IMPLICATIONS FOR IR&D DECISIONS USING OPTIONS PRICING THEORY

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ABSTRACT

DOD independent research and development (IR&D) funding is modeled as a three-stage option on final product manufacture. Financial options pricing theory is reviewed to develop insights into the way the DOD should view the IR&D investment, and the way contractors should market their IR&D projects in view of this to maximize IR&D funding.

The option analogy is then applied the resource allocation process within the firm. Relationships drawn from option theory are used to identify qualitative measures for R&D project generation and selection.

The historical development of IR&D legislation, and the negotiation process (a case) are reviewed. Analyses of these reveal that they do not support the allocation of IR&D funding in a free market option framework.

The option analogy is shown to be lacking in quantitative applicability, but places the value of investing in IR&D on: 1. holding an option on an uncertain, future market, 2. information for multi-stage R&D investment decisions.

Thesis Supervisor: Dr. J. Morris McInnes
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1. INTRODUCTION

The finance literature on option-pricing is well established, with well defined equations and identifiable parameters. Recent option literature has attempted to extend these formulae and parameters to the valuation of "real" options, and projects with option-like characteristics. Recognizing that the art of management can be likened to the art of creating and managing ongoing business options, we apply financial option theory towards the development of a corporate research and development strategy defined by the creation of corporate strategic options. We model the option strategy framework in the context of the Department of Defense's efforts to develop and maintain a portfolio of modern weaponry.

There is no doubt that the U.S. faces threats from other interests in the forms of military pressure, and, at times, violent military intervention. It is a given that the U.S. chooses to maintain military action as one avenue for protecting national interests. The military threats imposed are growing along two dimensions; increase in numbers of units deployed and technological advancements. The U.S. has a stated policy of relying on technological superiority in weapons systems to counter both the increase in numbers and changes in technology. An important question therefore is how best to obtain the necessary research and development effort to satisfy the Government's military
product needs. One solution is for the Government to assess its future military product needs, and dictate to the defense industry to fulfill these needs. A second solution, and the focus of this paper, is to take advantage of the market mechanism, and encourage the greatest possible independence and initiative from defense contractors. The embodiment of the spirit of market-driven research and development is found in Independent Research and Development (IR&D).

The basic theme of this thesis is that the Government is not purchasing IR&D per se, but is rather purchasing an option on future product development: if the research efforts are successful, in terms of creating the potential to meet a future strategic or tactical need, the Government will exercise its option and contract for future research and development efforts; if the efforts are not successful, the Government will simply let the option expire by stopping funding. After reviewing financial option theory, and deriving an IR&D model, we show the similarity between the Government as a purchaser of the IR&D option, and the technical new product development effort within any given firm. Once this has been established, we review the evolution of IR&D legislation, extracting key legislation and discussing the relevance of the particular legislation to fostering an environment conducive to an option approach to new product development. With the IR&D-option rela-
tionship developed, we extend the argument to a strategic-options approach to corporate strategy for the corporation facing a rapidly changing technological environment. We conclude with a discussion of the planning and organizational issues surrounding the strategic-options approach to corporate strategy.
2. MOTIVATION

Many marketing strategy authors have written about the new product development process within the firm. Kotler\textsuperscript{1} outlines the standard text-book approach to the process:

1. Idea Generation
2. Idea Screening
3. Concept Development and Testing
4. Marketing Strategy Development
5. Business Plan
6. Product Development
7. Market Testing
8. Commercialization

Sommers\textsuperscript{2} notes that the new product development process has become more sophisticated over time.

Sommer correlates increasing sophistication in new product development with a decline in the number of new products which fail upon introduction to the market. Sommer notes a Booz-Allen & Hamilton study conducted in the 1960's which indicated that the pattern outlined in figure 2 required approximately 60 ideas to generate one new product. Sommer continues that "significant efforts are now made during the product concept stage to learn what the consumer wants and needs." Additionally, consumer forecasting tools have increasingly been applied to early states in the process (EPS, LTM, COMP, ASSESSOR, and BASES).

This standard approach to new product development may be incomplete. While many, if not all, marketing textbooks outline new product development models, very few focus on perhaps the most important stage, idea generation. In particular, no textbook we have found discusses the issue of idea generation as a function of timing. Rather, the textbook approach assumes an idea is generated, and then moves on to other stages of the new product development process. Further, there is no explicit recognition of interactive dynamics between idea generation, marketing, and commercialization, all of which are the factors affecting timing in the decision making process. The increasing number of analytical models designed by market researchers

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3 Sommer, page 54
4 Ibid, page 55
have all been, in general, designed to reduce the probability that new product introductions will fail. Hence, there is a sense in which market researchers have devoted their energies to keeping products off the market, rather than to developing concepts and models to aid the firm in generating ideas and strategies for new product development.

By following this path, marketing strategy has succumbed to the "market-driven," trap, as illustrated by Hayes & Abernathy in the following series of quotes:

"'We have got to stop marketing makeable products and learn to make marketable products.'

'Customers may know what their needs are, but they often define those needs in terms of existing products, processes, markets, and prices.'

'Deffering to a market-driven strategy without paying attention to its limitations is, quite possibly, opting for customer satisfaction and lower risk in the short run at the expense of superior products in the future. Satisfied customers are critically important, of course, but not if the strategy for creating them is responsible as well for unnecessary product proliferation, inflated costs, unfocused diversification, and a lagging commitment to new technology and new capital equipment.'"

Finally, Hayes & Abernathy provide the following quote from two Canadian researchers:

"Inventors, scientists, engineers, and academics, in the normal pursuit of scientific knowledge, gave the world in recent times, the laser, xerography, instant photography, and the transistor. In contrast, worshippers of the marketing concept

5Hayes & Abernathy, page 71
have bestowed upon mankind such products as new-fangled potato chips, feminine hygiene deodorant, and the pet rock..."6

In this paper we present an alternative model for the first stage of the new product introduction process: an option model. The option model does not attempt to eliminate products from the development process; it seeks to introduce them. The option model explicitly recognizes that it is the responsibility of management, not consumer questionnaires, to initiate new product development, recognizing that not all new product ideas will come to fruition and enter the market. The option model is forward looking, and encourages innovation and radical product innovation (what standard marketing strategy might label risky).

The option approach is modelled via an examination of the market for IR&D where we show the similarity between IR&D and a financial option. The market for IR&D allows us to separate the holder of the option (the Department of Defense), and the originators' (Defense Contractors) roles in the new product development process.

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6Roger Bennett and Robert Cooper, "Beyond the Marketing Concept," Business Horizons, June 1979, page 76, as quoted from Hayes & Abernathy, Ibid.
3. **IR&D: A DEFINITION**

For purposes of this paper, we can define three general forms of products purchased by the Department of Defense. First, every year the Department of Defense (hereafter the DOD) negotiates and contracts with various defense industry firms for specific products. In this case, the DOD has internally defined it's current military product needs, and the role of defense industry marketing divisions is to ensure that their respective firms are invited to bid on products. Second, the contractors also negotiate for DOD allowances for research and development. In this case, the DOD contracts with one or more firms for research and development efforts on specific products, hence the term "directed research." Directed research contracts occur where the DOD has internally defined it's expected future needs, and directs the contractors towards fulfilling these needs. Finally, a third type of marketing interaction between the DOD and contractors is for IR&D funds. In this case, the DOD is neither buying a specific product, nor research directly leading to development of a specific product. Rather, IR&D funds are allocated to contractors for research into product/technology areas which are at the discretion of the contractor. It is the contractor's task to define what products the DOD may require in the future to counter generic military threats, and to begin research in that direction.
It is at this stage of idea development that real value can be generated. Technologies that firms are researching may not, at this time, be directed to answer an immediate military threat, but a generic threat (such as the star wars concept recently initiated for umbrella protection of the continental United States from any form of airborne penetration). This type of research can be described as an "end run," not taking on a known capability directly with a like response and battling it out in the trenches, but striving for absolute displacement of the perceived threat. Intuition would say that it is end runs, or radical new ideas that meet basic DOD needs that should be the strategic imperative of contractors undertaking IR&D.

Thus, whereas the first two forms of product marketing are reactive and directed, the marketing of IR&D may be considered pro-active, as the DOD contractors are marketing a product (IR&D) to the DOD for which there is no clearly defined present or future need.

In sum, we may define IR&D as:

"The ongoing, company-sponsored technical effort in (1) basic and applied research, (2) development, and (3) systems and other concept formulation studies. It focuses on advancing the company's technology base, improving current products, and developing new products in response to anticipated future military needs." 7

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4. STRATEGIC IMPORTANCE OF IR&D

As defined above, IR&D is "company initiated R&D undertaken to improve a firm's competitive standing by virtue of improvements in products, creation of new products, or advancement of the company's technological capability in general." Given this definition, IR&D becomes a significant strategic variable in growth and competitiveness. We can define the following strategic implications of IR&D: product protection versus new product development, experience curve factors, and market penetration.

A. Product Protection versus New Product Development

Throughout this paper we focus on the role of IR&D in the development of new products. In the arena of high technology products, initial R&D efforts are crucial in determining the technology constraints on new product development efforts. However, a second role of IR&D may be the protection of current products. IR&D may be focused on modifying a particular feature of a given product, as opposed to introducing an entirely new product. This modification, if successful, may prevent competitors from taking over the contract for the entire product solely because the competitor's product includes this one modification. Additionally, although the needs of the Government are constantly changing over time, these needs do not always translate into a need for a totally different product.
In this context, we can think of a firm as conducting two basic types of IR&D activity: one directed towards totally new products, and one directed toward developing a transition strategy as the Government's needs evolve over time.

B. IR&D as a Path to the Experience Curve

The Experience Curve has shown that, for many different manufacturing industries, the per unit cost of manufacturing a given product declines at a constant rate for each doubling of the cumulative sales by the firm. However, when we recall that successful IR&D leads to product development, and the first contractor to develop a product may win a large Government contract, the importance of IR&D becomes clearer: IR&D may lead to new product development, and the first firm into the market (especially where there is only one customer) will enjoy a large advantage over potential competitors. Indeed, the winner take all nature of the defense industry is exactly explained by this phenomenon: the first firm to develop a product may be the first to win the contract, and once the contract is awarded, the firm has the opportunity to move down the Experience Curve and prevent competitors from entering the market. Again, this is of particular importance where there is one customer, but several competitors.
C. Market Penetration

The DOD wears two different and sometimes opposing hats when evaluating contractor proposals for IR&D. As noted by Colonel Luke of the US Air Force, the DOD may use IR&D funds to foster competition in the Defense industry. The DOD does this by allowing several firms to work on similar IR&D projects at the same time. We call this the "competition policy hat." A second hat worn by the DOD is the "efficiency hat." As noted above, the technical product brochures which the contractors must prepare for the DOD must include a summary of past achievement in a similar research area. Therefore, firms with past experience in one area may be favored over firms without such past experience. This factor works to counter the fostering of competition, and suggests that firms may, by concentrating in certain research and new product development areas, gain strong market penetration in these areas. Hence, to the extent that the DOD favors its "efficiency hat," firms may use IR&D as a vehicle toward market penetration.
5. **A REVIEW OF FINANCIAL OPTION THEORY**

**Definition of Some Terminology**

The Webster's Third New International Dictionary defines a financial option as: "a right to buy or sell designated securities or commodities at a specified price during the period of the contract." In terms of the option as a financial instrument, it is an agreement between two individuals in which one individual has the **right**, not the obligation, to buy or sell an asset under certain conditions. The individual owning the option has the choice to make, and must pay the other individual for the privilege of being able to make such a choice.

The most common type of option is the **call option**. A call option gives the buyer the right to buy one share of a stock at a given price before a given date. A **European** call option allows the security to be bought only on (not before) the specified date. An **American** call option allows the security to be bought at any time up to and including the specified date. The act of buying the share is termed "exercising the option." The last date possible to exercise is called the "exercise date." The price at which the underlying security can be bought is called the "exercise price." As noted, the buyer of the call option must pay

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8Webster's Third International Dictionary, pg. 1585.
for the right to buy. The amount paid is termed the "option price."9

A put option is the right to sell one share of a stock at a given price before a given date. As is the case with call options, there exist both American and European put options, with American put options giving the holder the right to sell on or before the expiration date, while the European put option can only be exercised on the expiration date. It is important to remember that with both puts and calls no new capital is being created: an option is simply a contract between the buyer and seller of an option and thus a transfer of capital.

Valuation of Financial Options:

In order to keep the theory simple and applicable to the central topic of this paper, we focus our attention on valuing European call options on stocks which pay no dividends. The same relationships can be developed from the American call option.) European options are much easier to value than American options, yet the European option still provides sufficient insight necessary to translate financial option theory to a corporate strategic options strategy approach.

Define:

\[ P_s = \text{Price of the security on which the option is written} \]

\[ P_o = \text{Value of the option} \]

\[ T = \text{Time to maturity} \]

\[ R = \text{Risk free rate of interest} \]

\[ E = \text{Exercise price} \]

\[ I = \text{Initial price of the option, i.e. the price paid to own the right to buy the underlying security} \]

\[ V = \text{Variance of the price of the underlying asset} \]

**FIGURE 1**

**The Financial Call Option**

\[ P_o = \text{Value of Option} \]
The financial call option is shown graphically in Figure 1. Figure 1 illustrates that the value of an option only becomes positive when $P_s > E$. This is not entirely accurate, for as long as investors expect that there exists some non-zero chance that the stock price will exceed the exercise price before the option expires, the option will have value. This is an important point, and is shown algebraically below as Equation 1:

Equation 1: $P_o = P_s - E$

Equation 1 gives the value of the option on the expiration date. To derive the value of the call option before the expiration date, we can re-write Equation 1 as follows:

Equation 1: $P_{ot} < P_{st} - PV_t(E)$

where $PV_t(E)$ indicates the present value of the expected exercise price at time $t$. We label Equation 1 as Boundary Condition #1.

Two further boundary conditions on the price of a financial call option are needed. First, what is the most one would be willing to pay for such an option? Because a call option is converted to a security when the exercise price is paid, it is clear that the call option should never sell for more than the price of the underlying security itself. Hence, we write:

Boundary Condition #2: $P_o ≤ P_s$

Second, once we recall that an option holder owns a right and not an obligation, the option can never be
such that someone must be paid to hold it. This generates the third boundary condition: the price of an option can never be negative.

Boundary Condition #3: \( Po \geq 0 \)
The three Boundary Conditions are displayed graphically in Figure 2.

**FIGURE 2**

**BOUNDARY CONDITIONS**
Equation 1 can be used to derive five key determinants of option pricing. We rewrite Equation 1, and discuss these relationships below.

Equation 1: \( P_{0t} = P_{st} - PV_{t}(E) \)

Relationship #1: As \( P_s \) increases, so does the Present Value of the Option

Equation 1 clearly shows that, for a given exercise price and maturity date, the higher the price of the stock, the higher the value of the option. Again, the price of the option may be positive even if the price of the stock is less than the exercise price, as long as the option holder expects that there is a possibility that the stock price will move above the exercise price on or before the expiration date.

Relationship #2: As the Exercise Price Decreases the Present Value of the Option Increases

This relationship is immediately clear upon examination of Equation 1, and will be of significance when we discuss corporate option strategy later in this paper. Note for now that the exercise price is the price which the option holder must pay in order to acquire the underlying asset upon which the option was written. It is intuitive then that the lower the exercise price the greater the value of the option, as shown in Equation 1.
Relationship #3: As the Time to Maturity Increases, so does the Value of the Option

This relationship is not immediately obvious, but becomes clearer when we recall the underlying characteristics of an option. Examination of any published option pricing listing (i.e. the Wall Street Journal prints the Chicago Board Options Exchange price listing) will verify this relationship. The reason this relationship holds is that the greater the duration of the option, the greater the probability that the stock price will move higher than the exercise price. Recalling Boundary Condition #2, a call option with an infinite term to maturity will have the same price as the underlying stock (paying no dividends). The intuitive explanation is that, by definition of the term infinite duration, the European call option will never be exercised. Analytically, as the expiration date is pushed further and further into the future, the $\text{PV(E)}$ term in Equation 1 becomes smaller and smaller. At the limit as "t" approaches infinity, $\text{PV(E)}$ approaches zero, and $\text{Po} = \text{Ps}$.

Relationship #4: The Greater the Variance in the Price of the Underlying Stock, the Greater the Value of the Option

Again, this relationship is not immediately obvious, but becomes clearer when we observe that the greater the variance, the greater the chance that the price of the underlying security will move above, and further above
the exercise price. The following hypothetical example illustrates this relationship. Assume an investor has a choice between an option on one of two stocks, Stock A and Stock B. Both stocks have the same expected price, but Stock B is characterized by a higher variance, as shown in Figure 3.

**FIGURE 3**

**PROBABILITY DISTRIBUTIONS OF STOCKS A & B**

Since a financial option is theoretically a zero NPV investment (relative to a risk free investment), the positive (upside) potential created by the variance is truncated between the current value of Ps and the upper limit of the variance by an amount set by the term to maturity, and the risk free rate of interest. While it is true that the five relationships, as stated, lead to greater value of the option, the option holder must pay a fair price Po, to hold the option. The "fair" price is calculated using the option pricing formulas such that it is a zero NPV investment. Rearranging equation 1 shows this algebraically:

\[
0 = [P_{st} - PV_{t}(E)] - P_{ot}
\]
An option on Stock A has a chance of being "in the money" (Ps / Po). However, an option on Stock B will have a better chance at being further in the money, and hence be more valuable.

It is important to note that in this discussion of Relationship #4 we have limited our focus to the upside potential, with no apparent downside risk. This is exactly the notion of an option, and illustrates a very significant difference between the value of options, and the value of the underlying asset. Holding the actual asset is synonymous with being exposed to the payoff structure of the asset as defined by the entire probability distribution. Hence, the risk averse individual, disliking high variance, will choose a less risky security with lower expected returns. However, as an option holder, the same risk averse individual is exposed to the payoff structure of the option as defined by a portion of one tail of the distribution. Thus, the contingent claim aspect of options makes higher variance a desirable feature.

Relationship #5: As the Risk Free Rate of Interest Increases, so does the Value of the Option

Upon first inspection, this relationship is not obvious. From a technical perspective, Black and Scholes (1973) showed that a risk-free hedged position can be created by holding a long position in the stock and a short position in the option (individual writes a call). This conclusion
led them to suggest that the rate of return on the equity in such a hedged position is non-stochastic, hence it should earn the risk-free rate. As the risk free rate increases, so does the return on the hedged position, implying that the value of a call option will also rise with an increase in the risk-free interest rate. On a more intuitive level, Equation 1 shows that as the risk free rate increases, the present value of the exercise price declines, with a commensurate increase in the value of the option.

The above paragraphs provide intuition into the five factors relevant in deriving the price of a European call option: the price of the underlying asset, \( P_s \); the exercise price for the option, \( E \); the variance of the price of the underlying asset, \( \sigma^2 \); the risk free rate of interest, \( r \); and the term to maturity of the option, \( T \).

We conclude this general overview of financial option theory with a brief discussion of why investors trade options. We will compare and contrast the reasons why investors should trade options, and later apply the ideas to technology firms creating strategic options. The following paragraphs draw from a 1981 paper by Rubinstein and Leland.
entitled "Replicating Options with Positions in Stock and Cash."\textsuperscript{10}

Rubinstein and Leland note that a frequently stated reason for holding options is that options present the opportunity for new patterns of returns. However, they proceed to show that the returns on options can be duplicated by properly manipulating a stock-cash position. The authors suggest several other explanations, some of which may be relevant to our later discussion on why corporations hold strategic options.

The authors show in their paper that options may offer individuals more favorable implicit borrowing, margin requirements, transaction cost, or tax exposure. Also, options may offer opportunities either to take advantage of information about stock volatility ... or to hedge against their impact.\textsuperscript{11} We note these objectives here, and return later to discuss these objectives in terms of developing corporate strategic options.

To accomplish the jump from current option pricing theory to its application in strategic decision making in the IR&D environment, the definition of basic value of the option should be clearly stated. In the current literature (Black, Scholes, etc.) the value of the option

\textsuperscript{11}Ibid, page 68
is based on the underlying security price. In the application to R & D strategy, the value of the option is derived from the possible cash flows generated by creating a future market.
6. FINANCIAL OPTION THEORY AND VALUATION OF OPTION-LIKE ASSETS

Financial option theory took a quantum leap forward with important publications by Black and Scholes (1973), and Merton (1973). Since 1973, financial option theory has begun to be applied to the valuation of other assets which have option-like characteristics. The purpose of this section is to review the literature relating financial option theory to the valuation of option-like assets.

As noted by Myers12, a corporations' growth opportunities may be seen as call options, where the value of the option is a function of management's ability to recognize, and exercise (commit discretionary future investment) these "real options." Myers suggests that the value of a firm can be thought of as two components: the earnings derived from assets in place, and the earnings to be derived from investing in future growth opportunities,

\[ V = VA + VG \]

where VA is defined as the market value of assets currently in place, and VG is defined as the present value of future growth options. As Myers notes, "the usual interpretation is that a positive value of VG reflects future investments which are expected to yield a rate of return in excess

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12S. Myers, Determinants of Corporate Borrowing, JFE, page 147
of the opportunity cost of capital."13 The following proof illustrates Myers point:

Imagine a firm composed of two separate components:

- earnings from currently held assets which have already been paid for
- the net present value of a future growth opportunity

Assume that, at any moment "t," the market expects the firm to make an investment of \( I(t) \), with a perpetual return of \( P_t^*(I(t)) \).

Define:

\[
\begin{align*}
P(t) &= \text{Market rate of return} \\
P^*(t) &= \text{Return on growth opportunity asset at time } t \\
I(t) &= \text{Investment in growth opportunity at time } t \\
P^*(I(t)) &= \text{Perpetual return on investment } I(t) \\
X_0 &= \text{Earnings from currently held assets} \\
V(0) &= \text{Value of firm at time zero}
\end{align*}
\]

The net present value of the growth option at time \( t \) is determined:

\[
\begin{align*}
PV(t) &= \frac{P^*(t) I(t)}{P} \\
NPV(t) &= \frac{P^*(t) I(t)}{P} - I(t)
\end{align*}
\]

\[\text{13ibid, page 150}\]
the net present value at \( t = 0 \) is determined:

\[
NPV(0) = \frac{1}{(1+P)^{t+1}} \left[ \frac{P^*(t)}{P} I(t) - I(t) \right]
\]

\[
= \frac{1}{(1+P)^{t+1}} \left[ I(t) \frac{(P^*-P)}{P} \right] = VG 5.
\]

Equation 5 represents the present value of the growth option available to the firm. Thus we can write:

\[
V_o = \frac{X_o}{P} + \frac{1}{(1+P)^{t+1}} \left[ I(t) \frac{(P^*-P)}{P} \right] 6.
\]

where \( \frac{X_o}{P} \) = earnings from currently held assets (which are assumed already paid for).

Equations 5 and 6 illustrate a key concept in defining strategic growth options. The net present value of these options will only be positive where the return on the asset, \( P^* \) is greater than the market rate of return, \( P \).

In terms of capital markets and valuation of the firm, if the capital markets are efficient, then by definition of efficiency, \( P^* \) cannot be greater than \( P \), and a growth stock cannot exist. However, in terms of managements' discretion to develop strategic options for future exercise, if the real asset market of the R & D market (in the context of a rapidly changing technology environment) are inefficient, then it will be possible for management to initiate the development of strategic options which, if exercised, may generate a return of \( P^* \) greater than \( P \) (and hence the financial market is strictly inefficient).
Recall that the growth option is to be exercised at some future date "t." Unless management possesses an extremely accurate forecasting service (a crystal ball would do nicely), there will exist a degree of uncertainty as to the value of the strategic option at time t, as well as uncertainty as to whether management will exercise the option. The determining factor should be the state of the market at time t. It is precisely because the future is uncertain, especially in a rapidly changing technological environment, that strategic options are valuable. Strategic options allow the firm to take advantage of opportunities if and when they become "in the money."

Management, by possessing information not available to outsiders, and because real asset and/or R & D markets may be inefficient, should create these strategic options in order to capture opportunities where \( P^* \) exceeds \( P \). In this way, and indeed only in this way management creates value.

The literature on applications of option pricing to other areas such as capital budgeting and project valuation is growing. We now review some of this literature in an effort to determine which of the five option relationships previously derived are applicable in the development of corporate strategic options. The five relationships derived, holding everything else constant, were:

1. An increase in the price of the asset will increase the value of the option.
2. A decrease in the exercise price will increase the value of the option.

3. An increase in the variability of the price of the underlying asset will increase the value of the option.

4. An increase in the risk-free rate of interest will increase the value of the option.

5. An increase in the term to maturity of the option will increase the value of the option.

McDonald and Siegall apply option theory to the optimal timing of investment in an irreversible project. As noted by McDonald & Siegal:

"by not (irreversibly) exercising the investment option, the firm retains the right to gain in favorable movement on V-F (revenue less cost), yet it is protected from unfavorable movements because it also retains the option to forego the investment if it turns out that V<F."(note: competitor initiatives can affect timing, and make V<F forever)15

In discussing the option value of waiting, and by assuming risk neutrality, McDonald and Siegal confirm the first three relationships. They observe:

"this occurs because increasing the variance of changes in V (value of underlying asset) will increase the chance that V will have either large positive or large negative deviations from its expected path. The investor is not hurt any more by the large negative surprises than he would be by small negative surprises because in either case there is no need to invest; the investor does benefit from the large positive surprises, however. The result that value increases with variance is a standard property of options."16

14McDonald & Siegal, The Value of Waiting to Invest
15Ibid, page 5
16Ibid, page 17
McDonald and Siegal show that, in contrast to option theory and relationship #4, an increase in the risk-free rate decreases the value of the option to wait. This is because waiting to invest may involve the opportunity cost of waiting. Standard option-theory implicitly assumes that as the risk-free rate increases, so does the rate of return of the stock. In the case of waiting as an option, the costs of waiting (foregone rents) have also gone up.17 Note that McDonald and Siegal are saying that the value of the investment opportunity is lowered not because of any feature inherent in the investment, but because of the cost of waiting.

In another paper, McDonald and Siegal examine the investment decision of a firm undertaking risky projects, assuming that firms can halt the project if revenues fall below variable costs.18 The underlying assumption in this particular paper is that of risk-aversity. The authors derive an equation for the pricing of a claim on stochastic future profit as being equivalent to the expression for a call option on a stock, but replace the stock price with a futures price. They note their formula "exhibits some unusual properties because changes in parameters

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17Ibid, page 18
18McDonald & Siegal, Investment and the Valuation of Firms When There is an Option to Shut Down.
affect both the value of the claim given the futures prices, and the value of the futures prices themselves."

McDonald and Siegal again show that, consistent with option pricing theory, the value of the option increases with the term to maturity. McDonald and Siegal extend the option model and suggest that the time profile of an option claim may actually be hump-shaped, implying that a "claim on the cash flows from projects several years in the future may be worth more than a claim on cash flows from the same project tomorrow or in the far future." McDonald and Siegal add that the hump shape can be removed by (i) lowering the variance of the rate of price increase on the underlying asset, (ii) lowering the exercise price, or (iii) lowering the futures price. The first two alter the option component, while the third alters the futures price. Thus by adapting the option pricing model, McDonald and Siegal show that an option's value may follow a hump-shaped time profile, suggesting an optimum (although as of time zero still uncertain) exercise date.

In discussing variance, McDonald and Siegal conclude that under certain conditions, consistent with Relationship #4, an increase in the variance increases the value of the option. Basically, McDonald and Siegal find that

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19 Ibid, page 10
20 Ibid, page 20
21 Ibid, page 21
an increase in variability increases the option value for a given capital stock at a given point in time, but may lower the present value of a claim on future revenues.\textsuperscript{22} If the underlying asset is positively correlated with the market, this will lower the present value of the claim on the future revenues.

With respect to the risk-free rate, McDonald and Siegal suggest that the effect on value of a project option for a given change in the risk-free rate depends on

"whether the commodity has a price change which is positively or negatively correlated with the return on the market, and upon whether the market risk premium rises or falls with the risk-free rate."\textsuperscript{23}

Thus McDonald and Siegal state that the effect of a change in the risk-free rate is indeterminate, but, in principle, predictable.

Paddock, Siegal and Smith apply an option valuation framework to derive values for offshore petroleum leases.\textsuperscript{24} The authors note that an offshore oil well represents a series of options. First is the option to explore. If exploration is successful, the company then has the option to develop. If the company chooses to develop the offshore site, the company has then explicitly created

\begin{footnotesize}
\begin{itemize}
\item \textsuperscript{22}Ibid, page 3
\item \textsuperscript{23}Ibid, page 23
\end{itemize}
\end{footnotesize}
for itself a final option: whether or not to extract the underlying oil.

In discussing the development option on undeveloped reserves, the authors point to a significant difference between options on real assets (often termed "real options") and financial options. The authors note that, according to financial option theory, "there seems to be an easy solution to the seemingly complex question of when to develop reserves: wait until the last possible date allowed by the government."25 The logical extension is that, if the government would not set a relinquishment date, no company would develop its reserves! This may be the case if there were only one producing firm in existence. Since this is obviously not the case, competition for markets creates incentives for management to exercise the production option within the strategic and operating contexts of the individual firms.

At this juncture the authors point out the difference between a financial option and a real option,

"When a stock option is exercised ... there is no net addition to the supply of the underlying stock. When an undeveloped reserve is developed, however, the net supply of developed reserves increases."26

In spite of this important difference the authors conclude that two important comparative statics still

25Ibid, page 10
26Ibid, page 10
hold (ceteris paribus): (i) an increase in the variance of the price of the underlying asset will increase the value of each of the options, and (ii) the greater the term to maturity of the option, the greater the value of the option. This is consistent with relationships 4 and 3 above. That an increase in the price of the underlying asset and a decrease in future development costs (exercise price) increase the value of the option are intuitive. (Consistent with relationships 1 and 2.) The relationship between the risk-free interest rate and value of the option remains ambiguous.

Thus it is clear that finance theory has recognized that the value of the firm is derived in part by valuing future growth options and that many investment decisions have option-like characteristics. The test of good management is to identify those growth options which may provide a return greater than, or equal to the market return. Recent efforts have seen financial option theory applied to specific project valuation (McDonald and Siegal, June 1982, November 1982), Paddock, Siegal, Smith (February 1983). These papers illustrate that option pricing is applicable to project valuation, especially as many projects have option-like characteristics (option to wait, option to shut down, option to abandon, option to explore, develop, extract).
The papers reviewed in the previous section illustrate that the comparative statics of financial options theory (the five relationships) may not always apply perfectly to project valuation. We are encouraged by two factors: first, that increasing attention is being paid to the dynamic nature of management, i.e. that the art of management can be viewed as the art of managing options; second, that the parameters of option valuation (price of the underlying asset, variance, risk-free rate, term to maturity, and exercise price) have been identified. Management now has insight as to how these parameters affect real options. These factors can then be considered by management in their handling of corporate options.
7. DOD - BUSINESS INTERFACE

The DOD contractor negotiates an IR&D allowance from the Department of Defense. To be precise, DOD Instruction No. 4105.52 dated June 28, 1960 established the Armed Services Research Specialists Committee (ASRSC) which will, upon request by the DOD, review contractor requests for IR&D funds. Initial contractor requests are in the form of a technical brochure which documents the contractor's planned IR&D program on a product-by-product basis. The brochure includes the following information:

- title of the product
- length of time the project has been running and the total expenditure to date
- estimated completion date
- estimated total effort in terms of professional man-hours and the professional grade or classification of the various personnel to be utilized
- summary of past technical achievements under this and related projects in the same field
- a concise statement of the project's objectives, and a narrative description of the technical approach.

The brochures are submitted to the ASRSC by each branch of the military. Each individual project is scrutinized, and in the case of the Department of the Army, the ASRSC representative communicates, on the basis of a point ranking, the evaluation of the individual projects. It is important to note that from a legislative perspective, the only requirement that IR&D must meet is that it must "have military relevance." The technical reviews, and
product need assessments, are at the discretion of the DOD.
8. IR&D: SUMMARY OF CURRENT CONTROVERSY

There exists in congress considerable controversy over the nature of IR&D. There are essentially two opposing viewpoints. One asserts the legitimacy of IR&D, and maintains that the independent nature of IR&D is beneficial and should be maintained. It is no surprise that this is the view held by the defense industry and its various trade associations. The other asserts that IR&D should be more closely controlled by the DOD. The rationale for this argument is that DOD control will lead to a more efficient utilization of funds, and produce products the DOD is genuinely interested in.

To understand the issues, it is important first to gain insight into the nature of the defense industry. In a competitive environment, the costs of associated R&D are ex-ante allocated over the forecasted sales volume, and hence calculated into the sales price. The nature of R&D within the defense industry is different in two fundamental ways:

"First, government regulations on allowable costs (for specific products) and profit ceilings influence, to a large extent, the capital available for company funded IR&D .... Second, the common "winner-take-all" nature of the defense business, together with frequent shifts in emphasis and the attendant dynamic funding introduces a high degree of uncertainty into forecast sales which form the budget base for the company sponsored IR&D efforts."

27Tri-Association Ad Hoc Committee Report to Congress
Using the current widespread mistrust of government intervention, a Tri-Association Ad Hoc Committee on IR&D, under the auspices of the Aerospace Industries Association of America, Electronic Industries Association, and the National Security Industrial Association, presented a Position Paper on IR&D to the Senate Subcommittee on Monopoly and Anti-Competitive Activities. In emphasizing the importance of maintaining the independence of IR&D, the Tri-Association noted:

"It is important that customers do not have any direct control over these expenditures, for if they do, they would impact (and maybe even control) the destiny of the private firms."

The opposition to this view derives from those who want closer control over IR&D funds. In particular, Senator Proxmire and Admiral Rickover have been vocal in their concern over the misallocation and waste of IR&D monies.

The purpose of this paper is not to attempt to resolve this issue. However, we feel that by redefining IR&D as an option new insights into the issues can be gained.
9. **IR&D AS AN OPTION**

A 1970 Report to the Congress by the Comptroller General of the United States notes that:

"In many cases IR&D represents work taken by a contractor before award of a Government R&D contract. The contractor's performance of IR&D may, therefore, result in reduced costs to the Government because of exploratory work completed before the Government becomes committed to the execution of a formal contract." 28

Taken in this context, the Government is not buying IR&D per se. Rather, the Government is buying a product: a call option on a future potential Government R&D contract. That IR&D is analogous to a call option is clear from Figure 4.

**FIGURE 4**

**THE IR&D OPTION**

The Comptroller's Report suggests that by spending money now on IR&D (Stage 1), the Government may save money on future product specific R&D and final specific product

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28Ibid.
development. Additionally, and most important for this paper, should the IR&D prove inconclusive, or should the Government decide that it does not want (for whatever reason) to continue with the IR&D effort after the expiration of the contract, the Government may simply cease to fund the effort. In option terminology, if the option is not in the money, the Government will not exercise its option to continue the research, and will let the option expire at the end of the contract period.

Option Features

The IR&D Option

The main uncertainty attached to the IR&D decision is associated with creating new technology. IR&D can be thought of either as attempts to introduce a new technology, or extend an existing technology. The uncertainties surrounding introducing a new technology are intuitive: the technology has never been proven. The extension of current technology is also risky; as Foster notes, "all technologies have limits,"29 and the closer the firm moves to these limits, the more uncertain and more expensive it becomes to advance the particular technology. Resolution of uncertainties can only be accomplished by either acquiring the needed information from outside the firm (trade journals,

licensing, acquiring patents), or by developing the information in-house. Acquiring the information from outside the firm is obviously less risky, but virtually excludes the firm from developing a company-specific unique advantage. Additionally, we noted above the strategic importance of IR&D, all of which implicitly state the advantage of acquiring information proprietary to the firm, and as quickly as possible. Nevertheless, this discussion illustrates one key issue: the decision of whether or not to initiate IR&D is itself an optional decision, at the discretion of the Department of Defense.

The R&D Option

Once the IR&D has indicated that the technology can either be introduced or extended, the Department has the option to exercise, pay the R&D costs, and, if the R&D is successful, obtain the option to enter into final product manufacture. Hence, possession of an IR&D option is itself an option to obtain potential further research and development results by paying the research and development cost. Recall that this is analogous to a call option on a stock, where the holder has the option of acquiring the stock by paying the exercise price. Where the stock option has a prespecified exercise date, the R&D contract between the DOD and the contractor also has a fixed contract length, at the end of which the DOD makes the production decision.
The Final Product Manufacture Option

Once the DOD has exercised its research and development option, it now has the option of whether or not to manufacture the final product. Valuation of the completed R&D is difficult. However, the DOD could get an approximation on this value through the secondary market for patent and license agreements. At this point, however, all patents and licensing rights of DOD funded IR&D and R&D efforts accrue to the particular contractor, and not to the DOD. We note this inconsistency, and suggest that, in order for the DOD to be able to properly value its option, patent and licensing rights should accrue to the DOD. The market value for patent and licensing agreements will reflect the value of IR&D and R&D efforts with similar final manufacture costs and potential future sales as other projects.

Developing the IR&D Option Model in a Marketing Context

A stock call option gives the option holder the right to buy one share of stock at a given price on a given date. By moving from a single share to all the shares of a firm, and defining the IR&D project as a separate firm on which the option is written, the Government's position as an option holder becomes clear as we define:

\[ e(\cdot) = \text{the expectations operator}. \]

Due to the future uncertainty associated with R&D projects, all payoffs and costs will be in the form of expectations.
the benefits derived from IR&D. Benefits may be explicitly defined as the creation of an option on further development of the past technical effort, the creation of a new path stemming from the past technology effort, or the cancellation of the entire project. Numerically, benefits may be defined as the market price of accruing patents and potential licensing rights. The benefits of all efforts towards IR&D begin to accrue immediately upon initiation of the IR&D effort (learning). For purposes of this paper, we assume that all benefits accruing to the contractor also accrue to the DOD via an opportunity to acquire products technologically superior to those of a potential enemy.

exercise price. This may be thought of as the price at expiration which the government expects to pay for continued research or specific product development deriving from the initial IR&D contract. Cost estimates may be produced by the ASCSC by asking the question "if the IR&D is successful, how much will further research (Stage 2) and final specific product development cost (Stage 3)?"

government dollars invested in IR&D

time to maturity

price of the Government's IR&D option upon expiration of the IR&D contract.
SD = volatility as measured by standard deviation of benefits. Volatility calibrates the riskiness of the project.

The IR&D call option is shown graphically in Figure 2.

Figure 2 illustrates that the value of the IR&D option only becomes positive when \( B > e(E) \). This is the case where the IR&D is successful, where the IR&D option is in the money, and where a Government R&D contract is likely to follow. Upon expiration of the IR&D contract, the option will be in the money when the benefits accrued are great enough such that the DOD will be willing to pay the cost of exercising the option and funding further research or specific product development. This relationship is shown algebraically in Equation 1, and is directly analogous to the option valuation equation derived earlier.

\[
Po > B - PV(E) \tag{1}
\]

Recalling that the benefits begin to accrue immediately and are cumulative, and recalling that the exercise price occurs in the future, we can write the value of the option at any time \( t \) as:

\[
Po(t) > B(t) - PVt(E(E)) \tag{2}
\]

where the \( PVt(\ ) \) operator signifies the Present Value at time \( t \).

Equation 2 provides numerous insights into the value of IR&D to the DOD, and allows us to define option-like parameters which the DOD may use as a framework in valuing IR&D proposals. In order to develop these parameters...
we propose a strategic marketing strategy which the defense contractor may employ in the process of marketing IR&D to the Department of Defense. While we develop the IR&D option valuation framework in the context of a contractor marketing strategy, it is clear that this framework is also applicable to the DOD in their valuation of IR&D projects. Analogous to the financial option framework above, Equation 2 can be used to derive five key relationships. The following paragraphs develop these relationships from a strategic marketing perspective.

Relationship #1: As B Increases, so does the Present Value of the Option

Equation 2 clearly shows that as the cumulative benefits (B) increase, so does the present value of the IR&D option. The marketing strategy to be derived from this relationship is as follows.

The contractor must maximize the DOD's perception of the benefits of a proposed IR&D project, and must keep the DOD informed of the benefits accruing over the life of the project. For proposed projects, the benefits should be clearly detailed in the brochure. For ongoing projects local contractor representatives should keep the DOD informed of accruing benefits in order to allow the DOD to be aware of the value of its option. In delineating the benefits, it is important to note that the benefits accruing from
the IR&D process (Stage 1) may result in benefits accruing to R&D (Stage 2), and/or the final product (Stage 3).

Relationship #2: As $P(E)$ decreases, the Present Value of the Option Increases

This relationship tells the contractor that the DOD is not (or should not) view the IR&D expenditure in isolation. From an option perspective, the DOD should view IR&D in the context of Figure 1, such that IR&D is only the first stage of a three-part acquisition process: IR&D - to - R&D - to finished product. This reinforces the option nature of IR&D: the DOD has the option to halt the acquisition process at the IR&D stage. A key strategy immediately follows: the value of IR&D increases as the future costs of both stages 2 and 3 decrease. Thus the DOD contractor should emphasize it's production efficiencies and low cost for Stage 2 and Stage 3 operations. This may be accomplished by noting past performance, detailing some of the process technology to be employed, and outlining what internal controls have been established to ensure that cost estimated are adhered to.

Relationships 1 and 2 suggest that we modify Equation 2 as follows:

$$P_0(t) > [B(R&D)t - PV(E R&D)t] + [B(Prod)t - PV(E Prod)t]$$

or

$$P_0(t) > [B(R&D)t + B(Prod)t] - [PV(E R&D)t + PV(E Prod)t]$$

53
Equation 2 combines the strategic implications derived from Relationship #1 and Relationship #2. It is clear that the marketing of IR&D should emphasize the benefits accruing to both future R&D and final specific product development, as well as current R&D and final specific product development. Thus, from a strategic perspective, the total core benefit proposition should be clearly understood.

Relationship #3: As the Interest Rate Increases so does the Present Value of the IR&D Option

As delineated earlier, this relationship, although applicable to financial option valuation, is somewhat tenuous when applied to the valuation of real assets. Under differing assumptions about risk preferences and the type of option involved (the option to wait, the option to shut down), McDonald and Siegal derive different implications about the influence of interest rate movements in real option valuation. In discussing the option-like nature of offshore oil leases, Paddock, Siegal and Smith ignore this relationship. A full discussion of the relationship would involve a rigorous analytical approach, well beyond the scope of this paper. Nevertheless, for the sake of exposition, we continue as if Relationship 3 is valid. We leave it to future research to determine if the relationship is in fact quantitatively valid in the context of IR&D, new product development, or creating
corporate strategic options. For now we provide intuitive reasoning as to why this relationship may well be valid.

Upon first inspection, this relationship is not obvious. The key to understanding the relationship is to recall that the benefits from IR&D begin to accrue immediately and continue to accrue over time, while the exercise prices for future R&D and final product development occur some time in the future. Refer to Equation 2 for clarification.

Equation 2 tells us that the higher the interest rate, the lower the present value of the exercise prices, and the greater the value of the option. We assume for simplicity that changes in the interest rate are not reflected by changes in future R&D and product development costs. In other words, we assume that the DOD can set degrees of confidence around these future costs.

The strategic marketing implications follow immediately: DOD contractors should present the IR&D option as being more valuable when economic conditions dictate, or are expected to dictate, relatively high interest rates. This fact would negate any DOD argument that it cannot afford IR&D at a time when money is tight, and interest rates are high.

Relationship #4: As Time to Maturity Increases, so does the Value of the IR&D Option

This relationship is initially counter intuitive, and must be qualified with one major caveat. There is
a natural bias in the DOD to prefer rapid development of new weapons systems, hence a bias for short turn-around times on IR&D projects. In the context of Figure 1, this translates into a shortening of the time it takes to shift IR&D (Stage 1) to R&D (Stage 2) or final product development (Stage 3). This bias is the result of the immediate perceived threat from the Soviet Union.

The basic DOD attitude is one of "we need a new weapons system, and we need it now!" The effect of this short-range view is to encourage short-term IR&D projects. One implication follows: short-term IR&D projects cannot, almost by definition, produce major technological advancements. Rather, short-term IR&D projects will inevitably result in a tendency towards modifying existing technology. New and "novel" technology often requires time to develop. To the extent that such new and novel technology is preferred to modifications of existing technology, long-term IR&D, especially when viewed as an option, becomes more valuable than short-term IR&D.

The business literature has seen several articles criticizing management for its short-sighted approach to planning for the future. As noted by Hayes and Abernathy in their important article "Managing Our Way to Economic Decline:"

"Deferring to a market-driven strategy without paying attention to its limitations is, quite possibly, opting for customer satisfaction in the short-run at the expense of superior products
in the future. Satisfied customers are critically important, of course, but not if the strategy for creating them is responsible as well for unnecessary product proliferation, inflated costs, unfocused diversification, and a lagging commitment to new technology..."30

The strategic marketing implications of Relationship #4 follow immediately: long-term IR&D projects should be marketed as having more value than a short-term IR&D project. Not only is a longer-term project more valuable from an option perspective, but as Hayes and Abernathy illustrate, it may save both the contractors and the DOD from unnecessary product proliferation (modifications of existing technology), inflated costs, unfocused diversification, and a lagging technology (presupposes very accurate intelligence on the current and future Soviet initiatives).

Relationship #5: The Greater the Risk of the IR&D Project, the More Valuable is the IR&D Option

Again, this relationship is not immediately obvious. Traditional marketing theory tells us that consumer's are basically risk averse, demanding to know exactly what it is they are buying before they buy it. It is instructive to compare this traditional approach with the IR&D option approach, where the customer is uncertain of exactly what the final product will be, and in fact, is uncertain of whether or not there will ever be a final product!

30Hayes & Abernathy, op cit, page 71.
In the world of options, the greater the risk defined as standard deviation or variance of returns, the more valuable the option. This relationship has definite strategic marketing implications. For example, one derived strategy may be for the contractor to illustrate a range of reasonable core benefits which may result from the IR&D process. An excellent example is that of the space shuttle. In its initial development, and in the initial requests for IR&D funds, it is more than probable that contractor representatives proposed a wide range of core benefits to the Government. Some possible core benefit proposals already realized include:

- repair station for malfunctioning satellites
- shuttle astronauts to space stations
- launch new satellites
- scientific experimentation

Those core benefit propositions which may have been proposed, and may one day be realized include:

- interplanetary travel
- futuristic defense applications

It is important to note that all of the above examples show high up-side potential, with no apparent downside risk. Again, this is exactly the notion of an option. Once the IR&D option is purchased, i.e., the IR&D funds are allocated, the Government need not spend any more money. If the cumulative benefits do not justify the future exercise price, the DOD will not exercise. A moderately risky IR&D project may have a good chance of being in
the money \[ B > PV(E) \], but a risky project, by definition, will have a better chance of being further in the money. To give a hypothetical example, an IR&D option on a project which shows promise toward developing a jeep which can travel faster than the current model may be "in the money," i.e. \( B > E \). However, an IR&D option on a project which shows promise toward developing light transportation that performs as well as the current jeep, and is armored, yet has a similar cost based on new materials technology, may have a chance of being further in the money.

The IR&D Option Model: A Summary

Thus options pricing theory can be applied to give dramatic insights into the strategic marketing issues surrounding IR&D. We have shown that IR&D can be thought of as a call option, where the exercise price becomes the present value of R&D costs plus the present value of final production costs. Options pricing theory suggests, to maximize DOD cost sharing, that the marketing of IR&D should emphasize:

1. The cumulative benefits of IR&D,
2. The low cost nature of the firm,
3. The significance of the term structure of interest rates,
4. The benefits of longer-term IR&D,
5. The benefits of riskier IR&D projects.
10. **IR&D AS AN OPTION: A DOD PERSPECTIVE**

The evaluation of IR&D as an option was detailed above. In order to gain insight as to whether the DOD perceives IR&D as an option, we questioned Colonel Luke of the U.S. Air Force as to the validity some of the five relationships developed above.

**Question:** Does the DOD distinguish between long-term IR&D projects and short-term IR&D projects in terms of IR&D leading towards a product that the DOD can use?

**Answer:** By nature it tends to be shorter term because to show military relevance, it has to be somewhere where it looks like the application is not too far away ... IR&D, you'll find, tends to be much more applications driven, because we're really looking for (an answer to) "what future procurement is the IR&D going to address?"

The response to this question suggests that, in contrast to our option model, the DOD does not value long-term IR&D projects more highly. As mentioned previously, the perception of a Soviet military threat has the effect of reducing the strength of the time-value relationship. To liken this to a financial option, a financial option with, say, a five year term to maturity, will be worth less to an investor who only expects to live for two years.
We noted the dangers of following a short-term approach above. The United States as a nation, or a company as an ongoing concern, will obviously have no long-term unless it first has a viable short-term. However, while managing the short-term, the nation or company must develop strategies and options for the long-term. (The topic of a corporate option strategy is developed below.) The authors are obviously not qualified to conclude that the DOD is incorrect to have such a bias towards shorter term IR&D projects. We merely state that the DOD should weigh the current perceived Soviet threat with the fact that the IR&D option increases in value as it moves from short-term to longer-term to maturity.

**Question:** Does the DOD favor or disfavor high risk IR&D projects versus low risk IR&D projects?

**Answer:** When the evaluators evaluate the project, they will give high marks to a project that has high risk, but has a potentially very high payoff.

Here's one for the option model! Colonel Luke is restating Relationship #5.

**Question:** Do firms emphasize their low production costs in manufacturing the end product to which the IR&D will eventually lead?
Answer: Generally, unless IR&D is explicitly aimed at reducing costs, (the contractors) will generally not mention costs, and will only say "hey, look at what this thing will do for you," and later on (the DOD) worries about whether it costs ten times as much (i.e., only later does the DOD worry about how much the final product may cost).

This statement appears to be in conflict with Relationship #2 above. However, the Colonel continued: "You have to make it affordable too. They can develop all kinds of neat things that you (the DOD) just cannot afford."

The first quote suggests that the DOD contractors do not include an explanation of their manufacturing cost efficiencies. The second quote suggests that the DOD is somewhat price sensitive, that manufacturing costs do matter, and that contractors probably should include some data on manufacturing costs.

IR&D As An Option: A Contractor's Perspective

To evaluate the contractor's perspective on IR&D as an option, we conducted an interview with Dr. Ronald L. Fonte, Technical Assistant to the Vice President of Operations, AVCO Systems Corporation, Wilmington, Massachusetts. We asked basically the same questions of Dr. Fonte as we had previously asked of Colonel Luke.
Question: Does your firm operate under the premise that the DOD more highly values long-term IR&D projects or shorter-term IR&D projects?

Answer: We think that they will value long-term IR&D projects, and in theory we (more heavily) value long-term IR&D projects, but in practice we actually do medium range IR&D projects ... due to (internal) politics. But we do believe that the DOD does most appreciate the long range IR&D projects.

Dr. Fonte added a qualification that these long-term IR&D projects should probably have multiple year objectives, i.e., all benefits do not accrue at the end of the long-term, but may accrue over the life of the project. Dr. Fonte suggested that five years was a reasonable definition of long-term.

Question: Does your firm operate under the premise that the DOD more highly values high risk or low risk IR&D projects?

Answer: That's a very hard question to answer. I think we like to have a mix of high risk and low risk projects ... I think, personally, that the DOD wants that sort of thing. We try to have a balance, with a few high risk, and a few low risk, but most of them medium risk. We like the novel ideas, but we won't bank on all of them.
**Question:** Do final production efficiencies get mentioned in the IR&D brochure sent to the DOD?

**Answer:** Never ... the selling point is technical.

**Question:** So at the IR&D level you don't think the DOD worries how much the DOD will have to pay for the finished product?

**Answer:** No.

**Question:** Should the DOD worry about it?

**Answer:** Yes. But the people reviewing the IR&D proposals at the DOD are not qualified to evaluate this aspect. The evaluator ask the following questions:

- is it (the IR&D project) technically competent?
- is it well planned?
- is it a fairly novel idea?
- is it relevant to the DOD's interests?

Thus it is clear that whereas production costs/efficiencies should be included in the evaluation process, the personnel currently evaluating IR&D projects for the DOD are not qualified to evaluate this aspect.

**IR&D As An Option: Conclusion**

We conclude that, tempered by the perceived Soviet military threat, viewing IR&D in a manner analogous to a financial option is sound, and will provide strategic marketing insights into how the DOD does, or should, perceive and evaluate IR&D proposals. The relationship between risk and value was explicitly stated by the DOD. Dr. Fonte recognizes this fact, but states that AVCO prefers to
hold a portfolio of IR&D projects with varying degrees of risk. The relationship between manufacturing cost/efficiency and value was strongly alluded to, although not explicitly incorporated into current review practice. The relationship between time and value was, from the DOD's perspective, complicated by the perceived Soviet military threat, while the contractor found that the time-value relationship was complicated by internal politics.
11. EVOLUTION OF IR&D LEGISLATION: MOVING AWAY FROM AN OPTIONS APPROACH

The major impact Government has had on IR&D activity is through legislation. The basic philosophy of the legislation has been one of increasing monitoring and controlling of IR&D activities. The following paragraphs illustrate the evolution of such legislation. We present this section in order to try to understand the thought processes the decision makers followed. By understanding the underlying motivations of the decision makers we will hopefully point out some key issues corporations should be aware of as they plan their option strategy.

Before presenting the evolution of IR&D legislation, it is worth reviewing the objectives of the IR&D program. As noted by Acker,31 the

"overall DOD objective in supporting IR&D is to encourage the evolution and maintenance of a strong, up-to-date, and creative technology based industry, one from which the DOD can draw, as needed, new concepts and rapid responses..."

Acker goes on to note two subordinate objectives:

- Reduced technical risks and development costs through availability of competitive technical options for satisfying new operational needs

- Superior defense capabilities derived from competitive technical options available as a result of IR&D efforts by industry.32

32Ibid, page 44
It is clear from Acker's description that the DOD's objectives are to create technology options; options which the DOD may or may not decide to exercise at any given point in the future. As discussed elsewhere in this paper, the initiation and development of creative technology options necessitates a certain conducive environment. Within a corporation, management has the ability to create or destroy such an environment. The purpose of this section is to examine the Government's impact on IR&D, and to determine if this impact is consistent with a technology-option approach.

The first government mention of IR&D was a recognition that IR&D costs are in fact a necessary cost of doing business in a technologically advancing environment. This recognition took the form of Treasury Decision (TD) 5000 in August of 1940. In TD 5000, the Government was attempting to clarify the issue of allowable expenses that could be charged to revenues of contractors in determining profits that met the requirements of the Vinson Trammell Act, March 1934. The Vinson Trammell Act was designed to control the profitability of defense contractors. Excess profits, defined as "so much of the profits as the Secretary of the Treasury determines to be greater than 10 percent of the total contract cost,"33 were to be returned to the U.S. Treasury.

33Vinson-Trammell Act of March 27, 1934
TD 5000 contained the following description allowing contractors to be reimbursed for research and development efforts:

"Indirect engineering expenses, usually termed "engineering overhead," which are treated in this section as a part of general expenses in determining the cost of performing a contract or subcontract." 34

Hence, it is apparent that, from the year 1940, contractors working for the War Department (currently the Department of Defense), were undertaking research and development efforts and recouping the expenditures as overhead charges to Government contracts.

It appears that the Government, both as a customer and a manager, was beginning to view the defense business from a forward looking cash flow perspective. Costs of products not only had to include labor, materials, and associated overheads, but also had to include the costs of research and development needed to generate advances in technological applications. It is this tie of current expenditures on R&D (with its inherent uncertainties) to current products which has created tremendous conflict in Congress with regards to the entire nature of IR&D funding.

The motivations of the decision-makers of the time are clear: it is obviously necessary and important to account for all expenses when calculating profits. However,

34Ibid, 1934
what is not clear is the necessity of allocating R&D expenditures (benefits not directly related to current products) to current contracts or subcontracts. IR&D has been defined as an option, and often an option on several different future products or options on permutations of a given product. The strict application of expenditures for future product benefits to current specific product contracts distorts the option-nature of IR&D activities. The creation of future strategic technology options should be considered and accounted for, as an activity independent of the manufacture of current products. Later in this paper we present two techniques for resolving the issue of accounting and planning for the development of new technology options. Suffice now to note that, while we do not dispute the importance of recognizing IR&D as a justifiable expenditure, the allocation of this expenditure to current products/contracts is inconsistent with the option characteristics of IR&D activity. Allocating R&D to a current product/contract buries the IR&D option along with labor, materials and other expenses. It ignores the possibility that the particular IR&D, even if related directly to the current product, may also be related to a host of other products, or options on other future products. Thus burying IR&D along with other expenses may hide the strategic important of the IR&D option from the DOD who should be planning the country's strategic portfolio of military equipment options.
A further refinement of the definition of allowable R&D expenses occurred in April of 1942. There, the U.S. Navy split R&D into engineering expenses related to manufacturing of current products, and engineering directed towards the development of technology and future products. This division of cost categories is still in place today. These cost principles were entitled "Explanation of Principles for Determination of Costs Under Government Contracts," and became known as the "Green Book" from the color of the cover. The pertinent sections came under the heading "Engineering Development," and read as follows:

"32. Distinction has previously been made between engineering services related immediately to manufacturing operations (shop engineering expense) and research, experimental and development costs not related to current manufacture but devoted to future improvement in and application products. The cost of the latter research and experimental development work may be absorbed in manufacturing cost on a regular basis by means of absorption rates, on the principle that these activities are usually maintained under a consistent program independently and apart from current manufacturing operations, and that their benefit relates to products on a uniform scale over a period of years more properly than according to actual expenditures in any given year. When these costs are deferred or capitalized in conformity with a consistent plan, reasonable allocation may be treated as a cost of performing a contract.

"33. Alternatively, when it is the policy to charge off actual research, experimental and development expenses currently in each year rather than to use stabilized absorption rates,
a reasonable portion thereof may be allocated to the cost of performing the contract."

The "Green Book's" contribution to the evolution of IR&D policy is significant for several reasons. First, it is important to note the distinction being made between engineering services related to current products, and engineering services related to future products. Although the Green Book fails to address the strategic importance of this distinction, it is nonetheless significant that the distinction was being recognized. Second, it is important to recognize that two methods are outlined for determining R&D costs to be expensed annually by contractors. One allows contractors to "capitalize" R&D costs and amortize them through overhead "absorption rates" on future years. The other simply allows the current years expenses to accumulate and be charged to the current contract revenue. Contractors had their choice, but could not use both. Third, the Green Book did not attempt to define the terms research and development. The interpretation was left to be determined in the contract negotiation process. This is an important issue, as the very definition of IR&D was, and still is, the subject of considerable controversy in Washington.

The first contribution of the Green Book, that of drawing a distinction between engineering services related to current products and engineering services related to potential future products is important. There exists a clear difference between the nature of the work, the significance of the work, and the strategic implications of the work. The apportionment of engineering hours dedicated maintaining current product lines, and engineering hours dedicated to creating growth options for future product lines may reflect a company's fundamental strategy: developing the current product portfolio, or developing a portfolio of strategic technology options for the future. Both the DOD as a customer, and upper management as a charter of strategic direction, should be most interested in this apportionment.

The second contribution of the "Green Book" was in allowing contractors to choose between capitalizing and then amortizing the R&D efforts, or expensing the R&D efforts against current contract revenues. We identify two key issues. First, once IR&D or R&D is defined as an option, the option may have value, suggesting that IR&D expenditures should not be merely written off the books in the year they are occurred. If the option has value as an asset, this practice would understate the asset side of the balance sheet. Second, and in contrast to the above, expensing R&D costs has tax shelter benefits,
suggesting that R&D expenditures are more valuable expensed as opposed to capitalized.

The third contribution of the Green Book was actually made in omission. As noted, the Green Book did not attempt to define the terms research and development. We noted that this omission has been the source of much controversy in the Government. The issue of defining which activities constitute development of strategic options is also controversial. The definition of what constitutes R&D now becomes one of what constitutes development of options? This issue is discussed more fully below.

In March of 1949, an edition of the Armed Services Procurement Regulation (ASPR) was published with changes in the definition of allowable costs. Section XV of the ASPR contained "... standards for the determination and allowance of costs in connection with performance of cost type reimbursement contracts." Two examples of allowable and unallowable costs were given that were general enough to be interpreted liberally or restrictively, depending upon the procurement officer:

15-204 Examples of Items of Allowable Costs

(a) research and development specifically applicable to the supplies or services covered by the contract; ...

15-205 Examples of Items of Unallowable Costs

(j) general research, unless specifically provided for elsewhere in the contract.
As Deardorff notes, these regulations are vague and subject to varying interpretations. With respect to 15-204, it is not clear whether allowable R&D is that which is necessary to fulfill contractual obligations, or that any related IR&D should be included. With respect to 15-205, it is not clear what the significance was of the absence of the word "development." As a result of 15-204, defense contractors began insisting that a general research clause be inserted in the contract. The Air Force responded by requiring contractors to prepare an annual IR&D plan so that proposed IR&D could be evaluated by technical Air Force Personnel. The product of this process was an annually negotiated agreement between the contractor and the Air Force. This was the forerunner of the present procedure for negotiating advance agreements.

The Tri-Association Ad Hoc Committee on IR&D equates the 1949 ASPR as the beginning of a period of retrenchment, describing the regulation as one which "reversed all previous policies and made allowable only those development costs related to a specific contract." The Association observes that it found it odd that the Korean War did not have the effect of liberalizing the IR&D regulations, as would be expected during a period of crisis. The Association

37Tri-Association Ad Hoc Committee Report to Congress
38Ibid.
offers two possible explanations for this phenomenon. First, it is suggested that the Korean War was not perceived as a direct threat to the security of the United States. Second, the Association observes that there was considerable confusion with regard to exactly what technical effort was allowed, since there was no clear definition of "development, general research, or IR&D."39

This stage in the evolution of IR&D legislation illustrates a key managerial issue: the need for consistency of policy. The Association noted that it found it odd that the Korean War did not liberalize IR&D regulation. The Association noted that perhaps the lack of immediate threat to the United States was an explanation for this. Should the Association's explanation be accurate, it would indicate that the DOD ignored the option (future focused) nature of IR&D. Remembering that our option framework is itself an extension of contingency strategy, IR&D conducted during the Korean War would be undertaken to meet potential future military needs, should the needs arise. The fact that the Korean War, while it was being waged, posed no immediate or even foreseeable threat to the United States is immaterial. IR&D, as an option is not designed to meet current or necessarily even foreseeable situations. Rather, IR&D, by its nature as an option on future technology and products, is a contingent hedge against future and

39Ibid.
therefore uncertain (perhaps even unforeseeable) situations. Contingency planning, by way of developing strategic options, should be a continuous activity. It is naive and irresponsible on the part of the DOD (or the management of a firm exposed to a rapidly changing technological environment) to assume that, because the current status quo appears to pose no threat, (to the U.S. in the case of a military threat, or to a firm in the case of a technological threat) that: 1) there exists no threat, or 2) that there will in the future exist no threat. As we shall soon see, complacency in developing strategic options may eventually force the complacent party into playing the difficult and expensive game of catch-up. However, for purposes of this section, we note the Tri-Associations hypothesis explaining the reason for the increased restrictions imposed on IR&D in the 1949 edition of ASPR, and the danger such a scenario implies for the development of strategic options, both in the military and in "high technology" firms.

The early fifties saw the DOD come under pressure from the Appropriations Committee, the Comptroller General, and the Hoover Commission to design a uniform and complete series of cost principles. This effort came to fruition on November 2, 1959 with publication of a complete revision of ASPR Section XV. However, approximately two years before the publication of the revision, the U.S.S.R. launched Sputnik 1 (October 4, 1957). This resulted in a movement
towards liberalizing IR&D. The Association observes "The 1959 revision reflected in part this new mood and finally recognized IR&D as a legitimate cost of doing business."40

The process may not have been as simple as the Association describes. Deardorff notes that, in spite of the Sputnik launch, there was still a widespread DOD belief that at least some constraints and controls should be imposed to ensure that IR&D would be relevant and cost effective.41 In contrast, industry lobbied heavily for Government to avoid establishing controls which would impede contractor incentive to perform IR&D activity. Deardorff observes, however, that there existed a general consensus between industry and government, that IR&D should be encouraged. The question was how best to encourage it?

The debate surrounding control over IR&D activity in 1959 is a reflection of current debate surrounding control over in-house R&D activity. As noted by Rosenbloom and Kantrow in their important article entitled "The Nurturing of Corporate Research," the crucial element, however, is a balance that management maintains between research controls and the freedom and autonomy researchers require to be innovative.42 Rosenbloom and Kantrow further note that research managers they interviewed "strongly believe

40Ibid.
41Deardorff, op cit, page 3.
that the methods (supervision, resource allocation, control, etc.) should be strategic and not tactical."43 As applied to our discussion on the evolution of IR&D, it is clear that both industry and government seek the same end-state. What is not clear, and this is the issue raised by Rosenbloom and Kantrow, is whether ASPR regulations would serve the tactical (short-term) objectives of government (budgets) while potentially sacrificing the long-term (strategic option) objectives. The issue of control versus freedom in the development of corporate strategic options is discussed elsewhere in this paper. For now suffice that the evolution of IR&D legislation contains (at least) one episode where the issue was raised and debated.

The final adopted version of ASPR Section XV gave substantial freedom to firms in allocating R&D costs. Also included was a recommendation that for contractors doing substantial business with the Government, advance agreements on IR&D reimbursements should be negotiated. Three cost sharing approaches were proposed for allocating IR&D costs to Government contracts:

1. Acceptance of allocable costs of certain selected projects. This approach contemplated that non-Government work which benefitted from the projects would also pay its allocable share.

2. Establishment of a flat dollar ceiling for each contractor, an allocable

43Ibid, page 121.
share of which would be charged to DOD contracts.

3. Acceptance of an allocable share of a percentage of all IR&D costs. That is, a percentage of each dollar spent could be put into a cost pool and allocated in an equitable manner to all the contractor's work. This came to be known as cost sharing from the first dollar.

To operationalize the new ASPR cost principles, the DOD issued Department of Defense Instruction (DODI) 4105.52 on June 28, 1960. This instruction established the interface between Government and business in the following way:

1. The Armed Services Research Specialists Committee, ASRSC, was established to review contractor's IR&D programs for the purpose of determining the technical value of the program and to determine that a proper segregation had been made between research and development projects.

A requirement was established for the Military Department to designate a sponsoring department for each contractor whose IR&D costs were substantial in amount, whose business was substantially with the DOD, and who had contracts with more than one Military Department. The criteria for assignment included such considerations as which Department had the predominant amount of work in the plant, which had plant cognizance for contract administration, and division of workload equitably between departments.

Procedures were also set forth to:

1. Require contractors to submit technical brochures describing their proposed IR&D projects for the ensuing years, together with estimated costs.
2. Require the Armed Services Research Specialists Committee to perform technical reviews.

3. Require the sponsoring Military Department to conduct negotiations with contractors and invite the other Department to send representatives to participate.

4. Make the results binding on all Departments whether they send representatives to the meeting or not.

5. Provide that for the cases where agreements could not be negotiated in advance of the beginning of the contractor's fiscal year, negotiation of the contractor's program would be accomplished after costs were incurred.

The Army, Navy, and Air Force each issued instructions for implementing the new cost principles through service specific policy publications. At the time, each department had in place offices that negotiated overhead rates on cost contracts with the defense contracting firms. These offices were to implement the directives, and negotiate advance agreements for IR&D cost sharing and ceilings with contractors. Contractors were assigned to the three Military Departments on the basis of level of business. The negotiated overhead rates were then used across all DOD contracts with the particular firm. Current offices for the respective departments are divided into three segments of the military: Army, Navy, and Air Force.

The three offices became as known as the Tri Service Negotiation Offices. Their function prior to implementation of the 1959 cost principles was quite similar to what
was needed to negotiate the advance agreements for IR&D as noted in the previous paragraph. Thus they were assigned the responsibility for doing so. DODI 4105.52 stated that the advance agreements were to be negotiated:

"in all cases where such costs are substantiated in amount, a substantial portion of the contractor's business is with the DOD, and the contractor's defense work involves contracts with more than one Military Department."

Thresholds of negotiation were set by the Tri Services Offices at 1 million for IR&D expenses, and 50 percent or more of the contractor's total business as the interpretation of substantial.

DODI 4105.52 is a significant step in the evolution of IR&D, as for the first time the decision responsibility for reviewing and allocating funds to IR&D projects was focused at a high level (ASRSC). DODI 4105.52 reflects an understanding on the part of the DOD that there is a need for high level coordination of military technology strategy. As noted by Boris Petrov in his 1982 article entitled "The Advent of the Technology Portfolio," "there is now an emerging consensus that technology management is one of the responsibilities of top corporate management, and corporate technology strategy is an essential element of overall corporate strategy."44 Thus, consistent with now current technology planning philosophies, DODI

4105.52 illustrates the need for high level technology coordination. DODI 4105.52 is a significant step in the evolution of IR&D regulation, showing an increasing degree of sophistication in the evolutionary process.

Shortly after the new cost principles were initiated, controversy between government and contractors began to surface. Throughout the decade of the sixties, studies were initiated by both government and business to try to resolve the issues. The issues covered the full range of activities in the administration of IR&D accounts, including: levels of rates and ceilings, project selection, negotiation procedures, technical evaluation, and funding allocation. Specific recommendations were presented and debated by the DOD and other agencies involved or interested in IR&D. The Office of the Secretary of Defense formed steering groups to carry out studies and interface with the contractors. Cognizance of the studies spread to other offices and agencies in the Government. The increased interest and debate of IR&D policies within the Government created a very slow and deliberate climate for the development of new directives. As a result, no new policy was to be set until 1970, and this was only after a considerable amount of interaction between Government agencies and the defense contractors. Before action was taken in applying the new policies, Congress began to investigate the issues surrounding IR&D. Almost immediately, legislation was
passed as an amendment to an Authorization Act (Amendment 123 of PL 91-121). The last clearly stated limits and sources of IR&D funding, but proved to be impossible to apply, and was repeated the following year.

One interesting issue under consideration was the attempt to find a simple yet efficient way to evaluate the reasonableness of IR&D costs. As Deardorff notes, the process of negotiating advance agreements was very costly to contractors and the DOD because of the manhours required to prepare IR&D brochures, make the evaluations, and negotiate the agreements."45 To remedy this situation, an "industry norm" approach was suggested. The "industry norm" approach was to derive the relative proportions spent by different industry segments such as airframe, electronics, shipbuilding, etc., and to apply these norms (averages) as a multiplier to determine allowable IR&D costs. In such a scenario, the expenditures of an airframe manufacturer which exceeded the industry average, would be deemed unallowable. To gather data, a questionnaire was filled out by industry. However, the data showed a negligible correlation between contractor expenditures. Deardorff writes: "Some of the more innovative companies spent considerable sums while others whose business did not require the latest technology spent very little."46

45Deardorff, op cit, page 10.
The reader will not be surprised to learn that the "industry norm" concept was found to be inappropriate. Nevertheless, the search for a simple formula continued. Another proposed approach was to derive an individual company's historical IR&D expenditure, and calculate an average expenditure which would serve as a ceiling. Data from the larger contractors from the years 1963 through 1966 were applied, and a variety of formulae were studied. A copy of the January 1968 draft formula is presented below.

"The formula included in the January 1968 drafts was essentially the same as that now included in the present DAR cost principles except for the limit on cost increases. Under the present formula costs incurred for IR&D and for B&P in each of the past three years is related to sales or another acceptable base for each respective year to compute a ratio. The two highest of the three ratios are then averaged and the resulting ratio is applied to current year's sales (or other base if used) to establish the dollar ceiling. In a second step the actual costs incurred for each of the past three years are determined and the two highest are averaged. The resultant figure is multiplied by 120% to determine the absolute limit. The ratio computation then becomes the ceiling so long as it does not exceed the 120% limitation. A floor is also established by multiplying the dollar average by 80%. Thus if the ratio to sales computation produces a number below the 80% figure, the 80% computation governs and costs will be allowed up to that amount."

Thus it is clear that the 1960's was a decade of considerable uncertainty with respect to IR&D policy. What is not clear is the impact such uncertainty had on contractor IR&D planning and activity. We could not gather any evidence to show the impact of the uncertainty on
contractor IR&D efforts. However, we expect that to the extent that legislative uncertainty was equated with a higher business risk (i.e. legislative [government funding] risk is but one of the risks of doing business in the defense industry), IR&D projects which would have otherwise been accepted were either delayed or cancelled as contractors waited for a resolution of the uncertainties.

Intuitively, the more unstable the environment surrounding the development of IR&D and other strategic options, the less free are the relevant personnel in developing these options. In this context, Rosenbloom and Kantrow suggest that one key element in the strategic management of corporate research is the establishment of a "research charter."47 The purpose of a research charter is to create within a company an understanding of research's corporate mission, and to use this understanding to create a stable environment within which research can operate. Therefore we can learn from the evolution of IR&D legislation in the 1960's. We can hypothesize that unstable environments probably had an undesirable effect on contractor IR&D efforts.

Congressional interest grew rapidly and led to a series of hearings conducted by the Senate Ad Hoc Subcommittee on Research and Development in early 1970. The House also held hearings with the Armed Services Investigating Subcommittee of the House Armed Services Committee during

47 Rosenberg & Kantrow, op cit, page 119
March of 1970. The DOD prepared recommendations under the direction of the Deputy Secretary of Defense. Five points were contained in the DOD position and were presented to both subcommittees of Congress. The DOD also recommended that implementation of the policies should be accomplished without legislation. Both the House and the Senate generally accepted the five point recommendation, but the Senate favored legislation to implement the policies. The House and Senate had modified the DOD policies somewhat and were in disagreement on some of the details. These were resolved through the House and Senate Conference Committee before Senate legislation was drafted. Public Law 91-441 was passed in October 1970 containing IR&D and B&P legislation in section 203, and has remained unchanged, except for negotiation thresholds, to this day.

Again, the DOD had to prepare guiding regulatory publications. The final document, Defense Procurement Circular 90, was published in 1971 after revisions to the DOD IR&D and B&P cost principles had been made to reflect the enacted legislation. Here again, the only changes since have been in the negotiation thresholds to account for cost increases due to inflation. Major points contained in the circulars were:

1. Defense Procurement Circular number 75, which implemented the previous legislation in PL 91-121, was rescinded.

2. The requirement for technical evaluation of contractor's IR&D programs and
review for potential relationship to a military function or operation were made mandatory.

3. In accordance with the legislation requiring substantial reduction in payment for IR&D and B&P when no agreement was reached during advance agreement negotiations, a limit of 75% of the amount the officer would have allowed was established.

4. Each Military Department was directed to establish a three member appeals hearing group to hear appeals of contractors on advance agreement disputes.

Tracing the course of historical development of IR&D policy shows a lack of Congressional involvement until the 1970 hearings and legislation. Reasons for this are not clear, but speculation would indicate that the issue of IR&D funding was brought to the fore because of the strong initiative by President Nixon to cut research and development spending during that time.

Indicative of the cyclic nature of attention paid to IR&D and B&P funding by Congress was the action taken by the House at the end of the 1982 session during continuing resolution. In September of 1982, the House Appropriations Committee declared that IR&D funding was money the Government was not monitoring and that there was a lot of duplication of effort. Basically, they wanted to slash, actually to zero, the IR&D budget. Many Congressmen on the Defense Appropriations Committee had no idea that this was taking place. At the "eleventh hour" Congressman Adabbo attached a bill to the continuing resolution that nobody was prepared
for. Everybody was anxious to get home for the holidays, and supporters of strong defense on the appropriations committees had no idea that it was attached. The bill stated that the IR&D budget would be held constant for 1983, and that it would become a line item in 1984 and beyond — unless the Government could show that it would be counter-productive to do so. The continuing resolution was passed with the IR&D bill attached.

The bill immediately brought intense pressure from the Aerospace Industries Association, and many individuals within the defense contracting industry. The effect of the legislation would be eventual line item control of all IR&D expenditures, this being exactly the opposite of what defense contractors would prefer. Industry's position was, and is, that line item control of IR&D defeats its purpose. It was difficult for industry to understand how Congressmen could be saying that the survival of our nation depends on our superior technology, while at the same time trying to slash the IR&D budget whose express purpose is to advance the state-of-the-art of technology.

The Adabbo Bill of 1982 is an important stage in the evolution of IR&D legislation. Line item control means that each IR&D project would be a specific budget line item. Each IR&D project would have to be contracted to companies as a separate contract, with the requisite work breakdown, line item task description, project objective,
and payment for all of these agreed to by the Government in advance!

The Adabbo Bill is a clear movement away from viewing IR&D as an option on future military products. One key feature of a strategic options approach is the importance of flexibility and change. Line item control would result in a greatly reduced flexibility, and a much more rigorous application of financial control. We discuss the implications of such control on the development of strategic options elsewhere in this paper. For now we expose our bias and suggest that the Adabbo Bill is totally inconsistent with a goal of developing strategic options: independence is what makes IR&D unique as a government project. Contractors have the freedom to evaluate their IR&D projects on an ongoing basis. If a project doesn't look promising relative to needs of the customer (the DOD) then the contractor can cut the project off immediately. If, on the other hand, a project, or set of projects really looks promising in terms of eventual product development, the firm can escalate the funding quickly. Directed R&D contracts with the DOD can take many months to shut off or increase given the same resolution on the imminent success or failure of the project. In addition, there would be a tremendous amount of paper work, management and engineering time, and negotiation needed to administer the line item control of IR&D, burdening the firms with more overhead. The
defense contractors had a large stake in getting the bill rescinded from a purely business perspective, from a flexible options perspective, as well as a more personal national survival point of view. The bill was completely rescinded nine months later with a complete capitulation by the Chairman of the Defense Appropriations Subcommittee (Adabbo).

From a management perspective, Rosenbloom and Kantrow note: "Although an emphasis on financial rigor is usually good, many managers have learned that it can breed a corporate short-sightedness in which only near-term, quantifiable factors have weight in long-term strategic choices."48 The DOD, like any firm in a rapidly changing technological environment, should understand that the process has a large degree of uncertainty in the direction the threat will take, and the success of technologies being developed in response to those threats. Responsiveness in a rapidly changing environment is dependent on the number of options that are available to effectively handle the uncertainties of technology and threat.

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48Ibid, page 118.
<table>
<thead>
<tr>
<th>Date</th>
<th>Issue</th>
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<tr>
<td>August, 1940</td>
<td>Recognition of IR&amp;D as cost of doing business. IR&amp;D written off against specific product contracts.</td>
</tr>
<tr>
<td>April, 1942</td>
<td>R&amp;D divided into engineering expenses related to manufacture of current products and engineering expenses related to development of technology and future products. Two methods to determine R&amp;D costs: capitalize and amortize, or expense as incurred.</td>
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<tr>
<td>March, 1949</td>
<td>Vague distinction between allowable (R&amp;D related to specific contracts) and unallowable (general research). Restrictive regulations imposed during period of war.</td>
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<tr>
<td>1960</td>
<td>Creation of high-level organizations within the military to review IR&amp;D projects. Recognize need for focused strategic options planning.</td>
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<tr>
<td>1960-1968</td>
<td>Decade of uncertainty</td>
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<tr>
<td>1982</td>
<td>Adabbo Bill proposing IR&amp;D become a line item.</td>
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<tr>
<td>1983</td>
<td>Bill rescinded.</td>
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12. THE IR&D RATE AND CEILING NEGOTIATION

The following paragraphs are a paraphrased version of an interview with Mr. R. Millman, Director of Government Relations, AVCO Systems Division, Massachusetts. Mr. Millman is the corporate negotiator for IR&D funding. The authors feel that the attitudes and emotions expressed by Mr. Millman during the interview are relevant in that the negotiation is described as a purely adversarial event. The interview was edited to make it read as a narrative, with all emotion and language retained to capture the flavor of the negotiating process. The following paragraphs are a synthesis of the conversation with Mr. Millman.

Before the actual negotiation takes place, a briefing is prepared that explains why a major increase in allocated IR&D budget is justified. It is then presented to the procurement agency negotiators before the actual negotiation takes place. These individuals are representatives of the Tri Service Offices, and a procurement agency from one of the Military Departments. In AVCO's case, we negotiate with the Army. A few years ago it was with the Air Force. This was due to the fact that, at that time, we did over half of our business with them. In the interim, we shifted to over half with the Army, and now we are back to over half with the Air Force, but we are still negotiating with the Army for funds in their IR&D budget. Things haven't caught up yet. The Army gets an allocated budget
and we negotiate within their ceilings. Typically the Government only pays for about 50 percent of what they negotiated for a ceiling. They negotiate a ceiling that says you can spend this much on IR&D and B&P and that is part of your General and Administrative rate (G&A, i.e. overhead). Typically a contractor has 50 percent Government (DOD) work and 50 percent commercial work and, by law, you must charge the same rates for the same kind of work. So the commercial customers end up paying for half of the IR&D.

The negotiation is carried out with the procurement side of the department, not the technical side. The technical side does the technical monitoring of IR&D programs. They read reports and determine whether or not the programs have military relevance. To accomplish the technical evaluations they read reports (brochures) submitted by the contractors, and they listen to presentations at on-site visits.

Procurement people that we negotiate with are basically bean counters, they're professional negotiators. If you've ever been involved in a negotiation with an auto salesman, or a labor negotiation, you know it has nothing to do with the technical issues, it has nothing to do with your needs, your perceptions of your needs, or his perceptions of your needs. It's a negotiation, you chew a cigar, and you wait.
In an R&D (not IR&D) contract negotiation with the Government, you first go through a fact finding session, a formal term for having the technical side participate. They (Government) say "you (the contractor) say on page X in your BOE (Basis of Estimate sheets that were submitted to the procurement agency prior to the negotiation - these are estimates of the man hours necessary to do the work that has been broken down to the lowest possible task level) that its going to take 312 hours of engineer grade II, 57 hours of engineer grade I, and 502 hours of technician grade II to do that work. Well I don't believe it, its bullshit! On what do you base that?" And you answer "well last year we did similar work on a similar program and that is how long it took, or it took twice as long and this is simpler, or vica versa" (you get the idea). You can't write down based on good engineering judgment. The technical people argue up and back until they reach a position that is agreeable. Then they (the Government technical people) go away and reach a decision on how much they think the job is worth. Then you go to negotiation and its cigar smoking time. The Government says they will offer you this much for the work and if you don't agree to it, there is another contractor down the hall they can go to if they can't negotiate with you. We are looking at our tradeoffs on cost, risk, profit, etc., to decide what we want to offer as a counter. There is
a point the contractor gets to where if the negotiator doesn't give you that much cost, it's not worth it because you are likely to over-run the contract and blow your reputation. It's a negotiated settlement, all business and nothing to do with the technical aspects once a basis has been decided from the original technical discussion.

In IR&D negotiations, technical issues have absolutely nothing to do with it. You have a proposed bunch of tasks and the negotiator couldn't care less about them. You have scores from last year that show you have come up, you're doing better. You ask him if this has been taken into account and the negotiator says "yep, taken it under full consideration." This is the comment you get every time you bring up points mentioned in the DAR (Defense Acquisition Regulation). The negotiator does not care about all this, he wants to keep your number (dollar allocation) down because he gets brownie points for how much he shaves off of the number you requested.

As an example, last year the DOD came in with a decrease (as a result of the Adabbo bill) for us in IR&D and B&P as a starting point for the bargaining. We negotiated for a half a day and broke off. We could see that we would not get anywhere looking at what we needed and what they were offering. We went to see a general two levels above the negotiator and asked "how can we even think about a negotiation when you start at this point?" About
this time Congress was acting and rescinded the Adabbo bill. We eventually settled for a 14 percent increase after asking for 60 percent. Everyone thought we did so well with the flat budget constraint.

There is basically no formal appeals process if agreement cannot be reached. The Government will give the contractor what is called a "unilateral" if a negotiated settlement is not reached. A unilateral is a ceiling on IR&D and B&P reimbursement that is 75 percent of the Government's final, unaccepted offer. There is definitely an incentive here to reach a negotiated settlement. If a unilateral is given, the contractors will, almost invariably, go to their congressmen, and neither the negotiators nor the contractors want to involve congressmen at that level. So, they both try hard to reach an agreement.

In last year's case, because of the increase in business, AVCO went to the negotiations looking for what we though was a reasonable request for a 60 percent increase in allowable IR&D and B&P spending. Because of the large jump, and the fact that Congress had put a ceiling on IR&D, the negotiator came to the table with what appeared to AVCO a ridiculous offer. This offer was so far from what AVCO was asking, we knew agreement couldn't be reached without going to the head of the procurement agency, explaining the problem, AVCO's position, and asking for some relief
so the negotiation could go forward (which it eventually did).

The actual negotiation process starts with a sales pitch (introduction) with the message that AVCO has an excellent history of performance, is research and development oriented, has the resources to make the investment payoff, and has an overhead structure that will benefit from heavy IR&D funding up front. Forms have been submitted to the government which show past actuals (sales, IR&D, etc.) and proposed programs, forecasted sales, commercial government breakdown, etc. The government technical side has submitted a technical evaluation (score) to the negotiator, with a judgement on the potential military relevance (PMR). Some changes on PMR can occur at the beginning of the negotiation. Audit questions will come up early and the financial people will discuss those and clear them up. Most of the questions come from the forms showing projections. Then it's negotiation time. They give us a first offer and AVCO will caucus (go to the men's room and vomit) and decide on a counter offer, always keeping in mind that there is a point at which we are willing to split the difference. Some technical input will be presented to justify the counter but it is truly irrelevant. The negotiator is not a technical person and couldn't care less. It is a strictly adversarial process where both parties try to reach the point where splitting the difference
is attractive. Technical support is only called upon when added verbiage is needed by the contractor's negotiator. There is, at this point, no tie to what is trying to be achieved technologically. It is a dumb process. It is difficult to determine if you are really doing the best thing for the company by reaching a common agreement without any rationale. The process usually takes a day because you really have nothing to talk about. It is not mental or intellectual. You use the words, the verbiage, and timing as a tactic. The Government negotiator's responses to comments will be on totally different subjects. It's a negotiation, not a conversation.

Clearly, by the time AVCO went to the negotiation there was no opportunity to influence the outcome. Mr. Millman was queried regarding the level of IR&D funding expected for 1984, and he answered, "we know going in what we will settle for, we know what their offer is going to be, and we know what we are asking, so we know where the middle ground is."

At this juncture, the IR&D interface is purely adversarial, and probably of little value to either side except that the Government can control spending, to a degree, to the budgeted levels. An important factor in the entire process is the divergence of goals between the Government negotiator (representing the procurement side of the Department) and Mr. Millman. The Government negotiator is described
as a "bean counter." He is not interested in the projects themselves, their military relevance or the firm's ability to perform the projects. All the Government negotiator concerns himself with is dollars: What is his final dollar allocation going to be. Indeed, Millman suggests that the negotiator is to some degree rewarded according to how much he can reduce the firm's request. In contrast, while Millman is obviously negotiating for dollars, Millman is able to make the dollar allocation - importance of project connection. Thus, the company negotiator is actually negotiating for more than just dollars.

It is clear that decisions made as a result of these negotiations may have long-term strategic military implications. It is also clear that these long-term strategic military decisions are being based on an adversarial negotiation process where these strategic implications are rarely (never) discussed. The underlying explanation for this derives from the fact that, in separating the procurement and technical evaluation (read strategic) functions, the DOD has in essence mandated a division between the need for budgeting and control (procurement) and technical strategic evaluation (technical). By placing the final responsibility for budget allocation solely on the procurement side, any technical input beyond preliminary assessments are basically ignored, and the negotiation process becomes driven by dollars, not strategic planning.
From a corporate perspective, the IR&D negotiation process outlined above mirrors the often practiced separation of the strategic planning function from the resource allocation function. By separating these functions, and the bottom-line responsibility for each, management is in essence reducing the role of strategic planning to that of dollar negotiator. To the extent that the capital budgeting decisions concern themselves with time zero discounted cash flow calculations, the strategic planning function will find it difficult to discuss creating strategic options. In the next chapter we discuss the implications of the option analogy for strategic planning and capital budgeting. However, it is clear from the IR&D negotiation process that a distinct separation between these two functions may not be optimal.
13. **IMPLICATIONS FOR TECHNICAL NEW PRODUCT DEVELOPMENT**

Up to this point we have discussed the nature of IR&D as being analogous to a financial option purchased by the DOD. We have seen that the DOD is not purchasing IR&D per se, but is purchasing an option of further R&D effort and final product manufacture. Further, we have seen that the contractor can gain applicable strategic marketing insights by viewing IR&D in this context.

The purpose of this section is to apply the insights gained by this approach to the process of technical new product development within the firm. The IR&D option approach developed above can be applied to the case of technical new product development within a firm by allowing the customer for IR&D efforts leading to new product development be the top management of the firm (and hence the shareholders). The same factors that lead to the value of the IR&D option from the perspective of the DOD will also create value for, and influence the allocation of resources to various technical new product efforts within the firm.

We return to the new product development model present in Chapter 2 and specifically focus on facilitating idea generation and screening using the option analogy.

First it is appropriate to make some assumptions concerning the organizational structure within which the option analysis will apply. New product development can
be the responsibility of several groups within an organization. Some of these include the R&D group, Marketing, Main Line Business groups, and venture groups. The R&D unit is a logical starting point since it has the technical research knowledge and the product development capabilities. However, many have argued that the Marketing group is the key to new products since it retains the information about consumers and markets, and studies have shown that 60 to 80 percent of successful new products arise from the recognition of market needs and demands.49 In the case of DOD contracting there is a veritable plethora of information available as to current and future customer needs. The DOD publishes one year and five year procurement planning documents which are readily available to contractors. In addition, each of the three service arms has strategic and tactical (S&T) planners who use intelligence information on the threats, and available products and technologies in planning for the military needs of the future. The DOD and each service also have laboratories which are closely associated with the S&T planners. These laboratories often serve as a bridge between industry and the S&T function in transferring technology and product ideas back and forth between the contractors, labs, and S&T groups. We have found from industry experience and in the interviews

that contractor marketing personnel are most often the people charged with managing the interface with the government labs. Nevertheless, both R&D and marketing functions are vital to the successful development of new products. Marketing must identify new product needs while R&D must develop new products and technologies to fulfill those needs. This leads one to suggest a unit or group that integrates the two functions, a New Products group or a Venture group. These units employ both functional perspectives.

Overseeing the resource allocation is top management. Corporate executives have two broad responsibilities: maintaining and improving the efficiency of existing product lines and selecting new areas for future business growth. Top management controls the future course of the company by investing today in the projects of tomorrow through the resource allocation process. In this stage top management can award corporate resources to projects in two broad areas; opportunities identified in the main line businesses, and new technologies or products not directly associated with the main line businesses. We will make a distinction here that the venture groups are responsible for idea generation and product development in the area of new technologies and products.

During the resource allocation stage, Venture groups must compete amongst themselves and the mainline business
operations for scarce corporate resources. The reality here is that top management becomes a venture capitalist group looking for places to invest funds, while at the same time the Venture groups are attempting to get top management to buy-in to their ideas. In essence, Venture groups are developing options for the future of the organization. In this light, we can see the importance of operating in some approximation of a free-market environment where venture groups compete for funds within the organization.

At this juncture, we will make some assumptions about the overall objectives of top management in a DOD contracting firm. We will assume it is important to top management to:

- ensure the long term survival of the business
- foster entrepreneurial activity and talent
- retain technological competitiveness (see appendix to Chapter 14)
- sustain real, long term growth

These few assumptions by no means encompass all possible objectives of top management of a firm, but they suffice to justify the need for new technology/product development in an organization. Foster and others (see addendum to Chapter 13) have identified technological discontinuities as major threats to businesses based on mature technologies. The research also points out that very few firms are successful in transitioning from familiar to new technologies. The reasons given have to do with timing and culture. First,
by relying on economic indicators, they do not recognize that a discontinuity in technology has occurred. Thus the firms are often left in a position of playing catch up, or retrenching to a defensive position with the old technology. Both have been shown to be unsuccessful in reacting to technological change. Second, there are cultural barriers to absorbing and managing new technologies which take top management commitment and time to overcome.

We believe that the option approach to evaluating IR&D projects can be applied in a manner that specifically addresses the above issues. If base line businesses are subject to discontinuities, then the implication is that future growth options have the added burden of ensuring long term survival of the firm as well as growth over and above the base line business. It is not clear that a geometrically increasing risk adjusted discount rate takes the possibility of a discontinuity into account when treating cash flows of a firm as a perpetual annuity in valuing a firm. We suspect that it does not, indicating that technology based businesses are riskier than a DCF model would indicate. In other words, the capital market and other economic indicators may not be relied upon for predicting catastrophic results of a technological discontinuity (precisely what Foster says). Defensive tactics have the perverse effect of delaying the inevitable decline, producing a short term feeling of well-being, and absorbing

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resources that could be applied in a proactive stance, early in the game.

In this chapter, we will focus the option approach on new technology/product development with the intent of producing major new opportunities for a firm. We will return to the five option relationships and derive implications for idea generation and screening in an organization.

Relationship #1: As the Benefits From R&D Increase, so does the Value of the New Product Development Option

Relationship #1, as applied to the firm, states the intuitive reason to undertake IR&D into new products: to derive benefits. In this context, benefits may be defined as advancement of knowledge leading towards development and manufacture of the finished technical product. Again we restate that the fundamental value of IR&D lies in its link to future markets. The benefits of knowledge etc., are then the claim on future markets that a firm holds by investing in a new technology/product. We recognize the obvious nature of this relationship, but we warn that it is easier seen than done. This is an important point. Past new product development efforts still have value even if the final product has not yet been introduced to the market. These past efforts may give the firm the option of rapidly introducing the product if market conditions dictate. This is exactly the value of an option. In this context, IBM's recent research effort into Josephson
Junctions have given the firm a valuable asset: the right to introduce Josephson Junctions if and when the market is ready to accept it.

Intra-firm communication is therefore very important in order to allow management the information to properly value their new product development options. In the IR&D case, the contractors dispatch marketing representatives in order to keep the DOD informed of the value of its IR&D option. Translated to a firm level, it is clear that the Venture group should continuously inform management of the status of their work in order to allow management to monitor the current value of their options.

Relationship #2: As Production Costs Decrease the Value of the Product Development Option Increases

Relationship #2 clearly illustrates the need for a coupling of manufacturing strategy with overall corporate marketing and new product development strategy. Relationship #2 states that IR&D and new product development must be viewed as a component of the "big picture" i.e., the question should be asked at the new technology/product development stage "if the efforts are successful, how much will the life cycle costs of production of the finished product be? Further, by viewing the technical new product development effort as a three stage process, Relationship #2 serves to remind management that the time to exercise options
to expand contract, continue or cancel is early in the effort, before large scale production is initiated.

Relationships 1 and 2 can be integrated to further clarify the types of information to be communicated between top management and the venture groups. From a financial option perspective, the higher the stock price relative to the exercise price, the greater the value of the option. In new technology/product development, the stock price is analogous to the future market value of the product plus the growth opportunities arising from the new technology.

As the expected benefits of the new product increase relative to the costs of developing and producing, the value of the option increases and vica-versa. The combined relationship shows that it is important for the venture group to integrate the marketing and technical information at each stage to make an assessment of the spread between the project value and costs.

This concept is nothing new. Except for the growth options portion of value it could be forced back into a discounted cash flow model. For the firm searching for major new technologies/products, the growth options value will most likely dominate the value of the option. To sell, and keep sold, a project to top management, venture groups should highlight the growth options made available by investing in the project.
Relationship #3: As the Interest Rates Increases, so does the Present Value of the New Product Development Option.

This relationship is difficult to accept on an intuitive level, but does have merit when we recall that new technology/product development efforts provide instant benefits such as learning, while manufacturing and sales costs are still future costs. We anticipate the resistance such a relationship will meet in the business community. Indeed, it is exactly when interest rates are high that a firm may find itself in a cash squeeze, with R&D often a first target for cutbacks. Additionally, high interest rates impose high cutoff rates, often resulting in a further cutback on R&D and new product development activity. These phenomena could be present in firms applying a DCF approach to capital budgeting.

Relationship #3 challenges these forms of thinking, stating that new technology/product development efforts are more valuable in times of high or rising interest rates. We note that this option approach is not as far-fetched as it sounds, and is actually a formalization of the business principle: in times of a recession (often characterized by relatively high rates of interest), the firm should be planning for the upcoming boom; in times of a boom (lower relative rates of interest), the firm should be planning for the upcoming recession. The above discussion implies a decoupling of the R&D investment rate from short term fluctuations in sales. A strong case can be made
for insulating long term competitive imperatives, i.e. R&D, from short term profit pressures.

Relationship #4: The Value of R&D/New Product Development Efforts Increase as it's Duration Increases

As with the case of the IR&D option above, this relationship is at first glance counter-intuitive, and must be weighted by a major caveat. Just as the DOD prefers a rapid development of weapons systems in order to face the perceived Soviet threat, so does business prefer a rapid development of new products in order to meet competition and achieve sales/profit objectives. The implications of this short term approach were discussed above for the DOD and apply equally for new product development within firms.

The strategic implications of Relationship #4 are clear: new technology/product efforts should not be more highly valued solely if they are of a shorter duration. If a new technology/product is to be innovative in nature, it may take a longer-than-desired time to research and develop. The point is that this longer-than-desired time frame should not, in and of itself, lead to rejection or cancellation of a project. Indeed, the option model suggests that it is the longer term projects which may be the most valuable.
Relationship #5: The Greater the Risk, the Higher the Value of the R&D/New Product Development Option

By measuring risk as the standard deviation of expected benefits, we see that the value of R&D and new product development increases as the risk increases. Relationship #5 is counter to a "conservative business ethic" of attempting to avoid risk. This conservative ethic has no place in the dynamic arena of IR&D and technical new product development. It is clear that all the firm can lose is the price of the R&D/new product development option: i.e., the investment in the R&D and new product development effort. Hence the right hand side of the probability distribution is the relevant range of outcomes to focus upon. The greater the dispersion, the more valuable the option.

However, the left hand side of the probability distribution does become relevant when the firm considers its losses from not investing in the buy-in price should the market option come in the money. In this sense, the initial buy-in price, by providing the firm with an option, may prevent the firm from suffering revenues lost by not being in a position to exercise. Hence the higher the standard deviation, the more the firm will want to pay the buy-in price and create for itself the option to exercise.

Thus the option model serves to illustrate several key factors concerning new technology/product development. First, it is clear that such undertakings require a different management perspective. A different mind-set
is required to evaluate the new technology/product development option, with the manager having to consider factors in a fashion often diametrically opposite to traditional managerial philosophies. This type of approach is needed at the highest level of the corporation in order to ensure that the new technology/product development option is properly managed and evaluated.

The option approach to new technology/product development necessitates consideration of such "radical" notions as:

1. New technology/product development efforts should not be viewed as a "black box," and should include explicit consideration of the firm's ability to manufacture and sell the end product.

2. New technology/product development may actually be more valuable to the firm when interest rates (and correspondingly cutoff rates) are high.

3. New technology/new product development efforts may be more valuable if the effort is long-term in nature.

4. New technology/new product development efforts may be more valuable the greater the risk.

Given that top management recognizes the need for developing major business opportunities as opposed to incremental additions to basic line businesses, it is proposed that the option approach be used to qualitatively assess new product proposals. As pointed out the option approach will give more value to longer-term, riskier projects. These types of projects are more likely to have high payoffs (be further in the money in options

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jargon). They also are closely tied to the threat of technological discontinuities. Within the context of a given base line business, technology is a variable that can change the competitive position of a firm. Using the option approach for idea generation and screening can free up the culture of a firm and allow a proactive posture to be taken in new technology/product initiatives.

For the options framework to succeed, the firm must develop a culture for new product development. First of all, top management must thoroughly understand the theoretical arguments derived from financial option pricing. Once this is done, management must communicate this new framework to the venture groups responsible for idea generation and the new technology/product development process and must reinforce it during the resource allocation procedure. This way venture groups will apply the option framework in their own analyses, since they must sell their product options to top management when competing for funds.

Once top management and the venture groups employ the option approach, an environment will result that encourages idea generation focused on producing major opportunities.
ADDENDUM TO CHAPTER 13

SUMMARY OF TECHNOLOGICAL DISCONTINUITIES

Articles by Cooper, Schendel,50 and Foster51,52 point to a danger that technology based companies face revolutionary changes in technology. This section will summarize arguments as a basis for integrating financial options pricing theory as a supplement to the process of planning for major new business opportunities in an organization. We take it as a given that managers of large companies are interested in the long-term survival of the business entities they manage. If so, they must be concerned about developing new business opportunities that are not likely to be based on incremental additions to the base-line businesses the companies are currently running. As the research of Cooper, et. al. shows, in the long run firms must be aware of technological discontinuities that can occur which pose potential threats to their traditional lines of business.

A number of companies are identified in the studies which suffered major losses of business as a result of fundamental technological changes in their respective industries. Each of these companies was a leader in a

52Richard Foster, Why America's Technology Leaders Tend To Lose, Delivered to Town Hall of Los Angeles, L.A. California, March 8, 1983.

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market based on the technologies which were supplanted. These companies were well managed and had the classic advantageous position of being the leaders in technology, market share, and low cost production before they were overtaken by the new technologies. The examples given by Foster were: National Cash Register in electro mechanical cash registers, B.F. Goodrich in bias-ply tires, and RCA in vacuum tubes. Each of these companies incurred large declines in their respective businesses as a result of new entries based on radically new technologies.

Foster identifies some key factors that, acting over time, can lead to the demise of previously successful, technology based businesses.

1. Technological change is a major factor in the competitive nature of many industries.

2. All technologies have limits.

3. Technology improvements get more expensive as these limits are approached.

4. Technological discontinuities tend to occur as these limits are approached.

The fact that technology is a strategic variable to be reckoned with is not limited to what we classify as "high-tech" industries. In the examples stated before, tires and cash registers were subject to technological discontinuities, yet they would certainly not be classified as 'high-tech'. The point is that any industry can be subject to the threat, and management of companies must
be aware of the technology variable in planning for the future, regardless of the classification of the business.

Limits of technology are facts of nature that are set by physical laws. Materials have melting points, and limits to strength. Many processes are subject to the efficiency limits by the laws of thermodynamics. It is important to recognize that every business based on a technology will eventually have further development stalled by the limits of that technology.

Related to the idea of technology limits is the idea that improvement becomes more expensive as those limits are approached. At the outset of development progress is slow, but accelerates as knowledge increases. The man-hours to performance-increase ratio improves to a point, then begins to diminish as the technological limit is approached. Diminishing returns set in as solutions to problems become harder to achieve. Fisher and Pay have shown that technology development vs. cost (man-hours) follows an S-curve shape. The signs that the midpoint in the S-curve has been passed are listed by Foster:

1. An intuitive sense among top managers that the company's R&D productivity is declining.
2. A trend toward missed R&D deadlines.
3. A trend toward process rather than product improvement.

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4. A perceived loss of R&D creativity.
5. Disharmony among R&D staff.
6. Lack of improvement from replacement of R&D leaders or staff.
7. Profits that come from increasingly narrow market segments.
8. Loss of market share.
9. When significant variations in expenditure produce no significant differences in performance.
10. Smaller competitors that are taking radical approaches that probably won't work.

Top management awareness of the implications of these signs are critical and should spark an investigation into the possibility that technology limits are being approached.

As expenses begin to increase relative to performance gains there is incentive for companies to try alternatives that may be much more economical. If one of these proves feasible, a technological discontinuity is likely to occur. The strategic advantage shifts to the holder of the new technology, and the transition begins to take place. The evidence shows that precipitous drops in market shares occur over a time period that is short enough to preclude a reactive response by the firms holding the old technology. To prevent a loss of business by this mechanism, companies must be prepared to monitor their technology development performance and make the commitment to new technologies that are potential threats when the indicators show a discontinuity is likely to occur.
To achieve a shift, companies have to be willing to change and there are many barriers to doing so. If they do not understand the idea of technology limits, they will not be able to recognize them and take action. Managing a new technology may require changes in culture and personnel which can be difficult to effect. New technologies are often perceived as being very risky. But management often ignores the tremendous risks the business faces if they do not undertake a transition to a new technology. Familiarity with old technology biases the risk assessment, yet there are numerous examples of firms that have been successful in making technology transitions in the research reviewed.

Information is the key to managing a firm's technology. Management should be as informed on the scientific assessment of the technology base of their industry as they are on the competitors, markets, and operations of the company.
14. **IR&D ALLOCATION: A CASE STUDY**

The following paragraphs illustrate the nature of IR&D and new product strategy as practiced at AVCO Corporation, Systems Division. AVCO is a major Air Force defence contractor located in Wilmington, Massachusetts. Dr. Ronald L. Fonte, Technical Assistant to the Vice President of Operations provided us with the information to compose this section of the paper. Dr. Fonte manages the IR&D process from within the Systems Division, and is Chairman of the AVCO Systems Division IR&D Council (see below).

AVCO perceives IR&D as an integral component of its overall corporate strategy with respect to new product development and technology strategy. IR&D policy is developed through an IR&D Policy Council which consists of representatives of the company's four major business lines and the company's technology experts. The technology experts are chosen from the company's four technology divisions: Engineering, Technology (Physics, Chemistry), Materials, and Manufacturing. The basic question the Council asks itself is "what sort of technologies do we think we will be needing in the future." The Council takes a long-term perspective, asking the business line managers "what sort of products do you want to be bidding (to the DOD) in the 1990's?" The business lines are thus responsible for the marketing input to the process, and are charged with forecasting the DOD's future needs. It is important
to recall that the nature of IR&D is such that this forecast may include DOD needs for which the DOD itself has no current awareness. The technology representatives are charged with answering the question "given the marketing input of the business lines, what technologies can we get to given our current technology base?" From these two inputs, the Council derives a number of technical new product development objectives which become the cornerstone of a corporate-wide strategy.

Given the complex technical nature of AVCO's product lines, it is possible that the company will one day find itself requiring a technology which it will not possess. This technology may be required for development of new products. In such a case, AVCO must decide whether it will pursue the technologies internally, or acquire the technologies from outside the company. The IR&D Council gets involved in this issue, and is charged with giving a recommendation on the make or buy decision. The IR&D Council must decide whether the firm has the capability to derive the technologies inhouse, at what cost and within what time-frame, or whether the firm's new product development strategy dictates that the firm should subcontract the technology or buy the technology outright. Hence the IR&D Council, as a direct result of it's responsibility for coupling marketing and technology, is also responsible
for issues relevant to other business functions, i.e., Finance.

Once the Council has resolved the two questions of what products do we want to be bidding on in the 1990's, and what technologies can we expect to reach, the Council derives a list of new product development areas that the company should pursue. These areas are collated into a statement of long-range corporate new product goals. These long-range goals are then distributed throughout the company to directors, managers, and key technical personnel. These people are then charged with developing a series of tasks which will begin the firm moving in the direction of the long-range goals. The following paragraphs illustrate how this process was applied to fiscal year 1983 at AVCO.

The Council met and derived a statement of long-term objectives. These objectives were then distributed to directors, managers, and key technical personnel, as described above, with the tasks of these people being to derive a series of tasks to get the firm moving towards the direction the Council set. To quote Dr. Fonte, "the results were overwhelming!" The Council had expected to be able to fund (internally and with IR&D funds) approximately thirty tasks, but received one hundred and twelve proposals, representing nearly four times the amount of funds available.
The IR&D Council was then charged with filtering these proposals to determine which should be adopted, and which should be rejected. Each of the proposers was allowed to try to sell his/her task to the Council. Each presenter was limited to three or four viewgraphs, with the entire process consuming three full days. The IR&D Council rated each proposal on the basis of two criteria: business potential, and technology novelty.

Business potential was measured by application of an internally derived (if not somewhat arbitrary), multiplier. Basically, no IR&D proposal will be accepted unless it will lead to future sales of no less than five million dollars. This can be thought of as the bottom line. (Dr. Fonte was of the opinion that about thirty percent of IR&D projects lead to major sales.) The multiplier is flexible, and susceptible to internal political pressures.

Typically we're willing to invest $200,000 to $400,000 for a $10,000,000 to $15,000,000 contract. Sometimes we're willing to invest more. Again, this is where politics come in.

Dr. Fonte provided the following example of an IR&D project code named XM898:

Three years ago we consciously said there are certain technologies we need to win a procurement that we could see coming, and we put our money into those technologies. An XM898 is a win of $15 million, representing Phase 0. If it goes to the next phase, it will represent a contract of $69 million...so now we are putting in more IR&D tasks which we hope will allow us to win (the next phase).
With respect to technology novelty, the greater the novelty, given that the technology/new product proposal was included in the long-range objectives, the higher the ranking.

Of the two criteria, business potential was considered to be the most important. Business potential is measured in terms of sales, with a time horizon of approximately five years. Dr. Fonte emphasized the political nature of the decision process, noting that, in contrast to the IR&D Policy Council's long-term outlook, different business divisions lobby for different time horizons in order to ensure that the particular division meets its business objectives. Dr. Fonte called this political aspect the "impure factor in the way that the system works." Hence, in its evaluations, the IR&D council is not averse to longer-term IR&D projects, but the business units sometimes request shorter-term projects in order to meet their own objectives.

The result of this process is a prioritized list of tasks. The cutoff line was drawn once the firm determined how much in IR&D funding it could expect from the DOD. Important tasks which wind up below the cutoff line may be funded internally through a degradation of margin. Politics may enter here.

It is interesting to note that Dr. Fonte does not expect the same project selection process to be employed
for the next fiscal year. He expects that for the next fiscal year, the business lines and the IR&D Council will work more closely in defining the types of tasks to be submitted. This redesigned process will have the drawback of possibly filtering out ideas that the Council would never had thought of. Dr. Fonte observed that there were two such ideas in this year's submissions. Hence, the methodology will have to both limit the range of ideas yet encourage novelty. This is often a fine line in the new product process. Dr. Fonte defined two objectives for the task-submission process: (1) to improve the 30 percent efficiency ratio to approximately 50 percent, and, (2) to encourage new and innovative new product proposals. AVCO is learning by doing, in order to discover a method to manage this "fine line."

Progress on IR&D projects are monitored through quarterly review sessions where the business units present progress reports to the IR&D Council and top management. Each project is allotted twenty minutes to present the new product/technical achievements. These achievements are compared to a previously defined set of quarterly objectives.

The purpose of the review meeting are two-fold. First, the purpose is one of control — to track the new product/technical achievements with the predefined plan. Second, the IR&D Council, together with top management have the option to change the scope/direction of the project.
An excellent example of how the option approach can be applied was provided to us by Dr. Fonte. As noted, AVCO has quarterly progress reports where project heads present work to a central IR&D Policy Council and other top management. At these sessions the Council evaluates the new product development efforts relative to a predetermined set of objectives. The IR&D Council determines if the project has met these objectives.

As explained by Dr. Fonte, the IR&D Council has the option (which it has in the past exercised) of ordering a change of direction of current work. He cites one example of a task which was being performed by a particular unit without that unit, nor the IR&D Council fully understanding why the task was being done. After the first quarterly meeting, the IR&D Council came to the conclusion that the task was not going in an appropriate direction, so the IR&D Council directed the principle investigators to change the focus of the effort. Dr. Fonte concluded that, in retrospect, this was the right thing to do, as the IR&D and new product development are now on the right track.

This example clearly states the advantage of defining an options approach to new product/technology planning. Although not explicit in the above example, it is clear that the thought processes behind the process was one of the options. In this light, we note that our options
approach to new product and technology planning is an outgrowth of, and formalization of, contingency planning.

The preceding pages have illustrated how new product development is planned in a technical environment where the customer is the DOD. Recall that the "I" of IR&D stands for independent. Hence IR&D projects are totally up to the discretion of the firm. This case study has illustrated how AVCO manages this process.

AVCO has a central IR&D Council charged with collating the following issues into a strategic technical new product development plan, and has the option to change the scope/direction of the plan as it develops:

1. What types of products do we want to be selling in the future?
2. What types of technologies will we need in order to be able to produce these products?
3. How should we acquire these technologies?
4. Which of the possible projects do we accept?
5. How do we develop a prioritized list for these projects?
6. Once the projects have begun, should we change it's scope/direction?

Dr. Fonte feels that the entire process of IR&D/new product development strategy is still in the embryonic stage at AVCO. The company is learning how to couple it's technology with it's marketing in the development of a strategic marketing/technology focus.
15. **COMPARISON TO OTHER TECHNOLOGY STRATEGY APPROACHES**

In many respects, our options approach to technology strategy (R&D/technical new product development) is both a synthesis and formalization of other technology strategy approaches. Indeed, to the extent that management has degrees of freedom in expanding, cancelling, or maintaining R&D/technical new product development efforts, and to the extent that management wants to hedge its business against future technology and market risks, it is difficult to imagine how other authors of technology strategy could not, either directly or indirectly, concern themselves with the options nature of technology strategy. The following paragraphs compare and contrast our options approach to technology strategy with those of other technology strategy authors.

Allen M. Kantrow composed a review of corporate strategy and technology in his paper "Keeping Informed." Kantrow notes:

"Technology bears an integral relation to a company's strategic thinking by helping to define the range of its possibilities. At the same time, it provides a good portion of the means by which strategy, price decided on, is to be carried into effect."

In this quote, Kantrow is exactly describing the nature of an option. The "range of possibilities" is precisely the option. What Kantrow fails to point out is that a firm can and should manage the range of possibilities by investing in a strategic portfolio of technology options.
Kantrow appears to suggest that the technology firm should set a specific corporate strategy, and then dedicate itself to a specific technology to achieve this strategy. However, in such a case the firm is exposing itself to the risk that the specific technology may never become "in the money." Thus, Kantrow's one technology strategy is, at best, very risky. By viewing the technology-strategy relationship as a series of options, the firm can formulate a portfolio of such options, and exercise those most "in the money," and as they come into the money.

Returning to Foster's research: technological discontinuities appear when it becomes costly for one firm (Firm A) to advance the existing technology, and another firm (Firm B) comes along and introduces a new technology. Foster argues that Firm A - types lose first because they "do not make the strategic decision to enter the new technology in the first place," and second, because the firms were monitoring the technology with economic indicators, the economic indicators blinded the firms as to the emerging new technology.

Foster's language alludes to the importance of an options approach. We interpret Foster's first point as incorrect: firms do not enter a technology, they pay for the right to enter a technology should the technology option become in the money. What we would say is that the Firm A - types failed to establish a portfolio of
technology options, where these options could be exercised if and when the technology becomes in the money. We feel Foster's second point is valid. Positive economic indicators today do not predict the value of an option tomorrow.

Ansoff and Stewart (A&S) discuss technology strategies in their important article "Strategies for a Technology-based Business." 54 One key section of their paper deals with the need for "downstream Coupling." A&S note that "the success of the company's product introduction process depends on communication and cooperation between R&D and the manufacturing and marketing functions, which are further "downstream" toward the customer." A&S illustrate how different firms in different environments have different coupling requirements. This is exactly the message of Relationship #2 above, where we expand A&S by stating that the product introduction process itself has value as an option, and this value is partially defined by future downstream coupling costs (what options jargon terms the future exercise price).

Thus, based on our brief survey of some of the technology literature, we conclude that our options approach to technology strategy is both consistent with, and an expansion of, current technology thinking. We are encouraged with our application of financial options theory to the area of

technology strategy, and feel that there is much room for further applications of options strategy to this field.
16. VALUE OF AN OPTION

We have said that new technical product development, especially in a rapidly changing technological environment, necessitates incorporation of an options approach. We have detailed five key factors which serve to define the value of a new product option (Time to Maturity, Benefits, Risk, Interest Rates, Exercise Price), and the importance of keeping relevant divisions informed of the value of the option. Throughout this paper it has been implicit that, whereas the value of an option is defined by the five factors, the true value of an option is derived from the right to exercise the option, or to let the option expire.

A great deal of money may be spent on R&D and new technical product development only to have management decide to stop funding the effort. Traditionalists may say that the money has been wasted. Indeed, within the context of this paper, one of the loudest complaints against the military is that it spends massive amounts of money on weapons development only to cancel the project all together some time in the future, hence wasting the taxpayers money. The options approach provides new insight: these are merely examples where the firm/DOD are letting an option, which was "not in the money," expire.

The following example illustrates the value of having the right to exercise. IBM recently decided to halt research
on "Josephson Junctions," described as ultrafast switches surrounded by super cold liquid helium. IBM had dedicated a team of over one hundred scientists, and had spent more than $220 million on the project before allowing the option to expire. IBM dropped the project because it felt that other options may be more valuable, such as advanced semiconductor materials composed of gallium arsenide). While IBM has decided to let the Josephson option expire, the Japanese have not. To quote from Business Week (November 21, 1983), "the Japanese are keeping their options open and are pursuing both semiconductors and Josephson Junctions."

The word "option" is frequently used in the business literature when discussing R&D and new technical product development. In this paper we have shown that the option approach is both valid and can be applied rigorously. We have seen that IR&D is an option held by the DOD, just as management holds an option on internal R&D and new technical product development efforts. We have shown that the R&D/new technical product development process is comparable to a financial option, with the strategic significance of the five relationships. However, most importantly, once the process is defined as an option, we explicitly state that, at all times, the R&D and new technical product development process has value as an option. It is then the duty of management to assess this
value, and manage it's options, keeping in mind that the option's value comes from the right to exercise. Without this attention, the value of this right becomes uncertain.
17. **DISCOUNTED CASH FLOW AND OPTION PRICING, A COMPARISON**

Many firms apply, in one form or another, a discounted cash flow (DCF) model as an input to the capital budgeting decision. The general DCF rule is to invest in all positive net present value projects. Where projects are mutually exclusive, the DCF rule dictates investing in that project which has the highest net present value. The purpose of this section is to compare and contrast the DCF model with the option pricing model. In the next section we discuss the significance of these differences to the firm.

Finance theory states that the present value of a firm's future cash flow is represented in the firm's share price. It is important to note that the market often factors growth options into the current share price. The following is a simplified example:

Define:

\[
\begin{align*}
V_0 &= \text{current market value of the firm} \\
 &= \$130 \\

r &= \text{market discount rate} \\
 &= 10\% \\

X_0 &= \text{perpetual cash flow from present assets (already paid for)} \\

G &= \text{market's perception of growth opportunities}
\end{align*}
\]
Therefore:  
\[ V_0 = \frac{x_0 + G}{r} \]
\[ = \frac{120 + G}{0.10} \]
\[ 130 = 120 + G \]
\[ G = 10 \]

It is clear that, in this simplified example, the market has incorporated into the share price an allowance for future growth options ($10). It is our opinion that, just as the market factors a "bonus" for future potential growth into the share price, so should management factor an allowance for future corporate strategic growth options into the capital budgeting and planning processes. Indeed, as will become clear, it is management's responsibility to explicitly plan for such options. In this section we focus on the application of DCF and option pricing to IR&D valuation.

IR&D is analogous to an option, as described above. A DCF approach to IR&D would necessitate calculation of all future expected cash flows to the holder of the initial IR&D option (Stage 1). In order to derive these expected cash flows, it will be the analyst's responsibility to detail the statistical distributions for initial IR&D costs (Stage 1), probability of success and the value of any patents or licenses, research and development costs (Stage 2) and the value of any patents or licences deriving from the R&D effort, and final manufacturing
costs (Stage 3) with the associated price of the finished product. Adding complexity is the likelihood that these statistical distributions are not independent of each other. Further, at time zero (before the firm commits to Stage 1), the analyst must estimate whether or not it will be profit maximizing to exercise all or any of the three options. The analyst is therefore required (at time zero still) to make assumptions concerning the timing of each of the three stages, as well as the rate of final new product manufacture and sales. Paddock, Siegal, and Smith in discussing the valuation of offshore oil leases continue:

"then, using the prices, costs and quantities from a particular set of realizations, the time path of cash flows is determined. The path of expected cash flows is found by integrating over all possible sets of realizations from the statistical distributions. Typically this involves multivariate Monte-Carlo simulations. The set of risk-adjusted rates is derived in principle by determining the covariance of these respective cash flows with other assets in the economy and using a pricing model such as the Capital Asset Pricing Model."  

There are, of course strong theoretical bases for the DCF approach, from an analytic perspective. If the entire DCF calculation is properly performed (i.e. cash flows specified properly, statistical distribution and timing specified properly, etc.), then the discounted net present value will indeed be reflected in the market

55 Paddock, Siegal & Smith, op cit, page 4.  
56 Ibid, page 5
price. In the case of IR&D, properly performed DCF will aid management in deciding whether or not to undertake the project. The DCF approach has obvious weaknesses when applied to valuing assets with option-like characteristics. As related to IR&D, we note the following:

1. The timing of each stage in the IR&D option process cannot be known at time zero. The selection of timing by an analyst who may not have the "big picture" must therefore be somewhat subjective and hence prone to error. Differences of opinion with respect to timing may create conflict within an organization.

2. Different individuals, divisions, as well as managers, may have opposing viewpoints of future statistical distributions associated with each stage. This may lead to differing valuations, hence the all or nothing decision of whether or not to initiate the project must be made at time zero.

3. The entire issue of deriving an appropriate complement of risk adjusted discount rates is controversial, especially given the complex statistical structure of the future (and possible interdependent) cash flows. Firms may be tempted to apply a higher discount rate to early stages of IR&D in order to reflect the higher risk of research efforts. In any case, any "rules of thumb" may have a significant impact, as discounted cash flow calculations are often extremely sensitive to the discount rate applied.

4. Discounted cash flow valuations - for example Monte Carol simulations - are costly and often difficult to interpret.

5. DCF valuations are only as accurate as the inputs provided. These inputs are often provided by several different
divisions within any one firm. Assessments of technology risk, technology cost, and market timing may vary across divisions. This problem is particularly acute where there exists an interdependence of effort across different divisions.  

6. The DCF approach ignores any significant interrelationships between projects. Often, the closest project interrelationships come to being recognized in a DCF calculation is the apportionment of part of the cost of a past or current project to the expected cost of the future proposed project under analysis. Any strategic product planning or technology planning interrelationships are implicitly ignored by DCF.

Thus we conclude that discounted cash flow, while theoretically appealing, may be operationally very difficult to implement in a firm whose investments are characterized by option-like features, and especially where these option-like investment decisions must be made in a rapidly changing technological environment. The issues illustrated above clearly point to the fact that, in an uncertain environment at time zero, a proper discounted cash flow calculation necessitates a tremendous amount of very precise input (unbiased estimates of means). This input is then to be used, at time zero, to derive a figure representing the discounted cash flows from each of the three stages.

Therefore, and this is perhaps the key weakness of the DCF approach (especially in a dynamic technological environment) management must rely on the DCF calculation

57This discussion of the this weakness draws from Paddock, Siegal & Smith, Ibid, pages 5,6.
at time zero in deciding whether or not to initiate not just one project, but, in the case of IR&D, one project with options on two others. DCF lumps the three projects (stages) into one project, and forces management to decide today whether or not the firm will be in a position to enter later stages at some point in the future. DCF forces the decision on managers at a time when management will not have information accurate enough to properly assess these later stages.

The DCF approach provides management with a simple decision rule: accept all projects with a positive net present value (independent projects) or, in the case of mutually exclusive projects, accept the project with the highest net present value. The DCF approach has the tendency of reducing what should be a strategic decision to generate future possible growth options, to practically a day-to-day tactical decision: accept projects where NPV ... Thus the DCF approach serves to ignore the "G" component of Equation 1 above.

The option approach explicitly recognizes that each project is not singular, but is in fact composed of a series of options. An option approach recognizes that, for example, investment in Stage 1 of an IR&D project is in reality only a purchase of a call option on Stages 2 and 3. By recognizing this fact, the option framework
is in essence recognizing the dynamic nature of business investment decisions.

A second distinction between DCF and option pricing follows immediately. Because the DCF calculation includes the present value of all three stages (in the IR&D example), the DCF approach is implicitly defining the project as an all or nothing proposition. That is, at time zero, management is implicitly deciding on not only the immediate investment decision (Stage 1), but is also deciding (at time zero) on subsequent optional investment decisions. Indeed, as noted above, the DCF approach assumes that such calculations can be made.

In contrast, the option valuation process recognizes that, because each stage can be thought of as distinct, management can make a decision on the initial investment, and maintain the option of expanding, contracting, continuing or cancelling the project. The DCF approach, on the other hand, assumes the original planned investment will be followed through.

A third key distinction is that option valuation explicitly states value as a function of the market at the exercise date. DCF states value at time zero, which may be, for example, ten years before the exercise date. Myers provides the following example:

"We start with a firm with no assets in place (Va = 0) and only one future investment opportunity. The firm is initially all equity financed. It must decide whether to invest "I" one period
hence, at $t = 1$. If it Invests, the firm obtains an asset worth $V(s)$ at $t = 1$, where "s" is the state of nature then obtaining."58

What Myers states as "nature," we define as "market." Thus option theory explicitly states the tie between investment decisions made today (the creation of strategic options) and the value of the investment for a given state of the market. By stating this tie, option valuation recognizes a flaw which plagues DCF: that the future is indeed uncertain (especially in a high technology field), and that it may be best for management to divide up a large project into a series of smaller options, and exercise the options if and when they come into the money.

Option valuation can also be integrative. By recognizing that initial investments in IR&D spawn a series of future options, different but related divisions of a company may plan together to take advantage of a large scale option expected to come into the money at some time "t" in the future. Thus option valuation may allow for the identification, development, and planning of future cross divisional projects.

A fourth key distinction between discounted cash flow and option valuation is found in the basic composition of their respective formulae:

\[
\begin{align*}
\text{DCF:} & \quad \text{NPV} = \text{PV Revenues} - \text{PV Expenses} \\
\text{Option:} & \quad \text{Po}(t) = \text{Ps}(t) - \text{PV}(t)(E)
\end{align*}
\]

58Myers, op cit, page 150.
as defined above. Note that the DCF equation includes all revenues and all expenses necessary to produce these revenues. If the DCF approach were applied to, say, Stage 2 of the technical new product development process (see Chapter 2), then expenses would include all expenditures for Stage 1. We label expenditures on Stage 1 as the "buy in price" or initial required investment. DCF therefore includes the buy in price as part of the net present value calculation.

This is in contrast to the option valuation equation. Refer to Chapter 5, and note that in order to create an option, the option holder must pay "I." "I" is therefore the buy-in price: that price necessary to create the option position. The option valuation equation, however, does not include "I." Thus, the option valuation approach values the project from today looking forward. This is not to say, however, that investment "I" is irrelevant. On the contrary, option valuation implicitly recognizes that "I" - the initial buy in - created value: the right to take advantage of corporate strategic options if and when they come in the money. To this extent, option valuation separates the buy in price from the current value of the project, either as a going concern or as an option on future new product developments. One important consideration follows immediately: that by investing in the initial buy-in price, the firm has created a firm-specific asset,
an option contingent upon future states of the market. This is, in essence, the logic behind the often stated Wall Street expression: "firm X has put itself in an excellent position to take advantage of market condition Y." By excluding the initial buy in from the option valuation equation, the option approach implies i) the value of creating options, and ii) the importance of a forward-looking approach. DCF, on the other hand, by not being a dynamic approach, excludes the possibility of future options, and therefore excludes the possibility of multi-divisional identification, development, and planning of future option opportunities.

Thus we have illustrated four key differences between DCF and option valuation:

1. Option valuation divides projects into their option components, while DCF forces an all or nothing calculation.

2. DCF assumes that inputs provided at time zero are accurate enough to calculate a meaningful value. Option valuation recognizes the tie between the market and the option, such that valuation is only truly possible at a time in the future when the market can be observed.

3. DCF ignores the dynamic nature of managerial decision making, while options explicitly state the dynamic, ongoing nature of decision making.

4. DCF explicitly incorporates the buy-in price in its formula. Option valuation recognizes that the buy-in expense created a strategic asset: the option to expand, contract, maintain, cancel, or exercise an option on the project.
In a rapidly changing environment, management should not be making every decision on an all or nothing basis. Making decisions on such a basis implies that management has, at time zero, unbiased (or at least nearly unbiased) information about the future. In the context of an earlier discussion, this is equivalent to stating that management is able, at time zero, to identify strategic growth options, which won't be exercised until some future date, as well as offering a return in excess of the market return. This is, of course, unlikely to be the case on a consistent basis.

However, this is not to state that management cannot position the firm to take advantage of such opportunities if and when they appear. Indeed, for a firm facing an uncertain future, the only way to sensibly (efficiently) plan and operate is to recognize that their new product development efforts are in fact options. The forward strategic market planning and new product development activity should be concerned with identifying the market options available and an estimate of when, if at all, the new product development will come in the money. Matching the market options with the internal portfolio of new product investment (I) options is the key. DCF ignores the dynamic link between an internal portfolio of new product development options, and future states of the market.
From time zero, a cross sectional portfolio of options exists within a firm which have explicit, identifiable links to market options, links among themselves (other current new product development efforts), and links to future internal firm specific options (future new product development efforts). The future options are the paths the firm can develop that must be open when a market option comes in the money. Not all of the market options identified will come in the money, and therein lies the uncertainty associated with developing new technical products. Therein also lies the explicit link between option valuation, option strategy, and an uncertain future market.

By explicitly planning, valuing, and managing the internal cross section of today's options, and the time series options available for matching the firm's capabilities with the future options of the market, the strategic planning function should, by applying an option framework, be able to generate a reasonably efficient portfolio of investment/new product options. We have argued the errors and limitations of NPV as a normative decision tool from an options standpoint.
18. A CORPORATE OPTION STRATEGY: ISSUES AND DISCUSSION

A corporate strategy based on the creation of strategic options is aggressive, and by no means an only approach. Ansoff and Stewart (A&S) divide alternative strategies into four major groups. We quote A&S:

1. First-to-market: based on a strong R&D program, technical leadership, and risk-taking.

2. Follow-the-leader: based on strong development resources and an ability to react quickly as the market starts its growth phase.

3. Application engineering: based on product modifications to fit the needs of particular customers in a mature market.


The options strategy approach is consistent with A&S's first-to-market strategy. As described earlier, options planning implies timing is as critical for market success as the portfolio of options held. A case in point is the Personal Computer market. Introduction of PC's was technically feasible as early as 1973. Resolution of consumer needs occurred as different products came onto the market. IBM introduced its PC entry only after it was deduced that the major market was corporate users, and these users desired interactive capability between the PC's installed and corporate central processors.

59 Ansoff & Stewart, op cit, page 81.
Apple, a major player in the industry, was instrumental in driving out this information through their Apple II and Lisa models, but they failed to provide for the interactive option, should market resolution show that this was the key characteristic desired by the major consumer.

This simplified example shows where the value of options derives from, the market. It also shows that it is not necessary to be first to market in a given product area which is new, where innovation is occurring rapidly, and uncertainty of needs is attendant. It is necessary to be first to market when those needs have been identified, i.e., exercising when the option is in the money. Both strategies entail risk-taking, but both strategies also offer potentially large rewards. This risky approach has important repercussions, and necessitates a clear philosophy of doing business. From a corporate strategy perspective, some important repercussions of this strategy include:

1. A research intensive effort, development resources, and a management commitment to these efforts and resources.

2. A close proximity to the state of the art in the technology, or the goal of achieving this proximity.

3. High risk of failure for individual projects.60

A&S continue that in order to adhere to the first-to-

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60Ibid, page 82
market strategy, the firm:

"must often risk large investments of time and money in technical and market development without any immediate return. It must be able to absorb mistakes, withdraw, and recoup without losing its position in other product lines ... Such a company must have more than its share of long-range thinkers who can confidently assess market and competitive trends in their earliest stages and plan with both confidence and flexibility.61

The options approach is also consistent with a characteristic of excellent companies as identified by Peters and Waterman in their important best-seller "In Search of Excellence," namely, the "action bias on the excellent companies is their willingness to try things out, to experiment."62 Peters and Waterman suggest that unfortunately, many large corporations have forgotten how to test and learn, preferring instead analysis and debate.63 The reason, they suggest, is that these corporations are paralyzed by the fear of failure, however small.64

The value of each strategic option is uncertain, as it depends upon the state of the market at expiration, or, in the case of R&D, at some time in the future. As noted, the state of the market at any time t in the future is uncertain. One way to plan in a world of uncertainty would be to initiate a series of different R&D projects (assuming resources are available).

61Ibid, page 82
63Ibid, page 134
64Ibid, page 135
In studying the successful versus less successful oil wildcatters, P&W found that "if you had the best geologists, the latest in geophysical technique, the most sophisticated equipment, and so on, the success rate in wildcat drilling in established fields would amount to about 15 percent. Without all these pluses, the success ratio dips to around 13 percent. That finding suggests that the denominator — the number of tries — counts for a great deal."65 The authors suggest one reason for Amoco's success in drilling is that "Amoco simply drills more wells!"66

It is clear that an option cannot come into the money unless the option has first been created, and the buy-in price paid. However, this by no means suggests a strategy of random investments in strategic options. Peter J. Farley, founder of the biotechnology firm of Cetus Corporation in 1971 vowed that he would "build the next IBM," and "follow the technology wherever it leads."67 The result of this ambitious program was that, by 1982, Cetus's resources were spread far to thin, with over 20 major products in process in the laboratory, with no final products on the horizon.68 Robert A. Fildes took over as president of Cetus in 1983, cancelled 50 percent of the projects, and

initiated a five-year business plan focusing Cetus' business to the human health care field.

Thus, the option strategy approach does not suggest the random selection of R&D projects. Rather, it is management's duty to properly assess the company's goals, strengths, weaknesses, and competitive position.

In discussing the virtues of action and experimentation, W&P note that an option approach is not inconsistent with the gambling involved in stud poker.

"With each card the stakes get higher, and with each card you know more, but you never really know enough until the last card has been played. The most important ability in the game is knowing when to fold.

With most projects or experiments, no matter how many milestones you set or PERT charts you draw, all you are really buying with the money invested is more information. You never know, for sure until after the fact whether it has all been worthwhile or not. Moreover as the project or experiment gets rolling, each major step becomes much more expensive than the last one - and harder to stop because of sunk costs and, especially, ego commitments. The crucial management decision is whether to fold. The best project management and experimenting management systems we have seen treat these activities more or less like poker. They break them up into manageable chunks; review quickly; and don't over-manage in the interim. Making it work simply means treating major projects as nothing more than experiments, which is indeed what all of them are, and having the poker player's mental toughness to fold one hand and immediately start another whenever the current hand stops looking promising."69

69Peters and Waterman, op cit, page 143.
Here again, the information needed for decision making is market based. Is the market in the money? Is it likely to come in the money at some point in the future? Or, is it out of the money due to competitors initiatives or insufficient technical progress and dead ends in the R&D projects?

It cannot be overstressed that the fundamental value of buying in is the future market potential generated by undertaking R&D. R&D for the sake of R&D has no value in a business sense. Much like the cards on the poker game have no end-value, only the pot you are playing for. The cards give you access to that pot.
19. **ORGANIZATION ISSUES**

The creation of options has implications for planning, control, and organization design. The purpose of this section is to discuss some of the important organizational issues surrounding the option approach to corporate strategy. The dynamic nature of the option approach is contrasted with a discounted cash flow approach.

The nature of a rapidly changing technological environment places certain demands both on management and on the organization as a whole. By definition, the future of a rapidly changing technology is uncertain. Scientists and engineers will define this future uncertainty in terms of the technology. The Marketing function will, however, define this uncertainty in terms of final product design and sales. Therefore, with Vedin and others\textsuperscript{70} we acknowledge the existence of the following grid.

\begin{center}
\begin{tabular}{|c|c|}
\hline
\textbf{Technological Risk} & \\
\hline
\textbf{Market Risk} & \textbf{Low} & \textbf{High} \\
\hline
\textbf{Low} & & \\
\hline
\textbf{High} & & \\
\hline
\end{tabular}
\end{center}

One strategy may be to initiate a number of options for each quadrant. How many options, and of what dollar value to place in each quadrant will depend upon issues such

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\textsuperscript{70}Vedin, "Radical Product Innovation," page 13
as strengths and weaknesses of the firm (R&D, technology, marketing), the nature of the competition, the strategy of the firm, and the risk-preferences of management and shareholders.

According to the grid, few options in the high-high quadrant would ever come into the money. Interestingly, the very nature of the expression high-risk (characteristic of the high-high quadrant) is ambiguous, as before an option is even classified as "high risk," it is simply very uncertain. In this case, risk cannot be quantified, and DCF measures are largely inappropriate. What becomes appropriate in a very uncertain world is intuition, conjecture and hypothesizing: all of which are subjective in nature.

The word intuition creates havoc with a DCF approach to strategic business decisions, and herein lies the underpinning to the arguments made by Hayes and Abernathy above. Intuition has become synonomous with anti-intellectualism as it pertains to the modern manager. It is curious that it has been the area of high technology itself which has given birth to such an approach.

High technology sectors, especially where the concept of project teams evolved, has led the management of technological development in the direction of a more "scientific," rational, and systematic intellectual problem solving techniques.71 Technology forecasting, market forecasting,

71Ibid, page 14
PERT charts, CPM, econometric model adaptations, etc., have been produced to serve the apparent insatiable desire of scientific management for science-based (technology) sectors.

The product of these scientific approaches has been that short-term, urgent decision are allowed to be made on the basis of intuition, but the long-term to maturity option dictates the application of quantitative techniques. Hence, quantitative techniques are employed for precisely the type of situation where intuition and learning over time are appropriate. Intuition and allowing for learning over time are suitable exactly because the future, both in terms of technology and marketing, are uncertain.

One key emerging difference is of short-term versus long-term. DCF methods, by use of a risk-adjusted discount rate, tend to favor short-term projects over long-term projects if the cash flow means and discount factors are biased appropriately. We have seen that, in contrast, an options approach may favor long-term projects over short-term. Given this possible short-term bias of DCF, the rational short-term activity of the firm may be to manage existing investments effectively, making incremental changes with easily identifiable and measurable gains.72

The operative words are "short-term." While it is true that no firm can have a long-term without first having

72Ibid, page 15
a viable short-term, it is also true that it should be the long-term which defines the short-term.

It could be that a high degree of bureaucracy is associated with a DCF framework. Our earlier example (see Chapter 17) of the type of rigorous financial analysis needed for DCF (future cash flows probability and statistical relationships, timing of exercise dates for future options) would necessitate a rather extensive and rigorous bureaucratic environment just to accommodate all the paper-work and report generating activities needed to support such a calculation.

Hummel describes bureaucracy as a control instrument without compare. Hummel further describes control as a source of power, such that those with control stress only the visible portions of what those below them in the table of organization do. As a result, standard operating procedures and evaluating performance based compliance, becomes a normal and accepted panacea for the issue of control. "Eventually control comes to mean largely checking that procedures are followed instead of looking at output."74

This is what Hayes and Abernathy meant by analytic detachment.

The risk attitude of management may have some bearing on the need for quantitative analysis of projects, resulting in a perception of risk management. The approach-avoidance

73Hummel, "The Bureaucratic Experience," page 27.
74Ibid, page 27.
effect, as developed in the field of social psychology and applied to management by Vedin provides some insight.75

**FIGURE 5**

**THE APPROACH–AVOIDANCE PHENOMENON**

At a distance, i.e., before managers learn about R&D problems, market uncertainties etc, the new product idea may sound appealing: the advantages overshadow the risks. However, as the bureaucratic wheels begin to turn, and as data for the DCF calculation (and the uncertainty associated with the data) comes to the fore, the avoidance effect sets in. As Vedin observes, this presupposes that the new product development option is well defined to begin

Hence, it may be true that DCF and bureaucracy are symptoms of a larger issue: that of risk aversion.

An option approach is not inconsistent with gathering information before a decision is made. Rather, while DCF calculates a net present value based on the entire project, options recognizes that most projects can be broken down into their option components, and recognizes the associated option-characteristics. DCF calculations on cash flows far into the future will tend to elicit the avoidance effect. Options get around the avoidance effect by sub-dividing the project. It is the subdivision of projects into its option components which allows risk (standard deviation) to be seen as a favorable project feature. The options approach, like a game of stud poker, recognizes that all of the information will not be available at time zero. Creating a strategic option merely gives the company the right to continue a project (exercise) if the project is in the money (information available at the time dictates further funding). The information available at the exercise date will be, of course, more reliable than speculation on the information at time zero. Thus an option approach serves to reduce the avoidance effect by focusing on short-term information, while maintaining a high attraction by recognizing that the initial stage

76Ibid, page 15.
of the new product development process (IR&D) is an option on future development.
20. FINAL DISCUSSION OF THE OPTION ANALOGY

That the financial option framework presented is an analogy to be used in qualitatively assessing the value of undertaking IR&D projects should be clear. If it was a definitive model for project evaluation, quantitative methods for defining the parameters of benefits, risk, time to expiration etc., would be available. The subjective, judgmental nature of these components defines the nature of strategic decisions facing management in allocating resources for IR&D.

The option pricing models used for valuing options on securities, regardless of complexity, have known quantities, such as current stock price, and readily estimable quantities, such as variance, as a basis for valuation. When applying the model to IR&D project valuation, there is no surrogate for the security market data base. IR&D projects require continuous and varying investment patterns that in no way resemble the single step, purchase price of a financial option. A financial option is theoretically a zero net present value investment, yet IR&D investments are undertaken by firms to create competitive advantage, and economic returns. Options on securities are exclusive to the option holder, which is rarely the case in R&D projects. The end result of a successful R&D project is the creation of capital, in the world of financial options there is no new capital created, just a transfer of capital. Funda-
mental to the valuation of securities is the concept of risk defined as the historical variance of price of the base asset, the share of stock. In the world of research in new technology, the process is more uncertain than risky. 77 Risky projects can be evaluated using mathematical models which include objective assessments of the probability of success or failure. Because basic IR&D outcomes are uncertain, the objective probabilities cannot be known, and mathematics have little use in deriving a value for the project. When a financial option is purchased, the expiration date is known, and is also a variable in the option pricing models. R&D is, at the outset, an open ended option with exercise points being affected by resolution of technological market, and competitive uncertainties. Fundamentally, we believe that the major difference between financial options and options on real assets is that a financial option makes a market for transferring capital between investors based on the risk of the underlying asset, while an option on a growth opportunity gives the holder the ability to create capital in an uncertain environment.

Recognizing this and the other discrepancies that the analogy suffers from, one can conclude that rigorous cash valuation of IR&D projects is, at best, an exercise

in futility. We believe the real strength of the option approach lies not in explicit project valuation, but in properly defining investment in IR&D along two fronts:

1. the value of holding an option on a future market that is uncertain (the technological capability)

2. the value of information gained for making go/no go decisions relative to #1 in a multi-stage decision process.

Initially, project selection, using the option approach, will be biased toward long-term, risky projects. As the project converges to the exercise date, the spread between the final product value plus growth options, and the exercise price becomes the determining factor in the go/no go decision. At any time between the buy-in and exercise date, funding can be halted and reallocated. The firm still retains the value of the work done to date, and the option to restart at a future date if the market comes into the money. This approach places a heavy monitoring burden on top management and calls for as unbiased information as possible on technological progress, market value, and relative position of competitors. The questions that confront an organization then become: is it "tight" enough to gather and transmit information to make unbiased assessments of the parameters impacting IR&D allocations, and is it "loose" enough to respond to decisions that may range from project shut downs, major escalations of funding, shifts to new technologies, acquisitions, etc. We believe that the ideas presented in this thesis can be used to
foster a mentality attuned to managing in a world of uncertainty (vs. managing uncertainty).

We feel that our efforts have given us valuable insights into the nature of planning the future of businesses. Our perspective has been, from the outset, that of a general manager struggling with the issue of technology as a major variable affecting the future of a business. There is plenty of open ground in the area of research in applying option pricing theory to the valuation of projects being considered for investment. We expect that, over time, improvements in quantitative methods will be made that will allow quantitative analyses of investment opportunities with complex option characteristics to be accomplished. We do not expect quantitative techniques to diminish the value of intuition, vision, and commitment in the resource allocation process. Creating the future entails both the art and science of management. Nothing has reinforced this more in our minds than the research, thinking and discussion behind the writing of this thesis.
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