled "Historical Perspective of Technology Transfer Policy and Culture Within the US" (Appendix B.1).

Sections (1) and (2) constitute a direct correlation to the hypotheses posed in this dissertation. Sections (3) and (4) constitute supporting data to the hypotheses. The appendix serves to establish the broad perspective and background on which technology transfer is based.

(1) Technology Transfer Culture

For an organization to be effective at a prescribed mission or goal, it must have an appropriate capability and support culture. In this section, the culture to support technology transfer is reviewed. In particular, the culture of interest is that of the researchers at the federal laboratories. Federal laboratory researchers have operated under much the same guidelines and principles since World War II. After World War II, researchers' activities and reward systems came to closely resemble those of academics, with the exception of the teaching aspect. Publications have become the predominant and primary measurement tool for rewards and promotions. Researchers attain funding for research with the end goal being a publication. Under this model, a culture was created in which researchers became disassociated from the practical or economic relevance of their own creations. The goal for researchers was no longer development of a socially useful product, but the satisfying of a publication requirement.

Today, however, researchers are being challenged to readjust their culture to fit new expectations. Among these new expectations, federal laboratories are being asked to justify their research funding and show its relevance to the private sector. The shift in public and legislative thinking towards issues of global economic competition is forcing a new paradigm on the laboratories and, therefore, on the researchers.

The collapse of the cold war translated into a strategic change from guns to butter for federal laboratories. According to Shama, the emphasis moved from matching the Soviets in weapons strength to doing economic battle with Germany and Japan (Shama 1992). This change brought about fundamental philosophical changes in the mission, objectives, strategy, culture, skill mix, structure, and leadership at federal laboratories. These changes are challenging the current culture of the researchers at federal laboratories, and can be summarized as in Table 2.1.

Table 2.1: Technology Transfer Strategy Shifts in National Laboratories in Recent Years (Shama 1992)

Area of Change	From	To
Mission	Physical Security	Economic Security
Objectives	Produce physical deterrents	Produce economic growth
Strategy	Guns R&D	Butter R&D
Culture	Closed, rigid, DOE-oriented	Open, flexible, customer oriented
Skill Mix	Science and engineering	Science, engineering & business
Structure	Top-down	Top-down, bottom-up
Leadership	Scientific	Managerial, entrepreneurial

Legislation

The relatively recent shift in legislative focus on technology transfer is reflected in recent legislation drafted by Congress. In 1980, the Stevenson-Wydler Act became law (P.L. 96-480). The spirit of the law is captured in the following excerpt:

> It is the continuing responsibility of the Federal government to ensure the full use of the results of the nation's Federal investment in research and development. To this end the Federal government shall strive where appropriate to transfer Federally owned or originated technology to state and local governments and to the private sector. (Technology Innovation 1994, page 29)

The Stevenson-Wydler Act, the first of several acts aimed at technology innovation, called for and required an active role in technical cooperation by the federal laboratories. Section 3710 (a) of the Stevenson-Wydler Act further specified the role of federal laboratory managers and researchers:

> Technology transfer, consistent with mission responsibilities, is a responsibility of each laboratory science and engineering professional and that: Each laboratory director shall ensure that efforts to transfer technology are considered positively in laboratory job description, employee promotion policies, and evaluation of the job performance of scientists and engineers in the laboratory. (Technology Innovation 1994, page 30)

A new reward system for the researchers and royalty distributions were also addressed in the Stevenson-Wydler Act. Section 3710b required the head of each Federal agency making expenditures at a rate of more than $50,000,000 per fiscal year for research and development to propose and implement a cash awards program for exemplary technology transfer and commercialization activities. Section 3710c required that at least fifteen percent (15%) of royalties be paid to federal laboratory inventors with royalties not to exceed $100,000 in one calendar year (P.L. 96-480, Bagur and Guissinger 1988). Although the mandate is clear, the legislation had only a minimal impact on the federal laboratory rewards and promotions system and did little to change the culture of the researchers.

The Federal Technology Transfer Act of 1986 (P.L. 99-502) took an even stronger stance than the Stevenson-Wydler Act. The Federal Technology Transfer Act was specific in regards to the responsibility of federal laboratory managers and researchers. The Federal Technology Transfer Act included the following mandates:

- Made technology transfer a responsibility of all federal laboratory scientists and engineers.
- Mandated that technology transfer responsibility be considered in laboratory employee performance evaluations.
- Established principle of royalty sharing for federal inventors (15% minimum) and set up a reward system for other innovators.
- Provided specific requirements, incentives and authorities for the federal laboratories.

The executive branch also supported this change in technology transfer. In the addendum to the National Performance Review led by Vice-President Gore, the NASA Accompanying Report included two key recommendations regarding technology transfer (Gore 1993):

1. NASA field centers should provide technology transfer training for all its employees
2. NASA should devote ten percent (10%) to twenty percent (20%) of its budget to R&D partnerships with industry

In fact, Executive Order 12591 signed by President Bush had already directly addressed the lack of activity in technology transfer. The order acted to ensure that federal agencies and laboratories assist universities and the private sector in broadening the US technology base by transferring new knowledge from the research labs into the development of new products and processes (Codification of Presidential Proclamations and Executive Orders 1989).

Recent Measurements of Cultural Change

A study by the GAO in 1992 found that there was no improvement in the invention rate at 14 of 21 federal agencies after the introduction of the Federal Technology Transfer Act's revenue sharing legislation (Technology Transfer, Barriers Limit Royalty Sharing's Effectiveness 1992). Real improvement with six of the remaining seven agencies was not necessarily due to the legislation, but was attributed to the effects of scientific, legal, or other legislation on patenting activity that preceded or coincided with the Federal Technology Transfer Act and not to the implementation of royalty sharing.

Through the same GAO study, comments from a focus group of federal scientists helped define a culture that believes in obtaining patents for reasons other than obtaining financial results. Researchers were found to value peer recognition of research achievements, and were wary of any restriction or delay in publishing or discussing research results with peers. This wariness included concern over invention reporting. Further, scientists believed that collaboration on research between federal and private-sector scientists is difficult because of incompatibilities in the two groups' research objectives and time frames to achieve results.

In a study of 297 federal laboratories only forty-four percent (44%) of the directors were authorized by their parent agency to negotiate Cooperate Research and Development Agreements (CRADAs) and only about fifty percent (50%) had royalty sharing programs. This study came nine years after the enactment of the Stevenson-Wydler Act and three years after the Federal Technology Transfer Act (Diffusing Innovations: Implementing the Technology Transfer Act of 1986 1991).

Studies to date indicate that the Stevenson-Wydler Act and the Federal Technology Transfer Act have not been implemented on a wide scale by the federal agencies or their laboratories. A sample of technology transfer culture at federal laboratories studies and outcomes of those studies follows.

Studies of Technology Transfer Culture

The following studies include some perspectives on the culture present among the researchers or in the organizations at federal laboratories.

Bozeman Study

In a 1991 survey of federal laboratory directors, Bozeman found that the perceived benefit of technology transfer back to scientists or the laboratory was very minimal (Bozeman 1991).

Chapman Research Group Study

Interviews of NASA researchers uncovered a general attitude toward technology transfer as not being a career advancing tool. Although most researchers saw technology transfer as the right thing to do, a common comment was "transfer activities will not get anyone promoted" (Chapman Research Group 1991).

Denver Research Institute Study

Chapman, Hirst, and Bayton (1986) reported on scientists and researchers who serve as either principal investigators (internal R&D) or technical monitors (oversight of external R&D) on new technology development programs. Approximately seventy percent (70%) of the principal investigators responded yes to the following question: "Is technology transfer part of your job?" Of those that answered no, forty-four percent (44%) said there was no opportunity or inapplicable due to nature of work; thirty-one percent (31%) said it was not in their job description; and the remaining twenty-five percent (25%) considered publications, presentations, and fallout from regular tasks to be adequate.

The results of the study show that researchers believe the *agency* emphasizes technology transfer greater than the *work units*. Reasons given for little or no emphasis in the work unit included:

- forty-three percent (43%) said it was due to the nature of the work;
- thirty percent (30%) said technology transfer was not encouraged, was de-emphasized, had a low priority, had to be done on one's own time, or management was resistant; and
- twenty-seven percent (27%) said there was little or no knowledge of the system.

Researchers were asked: "What would prevent you from taking a very active role in technology transfer activities?" Answers cited most often were lack of time, followed by lack of management support, and lack of incentive or personal interest.

Creedon, Abbot, Ault, et al. Study

This NASA team recommended that each NASA field center should provide technology transfer training for all employees and assess, promote and reward employees according to metrics/contributions (Creedon et al. 1992).

Doctors Study

Doctors found that entrepreneurial activity, mobility of technical personnel and social networks seemed to be superior mechanisms for horizontal transfer as opposed to the NASA orientation towards dissemination of printed material (Doctors 1971).

Gibson and Smilor Study

This study suggests that four variables are central to technology transfer processes within and between organizations. The four variables are: (a) communication interactivity, (b) cultural and geographical distance, (c) technology equivocality, and (d) personal motivation. A survey using Likert scales was completed by 147 respondents at the Microelectronics and Computer Technology Consortium. One of the four hypotheses developed and supported by the results of this study was:

> Successful product/process application is more likely to occur when research and user organizations support and reward those involved in the transfer process (Gibson and Smilor 1991).

Kengor Study

Kengor identifies impediments in NASA's technology transfer process as bureaucratic delays in information flows, difficulty in responding to industry's technical queries, and poor employee incentives. The emphasis in of this study was the poor incentives for researchers to spend time on technology transfer (Kengor 1994).

(2) Measures of Technology Transfer

In the 1990s, technology transfer from federal laboratories to the private sector has became a popular issue. Perceived economic threat from other nation-states and a feeling of reduced economic welfare have caused a re-examination of our federal laboratory system. Technology transfer, as a field of study, benefited from this renewed interest. Policy analysts and researchers attempted to measure the most effective methods for achieving economic success. Studies by analysts and researchers resulted in a wealth of reports that, in most part, were inconclusive in their search for the measures of effectiveness. Most analysts, while being unable to identify effective measures, identified what despite differences in naming conventions, can generally be placed into the three categories as in Table 2.1. Through the compartmentalization of measures into these categories, a better understanding of the technology transfer issue arises.

Short-term measures, or measures of input, are exemplified by resources expended to perform technology transfer (money invested, number

Three Categories of
Technology Transfer Metrics

1. Input or Short-term
2. Intermediate or Activities
3. Outcome or Long-term

Figure 2.1: Three Categories of Technology Transfer Metrics

of personnel, human-years, etc.). Intermediate term, or measures of activity, are exemplified by the quantity of activity performed through utilization of the resources (e.g., number of patent disclosures, number of licenses, number of cooperative agreements). Long-term measures or outcomes are exemplified by the positive outcomes of the activities (e.g., royalties, profits, return on investment).

Technology transfer between federal laboratories and the private sector for economic strengthening is a relatively recent phenomenon, being traced back to the early 1950s and the science interest of that time. Science and technology were touted as solutions to many societal ills and the "spin-off" idea was born. More recently, in the 1980s, global economic competition with other nation-states in high technology fields brought the field of technology transfer to the forefront of Congressional debates and public concern.

Recent interest in technology transfer has led to academic studies of the phenomenon and an attempt to measure the effectiveness of technology transfer. Quantitative studies have been limited, not only by the relatively recent interest, but also by the nature of the subject. Technology commercialization typically has a long life cycle and, therefore, the measurement of technology cooperation is complicated. Time from laboratory to market is estimated to take, on average, seven to 20 years or more (Mansfield 1971). Many of the quantitative studies to date have concentrated on more short-term, measurable issues in an attempt to draw some conclusions.

The technology transfer studies presented and discussed here are outlined in two sections. The first examines those measurements and categories of measurements that have been identified and recommended for technology transfer; the second reviews those measurements that have been made and draws from them for some conclusions on technology transfer metrics.

Metrics Definitions

There have been a myriad of studies attempting to identify the measurement standard or categories of measurements. Most studies have similar findings in terms of measurement standards or categories, with perhaps just a change in semantics.

Spann, Adams, and Souder Study

Spann and her colleagues created standards and categories as displayed in Table 2.2 (Spann et al. 1993). Spann's categorization is presented first, since it serves as a good framework for discussion of other definitions. Spann's model contains three categories, including input measures, intermediate outcomes, and long-term outcomes. The input measures are characterized by resources and expenditures. The intermediate outcomes are characterized by activities. The long-term outcomes are characterized by results.

Bozeman Study

Bozeman categorized effectiveness into "out-the-door" measures and "market impact" measures (Bozeman 1991). Out-the-door measures are symbolized by the number of licenses, while market impact measures are symbolized by the commercial impact, the pecuniary benefit back to the laboratory, and the benefit to the researchers and scientists. Bozeman's out-the-door category is analogous with Spann's intermediate outcomes and his market impact is analogous with Spann's long-term outcomes (Table 2.3).

Table 2.2: Technology Transfer Measurement Standards and Categories

Input Measures

- Transfer Expenditures
- Transfer Budgets
- Time Spent
- Requests for Help
- Number of Site Visits

Immediate Outcomes

- Tech Briefs/Papers Published
- Tech Briefs/Papers Requested
- Technical Presentations
- Technical Problems Solved
- Licenses Granted
- Success Stories Published

Long-Term Outcomes

- ROI
- Cost Savings
- Productivity Gains
- Royalties
- Competitive Advantage Gains
- Market Share Gains
- New Commercial Sales
- Number of New Products
- New Commercial Customers
- User Satisfaction
- New Business Started
- Jobs Created

Bozeman and Coker Study

Bozeman and Coker postulated that future studies should include an opportunities cost model (Bozeman and Coker 1991). This model recognizes that money diverted to one technology transfer effort reduces the resources of another effort.

Table 2.3: Comparison of Bozeman and Spann Technology Transfer Metric Models

Bozeman	Spann
___________	Input Measures
Out-the-Door Model	Intermediate Outcomes
Market-Impact Model	Long-Term Outcomes

Carr Study, Part 2

Carr analyzes the three technology transfer models created by Sandelin, including the legal model, the administrative model, and the marketing model (Carr, Part 2, 1992). Most of the leading technology transfer universities utilize some variant of the marketing model, and Carr believes that the low transfer rates of federal laboratories can be attributed to a lack of understanding and utilization of the marketing model. The marketing model actively markets technologies available for licensing, with the objective of finding an appropriate licensee and concluding a license agreement expeditiously. In the marketing model, entrepreneurial staffs have experience in marketing as well as in specific technology areas. Offices employing the marketing model do not usually employ formal advertising of available technologies in order to limit curious inquiries and conserve staff time for the most promising prospects.

Carr points out that commercial successes may depend on a combination of factors, of which the transfer of federal technology is only one. Also, technology transfer measurements/evaluations are often carried out to justify existing federal research programs.

Carr categorizes quantitative metrics into four models: the out-the-door model, the market-impact model, the political model, and the opportunity-cost model. Carr has added one model to those also suggested by Bozeman. Characteristics of the four models are contained in Table 2.4.

Again, these models can easily be correlated with Spann's (Table 2.5). The Political Model corresponds to the input measures; the out-the-door model corresponds with the intermediate outcomes; and the market-impact model corresponds with the long-term outcomes. The opportunity-cost model is a new addition and offers a more realistic monetary accounting for long-term outcomes.

Table 2.4: Carr's Technology Transfer Measurement Standards and Models

Out-the-Door Model
Standard: Licenses, Cooperative Research and Development Agreements (CRADA's), etc.
Advantage: Ease
Disadvantage: Quality and magnitude of event counted is masked

Market Impact Model
Standard: Royalty income
Advantage: Gets directly to the heart of matter, economic impact
Disadvantage: Royalties tend to lag by many years from licensing

Political Model
Standard: Ability to spend authorized funding and bureaucratic successes
Advantage: Measures are short term
Disadvantage: No relationship to the real goals

Opportunity-Cost Model
Standard: compares results with other opportunities for the money
Advantage: Can compare competing technology transfer programs
Disadvantage: No measure towards end goal

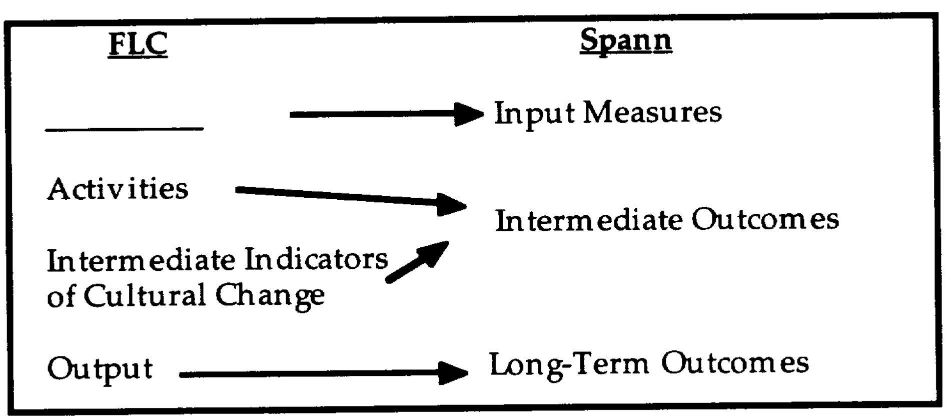
Table 2.5: Comparison of Carr and Spann Technology Transfer Metric Models

Carr		Spann
Political Model	→	Input Measures
Out-the-Door Model	→	Intermediate Outcomes
Market-Impact Model	→	Long-Term Outcomes
Opportunity-Cost Model	→	Long-Term Outcomes

Federal Laboratory Consortium Study

A study by the Federal Laboratory Consortium (FLC) suggests that measures should be placed in three categories including: (a) output, (b) activities and (c) intermediate indicators of cultural change (Technology Transfer in a Time of Transition 1994). The output and activities measures match well with the long-term outcomes and intermediate outcomes respectively (Table 2.6). The intermediate indicators of cultural change are characterized by measures such as the percentage of a researchers time spent on technology transfer. This corresponds well with the input measures of the Spann model.

Table 2.6: Comparison of FLC and Spann Technology Transfer Metric Models



NASA Langley Research Center Study

A Quality Action Team at NASA Langley Research Center selected five measures for success after studying the technology transfer measurement issue (Technology Transfer Metrics, Final Report 1995). The five measurements included:

- number of new patent license agreements
- income generated from patent royalties and software sales
- number of inquiries resulting from marketing and information dissemination
- estimated degree of industry participation in cooperative activities (formal and informal)
- number of documented uses of NASA Langley Research Center funded technologies by the partners

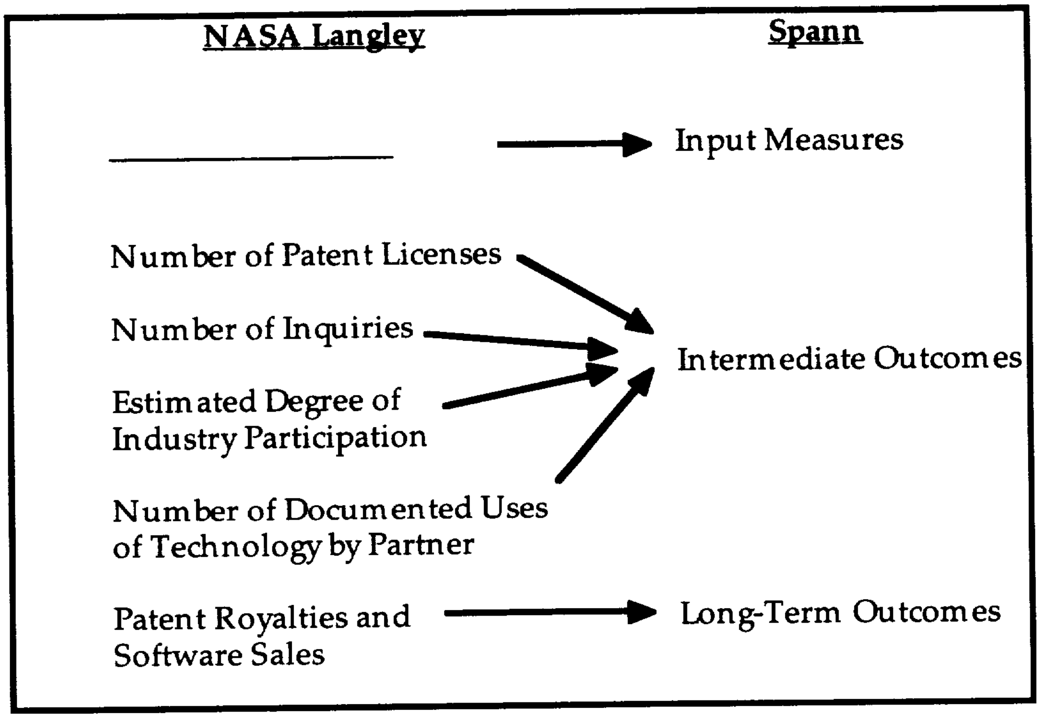
Four of these measures can be considered to fall within the intermediate category of Spann as activity related (Table 2.7). While only one of the measurements can be placed in the long-term category.

NASA Institutional Team Study

In a 1992 report to the NASA Administrator, the NASA Institutional Team on Technology Transfer recommended that technology transfer metrics for primary targeted customers include six factors:

- proportion of program endorsed by the customer
- length of time from development to use
- number of citations

Table 2.7: Comparison of NASA Langley and Spann Technology Transfer Metric Models



- number of acknowledged uses
- number of spin-off companies
- revenue from patent licenses

The Team also created five metrics for secondary technology transfer:

- number of secondary targeted application negotiations
- number of successfully completed activities as evidenced by a joint paper, joint patent, or process improvement initiated
- dollars reimbursed by recipient
- acknowledged benefit of consultation, and
- revenue from patent licenses

The Team believed that a marketing model for technology transfer has greater potential for success; that technology transfer is inseparable from the technology development process; and that effectiveness metrics are better than activity metrics. With about half of the metrics characterized as long-term outcomes and half as intermediate outcomes, this team was aggressive in its recommendations to NASA. The Team recommended that each NASA Field Center should provide technology transfer training for all employees and assess, promote and reward employees according to metrics/contributions.

Council on Competitiveness Study

The Council on Competitiveness, a nonprofit, nonpartisan organization of chief executives from business, and representatives from higher education and organized labor, made a strong recommendation that industry and government work together to develop meaningful technology transfer metrics (Industry as a Customer of the Federal Laboratories 1992). In the Councils report, "Industry as a Customer of the Federal Laboratories," one of the nine recommendations clearly states:

> Industry and the Federal labs should jointly establish metrics to determine how well the technology transfer process is working and review progress after 3-5 years. If insufficient progress has been made, both industry and the labs should reevaluate their involvement, and funds should be redirected to consortia, universities, non-profit research groups and other organizations that can work more effectively with industry for results.

Spann, Adams, and Souder Study

In the Spann study, adopters, developers and sponsors of technology transfer were surveyed. A disconnect was found between each partner's measure of success (Spann, Adams, and Souder 1993). This discrepancy made overall success difficult, as each partner had different goals and agendas. Spann found that *developers* were interested in new commercial sales, technical briefs and papers published. In contrast, the *adopters* were interested in productivity gains, competitive advantage gains, and number of new products. The *sponsors* of technology transfer were interested in the number of technical problems solved and the number of new products. The difference between the developers and adopters raised the greatest concern.

Developers were interested in market-impact numbers such as new commercial sales, while the adopters may not necessarily want or need new sales to improve profits (Table 2.8). The adopters typically had interest in improved productivity and competitive advantages.

Roessner Study

Roessner's survey found that private industry had the most interest in long-term, intangible aspects of technology transfer, such as laboratory visits, technical consultation, workshops, seminars, and cooperative agreements, in that order (Roessner 1993). Roessner sampled chief technical officers (CTO)

Table 2.8: Comparison of Measures of Success for Adopters and Developers in Technology Transfer Efforts

Developers		Adopters
Technical Briefs and Papers Published	≠	Productivity Gains
Commercial Sales		Competitive Advantage Gains
		Number of New Products

and laboratory directors of the private industry, to determine what forms collaboration should take, what expectations are realistic, and what metrics should be used. A subset of 68 members of the Industrial Research Institute (IRI) members was surveyed. The IRI, with 270 members, accounts for 85% of the industrial R&D in the US.

The CTOs and research directors ranked external sources of technology transfer in terms of significance to their company (Table 2.9).

The dominant positive influence a CTO or division director had for interacting with a federal laboratory was "access to unique technical resources." Expectations of commercial payoff had only a slightly positive influence.

Table 2.9: Significance Ratings of Technology Transfer Sources by US CTOs

External Source	Significance
Other US Companies Universities	Significant
Foreign Companies Databases	Moderate Significance
Federal Laboratories Government Databases	Somewhat Significant

Approximately 43% of the respondents said their labs had interacted "rarely" or "not at all" with federal laboratories. Informal interactions such as information dissemination, lab visits, seminars, and technical consultation occurred most frequently. Technology licensing and employee exchange were the least frequent means of cooperation.

Those respondents who reported at least "moderate" levels of interaction with federal labs ranked ten types of interactions in terms of "overall value to the division or lab." Contract research received the most first-place votes, by far. Licensing and employee exchange ranked very low. When asked what form of payoff occurred most frequently, responses fell into three broad categories: profit potential or business opportunity, the leveraging of R&D and sharing the risks of research, and access to expertise and new knowledge.

Roessner concludes that companies tend to interact with federal labs for reasons that have far more to do with long-term, less tangible payoffs than with expectations of short-term business opportunities or technology commercialization (Roessner 1993).

Roessner feels that Federal labs should make it a priority to ensure industry has intimate knowledge of the labs expertise, facility capabilities, and research portfolios. Roessner also feels that interactions between companies and laboratories should emphasize idea transfer rather than technology transfer (Roessner 1993).

Roessner believes that number of licenses and royalty payments will substantially underestimate the value of the federal lab and intermediate outcomes are more appropriate measures. The intermediate outcomes could include the number of technical papers authored jointly with industry, company patents and invention disclosures directly attributable to collaborative work, new development projects at companies that can be attributed directly to interactions with federal labs, and technical problems solved as a result of information obtained from the lab (Roessner 1993).

Doctors; Melkers; Schulte-Hillen, et al. Studies

Several studies have examined the use of publications as a means of technology transfer and found it to be an inadequate measure for technology transfer success (Doctors 1971; Melkers 1990; Schulte-Hillen et al. 1976). The distribution of publications fits into the category of input measure in the Spann model.

Carr Study, Part 1

Carr believes that quantitative measures do not capture a true picture of technology transfer and he suggests the use of qualitative measures such as:

- surveys of technology recipients
- collections of testimonials and positive anecdotal data
- case studies of spectacular successes

Carr thinks it unlikely that any magical formula for technology transfer evaluation will be uncovered (Carr, Part 1, 1992).

The discrepancy between the agendas of the technology transfer partners and a need by federal agencies to measure their performance, typically leads to poor measures.

> Signing of R&D agreements and transfers of intellectual property are among the few elements of technology transfer that lend themselves to measurement, thus they tend to be measured. Though they may be seen as the engine of technology transfer, personal contacts are the lubricant that allow the engine to run. Furthermore, nonpatented

> know-how, ideas, and suggestions often constitute information of considerable value, however difficult it is to measure and evaluate this sort of technology transfer (Carr, Part 1, p. 9, 1992).

Metric Definition Conclusions

Most of the studies of technology transfer metrics have identified three basic categories of measures:

1. Input/Expenditure/Resources
2. Intermediate/Activities/Cultural Changes
3. Outcomes/Long-Term/Economic Impacts

Each category has been recognized as distinct from the others, and no attempt has been made to find the connection between them. It is also clear that the partners in a technology transfer each have a different preferred measure depending on their particular position (e.g., transferor, transferee, etc.). If federal agencies have a goal of demonstrating economic impact and private sector relevance, it would make sense for them to be more interested in attaining success in the outcome category. Yet it is recognized by most of the studies that outcome measures are difficult to collect and even more difficult to utilize as a guiding tool due to their temporal aspect.

The solution to this dilemma, as is stated in the Introduction Chapter, is to try and link the outcome, intermediate and input measures through case studies of successful technology transfers.

Technology Transfer Metrics Studies

In the community of technology transfer practitioners in the US there is an upswelling of voices calling for metrics, debating the merits of each metric, and a general sense of urgency regarding metrics of technology transfer. There have been many studies lamenting the lack of metrics, proclaiming the importance of metrics, and suggesting effective metrics. Ironically, there have been few studies that include actual measurements utilizing the metrics. These studies are reviewed here, along with the conclusions derived from their results.

Bozeman Study

Bozeman performed a survey of 189 federal laboratory directors in order to evaluate laboratory effectiveness in technology transfer (Bozeman 1991). Bozeman found that laboratories, on average, report 6.28% of their budget as technology transfer expenditures with a standard deviation of 11.48%. The perceived benefit back to researchers or the laboratory was very minimal. Most importantly, the evaluation of market impact by laboratory directors is questionable. A more accurate measurement would be gleaned from the estimate performed by the recipients or customers of the technology transfer. The perception of technology transfer as a minimal benefit to researchers is an important finding in Bozeman's study since researchers play a key or critical role in the technology transfer process. With little or no incentive, researchers are likely to be unwilling participants.

Bozeman and Papadakis

Another study performed a few years later by Bozeman and Papadakis focused on the recipients of the technology transfer (Bozeman and Papadakis 1995). Bozeman and Papadakis performed a survey of directors and administrative heads of 219 firms that had cooperative experiences with federal laboratories. The total number of federal government laboratories cited was 27. Similar to Roessner's study, the Bozeman and Papadakis findings pointed to access to expertise, as opposed to job creation, as a key objective of companies. The decision to work with laboratories related to the skills and knowledge of laboratories scientists and researchers. Sixty-one percent (61%) of respondents cited this as the number one objective. The number two objective, to establish strategic pre-commercial research, was cited by fifty-one percent (51%) of respondents. The third ranked objective, cited by forty-five percent (45%) of the respondents, was access to unique resources of laboratory. Prior experience in cooperation with a lab and the desire to develop new products or services were equally ranked fourth by study respondents.

Vast differences in the outcomes of the cooperative efforts were found. Approximately 49% of the cooperative efforts resulted in some net positive benefits, 18% resulted in a zero net benefit, and 33% resulted in net costs. The average net benefit was found to be $1,087,500. Without looking at the entire data set, this value is a bit misleading since a few largely successful ventures skewed the results.

The Bozeman and Papadakis study also supports the idea that small, new, aggressive firms are more likely to create new products. In their study those companies that had already developed products as a result of the cooperation had three general characteristics:

1. The companies were smaller than average for all companies in the database (12,000 vs. 25,000).
2. The companies had high levels of R&D intensity as measured by R&D employees as percentage of all employees.
3. The companies were established more recently (average 27 years vs. 45 years for all other firms).

With more than ninety percent (90%) of the projects not resulting in a single new hire, job creation was the single criterion by which the laboratory-industry interactions were not considered particularly successful.

Another revealing finding in the report came from dissatisfied companies. Those companies that reported they were dissatisfied with the cooperative effort were more likely to have purchased a license, to have reduced personnel as a result of the interaction, and to have failed to market a product.

Mathematica Study

Expert opinion was used to determine the proportion of NASA R&D responsible for commercial success of four selected technologies (Mathematica 1976). It was assumed that the innovation stream would have occurred regardless of NASA participation, but that participation had an impact in accelerating the process. The four technologies involved were

- cryogenic multilayer insulation materials,
- integrated circuits,
- gas turbines in electric power generation, and
- computer programs for structural analysis (NASTRAN).

The savings calculated in the study are shown in Table 2.10.

Table 2.10: Estimated Acceleration and Benefits Attributed to NASA Participation (Mathematica 1976)

Technology	**Interval of benefits estimate**	**Estimated probable NASA acceleration (years)**	**Probable benefits attributed to NASA (millions)**
Gas Turbines	1969-1982	1.0	$111
Cryogenics	1960-1983	5.0	$1054
Integrated Circuits	1963-1982	2.0	$5080
NASTRAN	1971-1984	4.0	$701
Total			$6946

A total of $7 Billion in savings to the private industry were attributed to the technology development and transfer efforts of NASA. These numbers are significant since the NASA budget was approximately half this figure at the time of the study.

Tilton Study

Between 1962 and 1968 sales figures indicated that, at a minimum, federal space and defense funding subsidized the development and production of the integrated circuit until it became affordable for the private industry (Tilton 1971, Hook 1990). In 1962, 100% of the integrated circuit market was attributed to Defense and Space, the cost per circuit was $50 and the total market was $4M (Table 2.11). A short six years later, the price of the circuits had dropped by a factor of 20 times, the market had increased by a

Table 2.11: US Integrated Circuit Production and Prices and Importance of the Space and Defense Market, 1962-68 (Tilton 1971, Hook 1990)

Year	Total Production (millions of dollars)	Average price per integrated circuit (dollars)	Defense & Space Production (% of total production)
1962	4	50.00	100
1963	16	31.60	94
1964	41	18.50	85
1965	79	8.33	72
1966	148	5.05	53
1967	228	3.32	43
1968	312	2.33	37

factor of 78 and the private industry was able to start buying the integrated circuits (63% of the market).

Bozeman and Coker Study

One hundred fifty federal laboratory directors were surveyed. The results suggested that multi-faceted, multi-mission laboratories are likely to enjoy the most success in technology transfer, especially if they have low levels of bureaucratization, and either ties to industry or a commercial orientation in the selection of projects (Bozeman and Coker 1991).

Bozeman and Crow Study

An environmental dependence model of technology transfer activity was presented in this study. The model suggested that the influence of political authority was a major determinant of technology transfer activity. Results were based on a survey of 900 laboratories, focusing on a sub-sample of 134 government laboratories and 139 university laboratories. Findings included:

- Laboratories with larger total budgets and larger numbers of scientific personnel are more likely to be engaged in technology transfer.
- Laboratories with a more diverse mission are more likely to be engaged in technology transfer.

Wyden Study

The total royalties from technology transfer patent licenses of the 700 US federal laboratories was calculated in the Wyden study to be less than $4 million (Wyden 1990).

Chapman, Lohman and Chapman Study

Chapman et al. studied the benefits resulting from the application of those technologies that have been highlighted in the NASA magazine *Spinoffs* (259 cases) (Chapman, Lohman and Chapman 1989). Through extensive telephone interviews, a cadre of case studies was developed. Sixteen avenues of technology transfer from NASA to other sectors were identified with seven major categories:

- The direct use of NASA technology
- NASA helps to "make a market"
- NASA testing or use speeds commercialization
- Assistance through NASA-sponsored Industrial Applications Centers
- The spinoff of NASA employees
- Spinoff to other public agencies, and
- Spinoff from regular NASA activity

Four hundred forty-one (441) Spinoff cases were identified in the study. Three hundred sixty-eight of the 441 spinoff cases were acknowledged as having sales or savings, but only 259 could be accounted for. These 259 cases resulted in an estimated $21,331,190,000 in sales and $315,749,000 in savings for an average benefit of ~$84,000,000 per case.

Interviews revealed 67 instances in which a process, product or company would not have come into existence had it not been for NASA-furnished technology. These 67 instances represented 15% of all the spinoff cases.

The number of new jobs created was estimated by using the economic impact for each Standard Industrial Classification (SIC) code sector and other survey data as multipliers, as shown below. This analysis for was performed for all appropriate SIC codes and the study concluded 352,694 new jobs.

New Jobs = [revenues* x (payroll/business receipts)*]/current average wage**

*from 1985 County Business Patterns, US Summary
**from Employment and Earnings, First Quarter 1986 derived as the annual average pay by SIC code for the annualized weekly earnings

Wessel Study

Wessel collated R&D spending figures, numbers of patents, and patent royalty figures for NASA and its Field Centers from 1981 to 1990. The Centers were compared by numbers of patents, royalties per R&D dollars and average cost per patent and other similar measures. This approach was one of the few that gave rather undebatable quantifiable data on technology transfer, yet would not likely be utilized as a metric by the agency since the results do not include the qualitative issues and are discouraging. Table 2.12 shows that the average cost for each patent, as measured by the number of patents divided by the total R&D budget, is relatively large. The averages are compared for NASA's three research centers: Langley Research Center (LaRC), Lewis Research Center (LeRC), and Ames Research Center (ARC).

Table 2.12: NASA R&D Centers' Cost Effectiveness Summary for Fiscal Years 1981-1990 (Wessel 1993)

Center	Annual avg cost ($M)/disclosure	Annual avg cost ($M)/application	Annual avg cost ($M)/patent
LaRC	1.40	4.72	6.46
LeRC	3.25	22.55	29.55
ARC	4.61	26.44	21.62

The total amount of royalties paid to NASA for its licenses in the period of 1981 to 1990 was $651,000. Extrapolating that figure out to account for the real impact on the private industry (royalties are typically about 5% of the sales) results in $13M in sales.

Wessel closed by suggesting was that laboratories establish goals and recommended measuring contributions by using a quotient of royalty per R&D budget (Wessel 1993).

Johnston and Kokus Study

Johnston and Kokus calculated positive returns as a benefit to cost ratio in their study of NASA technology transfer returns. They conducted interviews and cost estimates to construct the costs and net benefits of a technology transfer. The benefits stemming from technology transfer effort were discounted by 10% as a method of accounting for lost opportunities. Results indicated a 6:1 payback for technology transfer efforts (Table 2.13).

Table 2.13: Benefits Stemming from NASA Technology Transfer (Johnston and Kokus 1977)

Program element	**Costs ($M)**	**Net Benefits ($M)**	**Benefit/Cost Ratio**
Publication program	10.9	135.6-151.8	12:1 to 14:1
Industrial Application Centers	17.0	44.4 - 52.2	2.5:1 to 3:1
COSMIC	1.7	43.5	26:1
Application program	32.3	133.6	4:1
Total	61.9	357.1 - 381.1	5.8:1 to 6.2:1

The Marshall Space Flight Center Technology Transfer Office

Surveys were mailed to 809 of NASA MSFC's 1241 Industrial Assistance Program partners and 283 questionnaires were returned. Surveys were mailed to 18 of their 56 Space Act Agreement partners and 16 responses were received (Technology Transfer Metrics, NASA , The Marshall Space

Flight Center Technology Transfer Office, September, 1994). Although a high percentage of those who responded agreed that the cooperation was helpful and they would welcome assistance again, the results may be misleading due to nonresponse bias. A nonresponse rate of 61% combined with a non-random sample brings serious concern to the extrapolation of the results to the sample population.

Utilizing a Department of Commerce economic model and the collected data, MSFC determined that a $358M impact on society, 182 new products and 5344 jobs were created as a result of their technology transfer efforts. This translates into 6.5 jobs per cooperative interaction. This is based on a $6M investment by the Technology Transfer Office. MSFC is thus quoting a 60:1 ($358M/$60M) payback from its technology.

These results are questionable since the jobs may not have actually been "new." One can only account for new jobs when they are not merely a replacement of existing ones. Additionally, saved jobs do not necessarily translate into multiplied efforts.

In a follow-on study at MSFC of economic impact, Table 2.14 was generated. Table 2.14 contains both the direct responses and the US economic benefit or impact based on multipliers of the direct responses. This data represents the economic impacts for 1994.

Table 2.14: Economic Impacts due to NASA Marshall Space Flight Center's Technology Transfer Efforts ("Technology Transfer Metrics," NASA , The Marshall Space Flight Center Technology Transfer Office, May 22, 1995)

Category	**Direct Reported Responses**	**US Economic Benefit/Impact (after mult. and/or extrapolation)**
Jobs	1,032	8,300 **7,400** 6,400
Products	118	**304**
Investment Savings Sales *Total*	$43,062,000 $35,343,000 $106,653,000 *$185,000,000*	***$654,000,000***

In addition to the sampling issues of this study, there is some question as to the validity of the multiplying factors.

The Southeast Alliance Study

The Southeast Alliance, composed of a few educational institutions, a regional technology transfer center and NASA Marshall Space Flight Center as its lead, mailed surveys to 1343 of their 2320 Industrial Assistance Program partners with 508 questionnaires returned. In addition, surveys were mailed to 18 of their 80 Space Act Agreement partners and 18 responses were returned. This study was an update of the information from the Marshall Space Flight Center study and has the same nonresponse bias flaw as that study (Technology Transfer Metrics, NASA , The Southeast Alliance, March, 1995).

Technology Transfer Metric Studies Conclusions

Most technology transfer metric studies have focused on identifying metrics, yet none have attempted to determine analytically those metrics which contribute to success as defined by economic impact. Studies that have gathered measures have either relied on the input or intermediate level measures, or have extrapolated from gathered data to achieve the long-term or outcome data. The input and intermediate measures prove little in terms of economic (long-term) success, while most studies claiming to have long-term measures are questionable due to their assumptions and extrapolations. Those few studies that have credible long-term measures *reveal nothing about how the success was achieved, only that it was achieved.*

The difficulty in creating effective measurements for technology transfer are lamented in Griliches' study of R&D and productivity (Griliches 1988). Griliches feels that economists may be seriously underestimating the true contribution of R&D to economic welfare by trying to measure its effects on standard productivity indexes. As an example, he considers the and brokerage houses, and jet engines:

> The fact that one can travel from the east to the west coast in less than half the time it took two decades ago leaves hardly a trace in the national productivity accounts. (Griliches p. 18, 1988)

Both quantitative and qualitative studies have been touted as methods for technology transfer measurements. The quantitative measures receive more credibility, but are very difficult to achieve with the temporal aspect of technology transfer. This difficulty may account for the relative lack of quantitative studies. The qualitative studies, while rich in information, are criticized as being anecdotal and non-significant.

Perhaps the best approach is not to rely on one or the other but to assemble a *portfolio approach.* Portfolio approaches pull together different measurement techniques to form a coherent group of measures covering the spectrum from quantitative to qualitative. Measurements that include those in the Spann model and others models along with case studies could provide a much better understanding and appreciation for the impacts of technology transfer.

The measurement models with their three distinct categories display the shortcomings of utilizing these measures alone. The first category of input measures reveals nothing about the success. The second, intermediate measures (activities) also reveals nothing about the success. The third category of outcome measures reveals the success but tells us nothing of how that success was achieved. Linking the three categories and supplementing them with case studies can reveal the level of success as well as the key critical elements contributing to the success (Figure 2.2).

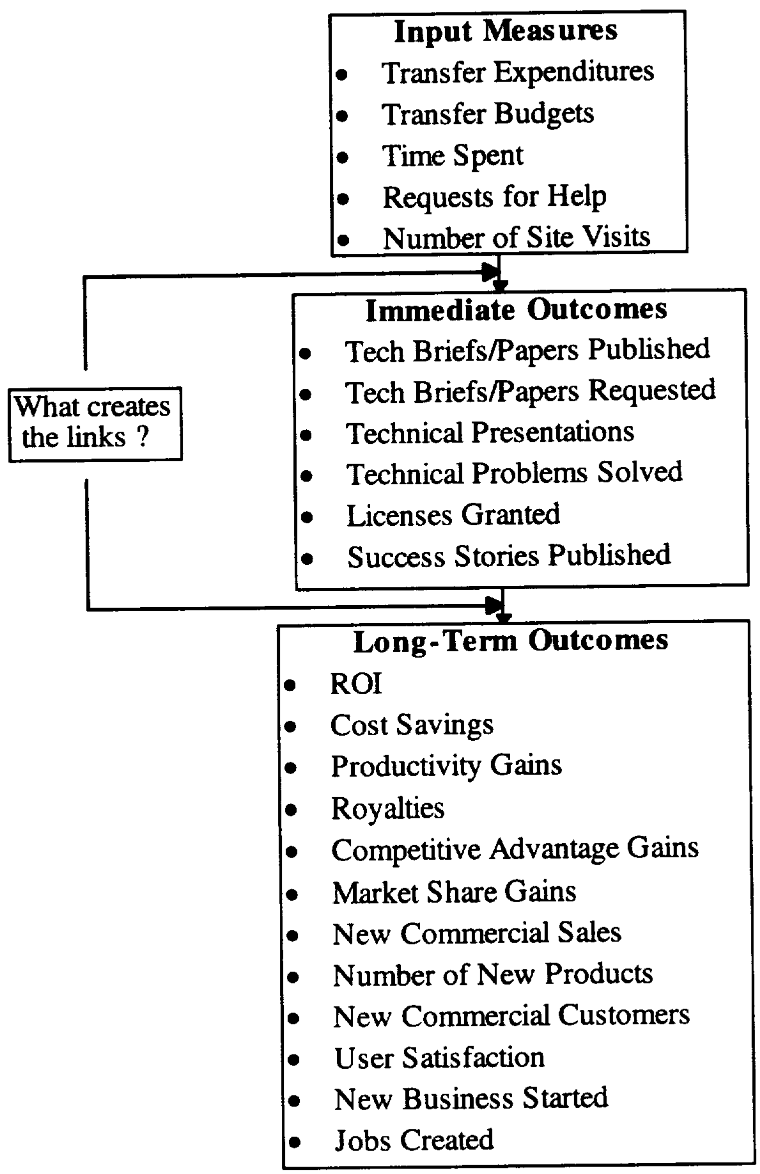


Figure 2.2: Linking of Metrics Categories

Input and intermediate measures are relatively easy to obtain but do not answer the real question of economic impact, while outcome (long-term) measures are much more difficult to obtain since commercialization takes a long time to occur (typically between 7-20 years, Mansfield). Perhaps the key is finding how the input and intermediate measures are linked to the outcome measures. There is a need to validate the intermediate metrics. In this study, the approach was to select those technology transfer efforts that have resulted in successful outcomes and trace backwards through the categories to obtain the key critical elements. This approach will involve measuring quantitatively, as well as performing case studies to reveal the hidden intangibles.

In support of this position, Roessner (1993) concludes that licensing revenues greatly underestimate returns; and Carr (Part 1, 1992) believes there is no magic formula to measure technology transfer and that studies should concentrate on case studies.

(3) Analysis of NASA Data

Since the creation of NASA as a federal agency in 1958 it has boasted of its impact on the nation's economy and the improvements to quality of life. Each year the agency publishes a document entitled *Spinoffs* that highlights the contributions of NASA to the general public welfare. The *Spinoffs* document serves several agendas including public awareness and, more importantly, a justification for funding.

Due to the increased pressure placed on Federal agencies in the 1990s to justify their funding levels, many agency administrators have reemphasized their outreach, transfer and commercialization efforts. Daniel Goldin, Administrator of NASA, has lead a renewed emphasis on technology transfer and commercialization. The agency's emphasis on technology transfer and commercialization is represented well in the NASA document, *Agenda for Change* (Agenda for Change 1994).

In the *Agenda for Change* document, the agency stated that a cornerstone of its commercial technology policy is to devote 10% to 20% of its budge for R&D partnerships with the private sector (Agenda for Change 1994). NASA field centers have opened new technology transfer offices or expanded existing ones in recent years. In 1994, NASA Langley created a new organization for technology transfer and gave it the same authority as the research groups. The director and the members of this new organization were selected from the research staff and were tasked with transferring NASA Langley's technology to the private sector. Two internal memos at NASA Langley Research Center, with the concurrence of the Center Director, called for a commitment of 10% of resources towards technology transfer (Appendices A.1 and A.2).

NASA has been reluctant to show the quantitative data on technology transfer issues, instead relying upon case studies, testimonials, and qualitative studies. Although these are important, the quantitative data must be evaluated in order to assess current and future positions and create a whole picture of the technology transfer challenge.

Regardless of the recent emphasis on technology transfer, the investment into technology transfer as a percentage of net R&D is very small (Figures 2.3 and 2.4). Data collected from NASA headquarters shows just how small the investment into technology transfer has been. On an annual basis,

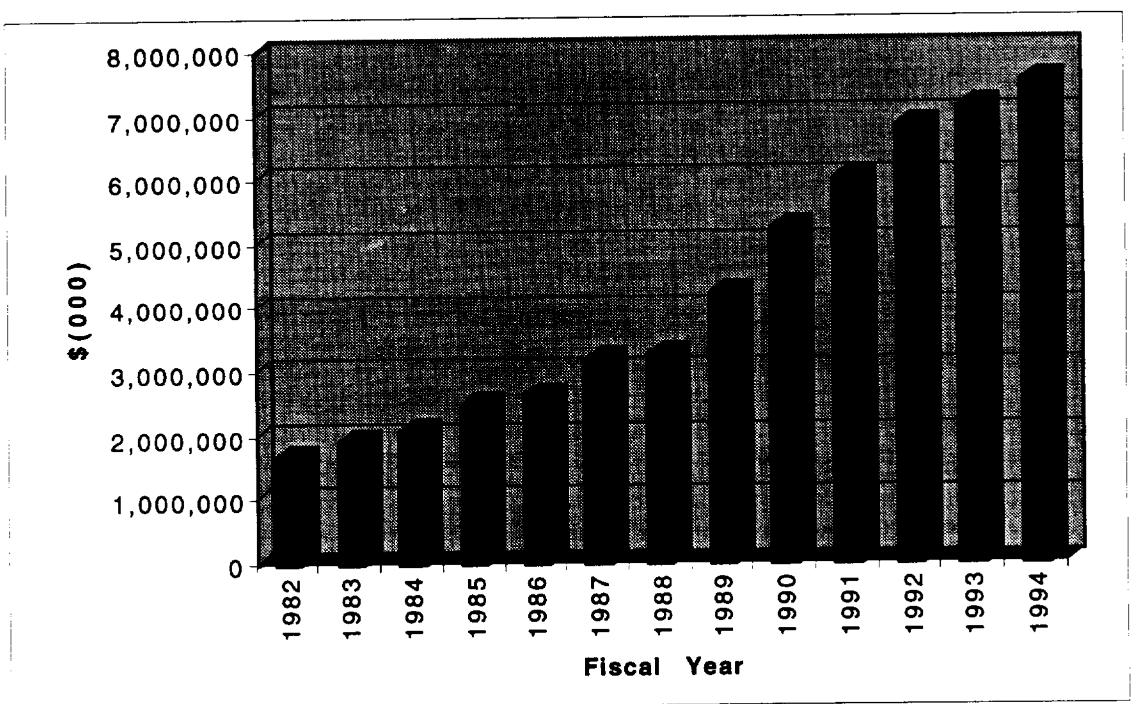


Figure 2.3: Net R&D Budget for NASA, 1982-1994

between the years of 1982 and 1992, technology transfer funding exceeded 0.5% only once while slipping below 0.2% once, and remaining between 0.3% and 0.5% for the other years. This is two orders of magnitude *lower* than the current goals for technology transfer.

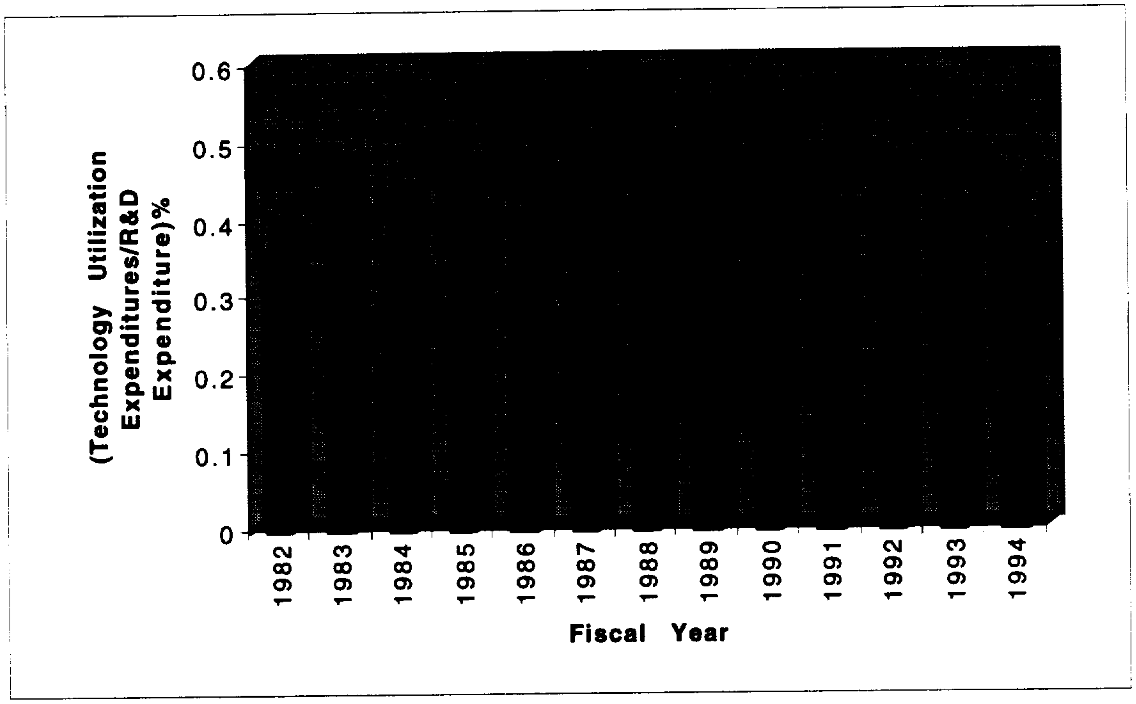


Figure 2.4: Technology Utilization Expenditures as a Percentage of the Net NASA R&D Budget, 1982-1994

Return-on-investment is small, as measured by royalties as a percentage of the investment in technology transfer per annum. As mentioned earlier, a truer return-on-investment figure would need to reflect the benefits of personnel exchange, information dissemination, and other tough to measure variables. A return on investment measured purely by the royalties received and the technology transfer expenditures depicts a dismal effort (Figure 2.5). In only two of the most recent years, 1991 and 1994, have the royalties as a percentage of technology transfer expenditures been above one percent (1%).

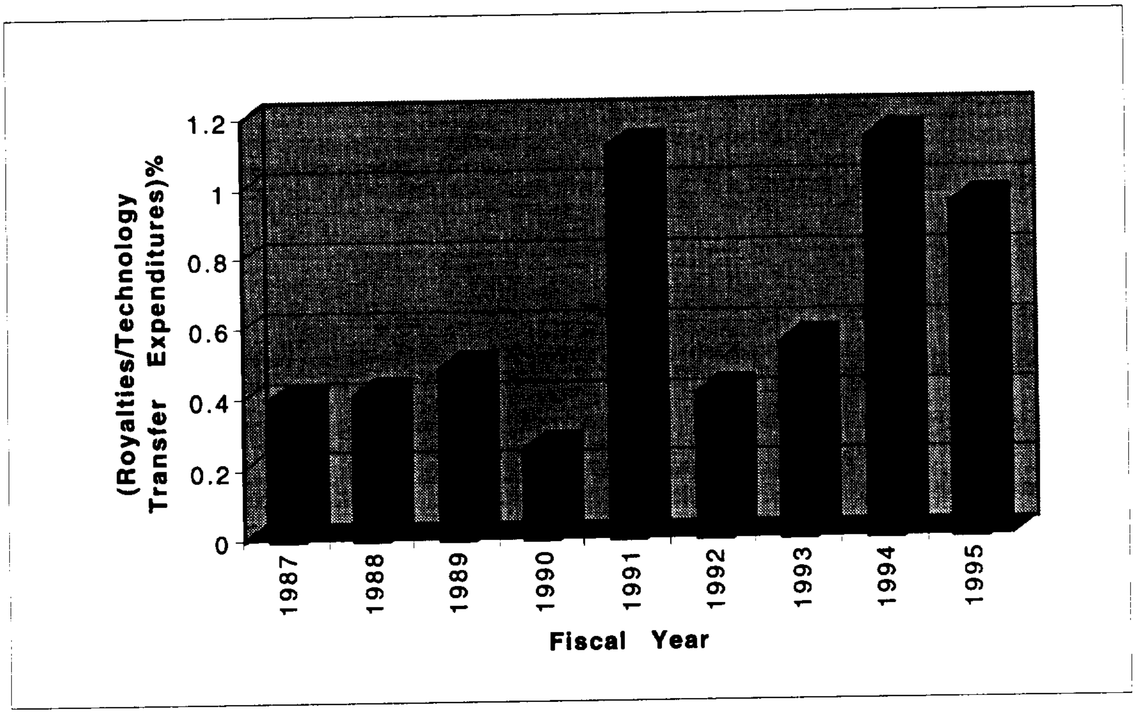


Figure 2.5: Royalties as a Percentage of the Technology Transfer Expenditure for NASA, 1987-1994

This type of simple analysis can be misleading though, since it misses the point of technology transfer. *Technology transfer is performed not primarily for the benefit of the return on investment to the laboratory but for the return on investment to the public good.* This would be better calculated by figuring the private sales from the licenses compared with the technology transfer expenditure (Figure 2.6). This calculation can only be estimated since the royalty figures at NASA include both the upfront royalties (fee paid at initiation of license agreement, typically $5000) and the running royalties (percentage of sales). Assuming that all of the royalties are running royalties (by definition, impossible, but for the hypothetical argument) and extrapolating those royalties into sales, one has a better picture of the economic impact. This analysis shows that, at best, the sales in the private sector account for just above 20% of the expenditures for technology transfer.

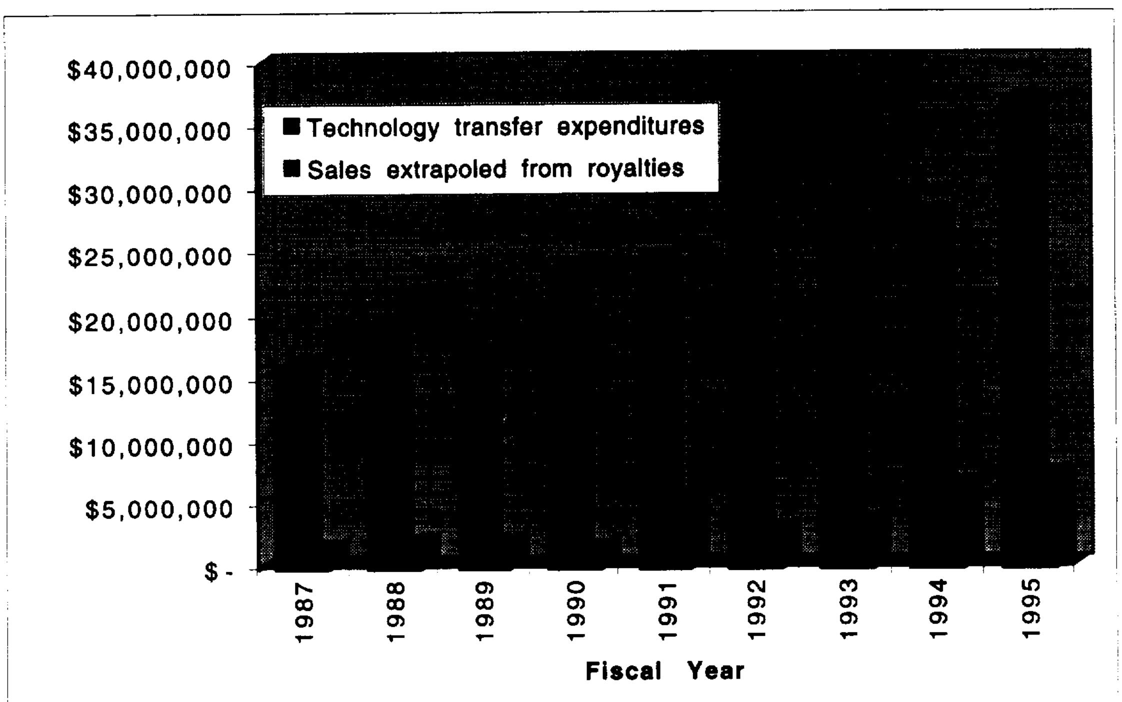


Figure 2.6: Extrapolated Sales Revenues vs. Technology Transfer Budget for NASA, 1987-1995

Complicating the concern of the effectiveness of NASA technology transfer efforts is its relative placing when compared with US universities. In

1993, NASA received $162,451 in royalties which would place it in 82nd place among 116 US universities. In 1994 those numbers were improved upon with NASA receiving $314,214 in royalties which would place it in 67th place. Although NASA increased their royalties again in 1995 to $348,533 they remained in 67th place.

Evaluations based purely on quantitative analysis are misleading since many of the benefits derived through technology transfer cannot be measured through royalties alone (See Chapter IV, Case Studies). Research into other less tangible parameters lead to the uncovering of software technology transfers. For years, government researchers were not permitted to copyright or patent software. This leads to an unfavorable market impact potential, since public domain products do not entice many companies to expend efforts, when their competitors have access to the same technology. But in at least one instance a large dividend was reaped from a NASA-funded and co-developed software, NASTRAN. Details of the NASTRAN development and market impact are contained in Chapter IV of this study. Of relevance in this case is the annual sales figures for the product. NASTRAN had over $70M in sales per annum (1994) with none of it going to royalties or otherwise being credited to NASA for it's creation. The annual sales of NASTRAN dwarf the technology transfer expenditures per annum and is one case of the immeasurable impacts of technology transfer (Figure 2.7).

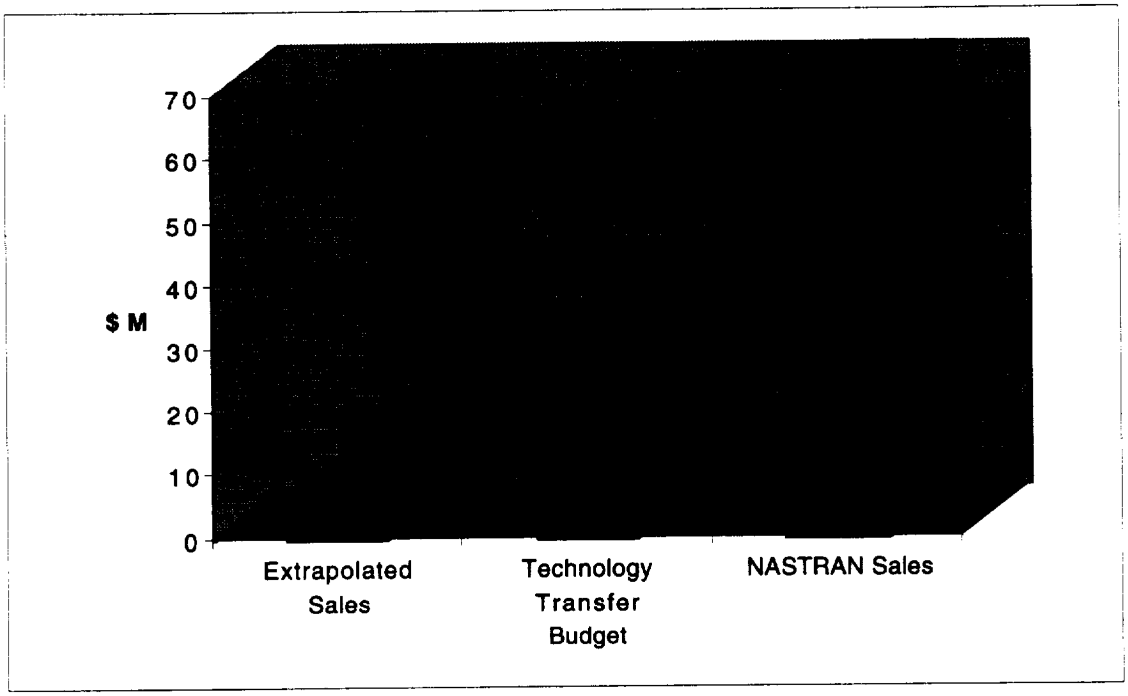


Figure 2.7: NASA Technology Transfer Budget compared with NASA Extrapolated Royalties Sales and NASTRAN Sales, 1994

As outlined by Mansfield and others, the average time to market can be on the order of seven to 20 years. Technology transfer from a federal laboratory to the private sector is similar to new product development with the additional hurdle of communication across cultural and organizational lines. Therefore, the recent active approach to technology transfer by NASA is not expected to show large measurable differences for some years. However, it is impressive that the royalties received by NASA in the two most recent years (1994-1995) have shown substantial increases over prior years (Figure 2.8).

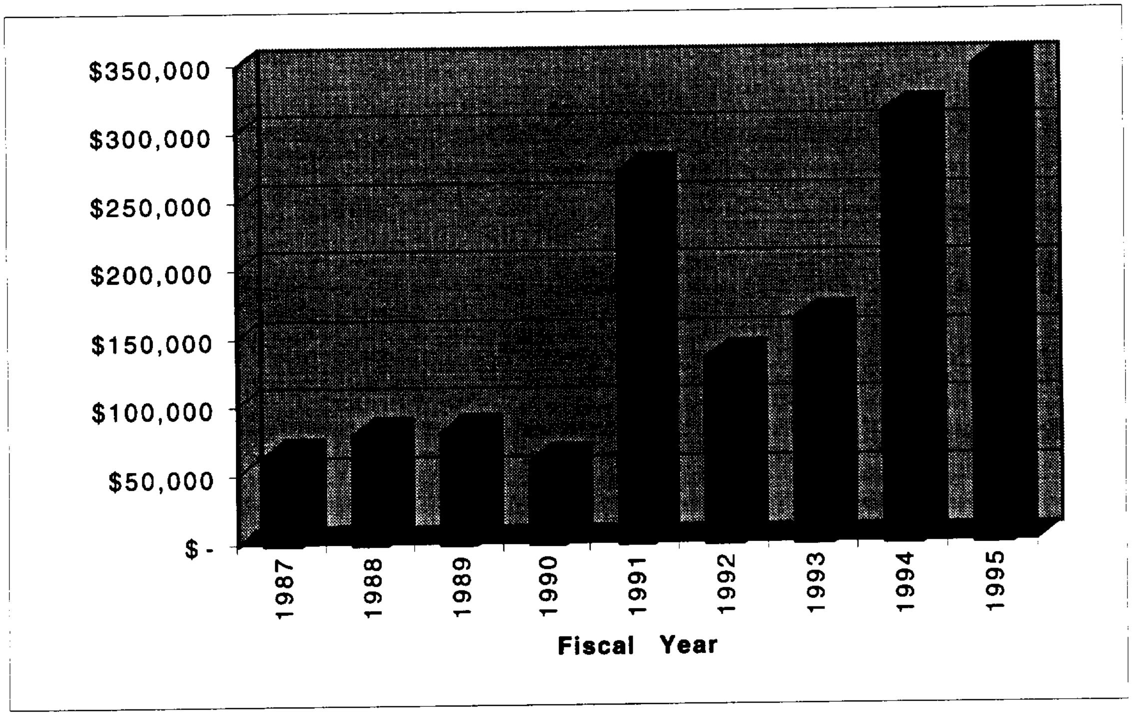


Figure 2.8: NASA Royalties per Fiscal Year, 1987-1995

In conclusion, the economic returns from NASA investment into technology transfer is questionable when looking merely at the royalties or extrapolated sales due to royalties. More accurate economic analysis must include case studies, like NASTRAN, to find all of the economic impacts. The NASTRAN case alone demonstrates how just one transfer can have significant impact. It is not unreasonable for NASA to aim for a ratio of royalties to technology transfer budget greater than one. The royalty return figures have already begun to escalate rapidly within just a few years of active technology transfer efforts.

(4) Analysis of AUTM Data

An extensive database of technology licensing efforts by US universities is maintained by the Association of University Technology Managers (AUTM). A collection of data of this size is rare in technology transfer. Federal agencies are not apt to release data on individual laboratories and private institutions consider their data confidential. The university data offers an opportunity to analyze and examine for relationships and significant correlations between the three categories of metrics (input, intermediate, and outcome).

The AUTM database is compiled annually. The 1994 version (1993 data) contains data from 116 US universities, 26 US hospitals and research institutes, 12 Canadian institutes, and 3 patent management firms. The variables of the database include:

- professional full-time employees,
- royalties received,
- licenses generating royalties,
- legal fees expended,
- legal fees reimbursed,
- invention disclosures received,
- US patent applications filed,
- US patents issued,
- total active licenses and options, and
- licenses and options executed.

The data includes information on expenditures (input), activities (intermediate-term), and results (long-term). The variables of the database are categorized as follows in Table 2.15. Correlation coefficients were calculated between all of the listed parameters. The correlation coefficients can be seen in the correlation matrix of Table 2.16.

Table 2.15: Categorization of AUTM Database Variables into Technology Transfer Metric Categories

Input (Expenditures, Resources)
Professional full time employees
Legal fees expended
Legal fees reimbursed
Intermediate (Activities)
Invention disclosures
US patent applications filed
US patents issued
Licenses & options executed
Long-term (Outcomes)
Royalties received
Licenses generating royalty

The three shaded boxes represent the interaction between the three categories. The upper-left hand box contains the correlations between inputs and intermediates. The lower-left box contains the correlations between the input and the outcomes. The lower- right box contains the correlations between the intermediates and the outcomes.

Table 2.16: Correlation Matrix of Technology Transfer Categories for AUTM Study

		INPUTS		INTERMEDIATES				OUTCOME
		Professional FTE	Legal Fees	Invention Disclosure	Patent Applications	Patents Issued	License Issued	Royalties
INPUTS	Legal Fees	0.694						
INTERMEDIATES	Invention Disclosure	[redacted]	[redacted]					
	Patent Applications	[redacted]	[redacted]	0.852				
	Patents Issued	[redacted]	[redacted]	0.813	0.84			
	License Issued	[redacted]	[redacted]	0.627	0.672	0.632		
OUTCOMES	Royalties	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
	Licenses Generating Revenue	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	0.768

The correlations in the upper-left box reveal what might be considered obvious, that activity correlates with the amount of expenditures. Simply, the more full-time employees and legal fees expended correlates with the numbers of invention disclosures and patent applications filed and the patents and licenses issued.

The correlations in the lower-left box are more revealing, implying that the inputs correlate well with obtaining some measure of success. There is a reduced correlation of inputs when moving from the intermediate measures to the more important measure of outcome, royalties. The investments have less correlation with results (as measured by royalties) than the activities. The numbers imply that a certain amount of the success is dependent on the individuals involved. The literature refers to many studies which also conclude that a key critical item in the technology transfer effectiveness is the *presence of a champion* (Carr 1992).

The correlations with royalties (lower-right and lower-left shaded boxes) reveal even more about the relationship between input, intermediate and outcomes measurements. The most important quantifiable measure of success is the royalties. Licensing has the highest correlation with royalties of any of the measurement variables. This makes perfect sense, since it is the last step in the process of attaining royalties. In addition, licensing is market driven, while all other measures are internally driven.

Further observations can be derived from a comparison of the different institutes: US Universities, US Hospitals & Research Institutes, Canadian Institutes, and Patent Management Firms. Totals and averages for the four types of institutes are calculated and presented in Tables 2.17 and 2.18. As might be expected, the patent management firms expend more resources by a factor of approximately 5 for full time employees and 2.5 to 7 times the legal fees expended by the other institutes.

Table 2.17: Input Averages of Institutes from the AUTM Study

Institute	Prof. FTE's	Legal Fees	Legal Fees Reimbursed	Total Legal Fees
US Universities	1.75	383,035	158,416	224,619
US Hospitals & Research Institutes	1.31	434,923	187,130	247,793
Canadian Institutes	2.17	161,132	54,164	106,968
Patent Management Firms	10	907,390	139,195	768,195

*FTE - Full Time Employees

Table 2.18: Intermediate Averages for Institutes from the AUTM Study

Institute	Invent. Discl.	Patent Appl's.	Patents Issued	Licenses & Options Activated	Total Active Licenses & Options
US Universities	52	24	10	14	56
US Hospitals & Research Institutes	30	21	7	1	35
Canadian Institutes	33	8	6	15	41
Patent Management Firms	273	35	17	20	46

Outcome measures were calculated and compared in Table 2.19. Again, the small sample for the patent management firms leaves question as to the validity of the comparisons based on institutes (Royalties/Institute, Licenses Generating Revenue (LGR)/Institute). The LGR/FTE, Revenues/FTE and the Revenues/Active Licenses give a good comparison of the success between types of institutes. Universities appear to pick winners more often as demonstrated by their large LGR/FTE value. However, patent management firms clearly are better at picking big winners as evidenced by the Revenues/FTE and Revenues/Active Licenses. The patent management firms have a order of magnitude over other institutes in Revenues/Active Licenses.

Table 2.19: Outcome Averages for Institutes from the AUTM Study

Institute	Royalties/ Institute	LGR/ Institute	LGR/ FTE	Rev/ FTE	Rev./Act. License
US Universities	1,696,808	25.5	14.2	893,252	29,311
US Hospitals & Research Institutes	2,844,965	15.7	12	1,984,323	75,196
Canadian Institutes	441,625	15.2	7	154,457	8,080
Patent Management Firms	19,557,998	64.7	6.5	1,878,980	405,535

*LGR - Licenses Generating Revenue, FTE- Full Time Employees

A comparison between NASA and these institutes shows NASA severely lagging in terms of outcome metrics (Table 2.20). NASA lags Canadian institutes by a factor of three and other US institutes by a factor between 10 and 20 in terms of royalties/institute. The revenues/licenses and LGR/institute help further explain the NASA situation. Although NASA has a respectable LGR/institute, its revenues/licenses points out its inability to obtain big winners. In fact, considering that most NASA royalties consist of upfront (one-time initialization fee) royalties that are on the order of $5,000 to $10,000, the licensing program economic success is questionable.

Table 2.20: Outcome Averages for Institutes from the AUTM Study Compared with NASA

Institute	**Royalties/ Institute**	**LGR/ Institute**	**Revenues / Licenses**
US Universities	1,696,808	25.5	29,311
US Hospitals & Research Institutes	2,844,965	15.7	75,196
Canadian Institutes	441,625	15.2	8,080
Patent Management Firms	19,557,998	64.7	405,535
NASA	162,450	27.0	6,016

CHAPTER III

METHODS

The methods for performing both the federal laboratory researcher technology transfer culture survey and the linking of metrics study are presented in this chapter.

Federal Laboratory Researcher Technology Transfer Culture Survey

The federal laboratory researcher technology transfer culture survey was designed to measure attitude, awareness, and perceptions of federal laboratory researchers toward technology transfer. The survey was performed at the NASA Langley Research Center in Hampton, Virginia, with 100 researchers. Availability and accessibility to federal laboratory researchers for a survey of this type are generally difficult because the managers and directors of such research laboratories are wary of the possible negative repercussions. Access to the NASA Langley was granted because of the author's employment with NASA.

The NASA Langley Research Center

The NASA Langley Research Center is located in Hampton, Virginia. NASA Langley, established in 1917, was originally the research center for the National Advisory Committee for Aeronautics (NACA). In 1958, with the transformation of NACA into NASA, the name was changed from the NACA Langley Aeronautical Laboratory to the NASA Langley Research Center.

NASA Langley has a long tradition of world-class aeronautics research in support of the commercial sector. The Center has won five Collier Trophies, an annual award for aviation's greatest achievement. Today, NASA Langley has the NASA lead for high-speed research, and other projects including composites, integrated wings, and general aviation. The facilities at NASA Langley cover approximately 788 acres, 221 buildings, with an original investment value of $687M and a replacement value of approximately $2.06B. NASA Langley has 24 wind-tunnels covering the entire speed range from 0 to Mach 25. The staff includes approximately 2300 employees of which 50% are considered researchers. The NASA Langley budget has hovered about the $600M mark over the past five years (Economic Impact 1995).

In 1994, NASA Langley was reorganized in order to better align the Center with its customer-base (funding organizations, research recipients, and others). As a result of the reorganization the directorates of Electronics, Structures, Aeronautics, Space, Flight Systems, Systems Engineering and Operations, and Management Operations were eliminated and in their place were formed the groups entitled Aeronautics Program Group (APG), the Space and Atmospheric Sciences Program Group (SASPG), the Research and Technology Group (RTG), the Technology Applications Group (TAG), and the Internal Operations Group (IOG). Reorganization shifted research from different, mission-focused directorates into one group, the RTG. The programmatics were left to the APG and SASPG, while the RTG performs the research. The IOG is a support and services group. The TAG was elevated from a three-person office to group-level with approximately 30 members and the responsibility of matching promising NASA Langley research with US businesses. The organization of NASA Langley prior to restructuring is represented in Appendix C.1, and the organization of NASA Langley following the restructuring is presented in Appendix C.2.

In order to accurately represent the missions and goals of the NASA Langley Research Center, the mission and goals statement is presented below.

NASA Langley Research Center Mission and Goals, 1995

The mission of the NASA Langley Research Center is to increase the knowledge and capability of the United States in a full range of aeronautics disciplines and in selected space disciplines, system analysis, and in atmospheric sciences. The mission will be accomplished by:

- Performing innovative research relevant to national needs.
- Transferring technology to users in a timely manner.
- Supporting U.S. government agencies, U.S. industry, other NASA centers, the educational community and the local community.

Specifically, we will strive to enhance our premier research capability and contributions in the following disciplines:

- Acoustics
- Aerodynamics
- Aeroelasticity
- Aerothermodynaics
- Airframe/Propulsion Integration
- Atmospheric Sciences
- Controls & Guidance
- Electromagnetics
- Flight Dynamics
- Hypersonic Propulsion
- Systems Analysis
- Materials
- Measurement & Testing Techniques
- Remote Sensing
- Structures

The Center will exploit opportunities for synergistic applications of the above disciplines in the development of technology for the following aerospace systems:

- Subsonic and Supersonic Transports
- Military Aircraft and Missiles
- Hypersonic Aircraft
- Space Transportation Systems
- Small Spacecraft
- Instruments

Our success will be measured by the extent to which our research results and technologies contribute to the design, development, and operation of future aerospace vehicles and missions and to the overall economic competitiveness of U.S. industry.

More broadly, the 1995 NASA Strategic Plan mission statement reads:

> It is NASA's mission to research, develop, verify, and transfer advanced aeronautics, space, and related technologies . . . We conduct aeronautics and space research and develop technology in partnership with industry, academia, and other Federal agencies to keep America capable and competitive (NASA Strategic Plan February p. 2, 1995).

The operating principle for technology transfer and commercialization calls for new ways of doing business that effectively align the agency's assets and enterprises with US economic security.

> We will implement our programs such that they align NASA assets and Enterprises into an alliance among Program Offices and Field Centers, creating a collaborative way of educating NASA staff on commercial applications, marketing our capabilities and establishing partnerships with industry, evaluating progress, and establishing an electronic commercial technology network. We will ensure that our technology-transfer activities and dissemination of information to the public benefits the national and economic security of the United States (NASA Strategic Plan p. 22, 1995).

These policies indicate that NASA and its field center, NASA Langley Research Center, have made a commitment to technology transfer with the intent of positively impacting the US economy.

Survey Design

A survey was designed to measure the awareness, attitudes, and perceptions of researchers at the NASA Langley Research Center federal research laboratory. The survey was intended to gain a deeper understanding of federal laboratory culture and researcher attitudes toward technology transfer. A GAO study of 1992 (Technology Transfer, Barriers Limit Royalty Sharing's Effectiveness 1992) utilized a focus group of federal researchers, but did not include a quantitative (statistical) analysis of the researcher culture. This study seeks to add depth to GAO findings by surveying 100 researchers.

In final form, it consists of 19 content and two demographic questions (age and education level). Questions were equally divided among measures of attitude, awareness, and perception (Table 3.1).

Table 3.1: Breakdown of Survey Questions by Measure

Measure	Number of Questions
Awareness	6
Attitude	6
Perception	6

*Note: Question 9 is an objective measure of the performance plan use.

A telephone survey conducted by the author was selected to achieve a high response rate. Prior surveys and market studies have shown that personal surveys and telephone surveys have significantly greater response rates than mail surveys. A mail survey would have incurred significant printing costs and, possibly, more time, in order to cajole respondents, while personal (face-to-face) surveys would have incurred significantly more time than either telephone or mail surveys in travel from office to office. Therefore, the telephone survey was probably the least expensive approach, since all calls were local and internal to the Research Center.

Survey design was constrained by the medium. In addition to the limitations of a telephone conversation, the attention span of the respondents was factored. Open-ended questions were kept to a minimum.

Closed-ended questions were composed mostly of ordinal ratings, with anywhere between two to five category scales. These guidelines aided in creating a survey that could be performed in less than ten minutes. Ten minutes was assumed to be the maximum amount of time that a researcher at NASA Langley would agree to participate. This estimate is based on the author's intimate, ten-year knowledge of the research staff at NASA Langley and the input of the focus group used in the course of survey instrument development.

The relative size of the sample (10% of the sample population) provides statistical inference validity. The use of a focus group builds a strong case for construct validity. Internal validity was verified by a demographic comparison of the random sample and the sample population (see Figures 3.1, 3.2, 3.3 and 3.4). External validity to other federal laboratories has not been addressed or proven in this study.

The survey instrument was strengthened through an extensive review process that included a focus group (2 meetings and follow-up), multiple reviews by the Deputy Director of the Technology Applications Group, and a pilot study.

Focus Group

A focus group of researchers representative of the sample population was assembled in order to attain a preliminary evaluation of the clarity of the questions and the survey in general. Focus group review of the survey was intended to identify questions that may be ambiguous or leading, critical questions that may be missing, inappropriate response options for questions, and any other problematic issues with the survey from a respondent's point of view.

Participants for the focus group were selected to represent a span of ages, a spectrum of the groups within NASA Langley, and a range of educational levels and experiences and gender. The participant demographics are summarized in Table 3.2.

Table 3.2: Focus Group Demographics

Gender	Age	Group	Highest Education Level Attained
F	26	RTG	BS
M	47	RTG	MS
M	62	SASPG	BS
F	31	SASPG	PhD

Meeting One

The focus group met for one hour. During this time members were briefed on the purpose of the survey, asked for their demographic information, asked to read the survey individually and then participate in an open discussion on the survey. Members were asked to respond to the survey questions (Table 3.3) so that they could better evaluate the questions as a typical respondent. The members of the focus group were encouraged to make written comments on the survey as they evaluated it. At the conclusion of the evaluation period, focus group members were asked to comment on the survey in general and for specific questions and issues. Suggestions from this group were incorporated into a revised survey.

Table 3.3: Original Survey Form, Prior to Focus Group

NASA Langley Research Center
Technology Transfer Culture Survey

Hello, my name is Lance Bush. I'm an employee of NASA Langley and am helping conduct a survey of the research staff. Results of this survey will be used by senior managers to guide policy. Would you take a few moments to answer a few questions. I assure you that your answers will be kept completely confidential.

1. Technology Transfer is one of NASA Langley's Missions.

Agree Don't Know Disagree

2. Technology Transfer is one of NASA's Missions.

Agree Don't Know Disagree

3. In addition to my research, technology transfer should be my responsibility.

Strongly Agree Agree Neutral Disagree Strongly Disagree

4. Technology transfer has been a component of my performance plan and/or performance appraisal.

Agree Disagree

5. Technology Transfer should be a component of the performance plan & performance appraisal.

Strongly Agree Agree Neutral Disagree Strongly Disagree

6. Technology Transfer should be a component of only the performance appraisal.

Strongly Agree Agree Neutral Disagree Strongly Disagree

7. If I were rewarded with royalties, I would be more interested in supporting technology transfer.

Agree Disagree

8. If it contributed to my promotions, I would be more interested in supporting technology transfer.

Agree Disagree

9. If I were rewarded with both royalties and promotions, I would be more interested in supporting technology transfer.

Agree Disagree

10. My immediate management supports technology transfer.

Strongly Agree Agree Neutral Disagree Strongly Disagree

11. My senior management (2-levels up) supports technology transfer.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

12. NASA Langley has committed what percentage of resources to technology transfer?

13. List the methods by which you can commercialize a technology at NASA Langley.

14. My technology council member is ______________________

15. What group would you contact for help in transferring technology?

Demographics:

Age ___________
Level of Education Achieved   BS   MS   PhD
Group _________
Division ____________

On average, members of the focus group took six minutes to review and answer the questions on the survey. One focus group member took five minutes, two of the members took six minutes, and one of the members took nine minutes. It was anticipated that a similar amount of time would be used by researchers randomly selected to participate in the survey study, even though the survey questions would be read to them over the phone by the author.

The critique of the focus group identified two main points that were missing from the original survey. The two additional questions suggested by the group were:

1. Do you believe your research has potential for technology transfer?
2. Do they (researcher) believe we (NASA LaRC and/or researcher) should be doing technology transfer?

The group felt that the results of these two questions would be even more revealing if the respondents also estimated their *perceived* potential for technology transfer. The term "technology transfer" had multiple meanings for the focus group. Members asked that a clear definition be read to each respondent prior to the survey. Questions concerning management support were deemed too vague. Rewording for those questions was suggested in order to differentiate between "lip-service" and tangible management support. Two other questions suggested by the focus group were:

1. What would help you to prepare for performing technology transfer?
2. How should researcher be involved in technology transfer?

Finally, the focus group made valuable suggestions concerning survey logistics. Members suggested that survey respondents be told prior to the survey that it would take approximately ten minutes of their time. Further, the focus group identified a flaw in the original sampling strategy. All members of the focus group thought that stratifying of the sample should be performed at the branch as opposed to the division level, since researchers associate with their most immediate organizational structure. Nevertheless, after obtaining this recommendation and reviewing the database of researchers for the study, a stratification by division or branches was decided against since the sample size (100) would not allow for statistically significant groupings at those levels.

These changes were incorporated into a new survey. The new survey (Appendix D.1) was reviewed by the Deputy Director of the Technology Applications Group to ensure that the results would be of interest to a senior level administrator of technology transfer. The Deputy Director made a few suggestions, and the survey took on a new form (Appendix D.2). The Deputy Director's suggestions focused on the clarification of the questions regarding attitudes toward rewards and the definition of technology transfer. The definition of technology transfer could play a pivotal role in the survey because it might influence respondent answers.

Meeting Two

The focus group convened a second time to review the revised survey. Members found that the revised survey resolved most issues identified in the first draft. Additional modifications were few and mostly dealt with an occasional change of wording. The revised survey from this meeting is displayed in Appendix D.3.

In survey question seven (7), the question response read: "Training on performance of technology transfer." It was modified to read: "Training on tools/mechanisms/processes for performance of technology transfer." This wording change served to make the option clearer and differentiate it from the option: "Education about the process."

The group further suggested removal of the phrase, "Stayed out of the way" because the midrange answer on the nominal scale for question 15. "Stayed out of the way" was deemed to be confusing, since it could be considered to have both positive and negative connotations with respect to management involvement. Another recommendation for question 15 was to reverse the number scale so that the value 10 corresponded to the positive answer (helped significantly) and the value 0 corresponded to the negative answer (inhibited). Suggested rewording for question 17 changed the nature of the question. The group felt that identification of mechanisms was not a responsibility of researchers but of the Technology Applications Group. The phrase "are you aware of" was changed to "would you use."

One additional recommendation regarded the implementation of the survey. A member of the group pointed out that some questions differed from others only by the replacement of the word "is" with "should be." In order to ensure that the question was answered correctly, it was advised that those words be emphasized when reading the question.

Most concern during this second meeting centered on wording in the informed consent introduction and the definition of the term "technology transfer". The focus group felt that it should be expressed clearly that Center management would receive these results. In addition, the definition of technology transfer was determined to be too vague. Suggestions to rectify the definition of technology transfer included a reference to research results as the object to be transferred and inference that the concern was with the transfer from NASA to a customer.

The group suggested that the first survey question determine whether or not the respondent was doing research. This would serve as an extra verification that the appropriate sample population was being surveyed. Finally, the group also felt that all researcher personnel below the level of branch head could be considered "non-management" and could, therefore, include section and group leaders.

Following the meeting, a new definition for technology transfer was drafted and circulated via email to the focus group. Through a series of emails, three of the four members agreed completely on the final wording. The final wording for the technology transfer definition can be viewed in Appendix D.4.

Pilot Study

The population for the pilot study consisted of nine researchers at NASA Langley Research Center. These respondents were selected randomly from a database of all researchers at the Center. The database of researchers was obtained from the Human Resources Division and included the names, job title, position classification, phone number, and organizational codes for each researcher. This database is titled "NASA Personnel/Payroll System." Individuals in the database who had an administrative code, which designated a management position, were removed from the database. Personnel left on the database were categorized by ten different groups (denoted by a 100, 200, etc.) identified by the NASA Position Classification Handbook (NASA Position Classification Handbook 1987). Those individuals identified as professional scientific, engineering, other technical positions, and life sciences positions were retained (200, 700, 900 groups). Individuals were then filtered again by the position classification standards code (NASA Position Classification Handbook 1987). Those individuals with position classification standards codes of 92, 94, 99, 91, (support personnel) and student trainees were removed from the database. In addition, those individuals associated with the Technology Applications Group and the Office of the Director were also eliminated. It is likely that the sampling frame (database) very closely represented the targeted population. The remaining sample population contained 1017 individuals.

The nine respondents were telephoned by the author in their offices. Respondents were read the informed consent paragraph, the definition of technology transfer, and then the questions. The surveying was performed in accordance with established interviewer techniques (Fink 1985; Fowler 1993; Fowler & Mangione 1990; Interviewer's Manual 1976).

With the exception of two questions, the survey mechanism was found to be unambiguous and clear to the respondents. During the survey, it was found that respondents preferred to answer question 7 (the only multiple choice question on the survey) with a letter response even though they had not been read one. In addition, it was not clear to them that they could choose more than one response. For the final survey, question 7 was revised to include letter responses and a statement that more than one response could be selected.

Question 11 (*"Technology transfer should be a consideration only during my performance appraisal and not necessarily a planned task"*) was interpreted in two different ways by respondents. The first interpretation (the intended one) was that technology transfer, like inventing, was hard to predict. Respondents felt more comfortable not being pressured to plan technology transfer, but being rewarded for technology transfer when it occurred. The second interpretation was that the researcher would be held, unfairly, accountable for technology transfer when it was not a agreed upon planned task. To alleviate what might be confusing results, question 11 was rewritten to obtain the information that was originally intended. The question was reworded to read:

> Given that the performance appraisal allows for a researcher to bring up positive accomplishments that may not have been planned for, technology transfer should be a consideration only during my performance appraisal and not necessarily a planned task.

Although the actual results of the pilot showed some interesting cultural trends, the sample was too small to draw any statistical significance and the results were discarded.

Main Study

The strategy was to survey 100 of the researchers at NASA Langley on their attitudes, awareness, and perceptions toward technology transfer. The survey was performed by the author over the telephone to the researchers.

Procedural Strategy

Respondents were called in the order they were selected from the database. The surveying was targeted to take approximately ten working days with an average of ten respondents surveyed per day. Respondents who were unavailable on a given day were recalled first on subsequent days. This approach was intended to minimize the non-response rate.

Statistical Sample Strategy

The sample for the main study was derived from the same database described in the pilot study, with the exception that respondents from the pilot study were removed. Two hundred researchers were randomly selected from the population. From this 200, the goal was to attain 100 responses. Respondents were contacted starting at the top of the list and after 100 responses were recorded the study was completed.

The demographics of the random sample were checked against those of the sample population. The percentage of survey respondents within the four groups (IOG, SASPG, APG, RTG) matched almost exactly with the percentage of researchers residing within those groups (Figure 3.1).

There was a reasonable match between the percentages of the sample population and the random sample for the three education levels (Figure 3.2). There was a maximum difference of approximately 10%. Sandra Duncan of the Human Resources Division, from whom the data was derived, stated that these sample population numbers might be slightly inaccurate. Updating of education level for an individual is dependent upon that individual supplying the Human Resources Division with the data. Ms Duncan felt that this responsibility was not being met by all employees.

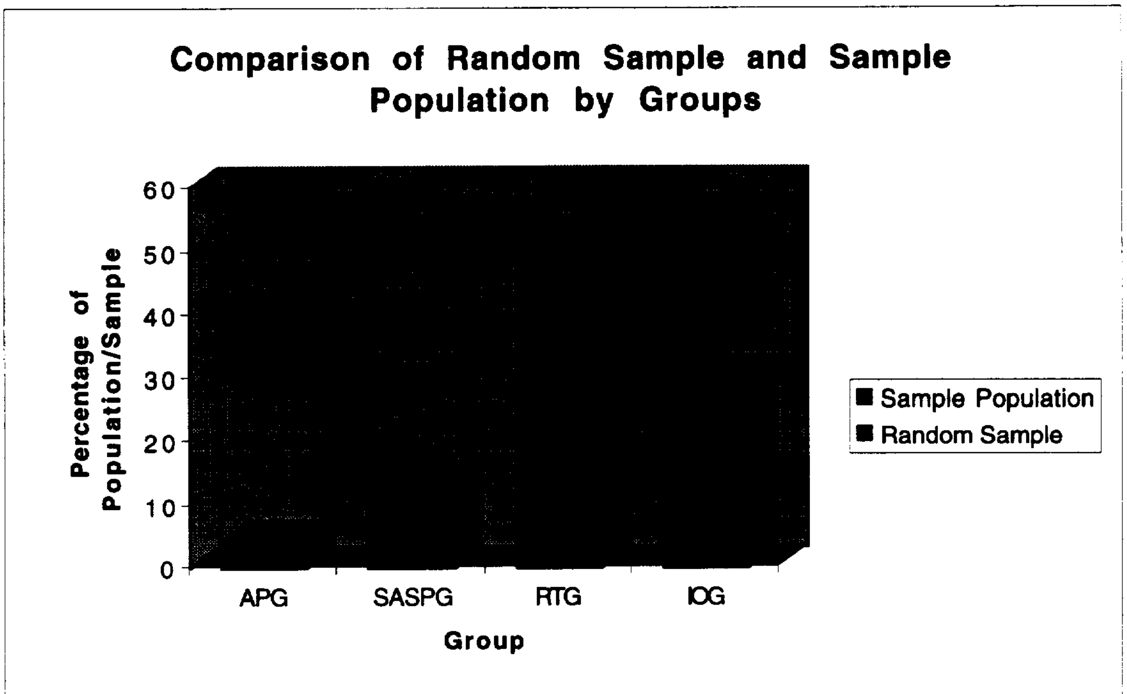


Figure 3.1: Comparison of Sample Population and the Random Sample by Group Affiliation

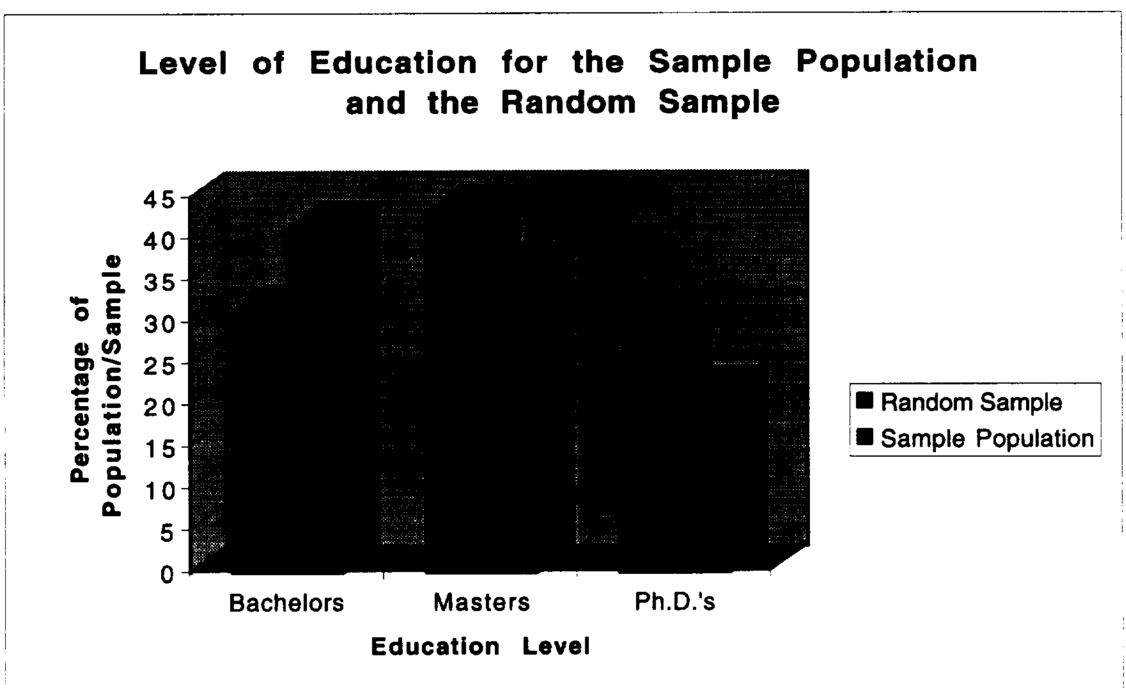


Figure 3.2: Comparison of Level of Education for the Sample Population and the Random Sample

Age distribution for the sample population and the random sample both show a bimodal distribution with significant portions of the employees in either their 30s or 50s (Figure 3.3).

The distribution of the sample population and random sample by age category are similar and differ by 9% at most for any one category (Figure 3.4).

The favorable comparisons of the sample population and random sample demographics for group, age, and education level indicate that construct validity was achieved (Figures 3.1 thru 3.4).

No contacted respondent declined to be interviewed and the non-response rate (~5%) consisted entirely of individuals who could not be reached. The non-response rate is defined as the quotient of the number of individuals who were randomly selected and unavailable for survey to the total number of randomly selected individuals for the study (5/105).

Shortcomings

The greatest potential for error in this study may be attributed to the interviewer. NASA Langley Research Center is a relatively small community with approximately 2,300 civil servants. The author, currently employed at NASA Langley Research Center, has served eight years as a researcher at the

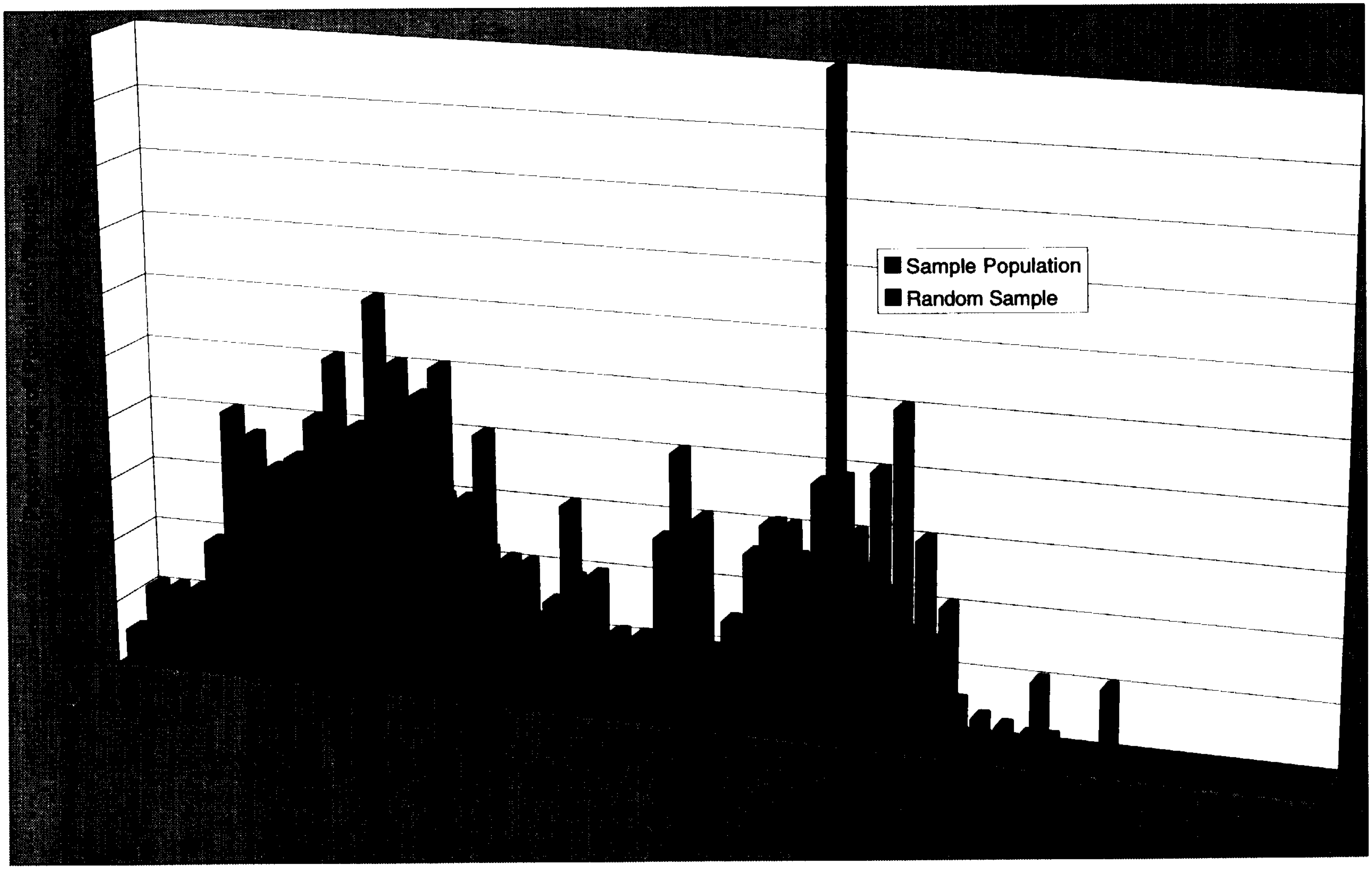


Figure 3.3: Comparison of the Sample Population and the Random Sample by Age

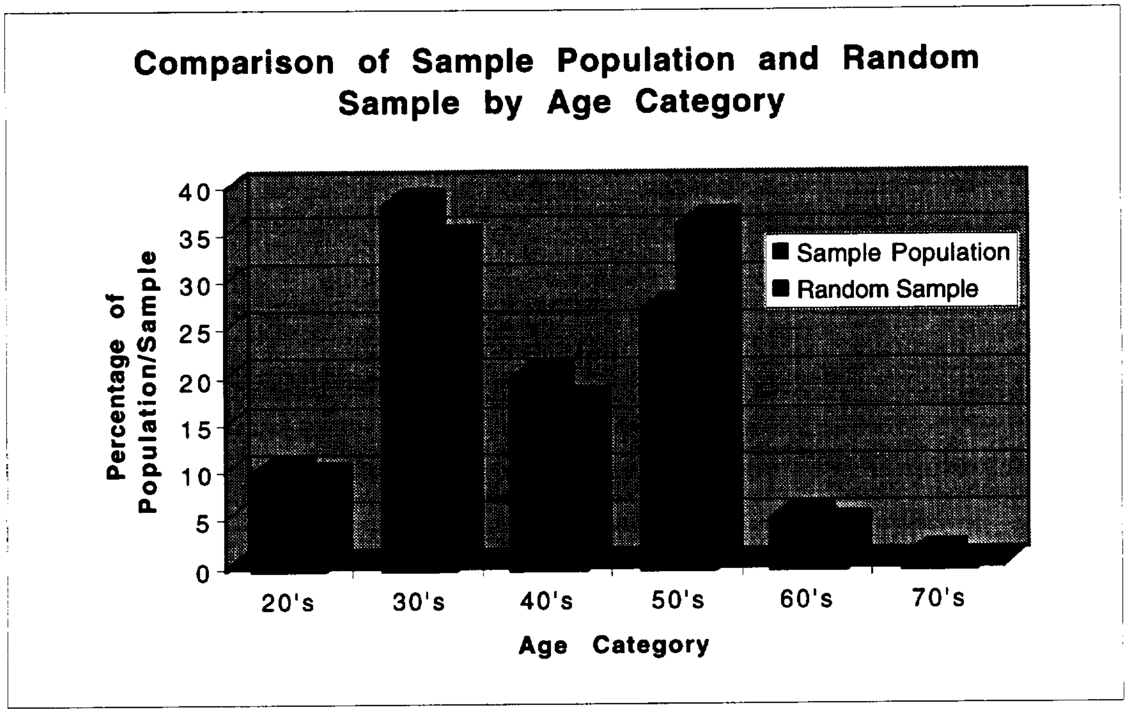


Figure 3.4: Comparison of Sample Population and Random Sample by Age Category

Center and is familiar with many of the researchers. Although a professional interviewer demeanor and attitude was maintained throughout the survey, several respondents may have given responses that were influenced by their relationship to the interviewer.

A second potential for inaccurate results stems from external influences on the researchers. Within the recent year, many changes occurred at NASA Langley Research Center causing stress and anxiety among the personnel. These changes included reorganization of the Center, shifting of missions and goals to be customer-based, declining support from Congress, federal budget impasse, and a perceived declining interest in NASA and space ventures in general from the public perspective.

Data Analysis

Collected data from the survey was analyzed both on an individual question basis and with respect to correlations between the questions. Most questions lent themselves to a graphical representation either in the form of a pie chart based on percentages or a bar chart on number of responses. Answers to open-ended questions were categorized and then presented as bar or pie chart forms.

Correlations (Pearson product moments) were calculated between all of the questions. The correlation coefficients and the variables were reviewed to determine which pairs of variables were correlated (Mendenhall 1993; Minitab Handbook 1991).

Case Studies for Effectiveness of Technology Transfer

The question intended to be answered by the case studies was: "What are the key critical elements that contribute to a successful technology transfer from a federal laboratory to a private sector?" The case study approach was selected over other study mechanisms because technology transfer is a relatively contemporary issue that involves subjective issues and human nature. Case studies are better tools than other research approaches (surveys, laboratory tests, etc.) for this particular study because they allowed for study of phenomena in its contextual environment.

Selection of the cases was guided by prior theories on the subject. Previous studies and theories on the success of technology transfer are presented in Chapter II. Essentially this research tested the measures of technology transfer that were derived in many previous studies (see Chapter II, Measures of Technology Transfer).

A multiple case approach was taken to achieve construct validity. Selected cases were those that demonstrated economically successful technology transfers from a federal laboratory to the private sector. The units of analysis were the individuals involved with the transfer and success. These individuals included the laboratory researchers, technology transfer agents, and the private business personnel.

Procedure for Case Studies

Construct validity was established by interviewing all of the principals involved within each technology transfer case. Principals were those identified as playing a central role in the success of the case. Typically, principal individuals for a case included both an internal and external person (e.g., president of company and researcher at laboratory). The multiple sources of evidence helped create a clear picture from both sides of the issue, including the private sector and the laboratory.

Although internal validity was much more difficult to achieve in a case study of this nature, the testimony of several people all with differing agendas and personal interests further substantiated the findings.

Although each federal laboratory has a different mission, perspective, and general culture, the culture issues measured in this study were of such a general nature as to assume that they would probably exist at other NASA research laboratories and similar US federal laboratories with a science orientation. Nevertheless, this study does not attempt to prove the external validity to other NASA Centers and similar US federal laboratories through additional surveying at other labs, but leaves that for future studies.

Along with the interviews of principals, the sources of evidence for the case studies included archival records and documents. The archival records included corporate information publications, such as yearly financial reports. The documents included company historical accounts and Thomas Business Register information (Thomas Business Register 1995). The interviews were conducted in an open-ended way allowing for personal insights and other unpredicted issues to arise. In the open-ended format the interview was guided by responses of the interviewees. Responses helped guide the interviewer to the next question as opposed to having a closed, structured interview where all questions were predecided.

In order to determine the key, critical elements of a successful technology transfer effort, the case studies were constructed from interviews with principals within the process of the technology transfer from the federal laboratory and the technology's success in the commercial sector. Individuals from the federal laboratory NASA Langley and the private company were interviewed in each of the case studies. A snowball design, such as that used in market research, was used to identify the key individuals in the transfer process (Aaker and Day p. 368, 1990). In the snowball design each respondent, after being interviewed, was asked to identify other appropriate people to be interviewed.

One question was central to each interview. The following question was asked of all interviewees:

> What were the key critical items that contributed to the economic success in terms of the transfer of the technology from the federal laboratory to the private sector?

Following the response of the interviewee, each interview then proceeded in an open format while the interviewer probed for the key critical elements and other principals involved with the technology transfer process (Fowler and Mangione 1990; Interviewer's Manual 1976; Stake 1995; and Yin 1994).

Selection of Case Studies

The key criterion for selection of the three case studies was the presence of a positive outcome metric, as shown in Figure 3.5. In order to consider a technology transfer a success, a private company needed to show either increased revenues, reduced costs, or some other significant economic improvement. *The key in selecting the cases for this research investigation was a success for the company and not an input or intermediate success measure that is typically used by federal laboratories.* A brief description of the three cases follows. A more detailed analysis of each case can be found in Chapter Four.

MacNeal-Schwendler Corporation (NASTRAN)

The MacNeal-Schwendler Corporation (MSC) is an industry leader in finite element modeling and analysis tools located in Los Angeles, California. MSC's primary product, MSC/NASTRAN, was initially developed jointly by NASA, MSC and a few other small companies through major funding by NASA. MSC now has over $100M in annual sales (MacNeal-Schwendler Corporation Annual Report 1995; Thomas Business Register 1995).

Input Measures
- Transfer Expenditures
- Transfer Budgets
- Time Spent
- Requests for Help
- Number of Site Visits

Immediate Outcomes
- Tech Briefs/Papers Published
- Tech Briefs/Papers Requested
- Technical Presentations
- Technical Problems Solved
- Licenses Granted
- Success Stories Published

Selection Criteria →

[redacted]

Figure 3.5: Outcome Metrics as Selection Criteria for Case Studies

Pressure Systems Incorporated

Doug Juanarena, a NASA Langley researcher until 1978, played a key role in developing a pressure sensor for use in wind tunnels. The development of these sensors was necessary in order to construct new wind tunnels being designed at that time. When NASA was left with no manufacturer for the pressure sensor, Doug Juanarena left NASA in 1978 and formed a private company (Pressure Systems Incorporated) to produce the sensors. Pressure Systems Incorporated became a very successful commercial entity, supplying pressure sensors worldwide. Doug Juanarena estimates his company sales are now at the level of $10M per year.

Técnico

Técnico is a ship repair company located in Chesapeake, Virginia. Due to the probability of a declining customer base, Técnico started to look for other potential markets to enter. This market scanning led the company to visit a technology exhibit at NASA Langley in 1993. At this technology exhibit, John Hildebrandt, a Group Manger with Técnico, found a technology, rubber expansion molding, that he believed could help give them an edge on competitors in ship repair while allowing them to break into new markets at a low initial investment. Since that time, Técnico has created a new group within the company, called the Advanced Materials Group. The technology transfer with NASA resulted in a new product, new commercial customers and jobs created. Since May of 1995, Técnico has hired eight skilled persons (engineers, technicians) into the Advanced Materials Group and has received over $800,000 in revenues.

CHAPTER IV

RESULTS AND ANALYSES

Introduction

Previous chapters served to introduce the metric work that has been done to date in measuring technology transfer and culture of researcher attitudes toward technology transfer. Methodologies for extending previous knowledge in these areas were also outlined. These studies provided a framework and a starting point for this study.

In this chapter, the analysis of and the results from the survey of the researchers at NASA Langley Research Center are presented. Also the analysis of successful technology transfer case studies are presented.

Survey of Researchers

The survey at NASA Langley Research Center included 100 researchers with a non-response rate of approximately 5% (5/105). Respondents were surveyed to determine their awareness, attitude, and perceptions regarding technology transfer. The survey results are displayed and the results then analyzed for correlative relationships between survey responses.

Statistical Relationships

The survey questions can be divided into three basic categories: awareness, attitude, and perceptions. Table 4.1 shows the categories and the corresponding survey question for each category. (Refer to Appendix D.4 for the survey questions themselves.)

Table 4.1: Survey Question Categories

Focus of Survey Question	Question Number
Awareness	1, 2, 16, 17, 18, 19
Attitude	3, 8, 10, 11, 12, 13
Perception	4, 5, 6, 7, 14, 15

*Note: Question 9 is an objective measure of the performance plan use.

Awareness

Six of the nineteen survey questions (questions 1, 2, 16, 17, 18 and 19) were directed toward collecting data on the level of awareness which NASA Langley researchers had toward the Agency's and Center's technology transfer policy. The results to these questions are presented in this section in an order which describes the culture (question 1, 2, 16, 19, 18, and 17) and not in the order in the survey. Responses to questions 1 and 2 (Figures 4.1 and 4.2) showed over ninety percent (90%) of the researchers were aware that technology transfer was a mission for the NASA Agency and NASA Langley.

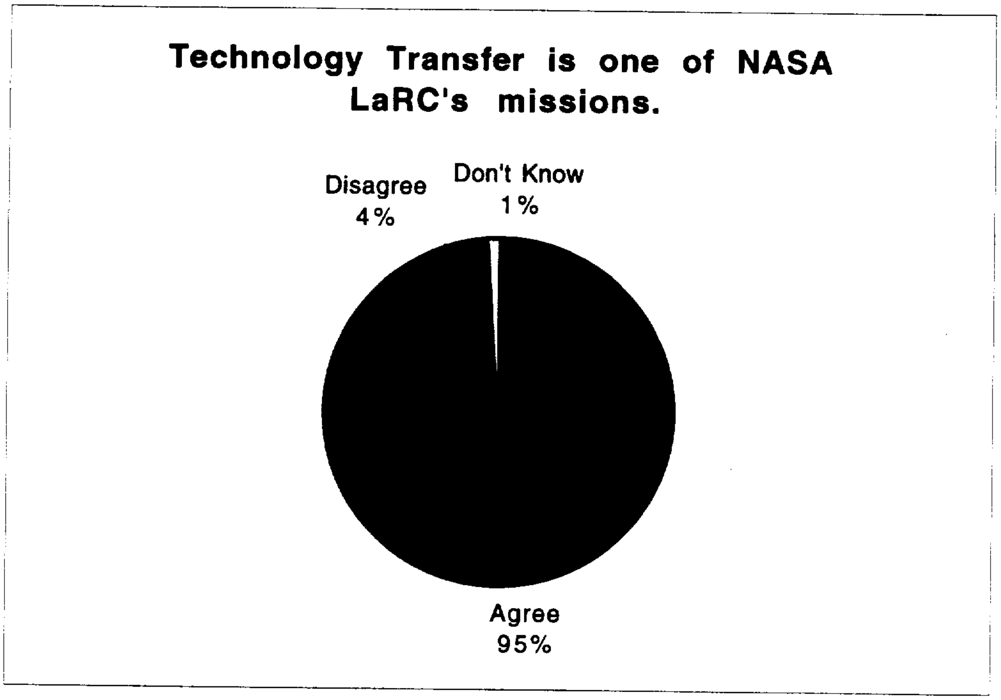


Figure 4.1: Results of Survey Question One

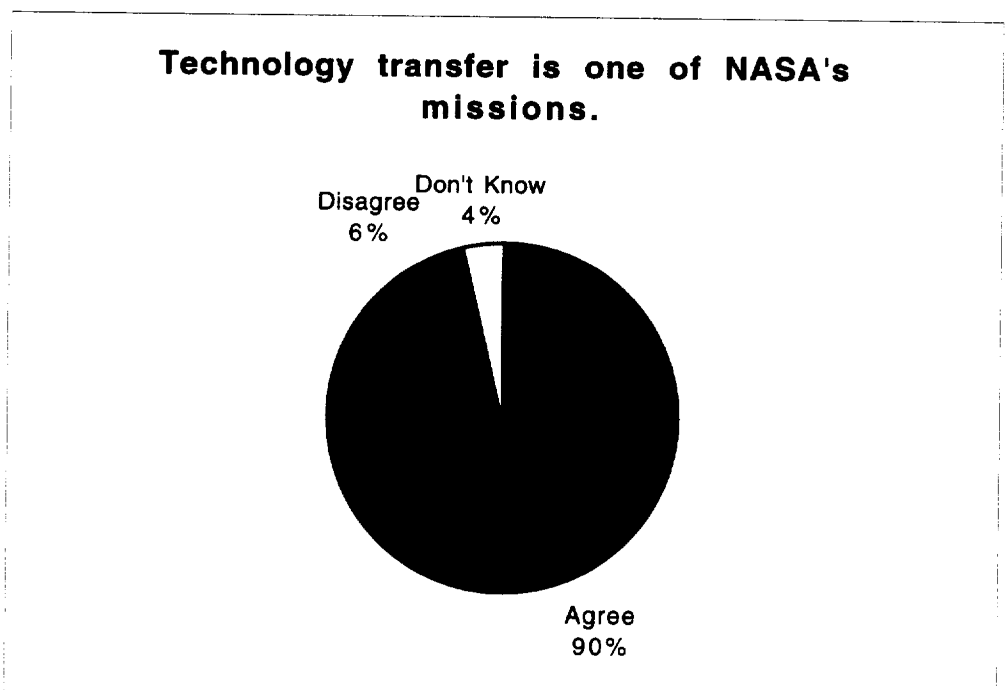


Figure 4.2: Results of Survey Question Two

Question 16 responses (Figure 4.3) indicated that, although researchers were aware of technology transfer as a mission statement, they did not know to what percentage or level that either the agency or Center supported technology transfer as a mission. Less than twenty percent (20%) of the researchers answered correctly for the more specific figure quoted by NASA Langley Research Center (10%-15%; see Appendix A.2). Less than thirty-five percent (35%) of researchers answered correctly for NASA as an

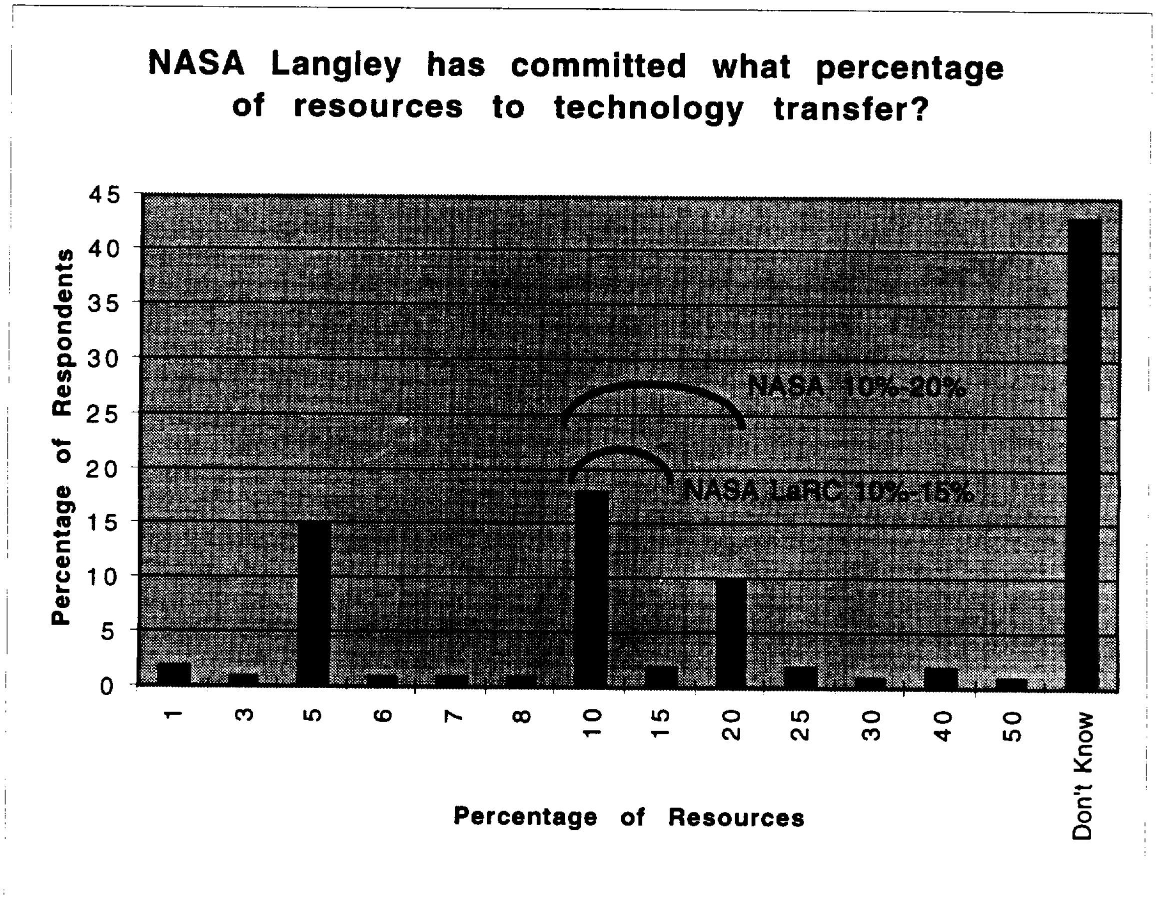


Figure 4.3: Results of Survey Question 16

agency (10%-20%; Agenda For Change 1994) . Forty-three percent (43%) responded "Don't know." The actual awareness may be even lower than the responses reveal. Many of those who responded with the correct answer usually prefaced their answer with the admission that they were guessing.

Results from question 19 (Figure 4.4) revealed that researchers were aware, but at a disappointingly low level, of the organization at the Center to contact for help in transferring technology. The correct response should have been the "Technology Application Group." Although sixty percent (60%) answered the item correctly, fourteen percent (14%) answered incorrectly, and

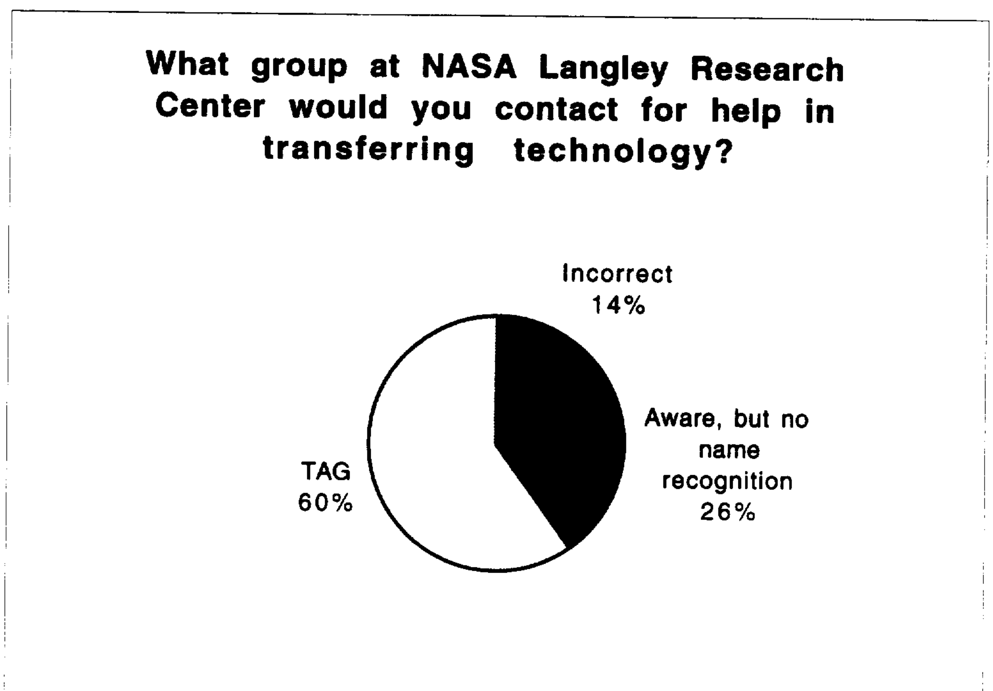


Figure 4.4: Results of Survey Question 19

twenty-six percent (26%) were aware an organization existed, but could not name the organization. It bears mentioning that this survey took place approximately 18 months after a major reorganization at NASA Langley Research Center. The reorganization might have had some impact on the relatively low recognition rate of the Technology Applications Group as the group to contact. At the same time, a higher level of recognition might have been expected since the Technology Applications Group was specifically created as a direct result of the Center placing increased emphasis on technology transfer as one of its primary missions.

Question 18 (Figure 4.5) asked the respondents to identify their technology council member. Each division at NASA Langley has a representative to the technology council. Each council member leads the development and implementation of his or her division's Technology Transfer Plan, which identifies promising new technology that can be transferred to a US industry partner. Council members serve as division focal points and advisors for transfer and commercialization efforts. The poverty of the results may be indicative of more than just researcher awareness and might be indicative of a lack of publicity. Eighty-eight percent (88%) either did not know who their representative was or gave an incorrect answer. The twelve percent (12%), representing those who did answer correctly, is misleading, since four percent (4%) of that total were the council member.

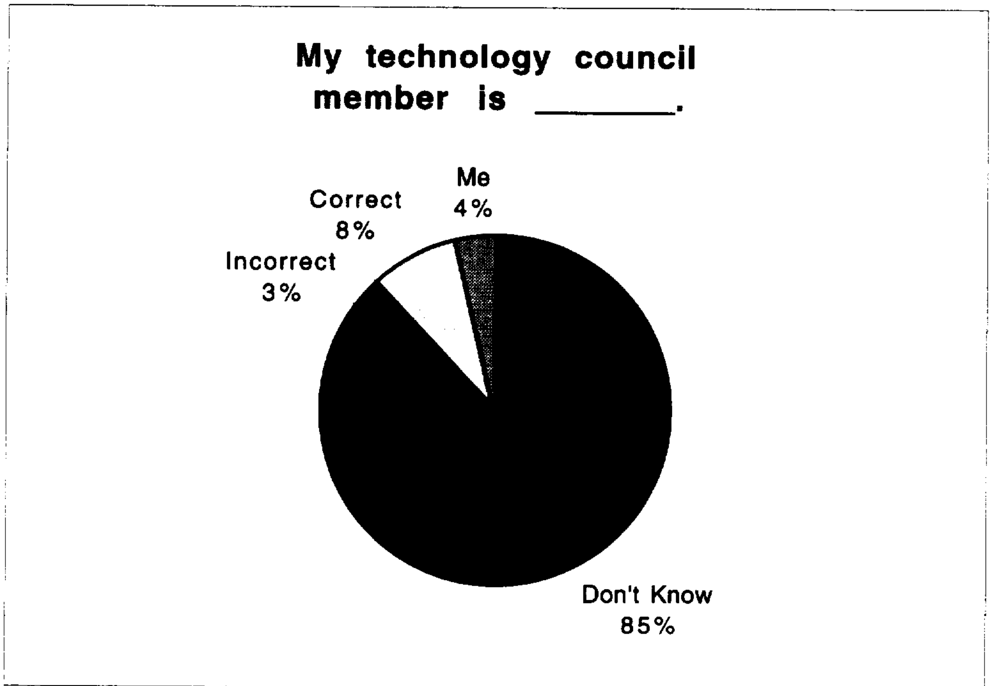


Figure 4.5: Results of Survey Question 18

Question 17 (Figure 4.6) was an open-ended question. Researchers were to list the mechanisms which they would use to transfer their technology to the private sector. Researchers could list any number of mechanisms. Responses to question 17 (Figure 4.6) were the most revealing about the level of awareness of researchers toward technology transfer. Publications ranked first as the mechanism of choice. Memoranda of Agreement and Memoranda of Understanding (MOUs and MOAs) ranked fifth, and were the highest ranked formal mechanisms. Other traditional measures of technology transfer activities ranked much lower: patents 7th; licensing 15th; problem statements 18th; and Small Business Innovative

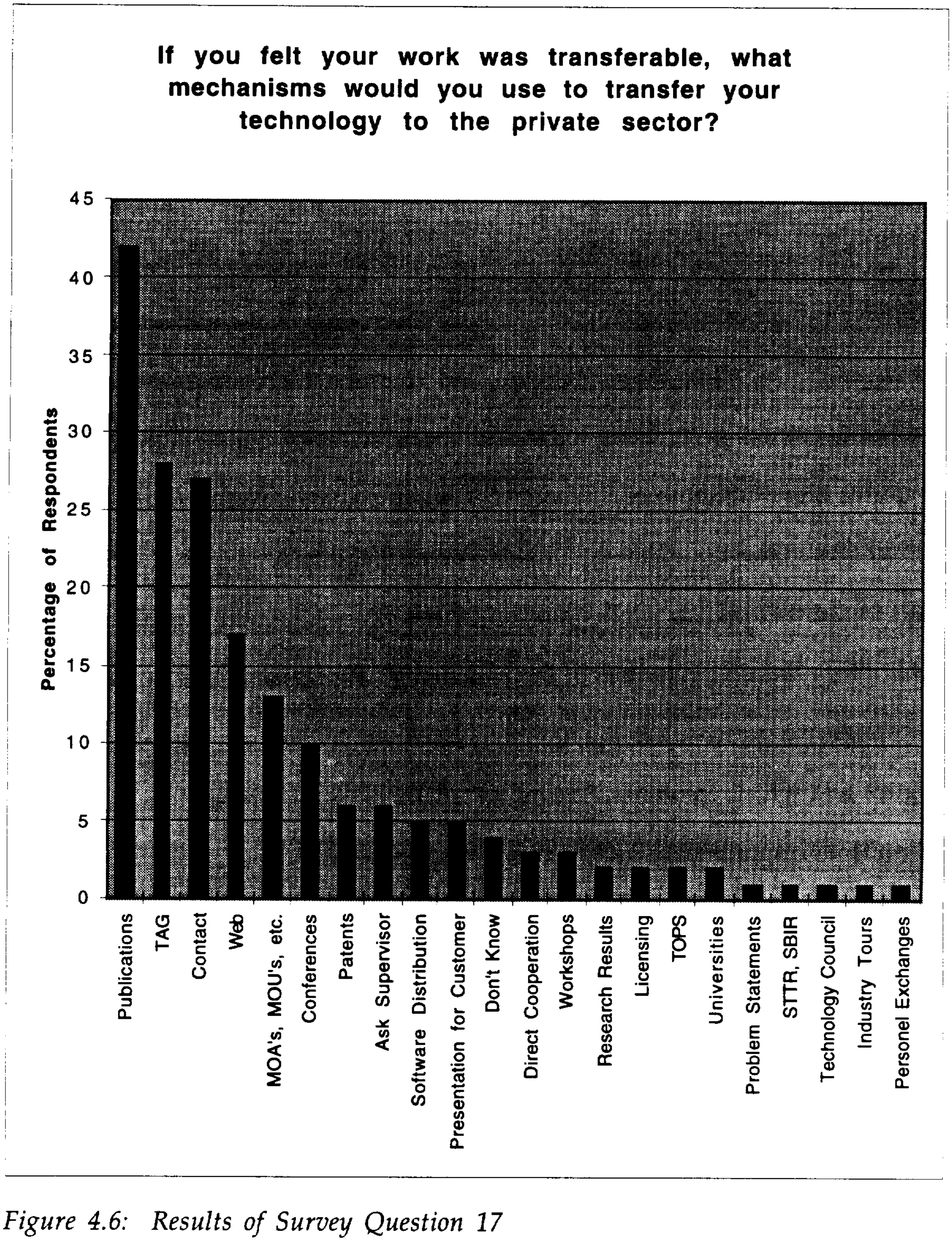


Figure 4.6: Results of Survey Question 17

Research (SBIR) 19th. Most of these traditional measures placed beneath "Don't know," which was 11th in listing.

Attitude

In this study, the measure of the researcher attitudes toward technology transfer is best understood when viewing the results of the attitude questions in totality. Questions three, eight, 10, and 12 probe the researchers personal attitudes toward performing technology transfer. Each question progressively requires more commitment, responsibility, and accountability from a researcher. Question three requires no accountability or responsibility on the part of the individual, while question 12 ties promotion status to the technology transfer activities of the researcher. Results for each of these questions are presented in the next four figures (Figures 4.7 - 4.10), followed by Figure 4.11 which combines Figures 4.7 - 4.10, in order to visualize the shift in attitude as responsibility and accountability increase.

The NASA Langley researchers strongly supported technology transfer as a mission at the Center, with over ninety-four percent (94%) agreeing with question three that the Center should be doing transfer (Figure 4.7). Over fifty percent (50%) of the respondents strongly agreed.

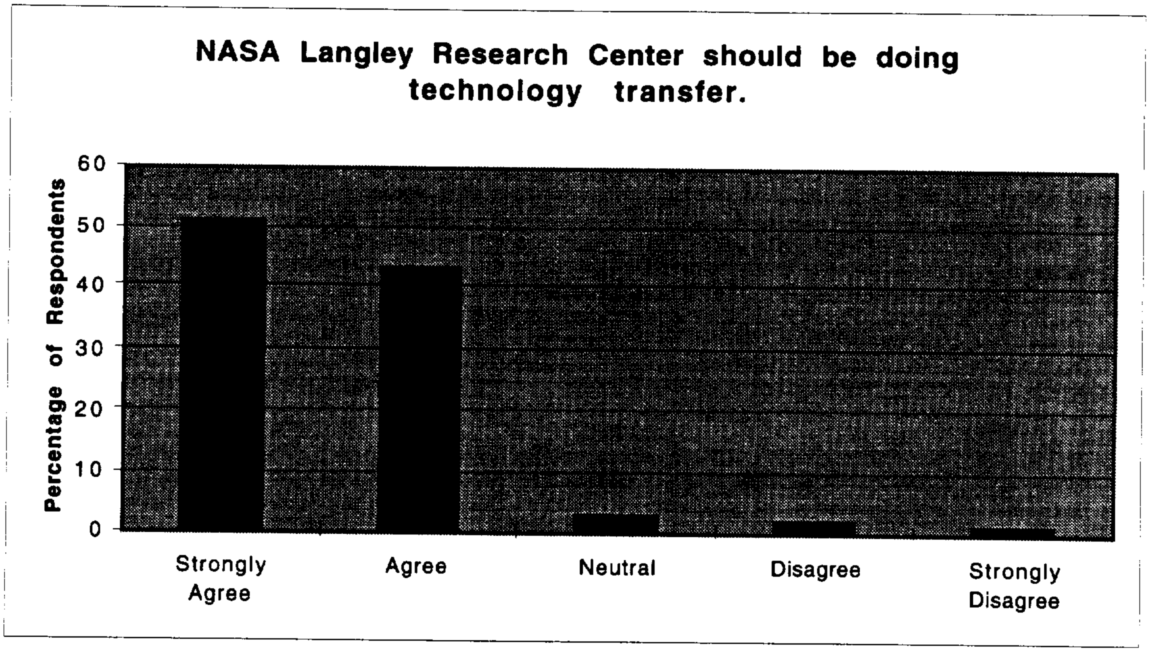


Figure 4.7: Results of Survey Question 3

Question eight (Figure 4.8) introduced the issue of technology transfer as a personal responsibility of researchers. The question conveyed the message that technology transfer activity was an element of the researchers responsibilities. The contrast in answers from questions three and eight indicated that there is an "It's someone else's responsibility" issue. Positive responses (strongly agree and agree) dropped from ninety-four percent (94%) in question three to sixty-four percent (64%) in question eight. Strongly agree was the dominant response in question three. Agree was the dominant response in question eight. A slight shift was noted in attitude as the questions proceeded from more general (e.g., Center's duties) to more specific (e.g., researcher duties).

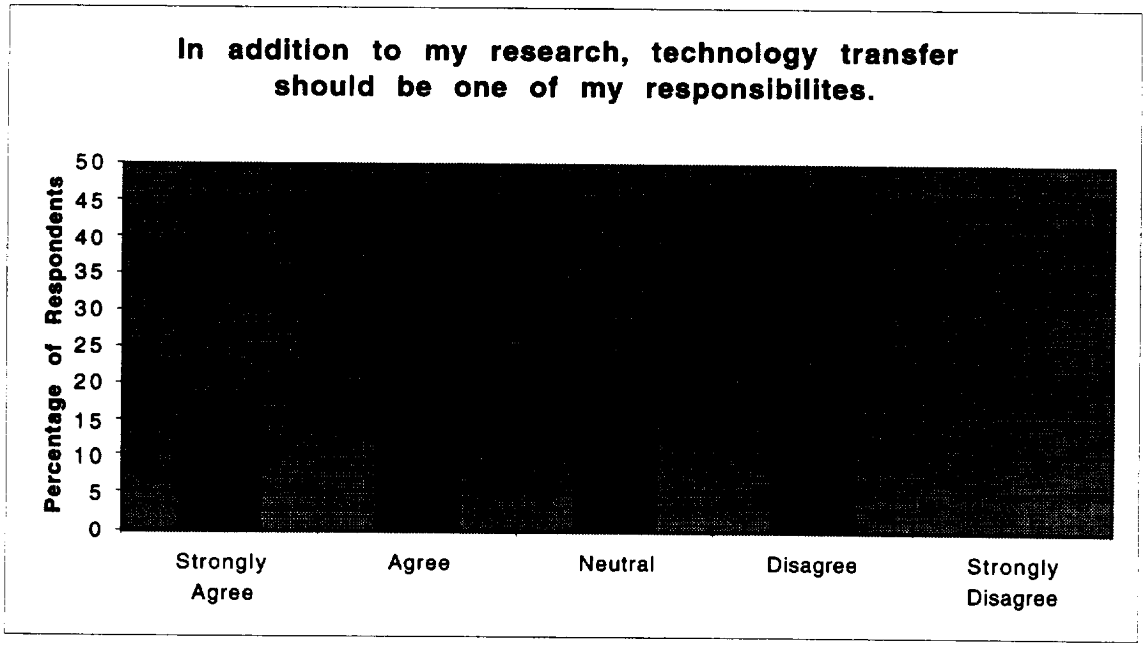


Figure 4.8: Results to Survey Question 8

Question 10 (Figure 4.9) became even more specific about the technology transfer responsibility of the researcher. This question presented the position that technology transfer should be a part of the researchers performance plan and/or performance appraisal. Strongly agree answers declined to eight (8%), and strongly disagree responses accounted for nine percent (9%). More respondents strongly disagreed than strongly agreed. Positive answers for the first time dipped below a majority level to forty-three percent (43%).

Question 12 (Figure 4.10) quantified the personal reward and risk implied by question 10 with its clear tie between technology transfer and

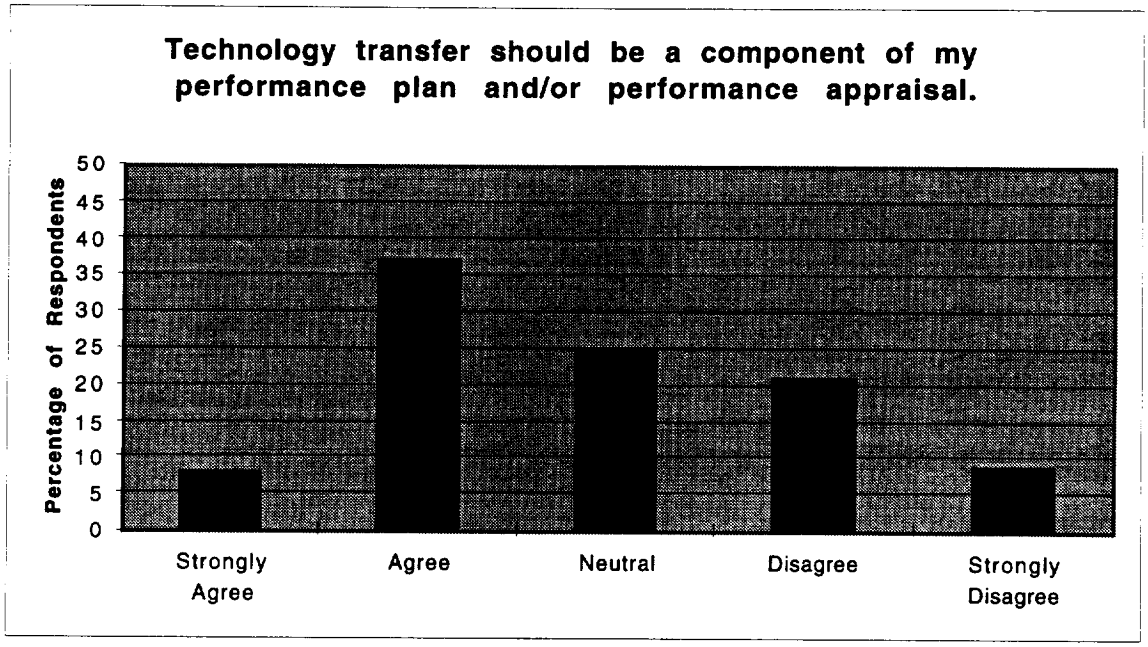


Figure 4.9: Results for Survey Question 10

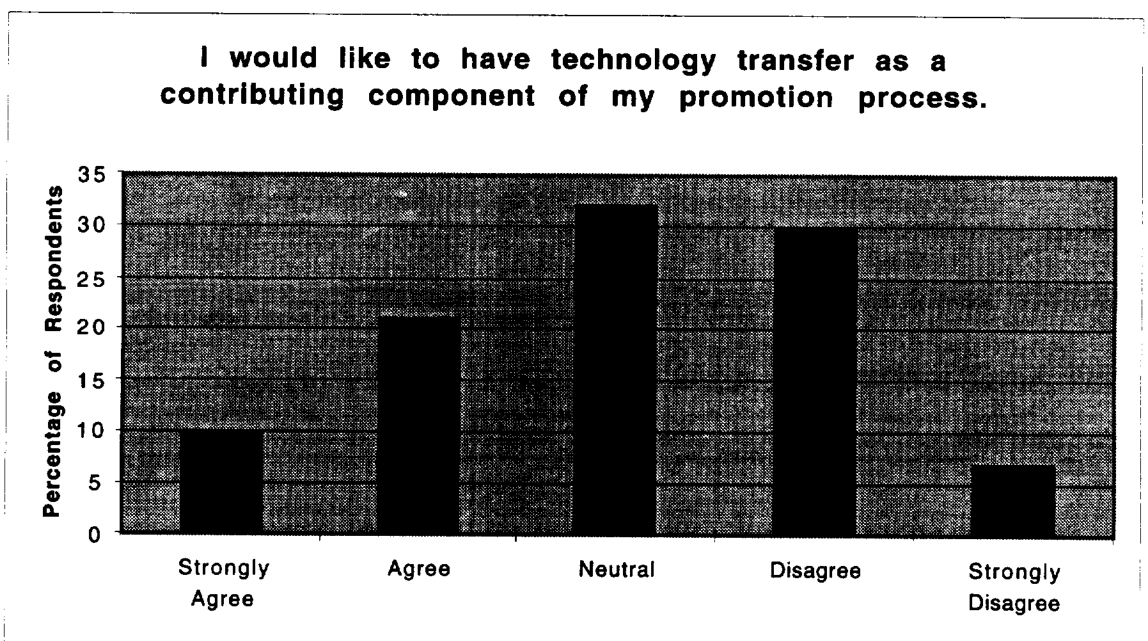


Figure 4.10: Results of Survey Question 12

promotions. This additional reward/risk issue shifted the majority of opinion from positive responses thirty-one percent (31%) to negative responses thirty-seven percent (37%).

Figure 4.11 combines the results from questions three, eight, 10, and 12 to graphically display the shift in attitudes towards technology transfer as personal responsibility and accountability increased.

Results for question 11 are more relevant when viewed in conjunction with the results of question 10. Question 11 was a lengthy statement intended to determine if researchers would prefer that technology transfer not be a planned activity on their performance plans, but an activity that they could place on their performance appraisal and receive due credit for unplanned successes. This question was included because it was expected that many researchers perceived technology transfer and technological breakthroughs similarly, in that both are very difficult and risky to predict. The majority of those researchers who answered with either a negative (disagree, strongly disagree) or neutral response on question 10, shifted responses to the positive (agree and strongly agree) side on question 11 (these are represented by the three lines on the right of Figure 4.12). This supported the hypothesis that the researcher does not want to feel obligated to perform technology transfer, but would like the option to receive credit when it is performed (a sort of "extra credit").

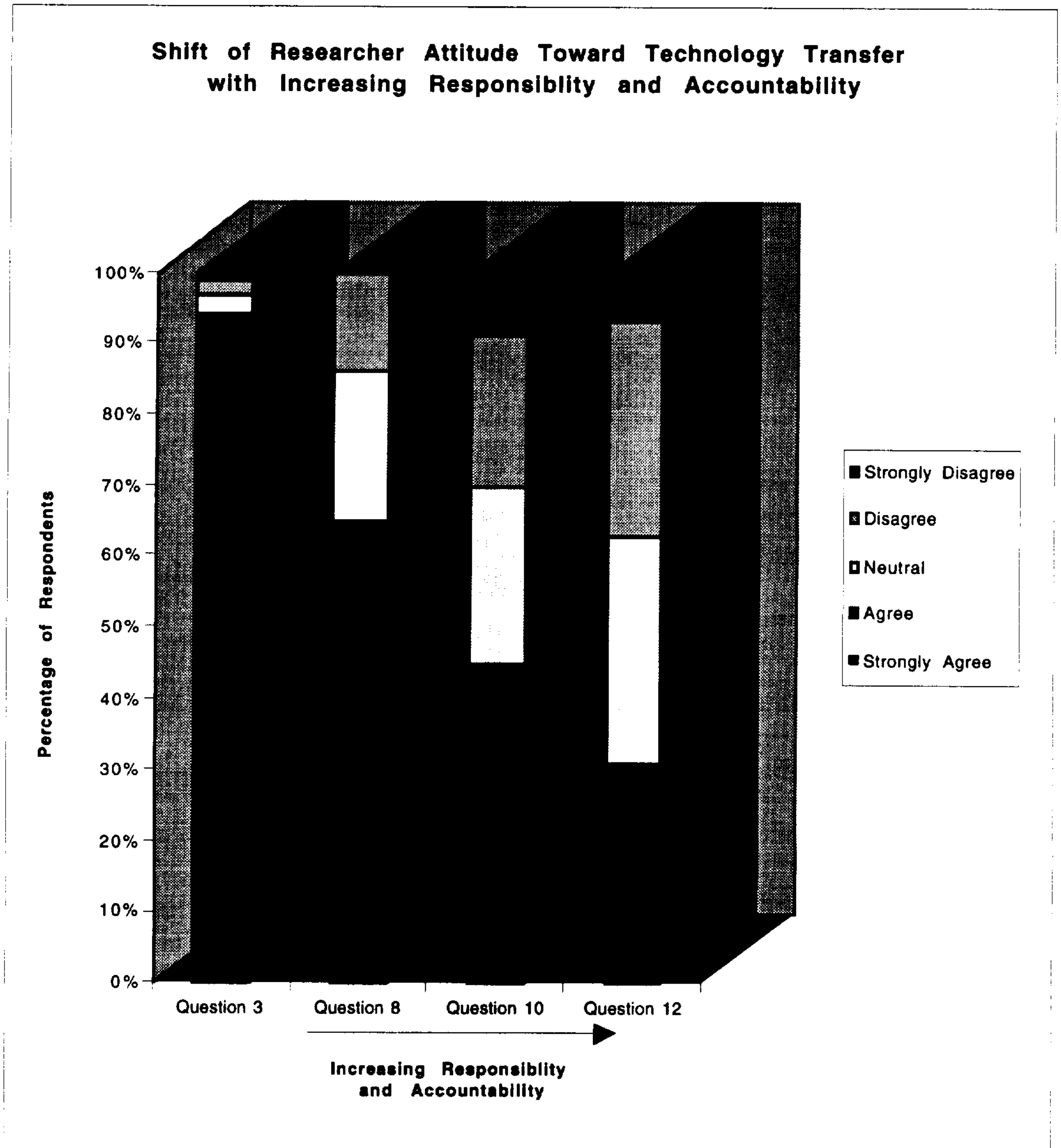


Figure 4.11: Combined Results for Survey Questions 3, 8, 10, and 12

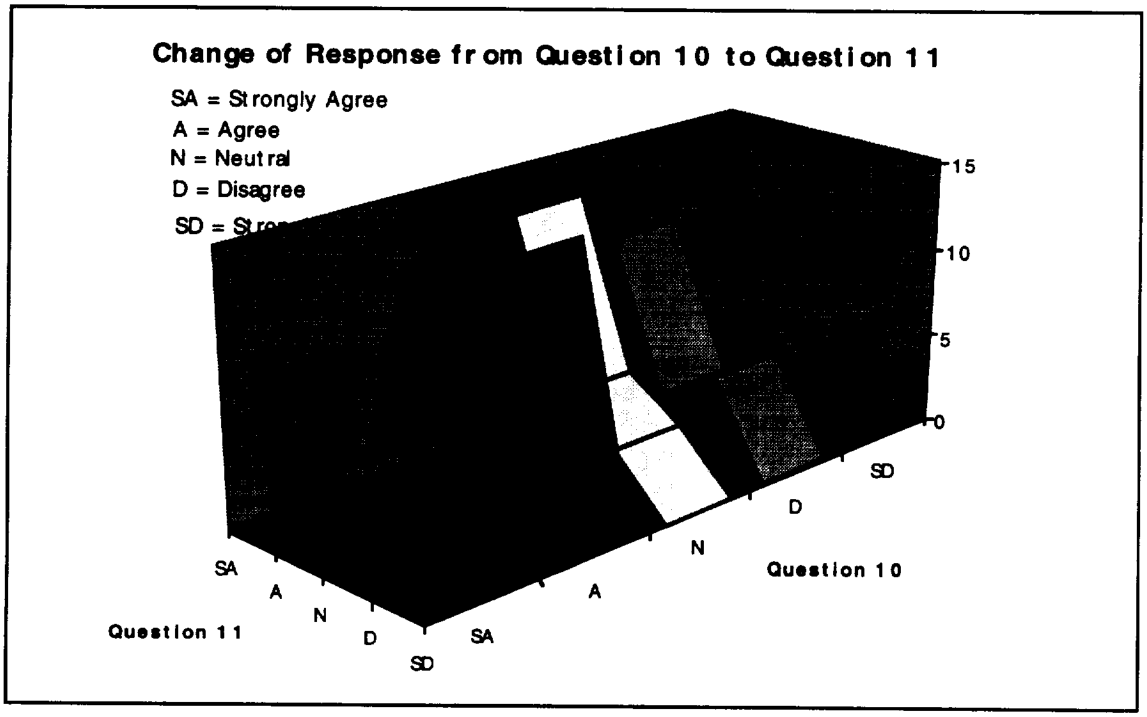


Figure 4.12: Change of Response from Question 10 to Question 11

An additional, unexpected result occurred in question 11. Many of those individuals who strongly agreed with question 10, took strong exception in question 11 (left most line, Figure 4.12). Recorded comments during the survey indicate that these respondents felt technology transfer was their job, and that it should not only be on the performance appraisal but should be planned for and therefore be placed onto the performance plan.

Those who responded with an agree in question 10, split between the attitude shared by those answering strongly agree to question 10 and taking a new position. Given the new option in question 11, almost half of these respondents sided with those who felt it should be only on the performance appraisal. Overall, fifty-three percent (53%) of the researchers were positive about having technology transfer on their performance appraisal and not necessarily a planned task. Seventy-five percent who gave negative results (disagree) in question 11 had originally, in question 10, agreed with having technology transfer as a component of the performance plan. If we assume that those researchers who strongly agreed or agreed with question 10 and disagreed with question 11 for "philosophical" reasons could be counted toward agreeing to the concept of having technology transfer only on the performance appraisal, then the percentage of researchers increases to an astounding eighty-three percent (83%).

Responses to question 13 (Figure 4.13) were interesting due to the expressed feeling which the respondents answered the question as if there were but one reasonable. Yet, respondents fell into three general categories. The first was those who answered positively and felt they had to act within whatever guidelines were established. The second was those who answered negatively because they would do technology transfer regardless of whether it was a component of the promotion process. The third was respondents who said their actions are independent of the reward structure. Overall, less than thirty percent (30%) said they would not put more effort into technology transfer if it were a component of the promotion process. Removing those who disagreed with the statement on grounds that they would perform

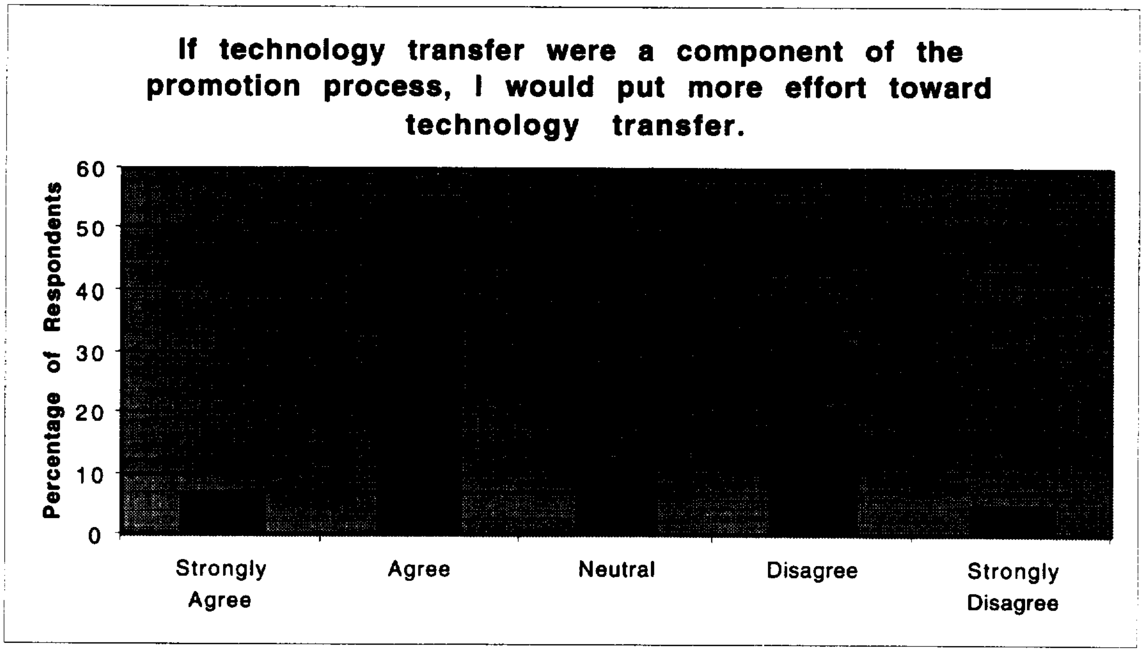


Figure 4.13: Results of Survey Question 13

technology transfer anyway, the percentage of researchers who objected to performing technology transfer was closer to twenty percent (20%).

Perception

Questions four, five, six, seven, 14, and 15 measured researcher perceptions of a potential to perform technology transfer. Specifically, questions four through seven measured the researchers' perceptions of their own technology transfer skills, while questions 14 and 15 measured their perceptions of management support for the researcher doing technology transfer.

When asked (question 4) to judge whether their research had potential for technology transfer, sixty-nine percent (69%) of the respondents felt their research had potential, seventeen percent (17%) believed that their research did not, and fourteen percent (14%) were unsure (Figure 4.14).

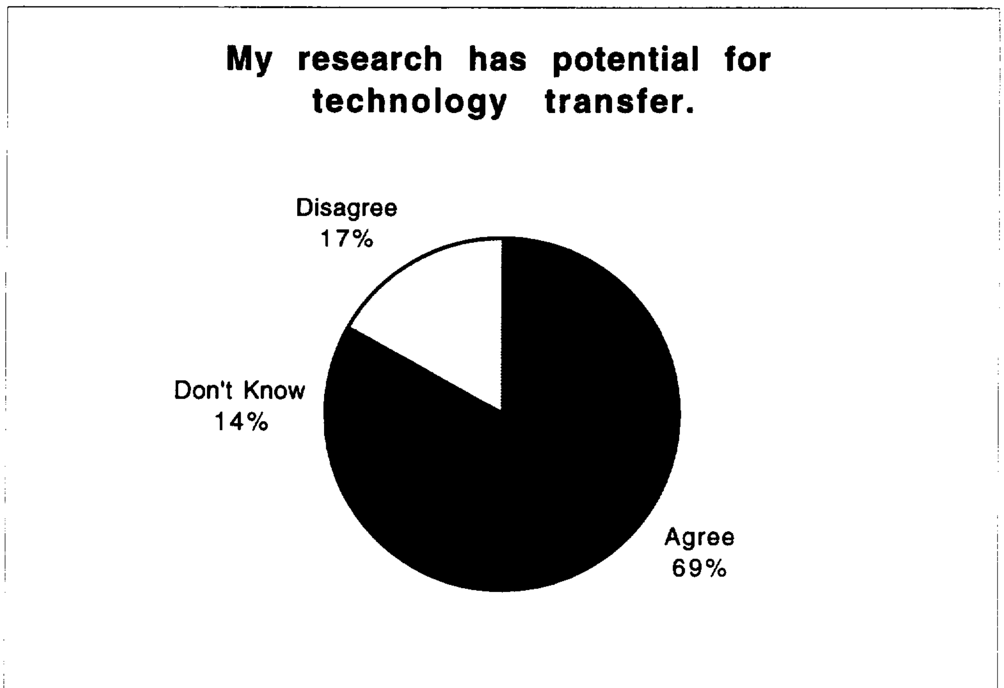


Figure 4.14: Results of Survey Question 4

When respondents were asked in question five to estimate the percentage of their research applicable to technology transfer, responses varied broadly (Figure 4.15). The median was twenty-five percent (25%) and the mean was thirty-four percent (34%).

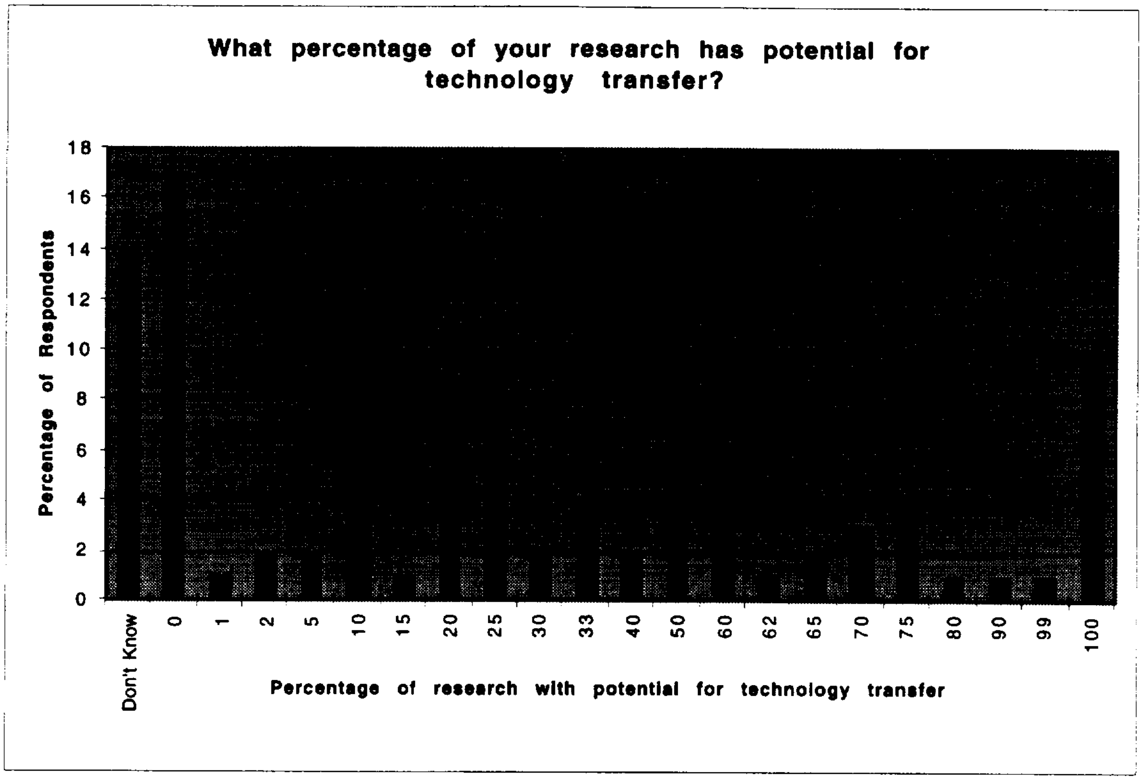


Figure 4.15: Results of Survey Question 5

Technology transfer cannot occur without some measured ability on the part of the researcher. In survey question six, sixty percent (64%) of researchers responded that they had not been adequately prepared to perform technology transfer and thirty-six percent (36%) felt that they had been adequately prepared (Figure 4.16).

As a follow-up to question 6, question 7 asked researchers to identify ways (e.g., training) which would help them to perform technology transfer. More than one answer could have been selected. The majority of

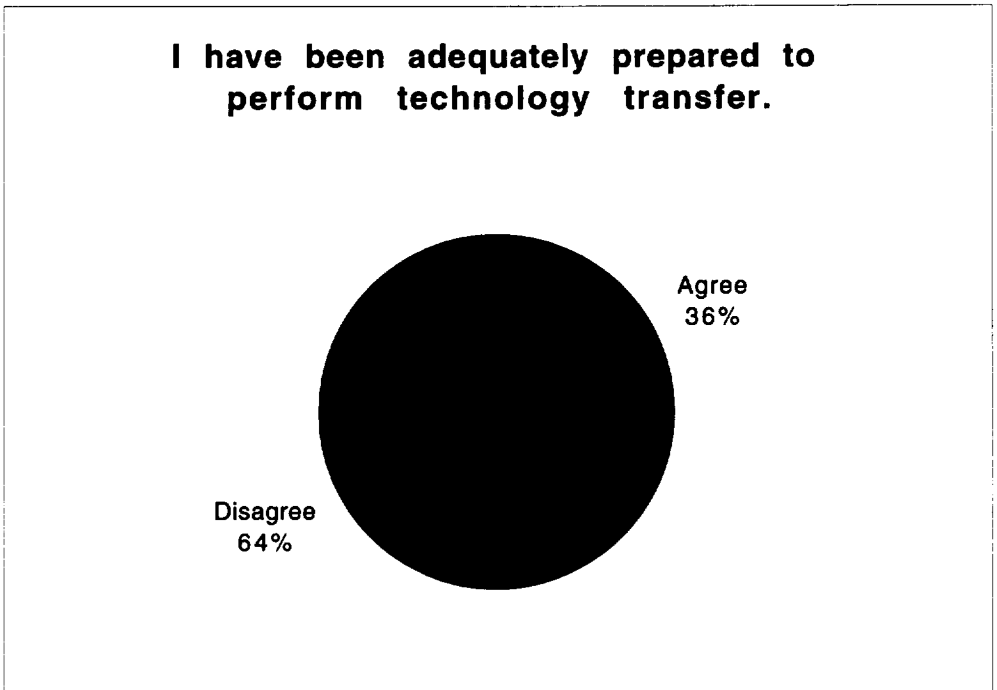


Figure 4.16: Results of Survey Question 6

respondents felt that education, training, or management support would help them to better perform technology transfer (Figure 4.17). Education about the process was selected most often by participants (57%) with an equal number selecting tangible support by management and training on performance of technology transfer (38%). Within the "other" category (20%), participants identified a range of items mostly indicative of a lack of understanding of technology transfer.

Question 14 picked up on the theme of management support, as introduced in question seven. Researchers were asked whether their immediate management provided tangible support (not just "lip service") to

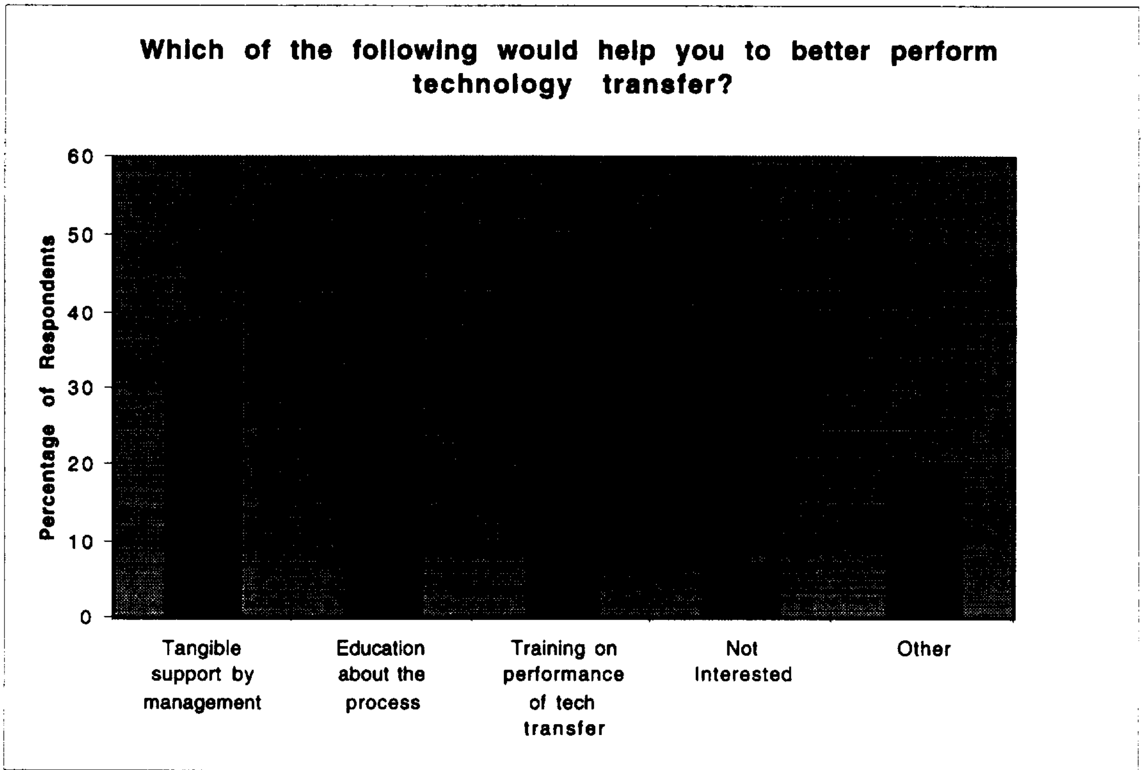


Figure 4.17: Results of Survey Question 7

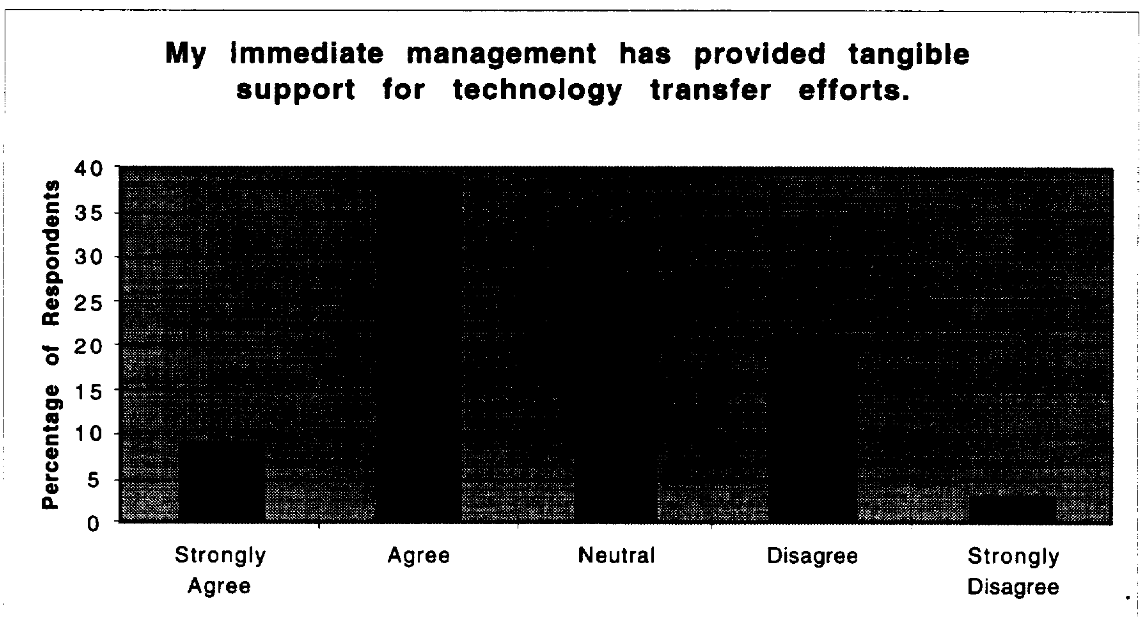


Figure 4.18: Results of Survey Question 14

technology transfer efforts. The majority of responses fell within the range of agree to disagree with the statement. Forty-eight percent (9% strongly agreed, 39% agreed) responded that their immediate management had provided tangible support for technology transfer, twenty-eight percent (28%) responded neutral, twenty-one percent (21%) disagreed, and three percent (3%) strongly disagreed. Thus, the perception of over fifty percent (50%) of those surveyed was that management did not provided tangible support to technology transfer efforts (Figure 4.18).

Question 15 asked researchers to rate, on a scale from 0 (inhibits) to 10 (helped significantly), the level to which their managers participated in technology transfer. Researchers gave generally good marks when rating their managers participation in technology transfer (Figure 4.19). These results are somewhat confusing considering that less than 50% of the researchers perceived their managers as giving tangible support (question 14) while 62% of the researchers gave a value of 6 or higher for their management in question 15.

Correlations

A Pearson product moment (correlation coefficient) was calculated for each pair of the survey results. The results are shown in Table 4.2. The table was constructed to reflect the categorization of the questions by awareness,

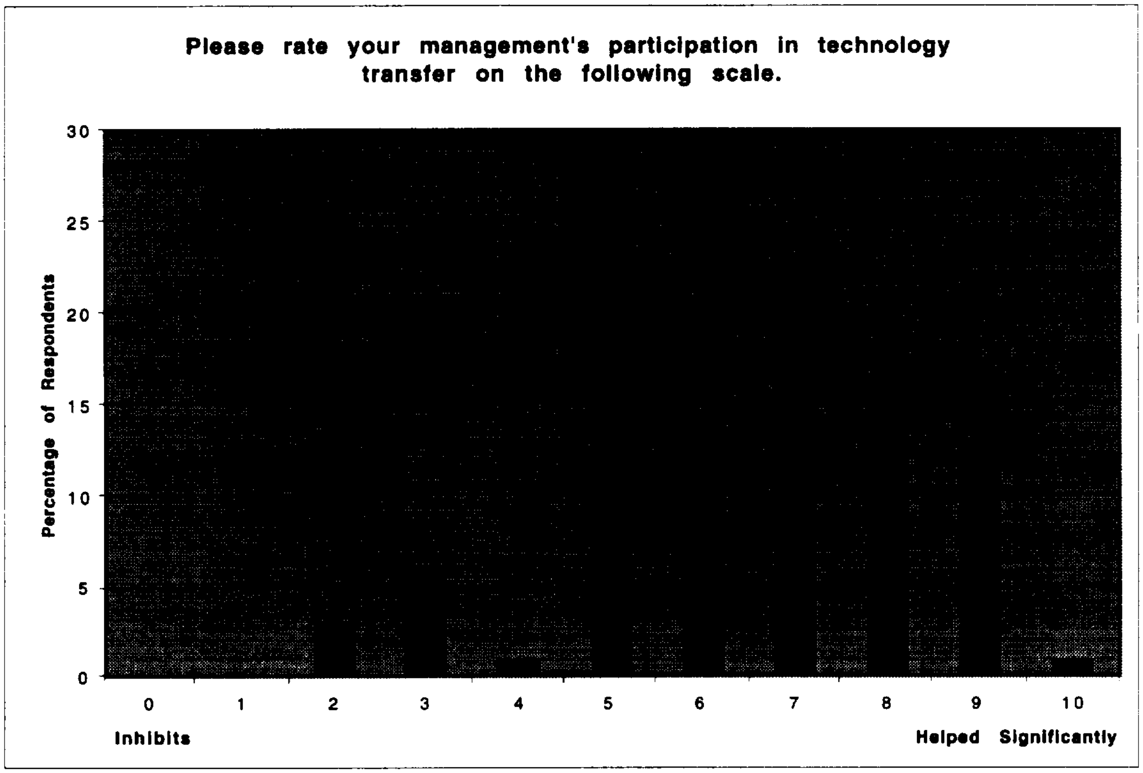


Figure 4.19: Results of Survey Question 15

attitude, and perception. Further correlations between the survey questions and researcher ages and education levels were performed. Figures 4.20 through 4.23 present the age and education correlations.

Correlations showed positive attitudes toward technology transfer (questions 3, 8, 10, and 12) related to both positive perceptions and more awareness. Positive responses to the attitude questions (3, 8, 10 and 12) seemed to be the common element in any significant correlation coefficient between awareness, attitude, and perception (see shaded areas of Table 4.2). Cause and effect cannot be extrapolated from this data.

Table 4.2: Correlation Matrix of Survey Responses

		Awareness		Attitude						Perception				
	Ques	1	2	3	8	10	11	12	13	4	5	6	14	15
Awar.	1													
	2	0.767												
Att.	3	0.496	0.392											
	8	0.194	0.215	0.363										
	10	0.207	0.218	0.345	0.615									
	11	-0.099	0.025	-0.034	-0.126	-0.272								
	12	0.199	0.191	0.289	0.457	0.514	-0.227							
	13	0.057	-0.036	0.031	-0.002	-0.011	-0.071	0.194						
Perc.	4	0.249	0.241	0.260	0.396	0.277	0.075	0.293	0.090					
	5	-0.190	-0.193	-0.290	-0.396	-0.405	0.089	-0.241	0.165	-0.634				
	6	0.064	0.073	0.148	0.319	0.186	0.064	0.097	-0.093	0.198	-0.143			
	14	0.042	0.215	0.037	0.286	0.188	0.051	0.156	-0.033	0.346	-0.248	0.297		
	15	-0.028	-0.080	-0.104	-0.121	-0.157	0.017	-0.185	0.150	-0.186	0.259	-0.111	-0.616	
	Age	-0.058	-0.130	0.108	-0.088	-0.089	0.073	0.088	0.325	0.053	0.111	-0.198	-0.185	0.047
	Educ	-0.018	-0.032	0.107	-0.006	-0.080	-0.074	-0.047	0.077	-0.218	0.211	-0.160	-0.060	-0.045

Age correlated strongly with one attitude measure and two perception measures. A strong correlation existed between age and willingness to perform technology transfer if it were part of the promotion process (question 13). The older the respondent, the less likely he or she was to agree to performing technology transfer if it were a part of the promotion process. Younger respondents were more apt to agree to perform technology transfer if it were part of the promotion process. Both the researcher's own sense of preparedness and his or her perception of management support correlated negatively with age. Thus, as age increased there were less positive responses to the perception of management support and researcher preparedness to perform technology transfer.

One significant correlation (questions 4 and 5 combined) between education and the survey responses was found. As the education level increased, the respondent's belief that his or her research had technology transfer potential increased (question 4, Figure 4.20 and Table 4.2). In addition, their estimated percentage of research that had potential for technology transfer increased with education level (question 5).

A bar chart of the responses to survey question six categorized by education level was revealing (Figure 4.21). Clearly, the PhDs were more likely to feel adequately prepared for technology transfer. Yet there is nothing to substantiate this belief, since, to date, no specific technology transfer

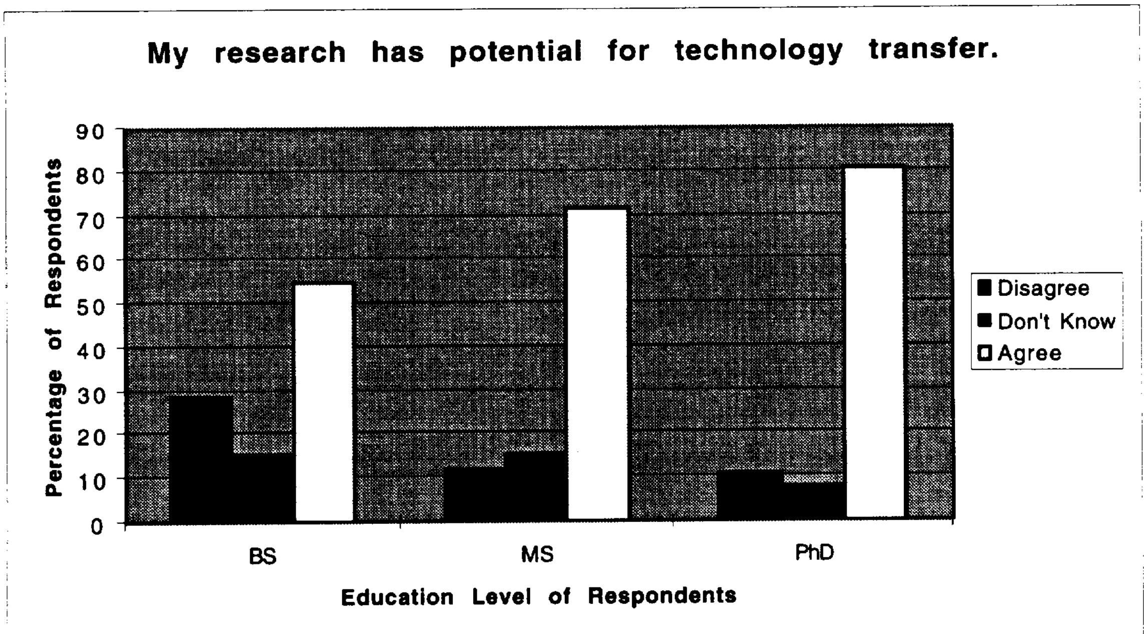


Figure 4.20: Results of Survey Question 4 by Education Level

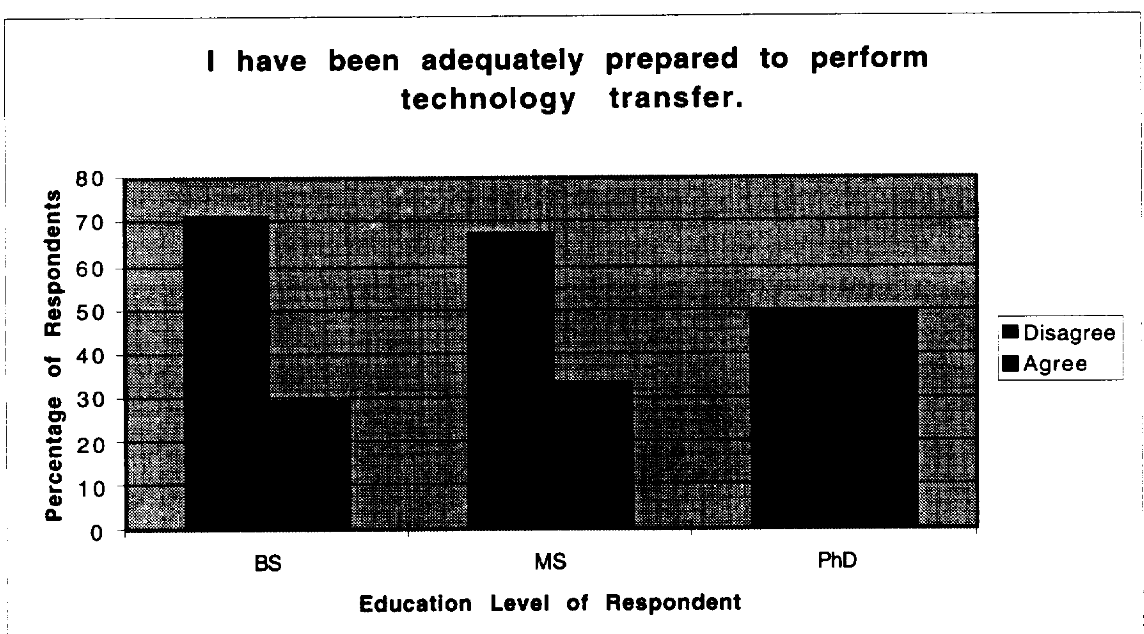


Figure 4.21: Results of Survey Question 6 by Education Level

education or training courses had been performed for any employees by the NASA Langley. There appears to be a linear relationship between the education level of respondents and the confidence in their potential.

Reviewing question nine by education level revealed that a significantly larger number of PhDs claimed that technology transfer was a component of their performance plan and/or performance appraisal (Figure 4.22). This question did not result in a linear relationship between education levels, but rather a distinct difference between the PhD respondents and all others.

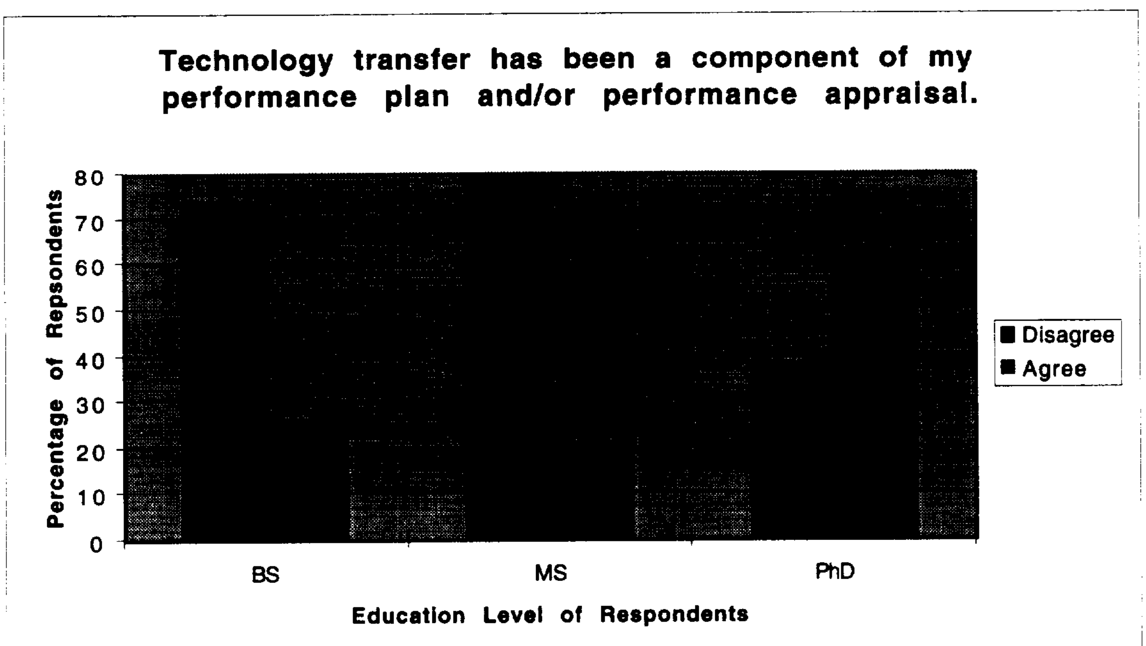


Figure 4.22: Results of Survey Question 9 by Education Level

Results to question 16 were interesting when contrasted with the previous education correlations. Although, PhDs were more likely to believe their research had technology transfer potential than other respondents, a larger percentage of the PhDs were the least informed among those surveyed about actual funding levels by NASA or NASA Langley for technology transfer (Figure 4.23). The percentage of PhDs who responded incorrectly was twice that of MS respondents and three times that of BS respondents. In addition, PhDs had the smallest percentage admitting ignorance, while MS researchers as a group had a majority admitting ignorance.

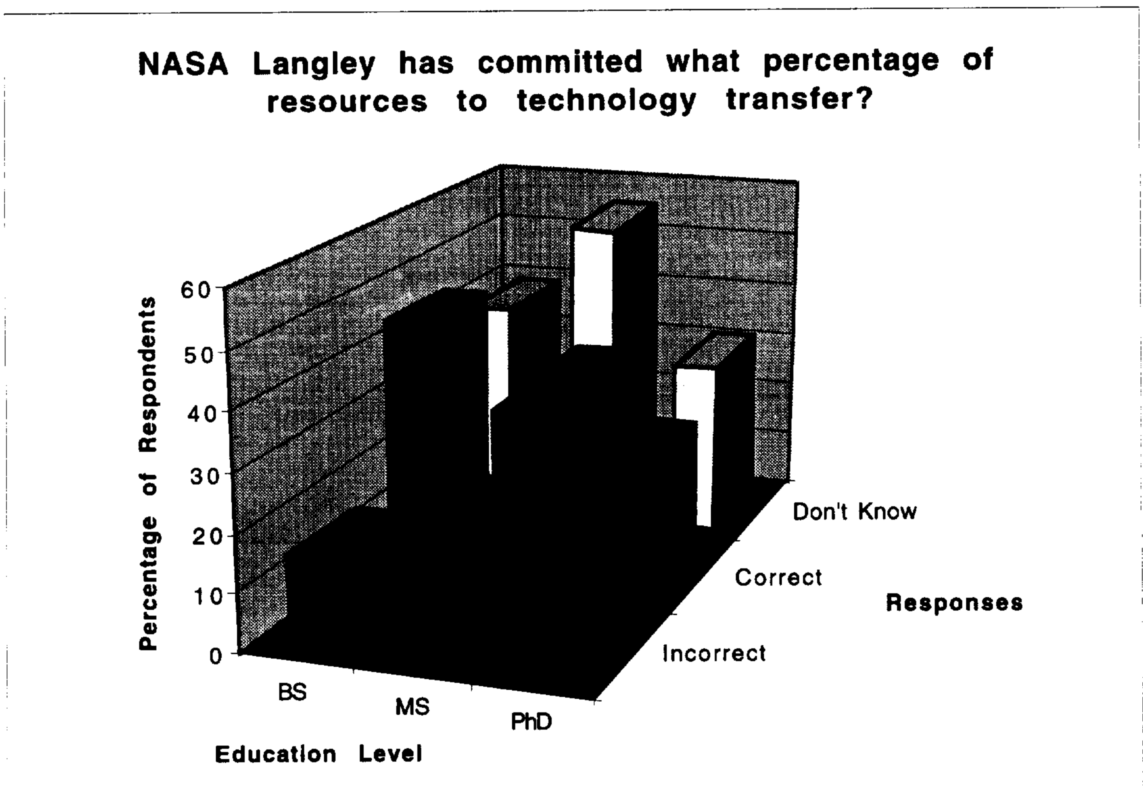


Figure 4.23: Results of Survey Question 16 by Education Level

Temporal Effect

At the time of the survey there were significant events affecting employee attitude, including continuing budget impasses, low morale, and announced work force reductions. Announcements of particular events could cause volatility in attitudes toward specific programs (i.e., technology transfer). The survey was performed over a two week period. During the sampling timeframe rumors and announcements were made concerning NASA's future. For each question a scatterplot of the responses versus the day they were collected was created. There was no evidence in these scatter plots that outside events significantly altered the responses. An observation made by the interviewer was that the respondents tended to be either more or less combative depending on the previous days work-related events (e.g., furloughed for one week).

Summary of Results for Survey

The survey of researchers at NASA Langley Research Center led to two major conclusions:

1. Researchers are aware of the technology transfer mission of the NASA agency and NASA Langley Research Center, but are minimally aware of the mechanisms to perform technology transfer and the appropriate individuals or organizations to contact within their Center to help them with technology transfer.

2. Although researchers feel that the Center should be performing technology transfer, they do not want to be held responsible or accountable for performing technology transfer.

Case Studies

Three cases of successful technology transfer from NASA Langley to the private sector were identified for closer examination. Success was defined by a positive economic impact on the partner. Potential measures for successful economic impacts are outlined in Table 2.2 (see Chapter II). These three cases were examined in an attempt to discover elements crucial to the success of the projects. The goal was to identify linkages between the outcome metrics, intermediate metrics, and input metrics. Each case was analyzed to determine the crucial elements leading to success and metrics linking. Quantitative data along with testimonials and historical documentation were collected and are presented for each case.

The three case studies are presented in a chronological order, with the oldest case first: MacNeal-Schwendler Corporation (1960s), Pressure Systems Incorporated (late 1970s and 1980s), and Técnico (1993-1996). This order, coincidentally, is the order of economic impact, with MacNeal-Schwendler Corporation in the $100M per year range, Pressure Systems Incorporated in the $10M per year range, and Técnico in the $1M per year range.

MacNeal-Schwendler Corporation

The MacNeal-Schwendler Corporation (MSC) was selected as a case based on its commercial success ($100M/annum) and on its cooperation with NASA to develop the software code it markets. MSC's interaction with NASA resulted primarily in a new software product line and new commercial sales.

MSC had annual sales of over $100M in 1995 and $79M in 1994 (Table 4.3). It is the world leader in mechanical computer-aided engineering software, as measured by annual sales, capturing over 30% of the global market. The next largest competitor had sales less than one-third that of MSC.

Table 4.3: MacNeal-Schwendler Corporation Annual Revenues, 1991-1995 (MacNeal-Schwendler Corporation Annual Report 1995)

	Annual Revenues $(000)				
Year	1991	1992	1993	1994	1995
Revenues	66,577	67,330	77,190	79,574	100,685

These annual revenues were primarily the result of the sales of software code MSC/NASTRAN. Thomas Business Register contained an excellent description of the MSC/NASTRAN product:

> MSC/NASTRAN is a large, sophisticated software program consisting of over 900,000 source statements. It is based upon the finite element method of analysis by which complex structures are divided into small elements which form a finite element model. The model is then subjected to computer analysis. MSC/NASTRAN is used to analyze structures in order to determine among other things, their strength, safety and performance characteristics (Thomas Business Register 1995).

MSC/NASTRAN is sold to aerospace, automotive, defense, and engineering industries. A brief history of the cooperation between NASA and MSC, and the ensuing development of MSC/NASTRAN follows. A comprehensive history of the company and the technology's development can be found in the book, *The MacNeal-Schwendler Corporation: The First 20 Years.*

MSC was incorporated in 1963 with $18,000 in private capital and three employees, including the two principals Richard (Dick) MacNeal and Robert (Bob) Schwendler. Originally MSC concentrated on consulting work utilizing analog computers but later recognized the demise of analog computers and became involved in the NASTRAN project.

In 1964 no finite-element programs were available to the public on a regular basis through payment of fees. About this time a NASA committee was formed to investigate the state of analysis in the aerospace industry community. The funding for this study came from Mel Rosche and Doug Michel at NASA headquarters. This committee was headed by Tom Butler of NASA's Goddard Space Flight Center. The committee recommended that

NASA sponsor development of its own finite-element program as a means to upgrade the analytical capability of the entire aerospace industry. The program eventually came to be known as NASTRAN. There were many people within NASA who thought this was a bad idea and voiced their displeasure toward the project. Against the voices of detractors, Rosche and Michel agreed to fund development of the program, based on the committee recommendation. An announcement of opportunity was released.

Although MSC was considered to be too small at the time of the bidding for the large NASTRAN contract, Dick MacNeal sought out a partnership with Computer Sciences Corporation (CSC) in order to have a better chance of competing. According to Phil Raney, the eventual manager of the NASTRAN office for NASA, CSC would not have gotten involved if it were not for Dick MacNeal from MSC (Raney 1996). The strategy worked. The CSC/MSC team won one of two Phase I bids for preparation of a Technical Evaluation Report. The Phase I bid award was for $83,000. Approximately $30,000 of this award was received by MSC (MacNeal p. 45, 1988).

Then in 1966 when the Phase II proposal was announced, the CSC/MSC teams proposal was selected to develop the NASTRAN code. The contract was worth $1,000,000, of which MSC eventually received $635,000. During the project, MSC was able to develop strong in-house expertise with the code, and consequently, was able to secure other commercial contracts relating to NASTRAN (MacNeal p. 56, 1988).

MSC's ability to secure both the Phase I and Phase II bids was incredible considering the size and historical background of their competition. During the Phase I proposal MSC had to compete against most of the large aerospace corporations, including monolithic Boeing. During Phase II, MSC was able to win by beating out Douglas, the other Phase I winner. Dick MacNeal's tenacity and aggressive nature was the key to securing the contracts. He did not let bigger, better equipped competition intimidate him.

Much of the development work for NASTRAN was performed outside the gates of NASA Langley in Hampton, Virginia. Although the contract monitor, Tom Butler, was located at NASA Goddard Space Flight Center, agency expertise in structural analysis resided at NASA Langley. MSC and its partner, CSC, set up an office outside the gates of NASA Langley in order to work closer with Langley personnel. Eventually, the Goddard Space Flight Center management decided not to support the program and guidance was transferred to NASA Langley where Phil Raney was selected to head the NASTRAN Systems Management Office.

In 1969 the development contract for NASTRAN ran out and in 1970 NASA decided to award a maintenance contract for NASTRAN. Phil Raney, as the NASTRAN Systems Management Office head, selected MSC as contractor for the maintenance contract. Again, this was against the wishes of some higher level managers. Phil Raney said that he awarded MSC the contract because they saw it as their lifeblood and were committed to its success even though they were still a small company with limited resources. Phil Raney was impressed with the commitment of MSC. According to Raney, Dick MacNeal believed in the commercial potential of NASTRAN so much that he mortgaged his house and car for funds when the company was having financial difficulty (Raney 1996).

At the same time the maintenance contract was released, NASA released a contract for development of new elements to include in the NASTRAN code. The contract for the element development was awarded to Bell Aerospace, against the better judgment of Phil Raney. Phil Raney said that MSC had better expertise in element development, but he gave into upper management wishes and awarded the contract to Bell Aerospace. According to Phil Raney and Dick MacNeal, much of Bell Aerospace's work had to be redone because of the poor quality, and was redone by MacNeal at no cost (Raney 1996; MacNeal 1988).

In a recent interview, Raney still recalled the problems he had with upper management's support. Most upper managers were afraid that NASA was marketing NASTRAN too hard and was treading in an area not fit for government agencies. When Raney received a letter from Grant Hedrick, Vice President of Engineering at Grumman, stating that Grumman decided to use NASTRAN for all of its engineering work as opposed to incurring the cost of developing its own code, Raney's supervisor believed that Hendricks had written the letter only of Raney's instigation. Raney stated this was ludicrous, since no vice president of a multi-million dollar company would do something like that simply at the behest of a government employee. In another meeting, one of the upper managers stated flatly that no industry was using NASTRAN. Phil Raney said he showed the manager and the rest of the group a letter from GM and a letter from Ford stating their pleasure with having received NASTRAN and their utilization of the product. According to Raney, the manager continued the meeting as if he had never said a thing (Raney 1996).

When the maintenance contract was eventually given to CSC in 1973, MSC reached another watershed in its development. At this point, MSC felt as if it had been the driving force behind NASTRAN and it were being treated poorly. MSC saw no commitment from NASA and in turn decided it owed no loyalty back. In order to maintain its revenue streams, MSC initiated consultations with private industry for installation of NASTRAN, and continued the development of the code by adding capabilities for other commercial customers. By this time there were 18 employees in MSC. The NASA-owned product, NASTRAN, was then available for public release through the COSMIC Distribution Center (a federally funded entity) located at the University of Georgia for a price of $1750 (MacNeal 1995).

In 1971, Dick MacNeal decided to offer a MSC version of NASTRAN called MSC/NASTRAN to the public on a lease basis. This was a bold move, but one that MacNeal was willing to risk. The MSC/NASTRAN version was based on the contract work that MSC had with NASA and modifications it made. The gamble paid off and over the next several years income from the leasing of MSC/NASTRAN grew at an annual rate of fifty percent (50%) (Figure 4.24).

In the 1980s, NASA sued MSC over the intellectual property rights of NASTRAN. MSC claimed its version, MSC/NASTRAN, was significantly different from the original NASTRAN. Essentially, the result of the legal actions ended in victory for MSC, and it was able to continue marketing its version. Once the lawsuit was resolved, MSC was able to concentrate its full energies on expanding its market base. MSC success grew so that on May 5, 1983, the company went public with an initial offering of stock at $23.00 per share. The stock closed that same day at $36.75 per share (MacNeal p. 154, 1988). Since that time MSC/NASTRAN has become an industry standard for finite-element analysis, and an economic success with sales revenues of over $100M per annum.

Tom Butler, the NASA contract monitor for many years was identified by both NASA and MSC individuals as one of the "internal champions." He attributed the technical and commercial success of MSC/NASTRAN to two elements:

1. Fortuitousness that many of the key element were in the right place at the right time.
2. A critical mass of individuals without whom success would never have occurred.

With respect to fortuitousness, Tom Butler said:

> Much of the success of NASTRAN depended on the necessary ingredients. The times were right, the ability to get funding was right, the research activity in aerospace was right, the computer technology was right, and the finite-element theory was right (Butler 1971, via MacNeal p. 123, 1988).

Butler recognized the value of both internal and external champions and felt obligated to credit their work in a technical paper. Butler's description of those individuals as "mavericks" is similar to that of the champion. Butler wrote:

> Seven people also created the critical mass, the absence of any one of whom would have caused the whole enterprise to collapse. They are Dr. Paul R. Peabody, for his fundamental system design; Dr. Richard H. MacNeal, for the theoretical cohesiveness of the structural mechanics; Prof. C. W. McCormack, for the melding of the disciplines into a workable unity; Keith H. Redner, for the forging of a quality of excellence into the programming; Thomas B. Butler, who kept things moving; and Melvin Rosche and Douglas Michel, who were the NASA Headquarters benefactors who sensed the timeliness and the importance of the program. There was an uncanny uniformity about all of these necessary people. Each had earned the label of maverick from his individual peers. Yet when thrown together these mavericks won each others' respect and solidified under this banner. Each devoted his energies in unbelievably tireless fervor. Each succumbed

> to selfless involvement. Each became indelibly identified with NASTRAN. This team was the crux of the management. They were not the types to be managed; they managed the program in a bond of mutual pride (Butler 1971 via MacNeal p. 124, 1988).

According to MacNeal the success of the company was attributable to two key element:

1. The capital investment of NASA into the development of the software code NASTRAN.
2. The key individuals who championed its cause.

Regarding the capital investment from NASA, MacNeal had this to say in his book:

> Viewed in retrospect, the company's success was a direct consequence of NASA's decision to fund the development of NASTRAN." "....It illustrates the legitimate role of government in providing seed money for an infant industry (MacNeal p. iii, 1988; see also Figure 4.24).

MacNeal estimated the cost to develop NASTRAN at approximately $3M dollars, of which $1M came from government contracts (MacNeal p. 57, 1988). Considering the $100M of annual sales in 1995 by MSC, this was a successful commercialization, even if unintended by NASA.

MacNeal had much more to say about the role of the key individuals. Although MSC had its problems with NASA, MacNeal still recognized the valuable role of key individuals within the agency who championed the cause. Tom Butler, the NASA contract monitor for so many years, was called the "father of NASTRAN" by MacNeal. MacNeal said about Butler:

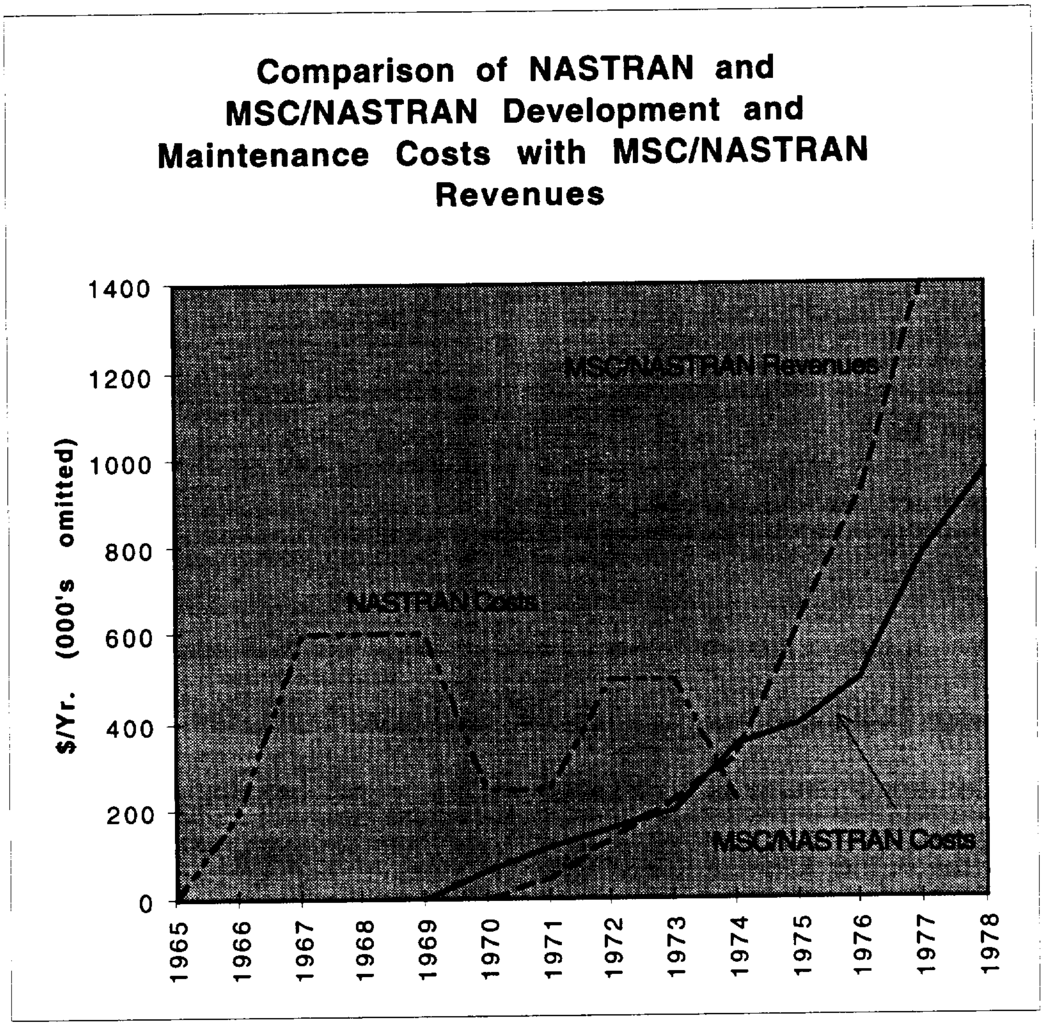


Figure 4.24: Comparison of NASTRAN and MSC/NASTRAN Development and Maintenance Costs with MSC/NASTRAN Revenues (MacNeal p. 161, 1988)

> He possessed a dedicated determinism and a rare idealism, both of which would be tested again and again in defense of the ideas embodied in the project (MacNeal p. 40, 1988) ... In truth, many people contributed mightily to the development of NASTRAN, but if I were asked to say who contributed the most, I would select Tom Butler. It was his vision that conceived the project and it was his strength of character that guided it through difficult days to its public debut. Others may have made greater technical contributions to NASTRAN, but without him it never would have been (MacNeal p. 58, 1988).

Phil Raney, head of the NASTRAN Systems Management Office, cited the dedication, devotion, and single-mindedness of both the NASA people involved and Dick MacNeal. He felt that without anyone of the following people, that MSC/NASTRAN would not be the commercial success it is today:

1. Mel Rosche and Doug Michel for their financial support.
2. Tom Butler for his helmsmanship.
3. Phil Raney for overcoming internal detractors and steering the contracts and NASTRAN the right way.
4. Dick MacNeal for incredible determination.

Ronnie Gillian, a current NASA Langley employee who originally helped develop NASTRAN as a former CSC employee during the 1960s and later oversaw development of NASTRAN within NASA Langley, stressed that one of the key elements to the commercialization of MSC/NASTRAN was Dick MacNeal (Gillian 1996).

Summary of Findings for MacNeal-Schwendler Corporation

In this particular case, there was no initial foresight by the federal laboratory (NASA Langley) to privately commercialize the product. The goal was to provide the aerospace industry with a much needed tool. In fact, the lawsuit that ensued might have stopped the commercialization. The efforts of the champions or mavericks, as Butler referred to them, appeared to make the difference.

According to the testimony of MacNeal, the crucial element at the input level was research dollars; and the crucial element at the intermediate level was the internal champion. MacNeal implied that the crucial contribution of NASA as an agency was the infusion of capital to fund the project and the efforts of Tom Butler to champion the process.

Phil Raney and Ronnie Gillian also recognized the importance of the individuals in the process.

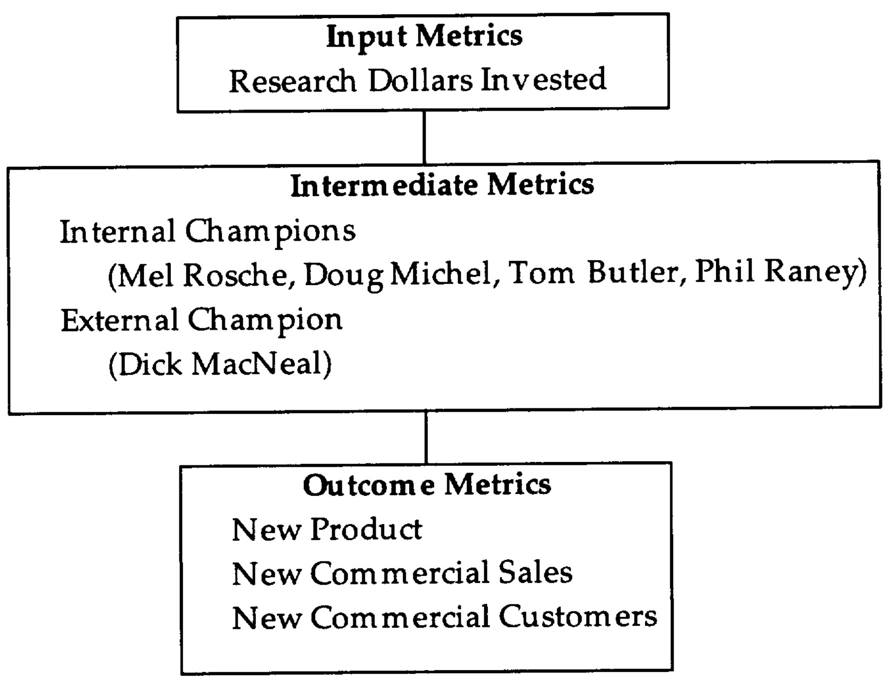


Figure 4.25: MacNeal-Schwendler Corporation Case Study Key Critical Elements as Metrics

Pressure Systems Incorporated

Pressure Systems Incorporated (PSI) develops, manufactures, markets, and services pressure measurement instrumentation for aerospace and industrial measurement applications. The company is headquartered in Hampton, Virginia, just outside the main gates of NASA Langley.

In the 1970s, NASA was designing a National Transonic Facility (NTF) wind tunnel. This wind tunnel would have unique characteristics over the existing wind tunnels. The Government Accounting Office (GAO), which has oversight on the construction of any new facilities for federal agencies, deemed the predicted operations cost for the NTF to be too high. Specifically, the acquisition of pressure measurements was exorbitant in cost. The GAO would only agree to approve the construction of the facility if the pressure measurement issue could be solved.

The Instrumentation Research Division (IRD) at NASA Langley took up the challenge of designing a new pressure measurement device. It was at this time that Doug Juanarena was recruited by NASA Langley to work on the project. Doug Juanarena graduated from Virginia Tech in 1975 in Electrical Engineering and joined NASA Langley in the IRD to help develop the pressure sensor. The IRD was able to develop a electron pressure scanner that was between 100 to 1000 times faster than conventional measuring techniques at that time and met the cost requirements of the GAO.

During sensor development, NASA Langley had enough vision to recognize that it would need a manufacturer for the pressure sensor and worked cooperatively with a pressure sensor firm in California. NASA Langley was prepared to give the firm licensing rights along with the manual that it had developed. However, the firm decided not to take advantage of the opportunity, feeling it was not a good financial decision.

When NASA was left with no manufacturer for the pressure sensor, Doug Juanarena formed a private company (Pressure Systems Incorporated) in 1977 to produce the sensors. NASA agreed to license the sensor technology to Pressure Systems Incorporated on a nonexclusive basis. In 1978, Doug Juanarena left NASA to work full time at Pressure Systems Incorporated. Pressure Systems Incorporated became a very successful commercial entity, supplying pressure sensors worldwide.

Doug Juanarena estimates his company sales are now at the level of $10M per year. Pressure Systems Incorporated exports to over 20 foreign nations. In one recent year, approximately 40 percent of the fiscal revenues were derived from export sales. Pressure Systems Incorporated customers include some of the largest manufacturing companies in the world (Table

4.4). The companies range from aerospace, aeronautics, and automotive to heavy machinery.

In 1984, the magazine *Inc.* selected Pressure Systems Incorporated as one of the 500 fastest growing companies in America. In 1988, Pressure Systems Incorporated was named Virginia's Exporter of the Year by the United States Department of Commerce; and in 1991 was presented the US

Table 4.4: Customers of Pressure Systems Incorporated

Customers of PSI	
Fisher Controls	Pratt and Whitney
Westinghouse	Teledyne
ABB	Honda
Garrett Turbines	BMW
McDonnell Douglas	Caterpillar
Toshiba	Ford
Nuovo Pignone	General Motors
Mercedes	Cessna
Chrysler	Eastman Kodak
General Electric	Volvo
ONERA	Lockheed
Boeing	Schwitzer
Ferrari	Aerospatiale
Cooper Industries	Rolls Royce
DLR	ETW
NASA	Union Carbide

President's "E" Award, designed to give special recognition to companies which have excelled in exporting.

In an interview with Doug Juanarena, he considered Pressure Systems Incorporated to be a classical case of technology transfer and felt that the key was the "combination of a technology and a champion." Doug Juanarena felt that NASA Langley was instrumental in the process by recognizing a "real world" need, funding the necessary research, and not stopping at theory but forging on to a practical prototype and working model. In addition, Juanarena saw NASA Langley's interest in grooming a manufacturer and working closely with that manufacturer as a positive step.

Summary of Findings for Pressure Systems Incorporated

In the Pressure Systems Incorporated case the internal champion and external champions were the same person. Doug Juanarena championed the development of the device while at NASA Langley and then created Pressure Systems Incorporated and championed commercial development of the pressure sensor. NASA Langley eased the transition of the technology from the laboratory by extending the research and creating practical prototypes.

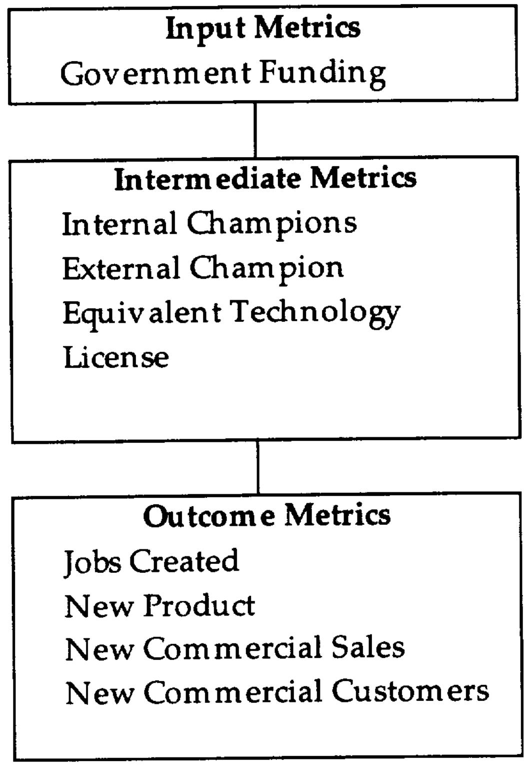


Figure 4.26: Pressure Systems Incorporated Study Key Critical Elements as Metrics

Técnico

Técnico is a privately-owned ship repair company located in Chesapeake, Virginia. Técnico was incorporated in 1991 and classified as a small business (SBA 8(a)) in October 1992. This was an advantage for Técnico, since some US government contract work is restricted to companies classified as small businesses or small, disadvantaged businesses. Most of Técnico's business was in the area of structural welding, piping, electrical, painting, rigging, blasting and dry-dock work. In addition, Técnico also offered shipboard furniture fabrication, sheet metal fabrications and extensive welding capabilities. The company included approximately 225 employees and was heavily dependent upon Department of Defense contracts for military ship repair (Hildebrandt 1996).

In 1993, Técnico was invited by Loral Vought, a company located in Texas, to investigate the possibility of producing the mid-body section for a PAC-3 missile. The PAC-3 missile is an extended-range interceptor which was to be incorporated into the Patriot PAC-3 system. The initial contact between Técnico and Loral Vought was made by John Hildebrandt, a manager at Técnico, who was doing a market scan for other potential applications of Técnico's expertise. Due to the probability of Navy funding cutbacks, Técnico started to look for other potential markets to enter and diversify its services. The alignment with Loral Vought made sense, but this required Técnico to produce composite material parts and the startup cost of getting into composite material production was prohibitively high (Hildebrandt 1996).

Simultaneously, Hildebrandt performed a market scan that led him to visit a technology exhibit at NASA Langley in 1993. At the technology exhibit, John Hildebrandt was introduced to a technique to produce composite materials with a small capital investment. The technique, called rubber expansion molding, held several advantages over conventional approaches to composite material production (Table 4.5). One of the most important

Table 4.5: Comparison of Traditional Process and Rubber Expansion Molding Process for Production of Composite Materials

Traditional Processes	**Rubber Expansion Molding**
Filament Winding Process	
Voids will occur	Reduced manufacturing costs
Limited configuration of parts	Lower labor costs
Slow process	No filament winding required
Computer controlled	No autoclave required
	Any furnace could work (300 deg. F)
Autoclave Process	Very easy to co-locate production facilities
Expensive to operate	Far superior surface finish
Long time to heat/pressurize	More complex shapes possible
High material costs	Much higher quality products
Many inherent problems due to induced pressurization and heat	
Requires highly trained personnel	

distinctions between traditional processes and the rubber expansion molding process was the capital investment cost. Hildebrandt said his capital investment requirement in equipment was cut from $2M to $20,000 by selecting to utilize the rubber expansion molding process (Hildebrandt 1996).

Técnico developed a close working relationship with NASA Langley to better understand the process of rubber expansion molding. On August 8, 1994, Técnico signed a Memorandum of Agreement (MOA) with NASA Langley to jointly explore taking the technology from the laboratory situation into a production facility. Based on the positive outcome of that cooperative venture, Técnico signed an exclusive licensing agreement. Técnico felt that the combination of the MOA and the license created a long-term relationship and allowed for joint effort on a variety of research and development projects.

Using the rubber molding technique, Técnico secured a contract from Loral Vought. In addition, the technique lead to a contract with IMO, a submarine outfitter. In the IMO contract, Técnico was able to construct a manway cover out of graphite using the rubber expansion molding technique. This graphite manway cover (21.5 lbs) constituted a order of magnitude of weight savings from the conventional titanium manway cover (220 lbs). Weight savings on submarines are critical and the US Navy is looking to utilize more of these types of creative solutions.

The new commercial activity created by the adoption of the rubber expansion molding technique lead Técnico to create a new group within the company called the Advanced Materials Group. The technology transfer with NASA resulted in a new production methodology and created new commercial customers and jobs. Since May of 1995, Técnico has hired eight skilled persons (engineers, technicians) into the Advanced Materials Group and has received over $800,000 in revenues (Hildebrandt 1996).

Greg Manuel, one of the two NASA Langley technology transfer agents responsible for facilitating the transfer of the rubber expansion molding technique from NASA Langley to Técnico, *attributed the success of the project to the "champions"* (his word). Greg Manuel thought that the commercial success never would have occurred without Técnico manager John Hildebrandt (Manuel 1996).

Barry Gibbens, the other NASA Langley technology transfer agent involved in the Técnico project, claimed that the success was due to the small capital investment that was required to utilize the technology and, again, to the effort of John Hildebrandt (Gibbens 1996).

Bob Baucom, the lead NASA researcher in developing the rubber expansion molding technique, felt that there were two crucial reasons for the success (Baucom 1996):

1. The technology was easily transferable into a commercial product.
2. The technology showcase exhibit which NASA Langley held resulted in bringing together the researcher (Bob Baucom) and the private industry (John Hildebrandt of Técnico).

In a lengthy interview with John Hildebrandt, he stated three crucial reasons for the commercial success of this technology transfer:

1. Técnico made a commitment to commercializing the technology.
2. The support of the NASA Langley researchers was critical. The technical support by the NASA researchers was an emotional support in addition to NASA's belief in the possible success of this technology made believers of Técnico and its customers.
3. Bob Baucom, was credited with being a catalyst with his excitement toward performing technology transfer.

Summary of Findings for Técnico

Two of the principals in this case identified the ease of adaptability of the technology from laboratory to production facility as a crucial element. Also, two of the principals recognized the role of the champions, both internal (Bob Baucom) and external (John Hildebrandt) to the success of the technology transfer. In addition, a patent and a license agreement existed in this technology transfer project and two NASA Langley technology transfer agents worked to help pave through the legal ends of the transfer elements between NASA and the private sector. The NASA Langley technology showcase exhibit was recognized by several persons as the key mechanism for creating awareness of the technology. Técnico felt that the support from the NASA researchers was crucial.

The evidence in this case suggests that there were two categories of crucial elements: champions and technology transfer mechanisms (Figure 4.27). The mechanisms for technology transfer included the technology showcase exhibit, the patent and the licensing agreement, and the two technology transfer agents. All but the technology transfer agents could be classified as intermediate metrics. The transfer agents could be classified as input metrics.

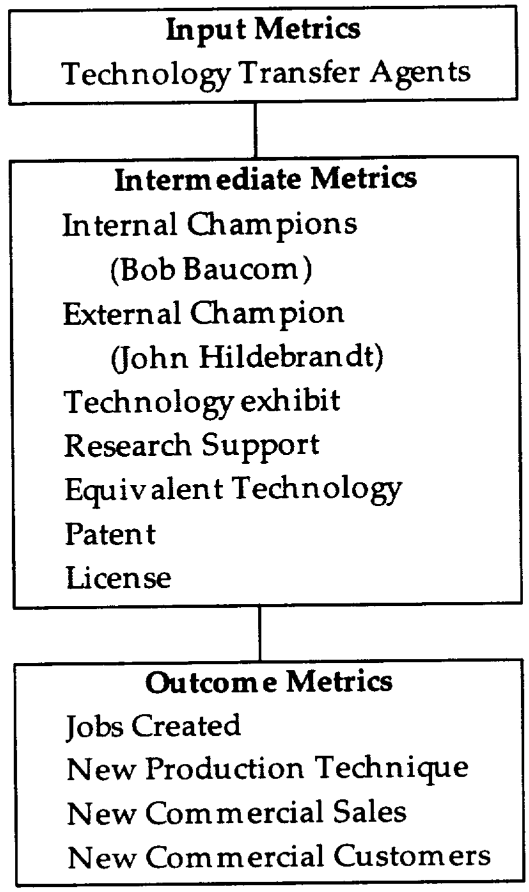


Figure 4.27: Técnico Case Study Key Critical Elements as Metrics

Summary of Results for Case Studies

In retrospect, the order of cases represents the changing approach to technology transfer by NASA. In the MacNeal-Schwendler Corporation case there was a reluctance by many individuals within the NASA to allow MacNeal-Schwendler Corporation to commercialize the NASTRAN product. Fortunately there were also a few individuals who had the vision to see the commercial potential and broke through management barriers. In the

Pressure Systems Incorporated case, an individual NASA researcher saw the potential for commercialization and, with the concurrence of NASA, left his position and created the successful Pressure Systems Incorporated. In the final case, a technology exhibit sponsored by NASA Langley brought the laboratory and private sector together. Then the actions of technology transfer agents to reach agreements on cooperation and licensing, along with the efforts of the NASA researcher and a Técnico representative, made this effort a success. The three cases thus illustrate a progression by NASA from hindrance, to concurrence, to a proactive stance on technology transfer.

While each case was distinct from the perspective of the transfer methodology, the common element contributing to the success in all three cases was the presence of (internal and external) champions (Figure 4.28). In two cases, government funding, equivalent technology and a license were also mentioned as keys (Figure 4.28). A closer analysis of these cases reveals that champions, early government funding, equivalent technology, and licenses were the crucial elements to successful technology transfer (Figure 4.29).

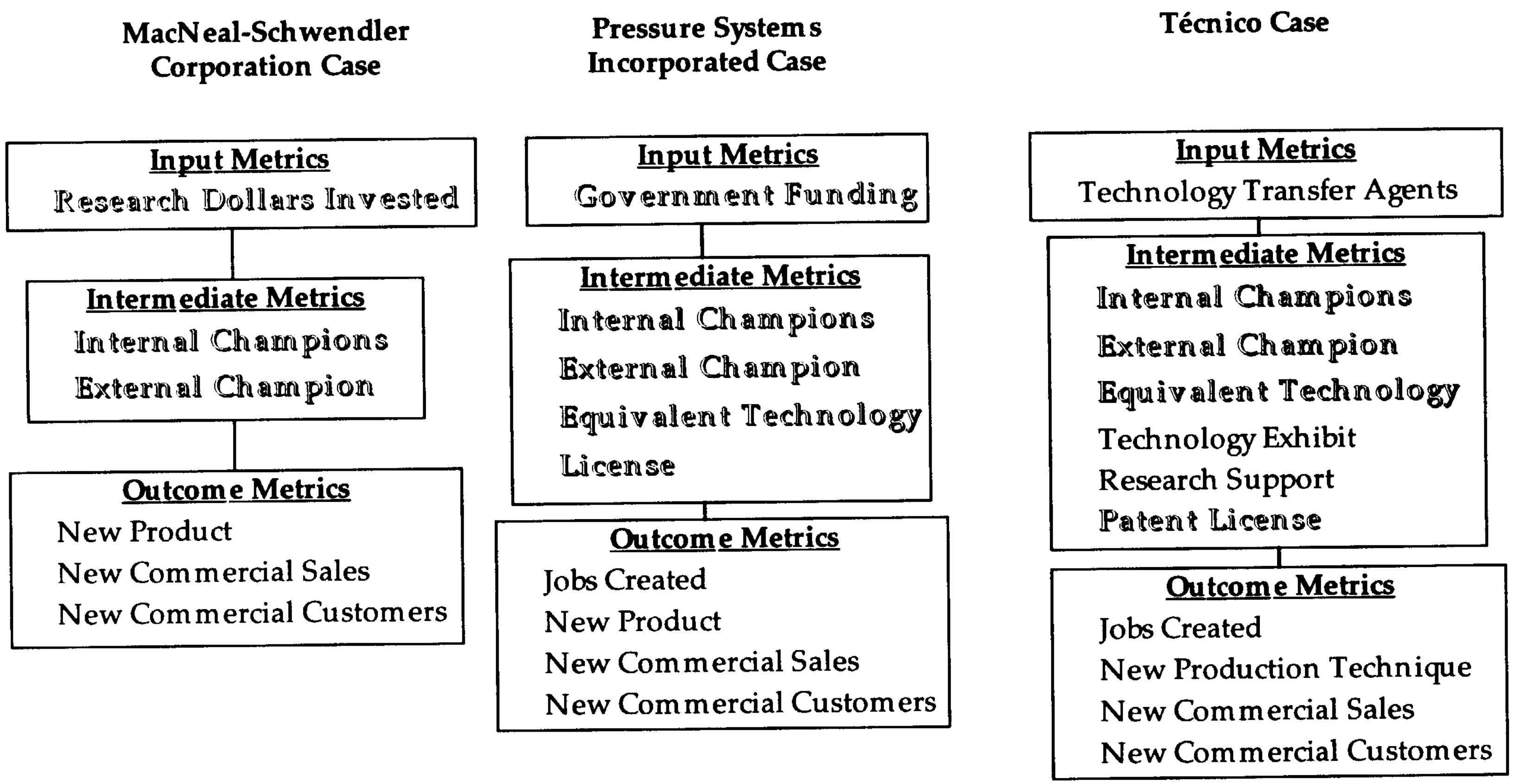


Figure 4.28: Comparison of Key Critical Element for the Three Cases

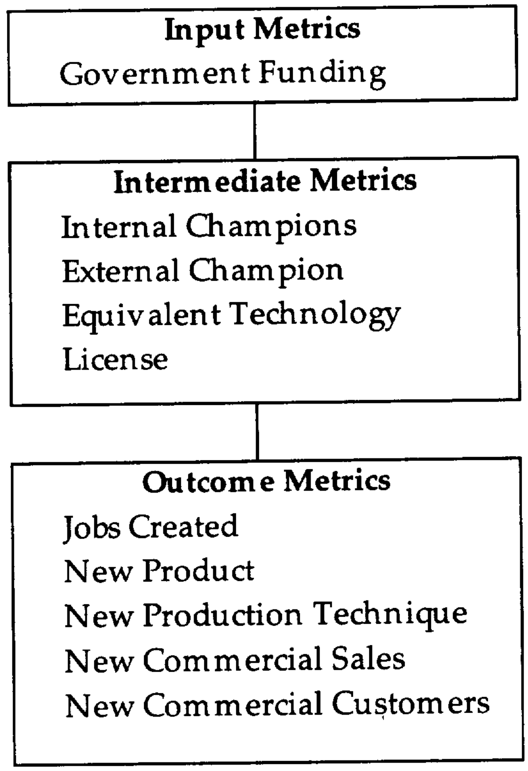


Figure 4.29: Common Key Critical Element for the Three Case Studies as Metrics

Summary of Hypotheses

The findings of the survey and case studies were used to evaluate the 12 hypotheses. Each hypothesis with the conclusions, that the survey data or case studies support, are presented below. The hypotheses have been separated into two sections, Survey Hypotheses (H(1) to H(10)) and Case Study Hypotheses (H(11) to H(12)). The boldface hypothesis in each null/alternative hypothesis pairing is the hypothesis that was supported.

Survey Hypotheses

According to survey respondents, only 36% had ever had technology transfer on their performance plan or performance appraisal. This was not considered to be widespread use of the performance plan and performance appraisal for technology transfer. Null hypothesis one is rejected and alternative hypothesis one is accepted.

$H(1)_{null}$ Technology transfer as a component of the performance plan and performance appraisal was widespread at NASA Langley Research Center.

H(1) Technology transfer as a component of the performance plan and performance appraisal was minimal at NASA Langley Research Center.

Over ninety percent (90%) of the 100 researchers surveyed were aware that technology transfer was a mission objective of NASA and ninety-five percent (95%) were aware that technology transfer was a mission of NASA Langley. Null hypothesis two could not be rejected and was accepted.

$H(2)_{null}$ Researchers at NASA Langley Research Center are aware of the technology transfer policies of the agency and the Center.

H(2) Researchers at NASA Langley Research Center are not aware of technology transfer policies of the agency and the Center.

The technology transfer mechanism identified by the most researchers (42% of respondents) was publications. Less than thirteen (13%) identified any of the formal mechanisms of technology transfer. Patents, as a mechanism of technology transfer, were identified by only six percent (6%) of the respondents. Licensing was mentioned by two percent (2%), which was a smaller percentage than those who responded with "Don't know."

Sixty percent of the respondents could identify the name of the group (Technology Applications Group) at NASA Langley Research Center responsible for technology transfer. However, eighty-five percent (85%) could not identify their division representative to the Technology Council which interfaced on their behalf with the Technology Applications Group. Null hypothesis three was rejected on the basis of these results and alternative hypothesis three accepted.

$H(3)_{null}$ Researchers at NASA Langley Research Center are aware of the technology transfer points of contact and technology transfer mechanisms.

H(3) Researchers at NASA Langley Research Center are minimally aware of the technology transfer points of contact and technology transfer mechanisms.

A series of questions aimed at measuring the researchers' attitude towards performing technology transfer were included in the survey. Each question progressively indicated more responsibility and accountability for the researcher. The results of the questions clearly showed that the researchers thought technology transfer should be performed, but they did not want to be held personally accountable or responsible. The null hypothesis is rejected based on the findings and the alternative hypothesis accepted.

$H(4)_{null}$ Researchers at NASA Langley Research Center want to be responsible or accountable for technology transfer.

H(4) Researchers at NASA Langley Research Center do not want to be responsible or accountable for technology transfer.

Researchers at the highest education level (PhD) were, in general, less aware of the technology transfer commitment of NASA and the Center. The percentage of PhDs incorrectly estimating the resources allocated to technology transfer was twice that of the MS respondents and three times that of the BS respondents. Null hypothesis five is rejected and alternative hypothesis five is accepted.

$H(5)_{null}$ Researcher awareness of technology transfer is not linked to educational level.

H(5) Researcher awareness of technology transfer is linked to educational level.

There is almost a linear progression from BS through MS to PhD in the percentage of respondents who believe their research has potential for technology transfer. The PhDs also significantly differed from the profile of the BS and MS respondents when asked if they have been adequately prepared. The results indicate that there were differences in perception. Null hypothesis six is rejected and alternative hypothesis six is accepted.

$H(6)_{null}$ Researcher perceptions about technology transfer is not linked to educational levels.

H(6) Researcher perceptions about technology transfer is linked to educational levels.

No significant relationships were found between education level and attitude. Null hypothesis seven could not be rejected and is retained.

$H(7)_{null}$ Researcher attitudes about technology transfer is not linked to educational levels.

H(7) Researcher attitudes about technology transfer is linked to educational levels.

No significant correlations were found between researcher age and awareness about technology transfer. Null hypothesis eight could not be rejected and is retained.

$H(8)_{null}$ Researcher awareness about technology transfer is not linked to age.

H(8) Researcher awareness about technology transfer is linked to age.

A strong correlation between age and attitude was found. The older the respondent the less likely they were to agree to perform technology transfer if it were part of the promotion process. Null hypothesis nine is rejected and alternative hypothesis nine is accepted.

$H(9)_{null}$ Researcher attitudes about technology transfer is not linked to age. **H(9) Researcher attitudes about technology transfer is linked to age.**

Correlations between age and perception were found. As age of the researcher increased, the researchers were less positive of management's support and were less positive about their own ability to perform technology transfer. Null hypothesis 10 is rejected and alternative hypothesis 10 is accepted.

$H(10)_{null}$ Researcher perceptions about technology transfer is not linked to age. **H(10) Researcher perceptions about technology transfer is linked to age.**

Case Study Hypotheses

Champions were recognized as a key critical component in each of the three case studies. This was the single most crucial element identified in all three cases. Based on this evidence, the null hypothesis was rejected and the alternative hypothesis was accepted.

$H(11)_{null}$ Success in technology transfer activities is not dependent upon individuals who take responsibility for the process and act as champions. **H(11) Success in technology transfer activities is dependent upon individuals who take responsibility for the process and act as champions.**

In the case studies, four crucial elements were identified. These elements aligned with the input and intermediate metric categories. The four crucial elements were internal champions, external champion, government funding, and equivalent technology. The identification of these elements were different from those identified in previous studies on measures of technology transfer (see Chapter II, Literature Review). Therefore, there appears to be key elements which provide the linkage between the input and intermediate metrics and contribute to the success of the technology transfer.

Based on these results, we can reject the null hypothesis and retain the alternative hypothesis.

$H(12)_{null}$ Successful technology transfer activities (i.e. positive economic impacts) are not linked with input metrics ($ spent, etc.) and intermediate metrics (activities).

H(12) Successful technology transfer activities (i.e. positive economic impacts) are linked with input metrics ($ spent, etc.) and intermediate metrics (activities) through some as yet unidentified common elements.

Summary

This chapter has presented the results of the technology transfer cultural survey of NASA Langley Research Center researchers and the results from three case studies of successful technology transfer. The 100 researchers surveyed were found to have a minimum awareness and a guarded attitude toward performing technology transfer. In the case studies, internal champions, external champion, government funding, equivalent technology, and licenses were found to be crucial elements leading to the success of a technology transfer. The integration of the findings of these two studies and possible reasons for these findings are discussed in the final chapter.

CHAPTER V

DISCUSSION, CONCLUSION AND IMPLICATIONS FOR FUTURE RESEARCH

Introduction

Changes in the domestic US economy resulting from global economic competition are causing the public and Congress to examine the methods in which US federal laboratories operate. The reason for this study was the recent debates surrounding and interest in Congress and federal agencies to transfer federal laboratory-developed technologies to the commercial sector. As a result of Congressional legislation and federal agency directives there is more emphasis on technology transfer and on showing the relevance of the federal research to the commercial sector. Agencies and their laboratories are struggling with the issue of measuring their activities and achievements in technology transfer. In addition, this technology transfer mission is a cultural change for many laboratories and their researchers.

In this study the technology transfer culture of the researchers at one federal laboratory (NASA Langley Research Center) was measured through a survey. Specifically, researcher attitudes, awareness, and perceptions toward technology transfer were measured. Without the willing participation of the researchers the attempt to transfer technology could become difficult. The results of this survey were intended to serve as a primary data point for federal laboratory directors to gauge the culture of the researchers toward technology transfer.

Further, the key critical elements contributing to successful technology transfers from NASA Langley Research Center to the commercial sector were examined by completing a case study on each of three successful transfers. The cases chosen had to satisfy some of the outcome metrics (new commercial sales, new jobs, etc.) identified by previous studies. The history of each case and the key critical elements leading to the success were documented through interviews with the principals involved and historical documents. The key critical elements for each of the cases, in terms of input and intermediate metrics, were identified to find the linkage between the three categories (input, intermediate, outcome) of technology transfer metrics.

In this chapter, the findings obtained in the study are discussed and interpreted. Implications and recommendations for future research are presented. In the following sections, the culture survey and case study findings are separately examined.

Culture Survey

This was the first documented study performed on survey federal laboratory researchers and their existent culture toward technology transfer. The results should be of much interest to federal laboratory directors, federal agency directors, and technology transfer policy makers and researchers, and Congressional leaders. The potential customers of this research may use the results to help guide future technology transfer policy. Specifically, the research is useful in identifying areas of potential improvement, personnel preparedness and measures.

Results indicate that although researchers concur with current mission directives for technology transfer, on a personal level they do not want to be held accountable or responsible for technology transfer. The results also indicated that the researchers were minimally aware of the emphasis (dedicated resources) being placed on technology transfer by the laboratory and the mechanisms by which to perform technology transfer.

The results of this study revealed that the researchers of NASA Langley Research Center believed technology transfer should be a mission. However, on an individual level, they did not believe it to be their responsibility or desire it to be. The federal laboratory researcher attitudes toward technology transfer has long suspected to be less than enthusiastic. This study confirmed that belief.

Although researchers realized that technology transfer was a mission of the NASA agency and of the NASA Langley Research Center, they were woefully uninformed of the mechanisms of technology transfer and only minimally aware of the appropriate personnel to contact. When asked to identify the mechanism they would use to transfer their technology, the single largest response (40%) was publications. The second largest response was to contact the Technology Applications Group (only 20%). Licensing, which was identified in two out of the three case studies as a key critical element, was identified by only 2% of the researchers.

A major interest in this study was the correlation of the researcher perceptions and awareness to education levels. In comparing the three education categories (BS, MS, PhD) those respondents with PhDs had the highest percentage who believed they were prepared to perform technology transfer. In contrast, the PhDs also had the lowest percentage of correct responses to one measure of their awareness of technology transfer policies (percent of resources spent on technology transfer).

In general, the conclusion to be drawn from the cultural survey of researchers was that the culture to support widespread technology transfer from a federal laboratory (NASA Langley) to the commercial sector does not currently exist. Further education, training, and cultural change must occur before technology transfer can truly become a supported mission. Or, alternately, technology transfer may be dropped as a explicit agency mission.

Case Studies

A review of previous studies of technology transfer metrics revealed a common categorization of metrics, with most studies identifying three categories: inputs, intermediates, and outcomes. Each category had particular metrics associated with it. The case studies performed in this study revealed that there were other variables with greater influence on the success of technology transfer than those previously mentioned.

Three cases were selected based on successful commercialization (outcome) metrics. Key individuals within each case were interviewed to identify the crucial elements leading to the successful technology transfer. These elements were then categorized as input/intermediate/outcome metrics. Success in the three cases was attributed to four key critical elements: champions (both internal and external), early government research funding, equivalent technology, and licensing.

Within all the quantifiable variables of the Association of University Technology Managers (AUTM) study, licensing was the best predictor (highest correlation) of royalties (Table 2.14). Results from the case studies and the AUTM data indicated that the best quantifiable metric was the number of licensing agreements. Since license agreements were the only intermediate metric that was dependent upon a market interest, this stands to reason as a good (quantitative) indicator of commercial success.

Other crucial elements that were identified in this study (champions, equivalent technology, and early government research funding) were not easily measured (qualitative) metrics. These elements may be better thought of as *goals* for the federal laboratories to achieve, with successful technology transfer to occur following their installment.

A study performed by Battelle Columbus Laboratories confirms the findings of this study that champions and early government funding play a major role in technology commercialization. In the Battelle study, the key factors and decisive events in the course of ten major twentieth-century technological innovations were identified. The following two quotes summarize the major findings of the Battelle study:

> The technical entrepreneur was important to nine of ten innovations. In three cases this champion persisted despite unfavorable market analysis (Battelle Columbus Laboratories p. 3-2, 1973).

> Government funding was instrumental in directly supporting seven of these innovations (Battelle Columbus Laboratories p. 3-2, 1973).

Equivalent technology was found to be one of the crucial items in two of the three case studies. An equivalent technology is one in which the technology readiness level can be characterized as at a prototype stage or greater. It is a technology in which the company receiving the technology does not have to perform a significant amount of work to obtain a functioning product. These results are supported by a study, performed by Gibson and Smilor, in which low equivocality was determined to be one of four variables central to technology transfer success within and between organizations. Equivocality is defined by previous studies (Technology Transfer in Consortia and Strategic Alliances 1992) as the level of concreteness of the technology to be transferred. A low equivocality rating for a technology indicates it is unambiguous, and is fairly easy to demonstrate and understand (Gibson and Smilor 1991). Highly equivocal technology is characterized as more ambiguous in its potential applications.

In this study, the only quantitative element identified as a crucial element for technology transfer success was licensing (two of three cases). Most federal agencies and laboratories currently measure the number of licenses generated per year. This is an easily tracked metric and may be the best quantifiable metric of all the intermediate metrics identified. A license agreement occurs only when a commercial entity is willing to pay in either upfront fees or royalties or both for the right to use the intellectual property protected by a patent. In short, a license agreement is a strictly free-market, capitalistic tool. The commercial sector (buyer) believes he or she can make money on this agreement.

Comparison of Culture Survey and Case Studies

The results of the cultural survey and the case studies taken together revealed a disconnect in the elements of a success and the resources available for success. The case studies revealed the internal champion as a key critical element. The results of the survey revealed that although the researchers feel technology transfer should be a mission of the NASA Agency and the NASA Langley Research Center, they do not want to be held personally responsible for technology transfer (Figure 5.1). There is a disconnect in these two results and it would appear that enacting technology transfer with a majority of the researchers may be problematic.

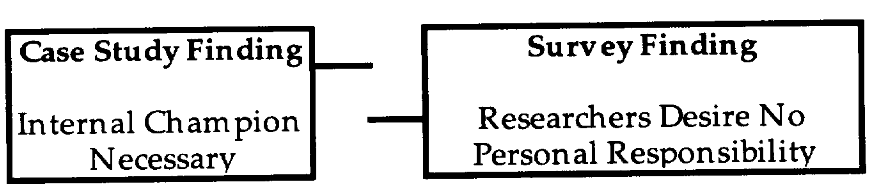


Figure 5.1: Comparison of Findings Regarding Researcher Role in Technology Transfer from the Case Studies and the Survey

In addition, almost two thirds (62%) of researchers said they would put more effort toward technology transfer if it were a component of the promotional process. But this overwhelming response is based on the reward system and not a personal interest, since only one third (31%) said they thought technology transfer should be a component of the promotion process. It is unclear whether those who would perform technology transfer because it was mandatory for promotions would fit the characteristics (or attributes) of being a champion or just an accomodator.

Currently, there is no formally stated policy on how to achieve a ten percent (10%) expenditure for the technology transfer mission at NASA Langley. One recommendation would be not to target the individual researchers, but the entire research laboratory. However, to help ensure a ten percent (10%) effort, education and training courses would, as a minimum, need to be put into place. Under such an approach, some researchers will have a natural affinity and interest in technology transfer and spend a large amount of time and energy on it. Other researchers will have no interest and spend little to no time on it. The end result may be an average research laboratory expenditure of ten percent (10%) of its resources on technology transfer. The key issue then becomes how to manage the funding of technology transfer across a research center provided this is retained as an explicit mission of the federal agency.

Licensing was identified by only 2% of the researchers as a mechanism they would use to transfer a technology. In two of the three case studies of successful technology transfer, a license was involved and was a key mechanism in the transfer of the technology. The case study results were aligned with those of the AUTM data analysis. In the AUTM data analysis, the strongest correlation to royalties came from licensing (Table 2.14). The lack of connectiveness between the survey and case studies on what mechanisms are necessary for instituting technology transfer raises concern over the preparedness of researchers to engage in successful technology transfer.

Conclusions and Recommendations

An awareness of the culture of federal laboratory researchers and the crucial elements of technology transfer success can assist laboratory directors, federal agency directors, and Congress in their technology transfer policy decisions. In this study, the culture of federal laboratory researchers is measured from three different aspects: awareness, attitude, and perception. In addition, case studies were performed to identify key critical elements leading to success. The practical implications of this study and recommendations for future studies follows. Recommendations are presented at two levels:

1. Recommendations for furthering studies at NASA Langley, and
2. Recommendations for expanding the scope to other Federal laboratories.

Practical Implications

In the contemporary era of rhetoric and worries about global economic competition, technology development and commercialization are commonly asserted to play vital roles to the economic well-being of nation-states. The US's dominant role in technology and economic wealth has diminished. The challenge for the US and its policy makers is to optimize the utilization of resources. With respect to federal laboratories, there is increasing interest in showing or at least rhetorically affirming relevancy, and to move toward purposive research and to ultimately realize economic windfalls from the investment in federal laboratories. This equates to a cultural change in policy for federal laboratories as well as for the individuals working there. The results of this study suggest that there may be several issues that need to be addressed if the federal laboratories generally and NASA Langley specifically are to better perform technology transfer and are to play a more significant role in economic successes.

Technology Transfer Awareness of Researchers

The level of researcher awareness of technology transfer mechanisms as measured from this study raises concern. Results indicated that many of the 100 surveyed researchers had minimal understanding of how to perform technology transfer or how to protect intellectual property and create economic success.

Recommendations:

1) Conduct further needs analysis on this issue and define gaps between actual and intended levels of knowledge. Establish training and education courses that address the defined gaps.
2) Other federal laboratories that maintain technology transfer as a mission should evaluate their researchers. If deficiencies in technology transfer are found, education on the mechanisms of technology transfer for researchers should be incorporated into employee development functions.

Technology Transfer Attitudes of Researchers

Researchers surveyed in this study felt that technology transfer should be a mission of the laboratory (94% of respondents), but did not desire to be held responsible for performing technology transfer. Less than 35% of the researchers felt technology transfer should be a component of the performance plan and appraisal and only 31% wanted technology transfer to be a contributing component during the promotion process. In 1980 the Stevenson-Wydler Act was passed with a Congressional mandate that efforts to transfer technology be stated positively in laboratory job descriptions, employee promotion policies, and evaluation of the job performance of scientists and researchers in a laboratory.

Recommendations:

1a) Investigate what percentage of the job descriptions, employee promotion policies, and evaluation that are currently in place at the Federal laboratory (NASA Langley) are aligned with the 1980

Stevenson-Wydler Act mandate. Compare this percentage to that found in this study. Assess reasons for lack of alignment.

2b) Assess managers on their awareness of the Stevenson-Wydler Act and ways in which they are trying to implement it.

3a) Survey researchers at other Federal laboratories and examine these laboratories to find the percentage of researchers with technology transfer appearing as a component of their performance plan and performance appraisal. Compare results to the results found in this original study.

4b) Future research should examine whether the culture of researchers is modifiable. If the researcher attitudes are inherent in the psychological or institutional makeup, there may be little reason to try to change it. On the other hand, perhaps external stimuli (reward system based on performance plan and appraisal) can change the culture.

Technology Transfer Perception of Researchers

The measured perception of researchers were contradicted by other responses of the researchers. But perceptions are difficult to measure and highly dependent upon the survey mechanism and terminologies used.

Recommendations:

1) Future studies should focus questions more specifically to each perception issue being addressed. For example, when asking the researchers if they received tangible support from their management, they should also be required to identify what that support was to ensure an accurate understanding of the question.

Overall Culture

The results of the survey defined a researcher culture that is aware of the technology transfer mission, feels the agency should perform the mission, but does not want to be held personally responsible and is not currently knowledgeable about the mechanisms to perform it. These may be indicators of a larger problem stemming from a lack of management support, understanding or education.

Recommendations:

1a) Measure the Center's managers on what they perceive as their responsibility in technology transfer, and the researchers' culture. This research should compare the difference between the management's perception and the researchers actual culture.
2b) Assess managers understanding of how to ensure successful technology transfer and mechanisms of technology transfer. This study may find that changes need to occur at other levels of the organization.

Internal Champions

Internal champions were identified as a key critical element of the technology transfer success in the three case studies.

Recommendations:

1) The Technology Applications Group should document each of its successful cases of technology transfer. The documentation could be multipurpose, including verifying the champion theory and identifying the characteristics of the champion.
2) Future studies may be performed to identify the characteristics, or attributes, of an internal champion and how those characteristics might be developed or further enhanced in individuals.

External Champions

An external champion was identified as a crucial element of the technology transfer success in the three case studies. From the case studies performed in this study, it appears that the smaller companies were more "hungry" than the larger ones, and more willing to take risks.

Recommendations:

1) The Technology Applications Group should keep statistics on the sizes of the companies and success rates to see if there are stronger correlations with smaller or larger companies and successful technology transfer. If it can characterize the traits of their typical external champion in successful technology transfers this could help in selecting future partners.
2) Collecting many federal laboratory technology transfer success cases or tracking licenses may help to better characterize the attributes of the external champions. This study might focus on measuring the difference in success rates between small and large commercial partners.

Equivalent Technology

In two of the three case studies, equivalent technology was identified as crucial elements of the technology transfer success.

Recommendations:

1) Currently, the Technology Applications Group evaluates the technology readiness level when doing assessments of technology. A formal study identifying the minimum level (see recommendation 2) of technology readiness level could help the group determine a cutoff for technologies.
2) A significantly larger sample size of federal laboratory case studies could better determine the level of technology readiness that is a minimum for technology transfer success. Future studies could also identify the median or mean level of technology readiness level that leads to success.

Licensing

In two of the three case studies, licensing was identified as an element of the technology transfer success. Although licensing played a role in two of the three cases, the case with the largest economic impact ($100M/yr.) did not involve a license. The lack of a license in the MacNeal-Schwendler Corporation case study is problematic, since the license is one of the few quantitative metrics available to the laboratory.

Recommendations:

1) The Technology Applications Group should attempt to document those cases in which cooperative research led to economic success but where a license did not occur.
2) A compilation of case studies from federal laboratories might determine what percentage of successes come from licensing and what percentage from other mechanisms. In addition, these future studies could identify the relative level of success of those cases where a license was present versus those in which a license was not present.

Early Government Funding

In two of the three case studies, early government funding was identified as a key critical element of the technology transfer success. Although little attention was given to this in the study, results indicate that more attention should be given in future studies. Often government involvement is welcomed in "market-failure" situations, that is, instances where market driven (private, commercial) enterprises can not afford to fund development and stay competitive.

Recommendations:

1) NASA Langley should obtain private industry input into the direction of technology development early in the process in order to identify potential partnering opportunities for economic success.
2) Studies should be performed to identify the best mechanism for determining which technologies hold the best promise for commercialization.

Topics for Future Research

In addition to the recommendations made above, topics are suggested that may be of interest for future research in this field.

1. A future study might follow the same approach used in studying the three case studies, while expanding the number of case studies to further test hypotheses 11 and 12. In this study, the three cases allowed the researcher to implement the open-ended interview method on a small model basis. Lessons learned from this study can be used to improve the technique and apply it to the larger sample of case studies.
2. Using the survey instrument from this study, a survey could be conducted with researchers at a few high-ranked and low-ranked federal laboratories in terms of their technology transfer success.

Results could then be compared to determine whether the culture of researchers differs between those laboratories successful in technology transfer and those that are not successful. And if so, where are the significant differences?

3. The question, "What are the characteristics of an internal champions?" could be further investigated. This is important in terms of education and training for technology transfer.
4. Similarly, the question, "What are characteristics of external champions?" could be investigated. Understanding may be important in better assessing potential private partners to invest federal personnel, time, and money.

Concluding Remarks

This review and analysis of technology transfer in a national government laboratory necessarily assumes as its background a particular socio-cultural history. The United States has, for most of the 20th century, emphasized a heritage of individualist liberty and restricted governmental initiatives in the commercial development of technology, although it has also been widely assumed that federal support for science and engineering has a largely beneficial spin off effect on the economy as a whole. Within such a context the strong support of science and engineering coupled with a laissez faire approach toward technology transfer activities that has been most characteristic of the post-World War II period appears to be a natural and rational policy.

However, stimulated by a variety of societal and economic factors -- from the end of the Cold War to rising federal deficits and worries about global competitiveness -- the issue of technology transfer has recently become a topic of debate within the federal government, with spill over implications for policies at the national laboratories. Although not all the factors that have stimulated this debate and attempts to make technology transfer policy more proactive are equally sound, it is nevertheless reasonable to reconsider the issue within this framework.

Perhaps the largest issue challenging the proactive federal laboratory technology transfer effort is the culture of the federal laboratory researcher. Although most federal laboratories are creating new organizations to perform technology transfer that include technology transfer agents, a critical link in the transfer chain is still the researcher. Without a committed effort from researchers the chance of technology transfer success is likely to be zero. Within this study, the culture of researchers has been evaluated through a survey. The survey results indicate that researchers believe technology transfer is a mission of the laboratory and agency, but do not necessarily feel it is their responsibility to perform it or desire to be accountable for it. In addition, researchers appear to be poorly informed on the mechanisms and policies concerning technology transfer. If federal laboratories are serious about performing technology transfer, researcher education must be considered.

This study also included development and utilization of a process for defining meaningful metrics. The process utilizes a portfolio approach with both quantitative and qualitative variables. Evidence suggests that pure quantitative measurements will underestimate the true value of technology transfer efforts. These measurements should be used in conjunction with other qualitative measurements for a portfolio approach. Quantitative variables identified in this study include licenses, and royalties per license. Qualitative variables include case studies that are comprehensive and probing.

More specifically, licenses appear to have the strongest correlation of all quantitative measures to economic impact (royalties). This is to be expected, since the stream of intellectual property activities (patent application, patent disclosure, etc.), with the exception of licenses, is internally driven. Alternatively, licenses are market driven. Licenses only occur when there is reasonable belief by an external organization that profits are possible. Of course, the sole use of licensing as a metric for technology transfer would be disastrous. If NASA were to generate many licenses that did not result in revenue streams for private industry then they would actually be a detriment to the US economy by creating opportunity costs. Licensing must be used in conjunction with a royalties per licensing ratio to ensure a true economic impact.

Even so, case studies show that there exist economically successful technology transfers that do not include licenses. Case studies should be selected based on their economic success or failure. Principal individuals involved in the attempted technology transfer should be interviewed, and historical documents and financial statements reviewed. The case study should trace the transfer effort back through the intermediate and input stages of the process to identify crucial elements leading to either success or failure. Compilation of many case studies can lead to a richer understanding of the transfer process. Thus the portfolio approach with quantitative variables (licenses, royalties/license) and the qualitative approach (case studies) are recommended as guiding metrics for NASA.

Currently NASA senior management has strongly urged the creation of success stories. An internal competition between NASA centers has erupted to generate the most success stories. These success stories are short descriptions of attempted technology transfers. Success in these stories do not necessarily include economic success, and in most cases do not. It appears that NASA is still using technology transfer as a public relations tool to sway congressional votes on the regional impact of technology transfer. This is an understandable approach in the political world of federal agencies, but NASA should show higher integrity by not misrepresenting its activities and overselling itself. NASA has plenty to be proud of already and should take a more professional approach to technology transfer. In-depth case studies and quantitative analysis should be utilized as measures of achievement, and as guides for policy.

Lastly, the results of future research might further support and enhance the creation and implementation of effective technology transfer policies by federal laboratory directors, heads of federal agencies, and Congress.

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APPENDIX A.1

NASA Langley Research Center Memo to Inform Employees of the Technology Transfer Commitment (July 22, 1994)

National Aeronautics and
Space Administration
Langley Research Center
Hampton, VA 23681-0001

Reply to Attn of: 118

July 22, 1994

TO: 106/Director

FROM: 118/Acting Director, Technology Applications Group

SUBJECT: Langley Technology Transfer Policy

This document sets forth Langley Research Center's policy for Technology Transfer and the functions of TAG. A Center goal is to commit 10 per cent of Langley resources, including personnel and funding, to technology transfer activities with industry (including Small Disadvantaged Businesses). Although TAG has the responsibility to facilitate and coordinate this action, it is the responsibility of all Center organizations and people to implement technology transfer. TAG also has the responsibility for the Center's technology transfer data base to account for the costs and the tasks. Project procurements shall include dual-use assessment and technology transfer in the development of RFPs.

TAG will facilitate technology transfer in APG and SASPG primary missions and will lead technology transfer to secondary and non-aerospace sectors. A small Technology Transfer Assistance Account (one or two per cent) will be established to assist the Center in meeting these goals. This account, supported by APG and SASPG, will be managed by TAG. The overall 10 percent must be linked to appropriate RTOPs to highlight program participation and to leverage dual-use for the 10 per cent goal.

The basic planning document for managing nonprimary technology transfer will be developed by TAG, concurred on by the Technology Council, and will include the Divisions' Technology Transfer Plans. This plan includes individual ideas, TAG-identified opportunities, industry pull, and technology push. Partnerships with industry early in the process are essential for success. TAG and the appropriate RTOP manager will nurture, accelerate, or terminate transfer projects based on their commercial potential and project progress.

Joseph S. Heyman
46005

cc:
118/TAG

Concur: Paul F. Holloway
Director

APPENDIX A.2

NASA Langley Research Center Memo Outlining Procedures for Accounting for Technology Transfer Expenditures (June 20, 1995)

National Aeronautics and
Space Administration
Langley Research Center
Hampton, VA 23681-0001

JUN 2 0 1995

Reply to Attn of: 109

TO: All Employees

FROM: 109/Comptroller
118/Director, Technology Applications Group

SUBJECT: R&D Resources Expended for Technology Commercialization

The Center Director has established a goal of expending 10 to 15 percent of R&D resources for technology commercialization. In order to measure the Center efforts toward meeting this goal, the following procedure is established.

1. <u>R&D Resources Used for Technology Commercialization</u> - Technology commercialization activities that use R&D resources ($'s and labor charges) from Aeronautics and Space RTR's/RTOP's shall be accounted for by using a "T" job order. A "T" job order is made by replacing the "R" or "H" prefix on established R&D job orders with "T". For example, a technology commercialization activity associated with the work area normally charged to R1234 would be charged to T1234. No additional action has to be taken, no new job orders have to be opened. The "T" job orders can be used for labor charges, procurement actions, and fabrication work.

2. <u>Resources Set Aside for Technology Commercialization</u> - Resources set aside by the groups for technology commercialization will have separate RTR's established for those resources.

3. <u>Direct Funding</u> - Resources received directly by the Technology Application Group will be accounted for under the RTR's established for those resources.

We ask for your help in identifying and recording our efforts in technology commercialization. If you have any questions concerning the application of this new procedure, please call Jim Gardner at extension 46003.

Joseph R. Struhar
48084

Charles P. Blankenship
46005

APPENDIX B.1

Historical Perspective on the Effect of Science and Technology Policies on Technology Cooperation Between the Estates of Science

(Note: This Appendix relies heavily upon Hunter Dupree's *Science in the Federal Government* and Bruce Smith's *American Science Policy Since World War II*. As the preeminent texts on the history of science and technology policy in the United States, these texts were used extensively to construct a picture of technology transfer since the framing of the Constitution. Apologies and gratitude to both authors for my extensive use of their expertise.)

The relatively young US has maintained a considerable share of technology leadership in the global market over the past 50 years. Yet this lead is slowly eroding. Since 1965, the US lead in share of exports in technology intensive products has begun to diminish. Competitors such as Japan, Germany, France, and the UK have increased their relative real gross domestic product per employed person (a measure of productivity) from a range of 20-50% to a range of 70-82% of that of the US (Figure B.1; Irwin 1993). In particular technology industries, the US has lost the export/import lead and this has left the nation pondering what it should do to stop the slide.

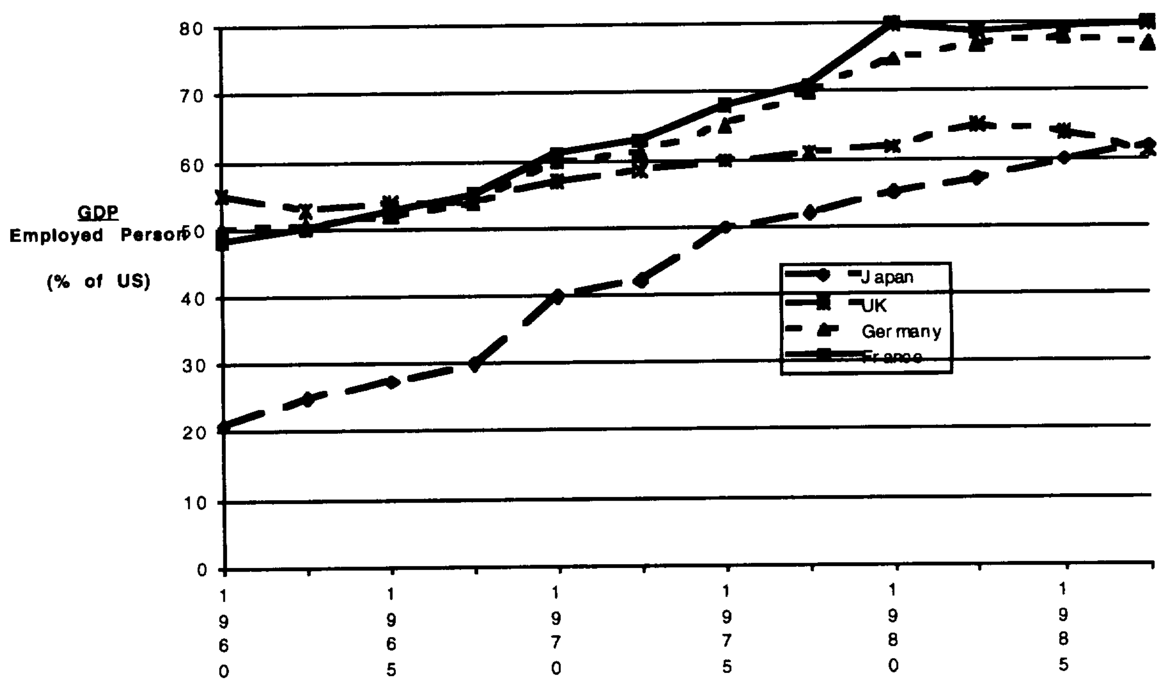


Figure B.1: Real Gross Domestic Product per Employed Person, 1950-1989, (Irwin 1993).

The US has traditionally had a laissez-fare government policy toward science and technology commercial development, leaving this concern to the private industry. This stance fits the US culture of individualism, liberty, and pioneer spirit. Yet cooperation between federal government, the private sector, and universities has proven successful in some instances. Recent global competition has spurred debate on the role of the estates of science, government, private industries, and universities. The most recent economic situation has deepened concerns about science and technology policy for the US, and most of the debate centers not on whether there should be government participation, but what that participation should be.

Policy is aimed at assembling, organizing, and directing national resources to meet the needs or wants of a nation-state. Those needs and wants are derived from the collective perspective of the nations' citizens and their representatives. The creation of policy in a democracy should be tied closely to the citizens' or societal belief systems. A nation-state and its citizens evolve and experience changes in priorities according to external and internal stimuli (wars, employment, wealth, etc.). The challenge of policy making is to address current concerns and belief systems of the citizenry, for the common good, and to allow enough flexibility for the future and its uncertainty. Good policy-making must therefore be preceded by an understanding of the contemporary issues facing a society and the lessons learned from similar or analogous historical events. Within this appendix, the science and technology policies of the US relating to technology transfer along with the prevailing circumstances surrounding such policies, are presented and analyzed to serve as a contribution to more informed policy-making in the future.

A review of previous policy decisions, circumstances and results is a good way to acquire insight for new policies. It is thus the aim of this study to bring a historical perspective to an understanding of contemporary issues so as to contribute to a vision for future policies. Information on US science and technology policy collected over the years creates a historical databank of empirical information. During review and analysis of these policies and consequential results, one must keep in mind that policy-making remains a empirical science. The outcomes of policies are analogous to the results of statistical hypothesis testing. In either method, a hypothesis or policy is never fully proven, merely alternative hypotheses or policies can be rejected. Policy analysis is especially difficult due to the extreme number of confounding variables. With these difficulties in mind, this review and analysis takes on a conservative stance especially with regard to extrapolating conclusions.

Circumstances of the day and realities have always driven science and technology policies in the US and shaped them for the future. From the framing of the Constitution to contemporary times, the role of science and technology within the federal government has mostly been influenced by immediate issues of war, budget, and jobs and not so much by the visions of public or politicians. As a result, US science and technology policy has resembled more of a continuum of incremental changes even when viewed within the framework of five distinct periods. Within this appendix, an attempt is made to establish a cognitive framework, based on history, to guide further policy making decisions.

Technology cooperation between the federal government and the private sector is marked by five distinct eras representing the early expansionist movement, the economic development period, the war period, the cold war period and the economic competitiveness period (Table B.1). Each of these eras is distinguishable by the defining needs, social characteristics, and internal and external stimuli of the nation-state. Even though there are five distinct time periods with one large break at the end of the war period, the science and technology policies with regard to technology cooperation can better be described as evolutionary and not revolutionary.

Viewing the five periods in their entirety, a clear vision evolves of a nation that lost its way following World War II. Up until the war, most science and technology activities in this country had been given their proper perspective and performed within a systematic approach. Science and technology were utilized as tools in conjunction with their applied functions. Applications were the drivers for the system. The nation developed as a group of pioneers who saw science, technology, and other disciplines as means to an end. The US has always been a competitive nation because of its ability to blend basic scientific research, applied research, development, financing, marketing, and management issues. Science and technology as a means to an end has been the sentiment up until the end of World War II.

At the end of World War II, the scientist claimed savior stature based on the development of the atomic bomb and the other wonders that "won the war and saved the world." The future world was to be bright, atomic, and clean. We would have an endless, clean supply of energy, a space station, flying cars, and a trans-Atlantic metro. To make this all come true, the nation was to invest in basic science that would spin-off these technologies. The idea had so much appeal that spin-off was marketed as a reason for funding, and slowly was ensconced as "truth" in the public and policymaker mind. Long forgotten was the idea of collaboration and systematic thinking that had developed to such success in the pre-war years. Now more than ever there is a need for that systematic thinking as the US faces the harsh realities of global economic competition. Technology can lead the way, but it must be through government and private sector cooperation. The nation must find a way to utilize all of its resources and use synergy between the estates of science to achieve a whole that is greater than the sum of its parts.

Table B.1: Periods of Technology Transfer in US History

Period	Timeframe	Definition	Activities
Expansion	Framing of Constitution 1770s- 1890s	Technology development and replication in support of expansion and exploration	• Various expeditions • Coast Survey • National Geographic Survey
Economic development	1890s - 1930s	Problem approach, commercialization, agency building	• Extension agents • NACA • Land Grant Act
War	1940s	Science and technology support weapon development and conservation	• World War II • National Resource Committee
Cold War	1950s - 1980s	Return to basic research, science held as panacea for national strength and defense	• *Science: The Endless Frontier* • NSF
Economic competitveness	1980s -->	Small steps toward commercialization, management of technology becomes a component of activities	• Stevenson Wydler Act • FTTC Act

Expansionism Period (1770s -1890s)

The expansionism period is distinguished by two activities: the exploration and survey of the resources of the nation, and later the harnessing and utilization of these resources. At the beginning of this period science was more of an amateur practice included within the liberal arts. It was, in today's language, an academic pursuit. In the expansionism period, the nation came to appreciate the possible benefits of science and more specifically technology.

Early in this period, the role of science and technology was debated to no conclusion by the writers of the Constitution. They, along with subsequent politicians, were unable to vocalize a clear vision of the role of science and technology for this burgeoning nation. Concerns focused mainly on taking stock of national resources through surveys and explorations and developing an infrastructure. Once a certain amount of resource accounting was accomplished, an interest emerged focused upon the utilization of these resources. The expansionism period takes the nation from its colonial roots to a realization of the relevance of science and technology to the private individual and the birth of fruitful government/university/private cooperation.

One must recall that Washington DC, at that time, was little more than a swampy area far removed from the accouterments and resources of established cities. Working under difficult constraints of a national debt, slow communications, and a very loose federation, the founding fathers tussled with the question of the role of the government in scientific discipline as just one of a plethora of many other issues, most of them seemingly more pressing. Concerns of the time were dominated by exploration, expansionism, and the development of basic infrastructure items.

One of the early champions for an active nation-state participation in science and technology was Charles Pinckney, a signatory to the Constitution. Pinckney laid forth plans granting charters for incorporation, patents for useful inventions, seminaries for the promotion of literature and the arts and science, public institutions, and rewards and immunities for the promotion of agriculture, commerce, trades, and manufacture. Pinckney's visions were drowned out in the sea of more immediate and practical needs, such as roads and canals. Universities and scientific societies were grouped along with the roads and canals as issues of "internal improvements," but relegated to a secondary status due to the countries more immediate need for infrastructure.

The US did not have a strong base of scientifically trained people at this time. The nation was composed primarily of farmers and rugged individuals whose interest in science and technology was in the utilization of it to improve the quality of life. The origin of the US as a nation of explorers helped shape its scientific and technological identity. In the decades that followed, the nation developed from its "hands-on" ingenuity (known to some as "Yankee ingenuity") which consisted of product improvements and process streamlines, marketing, and financing. American technological innovation was a perfect match for the capitalist society, where the concentration was on creating the product for profit. This capitalist attitude created a ingenuity that spanned the entire product development with no prejudices for basic or applied research or marketing, but focused on being successful. Alexis de Toqueville, the French liberal politician and social commentator who visited the United States during the 1830s found a worship for practical inventions, a concern for utility, an enthusiasm for the material consequences of applied sciences and documented them in his book *Democracy in America*. Even in the infantile stages of development the US had a natural bent toward economic development which blossomed in full a little over a century after its birth.

During the early 1800s, science was left as an academic or artistic pursuit of clergymen, amateurs, and America's new colleges. Technology was the natural response for the colonials' practical demands in the rugged environment. Thomas Jefferson had a great concern for applying science for useful ends. Jefferson shared the belief that Benjamin Franklin wrote in a letter to one of his colleagues: "I would recommend it to you to employ your time rather in making experiments, than in making hypotheses and forming imaginary systems, which we are all apt to please ourselves with, till some experiment comes and unluckily destroys them." The dedication of ingenuity supported by a "practical" science to domestic purposes was staunchly defended by Jefferson. It represented for him the democratic goal of a useful science, however humble those uses. Jefferson's ideal of a technology dedicated to the popular weal both reflected and enforced an attitude which would increasingly dominate the American culture (Pursell 1994).

Government support for innovations was at a minimum, and ties between basic research and technology development were weak during the expansionist phase. In truth, this expansionist period most strongly represents an applied science or technology development approach. L.J. Henderson's dictum, as noted by Dupree (1987), was most likely true that before 1850 science owed more to the steam engine than the steam engine owed to science. Most inventions sprang from empirical observations. Steamboats and Steam locomotives are products of the age of "cut and try" and "rule of thumb". In addition, some technology development was in reality technology transfer, both legal and illegal, from other nation-states. Some foreigners even to this day, dispute that it was not so much technology development that spurned the US on as it was the stealing of technology from abroad. Specifically, the textile industry was imitated from its predecessors in the United Kingdom and brought here by a few enterprising persons.

It is interesting to note that technology development preceded basic and applied science and that applied science came into play only later when some of the steam engines started to explode, creating a public outcry for government protection and intervention. The government supported studies to try and understand at a basic level the scientific issues involved so that it might better be regulated and standardized. The technology development approach still occurs today in many fields: witness the development of solid rocket propellants for space vehicles. Although the performance and macro-characteristics of rockets has been well documented, the thermo-chemical combustion at the micro-level have not yet been fully characterized and is only loosely modeled by theories.

In the expansionist period the bulk of government scientific activities and the focus of the science policies revolved around the Coastal Survey, and geographical surveys and exploration parties like Lewis and Clark. Most Congressional debates focused on the amount of money to be appropriated, and determining the recipient of the funding to perform the research. These efforts dominated most science policy debates and government activities for the first hundred years. In retrospect, the sum of these activities can be viewed as an infant nation-state examining itself and taking account of its belongings. Most government efforts had no focus on any type of commercial end. The geographical surveys and explorations served more or less as inventory activities from which the nation-state could eventually springboard into commercial activities. These activities also contributed to national security in securing lands that eventually became part of the nation. A capitalist bent can be loosely associated with the Coastal Survey and its interest in determining usable shipping ports and lanes.

During these formative years many internal improvements were leveraged through the sale of federal lands (Spence 1995). Expansion and growth in terms of geographic domain and culture, and more importantly in terms of wealth, were based on the natural resources of the United States. This is an important distinction from contemporary times, where the playing field has leveled out a bit with the other developed nations. A large portion of the natural resources of the US have already been leveraged, and international competition occurs mostly through the abilities or productivity of the citizenry. Irwin feels that the central issue in contemporary economics is the productivity of a nation (Irwin 1993).

During the expansion period, the introduction of the first science institute in the United States is a story filled with irony and humor, displaying the unease at which the US entered the science policy arena. After decades of debate about the introduction of a national institute of some sort, the impetus for the organization was the bequeathment of $500,000 by a English citizen, James Smithson in 1829. Smithson's will requested that his money be given to the United States "to found at Washington, under the name of the Smithsonian Institution, an Establishment for the increase and diffusion of knowledge among men." There were many stories of why Smithson, an Englishman, wanted to bequeath his wealth to the "colonists." These explanations ran from the simple, that he had no heir as a bachelor, to the eccentric, that he was angered by the Royal Society for not inviting him to join the prestigious group (Dupree 1987).

Even more bizarre than the bequest was the reaction of the US Congress to this windfall. It took a 31 to 7 vote to accept the funds and another 10 years to decide what to do with them, with the serious contention of returning the funds being broached several times. There were many Congressmen who felt the US was being belittled by accepting the gift and others who thought it would be used to further centralize control (these being mostly southern delegates). It is interesting to note the analogy between the representatives in this time period and the current 104th congress. The ordeal of the Smithsonian typifies the attitude of the majority of early American politicos toward science: fear, and ignorance.

The activity which best symbolized the nation's movement toward utilization of resources and technology cooperation, and is recognized as one of the most successful technology cooperation programs in US history, is the Morrill Act, more commonly known as the Land Grant Act. An early proponent from the University of Illinois, Jonathon Turner, envisioned "Industrial Universities for the People" (Dupree 1987). His plan featured a donation of land by the federal government instead of money, with the universities placing an emphasis on practical agriculture & mechanics. This is an example of how the US leveraged its natural resources in the early days to create growth.

In 1857, Justin S. Morrill of Vermont introduced the bill for the land grant colleges. This foundered for years largely due to opposition from the southern states and again a concern of centralization. To be fair, there were also opponents who broke along the debate lines of large vs. small state and states rights vs. federalists. In retrospect, the Morrill Act has been considered one of the best science policies ever enacted, and could be considered one of the positive outcomes of the Civil War. One of the most noted federal actions resulting in effective technology transfer, was a secondary result of the Civil War. The Morrill Land Grant Act that had a difficult time succeeding through the houses of Congress, finally passed easily on July 2, 1862, without the presence of the southern states.

The Morrill Act represented a major departure from the typical beliefs of the day. Pluralism ruled, as it does today, where there is a cacophony of voices representing the different perspectives of industry, government, and university. In addition, most research was privately funded. In a sense, the Morrill Act of 1862 was a watershed movement. It found its impetus in a national belief in self-sufficiency. The nation needed to improve its crop production and this led to the nation's first attempt to pursue both scientific and commercial leadership. The results of the Morrill Act were a improved crop production per acre and a positive balance of trade in agriculture. The Morrill Act therefore became a stepping stone into the next period of economic development.

Two features contributing to Morrill Act success were its geographical equity and stable political constituency. By placing the land-grant colleges under the control of the states, it created a sense of ownership and value along with political support. The Morrill Act was a natural fit to the interest of the nation as it was dominated by the agricultural profession and a boost was needed in this arena.

The effectiveness of the Morrill Act was augmented by a series of activities that led to what is still considered an exemplary model of technology transfer. In the 1870s a entomological commission was tasked with finding a solution for the locust-induced problem of blight. The approach brought into line aspects of both basic research and applied research and could be considered purposive basic research. The combination of laboratory research, communication, and field work brought solutions to the locust problem. The success of this first act served as a model for subsequent activities. Assistants were sent to the scene of outbreaks and had their first dramatic victory over insect pests. This was a very important activity, establishing the first utilization of the agent approach. Eventually, the commission merged into the Department of Agriculture as the Division of Entomology and the agent approach was recognized as an effective mechanism.

These activities dovetailed into another watershed legislation passed in 1914, the Smith-Lever Act, which put extension service on a separate and permanent basis. The Smith-Lever Act was a 50/50 plan in which each federal dollar was matched by one from the states. This provided a sense of ownership from the standpoint of both the nation and its states. The combination of laboratory work complemented by a two-way communication to and from the farmers produced a successful combination. The researchers had data and experience supplemented by "real world" results and issues.

It was within this time frame that another excellent example of government and industry cooperation was forged. Gifford Pinchot, took over as head of the Division of Forestry with a pragmatic view of forest growth management. He abandoned the complete documentation of the biology and life history of a forest approach and instead wanted to measure the things a ranger needed to know to estimate what should be done to sustain the yield in a given stand of trees. A key to his approach was to get support for the division by making it useful to private timber owners. A publication called "Circular 21" offered the division's assistance to anyone who wished to harvest timber and still have a second crop. Working plans and full practical directions were given by agents. Evidence of the interest in this service is the willingness of owners of larger tracts to pay the expenses of the division's parties. "Getting forestry into the woods" was the aim, and the division supported research that was empirical and clinical. Requests for aid flooded the division. Within a short time Pinchot forged an alliance between the lumbermen and the division. Because the larger operators had a greater margin with which to experiment on long-term methods, the Weyerhaeuser Lumber Company and other giants were foremost in adopting the recommendations and in praising Pinchot's work.

The assistant chief of the Division of Forestry, Henry S. Graves, left for Yale to head a new forestry school and set the standard for education in this specialty throughout the country. Graves consequently demonstrated another industry to university connection by transferring the industry know-how into the academic setting.

The economic development period was phased in and the expansion period phased out by these attempts/efforts to relate activities to immediate problems. A shift of emphasis on research from basic to applied occurred for many bureaus. The spirit was captured in the statement of Henry W. Henshaw, who helped shape many early government bureaus: "pursuit of science solely for its own sake, however commendable it may be, is not the spirit that animates our government in its support of scientific research. In its aims and ambitions this is a practical age" (Dupree p. 253, 1986).

Dr. John Shaw Billings, illustrious surgeon of the Army Medical Corps, went on to say "We may not rest and eat lotus; we may not devote our lives to our own pleasures, even though it be pleasure derived from scientific investigation. No man lives for himself alone; the scientific man should do so least of all" (Dupree p. 230, 1986).

During expansion period the US took stock of its resources through various exploration and survey teams, while developing a technology base through replication of skills from overseas. The idea of science and technology as a cornerstone of societal well-being was undeveloped. The nation at that time was primarily agricultural in nature. It is fitting then, that the Morrill Act, the first example of the systematic use of science and technology cooperation, was developed to aid the agricultural system. At the beginning of the expansionism period the role of science and technology appeared to be relegated to the realm of debate for future concerns. Yet, toward the end of this period real progress had been made. Methods of cooperation between the government and private sector developed and a appreciation of the potential emerged. The country with its pioneer roots preferred the pragmatic technology development approach over one based on unclear results from basic science.

This period of expansionism dovetailed into that of economic development. Dupree refers to the early days of this economic development as conservationism, where there was a realization that efficiency and synergy of efforts could establish more benefits from natural resources. The Department of Agriculture created a vision of government/industry cooperation for others to improve upon, and the nation was just beginning to realize its strengths with the advent of big oil companies and industrialization.

Economic Development Period (1890s - 1930s)

The stimuli and national character of this period of economic development were most like that of the current economic competitiveness period. Motives and therefore actions were mainly employed for capitalistic ends. This was the period of Thomas Alva Edison, in which private industry harbored a genius for both scientific and technical research as well as a genius for marketing and financing technology. Although the spirit of American entrepreneurship flourished, government participation also took place. The government was asked to take an active role where the private sector could not support research or standardization was necessary. It was during this period that the nation created several bureaus to aid the capitalist movement. These included National Advisory Committee for Aeronautics (NACA), the National Bureau of Standards, the Bureau of Census, and the Bureau of Mines.

Private sector research was strong during this time. The bureau building of this period was a move toward government involvement. Leading up to this period "much of the technological genius of America was a genius for organization, for management, for either linking an invention to a rapidly developing market or creating a new market for an invention" (Smith p. 26, 1990). This was the early spirit of America which, following World War II, was replaced by an emphasis on basic centralized science. During this early period the innovators were good at both downstream and upstream activities. It was during the following war period that a need for national military strength caused a refocusing on upstream activities.

The industry oriented bureaus sought answers to those problems industry needed to have solved but was unable or unwilling to answer for itself. These activities are classified as market-failure, or those where a free market cannot afford to support the activity. (In reality, there is no such thing as a market-failure sector: it is merely a matter of the definition of the market. For example, it is stated that the government builds roads due to a market failure. But in reality, this improves the national strength to compete in the global market and the investment by a national entity is a market move, albeit at a nation-state level market.) An additional benefit of these bureaus was the creation of a large number of trained scientists and engineers. These civil servants were subject to high turn-over rates, which created a direct technology transfer through experts migration into the private industrial sector.

In 1903 the Committee of Organization of Government Scientific Work took a position emphasizing the organization of research around a problem, and that "the individual sciences and arts should not be segregated in the separate bureaus and offices" (Dupree p. 296, 1987). This position reflected a concern toward addressing more immediate economic needs as opposed to long term investments.

One of the best US organizations in terms of technology transfer was created in this era. NACA, formed in 1915, was to determine the problems plaguing the US aeronautics community, obtain practical solutions through studies and disseminate the results. The impetus for creation of NACA was the recognition of aeronautics as a strategic national venture and the advances made by the European community (Roland p. 4, 1985). Alex

Roland, NACA historian, associates NACAs success with the representation of private industry on the committee. Private industry representation created a direct communication link between industry and government activities and helped guide NACA to purposeful research (Roland 1995). Arguments are made now that NASA still has private industry influence through industry and independent review committees. But there exists no real accountability in the current arrangement. Compare the 1980s, when there seemed to be a new advisory committee report to help steer NASA every three years (Augustine Report 1990, Leadership and America's Future in Space 1987, etc.). For the most part these reports were treated as academic exercises or at best visions, but were not used to form policies or programs.

NACA serves even to this day as a learning model for technology transfer organizations. Certainly NACA had its flaws, as pointed out by Roland, but in general the organization was responsive to the needs of the private sector. NACA held an annual technology exhibit for the benefit of the private industry and the congressional staff. In the early NACA years communication systems were still a bit slow, with the written word still tending to dominate. Thus, the exhibit created an opportunity for a more complete understanding and interchange between the NACA researchers and the public. Although today the communication systems have improved immensely with the advent of email, the web, and tele- and video-conferencing, there is still a need for the interpersonal exchange. NASA

Langley Research Center, the former NACA site, reinstituted (although somewhat unaware of the previous historical precedent) the technology exhibit in 1993 calling it the TOPS or Technology Opportunity Showcase (demonstrating the NASA tendency for acronyms).

This economic development period was slightly interrupted by World War I. The War and the needs placed on the country impacted science and technology thinking. It did not significantly alter the policies at that time but raised some technology and science cooperation issues that would be more seriously addressed during World War II. In response to World War I, the US recognized the importance of technological advances and attempted to find solutions to military problems through technology. The war brought an organizing committee under George Ellery Hale, a astronomer and member of the National Academy, that recommended "there be formed a National Research Council, whose purpose shall be to bring into cooperation existing governmental, educational, industrial and other research organizations" to strengthen the national defense (Dupree p. 309, 1987). This idea of pooling research for the betterment of the entire nation-state, although not entirely successful at the time, created a new paradigm in thinking that would be addressed and readdressed over the following years.

One of the biggest impacts of World War I, and to a bigger extent World War II was the infusion of research into production. The wars created a need to produce technological solutions in a rapid period of time. This need for new product developments created a strong industrial research component that has become one of the three "estates of science".

It was also during World War I that a Consulting Board was formed to review over 110,000 suggestions in a effort to find technological solutions. Only 110 inventions had enough merit for detailed examination by a subcommittee, and only one went into actual production. As Dupree so succinctly puts it, "No clearer proof is needed that in time of total war random ingenuity is no alternative to the problem approach by teams of highly trained men thoroughly aware of both scientific theory and the needs of the services" (Dupree p. 308, 1986). His statement reflects the comments of Dr. Barry Bozeman of Georgia Tech, who is inclined to believe that these "shopping lists" approaches are ineffective (Bozeman 1995).

In the decade directly following World War I, there was a return to the focus on business development. But even within this renewed focus on economic activity and profits, there also sprang up a concern for the future. Herbert Hoover, Secretary of the Department of Commerce at the time, warned that we were spending too much of our effort on applied research and too little on basic research. He felt that the floor would drop out of the economy due to a lack of basic research, and tried to establish a National Research Fund. This National Research Fund would support basic research in universities with a large and continuous flow of money contributed by industry. It stressed voluntary cooperation and eschewed any form of government control, relying on enlightenment of business leaders. It failed miserably and demonstrated the failure of industry to support a market-failure venture.

The economic development period also endured a depression, which impacted science and technology policy thinking. In a 1932 presidential campaign speech Herbert Hoover used the metaphor of science as the new frontier and pushed for basic science and an investment in the future, but people were in no mood for long range answers when the depression demanded immediate action. Public opinion has always had strong convictions about short-term issues and immediate concerns, making long-term science policy a difficult political issue. In a perceived contrast to Hoover, it was at this time that the New Deal Democrats promised to reduce government spending.

At this same time, Henry A. Wallace, the Secretary of Agriculture under Roosevelt, was also a champion of science, but from another perspective. He differed from Hoover by knowing the role of other institutes and disciplines. "Those who struggle beyond the new frontier will be those who know how to obey the economic traffic lights, and drive social machines on the right hand side of the road" (Dupree p. 349, 1986). Wallace was voicing a commitment not only to basic science but to other components of the new technology continuum that produce a stream of benefits for humanity. His idea was the embodiment of systematic thinking, that no one part of the process should supersede the others, but instead a balance of upstream and downstream activities should be integrated. The issue was, and still is, what policies and activities should be implemented to activate this thinking.

Wallace was quoted as saying, "Actually, science has not given us the means of plenty until it has solved the economic and social as well as the technical difficulties involved" (Dupree p. 349, 1986). Here is a key idea, that one must look at both the social and economic impacts of the science decisions to make them effective. The very idea of looking at the intertwined issues of science, technology, and society was not a new one, but Wallace was bringing it to the forefront again. On this topic Albert Einstein said, "Concern for people and their fate must always form the chief interest of all technical endeavors in order that the creations of our mind shall be a blessing, not a curse, to humanity. Never forget this amid your diagrams and equations."

Recognition of a system of "estates of science" occurred during this period. These estates consist of the university, private industry, and the federal government - along with an attempt to coordinate the efforts and break down the barriers. One of the oft-cited methods of cooperation during this period was the contracts given to universities to perform basic research for NACA.

The economic development period represented a strong period of science and technology impact on the economy and quality of life. Many new inventions sprang up at the turn of the century and the government found ways of working with private industry. Yet during this period, the successes stemming from science and technology led to an extrapolation of a system of product development to an emphasis on only one of the links, basic science. The idea of cooperation and deriving benefits from science and technology was being replaced by isolated basic science. Hoover's speech in 1932 painting a bright future based on basic research became the starting point for thinking that has now permeated our culture and to some extent supplanted the "Yankee ingenuity" paradigm. The roots of a belief system in basic science as the source for quality life sprouted and took hold immediately following the war period.

War Period (1940s)

The War period represents one of the more dramatic changes in the predominantly evolutionary development of the nation's history. Funding in research, particularly military, and depth of collective concern toward research made huge gains during this period. There was an effort to extract the full potential from the estates of science and this consequentially led to technology cooperation. The government funded private industry and universities to support the military program and the interchanges of information represented a technology transfer of information.

World War II had a dramatic effect on the activities and daily life of the US. The war years created a new collective patriotism that resulted in a fortified effort from all sectors and individuals to preserve their ideal of democracy. The science and technology community was not an exception to this spirit. In 1940 the National Defense Research Committee (NDRC) was created in an effort to bring all of the scientific resources of the country to bear on weapons research. Roosevelt and Vannevar Bush led the charge for this restructuring. Bush modeled the NDRC on the NACA by having a committee with military representation and a predominance of independent members. The committee was not so much interested in developing new labs or performing its own research as in figuring how to use existing resources by funding universities and industrial firms. The NDRC placed contracts with those best suited for each project without regard to any state or geographic politics. As in many war time activities, some of the political wrangling was dropped.

The NDRC had a shortcoming in its narrow focus on weapons development. Therefore with Vannevar Bush's direction, President Roosevelt created the Office of Scientific Research and Development. The OSRD was to bridge the gap between research and development and the creation of an actual battlefield weapon. The need for a systematic approach was recognized through the shortcomings of the original proposal. The OSRD then became the central focus for all scientific and technical activities in a country absorbed by the war. All estates of science were to be coordinated through this agency.

The OSRD found reasonable success in employing the talents of the scientific community for the war, but would be inappropriate for peace time direction. Vannevar Bush realized the shortcomings of the OSRD as a peacetime central science organization, and with his advice the OSRD was slowly relieved of its powers. The resultant organizations and the lessons learned during the war had a profound impact on the following Cold War period.

The war changed the future of science and technology policies in the US in permanent and lasting ways. Annual expenditures for research prior to the war were approximately $100 million. The war years raised the amount to $1.6 billion. There was a discontinuity in the funding spike that created a new plateau, the old one never being revisited. Many practices of the war period carried over into the Cold War period including the predominance of military research, wide spread use of research contracts to the universities, growing support of mission-related research by government agencies, and enhanced status for scientists and technical bureaus. During the war period a partnership between science and the government proved to be beneficial and struck up renewed and invigorated debate on the best approach to harness the benefits during times of peace.

Cold War Period (1950s - 1980s)

The Cold War period started with revolutionary thinking stemming from the World War II period and the end of the economic development period, and a vision for a bright future but developed into an endless debate with only evolutionary changes (Bush 1945). The Cold War brought with it a proposed structure to increase the nation's wealth through science and technology. Science as a panacea for national strength and defense was developed, then softened, attacked, and eventually debated endlessly resulting in no conclusive actions.

As the war effort wound down, Vannevar Bush pushed for the dismantling of the OSRD since it had never been meant to be a permanent organization and seemed an awkward one for the coming challenges. At this point Congress transitioned some of the activities into civilian charge with the Atomic Energy Commission created in 1946. The scientific community was busy touting itself as the saviors of humanity. For the first time in US history, scientists had taken a center stage for their part in ending the war through the wonders of the atomic bomb. The creation of an atomic bomb was a Herculean and ingenious effort by many, including scientists, engineers, technicians, and managers. But the bulk of the accolades were placed with the scientists, who took the opportunity to raise the level of importance and awareness of science to the public interest.

The public fascination with science as a solution to public ills, led to a belief that we were on the verge of a new frontier that science would open up (Fagen 1982). Basic science would be the driver of the system, providing the advances to sustain a significant pace of inventions, and the costs would be absorbed by the government. The government was viewed as the entity with deep enough pockets to nurture the effort. And in the words of Smith, "Commercialization was to occur almost automatically as a by-product from the government's support of basic research and more applied research and development operations" (Smith p. 37, 1990). The idea of "spin-offs" was becoming a central part of the scientific and economic policy of the country. The spin-off ideology brought about a policy of no policy towards commercialization to allow the natural flow of scientific work into commercialization.

Science: The Endless Frontier was published in July 1945, eight months after a request by President Roosevelt to his adviser Vannevar Bush. Bush was to create a report outlining the utilization of science for the post war period and respond to four concerns voiced in President Roosevelt's request: diffusion of scientific knowledge developed during the war, organizing a war on disease, how the government can aid in research activities both public and private, and how to develop scientific talent in American youth. This report has become one of the best known of all science policy reports in the United States and a focal point for debate continuing even today, fifty years later. President Roosevelt's first request on diffusion of scientific knowledge can be interpreted as a formalization of military to civilian technology transfer.

Although Bush's report contained balanced statements in support of basic research as just one of the components of success for the future of the nation, it was believed to be of fundamental importance to achieving vital national goals. This belief represented the paradigm of the day and the one that would continue throughout the Cold War period. The belief that a government investment in basic research and hands off approach to the remainder of the process, was rebutted by many during the social rebellion of the 1960s.

Bush's report recognized the absence of a national policy toward science or any central organization responsible for science. The major conclusion of the report was its proposal for development of a National Science Foundation (NSF) to direct the scientific resources of the nation. Five years later in 1950, the NSF became a reality. But the NSF that resulted was one quite different from that proposed. The teeth had been taken out of it, and the agency today is nothing more than a peer-reviewed source for funding, not the policy-setting agency that was envisioned.

Although Bush stands out in US science policy history, he was not without a counterpart in his day. Almost equally as well known is Senator Harley Kilgore of West Virginia and the chairman of the Subcommittee on Science Legislation of the Military Affairs Committee during the early 1940s. Kilgore also had an interest in a central science organization but for different reasons. Bush wanted to raise science to a higher priority and support basic research for the public good, while Kilgore saw a central organization creating better communication and information diffusion for the public good. The difference in philosophy about this structure caused long debate and tension between the executive and legislative branches. Kilgore's vision was to follow the successful model of the agricultural efforts, while Bush's was to create basic research and let things fall into place. Bush and his colleagues tried to revive the spirit of Herbert Hoover's effort in the 1920s to promote basic research. But this time they would use public money, essentially without public control. The NSF board approach takes the public influence out of the loop and places direction into the hands of scientists. This meant that the issues of private industry were not directing the efforts, which were to produce commercial results, but rather the peer-review process was used to determine which research would be performed. The US taxpayers would pay for the research and the scientists would control the funds and determine how to use them.

At the time of the report, US manufacturing productivity was more than twice that of its principal competitors and lent credibility to the idea of basic science and no commercialization policy as valid and successful. A continued growth would provide support to perpetuate the system. There was widespread support because all people would share in the benefits of expansion.

A political change caused the NSF to become a reality in the much watered-down version of Bush's model. In 1946, the Republicans swept the congressional elections and took control of the majority position in Congress. This moved the debate away from Kilgore's concept since he was divested of his chairmanship. Kilgore was replaced by H. Alexander Smith, who was sympathetic to the views of his friends on the Princeton faculty. The faculty stressed the importance of quality in scientific effort and the need to insulate research as far as practicable from politics. The peer- or merit- review process was born.

Originally Bush thought that basic research could not be administered effectively or performed within an agency that had operational responsibilities. This was one of the reasons behind his idea for centralized control of basic research. Later he softened this stance and came to believe that useful cross-fertilization can occur between development and basic research, provided that basic research had some measure of administrative independence from development activities. Therefore, basic research broadly relevant to an agency's responsibilities came to be known as "mission-oriented basic research."

This left some question about the role of the National Science Foundation, if even basic research was supported primarily by mission agencies. Smith poses the primary issue: "Whether it [NSF] would have pursued the goal of promoting the rapid progress of science, as Bush and other scientists wanted, or moved toward accommodating the goals of society as set forth by nonscientist, as Kilgore's preference, is a further question" (Smith p. 50, 1990).

The conclusion was that universities would perform most of the important basic research and set the direction for the nation's scientific efforts. Federal funds for development would make up the largest part of the R&D budget and be allocated mostly to industry, and the government's in-house efforts would continue to center on applied research relevant to agency missions.

The federal laboratories were left with those issues that were either deemed market-failure or of insufficient theoretical interest or of a national security nature. When industry saw no potential in the research (market-failure) or the universities saw the problem as not having a theoretical nature, the government laboratories were to respond. Yet there seemed to be no established position for the estates of science to work together. There was no conscious strategy to promote innovation. The idea of the automatic spin-off approach was created.

With the debate came a need to react to the realities of the day. Following on the heals of World War II, the nation was not blind to the coming challenges as reported in the Steelman report. The Steelman report posited that the nation was certain to confront "competition from other national economies of a sort we have not hitherto had to meet." The report also reasoned that wartime destruction would compel other nations to rebuild their industrial plants with more modern technologies, and many would pursue state-directed strategies. Yet, the Steelman report still looked to the basic research ideology as the answer: "Only through research and more research can we provide the basis for an expanding economy, and continued high levels of employment" (President's Scientific Research Board, Science and Public Policy: Administration for Research "Steelman Report" 1947 via Smith p. 59, 1986). No thought of downstream or system level thinking occurred, or even about retooling the industrial base, here.

International politics also helped shape thinking about the science policy of this period. The GATT regime would enforce trade rules and allay the Steelman report's fears of government-assisted trade expansion. And the Bretton Woods agreement would provide a stable currency framework for international transactions.

Within this framework an international trade economics theory was developed that was envisioned to be the model for the future (Vernon 1966).

> In this theory, advanced products would be developed by companies with strong research efforts (many of which would, of course, be American). Those products would dominate markets until replaced by the next generation of goods embodying a more advanced technology. The earlier generation of products would then be marketed in third world nations via license or other appropriate mechanisms. The foreign company or government entering into the licensing arrangement would acquire the technical skills to manufacture the product. After a while these skills would diffuse though the local economy. As the process was repeated with each new generation of products, third world nations would gradually become more fully integrated into the world economy. The implication was however, that they would be integrated as secondary markets for the goods of the industrial nations, not as serious competitors in the export of manufactured goods (Smith p. 67, 1990).

But as we know, other countries did not "play according to these rules" and overcame the US in many trade areas. The idea of relying on technological development was proven fallible and eventually the US became aware of the issues of the management of technology and the other "downstream" issues of product development.

Amid this Cold War period, the US was experiencing a social revolution and introspection beginning in the 1960s. The Vietnam War raged, civil liberties became a polarizing issue, and even science and technology were dragged into the fray. Science and technology were associated with big business and the military, which were not in favor with the ecology and peace movements of the time. Many demonstrations occurred on college campuses to protest the support of science and technology advances through the acceptance of research grants. This was not so much an anti-science sentiment as a criticism of corporate interests misusing technology for short-sighted economic gain. Intellectuals such as Jacques Ellul and Ivan Illich developed more comprehensive critical views of technology's effects on society.

Both the ideology of the leaders and the inherent downfall in the thinking was best put by Harvey Brooks:

> The implicit message of the Bush report seemed to be that technology was essentially the application of leading-edge science and that, if the country created and sustained a first class science establishment based primarily in the universities, new technology for national security, economic growth, job creation, and social welfare would be generated almost automatically without explicit policy attention to all the other complementary aspects of innovation (Brooks 1985).

Yet there existed a few exceptions to this market-failure approach to policy.

> The few exceptions to reliance on the marketplace, such as agricultural policy, simply underscored the nation's disregard for doctrinal purity. And even here there was a semblance of a market philosophy: public policies would support growing foodstuffs as commodities, but would stop that support once food entered the processing chain and became appropriable as a brand name product. Support for research in commercial aviation, dating from Franklin D. Roosevelt's order as assistant secretary of the navy in World War I to pool patents, and the applied research undertaken after the war by the National Advisory Committee on Aeronautics was also critical in the development of commercial aviation. Such government support could be justified because it improved the quality of a product it was purchasing. Much the same was true of support for atomic energy research after World War II (Smith p. 86, 1990).

The key issue identified by Smith is that government support is justified because it *improves the quality of a product it purchases.* This is what is now referred to as dual-use, mission-oriented technology transfer. Essentially, the policies of NACA and the Agricultural Department were market driven just like the philosophies of other disciplines or agencies, but in this case needs were ascertained and support given appropriately to the private industry.

There is evidence that during this period the greatest benefit between the sectors may have come when government was the customer of private industry. During the early phases of computers and aeronautics, the government was the primary purchaser, subsidizing development of those technologies which later yielded huge private sector markets. In the case of the integrated circuit, the government represented a vast majority of the market throughout the 1960s (Table B.2).

Table B.2: US Integrated Circuit Production and Prices and Importance of the Space and Defense Market, 1962-68 (Tilton 1971, Hook 1990)

Year	Total Production (millions of dollars)	Average price per integrated circuit (dollars)	Defense & Space Production (% of total production)
1962	4	50.00	100
1963	16	31.60	94
1964	41	18.50	85
1965	79	8.33	72
1966	148	5.05	53
1967	228	3.32	43
1968	312	2.33	37

NASA and the DOD assumed much of the risk for long-term research and development and encouraged close co-operation between business and government. In 1962, the total production of semiconductors in America was a mere $4 million and an integrated circuit cost $50. By 1968 NASA and DOD demand had swelled the semiconductor market to $312 million, in part by reducing the price of an integrated circuit to $2.33. This made it profitable for companies to utilize semiconductors in new applications like factory machines and calculators. Without the initial investment of the governments funds, the market for integrated circuits might have developed much slower.

With the inception of NASA, came the first agency to be mandated to technology transfer (P.L. 85-568). In 1962, Lyndon Johnson referred to funds for space as:

> investments which will yield dividends to our lives, our business, our professions, many times greater than the initial costs (Rosenbloom 1965).

In this same year NASA was the first federal agency to formally establish a technology transfer function.

Of the eight objectives stated in NASA's enabling legislation, two related to technology transfer. The fourth objective was stated as: "...the establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes." The Space Act's definition of functions included the words: "to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." At this time, technology transfer had been occurring informally at other government agencies, universities and industries, with agricultural extension programs leading the way. A mandated technology transfer task was relatively unprecedented (P.L. 85-568; Milliken pp. 161-170, 1984).

While NASA's motives remain complex even today due to a close tie to political agendas, it is still clear that secondary applications of the technology are at least fundamental even if not primary components. Even in 1963 there was a realistic view of the role of federal agencies in technology transfer. Then NASA administrator James Webb said:

> We in the Space Agency do not seek to justify our program on the basis of the industrial applications which will flow from it . . . since we are committed to this great effort in space, however, a responsibility exists to glean from it the maximum public benefits which can be obtained (Rosenbloom 1965).

Thus, NASA established a cultural image that balanced its primary motives with the responsibilities of benefiting mankind in a more direct manner. In the early days of NASA, its efforts in technology transfer were aided by its high visibility and image of perfection. Corporations sought out the aid of this center of seemingly limitless talents.

Yet as the years proceeded, NASA became mired in bureaucracy and self-consciousness of its mission and future. Cooperation with external partners in both primary concerns and technology transfer concerns became encumbered with paperwork. In essence, the technology transfer program became an impersonal technology information distribution process until it was reinvigorated in the 1990s.

President Kennedy's economic advisors were concerned about the sluggish performance of the economy in the early 1960s. The Presidents' Office of Science and Technology report, *Technology and Economic Prosperity* (1962) tried to address market imperfections. A Civilian Industrial Technology Program (CITP) was proposed that would combine research, extension services, and demonstrations for textile manufacturing, coal mining, and the housing industry. The program was to be much like the successful one in agriculture. But the bill was soundly defeated in Congress because of strong opposition from those it was intended to help. All three industries rejected the notion that the CITP would help them. In all fairness, the industries' claim that much of their problems stemmed not merely from technology but from downstream issues, was accurate. Private industries more immediate concerns outweighed the government's long-term concerns. The two needed to find a central ground of compromise, but the misunderstandings continued (Smith 1990).

President Johnson and his staff also pushed for invigoration of the civilian technology base. An act was drafted that stressed the exchange of technical information and consultation among industry, the universities, and state governments. This act avoided the controversial idea of the federal laboratories providing research on industry's behalf. Technology transfer would take on the form of information exchanges, and again this was received with little fanfare by the private industry.

Smith summarized the situation well:

> Advanced technologies were assumed to be commercially feasible, an assumption industry in general did not share. Industry saw public assistance for R&D as contributing relatively little toward reducing the total costs of innovation; most costs were downstream from research and the early phases of development. The naive public belief that R&D is all there is to innovation, in industry's view, simply increased the political pressure to make huge investments in new technologies that might not pay off (Smith p. 88, 1990).

Then in 1966 a White House panel found little evidence that the private sector neglected innovation and no compelling justification for government to provide technical assistance. The results of the study led the government into a familiar position of no position. Following the panel study, President Johnson's science and economic advisers remained split over whether more public assistance was necessary to speed commercialization of R&D. Science and technology policy remained stagnant.

With the Nixon administration came a similar approach to the issues. A program entitled "New Technologies Opportunities" attempted to transfer promising technologies to the private sector and then locate applications once the feasibility had been demonstrated. Again the program was criticized as the federal government intervention into the private industry realm. Nixon backed away from this policy as it was deemed inappropriate for the republican platform.

In typical fashion, a new administration brings new ideas, and President Ford preferred market mechanisms for support of research. Therefore, the new strategy was focused on deregulation, market failure, and federal support only in cases in which the government was the customer and primary user of the R&D. Administration strategists believed that market driven pricing and deregulation would help increase innovation. So the pendulum was swinging back to a compartmentalized government role with little interest in a synergistic effort.

With the Carter administration came a revisit to the cooperative idea in an effort to restore productivity growth and encourage industrial innovation. In a Presidential message to Congress in 1979, Carter advocated increasing government R&D for particular technologies to support industry, expanding the NSF to foster university-industry cooperative programs, strengthening the patent system by establishing uniform government policy, expanding the SBIR program, and establishing state and regional corporations for industrial development to assist high risk innovation. The results were similar to those of earlier attempts at cooperation, the industries balked and government blinked.

A Cooperative Automobile Research program to support research on combustion, structural mechanics, materials, and catalysis to help the auto industry was reluctantly agreed to by the five major US auto makers and died with the Carter administration. Likewise, the Ocean Margin Drilling program intended to support the oil industry, failed when oil companies reneged on support to the effort due to a drop in oil prices.

During the Carter administration, industries were more interested in federal tax policy than in any cooperative initiatives. Yet the best interest of the entire US economy is not necessarily served by the individual interest or belief of the private industry.

During the Cold War period the focus of international policies were aimed at stopping the spread of communism and containing the influence of the Soviet Union. Economic competitiveness was assumed to occur naturally from the systems established after World War II. The hands off approach to technology commercialization was the norm. The pre-occupation with the Soviet Union led to a general ignorance of the slow slide into economic equality with other nations. Many of the Presidents tried to gingerly address the issue but relinquished their stances rather easily in the face of politics. There was no central voice for the nation's science and technology concerns. The cacophony of voices returned that had been present in the expansionist period.

The predictions of the Steelman report were becoming true, but the proposed cures did not seem to be the answer. As predicted, the rebuilt industries of Japan and Germany were thriving, but these international markets did not remain as secondary markets but became primary players. As evidence of this, within the high-tech industries, the largest US firms held seventy-nine percent (79%) of world markets (including the domestic US market) in 1959. This share was reduced to only forty-seven percent (47%) by 1978. Within the same time period the market share of Japanese firms in some high technology industries had increased by a factor of four (Smith pp. 103-104, 1990).

As Smith so succinctly put it, "What remains unmistakable is that the United States no longer monopolizes advanced technology" (Smith p. 105, 1990). The gains made through the strong investment in technology during the war period were not able to be sustained on a basic science with spin-off approach to commercialization. Short product cycles, rapid diffusion of process technologies and global technological cooperation created a new economic global competitiveness. For these reasons, the limitless opportunities envisioned in *Science: The Endless Frontier* did not come true.

The Economic Competitiveness Period (1980s -->)

Recognition of strong international economic activity and the emergence of Japan and Germany as competitors to the once unchallenged

US, led to a reevaluation of science and technology policies. The 1980s brought about a flurry of debate and activity focusing on the economic outcome of science and technology policy. Congress passed two acts in 1980 (Stevenson-Wydler Act, Patent and Trademarks Amendment) that gave great latitude and direction for achieving technology cooperation between the estates of science. The impetus of global competition stirred the country to action much as it had during World War II. The difference was that this would be a economic war that required mobilization and implementation of a different sort. The leadership for science and technology policies passed from the executive branch to the legislative branch. Bills were drafted and acts passed to address the issues of concern. Yet it is hard to change the momentum inherent in the estates of science and the actual changes are slow in forming.

An important step in establishing the federal technology transfer framework was the Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480). This legislation made technology transfer an integral part of the research and development responsibilities of federal laboratories and their employees. It required technology transfer officers to be placed in each of the major federal laboratories and established the Center for the Utilization of Federal Technology as a clearinghouse for information on federally owned or originated technologies.

Following the Stevenson-Wydler Act was Public Law 96-517, commonly known as the Bayh-Dole Act. The Bayh-Dole Act was a result of Congressional hearings in which it was established that the private sector would not invest the time and money necessary to commercialize technology without title or an exclusive license to an invention, and that the federal government had assembled a huge portfolio of patents that were not being licensed. This legislation allowed government contractors the right to title patents resulting from government research. Those government contractors benefiting from this law were small businesses, universities, and not-for-profit institutions.

By the mid 1980s there still remained serious displeasure with the state of technology transfer from government agencies and labs to the private sector. In 1984 and 1985, the House of Representatives Committee on Science and Technology took testimony to understand the state of affairs. ("Technology Transfer From Federal Laboratories and Universities" 1992) Representatives from the private sector found it difficult to understand how to do business with the laboratories and federal laboratory employees involved in technology transfer did not feel their work was taken seriously by their management.

In response to these concerns the Federal Technology Transfer Act of 1986 (Public Law 99-502) was introduced as an amendment to the Stevenson-

Wydler Technology Innovation Act to permit government owned, government-operated laboratories to enter into Cooperative Research And Development Agreements (CRADAs) with entities in both the public and private sector (P.L. 99-502). The law authorized agencies to grant collaborating partners licenses to inventions made under CRADAs and mandated that agencies pay at least fifteen percent (15%) of royalties from inventions made at laboratories to the inventors.

Then in 1987, Executive Order 12591, Facilitating Access to Science and Technology, directed executive departments and agencies to encourage and facilitate collaboration among federal laboratories, state and local governments, universities, and the private sector, to assist in the transfer of technology to the marketplace (Codification of Presidential Proclamations and Executive Orders 1987). Together, Public Law 99-502 and E.O. 12591 made technology transfer the responsibility of all federal scientists and engineers, and mandated that this responsibility be considered in employee performance evaluations.

Even with the new legislation, the process of technology transfer remained encumbered and a level of dissatisfaction by many in the technology transfer field persisted. A 1991 survey by the General Accounting Office showed that early implementation of the Federal Technology Transfer Act by federal agencies and their headquarter offices were slow and uneven

(Diffusing Innovation 1991). The survey also revealed some legislative barriers to technology transfer remained, with the largest perceived legislative barrier being the inability of the federal government to copyright software. Legislative barriers were most quoted by private industry as impediments to technology transfer while cultural barriers were identified by federal agencies and employees. In response to the results of the GAO survey the Committee on Science and Technology held four more hearings in 1991 to understand the current views of industry representatives, review the results of the survey, and establish a legislative record to address the copyright of federal software.

Witnesses at the hearings also concluded that much more needed to be accomplished by agencies and laboratories in making technology transfer a priority mission and in addressing the cultural barriers between federal laboratories and industry. Results of the GAO survey found that almost one-third of the federal laboratories had not received guidance on implementation of the Act from their parent agency. Only forty-four percent (44%) of laboratory directors had received authority to enter into CRADAs. Less than one-half of the laboratories had established royalty-sharing programs and most had not established an awards program for technology transfer activities as required by the Act. This study came nine years after the enactment of the Stevenson-Wydler Bill (Diffusing Innovation 1991).

Resolution of the legal issues can lead to more effective technology transfer from the federal agencies and labs to the private industry. With the current public concern and emphasis on the political issue of economy, there appears to be ample momentum to overcome these obstacles. While legislation was able to address most of the structural roadblocks, it could not address the cultural roadblocks. Agencies have long been recognized as having lengthy institution times with regard to cultural changes. The legislative acts gave the agencies and laboratories the opportunity to perform technology transfer, the burden lies with those organizations to overcome cultural issues and perform technology transfer effectively.

Also in 1980, the Patent and Trademarks Amendments consolidated twenty-six policies, executive orders, and statutory guidelines covering patent rights for those performing R&D for the government. The act created a coherent framework providing for easier utilization and ownership of technical discoveries. This was an evolutionary step in that public and private funds were able to be mingled freely within a project, breaking down at least a financing barrier between the estates of science.

Once again, a new presidential administration did not necessarily mean a new science and technology policy direction. Under Reagan, the reliance on traditional market mechanisms, basic science as creator, and deregulation were the guiding philosophies. Early in Reagan's first term he embraced technology as the solution to major problems of national security and economic progress. His beliefs became tempered with time and reflected the entire postwar experience: optimistic faith followed by some disillusionment and then by a more realistic appreciation of what science could contribute to the solution of the nation's problems.

In the early days of the Reagan administration there was a return to the heady visions of Vannevar Bush of a bright future based on basic science. Reagan strongly supported big government programs in defense and space, like the Space Defense Initiative, the National Aerospace Plane and the Space Station. Yet, Reagan took a typically Republican stand and attempted to separate the estates of science. The administrations initial belief was to minimize government's role in economy, so they slashed budgets for the Carter energy demonstration projects and to stimulate industrial R&D looked to antitrust policies, patent laws, regulation and tax incentives.

There was a collision course charted between the ideology and reality. George A. Keyworth, Reagan's science adviser, convened a panel to look at phasing out aeronautic research programs at NASA. The aeronautics research at NASA directly supports the US aircraft industry (translation: Boeing and McDonnell Douglas). US companies have long held a positive balance of trade in aircraft and the technology support of NACA and NASA are major contributors to that success. The panel recommended that the program be maintained and even strengthened

In January 1985, a President's Commission on Industrial Competitiveness, headed by John A. Young, CEO of Hewlett-Packard, was created and developed a volume of supporting studies tilted toward a strategy of greater intervention in trade, technology development, and sectoral policies. The White House was not receptive to the ideas of the commission and it evolved into the privately funded Council on Competitiveness. The Council on Competitiveness report, "Industry as a Customer of the Federal Laboratories," called for cooperation between federal government and industry, even going so far as to suggest that ten to twenty percent (10-20%) of the federal laboratory budgets be spent on technology transfer ("Industry as a Customer of the Federal Laboratories" 1992). The report also called for more latitude for laboratories to work joint ventures with private industry, and other state and federal institutions.

In Reagan's second term he moved closer to a model of government support for fostering innovation, but did not give up on his basic science philosophy. Congress created the Federal Technology Transfer Act of 1986 to expand the commercial transfer of R&D conducted in federal laboratories. This act has become one of the strongest in support of cooperation. The act amended the 1980 Stevenson-Wydler Act, giving federal laboratories the authority to engage in cooperative R&D agreements (CRADA) with firms and consortia. The CRADA is now a widely used, standard form of cooperation.

As the threat of Japanese competition deepened, the government became more desperate to act. The government helped start Sematech, by matching $100 million in funds with private industry and state and local governments. Final judgment on this investment is still being debated. The Omnibus Trade Act of 1988 gave National Institute of Standards and Technology broadened powers to assist industry to develop technology, to modernize the manufacturing base and improve product quality, and to commercialize new technology rapidly.

The economic competitiveness period has found limited support in Congress and little interest by the executive branch. Presidents Reagan and Bush maintained the status quo of basic science, spin-off ideology. President Clinton has a strong advocate for technology development in Vice President Gore but has really not addressed the issue. Congress throughout this period has incrementally made strides with legislation and appeared to be a positive influence. Recent political issues may again make science and technology policy a casualty in the America. The 104th session of Congress has taken the basic-science-is-best approach and combined it with a budget slashing policy.

> As promised by the Republican leadership last January, the proposed seven-year spending plans laid out by House and Senate Budget Committees set the country on a course toward a balanced federal

> budget by the year 2002. One major difference between the two resolutions is the inclusion of a $340 billion tax cut in the House version and the absence of any such cut in the Senate plan--so far. As a result, the House resolution, shepherded through the Budget Committee by Chairman John R. Kasich (R-OH), calls for $1.4 trillion in savings between 1996 and 2002, while the Senate document maps out plans for only $961 billion in savings (Lubell 1995).

Highlighting an ignorance of concern for the future, the current budget bills for the Senate and House call for elimination of the Office of Technology Assessment (OTA). Serving a science and technology advisory role to Congress, the OTA has been widely recognized as a highly reputable source for non-partisan science and technology analysis. The OTA is only one of two organizations to fall beneath the legislative branchs' control and serves as both a balance to the science advisers of the executive and the source of science and technology information on which the lawmakers base policy decisions. The mere idea of abolishing the OTA without a proposal for a replacement system speaks volumes. Where is a unbiased analysis of issues to come from? Will science and technology policies be based upon purely political issues or mere opinions?

The economic competitiveness period resulted in a few laws to address global economic competitiveness and renewed interest in commercialization as the focus of science and technology. The laws have centered on making federal laboratories more responsible for cooperation through rewards and performance measures. This produced a technology push mechanism. There still remains no overall science and technology policy in the way of directing and utilizing the full capabilities of the estates of science and creating true cooperation between them. In short, the economic competitiveness period has created an awareness and concern for new methodologies to meet this new challenge but has left much undone.

Conclusions

There is little doubt that the activities of federal laboratories can play a positive role in the development of the United States. The question that has remained with the nation throughout its history is how to organize the policies and institutes of the government to best benefit the nation. With the exception of the economic development period, the nation has maintained a near strict belief in the pluralistic approach, with little latitude. This ideology calls for a separate and independent activity by the estates of science while expecting a maximum benefit from the whole of the system. Little has been done by politicians to mold a system that utilizes synergy to satisfy each of the estates and customers. Recently some legislation has made positive strides in that direction but in the almost 220 years since the nation's founding, the fear and ignorance of science and technology issues still pervades our federal politicians. The nation is left with a laissez-faire policy that may lead to a reduced position in the global economic competition.

Harvey Averch best summarizes the US science and technology policy:

> At no time in the history discussed here has there been tough, critical, systematic third-party analysis of the proposed policies and the means of implementation. And at no time has there been consistent comparison of alternative strategies and their cost. The US search for an innovation strategy has been marred by faulty design or, more accurately, by no design. Analysis has usually been placed in the hands of those with something to gain or lose. Alternative strategies have not been articulated or debated clearly, and values, facts, and predictions have never been clearly distinguished (Averch p. 71, 1985).

These words ring especially true in the haphazard policy making of the 104th Congress.

Bruce Smith goes on to implore a sensible examination of the issue.

> Answers to some of the most fundamental questions have remained elusive. What effect does the climate of government activity have on the pace and direction of innovation in the private sector? Does direct support from the government displace or induce additional private industrial research? Do industry and universities cooperate more effectively with, or without, government as a third partner? (Smith 1990).

In retrospect, the focus of the US government actions like its science and technology policies are a reflection of the challenges and desires of the day. As the periods of challenges and needs changed in the US (expansion, war, etc.) the emphasis changed from knowledge gathering to expand borders and exploit land, to creation of defensive tools to protect democracy, to an economic tool to compete in a global economy. The estates of science all contain talented and valuable people and programs, but they must find a way to communicate and operate in the challenges of the day. US history is rich with successful science and technology development, yet has not resolved the issues of cooperation.

The most sound advice came from an MIT Commission on Industrial Productivity which urged that "the federal government's support of research and development should be extended to include a greater emphasis on policies to encourage the downstream phases of product and process engineering" (Dertouzos et al. p. 154, 1989).

Therefore the answer is pragmatic and clear, that we as a people do not support science purely for science's sake. Science is not like art which is almost wholly embodied in intrinsic value. In our society science is supported for its extrinsic value (Mitcham 1995). That is, science and technology are utilized to outwardly add value. Basic and applied research do need to co-exist but they must be purposive. There can be a balance, but essentially the basic research should be guided by social needs. And the solution to the needs should utilize the combined efforts of all of the US science and technology community resources in a synergistic manner.

In closing, the nation needs to address at least the following issues:

- With regard to science and technology policies, establish a methodology and implement that methodology to perform critical, objective, third party evaluations of proposals that include cost effectiveness. (The demise of the OTA would create an even greater need for this assessment capability.)

- Balance federal guidelines between basic research, applied research, development, and other downstream activities.

- Find cooperative methods between the estates of science to create synergy for the best utilization of national resources. Create policies that create strong technology innovation and do not rely merely on a laissez faire approach and the current legislation that essentially creates government technology push.

- Find methods to link the upstream activities (research, development, etc.) with downstream activities (market research, financing, management, etc.).

Notes on Technology Transfer

Technology transfer and commercialization is but one of several issues supporting the US welfare through science and technology policy and should be placed within context and be given a proper sense of significance. The total US R&D budget for 1994 was approximately $160 billion or three percent (3%) of the GNP. Of that R&D budget, approximately half of it is federal and half industrial. But this distribution is a bit misleading, since the federal funds are distributed to universities, state institutions, and private entities. The federal government laboratories account for approximately eleven and one-tenth percent (11.1%) of the total US R&D expenditures or approximately three-tenths percent (0.3%) of the annual GNP (National Science Board 1989). In contrast the US defense budget is approximately $300 billion or five percent (5%) of the GNP. Technology transfer is but one aspect of R&D and a small one at that. Only recently have there been any suggested guidelines for funding levels of technology transfer ("Industry as a Customer of the Federal Laboratories" 1992, Gore 1993, Agenda for Change 1994) Most of the policies aim for a minimum of ten percent (10%) of federal laboratory budgets to be allocated to technology transfer and where appropriate, up to twenty percent (20%). Assuming the ten percent (10%) level, technology transfer efforts from federal laboratories to the private sector, would compose a mere three-hundredths percent (0.03%) of the GNP.

Although this issue of technology transfer is relatively small in comparison to other national policy issues in terms of both resources and efforts expended, it has the potential for great returns through a synergistic use of resources. Both the minuscule size of this effort and its potential benefits should be kept in mind for a fair but tempered analysis.

Addendum on a Proposed Department of Science

Recently Representative RobertWalker (R, PA), Chair of the Subcommittee on Science, Technology, and Space, has called for the formation of a Department of Science. Walker's argument for a Department of Science is based on a belief that it would raise science and technology to a higher priority within the government framework. Neither a Department of Science nor the belief that it could raise the priority of science and technology are new ideas. Throughout US history efforts have been made to establish national institutes of science, departments of science, and other centralized forms of science government. These attempts were always dashed in the face of pragmatic needs. Perhaps, the best evidence for a problem-based approach of federal government involvement lies in the failure to establish a discipline based approach over the past 220 years.

In addition to discussions of an institute of science during the framing of the Constitution, the idea of a Department of Science was thoroughly analyzed and debated by academics and politicians at the end of the 19th century and even more so in the early 1950s. The voice of plurality won out in both instances. According to Smith,

> The reasons the nation did not create one large science department are still relevant. Those who would be affected are unwilling to trust a single overriding vision on the proper goals of science policy, preferring the deeper rationality of multiple and partial visions of the common good. There is also fear that a large department would embrace too exclusively either Vannevar Bush's goal of generating knowledge or Harley Kilgore's goal of diffusing it (Smith p. 162, 1990).

No evidence exists to prove that a central scientific organization would raise the priority of science and technology. Even the reasoning is curious, since the priority of science (i.e. funding) is set by Congress, and its members opinions about scientific endeavors would not likely be affected by a mere change of structure. Hunter Dupree criticizes this idea even further,

> The concentration of all science in the government into one department, representing a special professional interest, might make control by Congress and the executive harder instead of easier. And the full potentiality of science in the government could be achieved only if it permeated the whole structure (Dupree p. 231, 1986).

Regardless of management and control issues, the real issue is whether a discipline-based agency (Department of Science) or several mission-oriented agencies (NASA, Department of Energy, etc.), or some other option, is most beneficial to the nation. The discipline-based agency is easily criticized by a simple analogy. Imagine the creation of a Department of Law. How would all of the legal issues within the federal government scope be separated from the missions they serve and placed within one central organization? The same is true for science and technology. The US culture is one of inventors, explorers, and capitalists who use science and technology as tools with extrinsic values. The tools should remain aligned with the mission. The benefit of creating a Department of Science is questionable at best, while the negative consequences could be devastating.

The idea for a Department of Science was strongly put forward in 1851 by Alexander Dallas Bache, an accomplished scientist who championed many science causes. Bache stated "an institution of science, supplementary to existing ones, is much needed in our country, to guide public action in scientific matters." He was ready for the inevitable states rights argument, going on to say, "the idea of a necessary connexion between centralization and institution [does not] strike me as a valid one" (Dupree p. 117, 1986). His proposal would have members residing in their own State and meeting periodically to discuss issues or results of studies. Research could be called for by both the executive or the legislative and would be funded by those two. Baches' idea received no open support then but seemed to serve as a seed for the future.

The question remained that plagued the framers of the Constitution: Where and how does science fit into the government structure? And how does the nation secure efficient and non duplicative science? In order to study the issue, a committee comprised of three members from each the House and the Senate was formed with Senator W. B. Allison acting as the chairman. Testifying before the commission, Secretary of the Navy William E. Chandler vocalized the need for the mission oriented approach. Chandler stated that all scientific or art work for the government "should be conducted within and under the direction of that Department which needs the scientific assistance . . . and that it would be a most anomalous proceeding to erect as a governmental department a department of science or of art." He felt that scientific activities should come under "that department with which it has the most natural relation" (Dupree p. 219, 1986).

The Allison Commission studied the problem over a period of two years with input from scientific leaders like Bache and Powell. Scientists such as Powell who wanted the Department only succeeded in debating the issue to inconclusive ends and in turn failing to support their own cause. The Commission finally pronounced that they felt that "no such duplication of work or necessary connection of these bureaus with each other . . . makes such an establishment essential to their efficiency" (Dupree p. 229, 1986). The inaction of the Commission affirmed both the current value of the science organization in place and denied the validity of a Department of Science.

Dr. John Shaw Billings, the famous Army medical doctor, voiced his disdain for a Department of Science: "As to the desirability of centralization and consolidation of scientific interests and scientific work into one department under a single head, I confess I have serious doubts" (Dupree p. 230, 1986). A department organized along the lines of the branches of science denies the problem approach. While taking advantage of every opportunity to increase knowledge, every scientific branch of the government should be tied to the "practical results" the legislators are trying to achieve.

The debate was rekindled again at the end of World War II by Vannevar Bush. Bush wrote *Science: The Endless Frontier*, in response to President Roosevelt's request for a plan to transition science and technology to peacetime efforts. Bush's report was insightful and to this day stands as a key document in the science and technology policy arena. A plethora of recommendations were filed within the report along with a call for the creation of a central scientific organization to coordinate all of the activities. Bush essentially called for both a mission-aligned and discipline-oriented approach. He realized the value of mission-aligned research being conducted within specific agencies and the danger in separating the research from the mission. But he also felt the need for a separate institute dedicated solely to basic research. He was concerned that basic research could not be administered unfettered within an organization that has a mission orientation. Therefor Bush called for the creation of a National Research Foundation that would be the bastion of basic research.

Standing on the other side of the debate from Vannevar Bush was Senator Harley Kilgore. Kilgore also wanted a central organization but had a different vision of its structure and objective. He believed that centralization would create better diffusion of knowledge and practical applications of that knowledge. The debate between the Kilgore camp and the Bush camp continued, a bill was passed by Congress, vetoed by President Truman, and after significant restructuring finally became a reality in 1947. A watered-down version of the NSF passed which left it neither making policy nor being the central focus of research but as a mere clearinghouse for funds based on the peer-review process.

Vannevar Bush and Harley Kilgore set the initial terms of the debate, and their allies and descendants have carried on the argument about the kinds of policies that would best promote scientific and technological progress and about the essential purpose of support for science programs.

Recently the issue of a Department of Science was examined by both professional scientists (National Academy of Science) and private industry (Council on Competitiveness). Interestingly, the privately funded Council on Competitiveness concluded that a Department of Science would create high visibility for science and technology issues and a consolidated front in order to establish a non-fragmented science and technology policy. Immediate opposition stated a concern that this approach would create a large bureaucracy built up of program elements torn out of the context of the user agency and would therefore be likely to impede rather than hasten technological implications. Furthermore there was a concern that any effort to centralize funding would create endless jurisdictional disputes.

Just as interesting is the response of the scientific community. The National Academy of Science's white paper "Federal Science and Technology Budget Priorities" concludes that existing agencies generally do a good job of deciding which technologies and research programs help them achieve their own program goals. The report also suggests that close coupling of R&D

funding and agency missions should remain a prominent feature of the research system. (National Research Council 1989)

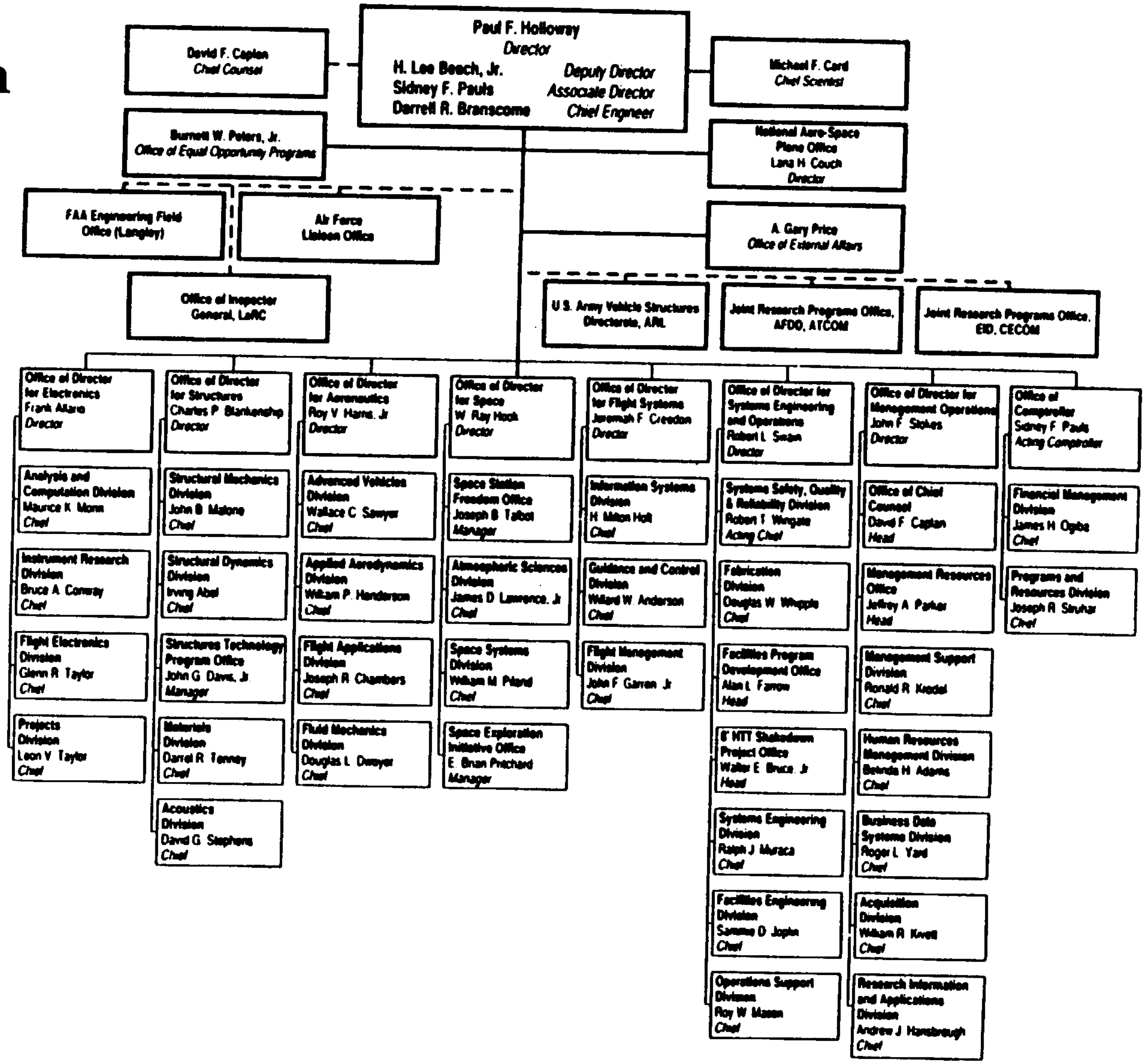
Smith feels that the issue has had a long examination period and concludes that, "The nation, in effect, decided finally by means of political compromise, without ever explicitly debating the matter, that generating and diffusing knowledge were both desirable and that one controlling vision was to be eschewed in favor of a plurality of approaches" (Smith p. 160, 1990). Therefore, Americans do believe in diffusion of knowledge but also favor plurality, and ironically the one thought that unites us is that we are against centralization. Representative Robert Walker certainly will have a challenge in taking on the scientific community and a Congress that is interested in decentralization to embrace a Department of Science.

APPENDIX C.1

NASA Langley Research Center Organizational Structure Prior to the Creation of the Technology Applications Group

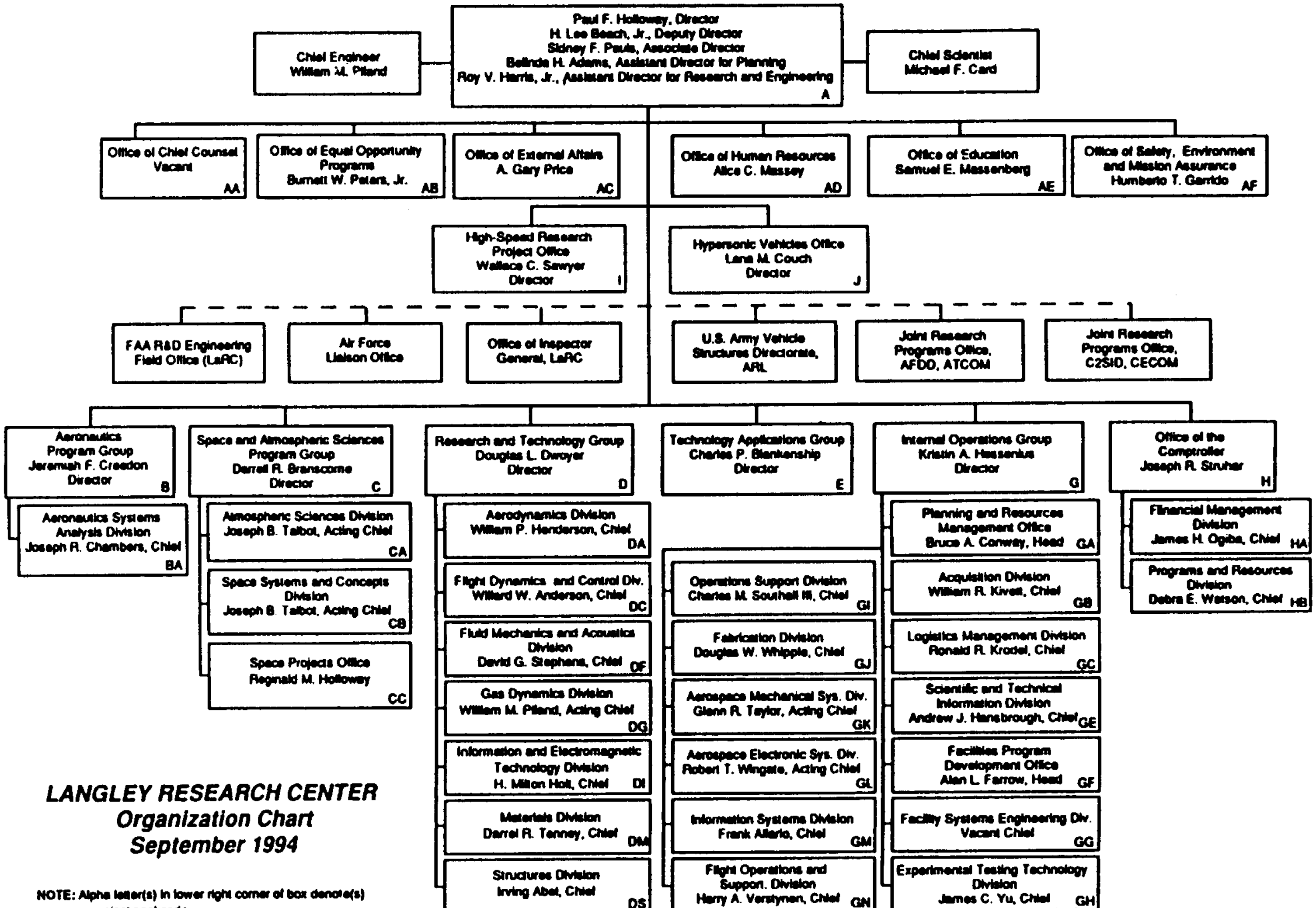
Langley Research Center

Organization Chart
November 1992



APPENDIX C.2

NASA Langley Research Center Organizational Structure After the Creation of the Technology Applications Group



LANGLEY RESEARCH CENTER
Organization Chart
September 1994

NOTE: Alpha letter(s) in lower right corner of box denote(s) organizational code.

APPENDIX D.1

Survey After Revisions by the Focus Group

NASA Langley Research Center
Technology Transfer Survey

1. Technology Transfer is one of NASA Langley's Missions.

   Agree   Don't Know   Disagree

2. Technology Transfer is one of NASA's Missions.

   Agree   Don't Know   Disagree

4. NASA Langley Research Center should be doing technology transfer.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

3. My research has potential for technology transfer.

   Agree   Don't Know   Disagree

4. What percentage of your research has potential for technology transfer?

   ____

5. I have been adequately prepared to perform technology transfer.

   Agree   Disagree

6. Which of the following would help you to better perform technology transfer?

   Education about the process
   Training on performance of technology transfer
   Not interested
   Other

3. In addition to my research, technology transfer should be one of my responsibilities.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

4. Technology transfer has been a component of my performance plan and/or performance appraisal.

Agree Disagree

5. Technology Transfer should be a component of my performance plan & performance appraisal.

Strongly Agree Agree Neutral Disagree Strongly Disagree

6. Technology Transfer should be a consideration only during my performance appraisal and not necessarily a planned task.

Strongly Agree Agree Neutral Disagree Strongly Disagree

7. Royalties would serve as an incentive for me to perform technology transfer.

Agree Disagree

8. Promotions would serve as an incentive for me to perform technology transfer.

Agree Disagree

9. Promotions and royalties would serve as an incentive for me to perform technology transfer.

Agree Disagree

10. My immediate management has provided tangible support for technology transfer efforts.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

11. Please rate your managements participation in technology transfer on the following scale.

helped significantly Stayed out of the way inhibited

1 2 3 4 5 6 7 8 9 10

12. NASA Langley has committed what percentage of resources to technology transfer?

    ____

13. If you were so inclined or felt your work was transferable, what mechanisms are you aware of to transfer your technology to the private sector.

    ____

    ____

    ____

14. My technology council member is ________________________________

15. What group at NASA Langley Research Center would you contact for help in transferring technology?

    ____

Demographics:

Age ____________
Level of Education Achieved BS MS PhD
Group __________
Division ______________

APPENDIX D.2

Survey After Review by the Deputy Director of the Technology Applications Group

Hello, my name is Lance Bush. I'm an employee of NASA Langley Research Center and am conducting a survey of the research staff here. This survey was designed to measure the attitudes, awareness and perceptions of researchers like yourself towards technology transfer. My hope is that the results of this survey will create a clear picture of the culture of the researchers towards technology transfer and in turn provide information that could shape the Center's stance toward technology transfer. This survey is also part of a Ph.D. dissertation study that I am completing. You were randomly selected from a database of all researchers at the center. Your participation in this research is confidential. Only I will have access to your identity and to information that can be associated with your identity. In the event of publication of this research, no personally identifying information will be disclosed. Results will be published only in aggregate form. Your participation is completely voluntary. You are free to stop participating in the survey at any time, or decline to answer any specific question. Having said all that, the survey should take no more than 10 minutes over the phone (probably less than time than this statement in fact). May I have your permission to proceed.

Before we start, I would like to read to you a definition of the term technology transfer that will be used throughout this survey. Technology transfer denotes the activities by NASA, private industry and universities that lead to cooperative partnerships resulting in an improved economy and quality of life. Although we practice technology transfer with our traditional customers in aerospace, for this study we are interested in only non-aerospace technology transfer.

NASA Langley Research Center
Technology Transfer Culture

1. Technology Transfer is one of NASA Langley's Missions.

   Agree Don't Know Disagree

2. Technology Transfer is one of NASA's Missions.

   Agree Don't Know Disagree

3. NASA Langley Research Center should be doing technology transfer.

Strongly Agree Agree Neutral Disagree Strongly Disagree

4. My research has potential for technology transfer.

   Agree Don't Know Disagree

5. What percentage of your research has potential for technology transfer?

   ____

6. I have been adequately prepared to perform technology transfer.

   Agree Disagree

7. Which of the following would help you to better perform technology transfer?

   Tangible Support by Management
   Education about the process
   Training on performance of technology transfer
   Not interested
   Other

8. In addition to my research, technology transfer should be one of my responsibilities.

Strongly Agree Agree Neutral Disagree Strongly Disagree

9. Technology transfer has been a component of my performance plan and/or performance appraisal.

Agree Disagree

10. Technology Transfer should be a component of my performance plan & performance appraisal.

Strongly Agree Agree Neutral Disagree Strongly Disagree

11. Technology Transfer should be a consideration only during my performance appraisal and not necessarily a planned task.

Strongly Agree Agree Neutral Disagree Strongly Disagree

12. I would like to have technology transfer as a contributing component of my promotion process.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

13. If technology transfer were a component of the promotion process, I would put more effort toward technology transfer.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

14. My immediate management has provided tangible support for technology transfer efforts.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

15. Please rate your managements participation in technology transfer on the following scale.

helps significantly Stays out of the way inhibits
0 1 2 3 4 5 6 7 8 9 10

16. NASA Langley has committed what percentage of resources to technology transfer?

____

17. If you were so inclined or felt your work was transferable, what mechanisms are you aware of to transfer your technology to the private sector.

____

____

____

18. My technology council member is ________________________

19. What group at NASA Langley Research Center would you contact for help in transferring technology?

____

Demographics:

In order to perform aggregate correlations of the results with age, I need to ask you your age. ________

Again, in order to perform aggregate correlations of the results with education, I need to ask your highest completed degree.

BS MS/ME/etc. PhD/Ed.D/etc.

APPENDIX D.3

Survey After Second Revisions by the Focus Group

Hello, my name is Lance Bush. I'm an employee of NASA Langley Research Center and am conducting a survey of the research staff here. This survey was designed to measure the attitudes, awareness and perceptions of researchers like yourself towards technology transfer. The results of this survey will create a clear picture of the culture of the researchers towards technology transfer and in turn provide information to senior management. This survey is also part of a Ph.D. dissertation study that I am completing. You were randomly selected from a database of all researchers at the center. Your participation in this research is confidential. Only I will have access to your identity and to information that can be associated with your identity. In the event of publication of this research, no personally identifying information will be disclosed. Results will be published only in aggregate form. Your participation is completely voluntary. You are free to stop participating in the survey at any time, or decline to answer any specific question. Having said all that, the survey should take no more than 10 minutes over the phone (probably less than time than this statement in fact). May I have your permission to proceed.

Before we start, I would like to read to you a definition of the term technology transfer that will be used throughout this survey. Technology transfer denotes the active participation by NASA to transfer research results to private industry and universities via formal or informal cooperative partnerships with the intention of improving (the) economy and quality of life. Although we practice technology transfer with our traditional customers in aerospace, for this study we are interested in only non-aerospace technology transfer.

NASA Langley Research Center
Technology Transfer Culture

1. Technology Transfer is one of NASA Langley's Missions.

   Agree   Don't Know   Disagree

2. Technology Transfer is one of NASA's Missions.

   Agree   Don't Know   Disagree

3. NASA Langley Research Center should be doing technology transfer.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

4. My research has potential for technology transfer.

   Agree   Don't Know   Disagree

5. What percentage of your research has potential for technology transfer?

   ____

6. I have been adequately prepared to perform technology transfer.

   Agree   Disagree

7. Which of the following would help you to better perform technology transfer?

   Tangible Support by Management
   Education about the process
   Training on performance of technology transfer
   Not interested
   Other

8. In addition to my research, technology transfer should be one of my responsibilities.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

9. Technology transfer has been a component of my performance plan and/or performance appraisal.

Agree Disagree

10. Technology Transfer should be a component of my performance plan & performance appraisal.

Strongly Agree Agree Neutral Disagree Strongly Disagree

11. Technology Transfer should be a consideration only during my performance appraisal and not necessarily a planned task.

Strongly Agree Agree Neutral Disagree Strongly Disagree

12. I would like to have technology transfer as a contributing component of my promotion process.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

13. If technology transfer were a component of the promotion process, I would put more effort toward technology transfer.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

14. My immediate management has provided tangible support for technology transfer efforts.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

15. Please rate your managements participation in technology transfer on the following scale.

Inhibits helped significantly

0 1 2 3 4 5 6 7 8 9 10

16. NASA Langley has committed what percentage of resources to technology transfer?

____

17. If you felt your work was transferable, what mechanisms would you use to transfer your technology to the private sector.

____

____

____

18. My technology council member is ______________________

19. What group at NASA Langley Research Center would you contact for help in transferring technology?

____

Demographics:

In order to perform aggregate correlations of the results with age, I need to ask you your age. __________

Again, in order to perform aggregate correlations of the results with education, I need to ask your highest completed degree.

BS MS/ME/etc. PhD/Ed.D/etc.

APPENDIX D.4

Final Survey

Hello, my name is Lance Bush. I'm an employee of NASA Langley Research Center and am conducting a survey of the research staff here.

This survey was designed to measure the attitudes, awareness and perceptions of researchers like yourself towards technology transfer. The results of this survey will create a clear picture of the culture of the researchers towards technology transfer and in turn provide information to senior management. This survey is also part of a Ph.D. dissertation study that I am completing at Penn State University. You were randomly selected from a database of all researchers at the center. Your participation in this research is confidential. Only I will have access to your identity and to information that can be associated with your identity. In the event of publication of this research, no personally identifying information will be disclosed. Results will be published only in aggregate form. Your participation is completely voluntary. You are free to stop participating in the survey at any time, or decline to answer any specific question. Regarding this survey, you may contact me at my office number of 864-4514. Having said all that, the survey should take no more than 10 minutes over the phone (probably less time than this statement in fact). May I have your permission to proceed.

Before we start, I would like to read to you a definition of the term technology transfer that will be used throughout this survey. Technology transfer denotes the active participation by NASA to transfer research results to private industry and universities via formal or informal cooperative partnerships with the intention of improving (the) economy and quality of life. Although we practice technology transfer with our traditional customers in aerospace, for this study we are interested in only non-aerospace technology transfer.

NASA Langley Research Center
Technology Transfer Culture

1. Technology Transfer is one of NASA Langley's Missions.

   Agree   Don't Know   Disagree

2. Technology Transfer is one of NASA's Missions.

   Agree   Don't Know   Disagree

3. NASA Langley Research Center should be doing technology transfer.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

4. My research has potential for technology transfer.

   Agree   Don't Know   Disagree

5. What percentage of your research has potential for technology transfer?

   ____

6. I have been adequately prepared to perform technology transfer.

   Agree   Disagree

7. Which of the following would help you to better perform technology transfer? (You may answer with more than one choice.)

   A. Tangible Support by Management
   B. Education about the process
   C. Training on performance of technology transfer
   D. Not interested
   E. Other

8. In addition to my research, technology transfer should be one of my responsibilities.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

9. Technology transfer has been a component of my performance plan and/or performance appraisal.

Agree Disagree

10. Technology Transfer should be a component of my performance plan & performance appraisal.

Strongly Agree Agree Neutral Disagree Strongly Disagree

11. Given that the performance appraisal allows for a researcher to bring up positive accomplishments that may not have been planned for, technology transfer should be a consideration only during my performance appraisal and not necessarily a planned task.

Strongly Agree Agree Neutral Disagree Strongly Disagree

12. I would like to have technology transfer as a contributing component of my promotion process.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

13. If technology transfer were a component of the promotion process, I would put more effort toward technology transfer.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

14. My immediate management has provided tangible support for technology transfer efforts.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

15. Please rate your managements participation in technology transfer on the following scale.

Inhibits ______________________________ helped significantly

0 1 2 3 4 5 6 7 8 9 10

16. NASA Langley has committed what percentage of resources to technology transfer?

____

17. If you felt your work was transferable, what mechanisms would you use to transfer your technology to the private sector.

____

____

____

18. My technology council member is ______________________

19. What group at NASA Langley Research Center would you contact for help in transferring technology?

____

Demographics:

In order to perform aggregate correlations of the results with age, I need to ask you your age. __________

Again, in order to perform aggregate correlations of the results with education, I need to ask your highest completed degree.

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13. ABSTRACT *(Maximum 200 words)*

A review of previous technology transfer metrics, recommendations, and measurements is presented within the paper. A quantitative and qualitative analysis of NASA's technology transfer efforts is performed. As a relative indicator, NASA's intellectual property performance is benchmarked against a database of over 100 universities. Successful technology transfer (commercial sales, production savings, etc.) cases were tracked backwards through their history to identify the key critical elements that lead to success. Results of this research indicate that although NASA's performance is not measured well by quantitative values (intellectual property stream data), it has a net positive impact on the private sector economy. Policy recommendations are made regarding technology transfer within the context of the documented technology transfer policies since the framing of the Constitution.

In the second thrust of this study, researchers at NASA Langley Research Center were surveyed to determine their awareness of, attitude toward, and perception about technology transfer. Results indicate that although researchers believe technology transfer to be a mission of the Agency, they should not be held accountable or responsible for its performance. In addition, the researchers are not well educated about the mechanisms to perform, or policies regarding, technology transfer.

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