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An Exploratory Study of the Benefits Received by Wright Laboratory (WL) from Technology Transfer Activities

Clinton J. Braun

AN EXPLORATORY STUDY OF THE BENEFITS
RECEIVED BY WRIGHT LABORATORY (WL) FROM
TECHNOLOGY TRANSFER ACTIVITIES

THESIS

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DEPARTMENT OF THE AIR FORCE
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Clinton J Braun

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Abstract

The allocation of resources should be a rational decision making process where alternatives can be compared based on their estimated costs and benefits to the organization. In order to justify technology transfer activities, a sound methodology must be developed that will document the benefits derived from transfer activities. The risks or uncertainties associated with those benefits must also be estimated and analyzed. By detailing the costs, benefits, and uncertainties associated with technology transfer activities, decision makers will have a logical framework that can be used to determine the cost effectiveness of technology transfer. This will help decision makers understand the returns on investment that are gained by the DoD through technology transfer activities.

Leaders within the technology transfer arena are searching for better ways of quantifying the tangible and intangible benefits of technology transfer. The goal of this research is to build an acceptable methodology that can be used to identify and quantify the tangible and intangible benefits received within Air Force Materiel Command (AFMC) as a result of technology transfers. This exploratory study employs a structured interview methodology to identify and quantify the benefits received by the Air Force through its technology transfer activities.

This study identified several findings on the benefits received by WL from technology transfer. Most notable: The benefits received through technology transfers do match up with the benefits expected and identified by the AFMC technology transfer office; a majority of the CRDAs in this study are producing revenues, in many cases the revenues are substantial; and clearer objectives are needed in order to better focus future technology transfer activities. In addition, this researcher provides recommendations to improve the measurement of benefits received through technology transfer activities and offers future research opportunities in the area of measuring success of technology transfer.

AN EXPLORATORY STUDY OF THE BENEFITS

RECEIVED BY WRIGHT LABORATORY (WL) FROM

TECHNOLOGY TRANSFER ACTIVITIES

I. Introduction

Background

Recent changes to the Federal Acquisition Regulation (FAR) mandate that Department of Defense (DoD) acquisition strategies must account for and focus on the commercial applications of government-sponsored technologies. By incorporating such a technology transfer process into its acquisition strategy, the DoD will be able to better utilize the nation's research and development (R&D) resources (Federal Acquisition Regulation 1996). In situations when a developed technology may or may not be used to enhance our nation's warfighting capabilities, commercialization of those government-sponsored R&D activities is a means of realizing a greater return on investment. Government-sponsored R&D can often be used by a private firm to develop new products and improve its competitiveness within a given industry. This situation benefits society as a whole with improved socio-economic benefits to the nation (16: 2).

Technology transfer also puts an additional burden on military professionals who work to procure weapons systems for the DoD. Additional resources (manpower, funds, and materials) are used in the technology transfer process. In an era of downsizing, military professionals are asked to do more with less and senior leaders are tasked to allocate resources as efficiently and effectively as possible. Therefore, committing resources to technology transfer activities takes resources away from other research, development, and acquisition activities. This requires decision makers to be highly analytical to justify the allocation of resources in support of technology transfer efforts, since those resources could potentially be used in other ways.

The allocation of resources necessitates a rational decision making process where alternatives can be compared based on their estimated costs and benefits to the organization and the nation (38: 64). In order to justify technology transfer activities, a sound methodology should be utilized that will document the benefits derived from transfer activities. The risks or uncertainties associated with those benefits should also be estimated and analyzed. By detailing the costs, benefits, and uncertainties associated with technology transfer activities, decision makers will have a logical framework that can be used to determine the cost effectiveness of technology transfer. The goal of this research is to develop a sound methodology that can be utilized by senior leaders to accurately calculate the benefits of technology transfer. This will help decision makers understand the returns on investment that are gained by the DoD through technology transfer activities.

Research Objectives

The goal of technology transfer is to promote the use of technology with military applications for commercial use. Since the Federal Technology Transfer Act (FTTA) of 1986, technology transfer efforts have increased dramatically (31: 18; 5: 970). The question that is often asked is: "What do government agencies receive in return for their efforts?" This is a difficult question to answer since many of the benefits received by the

Department of Defense and the federal laboratories are difficult to quantify. Because the tangible and intangible benefits are often difficult to quantify, the rising costs attributed to technology transfer efforts are becoming more difficult to justify.

Much research has discussed and documented the need for successful technology transfer. The national benefits derived from technology transfers are enormous, but in many ways unquantifiable (16: 4). Some research has been done in an attempt to quantify the national benefits derived from technology transfers. Unfortunately, attempts to directly measure the national benefits derived from technology transfers and quantify them at hierarchical levels has been unsuccessful (16: 6). Many Air Force organizations have collected data on the revenues produced by transfers, such as license fees, royalty payments, or leasing fees (16: 6-9). Unfortunately, there have been no efforts to link the revenues generated by transfers to the specific transfers that generated the revenue. Additionally, there have been few efforts to quantify the intangible benefits received by government agencies as a result of technology transfers. The objectives of this research are as follows:

1. Identify and document methods used in other organizations to quantify the tangible and intangible benefits received from technology transfers.

2. Build an acceptable methodology that can be used to identify and quantify the tangible and intangible benefits received within Air Force Materiel Command (AFMC) as a result of technology transfers.

3. Develop a methodology that will estimate the expected return on investment (ROI) generated by technology transfers based on the tangible and intangible benefits derived from the transfers. This methodology must take into consideration the uncertainties involved with estimating the benefits derived from a given transfer.

Scope

This research focuses primarily on the development of processes that can be employed within AFMC to justify their technology transfer efforts. There are currently no methodologies in place to accurately measure the benefits received by AFMC as a result of the technology transfer program. A considerable amount of resources are used within AFMC to transfer the technologies developed by Air Force laboratories to the private sector. It has been difficult to measure the return on the resources invested in the technology transfer program because current measurement techniques are inadequate (16: 14,15). Benefits received are difficult to identify and hard to quantify once they have been identified.

Other organizations are studied to identify current methodologies being used to quantify tangible and intangible benefits. Once identified and validated, these methodologies are applied to the AFMC technology transfer program to determine their usefulness. This research does not focus on identifying the inadequacies of the methodologies used by other organizations in quantifying intangible benefits. The sole purpose is to identify or build an appropriate methodology that can be employed by the AFMC Technology Transfer Office (TTO) to quantify the tangible and intangible benefits of their technology transfer efforts.

Definition of Terms

The following section lists and defines several key concepts that are used throughout this research. The definitions listed below provide the reader with an overview of the key concepts presented in this paper and how those concepts are used.

Accounting rate of return - A measurement of a project's contribution to the net income of the organization (6: 391).

Capital budgeting - A process of analyzing potential capital expenditures and deciding which investments a organization should undertake (6: 384).

Commercialization - Innovation for profit; the development of a technology into a marketable product, service, or process that is in demand in the private sector.

Developer - An organization (usually a federal laboratory) that invents or develops a technology for government use.

Hurdle Rate - An organization's cost of capital; usually the interest rate charged to an organization when it borrows money or the expected return on an alternative project (6: 395).

Internal rate of return - A discount rate which results in the present value of a project's future cash inflows (revenues) to equal the present value of the projects cash outflows (costs). An acceptable project would have an IRR greater than the organization's cost of capital (6: 394).

Net present value - The value of a project's cost minus the sum of the project's revenues after the revenues are discounted at the project's cost of capital. An acceptable project would have a positive net present value (6: 392).

Payback period - The expected number of years required to recover the original investment in a project (6: 388).

Technology sponsor - A third party responsible for identifying technologies available for transfer, marketing, and actually transferring the technology (33:27).

Market pull - A "needs" generated technology transfer process model where there is a market demand for a specific technology developed by the Air Force laboratories (33:27).

Technology push - A "means" generated technology transfer process model where a specific technology is developed in the Air Force laboratories and supplied to the market before it is solicited (33: 27).

Technology Transfer - The dissemination of government-developed technology to the private sector for commercial application.

Relevancy

One of the most difficult aspects of the technology transfer process is that the benefits received by the developer are not obvious to the casual observer. Prior to making any capital investment, managers in the business world analyze the potential returns and the risks associated with those returns. These returns are then measured against the potential investment. When potential returns exceed the initial investment, the investment is justified. Discounted cash flow methodologies like net present value (NPV) and internal rate of return (IRR) are often used to justify a capital investment (9: 69; 25: 28). Unfortunately, the technology transfer process does not lend itself easily to these methodologies.

Royalty payments or licensing fees are the only obvious cash revenues received by the developer. However, these payments are often not received in a timely manner. In addition, many of the transfers that take place do not generate any revenues in the form of royalty payments or licensing fees (16: 6-10). These transfers benefit the developer and society as a whole, but the benefits are often intangible, or tangible and difficult to quantify. In fact, it is argued that the main reason for technology transfer is the accumulation of socio-economic benefits and not cash revenues (16: 10). The goal of technology transfer is to utilize government-sponsored R&D technologies as effectively as possible. By providing technologies to the private sector, the government provides private firms with the opportunity to commercialize the technology and provide additional benefits and wealth to society as a whole (16: 6).

Leaders within the technology transfer arena are searching for better ways of quantifying the tangible and intangible benefits of technology transfer. By identifying and quantifying the benefits or non-cash revenues received as a result of technology transfers, future technology transfer efforts can be more readily justified.

Thesis Overview

Chapter Two of this research provides background information on the technology transfer process, a closer look at the policies and processes that have been implemented to enhance transfer activities, analysis of the measurements used within AFMC to measure technology transfer success, a discussion on current return on investment methodologies, and a look at existing methodologies used in the private sector to quantify and measure the intangible benefits of technology. This information will be used to build a methodology for identifying and quantifying the intangible benefits of technology transfer within DoD.

The methodology presented in Chapter Three will be an exploratory study of technology transfers that have taken place within Wright Laboratory. Interviews will be conducted and "encoded" to develop estimates of the tangible and intangible benefits associated with transfer activities. These benefits, once quantified, will be combined with the cash revenues received in the transfer to calculate the return on investment (ROI) based on the project's NPV. Chapter Four will present the data collected during the interview process and document the process of quantifying the data and using it in the ROI calculation. Chapter Five will present the conclusions and managerial implications of this research and will identify an agenda for future research.

II. Literature Review

Background

The overall goal of the technology transfer process is to better utilize the nation's research and development (R&D) resources. The main thrust of DoD-driven R&D is always the improvement of the nation's war-fighting capabilities. However, there are instances where DoD-driven technology cannot be utilized by the military. In these cases, commercialization of government-sponsored R&D activities is the best means of realizing a full return on the nation's R&D dollars. Government-sponsored R&D can often be used by private firms to develop new products and improve their competitiveness within a given industry (38: 24; 33: 19; 26: 33). This situation is beneficial to our nation as a whole (16: 6).

There is a growing perception that the U.S. is not getting an adequate return on its federally-funded R&D budget (33: 20). This may be an accurate assessment for two reasons. It is certainly possible that valuable technologies have failed to reach the private sector, depriving society of benefits and the government of licensing fees and royalty payment revenues. However, the lack of appropriate technology transfer effectiveness measures is a more likely reason for the afore mentioned perception (33: 19-21; 16: 7-11). Technology transfer organizations are being tasked to develop quantifiable measures of their transfer effectiveness (33: 19-21). In an effort to meet this challenge, several different methodologies are in place to measure the effectiveness across a variety of technology transfer organizations. Unfortunately, this scenario has led to a lack of measurement standardization among different organizations (33: 19-21). This has made it difficult for senior decision makers to assess the effectiveness of technology transfer activities.

As a result of DoD "drawdowns," large U.S. federal laboratories are faced with cutbacks, consolidation, and possible closure. This environment has helped to increase the importance of the "technology transfer mission" within the federal laboratories. The Clinton administration's policy towards technology transfer openly encourages collaboration between federal laboratories and private industry (25: 64; 38: 26). Technology transfer is not a new concept; however, it now has a much higher profile and is more important than ever before (25: 64). This high profile has increased the importance of more effective, quantifiable measurements of technology transfer activities. The purpose of this research will be to develop more effective measures of technology transfer activities. By doing this, an accurate picture of the effectiveness of the Air Force's technology transfer program can be developed.

Technology Transfer Policies and Processes

Congress has passed a series of legislation aimed at improving the commercialization of technologies arising from the federal investment in research and development. The Stevenson-Wydler Technology Innovation Act of 1980 established technology transfer as a mission of the federal government (5: 970,971; 31: 20; 22: 73; 38: 23). It specifically states that the government is responsible to ensure the full use of federal investment in R&D and mandates that transfer of technology to the private sector when appropriate. This act also established the Offices of Research and Technology Applications (ORTAs) within the federal laboratories to disseminate information about federal products, processes, and services (38: 23; 2). The Federal Technology Transfer Act (FTTA) of 1986 laid the foundation for Cooperative Research and Development Agreements (CRDAs) between federal laboratories and private enterprises (38: 23,24). This act gives government agencies the authority to conduct cooperative research with outside parties and negotiate patent licenses. In addition, the FTTA established the Federal Laboratory Consortium (FLC) which supports and helps laboratories with transfer activities (38: 23; 2). The National Competitiveness Technology Transfer Act of 1989 was implemented to aid in authorizing CRDAs for Government-owned, contractor-operated (GOCO) organizations. This act also protects trade secret information developed under a CRDA from disclosure under the Freedom of Information Act. These policies and additional directives have provided a foundation for successful transfer activities (38: 24; 2). In spite of mechanisms being in place for successful technology transfer, the federal government and private industry must still work to improve the effectiveness of their transfer activities (38: 28).

Despite the legislative attention given to technology transfer and the commitment of government agencies to make it work, successful commercialization only happens when and if technology translates into a profitable product or process with an economic benefit (38: 28). From a business point of view, certain basic steps are required for a successful transfer. They include identifying a need, sourcing the technology, assessing the technology, acquiring the technology, financing the project, transferring the technology, implementing the technology, and eventually terminating the transfer

(38: 24). Technology transfers that do not meet the above criteria are likely to be unsuccessful and could waste valuable resources in the public and private sector.

Technology transfer commercialization success can not be the sole measure of the government's technology transfer success because many activities are out of the government's span of control (16:11). AFMC has a well defined, hierarchical transfer management process in place. The management process includes the following six steps:

a. Develop transfer strategy
b. Identify technologies
c. Market the technologies
d. Develop the transfer agreement
e. Transfer the technology
f. Post transfer administration

These steps are at a command (macro) level. At the laboratory or product center level, the process has many steps which fall within the six steps of the command process (32: 6; 2). In other words, the process can be tailored to meet the needs of each given organizational level. These differences provide each laboratory or center the flexibility required to efficiently carry out the transfer process as they see fit. The logic behind this is that it maximizes resources at every level and leads to effective technology transfer activities. There is a sound process in place, but measurement of the process has been a difficult task. The goal at AFMC is to develop measures at the command level that will indicate the success of technology transfer activities in the labs and centers.

Technology Transfer Measurements

Technology transfer has been defined as the managed process of conveying a technology from one party to its adoption by another (34: 65). There are three distinct roles within the technology transfer process: sponsor, developer, and adopter. Sponsors fund technology development and disseminate information about government-sponsored technology to the private sector and facilitate transfer. Developers develop or apply technology under government or private sponsorship and funding. Adopters are the users or potential users of government technology (34: 66-68). Within the three roles, the success of technology transfer has been difficult to measure. Some of the most common measurements of technology transfer are included below:

a. The attainment of transfer objectives.
b. Changes in the user's revenues or costs, resulting from the transfer.
c. The number of products launched.
d. The degree of technology adoption or rejection.
e. The degree to which a significant emotional and financial commitment is made to the routine use of the technology (34: 70).

These measurements are certainly useful, but their focus is primarily on the success of the transfer in terms of the adopter's objectives. It is difficult to make inferences about the success of developer's and sponsor's transfer efforts based on these common measurements of technology transfer activities. These measures could be classified as firm level measurements because they are more applicable to the private firm or company that adopts the technology. Some more specific firm level technology transfer performance measurements are relevant. They include: number of new products developed, number of patents filed, and accounting measures of financial performance such as return on investment (34: 70-72). Unfortunately, these measures fail to address the needs of the government which seeks valid performance measurement of the transfer process itself.

Two important areas of concern within the government are the measurement of intangible benefits such as goodwill within the community, the cost/work avoidance arising from transfer activities, and the measurement of economic costs associated to trade-offs made by federal laboratories in the use of funds, human resources, and time (33:21-23). The government has been unable to develop and document a valid methodology for quantifying the tangible and intangible benefits of its transfer efforts. The consensus is that these benefits are critical to the success of transfer activities and should be weighed heavily when building a transfer strategy (33:23-27). However, there are very few decision makers in any business that feel comfortable measuring the success of their programs or policies using a decision support system based on unquantified, intangible benefits (25: 26; 37:35). To accurately measure the success of government transfer activities, a model must be developed that combines the tangible revenues received by the government with the intangible benefits (revenues or costs avoided). This will lead to a more accurate measure of transfer effectiveness (17: 7).

Many existing models fail to adequately measure transfer activities because of the inherent difficulty associated with capturing transfer outcomes. First of all, in the case of revenues received (transfer payments, licensing and royalty fees) outcomes are often delayed by long development or payback times. This leads to difficulties since revenues can rarely be linked to specific transfers (17: 4). Therefore, it is difficult to link the results of a given transfer to the transfer itself, making it impossible to benchmark the process used in successful transfers to the process used in less successful transfers. Secondly, the different organizations involved with the transfer may have different transfer goals and measurements of success. Finally, the commercial success of a given transfer depends on factors other than a successful transfer. These differences contribute to the difficulties in measuring transfer progress, success, and overall effectiveness (17: 3-6; 33: 23).

Current measurement within AFMC focuses on the potential socio-economic benefits derived from transfer activities. The command is measuring the number of transfer agreements by fiscal year and the total dollars invested by the government and outside partners that can be linked to transfer agreements. The logic in using these measures is that increases in agreements and investment will likely result in increased potential positive impacts in the form of socio-economic benefits (17: 3-6). The current trend is that both agreements and investment are increasing within AFMC. This indicates that the technology transfer program is working and providing socio-economic benefits. Another measure of transfer success is the amount of revenue received by AFMC in the form of royalty payments and licensing fees. These revenues represent increased value to the outside partner that can be attributed to the transfer. Socio-economic benefits will increase as the worth of the transfer grows to the outside partner. Unfortunately, this relationship is difficult to measure because the outside partner, not the Air Force, owns the data (17: 3-6).

By taking a closer look at two common measures of transfer effectiveness, number of licenses granted and the royalty income generated, it is easy to see why additional measures should be considered. Simply looking at the number of licenses granted gives no indication of the impact or benefits derived from the transfer and the royalty payments usually lag behind the licensing activity, thus providing a tardy measure of transfer success (33: 20-23).

Strategy plays a key role in the measures used to assess the effectiveness of transfer activities. Technology push and market pull strategies result in two distinct types of performance measurements. Technology push strategy effectiveness can be measured by the number of licenses, site visits, technical briefs or papers, technical presentations, time spent on transfer activities, transfer budgets, and transfer expenditures. These measures indicate the cost of transfer activities and the level of effort put forth by the sponsor or developer of a given technology. They are short term measures of effectiveness, while technology pull metrics are long term measures of effectiveness. Market pull measures include competitive advantage gains, cost savings, jobs created, market share gains, new businesses started, commercial sales, new products, productivity gains, royalties, return on investment, success stories, technical problems solved, and user satisfaction. These metrics are long term measurements that indicate the success of adopters in utilizing the technology after it has been transferred (33: 24,25). Market pull measures are out of the government's span of control and therefore, may not be an accurate measure of government technology transfer effectiveness (16: 8). These measures are useful in measuring the effort the government puts into transfer activities, but there is no methodology in place to measure the specific returns or benefits received by the government as a result of it's effort.

Given that data is available, a cost/benefit analysis model is a logical choice for a methodology to be used by the government to assess the effectiveness of its transfer activities. Measuring the costs or effort put forth in transfer activities (technology push metrics) is not difficult, but the data on the benefits of technology transfer is limited and not readily available. Items such as revenues received in the form of license fees, royalty payments, or leasing fees represent cash payments to the government that can be used to formulate a discounted cash flows return on investment model that measures the effectiveness of government transfer activities. Although these revenue streams are important, there are many intangible benefits received by the government as a result of its transfer activities. These intangible benefits which usually exceed the benefits of cash revenues generated by transfer activities are difficult to quantify. Therefore, they are often overlooked by senior decision makers. To get a true measure of technology transfer success, these intangible benefits must be analyzed by decision makers.

Measuring Return on Investment (ROI)

The four most commonly used methodologies for ranking projects based on their projected cash flows are payback period, accounting rate of return (ARR), net present value (NPV), and internal rate of return (IRR) (23: 131-135; 6: 384). This section will explain each methodology and examine strengths and weaknesses of each methodology. Once an acceptable methodology is identified, it will be incorporated into Chapter Three and used to calculate the ROI for the transfers highlighted in Chapter Four.

The payback period is probably the simplest and quickest ROI methodology available to the decision maker. It is simply the expected number of years required to recover the projects original cost. It is calculated by estimating a project's initial cost and its projected cash flows. The cash flows are then subtracted from the original investment until the cumulative total value reaches zero; the point where the project has paid for itself (6: 389-391). The example below provides a quick glance at how the payback period would be calculated:

Both project X and Y have the same initial first year cost ($700.00) but project Y could be paid off in only three years while project X would not be paid off until the beginning of the fifth year. Based on the payback period methodology project Y would be preferable to project X, but whether Y would be accepted over Y would depend on the accepted payback period.

YEAR	**Project X**	**Cumulative X**	**Project Y**	**Cumulative Y**
0	$(700.00)	$ (700.00)	$(700.00)	$ (700.00)
1	100	$ (600.00)	300	$ (400.00)
2	50	$ (550.00)	200	$ (200.00)
3	300	$ (250.00)	200	$ -
4	200	$ (50.00)	100	$ 100.00
5	800	**$ 750.00**	50	**$ 150.00**
Total CF	**$ 1,450**		**$ 850**	

FIGURE 2.1 Project X and Y Payback Period Example

The payback period is most useful as a break-even analysis tool. It provides the decision maker with an idea of how long funds will be tied up in the project. It is a good method for evaluating the liquidity of two competing projects. Unfortunately, the payback period does not take the time value of money into consideration and it does not consider cash flows that occur after the payback period is over (6: 390). For instance, in the above example project X had an expected $750.00 positive cash flow at the end of year five which was greater than the expected $150.00 cash flow provided by project Y. By only using the payback period, project X, the more profitable alternative would have been rejected.

The ARR focuses on a project's contribution to a firm's net income rather than cash flows. This methodology takes depreciation into consideration when evaluating an investment project. ARR is measured as a ratio of a project's average annual net income to its average investment (6: 391). See the example below for a detailed explanation; calculated using straight line 5 yr. depreciation and zero salvage value:

Average annual income = Average cash flow - Average annual depreciation

Project X avg. annual income = ($ 1450/5) - ($ 700/5)
= $ 290 - 140
= **$ 150**

Project Y avg. annual income = ($ 850/5) - ($ 700/5)
= $ 170 - 140
= **$ 30**

Average investment = (Cost + Salvage value) / 2

Avg. investment for both projects = ($700 + 0) / 2 = **$ 350**

ARR = Average annual income / Average investment

ARR for Project X = $ 150 / $350 = **42.8 %**
ARR for Project Y = $ 30 / $350 = **8.5%**

Based on this example, Project X is the best alternative because it has a much higher ARR at 42.8%. The ARR does address cash flows that occur after the payback period. However, it fails to account for the time value of money and therefore, could lead to poor business decisions. For this reason, the NPV and IRR methodologies are more effective for business decisions (6: 392; 23: 133).

The net present value calculation is a popular return on investment (ROI) methodology used by decision makers in deciding between two alternative projects. A project's net present value is calculated by comparing the discounted cash flows of a project to the costs associated with a project to determine the project's real value. The cash flows are discounted at the company's cost of capital (the interest rate they could have earned by making a low risk investment) to account for the time value of money. Projects with discounted cash flows (revenues) greater than the initial cash outlay (project cost) are acceptable and are deemed good business decisions (6: 394; 23: 133-134). The greater the project's net present value, the higher its return on investment and therefore, the more desirable it is. The tables below provide an example of how NPV is calculated and how it can be used to decide between two alternative projects:

for this example assume:
k = 10% interest rate (the firm's cost of capital)
t = The year cash flow was produced

Project 1 Net Present Value Calculation (Return On Investment)

Initial Cost	year 1	year 2	year 3	year 4	Total Cash flow
$ (450.00)	$125.00	$125.00	$125.00	$200.00	$ 575.00
	(1 + k)^ t	(1 + k)^ t	(1 + k)^ t	(1 + k)^ t	
$ 113.64					
$ 103.31					
$ 93.91					
$ 136.60					
$ (2.54)	NPV				

Project 2 Net Present Value Calculation (Return On Investment)

Initial Cost	year 1	year 2	year 3	year 4	Total Cash flow
$ (450.00)	$200.00	$225.00	$100.00	$ 50.00	$ 575.00
	(1 + k)^ t	(1 + k)^ t	(1 + k)^ t	(1 + k)^ t	
$ 181.82					
$ 185.95					
$ 75.13					
$ 34.15					
$ 27.05	NPV				

FIGURE 2.2 Project 1 and 2 Net Present Value Example

In this short example, project 2 has a higher net present value because of its large cash flows in years 1 and 2. These cash flows minimize the impact of discounting or the time value of money and makes project 2 acceptable, whereas project 1 would be rejected.

The internal rate of return is another popular ROI methodology that can be used to analyze a project's value to the firm based on discounted cash flows. The internal rate of return (IRR) is the interest rate that causes a project's net present value to be zero. The higher the project's IRR, the more desirable it is. Ideally, the IRR should be higher than the firm's cost of capital for the project to be considered a success (6: 396; 23: 134). IRR is often used by decision makers in the business world because it is easy to understand and it is easily compared to alternative uses of capital. The IRR for a project can be easily compared to the interest rate earned on an alternative investment or a given industry's hurdle rate. For example, if a project has an initial cost of $10,000 and provides an IRR of 11%, it would be less desirable than the alternative of investing that $10,000 into a mutual fund that was currently showing a 15% return on investment.

The NPV and IRR are both useful, sound decision criteria for analyzing a project's worth to the firm or organization. In order to calculate the IRR or NPV, the following steps must take place:

a. The cost of the project must be determined.
b. The cash flows and revenues from a project must be obtained or accurately estimated. This would include revenues linked to the intangible benefits of a project.
c. The riskiness of a project's cash flows must be estimated to develop probability distributions for the expected revenues or cash flows.
d. Management determines the appropriate cost of capital for a project based on the riskiness of that project's expected returns or revenues.
e. Expected cash flows are discounted to obtain the project's NPV (6: 387).

These steps are not difficult to understand or implement. The difficult aspect of using a conventional ROI methodology to evaluate technology transfer activities is that developing estimates of a project's actual or projected revenues and benefits can be an extremely difficult and cumbersome task. The reason for this difficulty is that a transfer's intangible benefits are sometimes impossible to quantify and therefore, can not be used in the traditional ROI methodologies. When decision makers can not see the actual benefits of a project in terms of dollars, they may find it difficult to justify investments in that project. This could lead to poor business decisions when intangible benefits are not considered and their contribution would cause the project's benefits to outweigh the project's costs. Another problematic scenario is that sometimes intangible benefits are considered as a decision criteria, but are overstated, understated, or not quantified. The intangible benefits, which can be very subjective, can cause decision makers to be overly optimistic about a project's returns and could lead to a project being accepted when it should be rejected (37: 35,36).

The nature of intangible benefits is that they often appear or effect areas in an organization that decisionmakers never accounted for when making the initial decision on a project. Many times, intangible benefits, when realized, are not attributed to the project that created them in the first place (25: 27). This situation could potentially cause a misallocation of benefits or revenues to a given project. The need to identify and define intangible benefits is critical to the evaluation of a project like technology transfer activities. This can be viewed as a two part process. First, the intangible benefits, once identified, should be put into some quantifiable form. Second, the magnitude of the value must be specified (25: 27). Once these two steps are accomplished, probability distributions can be assigned to the intangible benefits of a project. The use of probability distributions are necessary when calculating technology transfer ROI because by nature the intangible benefits used in the ROI calculation can never be known with certainty. The magnitude of the intangible benefits are usually an unknown and analysts are often uncertain about whether or not the intangible benefits will materialize.

Existing Methodologies

There have been no published methodologies used to quantify the intangible benefits of technology transfer activities. However, the information technology (IT) arena faces many of the same difficulties as technology transfer activities. IT investments are usually beneficial to the firm and increase productivity, but many of the benefits derived from IT investment are intangible and difficult to quantify (30: 45). Decisionmakers have been coping with the problem of IT investment justification for many years. As a result, there are several published methodologies that have been used to quantify the intangible benefits of IT investment. These methodologies could potentially be utilized to quantify the benefits of technology transfer activities.

Oracle Corp. has developed a model called CB-90 which takes decisionmakers through a step-by-step approach to analyzing an IT investment decision. This three step approach requires decision makers to look at the tangible cost/benefit analysis of competing projects, the intangible benefit analysis of competing projects, and the risks associated with those intangible benefits (30: 45). The first part of the CB-90 model is the tangible cost/benefit analysis where the NPV and IRR are used to evaluate competing

IT investment projects against the status quo. The tangible and intangible benefits are identified and agreed upon by a group of decision makers. Once this is accomplished, weights are assigned to the tangible and intangible benefits and the intangible risks. For example tangible benefits might be given a 60% weight, intangible benefits a 15% weight, and intangible risks a 25% weight. Each benefit and risk is then rated on a scale of 1-5 as to the likelihood of the proposed outcome. The weight factor is then multiplied by the rate to arrive at a score for each option. The investment decision with the highest score is selected (30: 46). The example below demonstrates the CB-90 model:

In this hypothetical situation, options 1 and 2 are competing projects. Their tangible and intangible benefits and risks have been identified and computed using the NPV method. Weights were assigned to each of the project's benefits and risks. The rates represent the likelihood of each outcome occurring. Option 2 has the higher total score and would be preferred over option 1.

		Option 1		Option 2	
Tangible Benefits	**Weight**	**Rate**	**Score**	**Rate**	**Score**
Cost Savings	30%	2.2	0.66	2.7	0.81
Other Tangibles	35%	2.2	0.77	2.7	0.945
Total Tangible Score	**65%**		**1.43**		**1.755**
Intangible Benefits					
Flexible Budgets	5%	2	0.1	4	0.2
Improved Reporting	5%	2	0.1	5	0.25
Improved Analysis	5%	4	0.2	5	0.25
Productivity Increases	5%	3	0.15	4	0.2
Subtotal intangible score	**20%**		**0.55**		**0.9**
Intangible Risks					
Poor Integration	3%	-2	-0.06	-2	-0.06
Resistance to Change	4%	-2	-0.08	-1	-0.04
Incomplete Implementation	5%	-4	-0.2	-2	-0.1
Losing Employees	3%	-1	-0.03	-1	-0.03
Subtotal Intangible Risks Score	**15%**		**-0.37**		**-0.23**
Total Benefits	**100%**		**1.61**		**2.43**

FIGURE 2.3 CB - 90 Model Example

This decision making model is suspect due to the amount of subjectivity in the development of weights and ratings. The weights and rates were developed by a committee of decision makers. Unfortunately, there is no explanation of the methodologies used to develop these factors. CB-90, although suspect, is a step in the right direction in that it requires decisionmakers to identify and discuss the potential intangible benefits and risks associated with a given project. In addition, CB-90 does offer a structured approach in the form of an investment decision matrix which can be easily understood and used by decision makers (30: 47). In order to make this model more useful, formal risk analysis techniques could be used to develop the rates for each outcome.

In his research, Mathias Schumann (1989) develops a similar, but more in-depth approach to quantifying the intangible benefits of office automation. Shumann explains that an office automation system can cause a shift towards higher valued work activities as well as a reduction in non-productive work time (28: 21). Office automation is classified into three categories:

a. Substitutive applications replace manual process and lead to the most obvious benefits;

b. Complementary applications - offer additional support functions and tools to make workers more productive, but the benefits are difficult to identify and quantify;

c. Innovative applications - yield competitive advantages and result in increased revenues.

The major source of savings or benefits is the increase in productivity associated with automation. The model documented by Schumann attempts to bring this out (28: 22-25). The following five step framework was used to build the model:

1. Employees were grouped into different categories based on their activities.
   - Managers - top and middle management
   - Professionals - technical, administrative, and scientific
   - Administrative
   - Clerical;
2. Decomposition of work activities at each level and the percentage of time spent on each activity was determined;
3. Evaluation of the task breakdown of the different activities for each employee;
4. Estimation of the office automation savings potential related to these tasks;
5. Derivation of possible time savings, productivity improvements, and total savings quantified with labor costs.

A sample work profile was developed that showed the percentage of a worker's total work that was taken up by each individual work task performed by that worker. Another table was developed to display the potential work savings over a given year for middle managers. This work savings was calculated as the decrease in percentage of time to perform a given work task that resulted from office automation. For example, office automation may enable a middle manager to reduce the amount of time used to handle documents by 45%. If that task (document handling) made up 5% of the managers total work day, then it would be reduced by 2.25%, leaving him or her additional time to spend on other work tasks. The table follows that logic throughout and results in a total percent work savings resulting from office automation. This total percentage is then multiplied by a dollar amount (e.s., worker's salary) to obtain an annual cost valuation (or dollar savings). The results of the table are broken down by triangular distribution parameters (pessimistic, most likely, and optimistic), but there is no indication that any formal risk analysis was done to arrive at the outcomes.

Because the study is focused at the individual worker level of the organization, the results do not directly apply to the needs of AFMC and the Technology Transfer Office. However, some of the tools used can be applied at a higher organizational level. The same methods used to decompose the work into specific tasks can be applied when trying to determine the types of intangible benefits that can be applied to technology transfer activities. The study conducted by Shumann is another step in the right direction, but would have to be modified to be applicable to AFMC.

Another methodology described by Richard Pastore discusses the need to identify tangible and intangible benefits and ensure that they align with the organization's goals and objectives. Information Economics (IE) is a system of quantifying intangible benefits of a project and ranking the projects based on their expected contribution to business objectives (24: 66).

The first step in this process is for top executives to identify corporate objectives and give them a relative weight based on their importance. The second step in the process is that proposed projects are given a score based on their estimated impact to each objective. In this system, ROI still receives a significant weight, but it is no longer the only criteria for evaluating alternative projects. The third step in the process is a peer review, where each alternative project proposal is brought to the table with scores filled in. The projects that align closely with the corporate strategy, goals, and objectives will most likely be accepted and projects that do not fit into the corporate strategy will be rejected. IE provides a common sense, team approach to evaluating projects based on criteria other than ROI (24: 67-70).

The IE approach also has some flaws that may make it difficult to implement within the DoD. IE can be a difficult concept to grasp. In addition, it can take a great deal of time for managers to go through the IE process when looking at alternative projects. Because IE places a strong emphasis on linking projects to the organization's strategic plan, involvement by senior executives is vital. Therefore, IE can be a costly methodology to implement. The biggest drawback to IE is its lack of a system to measure post-implementation benefits. Finally, IE is not a hard science and all this work may provide very little solid justification or hard numbers to support management decisions (24: 73).

Probability encoding is an interview process used to extract and quantify an individual's judgment about certain quantities or outcomes. Probability encoding is commonly used during the probabilistic phase of decision analysis where uncertainty can be incorporated into the analysis by assigning probability distributions to important outcomes or variables. By using probability encoding, the risks involved with quantifying intangible benefits can be accounted for (35: 340-342). Estimates of a transfer's intangible benefits can be made using expert judgment or opinion. Once these numbers are provided, a probability distribution can be built for the estimates and these estimates, once quantified, can be added to the ROI calculation.

Probability encoding is a structured interview process. The following guidelines apply when attempting to encode uncertain quantities:

a. Choose only uncertain quantities that are important to the decision. There is no sense encoding the quantity of an intangible benefit that does not have a major impact to the organization;

b. Define the quantity as an unambiguous state variable;

c. Structure the quantity carefully so that it is understandable to the interviewee and is appropriate for cost benefit analysis;

d. Clearly define the quantity. Precision is critical to probability encoding;

e. Describe the quantity using a scale that is meaningful to the subject.

"By following these guidelines, reasonable estimates and distributions can be built for uncertain quantities (35: 343)." These estimates can then be used in decision making models or ROI calculations.

One difficult aspect of probability encoding is that it is a process that relies on human judgment. In many cases, judgment can be impaired by individual bias. Biases can take one of two different forms. Displacement bias is characterized by a shift in the distribution either upward or downward, while variability bias results in a change in the shape of the distribution itself. For example, the tendency of an expert to estimate high and low values unrealistically close to the estimated mean would be a form of variability bias. This situation would result in a tighter distribution. The interviewer must always guard against bias and take the necessary steps to prevent it when possible (35: 345; 4: 64-66).

Most encoding methods are based on questions that lead to answers that can be expressed as part of a cumulative density function. There are three basic types of encoding methods. The P-methods require the subject to respond by specifying points on a probability scale while the values remain fixed. The V-methods require the subject to specify points on the value scale while the probabilities remain fixed. Finally, PV-methods require the subject to respond to both scales jointly. The type of method used varies according to the outcome or variable that is being quantified (35: 350).

The probability encoding technique can easily be integrated into any of the above mentioned methodologies to make them more robust. For example, it could easily be incorporated into the CB-90 model to replace the rate factor calculations. By incorporating probability encoding and some basic risk analysis techniques into the CB-90 model, a robust model could be developed to quantify the intangible benefits of technology transfer activities. The result of this methodology would be a ROI calculation similar to the NPV example, but the NPV calculation could be stated as a confidence interval with a range of likely outcomes. This methodology would provide decision makers with a rational decision making tool and would allow them to compare projects that contain tangible and intangible benefits.

Summary

This chapter focused on the current technology transfer and return on investment literature. Specific areas addressed were technology transfer policies, current measurements of transfer success, ROI measurements, and existing methodologies used to quantify tangible and intangible benefits. The goal of this research is to build an effective methodology that will enable decision makers to analyze the benefits of technology transfer activities. Chapter Three will focus on building that methodology.

III. Methodology

Overview

After reviewing the literature, it is clear that a more effective methodology is necessary to measure the return on the government's technology transfer efforts. The purpose of this section is to detail the process that will be used to gather and analyze the data in support of this research. This is an exploratory study that will rely on both quantitative and qualitative data. Recent technology transfers conducted at Wright Laboratory are used as the primary source of data. Data bases at Wright Laboratory provide secondary data on revenues attributed to given transfers. In addition, personal interviews with transfer focal points are used to collect primary data on other quantifiable and nonquantifiable benefits.

During this exploratory study, a ROI methodology is used to estimate the expected returns on technology transfers within Wright Laboratory (WL). Recent cooperative research and development agreements (CRDAs) are used as a source of data for this research. Due to time constraints, the opportunities to validate the ROI model are limited. A potential follow-on research effort can validate estimated returns provided by the methodology by examining the actual future returns received at WL. Also, the lessons learned section of the interview process provides some additional research avenues.

Research Approach

This is an exploratory study that utilizes probability encoding interview techniques to gather data that is not readily available or located in a database. Since the control by the researcher over the variables is limited, it is an ex post facto study. Once data is collected through the interview process and probability distributions are postulated for the estimated tangible, quantifiable benefits, Monte Carlo Simulation is used to facilitate the ROI calculations. This methodology is broken down into three processes: the identification of quantifiable/tangible and nonquantifiable/intangible benefits; the specification of those benefits; and the return on investment calculation.

Before a ROI methodology can be implemented, the tangible and intangible benefits must be identified and quantified. The tangible benefits, such as cash revenues received in the form of licensing fees and royalty payments, are available at Wright Laboratory for each individual transfer. Also, any obvious dollar cost savings that are to be achieved as a result of transfer activities are available in the CRDA. The first step in the interview process is the validation of all benefits spelled out in the CRDA. After the tangible benefits and costs have been identified and quantified, a structured interview process is used to identify other quantifable/tangible and intangible benefits. The following list of benefits was developed during an interview with Steve Guilfoos AFMC TTO/TTR (15).

The list below contains four main categories of benefits. The first category is revenues received from CRDAs which can be defined as direct cash payments made to WL. The second category, quantifiable (non-revenue) benefits that can be expressed as dollars, are tangible benefits that represent services or products provided by the outside partner at no cost to WL or payments made to WL for the use of its resources. The third category, other quantifiable (non-revenue) benefits, are tangible benefits that must be translated into dollars after being received. The fourth category, other nonquantifiable intangible benefits, are real benefits that can not be expressed in dollars. The list is not all inclusive, but it represents AFMC TTO expectations of the anticipated tangible and intangible benefits received by the Air Force through CRDAs.

Revenues received from CRDAs:
- Licensing Fees
- Royalty Payments

Quantifiable (non-revenue/tangible) benefits that can be expressed as dollars:
- Cash Reimbursables for services provided by DoD personnel to the private sector (ex consulting fees)
- Work avoidance resulting from collaborator efforts to be measured in man hr. saved
- Cost avoidance resulting from collaborator efforts to be measured in the dollar value of resources saved as a result of the outside partner's efforts

Other quantifiable (non-revenue/tangible) benefits:
- Productivity and efficiency increases resulting from information exchange with CRDA partner
- Cost avoidance through more effective utilization of federal laboratory resources
- Time and costs savings resulting from formal data exchange with CRDA partner

Other nonquantifiable (non-revenue/intangible) benefits:
- Improvements in managerial and business practices resulting from relationship with CRDA partner
- Improvements in the morale of Lab personnel through science and technology fulfillment
  -- Personnel see scientific goals being met
  -- Personnel see program objectives being met
  -- Commercialization of technologies developed in federal laboratories

Interview Process

The interview process is critical to building the estimates for the intangible benefits of a given transfer. A focal point or expert was identified within Wright

Laboratory for each specific transfer. Each focal point has in-depth knowledge about how the transfer agreements were developed and what the government's goals were before entering each agreement. Once a focal point is identified, the interview is scheduled.

The first step of the interview is a brainstorming session to identify the benefits of the transfer that were spelled out in the CRDA. Once the benefits are identified, they are ranked or categorized based on their importance to the government and the impact they could potentially have on the organization. After the potential impact has been identified, the uncertainty or likelihood of that benefit occurring must be established. Probability encoding is used to develop a distribution for the proposed benefit.

"Experts are usually capable of making accurate forecasts on a future outcome when the variable being forecast has been defined in terms they can understand (35: 353)." The interview process is divided into five distinct phases:

a. The **Motivating** phase introduces the subject to the encoding process by explaining its purpose and its importance in decision making. The motivating phase also helps the interviewer determine the subject's bias;

b. **Structuring** is the phase where the benefit is defined and quantified;

c. The **Conditioning** phase is used to help the subject think fundamentally about his judgment and to avoid cognitive bias;

d. The **Encoding** phase is used to quantify the subject's judgment in probabilistic terms;

e. **Verifying** is the phase where the responses are cross checked to ensure they are valid.

The following information describes the specific process used to develop subjective probability density functions for the purpose of technology transfer ROI estimates.

Pre-Interview Research:

The first step in the interview is reading through the CRDA. This helps the interviewer become knowledgeable on what type of technology is being transferred and helps in the formulation of some initial questions for the respondent. The interviewer reads through the CRDA appendix and the CRDA work plan which contains a listing of the expected benefits the government was to receive from the agreement and the services the government provided in exchange for those expected benefits.

Phone Call to POC:

The database listing provided by WL ORTA lists the POCs for each CRDA. Once the interviewer has read through the CRDA and formulated questions, the POC is contacted and a meeting time for the interview is scheduled. During the phone call, the interviewer explains the purpose of the interview. The interviewer lets the respondent know that he is interested in verifying the benefits received by the government. In addition, additional benefits that may not have been spelled out in the agreement are discussed.

Interview:

The interview begins by discussing the CRDA itself. The respondent is asked about the technology involved, how the CRDA was formed, and the work involved in putting together the CRDA. Questions are asked about the outside partner's involvement in the CRDA process (how interested were they in the technology? did they come to government? etc..). The interviewer then works from the questionnaire and begins the encoding process.

The interviewer explains the data sheet and what is expected in terms of a probability distribution. The POCs usually have an in-depth understanding of statistics and have had little problem with quantifying the benefits in terms of a distribution. The following listing describes the process:

a. Identify a starting point, usually a most like likely estimate or end points (extreme values) for the distribution provided by respondent;

b. Develop an idea of how the benefit or input parameter might behave (positively or negatively skewed, upper and lower limits, range of values);

c. Build the estimate and sketch it out, beginning with worst case and best case scenarios for input parameters;

d. Verify the estimate with the respondent.

After all of the benefits have been identified and quantified, the interview sheet is reviewed with the respondent. The interviewer works to get additional listings of people that have worked on other CRDAs. The final step in the interview process has been the identification of the lessons learned by the respondent during the CRDA process. The goal of the lessons learned section is to identify any traits common to successful or unsuccessful CRDAs.

This process leads to an estimated value (a mean or most likely value) and a subjective probability density function (PDF) for each tangible and intangible benefit (35: 345). These PDFs are used in the simulated ROI calculation.

Once the benefits are identified and specified, the potential dollar amounts of the benefits are estimated and the probabilities of obtaining these estimated outcomes are also specified. For example, a triangular distribution is used where optimistic, pessimistic, and most likely values are identified for given parameter estimates. From this data, a Monte Carlo Simulation is used to provide estimated values for given outcomes based on the input parameters for the specified distribution. The result of the simulation is a confidence interval for each outcome or parameter and an overall estimate of the benefits received from a CRDA that can be used for decision making.

The ROI calculation is accomplished once the all of the benefits and have been identified and estimated and the parameter estimates and distributions have been specified for the quantifiable benefits. Microsoft Excel™ is used in conjunction with the Crystal Ball™ program to build spreadsheets that perform the ROI calculation.

Crystal Ball™ is a windows application the was designed to perform risk analysis in conjunction with Microsoft Excel™, thus extending the forecasting capability of a spreadsheet. Two major limitations of spreadsheets are that they only allow changes one cell at a time and they do not indicate the likelihood or the probability of achieving a desired outcome (10: 8). Crystal Ball™ allows the analyst to describe a range of possible cell values in terms of probability distributions or assumptions. Using Monte Carlo Simulation, Crystal Ball™ shows the analyst the entire range of possible outcomes and the likelihood of achieving them. This process provides the analyst with a statistical picture of the range of possibilities based on the probability distributions associated with each cell value (10: 8-10). The benefits, to the decision maker, of using this approach are improved accuracy and greater understanding of the risks and returns associated with a desired outcome (10: 10).

Data Requirements

The goal of this thesis is to build a useful methodology that can be employed by the AFMC TTO to calculate the ROI for their transfer activities. Monte Carlo Simulation is used in conjunction with discounted cash flow techniques to determine the ROI of technology transfer activities. In order to build this methodology, data on a transfer's revenues and non-revenue and nonquantifiable/intangible benefits are required. The data on the revenues and non-revenue benefits are not consolidated in a database at WL. Therefore, this data is obtained using the probability encoding interview techniques described in Chapter Two. Through the use of the probability encoding techniques, each tangible benefit can be given a quantifiable value (usually a most likely estimate or a mean). This value is then specified in terms of a standard deviation or high and low estimates. As a result of the encoding process, each tangible benefit can be stated as a probability density function. This function is then incorporated into the ROI calculation.

The result is a ROI calculation that can be stated in terms of probabilities. The example below is a demonstration of a NPV calculation using Monte Carlo Simulation.

The return on investment calculation below was developed using a 500 iteration Monte Carlo Simulation. The intangible benefits for years 1 through 4 are stated in terms of probability density functions. The shaded values shown in the table below are the mean values for each intangible benefit. The total revenue and PV calculations were calculated by summing the mean values for each intangible benefit. For the example below, there is a 50% probability of obtaining the NPV of $ 24,841.11

	Year 1	Year 2	Year 3	Year 4	
Project Cost	**$100,000.00**				
Cash Revenue	$ 18,000.00	$12,000.00	$10,000.00	$ 8,000.00	
Intangible Benefit 1	$ 12,688.19	$10,716.00	$ 7,683.07	$ 7,634.15	
Intangible Benefit 2	$ 9,594.75	$ 9,545.63	$ 8,310.74	$ 5,870.51	
Intangible Benefit 3	$ 5,673.38	$ 7,341.47	$ 8,387.87	$10,675.51	PV of cash flows
total revenue	**$ 45,956.33**	**$39,603.09**	**$34,381.68**	**$32,180.17**	***$124,841.11***
NPV of the Project	**$24,841.11**				

FIGURE 3.1 Return on Investment Calculation Example

Data Analysis

The most important aspect of the methodology is the data analysis section. The data is analyzed to determine whether or not the benefits derived from technology transfers are in fact collectable, quantifiable, measurable, and appropriate. According to previous research by West (1995), there are no formal data collection methods in place at WL to collect data on the benefits received through CRDAs. The information provided in the West thesis indicates that benefits or revenues received by WL through technology transfers are probably the best measure of technology transfer success. The question that must be resolved is; "Does the collection and or estimate of revenues received by the government through technology transfers provide an effective management decision making tool that warrants the time and effort used in collecting the data?"

During this phase in the research, the benefits received from transfers are evaluated using the ROI calculation. The transfers that show the highest return on investment are analyzed more closely. The focus of this analysis is to determine if the quantifiable/tangible benefit estimates (input parameters or subjective PDFs) are reasonable in the first place. A key point to remember is that estimates developed using subjective PDFs are only as good as the parameter inputs themselves. Several factors must be considered to determine the usefulness of the estimates and the subjective PDFs.

The first factor that must be considered is the amount of and type of bias contained in the PDFs. Biases and the sources of biases must be identified when subjective PDFs are used in the ROI calculations. As explained in Chapter Two, bias can be prevalent whenever individual expert opinion is being used to develop PDFs based subjective assessments of potential outcomes. The existence of biases in an estimate will often lead to an understatement of the variation or cost risks associated with a given project (4: 64-67). Another factor that must be addressed is whether or not the type of PDF used in the estimate is appropriate, applicable, and suited for cost risk analysis. In other words, do the PDFs used to develop the estimate pass the common sense test.

In addition, the variance contained in the PDFs should accurately represent the respondent's confidence in the PDF inputs. The researcher should expect the amount of variance contained in the PDFs to coincide with the amount of uncertainty in the estimate. Higher degrees of uncertainty should be reflected by higher variances in the subjective PDFs and wider confidence intervals for the ROI estimate. In cases where there is a high degree of uncertainty in the quantifiable benefit parameter estimates and the ROI calculation is favorable, revisiting the estimate to identify any parameter estimates that are overly optimistic and contain high degrees of variation is advisable. This is simply meant to be a system of checks and balances to guard against overly optimistic estimates that could potentially lead to poor decisions by managers.

Another factor to be studied is any estimate that contained a high degree of correlation between parameter inputs. A certain transfer may provide a favorable ROI number, but it may contain high degrees of correlation between input parameters. The existence of correlation between parameters could potentially lead to a higher than expected amounts of variation in the ROI calculation. Estimates that contain high degrees of variation resulting from correlation between parameter inputs may not be reliable for the purposes of managerial decision making and should be examined more closely.

Expectations

The interview process should provide reliable and effective PDFs that can be used in the ROI calculation. The shape of the distributions should be defined based on the logic of the given quantifiable/tangible benefit and the subject's expert opinion of potential outcomes. The ROI calculations should demonstrate that the technology transfer activities taking place within AFMC are beneficial to the DoD, the Air Force and the military laboratories.

Limitations

Using probability encoding techniques to develop subjective PDFs, and then using these PDFs in a ROI calculation that incorporates Monte Carlo Simulation can be a difficult task. The ROI calculation is only as reliable as the subjective PDFs that go into it. This is an advanced approach in the area of risk analysis and there are several reasons why this approach is not often used. First, specification of a subjective PDF is not an easy task; much of the burden lies with the interviewer. An additional factor that must be considered is that variables are often correlated to one another. Unfortunately these correlations may be difficult to identify in the first place and once identified, specification errors are common. Finally, the use of simulation may not lead to a clear cut decision rule for decision makers. A mean value for the ROI calculation is obtained and the probabilities associated with certain outcomes are identified. Unfortunately, this information may not be adequate for some senior decision makers.

Summary

This chapter presented the research approach, sample population, interview process, data requirements, data analysis, expectations and limitations. The method of collecting data is focused interviews with knowledgeable points of contact. Probability encoding is used to define the assumptions associated with each quantifiable outcome. The data is analyzed through the construction of a ROI model that can be utilized by AFMC to identify the technology transfer benefits received by the Air Force from CRDAs. Chapter four presents the results of the data collection and analysis effort.

IV. Results

Introduction

The objective of this research is to collect data on the benefits received by the Air Force through the use of cooperative research and development agreements (CRDAs) between one government laboratory, Wright Laboratory (WL), Wright-Patterson Air Force Base, Ohio, and its collaborators in the private sector. The data collected will provide insight into the success or failure of the technology transfer program within WL. Research objectives are as follows:

1. Identify the benefits that were expected to be received by the Air Force or WL from involvement in technology transfer with outside partners.

2. Determine whether or not the expected benefits spelled out in the CRDAs were actually realized during the technology transfer process in WL.

3. Quantify the benefits received by WL and utilize the return on investment methodology described in the previous chapter to provide measures that can be used to assess the success of our government's technology transfer efforts.

4. Analyze the data provided in the interviews to determine whether or not the benefits derived from technology transfers are in fact collectable, quantifiable, measurable, and appropriate.

5. Identify any lessons learned by WL personnel about the CRDA process or specific reasons why a given CRDA was a success or failure.

This chapter discusses the data collected during 15 personal interviews with CRDA POCs in WL. This exploratory study is discussed through three main areas. First, the method of collecting, analyzing, and presenting the data is provided. Second, the data is discussed with respect to three categories of benefits received by WL as a result of the technology transfer process. These three categories are:

1. CRDAs that resulted in no benefit to WL;

2. CRDAs that resulted in or are expected to result in nonquantifiable benefits to

WL;

3. CRDAs that have resulted in or are expected to result in revenues or quantifiable benefits to WL.

Finally, the ROI calculations will be revisited and analyzed to address any areas of concern like bias within the subjective PDFs, correlation between assumptions, variance in the estimate, and reasonableness of the ROI calculation. The three categories and the benefits received are analyzed in accordance with the lessons learned section of the interview to determine if there are traits common to transfers that provide higher than normal returns to the government.

Data

The data used in this study comes from the 15 interviews conducted with CRDA points of contact (POCs). The data is self-reported and internally consistent with the interview format developed and explained in the previous chapter. No additional procedures or processes were used to verify the data reported by WL POCs during the interviews. All of the respondents were frank, honest, and candid about the development, benefits, and administration of the CRDAs they managed. They were all extremely cooperative in sharing their experiences and insights about the CRDA process and the relationship between Air Force and the outside partner or collaborator. The cooperation and honesty of the respondents leads this researcher to believe that the information and responses provided during the interviews are true to the best of the respondents' knowledge.

The summary of the CRDA POC interview data is presented in Appendix B. The data was collected using the CRDA interview form presented in Appendix A and the probability encoding process described in Chapter Three.

Benefits to WL

The results of the data collection process showed that WL is in many cases actively and effectively transferring technology to the private sector. Of the 15 CRDAs that were studied by this researcher, only four had resulted in no benefits to the government or WL. Of the remaining 11 CRDAs, nine had either already resulted in revenues to the government or the respondent felt that it was appropriate to calculate future revenue estimates resulting from the CRDA using the ROI methodology explained in Chapter Three. See graph and table below:

No Benefits to Govt.	**4**
Nonquantifiable Benefits	**2**
Quantifiable and Non-Quantifiable Benefits	**9**

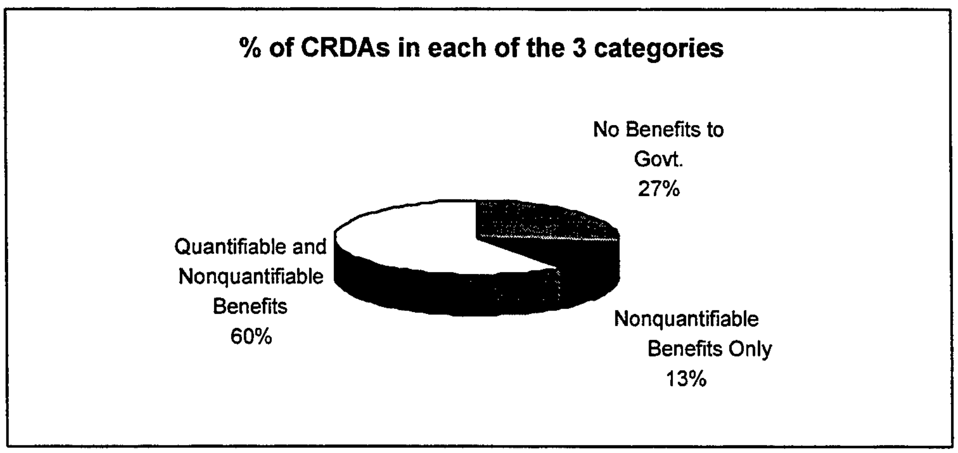


FIGURE 4.1 Number and Percentage of CRDAs in each of the Three Categories

The percentages shown in the above graph are not necessarily representative of all CRDAs developed and administered at WL. More extensive sampling would be required to determine whether or not the sample shown above is representative of all CRDAs developed at WL.

The next step in analyzing the data is to identify the benefits that are being received by the government or WL. By analyzing the 11 CRDAs that were providing benefits to WL, a listing of benefits could be identified. The benefits are categorized according to the listing of expected benefits presented in Chapter Three. Additional benefits not specified in Chapter Three have been added to this listing. The interview summaries contained in Appendix B provide comprehensive explanations of the benefits received by WL as a result of the 15 CRDAs used in this study. The categorized listing below is followed by explanations and examples of the benefits:

The benefits contained in the following table are a summation of all benefits received and are not traced specifically to individual CRDAs. In other words, there were some CRDAs that provided multiple benefits in the same specific category (e.g., resource savings). Those benefits were accounted for each time they occurred and were not consolidated when they resulted from only one CRDA.

TABLE 4.1 Benefits Received by the Air Force/WL

Benefits Received by the Air Force/WL

Revenues	**4**
- Royalty Payments	4
Quantifiable Benefits in $	**14**
- Cash Reimbursements	2
- Work Savings	4
- Resource Savings	8
Other Quantifiable Benefits	**11**
- Productivity Increases	1
- Effective Resource Utilization	7
- Data Exchange savings	3
Nonquantifiable Benefits	**32**
- Public Relations and Goodwill	6
- Enhanced Morale, Knowledge, or Expertise of Lab Personnel	6
- Dissemination of Technology	4
- Improvements in Technology	6
- Use of Additional Technologies	1
- Enhanced Society Wealth	1
- Follow-on CRDA Activities	4
- Transfer Process Improved	4

The revenues category is made up of expected royalty payments to be received by WL as a result of transfer activities. Four of the 11 respondents responsible for benefit-producing CRDAs felt that the potential possibility of royalty revenues was high enough to warrant the inclusion of a royalty revenue stream in the ROI calculation. This data does not necessarily represent revenues that have been received by WL in the form of royalty payments. This data only represents the fact that there is the potential in a given CRDA for a revenue producing royalty stream.

The second category, quantifiable benefits that can be expressed in dollars, contains cash reimbursables, work savings resulting from collaborator efforts, and resource savings resulting from collaborator efforts. Examples of cash reimbursables include consulting fees or payments made by the outside partners for WL expertise/resources. Examples of work savings include man-years of effort (usually quantified in terms of a salaried employee) saved in the marketing or enhancement of a technology or the development of a database by the collaborator. Examples of resource savings include work done by the outside partner to improve a technology, making it more operationally-effective or cost-effective for government use. Other examples include manuals, testing, or other resources provided to WL at no cost as part of the CRDA.

The third category of benefits, other quantifiable benefits, includes productivity increases, more effective utilization of government resources, and time and costs savings resulting from formal knowledge and data exchange with CRDA partners. Examples of cost savings due to effective utilization of WL resources include additional use of testing facilities at WL resulting from CRDAs and the use of equipment already purchased by WL that was utilized more effectively as a result of the CRDA. Examples of time and cost savings resulting from data exchange and knowledge transfer with outside partner include insights gained about commercial aircraft industry.

The fourth category of benefits, other nonquantifiable benefits, are made up of benefits that are real and valuable to the government and WL. The benefits include but are not limited to the above listing. They are all self explanatory. However the three most common nonquantifiable benefits: public relations and goodwill, enhanced morale, expertise, and knowledge of WL personnel, and technology enhancements seemed extremely important to most of the respondents. At least one of these three benefits were identified in each of the 11 benefit-producing CRDAs. Many of the respondents pointed out that the fact that they were actively and effectively doing technology transfer was important to the WL mission and society as a whole. On several occasions, respondents mentioned that these benefits may even be more important to WL than the quantifiable categories of benefits mentioned above.

After compiling the data, it is clear that the nonquantifiable benefits were more common than the other categories of benefits. The graph on the following page shows the overall number of benefits that were identified in each of the four main categories. The research indicates that there are real benefits to WL resulting from technology transfer. The graph shows that these benefits are in many cases nonquantifiable. In fact, the nonquantifiable benefits outnumbered the other three categories combined. Because over 50% of the benefits identified are nonquantifiable, the use of a basic ROI methodology may, at times, be inappropriate or difficult to apply when used exclusively to evaluate the benefits received by the Air Force through technology transfer.

This graph represents the summation of all benefits received by WL through CRDA activities. Benefits are accumulated in total and not traced to individual CRDAs. Therefore, several of the CRDAs provided multiple benefits by major category.

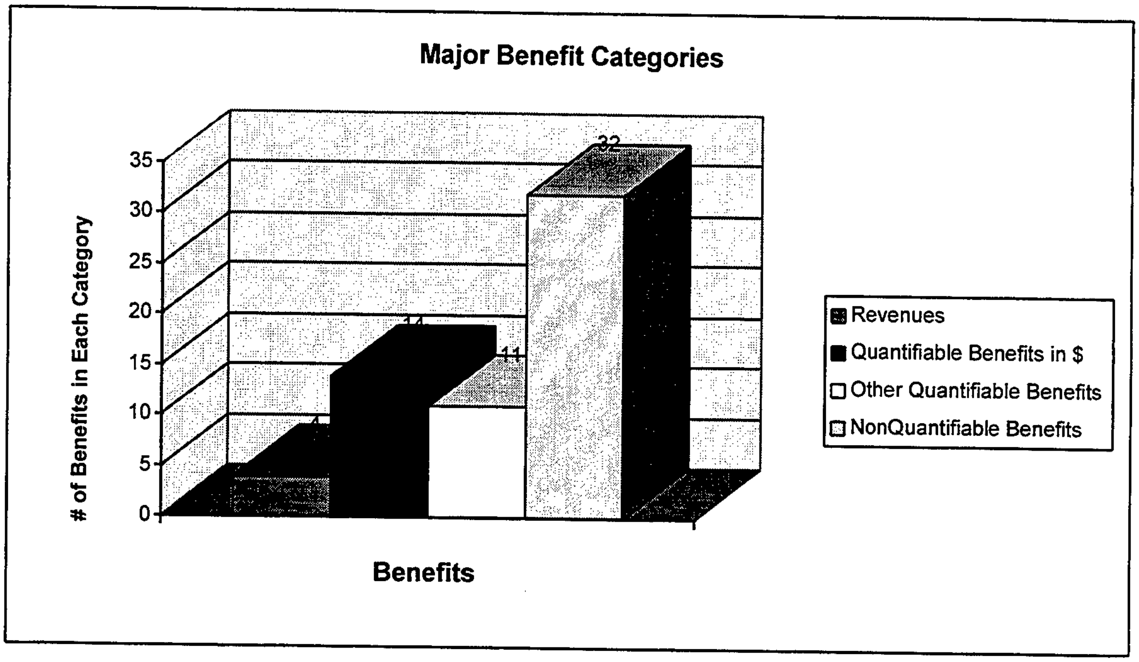


FIGURE 4.2 Major Categories of Benefits Received Through Technology Transfer

When looking at the major categories of benefits received by WL through technology transfer, it becomes clear that the intangible, non-quantifiable benefits are extremely common. The respondents explained that these non-quantifiable benefits are important to WL and the WL mission. The next step in analyzing the benefits was to identify the specific benefits that were most commonly received by WL through technology transfer. The research indicates that the most common benefit received by WL through technology transfer is the resource savings experienced as a result of collaboration with outside partners. The resources saved through technology transfer can be quantified in many cases and represent hard evidence that the Air Force is getting some return on their technology transfer efforts. The graph below represents the most common specific benefits received by WL through the 11 benefit producing CRDAs.

The benefits contained in the graph below represent a summation of all benefits received in specific categories and are not traced specifically to individual CRDAs. In other words, there were some CRDAs that provided multiple benefits in the same specific category (i.e. resource savings). Those benefits were accounted for each time they occurred and were not consolidated when they resulted from only one CRDA.

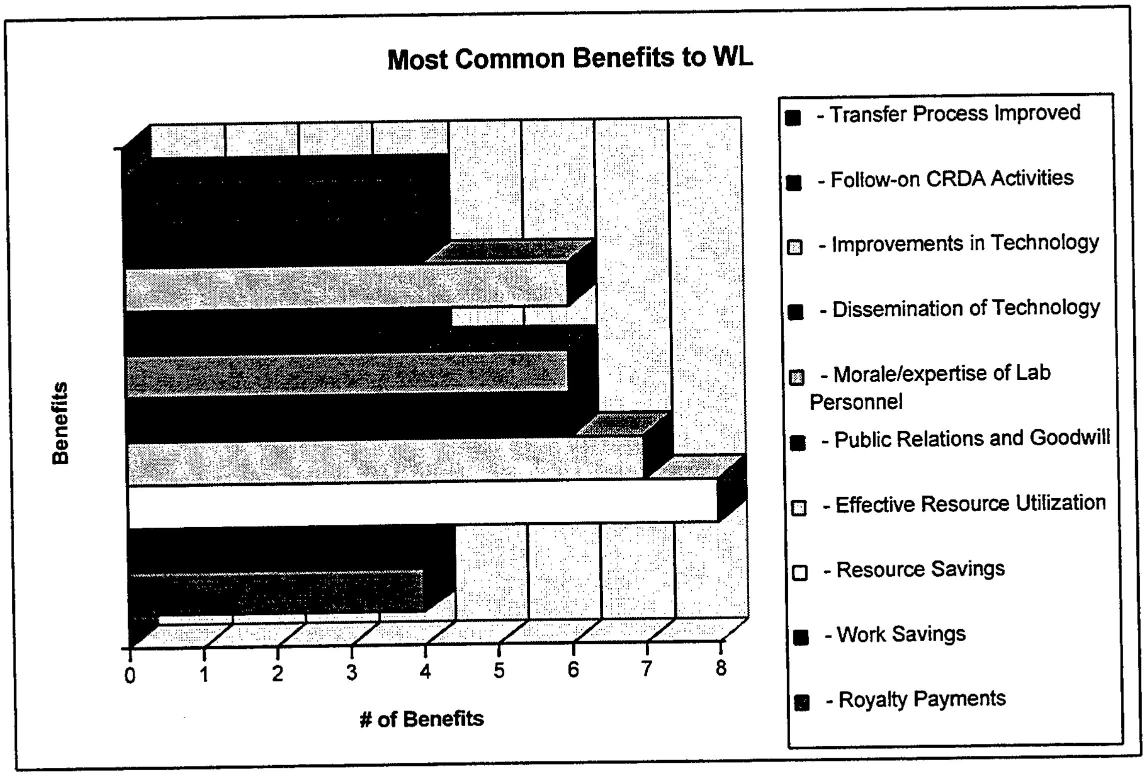


FIGURE 4.3 Most Common Benefits Received by WL Through Technology Transfer

The fact that there are quantifiable benefits being received by WL through their technology transfer efforts provides justification for the use of the ROI methodology described in Chapter Three. Effective resource utilization, resource savings, work savings, and royalty payments are all factors that federal laboratory decision makers can look at more closely as future decision making criteria. Additional revenues to WL and costs savings resulting from technology transfer efforts will allow WL to ration out their R&D dollars more effectively. In many cases, WL has been able to utilize CRDA revenues to fund capital expenditures that would have not been possible due to funding limitations.

<u>CRDA Revenues</u>

In many cases, the expected benefits spelled out in the CRDA work plans were realized or are expected to be realized by the government. The following table displays the estimated mean net present value of the quantifiable benefits received in the 9 revenue producing CRDAs. The values range from a low of $ 2,000 to a high of $ 834,574. The estimates were developed using the ROI methodology described in Chapter Three. Appendix B contains the spreadsheet calculations and Crystal Ball reports for each estimate. In many cases, the cash flow estimates were developed using the probability encoding techniques described by Spetzler (35: 350). Subjective PDFs were built based on the expert opinion of the CRDA POCs (35: 350). There were no real difficulties in obtaining the estimates because all of the respondents had some knowledge of statistics and probability density functions. In order to guard against overly optimistic estimated values, subjective PDFs were built only for potential benefits in cases where the respondents felt there was a strong chance of the benefits being realized. The values listed below are an accurate and documented estimate of the revenues expected from the individual CRDAs.

The revenues already realized represent actual dollars or estimated actual dollars that have already been received by WL. In many cases, these revenues were in the form of payments to WL for services, resources, or expertise provided under the terms of the

CRDA. In other cases, these revenues already realized were calculated using probability encoding techniques and Monte Carlo Simulation. The estimated revenues represent revenues contained in the ROI calculation that are expected in the future but have not yet been realized.

TABLE 4.2 Estimated Net Present Value of Revenues Received Through CRDAs

CRDA #	Revenues Already Realized	Estimated Revenues	Mean Net Present Value Estimate
94 - 173 - WL	$ 45,000.00	$ -	$ 45,000.00
93 - 335 - WL	$ 44,094.00	$ 36,151.00	$ 80,245.00
95 - 004 - WL	$ 2,000.00	$ -	$ 2,000.00
94 - 132 - WL	$ 43,551.00	$ -	$ 43,551.00
95 - 335 - WL	$ 21,000.00	$ 95,123.00	$ 116,123.00
95 - 075 - WL	$ -	$ 249,938.00	$ 249,938.00
95 - 201 - WL	$ -	$ 834,574.00	$ 834,574.00
94 - 083 - AS	$ 96,400.00	$ 119,228.00	$ 215,628.00
96 - 000 - WL	$ -	$ 246,826.00	$ 246,826.00

There is a wide disparity between the revenues expected from the individual CRDAs. The estimated royalty revenue streams are the main drivers in the high end estimates. There is a greater degree of uncertainty involved with these estimates because the cash flow estimates are based upon unknown future demand for the goods and services of the outside partner. The four CRDAs with estimated royalty revenue streams are all over $ 200,000 in mean estimated net present value. The graph below displays and emphasizes the disparity between the expected benefits of the five none royalty revenue stream CRDAs and the expected benefits of the four royalty revenue stream CRDAs. The four CRDAs containing estimates of royalty revenue streams are:

CRDA # 94 - 083 - AS
CRDA # 96 - 000 - WL
CRDA # 95 - 075 - WL
CRDA # 95 - 201 - WL.

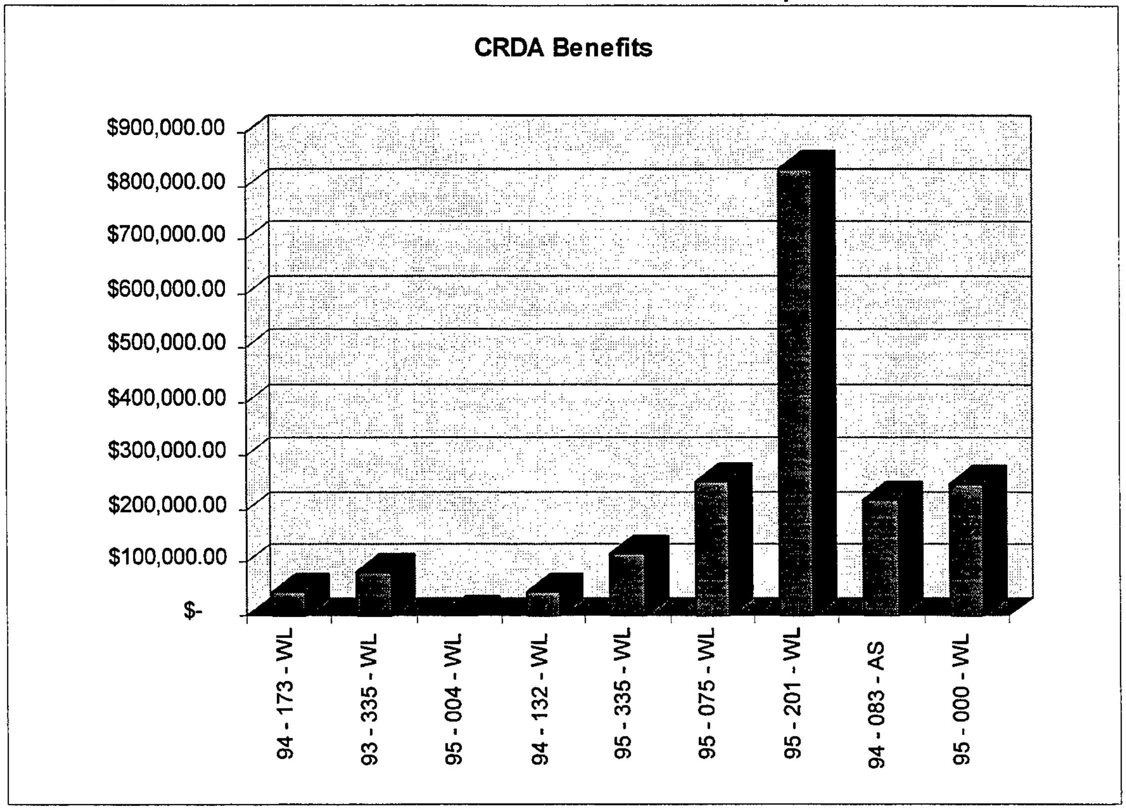


FIGURE 4.4 Estimated Mean Net Present Values for Revenue Producing CRDAs

With the exception of CRDA 95 - 004 - WL, the estimated mean net present value estimates are substantial in terms of dollar value provided to WL and the Air Force. Due to the high dollar values contained the ROI calculations, further evaluation of the estimates was necessary. In order to determine the usefulness of the ROI methodology as a management decision making tool, the data was analyzed based on the following criteria:

a. Bias within the estimates;

b. Specification of the PDFs--are the PDFs reasonable and appropriate?

c. Variance in the estimate--does it coincide with estimate uncertainty?

d. Correlation between input parameters.

The data summaries and Crystal Ball reports (see Appendix B) were utilized to conduct data analysis.

Estimate Bias

Any methodology that uses the subjective inputs of an expert to develop estimates of an outcome based on the probability of future events is subject to biases. Research by Biery and Spetzler has shown that experts consistently display bias when estimating the probability of future events. They explain that these biases are usually not due to an expert's failure to remain objective, but are part of a systematic cognitive process (4: 64; 35: 350). Much of the responsibility for removing bias from a subjective input lies with the researcher conducting the interview.

According to research conducted by Spetzler and Biery three of the most common biases exhibited in cost analysis are representativeness where the researcher and respondent become overreliant on certain information and neglect other information, availability where the most recent events are recalled in order to build distributions, and anchoring where a point estimate is first determined and a distribution is then built around the point estimate process (4: 64; 35: 350).

The most difficult biases to overcome in building PDFs for the ROI calculations were representativeness and anchoring. In most cases, availability bias was not a factor because the respondents were providing data on situations that they had not dealt with in the past. Therefore, there were no recent events to be recalled when building the distributions. Anchoring bias was minimized in most cases by discussing the end points of the distributions prior to the most likely values or mean values of the distributions.

Due to the inexperience of the researcher, there were several occasions where the distributions were built by first identifying the most likely values and then the end points. When this occurred, the distributions were often expanded to provide greater variances and extend the range of the end points of the distribution provided by the respondent. This allowed for a greater variance in the estimate and minimized the possibility of understating the entire range of possible outcomes. For example, on more than one occasion, a work savings was quantified in terms of a salaried employee. When the respondent provided an estimated man-year of effort in terms of a most likely salary and pessimistic and optimistic end points, the end points were further extended to include salaries considered to be out of the norm. On most occasions, the respondents felt that the revised distribution was acceptable. Because CRDAs are new and different work situations for most of the respondents, there is a possibility of some representativeness bias in the ROI calculations. The methods described above were also used in order to compensate for the possibility of representativeness bias.

PDF Specification

Only two types of distributions were used in building the ROI calculations. On several occasions, the normal distribution was used. The normal distribution was used in situations where the respondent felt there was an equal likelihood of the estimated value falling above or below the mean and a standard deviation could be estimated.

The triangular distribution was the most widely used distribution in this study. According to Biery (1992), the triangular distribution has several advantages over other distributions (4: 65). For instance, it is easy to manipulate mathematically and does not require the analyst to provide additional information like parameter shape, and unlike the normal distribution, it allows for skewdness in the parameter input.

The respondents were all extremely helpful in developing the distributions. The distributions were specified in terms that the respondents could easily understand. Most inputs were put in terms of units sold, dollars paid for resources, or time spent in terms of hours or years of effort. All of the input parameters were specified and then revisited to assess reasonableness. In every case, the respondents felt that the input parameters provided a fair and reasonable range of possible outcomes.

Estimate Variance

The variances contained in the ROI calculations were based upon the uncertainty of the input parameters. There were two basic categories of input parameters: the speculative and the well-defined. Examples of the speculative inputs include estimates of future demand for the products or services resulting from the privatization of the technology. Examples of well-defined input parameters include payments to WL for testing that has already been scheduled as part of the CRDA or work savings quantified in terms of a salaried employee, resulting from the collaborator's effort during the CRDA.

The distinction between the two types of inputs is easily made because the well-defined inputs are based on events that have or are certain to occur. These events are also expressed in familiar terms by the respondents. The respondents have well defined knowledge on the cost of tests conducted at WL or the salaries paid to engineers or researchers at WL for work performed. Speculative inputs are based on relatively unknown future events that may or may not occur. Of the nine revenue producing

CRDAs, only four contained speculative inputs. These speculative inputs were limited to the units sold category of input parameters which were used to calculate royalty revenues. Therefore, the four CRDAs that contained royalty revenues in the ROI calculation contained the highest degrees of variance in the estimate. It is important to note that the four CRDAs expected to provide royalty revenues also have provided or are expected to provide additional more well defined benefits in the form of work or resource savings. This being the case, WL is almost certain to receive revenues in some form from the four CRDAs containing the highest amounts of variance in the estimated ROI calculation. The table below consolidates the most relevant information contained in the Crystal Ball reports for each individual CRDA.

TABLE 4.3 Consolidation of Crystal Ball Report Information

CRDA #	Mean Net Present Value Estimate	Range Min	Range Max	Range Width	Mean Std. Error	Variance in Millions
94 - 173 - WL	**$ 45,000.00**	$ 45,000	$ 45,000	$ -		$ -
93 - 335 - WL	**$ 80,245.00**	$ 68,998	$ 98,624	$ 29,626	$ 132	$ 17
95 - 004 - WL	**$ 2,000.00**	$ 2,000	$ 2,000	$ -		$ -
94 - 132 - WL	**$ 43,551.00**	$ 28,775	$ 55,627	$ 26,852	$ 182	$ 33
95 - 335 - WL	**$ 116,123.00**	$ 104,327	$ 131,061	$ 26,734	$ 187	$ 35
95 - 075 - WL	**$ 249,938.00**	$ 154,870	$ 342,666	$ 187,796	$ 1,120	$ 1,254
95 - 201 - WL	**$ 834,574.00**	$ 523,003	$ 1,076,825	$ 553,822	$ 3,236	$ 10,476
94 - 083 - AS	**$ 215,628.00**	$ 171,641	$ 261,574	$ 89,933	$ 458	$ 210
95 - 000 - WL	**$ 246,826.00**	$ 192,733	$ 293,790	$ 101,057	$ 544	$ 296

On the surface, the amount of variance in the ROI calculations appears to be appropriate given the uncertainty of the input parameters and the magnitude of the estimated values of the ROI calculations. The above table displays the fact that the range width, mean standard error, and the estimate variances are of greater magnitude for the four CRDAs containing inputs on royalty revenues. These are as expected given the amount of uncertainty involved with estimating units sold in the future.

Input Parameter Correlation

Correlation can be defined as the systematic relationship or level of interdependence existing between to variables or input parameters. The existence of correlation between input parameters will increase the magnitude of the total variance of an estimate. In cases where it is assumed that all of the input parameters are statistically independent from one another, the total estimate variance will be understated if correlation does, in fact, exist between input parameters.

It is believed that there is at least some correlation in the parameter estimates for units sold by the outside partner. In other words, it is probably unrealistic to expect that the demand for goods and services produced by the outside partner would be statistically independent from year to year. In computing the ROI for CRDAs containing estimates of royalty revenues, at least some correlation was assumed between the units sold input parameters from year to year. The estimated correlations between input parameters are shown in the Crystal Ball reports provided in Appendix B. The correlation values between input parameters range from .15 to .35, indicating weak to slightly moderate correlation between input parameters.

As expected, the magnitude of the variances did increase in the ROI estimates where correlation between input parameters was assumed. However, it must be noted that the magnitude of the variances contained in the ROI estimates was already expected due to the degree of uncertainty involved in estimating the input parameters for units sold. Therefore, the correlation contained in these estimates was not the sole contributing factor towards the disparity between variances in the estimates. The graph below provides a visual representation of the disparity between the variances contained in the ROI estimates for each revenue producing CRDA. The variances below are presented in millions of dollars.

***CRDA # 95 - 201 - WL** contained a variance of $10,476,257,251 and has been left out from the graph below. The magnitude of this data point made a graphical display of the CRDA variances ineffective because none of the other variances were of the same scale on the graph. The three largest variances in the graph below are attributed to the other three CRDAs that contain estimated royalty revenue streams.*

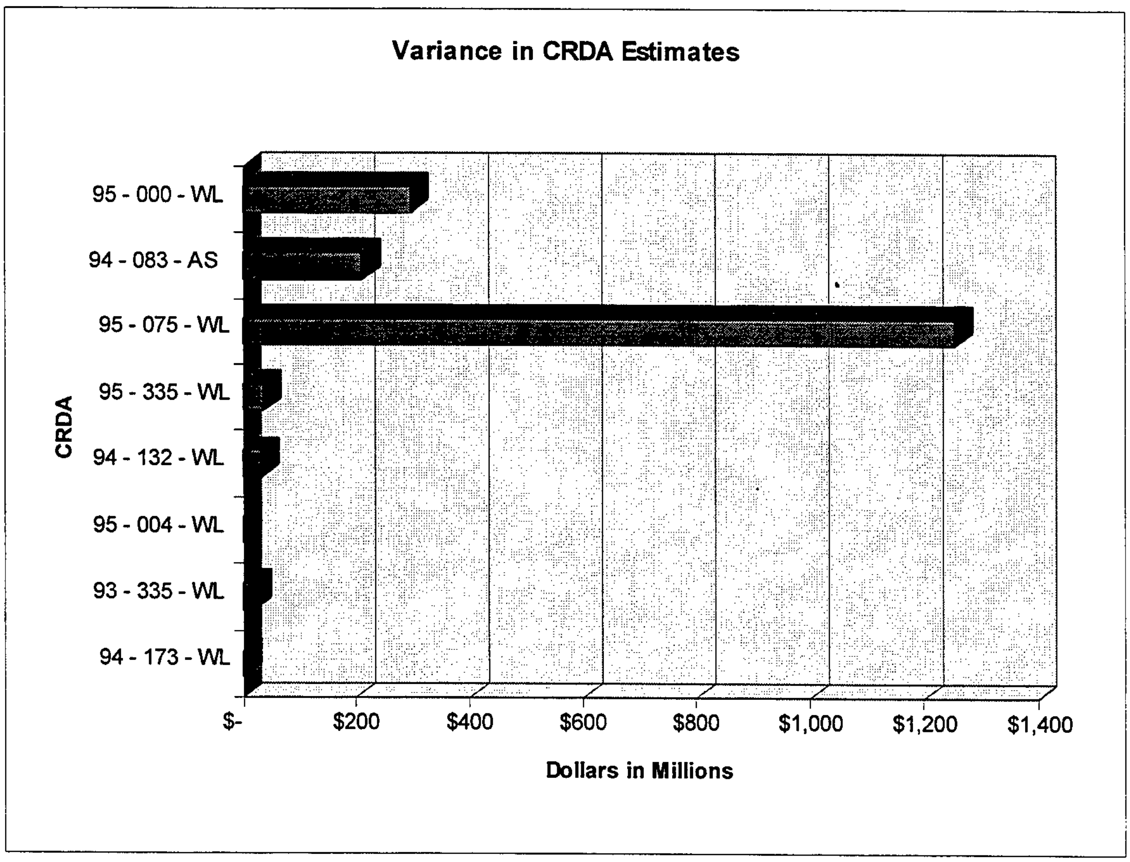


FIGURE 4.5 Variance in Millions of Dollars for CRDA ROI Estimates

Several conclusions can be drawn from reviewing the ROI estimates. First of all, there is a wide range of estimated revenues from the CRDAs in this sample. Second, the estimated dollar values of the high revenue producing CRDAs are subject to a great deal of speculation and variance. However, each of these CRDAs do contain well defined input parameters that represent significant work or resource savings to WL. Finally, the respondents were successful in specifying PDFs that were applicable, appropriate, and usable for the ROI methodology described in Chapter Three.

Lessons Learned

Each interview session concluded with the respondent providing lessons learned from the development and administration of his/her individual CRDAs. For reporting purposes, the lessons learned will be categorized according to the success of CRDAs. The lessons learned from the unsuccessful CRDAs will focus on reasons why the CRDA failed to provide benefits to WL. The lessons learned from the successful CRDAs will focus on reasons why the relationship with the outside partner worked to benefit WL.

The common theme to all of the unsuccessful CRDAs was that the outside partner appeared to be motivated solely by profits and displayed no real interest in helping WL to further develop the technology. In one case, the outside partner simply did not have the resources to work on the project and even when prompted by further government support, failed to hold up its end of the partnership. Another respondent felt that the CRDA relationship, because it is not binding, causes the outside partner to make work covered under the CRDA the lowest of its priorities when they had additional projects going on.

The lessons learned from the unsuccessful CRDAs reinforced the idea of doing technology transfer smarter in the future. The conventional wisdom is that as long as the outside partner is committed to the technology, the other benefits will come to WL naturally. Developing CRDAs only for the sake of increasing the number of CRDAs results in no real benefits to the government and often will lead to worker frustrations and a waste of time and resources.

The most common themes from the lessons learned in the successful CRDAs are listed below.

a. Outside partner and WL established a strong working relationship with one another; CRDA was a cooperative effort between the two parties;

b. Outside partner had a genuine interest in the technology that went beyond a profit motive;

c. Outside partner found out about the technology through informal methods such as word of mouth or personal contacts;

d. Outside partner usually approached WL or expressed interest about a technology--market pull was more common to successful CRDAs;

e. Outside partner had an in-depth knowledge of the technology covered under the CRDA.

Most of the respondents pointed out that the success of a given CRDA is usually depends upon the efforts of the outside partner. In situations where the outside partners are motivated and interested in the technology, the other benefits in the form of revenues will come to the government naturally. Two of the respondents had worked on both successful and unsuccessful CRDAs. They were able to offer opinions on why the CRDAs succeeded or failed. They pointed out that they CRDAs that failed seemed doomed from the start because the outside partners did not seem willing to put forth the effort required under the terms of the CRDA. The respondents felt that valuable time and resources were used in developing the CRDAs and that WL failed to get an adequate return on their investment.

Summary

During the interview and data collection phase of this study, one issue that was consistently raised by respondents was that WL is now beginning to effectively focus its technology transfer efforts. Most respondents felt that the early emphasis was on developing CRDAs for no real reason other than to bolster the number of CRDAs within WL. Respondents now feel that recent CRDAs are being developed to create a mutually beneficial partnership between WL and the outside partner. The prevailing wisdom within WL is that it is doing technology transfer less frequently, but much more successfully than before. Considering the high percentage of benefit-producing CRDAs, the results of this study seem to validate this belief. If WL and other federal laboratories are effectively transferring technology to the private sector, then effective measures of success are needed. Research conducted by West (1995) and others has indicated that the quantifiable benefits received by government laboratories is an appropriate measure of technology transfer success.

The most important result from this exploratory study was that WL is in fact experiencing benefits from their technology transfer efforts. In a majority of the CRDAs researched in this study, the benefits received through technology transfer efforts could be quantified by the ROI methodology described in Chapter Three.

The benefits received through WL CRDAs could be categorized in to one of four major categories. More than half of the benefits resulting from WL CRDAs were categorized as other nonquantifiable benefits. However, it is important to note that respondents felt that these benefits, although not quantifiable, were important to the WL mission and represented real benefit to the Air Force. A closer look at the benefits received by WL revealed that the most common specific benefit to the government came in the form of resource savings to WL. Therefore, costs were avoided as a result of technology transfer efforts and these savings could be quantified and used in the ROI methodology described in Chapter Three.

The ROI methodology described in Chapter Three produced a wide range of estimated benefits to WL. The estimated mean net present value of the quantifiable benefits received in the 9 revenue producing CRDAs ranged from a low of $ 2,000 to a high of $ 834,574. The CRDAs containing royalty revenue streams provided the biggest numbers in terms of estimated net present value. It must be remembered that there is a great deal of uncertainty included in these estimates due to the speculative nature of the input parameters. However, it is important to note that all of the CRDAs containing speculative revenues also provided more well defined revenues to WL in the form of resource savings.

The lessons learned section demonstrated that the most important aspect of a successful CRDA was the effort put forth by the outside partner to further enhance the technology. In situations where WL and the outside partner had a cooperative relationship with one another and were willing to work towards the advancement of a given technology, the government was assured some form of benefits.

Chapter Five utilizes the results of this data and additional evidence gathered during the study's interview process to develop some general recommendations to improve the Air Force's efforts in measuring the benefits received from technology transfer efforts. In addition, it presents several areas that surfaced during this study that require further research.

V. Conclusion

Introduction

This chapter offers the conclusions and recommendations resulting from the exploratory study conducted on the benefits received by the Air Force through its technology transfer efforts. The conclusions will offer answers to the research objectives outlined in Chapter One and discussed throughout this research. The conclusions will specifically address the benefits identified by CRDA POCs during the probability encoding interviews, the quantification of those benefits, the feasibility and usefulness of methodology used to quantify those benefits, and the lessons learned about technology transfer efforts at WL. In addition, this chapter will document any future research topics stemming from this exploratory study on the benefits received by the Air Force as a result of technology transfer activities.

Conclusions

Analysis of the probability encoding data and the qualitative evidence obtained through personal interviews with CRDA POCs reveals that, in most cases, WL receives benefits from its technology transfer activities. Several conclusions can be drawn from the data collected during this study.

1. These benefits are often quantifiable and in some cases represent a substantial return on investment from CRDAs developed at WL.

2. The benefits obtained by the Air Force through its technology transfer activities are identifiable and are consistent with the benefits expected by AFMC/TTO. However, there is no useful method currently in place to evaluate the importance of the nonquantifiable benefits.

3. A net present value calculation incorporating the uncertainty of the future revenue streams generated CRDAs is a usable methodology for the purposes of calculating the ROI of technology transfer activities.

4. A considerable amount of variation and uncertainty is contained in the ROI calculations built during this study. Further research and data is needed in this area to validate this methodology as a usable management decision making tool.

5. Cooperation between the outside partner and government agency is the key component of technology transfer success. The most successful technology transfers occur when the outside partner has a genuine interest in further developing a given technology.

Quantifiable Benefits to WL. The quantifiable benefits described by the respondents were numerous and significant in terms of revenues to WL. The most common quantifiable benefit received by WL was in the form of resources saved, resulting from the efforts of the outside partner in the CRDA. The benefits were quantified using a net present value calculation that incorporated probability density functions and Monte Carlo simulation to account for the uncertainty involved with estimating future revenue streams. During the data collection phase of this exploratory study, respondents provided quantifiable benefits on nine of fifteen CRDAs. More importantly, of the eleven CRDAs that produced benefits, nine of them produced quantifiable benefits. Of these nine revenue producing CRDAs, only one CRDA produced quantifiable benefits that were less than $10,000. In addition, six of the nine revenue producing CRDAs produced estimated revenues that were greater than $100,000. The data indicates that a majority of the CRDAs developed at WL are producing significant revenues for the Air Force. More research is needed to determine whether or not the sample used in this study is an accurate representation of the total population of technology transfers in WL or the Air Force.

The data indicates that revenues totaling more than one hundred thousand dollars are not out of the ordinary. In situations where a CRDA is expected to result in a resource savings to the Air Force and the commercialization of a technology, the revenues received can total several hundred thousands of dollars.

Non-Quantifiable Benefits to WL Resulting from CRDAs. The data collected during the interview process provided evidence that WL is experiencing benefits from technology transfer activities. These non-quantifiable benefits were easily identified by CRDA POCs during the interview process. These benefits matched up with the expected benefits identified by AFMC/TTO. It is important to note that the actual benefits received through technology transfer efforts match up with the expected benefits. The majority of benefits received by WL were in the form of non-quantifiable benefits.

The respondents were quick to point out that these non-quantifiable benefits provided real value to the Air Force in terms of positive public relations or goodwill to WL. However, problems arise when attempting to develop a calculation that puts these benefits in quantifiable terms. First, there is no generally accepted measure available to help put these benefits into meaningful quantified terms for the purposes of a decision making model. There would also be a considerable resource cost in terms of man hours used to develop a quantified estimate of a qualitative benefit's value to WL. Finally, any quantitative estimate developed from a purely qualitative benefit would be highly subjective and unlikely to be free of bias on the part of the respondent and or estimator.

The most logical approach would be to identify the potential non-quantifiable benefits expected from a given CRDA. Once these benefits are identified, they can be evaluated against WL technology transfer objectives. The decision to pursue a given technology transfer based solely on its potential for providing intangible, non-quantifiable benefits would be difficult to justify. However, it is clear that intangible benefits provide real value to WL and they should be evaluated any time technology transfer activities are being considered. In situations where technology transfer activities are competing for resources and they are expected to provide similar returns in the form of quantifiable benefits, then intangible benefits should be considered as a decision-making criteria.

Unfortunately, past research by West and others indicates that WL has no clear cut objectives for its technology transfer efforts. Therefore, there is no current benchmark or formal objectives available that can be used to evaluate the impact of the qualitative non-quantifiable benefits received by WL. Once these objectives are identified, formulated, and advertised to WL personnel, a useful set of criteria can be established for the purposes of evaluating the nonquantifiable benefits received by WL through technology transfer activities.

Net Present Value Methodology. Estimates of the revenues received by WL from technology transfer activities were calculated using a net present value methodology. Uncertainty was incorporated into the estimates through the use of subjective PDFs and Monte Carlo Simulation. The result was a ROI calculation that accounted for the time value of money and provided a cumulative density function to express the probabilities of potential revenues to WL.

The methodology was easily understood by all of the respondents and the use of probability encoding techniques enabled this researcher to obtain estimated values for the input parameters (revenue streams). During the interview process, respondents were helpful in determining whether or not it was reasonable to quantify specific benefits. In many cases, benefits were identified, but not quantified, because respondents felt that it was unreasonable to put them into quantifiable terms. Steps were taken to prevent overly optimistic revenue estimates and minimize the impact of bias on the estimates. However, it is this researcher's conclusion that there is still some bias present in the ROI calculations. Even for an experienced analyst, the probability encoding technique is a difficult task. Gathering the data for this study was a rather complex process that required one on one interviews with knowledgeable CRDA focal points. The time consuming nature of the interview process, combined with the complexity and subjectivity involved with probability encoding interview techniques, would make it difficult to efficiently implement this methodology on a large scale.

The ROI methodology used in this study provided estimates of revenues generated by technology transfer activities. In order to assess the reasonableness of the estimates, data will need to be collected on the actual revenues received from these CRDAs. There is no current formal process in place to collect data on revenues generated by CRDA activities. A more effective data collection mechanism must be implemented at WL so that revenues received can be traced to the CRDA that generated the revenue. Once an effective data collection process is implemented at WL, the ROI methodology used in this study can be assessed to evaluate its usefulness and robustness as a predictor of future revenues from technology transfer efforts.

Variation and Uncertainty in the ROI Calculation. Many of the estimated revenues obtained in this study were significant, but high degrees of uncertainty and variation were present in the estimated values. The high degrees of variation in the estimates make them somewhat suspect. The speculative nature of the parameter inputs used to estimate future royalty revenue streams should lead decision makers to proceed with caution. The revenues received through resource savings and work savings are more well-defined and represent a more immediate and tangible result to WL from its technology transfer activities. These revenues should probably be given more emphasis in the future than what they were given in this exploratory study. This study showed that resource savings are the most common benefit received by WL from technology transfer activities.

It is important to note that the degree of variation in the ROI calculations coincided with the number of well-defined or speculative inputs contained in the estimate. The ROI calculations that contained only well-defined parameter inputs provided estimates where the CDF of the total outcomes was expressed as a tighter confidence interval. This result is consistent with this researcher's expectations. Therefore, it is assumed that the degree of variation contained in the ROI estimates of this study is reasonable and is logically tied to the amount of uncertainty expressed by the respondents about the parameter inputs. On the surface, this methodology appears to be an appropriate tool that captures and accounts for the uncertainty contained in an estimate.

Lessons Learned. The lessons learned from this exploratory study showed that cooperation between the outside partner and the government agency was the most likely indicator of technology transfer success or failure. The most common trait associated with successful technology transfer was the willingness of the outside partner to further develop and enhance the technology covered under a given CRDA. Respondents felt that the unsuccessful CRDAs seemed doomed form the start. They also pointed out that doing fewer technology transfers with outside partners that are committed to further development of a given technology is probably the best possible way to maximize the government's return on its technology transfer efforts. There is no formal screening process in place to help personnel at WL screen prospective outside partners based on the amount of effort or resources they are willing to put towards the enhancement of the technology transferred to them.

Managerial Implications

The most common quantifiable benefit received at WL from its technology transfer efforts are work savings and cost avoidance resulting from the efforts of the outside partner. In order to better focus its technology transfer activities, managers at WL could attempt to identify potential areas where work savings could be achieved with the help of an outside partner. Once potential work savings and cost avoidance opportunities are identified, potential outside partners could be screened based on there ability to perform the identified work and their willingness to further advance the technology covered under the terms of the CRDA. Screening of outside partners could potentially go a long way in better focusing WL technology transfer activities. Identification of potential work savings and screening of potential outside partners could help WL improve its technology transfer focus and increase quantifiable benefits to the government.

WL is currently experiencing both quantifiable and intangible benefits from its technology transfer activities. However, it unclear as to which type of benefits are most important to the WL mission. In order to assess the effectiveness of its technology transfer activities, managers need to develop clear technology transfer objectives. The accumulation of quantifiable benefits through CRDAs is probably the most effective measure of transfer success. Unfortunately, that does not take into account the numerous and very real intangible benefits that are currently being received. The decision to allocate resources towards technology transfer activities based solely on the potential for intangible benefits would probably be difficult to justify. A system is needed where decision on technology transfer activities can be based on the expected quantifiable benefits received from a given transfer. Once this system is developed, the expected intangible benefits could be used as a decision-making criteria in situations where competing transfer activities are expected to yield similar quantifiable benefits.

Currently a CRDA is considered successful as long as it provides some type of benefits to WL. Unfortunately, the lack of centralized data collection and reporting procedures have caused several successful CRDAs to go unrecognized. The collection and reporting of data on technology transfer activities is left to the CRDA points of contact and data on the revenues received from CRDAs is not maintained in a centralized database. Maintaining a database on the benefits received from CRDAs at WL would give managers an excellent tool that could be used to quickly identify technology transfer successes and failures. The lack of a centralized data collection and reporting process makes the evaluation of technology transfer activities a difficult and cumbersome task.

Recommendations for Follow-on Research

The data collected during this study demonstrates that the nonquantifiable benefits experienced by WL are numerous and represent real value to the Air Force. Unfortunately, WL has no formally established technology transfer objectives. A clear set of objectives would help decision makers to evaluate the value of nonquantifiable benefits resulting from CRDA activities. Several of the nonquantifiable benefits documented in this research would provide a solid foundation that could be used as a starting block to build formal objectives for WL technology transfer efforts. Examples of significant nonquantifiable benefits include the dissemination of technology, public relations and goodwill, enhancements to WL developed technology, and improvements in the morale, expertise and knowledge of WL personnel. Any expert would agree that these benefits, although difficult to measure, could be used as qualitative factors when analyzing the return on technology transfer activities. By developing formal objectives for technology transfer efforts, researchers will be able to assess the value of technology transfer nonquantifiable benefits.

Quantifiable benefits were identified in nine of the 15 CRDAs evaluated in this study. Additional data would be needed to determine whether this sample was representative of the total CRDA population within WL. CRDAs were selected randomly for this data set and the benefits were analyzed using a ROI methodology. A general survey or questionnaire could be to disseminated to all CRDA POCs in order to determine the total number of CRDAs that are providing some benefits to WL. This survey would provide researchers with an accurate percentage of benefit versus non-benefit producing CRDAs. Once the total benefit producing CRDAs are identified they could be evaluated more closely to determine their actual revenues or benefits.

At this time there is still no formal method in place to effectively measure the effectiveness of Air Force technology transfer efforts. Evidence suggest that the success or failure of technology transfer lies with the efforts of the outside partner. At this time, there are no formal screening procedures in place to effectively screen prospective CRDA partners. A formal approach to screening CRDA partners could result in the Air Force selecting outside firms that are genuinely interested and willing to put forth the effort required to enhance a given technology.

Future Research

Anecdotal evidence suggests that WL is transferring technology more effectively now than ever before. As a result, it is hypothesized that quantifiable benefits are more common in recent CRDAs. An approach that could be used to study this question further would be to evaluate a random sample of CRDAs from 1995 against a random sample of CRDAs from 1993 to determine if WL is in fact receiving more benefits from recent CRDA activities.

This study pointed out that there are traits common to revenue producing CRDAs. Additional research could focus specifically on a larger sample of revenue producing CRDAs. By focusing exclusively on revenue producing CRDAs, a set of well defined characteristics can be established. The ROI can be calculated for each individual revenue producing CRDA. These CRDA characteristics and revenues could then be compiled into a data set and used to build a parametric models to predict future CRDA revenues based on their characteristics.

Research conducted at the WL technology transfer office suggests that an effective measure of technology transfer success would be the level of effort put forth by the outside partners. The evidence provided by respondents in this study suggest that the outside partner is the driving force behind CRDA success. Therefore, the measurement of outside partner effort as a means of determining technology transfer success appears reasonable and logical. Additional research in this area could provide an effective measure of transfer success.

Appendix A. Interview Form

Cooperative Research and Development Agreement (CRDA) Point of Contact Interview Form

CRDA Tracking Number : ______________________________

Company Involved : __________________________________

Point of Contact/Office Sym/Phone # : _______________________

Identification and Specification of benefits described in the CRDA:

Identify All the expected benefits received from the CRDA:

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

Identification and Specification of emergent benefits not described in the CRDA:

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

Provide a quantified estimate (if possible) for each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

Identify any lessons learned about the CRDA process during the development of this CRDA

Appendix B. CRDA Benefits Data

CRDA Tracking Number : 95-263-WL-01

Company Involved : Butler County Engineers

Point of Contact/Office Sym/Phone # :

Purpose: Provide cost effective rehabilitation scheme that uses advanced composite materials to reinforce ailing infrastructure.

Identify All the expected benefits received from the CRDA:

1. Wide spread use of composite materials will result in cost savings to the government--high production rate of composite materials would spread out overhead costs and reduce total cost to customers.

-- These benefits not yet realized--10 - 20 year time frame before nationwide implementation of this technology would take place--additional interest has already been generated in the state of Ohio.

2. Royalties would be paid to the government (WL) as a result of this technology being implemented--patent has been written for the process developed under this CRDA

3. Improvements in national infrastructure and better use of taxpayer dollars

-- Very real benefit that will be realized in the future as advanced composite materials are used to repair our nation's infrastructure. The use of more durable and cost effective advanced composite materials will provide cost savings to the government as roadways and bridges are rebuilt and reinforced. Annual future costs savings to our nation could be in the billions.

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

1. Patent currently being developed for the vacuum bag processing to externally reinforced structural members with advanced composites.

- The potential cash reimbursements to WL have been estimated in the millions; however, these revenues are not expected to be realized for another 10 to 20 years.

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. All composite vehicle bridge built by Lockheed may be used at a Butler County site this summer--providing a free test site to a government contractor to prove and validate this technology.

2. Ohio Department of transportation CRDA being written and developed.

3. Accelerating the progress of this technology through WL participation with other govt. agencies--WL used as a neutral objective third party; knowledgeable scientists and researchers rather than private vendors are advocating the use of this technology, helping it achieve widespread acceptance as a viable solution for improving our nation's infrastructure.
Provide a quantified estimate (if possible) for each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

1. Good will and publicity to WL which resulted in credibility being added to the technology of composites.

2. Press coverage: Articles in magazines and journals, describing how the technology was passed on to the private sector (ex. Civil Engineering article March 1996)

3. Tours of high level personnel: Senators, Congressman and high ranking military leaders (ex Senator John Glenn)

Identify any lessons learned about the CRDA process during the development of this CRDA

1. Both partners were eager and motivated to do the CRDA--the were willing to put forth the effort to make the agreement work out.

2. Process started with general discussions and a small scale proof of concept work before the CRDA was even written and signed.

__CRDA Tracking Number :__ **94-173-WL-01**

__Company Involved :__ **Firefox Industries**

__Point of Contact/Office Sym/Phone # :__

Purpose: To develop an understanding of fire suppression systems extinguishing fire on high speed vehicles.

Identify All the expected benefits received from the CRDA:

1. Royalty free use for govt. purposes in the understanding gained from the tests

2. Compensation for use of wind tunnel for testing and technical support
   - Data on (Halon vs. water and oils) generated as a result of the test--data informative but not necessarily useful in an operational military setting

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

2. $45,000 paid to WL for use of test facilities and manpower

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. Partnership for a new generation of vehicles, collaborative effort between govt. and automotive industry, was aided by this CRDA in that it demonstrated a willingness by WL to work with outside private partners.

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

- Free publicity resulting from the success of this CRDA
- De-mystified the CRDA process--the Firefox CRDA demonstrated that CRDAs are an effective and viable means of collaborating with outside partners. As a result of the Firefox success, other companies are seeking WL expertise and are willing to use CRDAs as the mechanism to build new products and services.
- WL personnel gained extensive knowledge about the formulation of CRDAs

Identify any lessons learned about the CRDA process during the development of this CRDA

<u>CRDA Tracking Number</u>: **93-336-WL-01**

<u>Company Involved</u>: **Cold Jet**

<u>Point of Contact/Office Sym/Phone #</u>:

Purpose: Create a capability to analyze and improve the design of nozzles for aerodynamic particle acceleration for dry ice pellet blasts surface cleaning and preparation equipment.

Identify All the expected benefits received from the CRDA:
No benefits were realized from this CRDA; expected benefits were as follows:
- Looking to expand the capability of CFD and gain additional nozzle design expertise
- Detailed test data
- Royalty fees

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :
- WL personnel gained knowledge about the CRDA process during the development of the Cold Jet CRDA

Identify any lessons learned about the CRDA process during the development of this CRDA
- Goals and expectations for the project were to aggressive at the outset
- Outside company never provided the resources to work on the project--no dedicated staff to work on the project.
- The outside partner initiated the contact but was not ready to commit to the project
- The govt. prompted the outside partner on several occasions by offering additional services without cooperation from the outside partner

CRDA Tracking Number : 95-222-WL-01

Company Involved : **Systran Corporation**

Point of Contact/Office Sym/Phone # :

Purpose: Transition WL/FPIG software into a product for sale in the private sector (Multi Plane Instrumentation Software)

Identify All the expected benefits received from the CRDA:
No benefits realized in this CRDA due to lack of effort by outside partner; expected benefits were as follows:

1. Supporting the development of a software library that will be maintained and enhanced by the collaborator for use in military and other govt. operations.
2. Govt. will receive free software packages and user's manuals
3. the Unit will earn a royalty on the licensing of these improvements and inventions by the collaborator.

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

Identify any lessons learned about the CRDA process during the development of this CRDA

<u>CRDA Tracking Number</u>: **95-170-WL-01**

<u>Company Involved</u>: **Metrolaser**

<u>Point of Contact/Office Sym/Phone #</u>:

Purpose: Develop and evaluate OSS sources to be used in the measurement of aerodynamic parameters

Identify All the expected benefits received from the CRDA:
Due to lack of effort by the outside partner, the expected benefits were never realized. Expected benefits were as follows:

1. Govt. would have access to new and beneficial OSS sources
2. Royalty free use of new OSS sources

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

Identify any lessons learned about the CRDA process during the development of this CRDA

- CRDA not binding to the outside partner; therefore, project covered in the CRDA became the lowest priority for the outside partner
- Agreement developed from two earlier SBIRs (CRDA seemed logical but outside partner had to many other projects going on)
- Outside partner motivated strictly by profit; they did not seem willing to put forth the effort required to make the CRDA work
- Backwards from a traditional CRDA in that the outside partner was going to develop the technology and the govt. was going to provide the test and evaluation on the developed technology

<u>CRDA Tracking Number</u>: **95-004-WL-01**

<u>Company Involved</u>: **Applied sciences Incorporated**

<u>Point of Contact/Office Sym/Phone #</u>:

Purpose: Develop a better VG carbon fiber reinforced composite system for use in Air Force and commercial structures and bearings

Identify All the expected benefits received from the CRDA:

1. Development of a new process to make composites with VGCF (cooperative R&D effort)
2. Outside partner providing raw materials in the form of VGCF--raw materials inexpensive; therefore, no real cost avoidance to the govt.
3. Royalty on the process developed by WL personnel--up to 5 years after CRDA is closed 4% of gross sales

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. Additional testing through points of contact done at no costs to WL--samples sent to ASI and tested at Ohio university (total costs avoided: $2,000)
   * Three to five samples tested at an average cost per test of $700

2. Transfer of knowledge with private industries (ex Goodyear, G.M.) through participation in meetings

3. Sparked interest in other DoD contractors (building industrial base for these composites)
   - Could potentially decrease the costs of composites made from these fibers
   - Composites with similar properties at reduced costs--composites currently being used for thermal management for electronic components costs about $1,500 per pound while costs of new composites are estimated at $3 per pound

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

Identify any lessons learned about the CRDA process during the development of this CRDA

1. Great relationship with outside partner--weekly informal communication--foreign sources of expertise have been brought in by outside partner

2. ASI approached WL with the idea of developing this CRDA

CRDA Tracking Number : **94-241-WL-02**

Company Involved : **Systems Research Laboratory**

Point of Contact/Office Sym/Phone # :

Purpose: Development of the Automatic Scan-Plan Generation System

Identify All the expected benefits received from the CRDA:

The benefits spelled out in the CRDA were never realized due to lack of effort by the outside partner; the following benefits were spelled out in the CRDA:

1. Broad and rapid dissemination of technology
2. Royalties expected through he dissemination of the technology
3. Long term costs savings anticipated for future development of scan plans for additional engine parts
4. development of an electronic information link between WL and the outside partner

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

- Learned to automate the development of scan plans

Identify any lessons learned about the CRDA process during the development of this CRDA

- The only real motive for the outside partner was to obtain the use of a developed technology--outside partner put forth no effort to license an already patented technology

- SRL had no real interest in improving productivity of the technology itself

CRDA Tracking Number: **94-12-WL-01**

Company Involved: **Technosoft Incorporated**

Point of Contact/Office Sym/Phone #:

Purpose: Development of a memory driven design system capable of integrating product descriptions with materials and processing knowledge.

Identify All the expected benefits received from the CRDA:

1. Unusually broad and rapid dissemination of its technology
   -- Effectively licensing some of the patents and making modules developed from the technology part of the outside partner's system--5% royalty to WL on the sale of each module

2. Further enhancement of this technology through involvement of industrial design system houses and tool vendors--using the technology in private industry

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. The use of additional technologies by outside partners

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

- Public relations: Technosoft has advertised the fact that the technology they are marketing was developed at WL

Identify any lessons learned about the CRDA process during the development of this CRDA

CRDA Tracking Number : **94-132-WL-01**

Company Involved : **Technology Assessment and Transfer Incorporated**

Point of Contact/Office Sym/Phone # :

Purpose: The identification of dual use partners for the commercialization and or enhancement of molecular beam epitaxy (MBE) thin film disposition technology.

Identify All the expected benefits received from the CRDA:

1. Broad and rapid dissemination of molecular beam epitaxy (MBE) technology--outside partner performing the marketing function to get the technology to private industries
   * One man year saved marketing the technology to industrial users (60 k)
2. Identifying dual use partners for the MBE technology and presenting these sites to WL

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

CRDA # **94 - 132 - WL - 01**
Company : **Technology Assessment and Transfer Corporation**

Expected Benefits	**1996**	**1997**	**1998**	**1999**	**2000**
Marketing of MBE	$ 46,599	0	0		
- 1 man year effort					
Cost Avoidance					
Present Value	$ 43,551				

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. Assist and guide WL in the development of MBE technology training manuals
   - Authoring the current manual and rewriting the manual for commercial use
   - Outside partner provided additional insight into the needs of the end-users
     * one person used for this effort

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

1. This CRDA allowed WL to do technology transfer between federal agencies: University of Maryland working exclusively with the National Security Agency was able to gain insight into the use of MBE technology

Identify any lessons learned about the CRDA process during the development of this CRDA

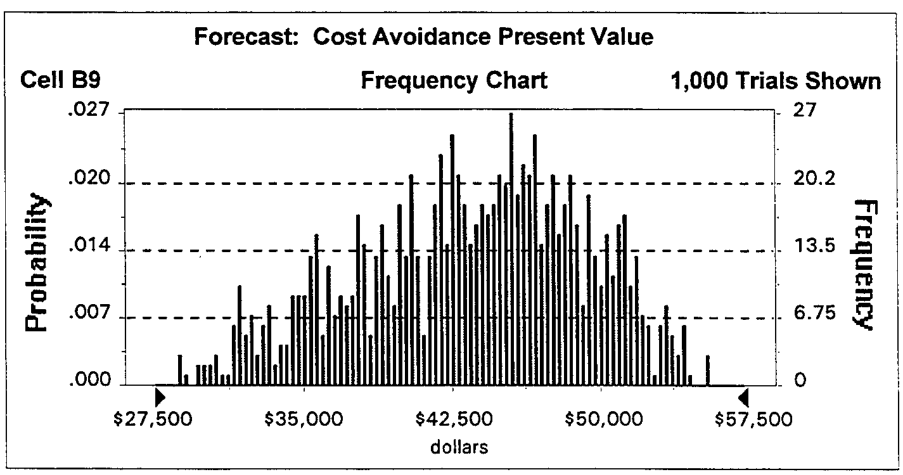
1. Outside partner found out about the technology through SIBR relationship formed prior to the CRDA--TA&T approached WL about the technology

Crystal Ball Report
Simulation started on 7/17/96 at 20:18:55
Simulation stopped on 7/17/96 at 20:19:05

Forecast: Cost Avoidance Present Value

Summary
:
Display Range is from $27,500 to $57,500 dollars
Entire Range is from $28,775 to $55,627 dollars
After 1,000 Trials, the Std. Error of the Mean is $182

Statistics :	Value
Trials	1000
Mean	$43,551
Median (approx.)	$44,206
Mode (approx.)	$42,873
Standard Deviation	$5,758
Variance	$33,156,607
Skewness	-0.31
Kurtosis	2.38
Coeff. of Variability	0.13
Range Minimum	$28,775
Range Maximum	$55,627
Range Width	$26,852
Mean Std. Error	$182.09



Forecast: Cost Avoidance Present Value (cont'd)

Percentiles:

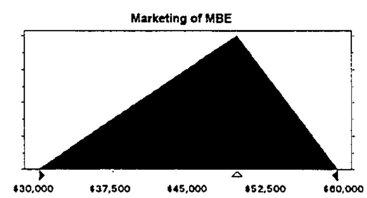
Percentile	dollars (approx.)
0%	$28,775
10%	$35,348
20%	$38,144
30%	$40,523
40%	$42,537
50%	$44,206
60%	$45,666
70%	$47,020
80%	$48,713
90%	$51,018
100%	$55,627

Assumption: Marketing of MBE **Cell: B6**

Triangular distribution with parameters:

Minimum	$30,000
Likeliest	$50,000
Maximum	$60,000

Selected range is from $30,000 to $60,000
Mean value in simulation was $46,599



CRDA Tracking Number : 95-335-WL-01

Company Involved : Holman Plating

Point of Contact/Office Sym/Phone # :

Purpose: Reduce the cost and improve the quality of Titanium Nitrate (TIN) technology through involvement with outside partner. The developed TIN coating will be available for Air Force use

Identify All the expected benefits received from the CRDA:

1. Govt. will explore the implementation of in-site plasma control and electric arc physical vapor disposition processes while simultaneously allowing a reduction in existing military component coating costs.

   - Some of the parts that have been coated are already flying on operational aircraft--process refinement has already been achieved

   * Added instrumentation involved in the refinement process would have costs the Air Force 100k had we not used CRDA

2. WL paid a consulting fee for 99 hr. of time spent by WL personnel--$21,000 paid for 99 hr. of work

   -- work included set-up, equipment implementation, system integration, sample generation, XPS analysis, and post analysis

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

CRDA # 95 - 335 - WL - 01
Company : Holman Plating

Expected Benefits	1996	1997	1998
Consulting Fee	$ 21,000		
Cost Avoidance	$103,252		
- Added instrumentation			
Total Revenues	$124,252		
Present Value Revenue	**$116,123**		

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. Parts coated with the process may lead to improved life and durability of our aircraft.

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

1. Good PR for WL and the Air Force as a whole

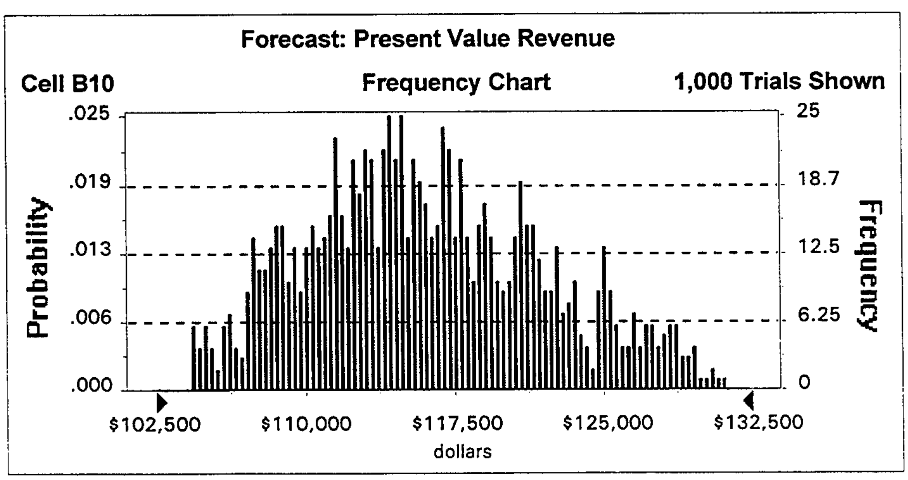
Crystal Ball Report
Simulation started on 7/17/96 at 19:34:47
Simulation stopped on 7/17/96 at 19:34:56

Forecast: Present Value Revenue

Summary:

Display Range is from $102,500 to $132,500 dollars
Entire Range is from $104,327 to $131,061 dollars
After 1,000 Trials, the Std. Error of the Mean is $187

Statistics:	Value
Trials	1000
Mean	$116,123
Median (approx.)	$115,573
Mode (approx.)	$114,352
Standard Deviation	$5,927
Variance	$35,127,545
Skewness	0.29
Kurtosis	2.43
Coeff. of Variability	0.05
Range Minimum	$104,327
Range Maximum	$131,061
Range Width	$26,734
Mean Std. Error	$187.42



Forecast: Present Value Revenue (cont'd)

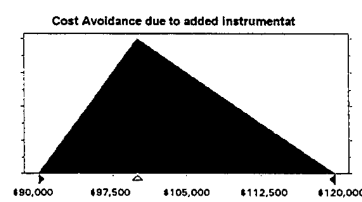
Percentiles:

Percentile	dollars (approx.)
0%	$104,327
10%	$108,471
20%	$110,803
30%	$112,644
40%	$114,174
50%	$115,573
60%	$117,249
70%	$119,102
80%	$121,348
90%	$124,823
100%	$131,061

Assumption: Cost Avoidance due to added instrumentat **Cell: B7**

Triangular distribution with parameters:

Minimum	$90,000
Likeliest	$100,000
Maximum	$120,000



Selected range is from $90,000 to $120,000
Mean value in simulation was $103,252

<u>CRDA Tracking Number</u>: **95-075-WL-01**

<u>Company Involved</u>: **Aviation Environmental Compliance Incorporated**

<u>Point of Contact/Office Sym/Phone #</u>:

Purpose: A design effort on the part of WL to improve the existing nozzle configuration and compressed air system for (forced air de-icing system) FADS

Identify All the expected benefits received from the CRDA:

1. Expanding its nozzle design experience into new applications--process currently being refined and validated for commercial and Air Force use.

2. Royalties expected from the licensing of a new nozzle design (2 - 5 years in the future based on industry demand)
   * $500 royalty fee paid to WL for every nozzle sold commercially. Sales estimates will vary based on industry demand.

3. Reduced logistics costs associated with glycol storage, usage, and disposal for de-icing operations
   * Total costs savings per plane estimated at $10 per gallon of glycol not used (this $10 per gallon of Glycol cost includes procurement, storage, and disposal costs). A 70% to 90% reduction in glycol use is expected if the new nozzle design and process is validated for Air Force use. Currently 70 - 80 gallons are used per minute when de-icing a plane. Estimates for de-icing a plane range from 15 - 30 minutes. Potential for costs savings attributed to the reduction in glycol use estimated at $12,000 per plane.

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

CRDA # 95 - 075 - WL - 01
Company : Aviation Environmental Compliance Inc.

Expected Benefits	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**Net Present Value at 7%**
Royalty Revenues	$ -	$ 50,419	$ 60,314	$ 69,992	$ 74,867	$ 74,872	
- Rev. per Nozzle	500	500	500	500	500	500	
- Nozzles sold	0	100.8377	120.6285	139.9835	149.7348	149.7432	
Reduced Log. costs	$ 12,159	$ 12,163	$ 12,022	$ 12,176	$ 12,136	$ 12,021	
- Glycol cost per gal	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10	
- Gallons per min.	70	70	70	70	70	70	
- Min to De-ice plane	21.65883	21.61457	21.49213	21.63273	21.66536	21.50181	
- % of Glycol not used	80%	80%	80%	80%	80%	80%	
PV of Royalty Rev.	$ -	$ 44,038	$ 49,234	$ 53,396	$ 53,379	$ 49,890	**$ 249,938**

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. Increase in the personal experience of WL personnel

2. Potential for future CRDAs with different technologies (ex spray wash with glycol capabilities)

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

1. Substantial amount of positive publicity for WL and Air Force, resulting from CRDA

2. Established a strong relationship with Wright Technology Network

Identify any lessons learned about the CRDA process during the development of this CRDA

1. Worked according to prescribed TT process--collaborator questioned WTN about a technology and WTN facilitated transfer between WL and collaborator

2. Outside partner had an interest in the technology that went beyond profit motivation

3. This was a true partnership in every sense of the word. WL consultation actually saved AEC on development costs by recommending that the proposed test plan be simplified and scaled down to include only the necessary tests to validate and verify the FADS process. AEC saved extensive tests dollars and effort that would have been spent without the help of WL personnel.

4. There was a clearly defined goal for this CRDA--objectives were clear and obtainable

Crystal Ball Report
Simulation started on 7/16/96 at 17:36:30
Simulation stopped on 7/16/96 at 17:37:05

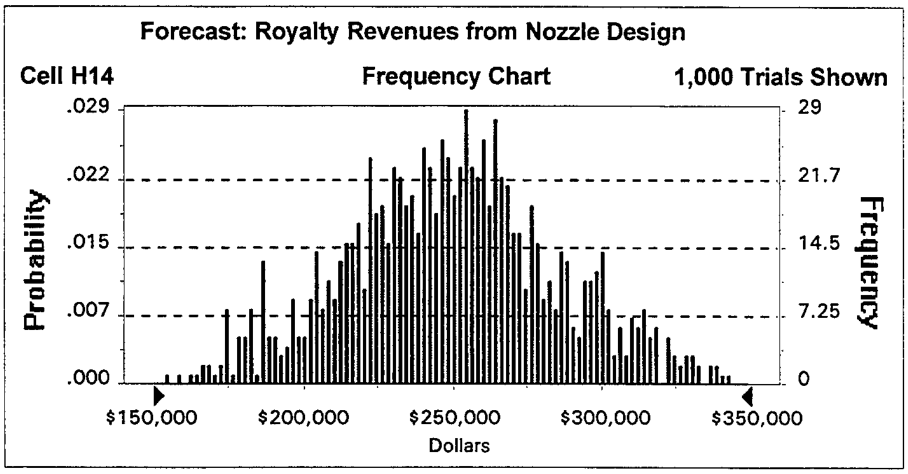
Forecast: Royalty Revenues from Nozzle Design

Summary:

Display Range is from $150,000 to $350,000 Dollars
Entire Range is from $154,870 to $342,666 Dollars
After 1,000 Trials, the Std. Error of the Mean is $1,120

Statistics:	Value
Trials	1000
Mean	$249,938

Median (approx.)	$249,811
Mode (approx.)	$247,829
Standard Deviation	$35,421
Variance	$1,254,665,367
Skewness	0.04
Kurtosis	2.74
Coeff. of Variability	0.14
Range Minimum	$154,870
Range Maximum	$342,666
Range Width	$187,796
Mean Std. Error	$1,120.12



Forecast: Royalty Revenues from Nozzle Design (cont'd)

Percentiles:

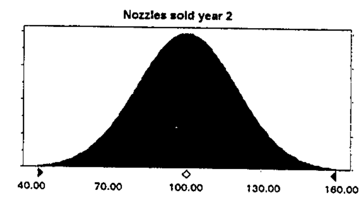
Percentile	Dollars (approx.)
0%	$154,870
10%	$204,740
20%	$220,129
30%	$231,240
40%	$241,256
50%	$249,811
60%	$258,534
70%	$266,783
80%	$278,972
90%	$298,221
100%	$342,666

Assumption: Nozzles sold year 2

Normal distribution with parameters:

Mean	100.00
Standard Dev.	20.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 100.84



Correlated with:

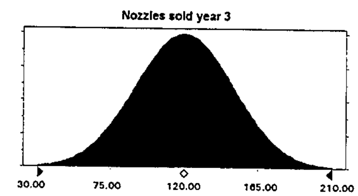
Nozzles sold year 3 (D8)	0.25

Assumption: Nozzles sold year 3

Normal distribution with parameters:

Mean	120.00
Standard Dev.	30.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 120.63



Correlated with:

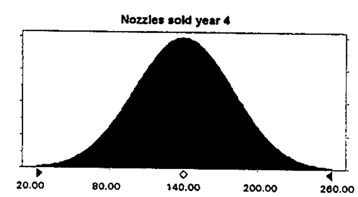
Nozzles sold year 2 (C8)	0.25
Nozzles sold year 4 (E8)	0.25

Assumption: Nozzles sold year 4

Normal distribution with parameters:

Mean	140.00
Standard Dev.	40.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 139.98



Correlated with:

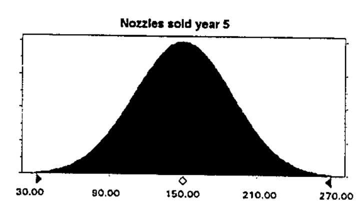
Nozzles sold year 3 (D8)	0.25
Nozzles sold year 5 (F8)	0.25

Assumption: Nozzles sold year 5

Normal distribution with parameters:

Mean	150.00
Standard Dev.	40.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 149.73



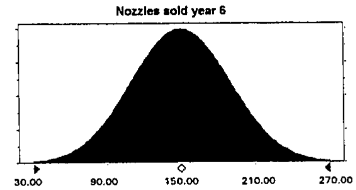
Correlated with:

Nozzles sold year 4 (E8)	0.25
Nozzles sold year 6 (G8)	0.25

Assumption: Nozzles sold year 6

Normal distribution with parameters:

Mean	150.00
Standard Dev.	40.00



Selected range is from -Infinity to +Infinity
Mean value in simulation was 149.74

Correlated with:

Nozzles sold year 5 (F8)	0.25

CRDA Tracking Number : **95-201-WL-01**

Company Involved : **Paragon Aircraft**

Point of Contact/Office Sym/Phone # :

Purpose: Analyze and develop the design of a single turbo-fan engine aviation aircraft which has the following attributes:

- Inlet over the fuselage, a high aspect ratio straight wing and utilizes a composite structure
- Performance analysis will refine the aerodynamic characteristics of a new air flow and will work to ensure the structural integrity of the composite airframe

Identify All the expected benefits received from the CRDA:

1. Flight Dynamics Branch gaining increased experience in CFD and Flutter analysis and ground vibration tests

2. Usable test data derived from the CRDA--test conducted here at WPAFB

3. Wind tunnel testing still to be conducted (future of the facilities may be in jeopardy this CRDA provides additional justification to keep this facility operational)

4. Royalty stream expected to recoup man hr. expended during this CRDA.

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

CRDA # **95 - 201 - WL - 01**
Company : **Paragon Aircraft in conjunction with WL Flight Dynamics Branch**

Expected Benefits	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**Net Present Value at 7%**
Royalty Stream	$ -	$ -	$ -	$ 51,622	$ 98,514	$ 37,465	
- Aircraft Sold	0	0	0	2.671945	5.099084	1.939162	
- Rev. per Aircraft	$ 19,320	$ 19,320	$ 19,320	$ 19,320	$ 19,320	$ 19,320	
Payment for testing		$801,417					
** Fatigue and Static test to be conducted at WL facility*							
Total Revenue	$ -	$801,417	$ -	$ 51,622	$ 98,514	$ 37,465	
Present Value at 7%	$ -	$699,988	$ -	$ 39,382	$ 70,239	$ 24,964	**$ 834,574**

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. The CRDA provided an opportunity to demonstrate and validate existing capabilities at WL for a whole airplane
   - Additional breadth gained by conducting developmental testing on an entire aircraft

2. The CRDA helped to justify the resources used to do testing on the aircraft

3. Insight gained into the commercial aircraft industry--the feeling was that WL had lost touch with the civilian aircraft market; this CRDA helped us get our foot in the door and gain additional insight into the civilian aircraft industry

4. Fatigue and static test to be conducted at WL structures test facility--Facility contractor will receive payment for testing conducted at WL as well as additional work that will help to smooth out the testing schedule. Additional knowledge will be gained in the area of flutter analysis

* Paragon will pay the total costs of static testing to the contractor that runs the structure test facility.

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

- Public relations benefit--goodwill towards the military and Air Force in general

- Provides insight into the FAA certification process--this will provide WL the opportunity to see another approach to solving problems

- Increased capability at lower costs

Identify any lessons learned about the CRDA process during the development of this CRDA

- Mutually beneficial agreement where both sides pursued the agreement and are actually working to achieve a desired outcome.

Crystal Ball Report
Simulation started on 7/16/96
at 15:32:38
Simulation stopped on 7/16/96
at 15:33:02

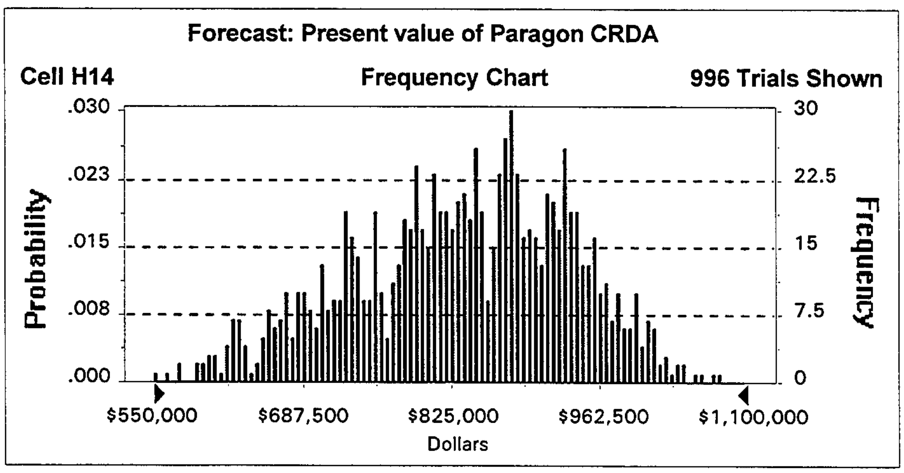
Forecast: Present value of Paragon CRDA

Summary
:

Display Range is from $550,000 to $1,100,000 Dollars
Entire Range is from $523,003 to $1,076,825 Dollars
After 1,000 Trials, the Std. Error of the Mean is $3,237

Statistics — Value
:

Trials	1000
Mean	$834,574
Median (approx.)	$843,481
Mode (approx.)	$935,600
Standard Deviation	$102,354
Variance	$10,476,257,251
Skewness	-0.35
Kurtosis	2.60
Coeff. of Variability	0.12
Range Minimum	$523,003
Range Maximum	$1,076,825
Range Width	$553,822
Mean Std. Error	$3,236.70



Forecast: Present value of Paragon CRDA (cont'd)

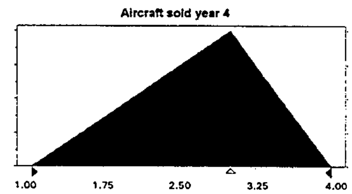
Percentiles:

Percentile	Dollars (approx.)
0%	$523,003
10%	$690,380
20%	$740,839
30%	$786,464
40%	$814,682
50%	$843,481
60%	$873,552
70%	$896,525
80%	$928,348
90%	$958,340
100%	$1,076,825

Assumption: Aircraft sold year 4

Triangular distribution with parameters:

Minimum	1.00
Likeliest	3.00
Maximum	4.00



Selected range is from 1.00 to 4.00
Mean value in simulation was 2.67

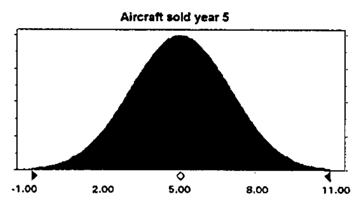
Correlated with:

Aircraft sold year 5 (F7)	0.25
Aircraft sold in year 6 (G7)	0.15

Assumption: Aircraft sold year 5

Normal distribution with parameters:

Mean	5.00
Standard Dev.	2.00



Selected range is from -Infinity to +Infinity
Mean value in simulation was 5.10

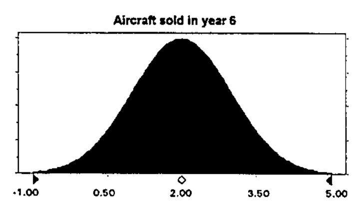
Correlated with:

Aircraft sold year 4 (E7)	0.25
Aircraft sold in year 6 (G7)	0.25

Assumption: Aircraft sold in year 6

Normal distribution with parameters:

Mean	2.00
Standard Dev.	1.00



Selected range is from -Infinity to +Infinity
Mean value in simulation was 1.94

Correlated with:

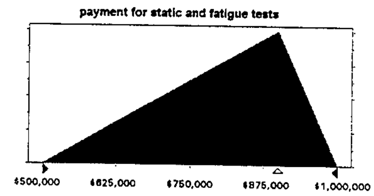
Aircraft sold year 4 (E7)	0.15
Aircraft sold year 5 (F7)	0.25

Assumption: payment for static and fatigue tests

Triangular distribution with parameters:

Minimum	\$500,000
Likeliest	\$900,000
Maximum	\$1,000,000

Selected range is from \$500,000 to \$1,000,000
Mean value in simulation was \$801,417



<u>CRDA Tracking Number</u>: **94-083-WL-01**

<u>Company Involved</u>: **I. M. Systems Group**

<u>Point of Contact/Office Sym/Phone #</u>:

Purpose: Provide commercialization of the Air Force Acquisition Model technology software and effective continued development of the AFAM

Identify All the expected benefits received from the CRDA:

1. Enhancements to the AFAM at no expense to the govt.
   * One man year of work saved under the terms of the CRDA--estimated at 2000 hr. per year at a cost between $47 - $55 per hr.

2. 20 % of all revenues received in the sale of AFAM by I. M. systems (for the lifetime of the product)
   * 20% of each unit sold at a costs of $80 per unit estimates 10,000 unit demand in other govt. agencies and an additional 1000 units to contractors

3. Provided access to the test bed and the books and manuals to go along with the test bed--test bed developed by I.M. systems at an off base location.
   * Manuals estimated between $200 to $400 per year.

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

CRDA # **94 - 083 - AS - 01**
Company : **I. M. Systems**

Expected Benefits	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Net Present Value at 7%**
One man-yr. work saved	$ 102,637					
- hr. per year	$ 2,001					
- cost per hr.	51.3039212					
Test Bed and Manuals	$ 309	$ 311	$ 310	$ 309	$ 311	
CompuServe Account	$ 201	$ 199	$ 200	$ 200	$ 200	
AFAM Revenue 20% of GS		$ 15,870	$ 39,939	$ 55,808	$ 40,077	
- price per unit		$ 80.00	$ 80.00	$ 80.00	$ 80.00	
- estimated units sold		991.868391	2496.19093	3488.02065	2504.80486	
Total Revenue	$ 103,148	$ 16,380	$ 40,448	$ 56,318	$ 40,588	
Present Value at 7%	**$ 96,400**	**$ 14,307**	**$ 33,018**	**$ 42,965**	**$ 28,939**	**$ 215,628**

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. CompuServe account provided at no costs to govt.
   * several hundred dollars per year

2. CRDA resulted in a strong relationship between the govt. and I.M. systems

- Because of the govt. confidence in the work performed by I.M. Systems we were able to offer another contract to small business set aside companies and avoid the larger contractors that would have most likely charged the govt. a higher price for the work to be performed under the contract.

  * diminished risks associated with offering a small business set aside contract.

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

1. Improved working relationship between I.M. Systems and govt. because I.M. Systems now had a stake in the success of an Air Force developed product.

2. The fact that the unit has a CRDA in place was an additional benefit because it proved that CRDAs are an effective tool that can used by the Air Force to transfer technology.

Identify any lessons learned about the CRDA process during the development of this CRDA

1. CRDAs should only go to companies that have a definite interest in the technology and are willing to put forth the effort required to make the agreement work.

2. Good working relationship between the unit and collaborator made this CRDA a cooperative effort where both parties were working towards a common goal.

3. The outside partner had an in-depth working knowledge of the AFAM; they were able to present the information in a user friendly environment through a personal computer.

4. Realizing that a CRDA is an additional marketing tool that can be used to get our products to private industry and create benefits for the govt. will help motivate future CRDAs.

Crystal Ball Report

Simulation started on 7/16/96 at 10:24:46

Simulation stopped on 7/16/96 at 10:25:33

Forecast: Net Present Value of AFAM CRDA

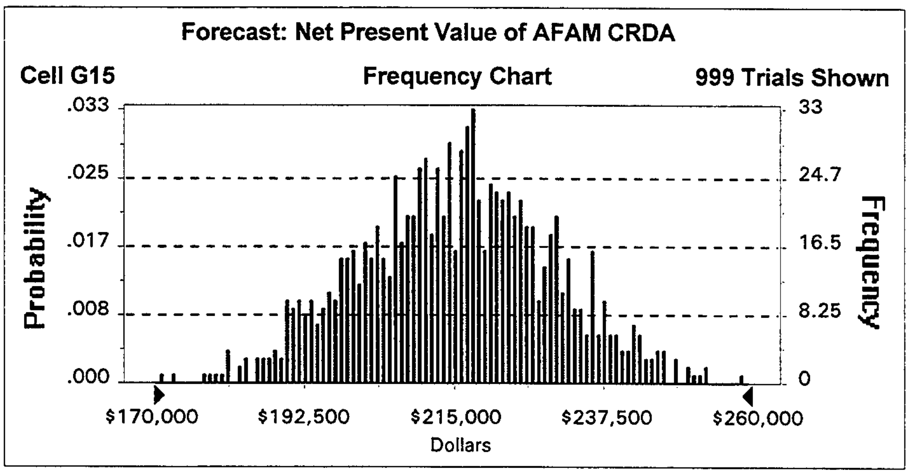
Summary
:

Display Range is from $170,000 to $260,000 Dollars
Entire Range is from $171,641 to $261,574 Dollars
After 1,000 Trials, the Std. Error of the Mean is $458

Statistics Value

:

Trial s	1000
Mea n	$215,630
Median (approx.)	$215,948
Mode (approx.)	$214,360
Standard Deviation	$14,492
Variance	$210,005,822
Skewness	0.01
Kurtosis	2.80
Coeff. of Variability	0.07
Range Minimum	$171,641
Range Maximum	$261,574
Range Width	$89,933
Mean Std. Error	$458.26



Forecast: Net Present Value of AFAM CRDA (cont'd)

Percentiles:

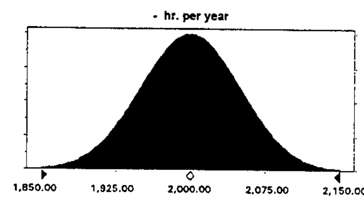
Percentile	Dollars (approx.)
0%	$171,641
10%	$196,523
20%	$202,989
30%	$207,989
40%	$212,068
50%	$215,948
60%	$219,119
70%	$223,383
80%	$227,645
90%	$234,295
100%	$261,574

Assumption: - hr. per year

Normal distribution with parameters:

Mean	2,000.00
Standard Dev.	50.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 2,000.57

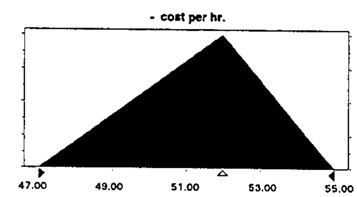


Assumption: - cost per hr.

Triangular distribution with parameters:

Minimum	47.00
Likeliest	52.00
Maximum	55.00

Selected range is from 47.00 to 55.00
Mean value in simulation was 51.30

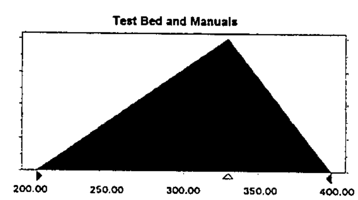


Assumption: Test Bed and Manuals

Triangular distribution with parameters:

Minimum	200.00
Likeliest	330.00
Maximum	400.00

Selected range is from 200.00 to 400.00
Mean value in simulation was 309.26

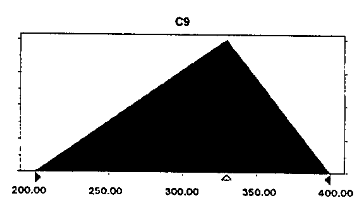


Assumption: C9

Triangular distribution with parameters:

Minimum	200.00
Likeliest	330.00
Maximum	400.00

Selected range is from 200.00 to 400.00
Mean value in simulation was 311.16

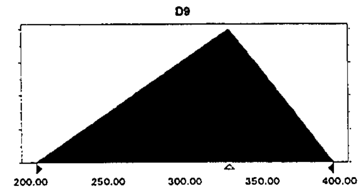


Assumption: D9

Triangular distribution with parameters:

Minimum	200.00
Likeliest	330.00
Maximum	400.00

Selected range is from 200.00 to 400.00
Mean value in simulation was 309.64

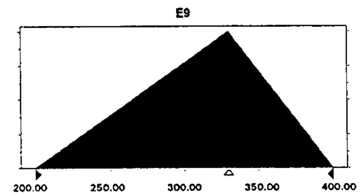


Assumption: E9

Triangular distribution with parameters:

Minimum	200.0
Likeliest	330.0
Maximum	400.0

Selected range is from 200.00 to 400.00
Mean value in simulation was 309.00

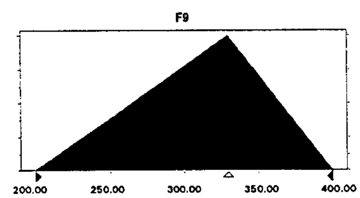


Assumption: F9

Triangular distribution with parameters:

Minimum	200.00
Likeliest	330.00
Maximum	400.00

Selected range is from 200.00 to 400.00
Mean value in simulation was 311.04

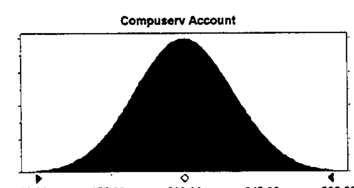


Assumption: Compuserv Account

Normal distribution with parameters:

Mean	200.00
Standard Dev.	30.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 201.44

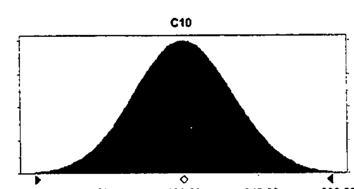


Assumption: C10

Normal distribution with parameters:

Mean	200.00
Standard Dev.	30.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 199.19

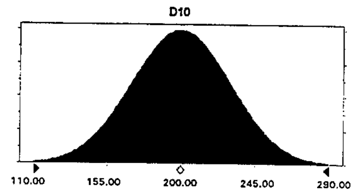


Assumption: D10

Normal distribution with parameters:

Mean	200.00
Standard Dev.	30.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 199.76

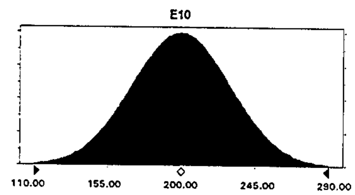


Assumption: E10

Normal distribution with parameters:

Mean	200.0
Standard Dev.	30.0

Selected range is from -Infinity to +Infinity
Mean value in simulation was 200.39

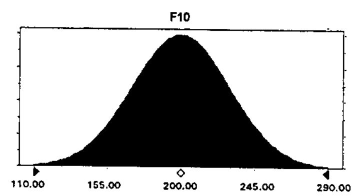


Assumption: F10

Normal distribution with parameters:

Mean	200.0
Standard Dev.	30.0

Selected range is from -Infinity to +Infinity
Mean value in simulation was 199.89

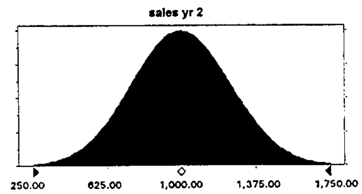


Assumption: sales yr 2

Normal distribution with parameters:

Mean	1,000.00
Standard Dev.	250.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 991.87



Correlated with:

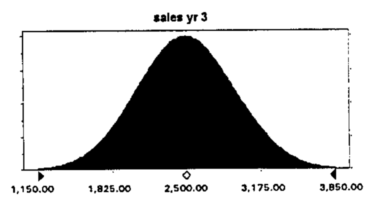
sales yr 3 (D13)	0.25
sales yr 4 (E13)	0.13

Assumption: sales yr 3

Normal distribution with parameters:

Mean	2,500.00
Standard Dev.	450.00

Selected range is from -Infinity to +Infinity
Mean value in simulation was 2,496.19



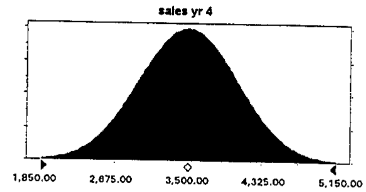
Correlated with:

sales yr 2 (C13)	0.25
sales yr 4 (E13)	0.33
sales yr 5 (F13)	0.15

Assumption: sales yr 4

Normal distribution with parameters:

Mean	3,500.00
Standard Dev.	550.00



Selected range is from -Infinity to +Infinity
Mean value in simulation was 3,488.02

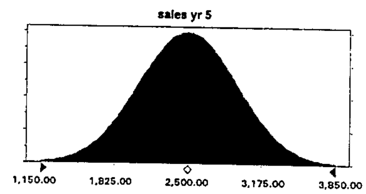
Correlated with:

sales yr 2 (C13)	0.13
sales yr 3 (D13)	0.33
sales yr 5 (F13)	0.50

Assumption: sales yr 5

Normal distribution with parameters:

Mean	2,500.00
Standard Dev.	450.00



Selected range is from -Infinity to +Infinity
Mean value in simulation was 2,504.80

Correlated with:

sales yr 3 (D13)	0.15
sales yr 4 (E13)	0.50

CRDA Tracking Number :

Company Involved : **Paragon Aircraft**

Point of Contact/Office Sym/Phone # :

Purpose:

Identify All the expected benefits received from the CRDA:

1. Expanding the data base on composites (new material being used for Paragon)
   * One man year of effort saved in the development of data base and knowledge transfer--savings estimated between 90 - 125 k in salary that would have been paid to WL engineer

2. Knowledge transfer back to the unit that would have taken at least one man year to obtain

3. Consultation with collaborator during FAA certification and approval process

4. Knowledge gained in adhesively bonded structures

5. Royalty payments to WL Materials Branch on the first ten aircraft developed and sold under the agreement--$10,120 paid to WL on each aircraft sold. This royalty stream will be used for time and services rendered by WL engineers.

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

CRDA #
Company : PARAGON Aircraft Development of Light Commuter Plane

Expected Benefits	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total PV Revenues**
Aircraft sold by Paragon	0	0	1.66286268	4.76313687	2.33819591	
$10,120 per aircraft sold	0	0	16828.1704	48202.9451	23662.5426	
Man Year 1 work saved	$ 105,422					
Man Year 2 work saved	$ 86,583					
Total Revenue	$ 192,005	$ -	$ 16,828	$ 48,203	$ 23,663	
Present Value at 7%	$ 179,444	$ -	$ 13,737	$ 36,774	$ 16,871	**$246,826**

- **Man year 1** represents the work savings resulting form Paragon's involvement in data base expansion on composites, knowledge transfer to WL in seeing composite structures built, and consultation with collaborator during FAA approval process.
- **Man year 2** represents the work savings associated with advertising, marketing, and finding an outside partner willing to work with and test the ISO grid composite structure.

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. WL found a use for the low tech ISO grid composite design--a developed structure can now be used by an outside partner and performance data can be obtained at no cost to WL.

* One man year of marketing and advertising effort saved by finding a customer for the ISO grid structure

2. Fabrication to take place at the Dayton International Airport--logistics an systems support may be provided by WL and we will get the use of an airplane test bed.

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

- Not just a testing agreement; a great deal of knowledge obtained during this CRDA that will benefit WL.

Crystal Ball Report
Simulation started on
7/14/96 at 7:36:32
Simulation stopped on
7/14/96 at 7:36:55

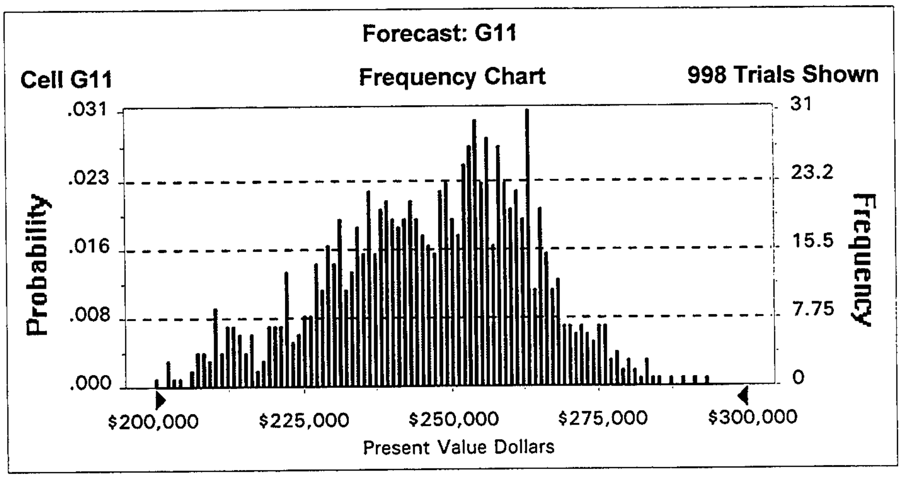
Forecast: G11

Summary
:

Display Range is from $200,000 to $300,000 Present Value Dollars
Entire Range is from $192,733 to $293,790 Present Value Dollars
After 1,000 Trials, the Std. Error of the Mean is $545

Statistics :	Value
Trials	1000
Mean	$246,826
Median (approx.)	$248,718
Mode (approx.)	$254,883
Standard Deviation	$17,223
Variance	$296,639,136
Skewness	-0.32
Kurtosis	2.73
Coeff. of	0.07

Variability	
Range Minimum	$192,733
Range Maximum	$293,790
Range Width	$101,057
Mean Std. Error	$544.65



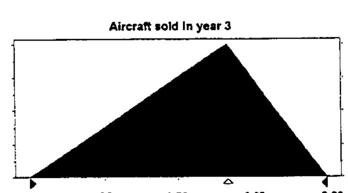
Percentiles:

Percentile	Present Value Dollars (approx.)
0%	$192,733
10%	$222,825
20%	$231,808
30%	$238,239
40%	$243,219
50%	$248,718
60%	$253,367
70%	$257,129
80%	$261,721
90%	$266,937
100%	$293,790

Assumption: Aircraft sold in year 3

Triangular distribution with parameters:

Minimum	0.00
Likeliest	2.00
Maximum	3.00



Selected range is from 0.00 to 3.00
Mean value in simulation was 1.66

Correlated with:

Aircraft sold in year 4 (E6) 0.50

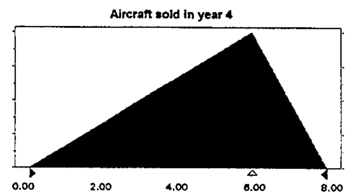
Aircraft sold in year 5 (F6) -

0.15

Assumption: Aircraft sold in year 4

Triangular distribution with parameters:

Minimum	0.00
Likeliest	6.00
Maximum	8.00



Selected range is from 0.00 to 8.00
Mean value in simulation was 4.76

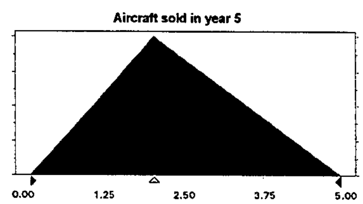
Correlated with:

Aircraft sold in year 3 (D6)	0.50
Aircraft sold in year 5 (F6)	-0.33

Assumption: Aircraft sold in year 5

Triangular distribution with parameters:

Minimum	0.00
Likeliest	2.00
Maximum	5.00



Selected range is from 0.00 to 5.00
Mean value in simulation was 2.34

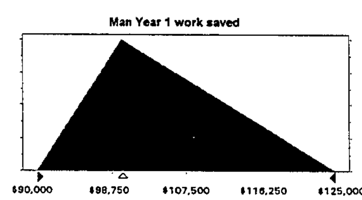
Correlated with:

Aircraft sold in year 3 (D6)	-0.15
Aircraft sold in year 4 (E6)	-0.33

Assumption: Man Year 1 work saved

Triangular distribution with parameters:

Minimum	$90,000
Likeliest	$100,000
Maximum	$125,000



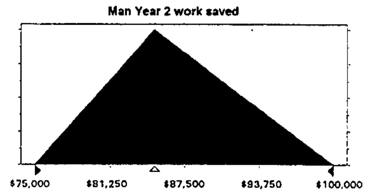
Selected range is from $90,000 to $125,000
Mean value in simulation was $105,422

Assumption: Man Year 2 work saved

Triangular distribution with parameters:

Minimum	$75,000
Likeliest	$85,000
Maximum	$100,000

Selected range is from $75,000 to $100,000
Mean value in simulation was $86,583



CRDA Tracking Number : **93 - 335 -WL - 01**

Company Involved : **Wright State University**

Point of Contact/Office Sym/Phone # : **Ed Stuts / 5-8658**

Purpose: Use government facilities and expertise to help a university carry out research and testing requests by industrialized organizations and other governmental agencies

Identify All the expected benefits received from the CRDA:

1. WSU paid WL for test facilities and expertise provided by WL and WL personnel
   -- WSU requested information, expertise, or resources from WL--WL was not paid for each research request but was paid in lump sums for research that was within the scope of the WL mission.
   -- WL effort towards the CRDA was limited to only research that was mutually beneficial to WL and WSU

2. Advancement of research and access to data in technical areas

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

Estimated cash flows for years 97 and 98 discounted using 7% interest rate.

CRDA # **93 - 335 -WL - 01**
Company: **Wright State University**

Year :	*Nov-94*	*Apr-95*	*May-96*	*May-97*	*May-98*	***Total Revenues***
Revenues :	**$ 4,609**	**$ 17,120**	**$ 22,365**	***$ 19,948***	***$ 20,045***	***$80,245***
Disc. CS				**$18,643.05**	**$17,508.20**	

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

- Money received through CRDA used for capital improvements at WL--mission at WL has been helped by these expenditures because the equipment that was purchased (special lasers) wouldn't have been purchased due to funding limitations.--WL has been able to due research that wouldn't have been possible without equipment expenditures.

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

- The fact that WL has been effectively transferring technology to an outside partner.

Identify any lessons learned about the CRDA process during the development of this CRDA

1. WL already had an ongoing contract with WSA--the bond between the two agencies made them more willing to adhere to the agreement and make it work.

2. The objectives for this CRDA were very open and general--this gave WL the freedom to pursue a wide range of activities under this CRDA--WL's main requirement was that the activity bring in revenue and fall under the scope of the WL mission.

3. WL had the freedom to pick and chose the research they were willing to perform under this CRDA.

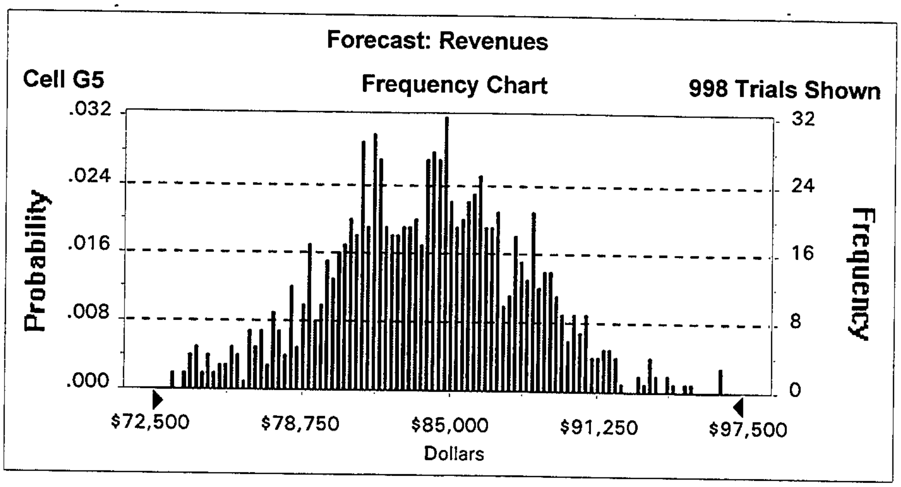
Crystal Ball Report
Simulation started on 7/13/96 at 14:34:30
Simulation stopped on 7/13/96 at 14:34:42

Forecast: Revenues **Cell: G5**

Summary:

Display Range is from $72,500 to $97,500 Dollars
Entire Range is from $68,998 to $98,624 Dollars
After 1,000 Trials, the Std. Error of the Mean is $132

Statistics:	Value
Trials	1000
Mean	$84,087
Median (approx.)	$84,233
Mode (approx.)	$84,848
Standard Deviation	$4,185
Variance	$17,511,090
Skewness	-0.02
Kurtosis	3.05
Coeff. of Variability	0.05
Range Minimum	$68,998
Range Maximum	$98,624
Range Width	$29,626
Mean Std. Error	$132.33



Forecast: Revenues (cont'd)

Cell: G5

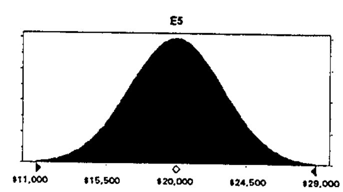
Percentiles:

Percentile	Dollars (approx.)
0%	$68,998
10%	$78,893
20%	$80,717
30%	$81,816
40%	$83,004
50%	$84,233
60%	$85,122
70%	$86,304
80%	$87,728
90%	$89,390
100%	$98,624

Normal distribution with parameters:

Mean	$20,000
Standard Dev.	$3,000

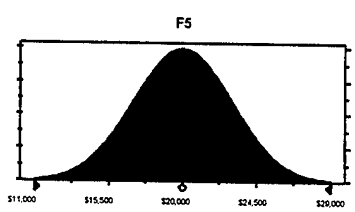
Selected range is from -Infinity to +Infinity
Mean value in simulation was $19,948



Normal distribution with parameters:

Mean	$20,000
Standard Dev.	$3,000

Selected range is from -Infinity to +Infinity
Mean value in simulation was $20,045



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Vita

First Lieutenant Clinton J Braun graduated in 1992 from the University of South Carolina at Spartanburg with a Bachelor of Science degree in Business Administration with a concentration in Economics and Finance. He was Commissioned in the United States Air Force through Officers Training School in April of 1993. He served his first tour of duty at Edwards AFB, CA with the 31st Test and Evaluation Squadron where he was the Squadron Executive Officer and later the Squadron Section Commander. In May 1995, Lieutenant Braun was selected to attend the Air Force Institute of Technology Graduate Program for Cost Analysis. He will graduate in September 1996, and will be assigned to the Aerospace Systems Center, Eglin AFB FL following graduation.

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 074-0188
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13. ABSTRACT *(Maximum 200 Words)*

The allocation of resources should be a rational decision making process where alternatives can be compared based on their estimated costs and benefits to the organization. In order to justify technology transfer activities, a sound methodology must be developed that will document the benefits derived from transfer activities. The risks or uncertainties associated with those benefits must also be estimated and analyzed. By detailing the costs, benefits, and uncertainties associated with technology transfer activities, decision makers will have a logical framework that can be used to determine the cost effectiveness of technology transfer.

Leaders within the technology transfer arena are searching for better ways of quantifying the tangible and intangible benefits of technology transfer. The goal of this research is to build an acceptable methodology that can be used to identify and quantify the tangible and intangible benefits received within Air Force Materiel Command (AFMC) as a result of technology transfers. This exploratory study employs a structured interview methodology to identify and quantify the benefits received by the Air Force through its technology transfer activities.

14. SUBJECT TERMS			15. NUMBER OF PAGES
Technology Transfer, Return on Investment, Probability Encoding, and Benefits Received from Technology Transfer Activities			131
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298-102

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The purpose of this questionnaire is to determine the potential for current and future applications of AFIT thesis research. **Please return completed questionnaire** to: AIR FORCE INSTITUTE OF TECHNOLOGY/LAC, 2950 P STREET, WRIGHT-PATTERSON AFB OH 45433-7765. Your response is **important.** Thank you.

1. Did this research contribute to a current research project? a. Yes b. No

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not researched it?
a. Yes b. No

3. **Please estimate** what this research would have cost in terms of manpower and dollars if it had been accomplished under contract or if it had been done in-house.

Man Years__________ $__________

4. Whether or not you were able to establish an equivalent value for this research (in Question 3), what is your estimate of its significance?

a. Highly Significant b. Significant c. Slightly Significant d. Of No Significance

5. Comments (Please feel free to use a separate sheet for more detailed answers and include it with this form):

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Organization

Position or Title

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