REAL OPTIONS ANALYSIS OF MINING PROJECTS

by

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Abstract

When long life assets are being evaluated based on constant predictions of future variables and the assumptions of zero management flexibility, is value being missed? In project evaluation today, the most common evaluation methods that calculate a net present value are discounted cash flow (DCF) analysis, decision tree analysis and Monte Carlo simulation. A fourth method, which is beginning to gain ground in terms of its use in the mining industry, is real option analysis (ROA). ROA utilizes a stochastic process and expected asset volatility to more sophisticatedly allocate investment risk at the source, as opposed to the aggregate period cash flows as in more traditional models.

The purpose of this paper will be to review the evaluation models currently used in the mining industry and to understand their differences, going in-depth into the use of ROA to understand its advantages and limitations. A mining project is evaluated using the applications of DCF analysis and ROA for the purpose of comparing the results of the more traditional valuation method and one which values uncertainty in a more advanced manner.

The paper concludes with the advantages that ROA can provide to management decision making and outlines when the use of ROA is most beneficial.

Executive Summary

The purpose of this paper is to provide an overview of current net present value analysis techniques currently used for project valuation in the mining industry as well as demonstrate the need for proper quantitative evaluation of flexibility that is intrinsic in many projects. The techniques explained are traditional discounted cash flow (DCF) analysis, decision tree analysis (DTA), Monte Carlo simulation (MCS), and real options analysis (ROA).

The valuation method that is focused on for valuing flexibility and uncertainty is ROA. Real options equate project cash flows to an equivalent market portfolio, where future costs are equated to a loan, and future cash flows are equated to an asset whose value changes according to its market volatility. Financial options theory is applied to this portfolio of "stocks and bonds" to calculate a current option value (call) of the asset, which is the current value of the option to commission the project. Whether the exercise/project commissioning date is fixed (European option) or variable (American option) it can be valued using the Black-Scholes formula in the case of the former, or by using the binomial method in the case of either option.

The value of an option is directly related to the uncertainty and risk associated with a project. In fact, it can be said that the option value is the value of the uncertainty. For example, increased uncertainty, such as higher asset volatility, will increase a project's option value as the "upside" increases future revenues while the "downside" is mitigated against through management flexibility. The value of this uncertainty is highest in relation to project value when projects are marginal, as projects with firm footing "in the money" have little value added through the quantification of their uncertainty.

The Daedalus project, a sizable copper-nickel sulphide deposit was evaluating using traditional DCF techniques to provide an NPV of negative $109M. An ROA on a five-year project deferral option was conducted in parallel and calculated an option value of $704M with a difference of only 0.23% between the two methods used to calculate the real option. This difference can be attributed to one model using discrete time steps (binomial) and the other (Black-Scholes) assuming a continuous process.

The added value to the project of the ROA is $813M (difference between ROA and DCF NPV). Without using ROA to quantify the deferral option of Daedalus, this value would have been considered qualitatively. However, without the quantitative measure obtained through ROA, management would be in a difficult position in regards to incorporating this qualitative value into a total current project value.

Sensitivities ran on volatility, copper price, and risk-free rate showed a positive correlation to option value. As these variables increased so did the option value. Sensitivity on discount rate showed a negative correlation to option value, which is not surprising as asset value decreases with discount rate and asset value is what option value is based on. However, the DCF NPV decreases with increasing discount rate faster than the option value whose value approaches zero. In other words, as discount rate increases, the difference between the option value and DCF NPV increases, meaning the DCF model is more sensitive to discount rate then the real options model.

In the world of project evaluation and capital budgeting, the best decisions will be the most informed decisions. This information can be garnered through thorough evaluation of a project, looking at different evaluation methods and project sensitivity, and the reasons for differences and sensitivities. This understanding of the project dynamics, the flexibility available to management, and the value inherent in the uncertainty of the project is what leads to more accurate project evaluations. ROA is another evaluation tool available to management and one that should not be overlooked, especially when projects are marginal, or in the negative, and option value is at its highest.

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Glossary

CAPM	**Capital Asset Pricing Model:** A model that describes the relationship between risk and expected return and is used in the pricing of risky securities.[1]
DCF	**Discounted Cash Flow:** A valuation method used to estimate the attractiveness of an investment opportunity. Discounted cash flow (DCF) analysis uses future free cash flow projections and discounts them (most often using the weighted average cost of capital) to arrive at a present value, which is used to evaluate the potential for investment. If the value arrived at through DCF analysis is higher than the current cost of the investment, the opportunity may be a good one.[1]
DT	**Decision Tree:** A schematic tree-shaped diagram used to determine a course of action or show a statistical probability. Each branch of the decision tree represents a possible decision or occurrence. The tree structure shows how one choice leads to the next, and the use of branches indicates that each option is mutually exclusive.[1]
DTA	**Decision Tree Analysis:** Analysis based on the use of decision trees (see Decision Tree above).
IRR	**Internal Rate of Return:** The discount rate often used in capital budgeting that makes the net present value of all cash flows from a particular project equal to zero. Generally speaking, the higher a project's internal rate of return, the more desirable it is to undertake the project. As such, IRR can be used to rank several prospective projects a firm is considering. Assuming all other factors are equal among the various projects, the project with the highest IRR would probably be considered the best and undertaken first.[1]
MCS	**Monte Carlo Simulation:** A problem solving technique used to approximate the probability of certain outcomes by running multiple trial runs, called simulations, using random variables.[1]
NPV	**Net Present Value:** The difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyze the profitability of an investment or project. NPV analysis is sensitive to the reliability of future cash inflows that an investment or project will yield.[1]

[1] (Investopedia, 2011)

RFR **Risk-Free Rate:** The theoretical rate of return of an investment with zero risk. The risk-free rate represents the interest an investor would expect from an absolutely risk-free investment over a specified period of time.[1]

ROA **Real Options Analysis:** Real options analysis, (ROA) applies option valuation techniques to capital budgeting decisions.[2]

WACC **Weighted Average Cost of Capital:** A calculation of a firm's cost of capital in which each category of capital is proportionately weighted. All capital sources - common stock, preferred stock, bonds and any other long-term debt - are included in a WACC calculation. All else equal, the WACC of a firm increases as the beta and rate of return on equity increases, as an increase in WACC notes a decrease in valuation and a higher risk.[1]

Working Capital **Working Capital:** A measure of both a company's efficiency and its short-term financial health. The working capital ratio is calculated as: Working Capital = Current Assets – Current Liabilities. Positive working capital means that the company is able to pay off its short-term liabilities. Negative working capital means that a company currently is unable to meet its short-term liabilities with its current assets (cash, accounts receivable and inventory).[1]

[2] (Wikipedia: Real Options Analysis, 2011)

1: Introduction

The mining industry faces declining resource quality as mines continuously develop from high value deposits to marginally valuable deposits. Because of this naturally created dilemma, the challenge for the industry's mineral resource evaluators is to value the remaining undeveloped deposits accurately and appropriately, as to differentiate between them based on their value added. The accuracy of any valuation is an issue, which all valuation modellers must deal with, but just as important is the appropriateness of the valuation method selected for use in the model. Appropriateness is judged by what management seeks to measure against and usually correlates with what the company intends to achieve through development of the resource in question, i.e. payback, free cash flow, and shareholder value. For the purpose of this project, management's objective is to increase shareholder value through project implementation. The contribution to shareholder value of a project in execution is based on its net present value (NPV) per number of shares outstanding. Therefore, the models of interest are those that calculate future project cash flows to a present value. Knowing the arsenal of valuation methods available, and associated pros and cons, is important to a mining company with a portfolio of potential projects, as the differences in the projects may be better valued by different methods. This allows for accurate differentiation between projects.

In business evaluation, four common methods for valuing projects based on an NPV calculation used today are discounted cash flow (DCF) analysis, decision tree analysis (DTA), Monte Carlo simulation (MCS), and real options analysis (ROA). The most heavily used business evaluation method in Teck Resources is DCF, often referred to as NPV analysis, as it discounts all future cash inflows and outflows to a present value. The other three methods are not entirely different from DCF, as their results are determined through the discounting of expected future profits. However, they do build on the DCF method by adding levels of complexity into their estimates in an attempt to quantify issues not addressed by standard DCF. DTA takes into account decisions which management may take at predetermined times, with probable outcomes and expected returns for each decision. Starting with the decision to execute the project at time zero, the decision tree grows as time moves forward. Using the expected value technique, probabilities and returns are calculated back to a NPV at time zero. Where there is often criticism for DCF's deterministic approach, MCS utilizes probability distributions of input variables and several computer simulations to report an NPV's probability of occurring. Though the MCS method has critics of its own, it endeavours to quantify and calculate the uncertainty of input variables. Real options analysis, also referred to as real options valuation, applies option value techniques pioneered for financial options to the capital budgeting process. ROA considers management's ability to make decisions throughout the project life, as well as the uncertainty due to variability in project value. Due to management's ongoing decision-making, ROA values projects at a lower risk than the traditional DCF method, which puts the project on a deterministic trajectory at a higher risk premium. MCS and ROA can be used in unison, and both force the modeller to be specific regarding its projections and assumptions for the future. The four valuation methods each have their strengths and weaknesses. They should be viewed as available tools, each with suitable uses.

The cyclical nature of historic commodity prices has caused mining to be a more conservative industry, and as one, innovative ideas and methods take a longer time to gain acceptance and become standard practice. In terms of industry approval, MCS and ROA are at a disadvantage compared to DCF and DTA, which have been in use for much longer and have gained familiarity and comfort within the industry. With the limited use of ROA in the mining industry, this paper's focus will be to highlight the ROA method and illustrate its appropriate use.

2: Project Valuation

The following section will discuss the objectives of valuation and provide an overview of valuation methods currently used in project evaluation. A more in-depth description of ROA will be presented, along with a description of differences of the methods and the strengths of ROA. Concluding with explanations regarding the appropriate use of ROA and how it can add value to Teck Resources' capital budgeting process.

2.1 Valuation Objectives

The main intention of many project valuations is to determine if the implementation of a project will add value to a company by increasing shareholder value with positive net present value. However, even though a project may be well into positive NPV territory, having an accurate estimate of project value is important as well. Accuracy within the valuation of projects in a company's portfolio is a necessity when determining where to allocate limited capital to have the highest impact on company objectives. In comparing projects, it is important to make sure they are on equal footing, meaning they have been valued properly. Understanding their differences and how those differences should be valued is key to accurate valuation. Several factors used during evaluation are company assumptions, such as long-term commodity prices, input costs, and even geotechnical constraints like mine wall angles – all of which affect project profitability. Changes in certain variables will affect projects differently, which is why sensitivity analysis of key factors is important. Determining a project's sensitivity to the variables in its valuation is important because if the sensitivity is not considered in a quantitative manner (e.g. with probabilistic analysis) it should be noted qualitatively so judgement can be based on the sensitivity as well.

There are two categories of valuation methods: positive and normative.[3] Positive valuation methods are based on quantitative things, such as revenues and costs, while normative methods are based on harder to quantify factors, such as corporate social responsibility, license to operate, ethics, and company value judgements. A project should be evaluated using methods from both categories; however, this paper will focus on the positive methods.

[3] (Torries, 1998)

During the early stages of positive valuation, simplistic methods were used, such as free cash flow and payback period. Little thought was given to the timing of revenues and expenditures. However, the timing of cash flows is arguably one of the most significant factors in determining the value of a project. A major issue with these earlier methods was that they failed to consider the time value of money and any risks associated with the cash flows of the project. As the valuation field developed, more sophisticated methods were created based on determining net present value by discounting future free cash flows. Discounting future values to present values can be done by applying the following formula:

$$PV_t = \frac{FV_t}{(1+i)^t}$$

Equation 1: Present Value (Discrete Time Discounting)

Where PV_t is the present value of the expected future value, FV_t, discounted at a period rate i in time period t. This formula is based on discounting future values for discrete time intervals t at a discount rate i which is specific to t. In the case where the continuous discounting of cash flows is desired the present value formula changes to Equation 2: Present Value (Continuous Discounting).

$$PV_t = FV_t e^{-it}$$

Equation 2: Present Value (Continuous Discounting)

The continuous discounting method simplifies the equation nicely and since the time increments approach zero, the formulas assumptions allow for the tools of calculus to be used. The conversion of a time discrete interest rate to a continuous rate is often important for the above reason (as will later be seen in the implementation of the Black-Scholes formula) and can be done by applying Equation 3: Continuous Rate Conversion where R is the discrete rate and r is the continuous rate. The time increments are cancelled out of the conversion formula but must be considered when using the PV formulas.

$$\ln(1 + R) = r$$

Equation 3: Continuous Rate Conversion

Discounting future values has two effects; firstly, it discounts the value of future cash flows, giving more value to revenues produced sooner in the timeline of the project. It also reduces the risk associated with the assumptions of future variables, such as commodity prices. The further out the revenue stream is, the greater effect discounting will have on value, as it is raised to the power of the time period.

2.2 Valuation Methods

One of the major issues with deterministic valuation models, such as DCF analysis, is the uncertainty of which possible future and its corresponding actualities (commodity price, input costs, tax rates, exchange rates, etc) will make itself present of all the probable futures that exist. DTA and MCS analysis have made great strides in valuing this uncertainty, but it is ROA that incorporates management flexibility during the time the project is running. This managerial flexibility reduces much of the risk that is added into other evaluation models.

2.2.1 Discounted Cash Flow and IRR

DCF analysis is the core valuation method that forms the basis for several of the other positive methods. DCF calculates the present value of all future cash flows using the present value formula presented in Equation 1: Present Value (Discrete Time Discounting). The DCF formula is presented below:

$$DCF_t = \frac{CF_t}{(1 + i)^t}$$

Equation 4: Discounted Cash Flow

The first step in DCF analysis is determining project cash flows by period for *t* periods. The next step is to determine an appropriate discount rate *i* for the project. There are several ways of choosing discount rates commonly used in DCF analysis such as the theoretically correct opportunity cost of capital, weighted average cost of capital (WACC), risk-free alternative, risk-adjusted rate of return (CAPM), hurdle rate, and historical rate of return. In addition, a more complex DCF analysis can use a discount rate that varies over time or by cash flow line item to account for differences in risk based on time or based on cash flow source. With the abundance of discount rate choices, it is crucial to ensure there is consensus on which discount rate is used by the evaluators and those who base their decisions on the valuations. A higher discount rate exhibits an uncertainty in the future and produces lower NPV than a lower discount rate would.

Discount rate is one of the NPV's driving variables in a DCF analysis. A graph showing the discount rate affect on cumulative DCF for a $1,200,000 project with a 17-year life and yearly cash flows of $400,000 is shown below:

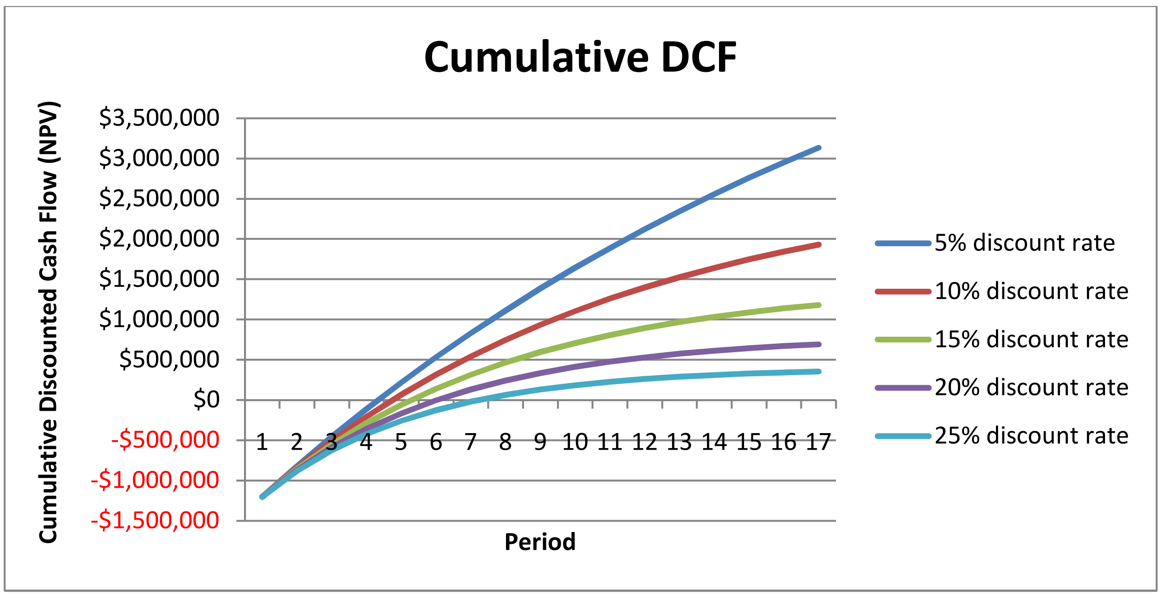

Figure 1: Discount Rate Affect on Cumulative DCF (NPV)

More than just reducing the overall net present value of a project, a high discount rate also reduces the time period that passes for the majority of discounted cash flow to be realized.[4] In the above example 90% of cumulative DCF are realized by years: 14, 13, 12, 11, and 10 for discount rates: 5%, 10%, 15%, 20%, and 25% respectively. This illustrates that a higher discount not only places more risk on future cash flows, but that this risk is compounded overtime as well. Thus, high rates give higher discount factors for years further out from project implementation.

[4] (Torries, 1998)

The effect that inflation has on future revenues and costs can be significant as well, and the question as to whether inflation should be included in the DCF analysis is an important one. Accounting for inflation would decrease the value of future revenues. Ignoring inflation would calculate revenues in constant dollars, while adjusting for inflation would calculate in current dollars. If inflation can confidently be forecasted, an argument can be made for evaluating in current dollars; however, when uncertainty exists regarding inflation, it is recommended that constant dollars be used.[5]

Another valuation method used, closely related to DCF, is internal rate of return (IRR). IRR is the discount rate that calculates an NPV of zero. IRR is a rate quantity giving an overall project efficiency, as opposed to NPV, which provides a magnitude of value for an investment. For this reason, IRR should not be used to rank mutually exclusive projects, but should only be used to evaluate an individual project. A criticism of IRR is that it assumes that reinvestment of cash flows occurs at the IRR, which is not necessarily the case. Project owners are not guaranteed the opportunity to invest the cash flows into new projects that are creating the same return as the project currently producing cash flows, and the higher the IRR, the more unlikely the reinvestment scenario becomes.

2.2.2 Decision Tree Analysis

DTA considers uncertainty by using a model of future decisions and their possible outcomes. DTA uses a decision algorithm, laid out in a graphical format, to identify a strategy that has the highest probability of achieving a goal. A decision tree (DT) is usually illustrated from left to right, with the tree starting at decision naught and time equals zero and progressing to the right. A decision tree usually consists of three node types: decision nodes, chance nodes, and end nodes.

The decision tree branches out from decision nodes and chances nodes, and branches terminate at end nodes or outcomes. The paths split and typically do not converge, thereby making the tree grow quickly. It is often difficult to draw out fully for projects with several decisions and probabilities, and over a long life. A sample DT is illustrated below:

[5] (Torries, 1998)

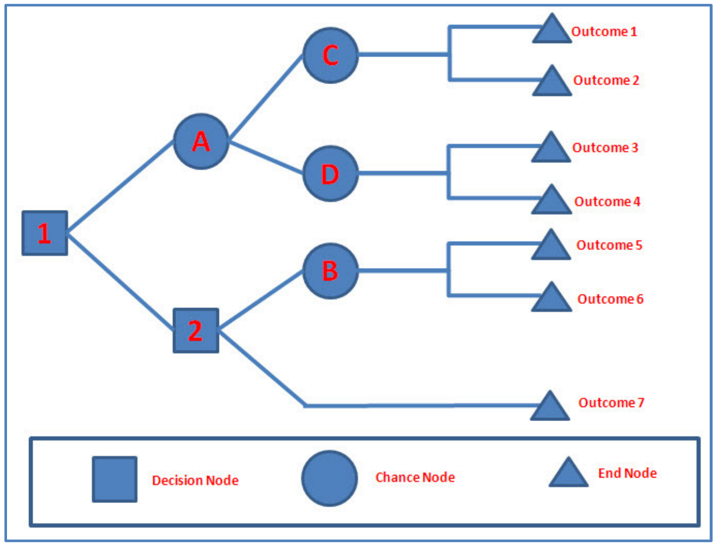

Figure 2: Decision Tree

To evaluate a DT, the value of each chance node and decision node must be calculated. Firstly, the outcomes must have an expected value given to them. Next, each chance node must be looked at with probabilities given to each possible result. Probabilities at each chance node must sum total 1, so all possible outcomes are accounted for at that node. The calculation of the decision tree is performed by determining the value of the chance nodes and the decision nodes.

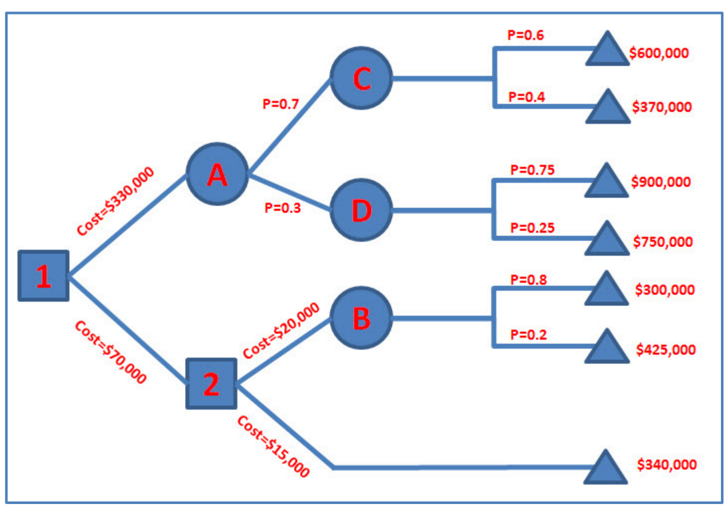

Figure 3: Decision Tree with Expected Values and Probabilities

The chance nodes are calculated by summing the product of expected values with the probability of them occurring.

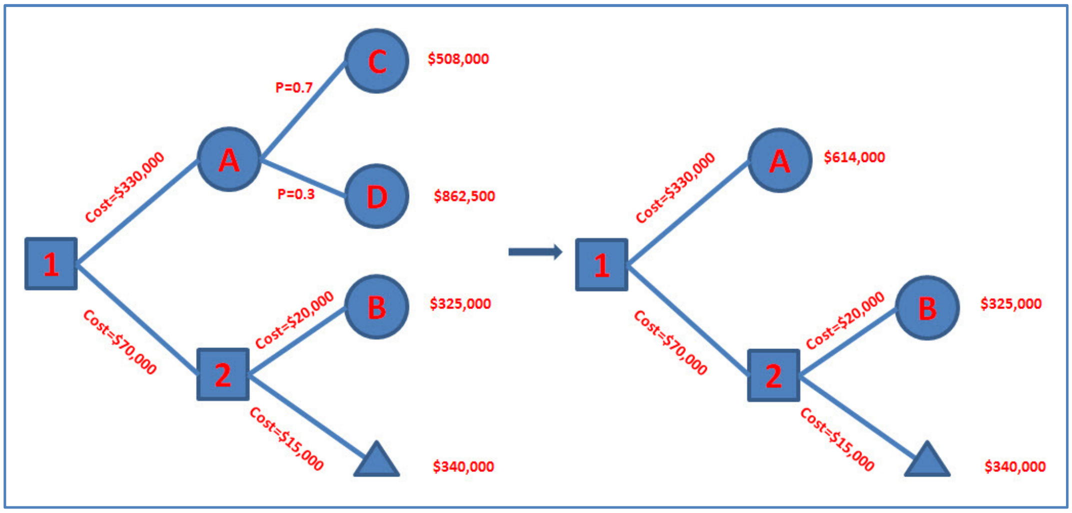

Figure 4: Decision Tree with Chance Calculations Performed

The decision nodes are calculated by subtracting the cost associated with a particular decision from the value of the decision's probable outcomes, to give you the added value of that decision.

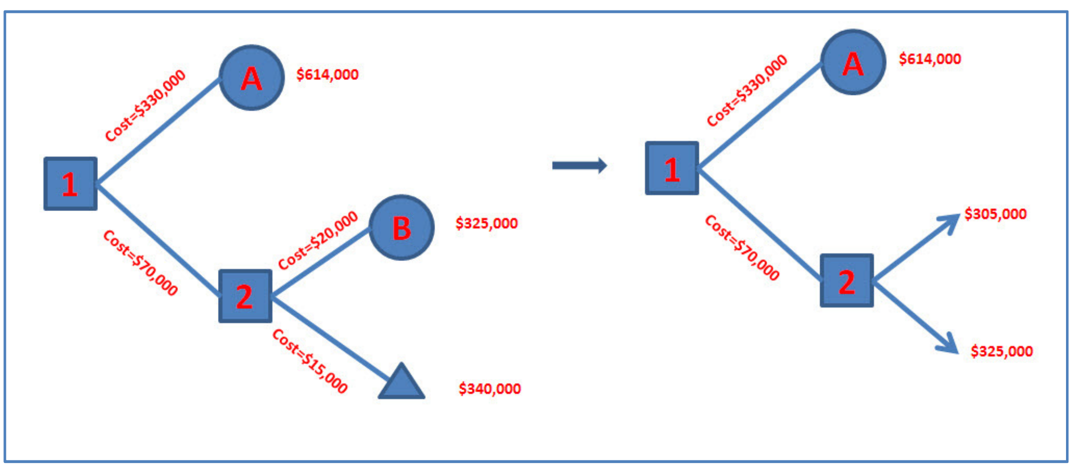

Figure 5: Decision Tree with Chance and Decision Calculations Performed

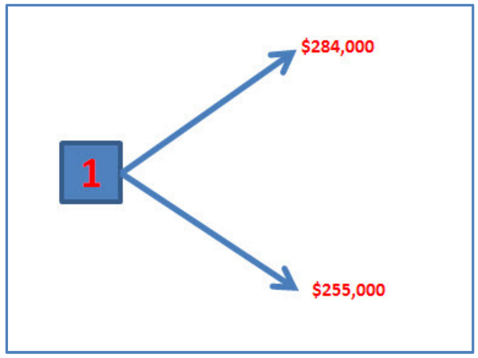

Figure 6: Decision Tree Collapsed to Decision 1

The DT example shows that based on the probabilities, the first decision to be made should be the one that puts the project on the path of the $284,000 expected value. However, this decision has a probability of 0.28 (0.7 x0.4) that the present value will be $40,000 ($370,000-$330,000). While the alternate decision at decision node 1 would provide a guaranteed present value of $255,000 with the correct decision being made at decision node 2.

What DTA does not take into consideration is the appetite for risk senior management has. For this reason, a sensitivity analysis should be run on expected values, as well as the probabilities at chance nodes. Nevertheless, because one benefit of the DTA method is that the trees themselves are clearly laid out and easy to interpret, it is straightforward for decision makers to investigate all options before them. They can choose the path of the best long-term probable outcome, but limit their decisions to the current ones that must be made in order to put them on the desired path.

2.2.3 Monte Carlo Simulation

The limitations of the majority of positive valuation methods are that they are deterministic in their approaches. Deterministic algorithms behave quite predictably in that they will provide the same results repeatedly given the same inputs. An issue with a deterministic approach is that the method has issues with the variability of inputs. One way of dealing with the variability issue is to use different sets of variables in the deterministic algorithms to create a best, worst, and most likely case, based on variables which management believes fit the scenarios. Stochastic algorithms, on the other hand, are based on variables that are chosen randomly, to pseudo-randomly, with interrelated correlations and will give different results during iteration. However, after a number of iterations, the results usually converge toward the more probable outcomes.

Monte Carlo simulation (MCS), named after the famous casino in Monaco, is a group of stochastic methods that use computer simulations of computational algorithms using random and pseudo-random variables in their calculations. The variables could have a random walk distribution, a mean reverting distribution, or be constrained by any probabilistic distribution. These distributions, however, are based on management's belief as to how variables will vary in the future. The method is used to calculate several hundred or thousand solutions, which are used to assign the probability of certain outcomes. The result of an MCS is NPVs with probabilities attached to them, such as a project having a 90% probability of having an NPV lower than X, and a 10% probability of having an NPV higher than Y.

The strength and appeal of MCS lies in that, if one is confident in the distribution of the project's value driving variables and their correlations to each other, the number of iterations run based on the distributions provides results that are much more probable than a deterministic model would provide. There is also a number of user-friendly software available to run MCS, such as Crystal Ball™ from Oracle, which makes valuation using MCS much less complicated then the theory behind it, would have some believe. MCS is mainly used on DCF models, but can just as easily be used with DTs. Even in ROA, it is called "Monte Carlo Option Model". Another benefit similar to that of DTA is that MCS makes the decision makers and evaluators agree on future expectation by having to agree on probabilistic distributions and correlations.

The main criticism with MCS, much like some deterministic methods, is the choice of variables to use. However, with MCS the choice is not only on the variable, but also on probabilistic distribution over the life of a project. There are several different methods to determine a distribution, such as basing future distribution on past distributions. Another difficulty with MCS is correlating variable inputs so that the pseudo-random choices in their probabilistic distributions still obey assumed correlations. An example would be a strong correlation between commodity price and the cost of a commodity input (i.e. steel, fuel). The task of determining probabilistic distributions and their correlations is often better suited for an economist as opposed to a project engineer. The necessity for this added expertise on the valuation team is often viewed as a disadvantage of the MCS method, however, added value is rarely considered under this negative judgement. Many of the people basing their decisions on project valuation either do not understand probabilistic analysis, are unfamiliar with it, or are more confident with scenario and sensitivity analysis. The weariness toward probabilistic analysis is likely due to the method not providing a single decision figure.[6] Instead, it provides the probabilities associated with a maximum decrease in value, maximum increase in value, and the expected value. These ranges of values and probabilities make project comparison less

[6] (Kodukula & Papudesu, 2006)

straight forward. Indeed, the abundance of useful information seems to give decision makers analysis paralysis with MCS results. However, many senior decision makers are comfortable with these more sophisticated methods of valuation. The number is increasing every day, much as the comfort with DCF has increased steadily over the last several decades to where it has become a standard. MCS also suffers from the same problem as the conventional DCF method, in that it does not allow for management decisions during the course of a project, such as a production change in response to commodity price fluctuations, thereby being a conservative valuation.

2.2.4 Real Options Valuation

Options valuation was first pioneered by Fischer Black and Myron Scholes in their 1973 paper, *"The Pricing of Options and Corporate Liabilities."* Richard Merton followed Black and Scholes with his own work, which elaborated on the mathematics of the Black-Scholes model, now often referred to Black-Merton-Scholes model. In 1997, Merton and Scholes received the Nobel Prize in Economics for their work on options valuation, Black being ineligible for a posthumous award after his death in 1995.

To understand real options, it is important to understand the financial instruments that they are based on. In finance, an option is a contract that conveys upon the owner the right, but not the obligation, to buy or sell a stock at a predetermined price on (European) or before (American) a predetermined date. In return for granting the option, known as writing the option, the writer receives a fee, or option premium.

An option to buy is called a "call" and is referred to as going "long", whereas an option to sell is called a "put" and is referred to as going "short". The agreed upon price in the contract is the strike price, or exercise price. Call options are only exercised when the price of the underlying security is above the strike price, while put options are only exercised when the price of the underlying security is below the strike price. Being in a position to gain through the exercise of an option is referred to as being "in the money". For a call with a strike price of $15, if on the exercise date the stock price were $20, the option would be exercised, as the owner would be making $5 per option. For a put with a strike price of $15, if on the exercise date the stock price were $10, the option would be exercised, as the owner would be making $5 per option. The cost of the option is irrelevant for the determining if the option is in the money. It is a sunk cost, as the options are already bought. However, the cost would be needed in order to calculate if the owner of the exercised options is indeed in the money with respect to the total investment.

Financial options are based on financial assets, whereas real options are based on real assets. The term "Real Options" was coined in 1977[7], while real options application to natural resource investments was first suggested in 1979[8]. The application of financial options theory to natural resource investments is ideal, as their structures are very similar, sharing price uncertainty and correlation to markets (commodity). The principles that form the foundation of ROA are the assumptions that allow financial options methods to be applied to real options. The two main assumptions that permit the mathematics of financial options to be applied to real options are:

1) No Arbitrage Opportunity
2) Replicating Portfolios

" In economics and finance, arbitrage is the practice of taking advantage of a price difference between two or more markets: striking a combination of matching deals that capitalize upon the imbalance, the profit being the difference between the market prices".[9] In principle, arbitrage provides a riskless profit; however, in reality, risk does exist even in arbitrage opportunities. For financial options methods to be applied to real options, the market must be considered efficient, meaning no arbitrage opportunities exist. The criticism against this assumption is that real assets are not as liquid as financial assets. This illiquidity creates arbitrage opportunities. The existence of arbitrage opportunities, however, is only a limitation to the model and does not invalidate its use. There are methods to overcome this limitation through proper adjustments.[10] Such adjustments are around the discount rate and require a slightly higher risk-free discount rate to calculate the option-pricing model, a slightly higher discount rate to calculate the project DCF, or an illiquidity discount factor to apply to the final option value.

The second assumption that must be met in ROA is that of the replicating portfolio. The idea behind a replicating portfolio is that a series of future cash flows from a project can be replicated by a certain number of shares of the underlying financial asset and riskless bonds. With the replicating portfolio having the same payoff as the project, and if no arbitrage opportunity exists, the current value of the replicating portfolio would be identical to that of the option (project). ROA allows for two things this way: an arbitrary discount rate is not required, and the term structure of interest rates is automatically taken into account.[11]

The rationale behind ROA is to value the uncertainty and management flexibility in projects that are missed in conventional DCF analysis. Unlike DCF analysis, the risk adjustment

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[7] (Myers, 1977)
[8] (Tourinho, 1979)
[9] (Wikipedia: Arbitrage, 2011)
[10] (Kodukula & Papudesu, 2006)
[11] (Kodukula & Papudesu, 2006)

in ROA is added to the uncertainty calculations, as opposed to the net cash flow. The cash flows are discounted at the risk-free rate, as to not double count for risk. The risk-free rate can be viewed as the time adjustment for the cash flows. The DCF method aggregates the risk-free rate with an appropriate risk rate, to create what is referred to as the risk-adjusted discount rate (RADR). By accounting for the project risk in uncertainty (i.e. price uncertainty), the risk is being adjusted at the source. If risk structures are dependent on profit margins, it is better to use ROA, as opposed to DCF, to value the project more appropriately.

To illustrate this point, take into consideration a varying operating cost example: two copper mines, Mine A with a low operating cost of $1.00/lb and Mine B with a higher operating cost of $1.30/lb. Looking at a base case scenario of Mine A with a capacity of 10mlbs/yr and Mine B with a capacity of 13mlbs/yr and a commodity price of $2.30/lb, both mines produce an expected cash flow of $13M.

Base Case Cash Flows

Mine A

$$10M\ x\ (\$2.3 - \$1) = \$13M$$

Mine B

$$13M\ x\ (\$2.3 - \$1.3) = \$13M$$

Upside Cash Flows

Mine A

$$10M\ x\ (\$3 - \$1) = \$20M$$

Mine B

$$13M\ x\ (\$3.0 - \$1.3) = \$22.1M$$

Downside Cash Flows

Mine A

$$10M\ x\ (\$1.6 - \$1) = \$6M$$

Mine B

$$13M\ x\ (\$1.6 - \$1.3) = \$3.9M$$

Calculation 1: High Cost vs. Low Cost Mine Cash Flow Sensitivities

With an upside and downside commodity volatility of 30% ($0.70), it is clear that the cash flows of the mines behave differently to price uncertainty. The cash flow volatility for Mine A is $CF(\sigma) = \pm 54\%$, while the cash flow volatility for Mine B is $CF(\sigma) = \pm 70\%$. The increased uncertainty of high cost projects would not be quantitatively evaluated using conventional DCF, but could be quantified using ROA.

It is a common misconception that a project evaluated using real options analysis always returns a higher value than that of conventional DCF. The option value of a project is based on the project structure (as the varying operating cost example above illustrates). For the most part, evaluating flexibility and discounting discretionarily, as opposed to aggregating, will provide higher values. However, some project structure will show results of early project closure or abandonment, which returns a lower present value than the deterministic DCF method would have. DFC would run a longer project life because it does not value the risks properly. This higher NPV can be viewed of as erroneous of course, if one puts higher credence into how ROA accounted for uncertainty in the project.

The underlying asset value (S_O) is the present value of the asset being valued. This value is easily calculated by discounting all of the future cash flows of the mining project to time equals zero. Any risk inherent in these potential cash flows must be accounted for by an appropriate risk adjusted discount rate. The value of the underlying asset is assumed to change in a continuous process, up and down based on its volatility. This volatility in rates of return is referred to as the asset volatility factor (σ). In the options models, the volatility is calculated as the standard deviation of the natural logarithm of the cash flow returns. These returns are ratios themselves and are calculated as the cash flow of one period over the cash flow of the preceding period. The volatility factor, much like RADR in DCF analysis, is an aggregate value amassed from several sources of volatility, such as commodity price uncertainty, production uncertainty, and cost uncertainty. Much like a more sophisticated DCF analysis may use different discount rates to represent different risk for commodities or costs, ROA can utilize different volatilities for distinct commodities or costs. Moreover, like discount rate, volatility is a variable that has much discussion around it, in particular, how one chooses an appropriate volatility factor.

There are five typical methods for determining volatility factors for a project: management assumption, project proxy, market proxy, logarithmic cash flow returns, and Monte Carlo simulation. The management assumption method uses management's estimates of a best case asset value (S_{opt}), an average case asset value (S_o), and a worst case asset value (S_{pes}). Where asset value has a 0.98 probability of not exceeding S_{opt}, a 0.50 probability of being equal to S_o, and a 0.98 probability of exceeding S_{pes}. Knowing these estimates, and assuming a lognormal distribution of project cash flows, the volatility can be back calculated from the equations below.

A lognormal distribution is assumed as lognormal distributions are commonly used for projected cash flows in financial asset forecasting[12].

$$\sigma = \frac{\ln\left(\frac{S_{opt}}{S_o}\right)}{2\sqrt{t}}$$

Equation 5: Volatility (S_{opt}, S_o)

$$\sigma = \frac{\ln\left(\frac{S_o}{S_{pes}}\right)}{2\sqrt{t}}$$

Equation 6: Volatility (S_o, S_{pes})

$$\sigma = \frac{\ln\left(\frac{S_{opt}}{S_{pes}}\right)}{4\sqrt{t}}$$

Equation 7: Volatility (S_{opt}, S_{pes})

The market proxy method is based on finding a traded company with a very similar risk and cash flow profile as the project in question. The value of the company can be used as a proxy for the value of the project, with historical company data used to calculate the volatility. Simple in theory, the task is much harder in practice; several factors make up the market value of a company, such as diversified revenue streams, dual class structure, or market perception, which may not be applicable to the project in question. The project proxy is much the same, except that a similar project with similar cash flows to the proposed project is used as a proxy, and historical data is compiled, and volatility calculated. The logarithmic cash flow returns method is based on the volatility of the estimated cash flows used to determine the underlying asset value. A return is calculated for each year by dividing the period cash flows by the previous period cash flows. Then, the natural logarithm of each return is taken and the standard deviation of the natural logarithm for each time period is taken. This is the asset volatility for that period and the yearly average volatility can be calculated from the history of data. Monte Carlo simulation uses several cash flow simulations, each of which a volatility factor is calculated for, using the logarithmic

[12] Calculation 2: Proof of EV Lognormal Distribution

cash flow returns methods discussed previously. This Monte Carlo method provides as many volatility factors as there are simulations, thereby giving a distribution of volatility factors based on a distribution of the underlying asset value.

In economic theory the assumption that the probability distribution of asset values (expected value) is lognormally distributed is utilized quite often, the proof behind this assumption can be followed below.

$$EV = \sum_{i=1}^{n} V_i = V_1 \times V_2 \times \ldots \times V_n$$

$$ln(EV) = ln(V_1 \times V_2 \times \ldots \times V_n)$$

$$ln(EV) = ln(V_1) + ln(V_2) + \cdots + ln(V_n)$$

Calculation 2: Proof of EV Lognormal Distribution

Where *EV* is the expected value and *Vi* represents the relative period returns (the ratio of a periods return over the preceding periods return). A natural logarithm can be taken of both sides of the expected value equation. The $\sum_{i=1}^{n} \ln(V_i)$ side of the equation can be thought of as representing a random set of probable future relative period returns. According to the central limit theorem, as the number of random variables increases, their distribution approaches normal. Hence, the larger the set of random variables, the more normal its distribution. Therefore, if *ln(EV)* is normally distributed, then *EV* is lognormally distributed. This normal distribution of expected values is a key assumption in the Black-Scholes formula.

The two most common methods for calculating real options are the Black-Scholes method and the binomial method. The Black-Scholes method is simply based on the use of the Black-Scholes equation and was formulated for use on European options, those with a fixed exercise date.

$$C = S_0 N(d_1) - Xe^{-rT} N(d_2)$$

Equation 8: Black-Scholes Equation

The equation can be divided into two parts, the first being the expected value from owning the stock outright $S_0 N(d_1)$. Where S_0 is the stock price and $N(d_1)$ represents the change in the call premium with respect to a change in the stock price.

The second part of the equation is the value that can be expected from exercising the option on the option expiry date $Xe^{-rT}N(d_2)$, where Xe^{-rT} is the present value (continuous discounting) of the exercise price and $N(d_2)$ is the risk neutral probability of the option being in the money. It is important to note that risk neutral probability should not be confused with objective probability which is the probability of an event occurring. Adjusting objective probabilities for risk creates a risk neutral probability (a mathematical operator) which can be used with the risk-free expected value to calculate a risk adjusted expected value. The market value of the call option is the difference between these parts of the equation.

The variable of the Black-Scholes equation can be identified in Table 1: Black-Scholes Equation Variables.

Variable	Definition
C	Option Value
S_0	Asset Value
X	Strike Price
r	Continuous Risk Free Rate
T	Time to Expiration
d_1	Standard Normal Stochastic Variable 1
d_2	Standard Normal Stochastic Variable 2

Table 1: Black-Scholes Equation Variables

The derivations for the calculation of the distribution variables d_1 and d_2 are complex and their derivation will not be covered in this paper. However, when the cumulative normal distribution function, N() , is the statistical operator used to calculate their cumulative distributions, they themselves can be calculated as the equations show below.

$$d_1 = \frac{\ln\left(\frac{S_0}{X}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

Equation 9: d_1 Standard Normal Stochastic Variable

$$d_2 = \frac{\ln\left(\frac{S_0}{X}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

Equation 10: d_2 Standard Normal Stochastic Variable

Their significance is that they are calculated from a stochastic process (Gaussian Process –Random Walk) which assumes probable future returns are independent and identically distributed and follow a normal distribution. This means returns are not based on prior period results, the probability of a return increase in a period is equal to the probability of a decrease in the return, and all randomly generated returns are normally distributed. The specific values of d_1 and d_2 are their locations on a normal distribution space, where mean is 0 and standard deviation is 1, representing the expected stochastic values.

The variable $N(d_1)$ and $N(d_2)$ are the standard normal cumulative distributions at d_1 and d_2 and can most easily be calculated using the function *Normsdist( ) in Microsoft Excel®* or from calculations made with the use of a cumulative normal distribution table. Simply put, the standard normal cumulative distribution at d_1 is the probability of the value of d_1 being less than or equal to itself. In respect to the Black-Scholes formula $N(d_1)$ and $N(d_2)$ would be the risk neutral probabilities of the option being in the money at the option expiry date.

The Black-Scholes method is based on the following assumptions.

- The stock pays no dividend during the options life, nor are commissions charged
- Options can only be exercised on the expiry date (European option)
- Markets are efficient, random and unpredictable
- Interest rates remain constant
- Future returns are lognormally distributed, meaning returns on the underlying stock are normally distributed

The binomial method was developed by John Cox, Stephen Ross, and Mark Rubinstein in order to value financial options.[13] Where the Black-Scholes formula can be viewed as a black box equation, the binomial method is transparent, making it easy for practitioners and evaluators to follow. It is also applicable to American and European options.

[13] (Cox, Ross, & Rubinstein, 1979)

The binomial lattice looks and operates very much like a DT; however, it has a much more advanced form of discounting applied to it. The time direction of the lattice begins on the left at S_O, the underlying asset value at time equals zero, and proceeds to the right. With each time increment, each probable value can increase or decrease based on the variance of the asset value (volatility factor). Due to the volatility of an increase being equal to that of a decrease, each increase in value at a time period may coincide with a decrease in a higher value from the previous time period. Below is illustrated a three period binomial lattice:

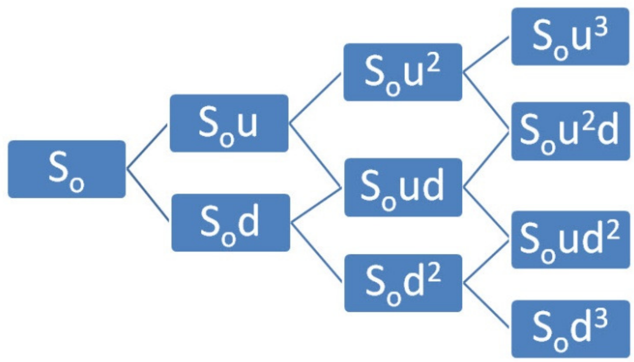

Figure 7: Binomial Lattice

In the above binomial lattice, an increase in value is represented by the letter "u", with a decrease represented by the letter "d". Exponents represent the number of increases or decreases in value. In the final time period, the highest and lowest values represent the range of possible asset values. The distribution of objective probabilities are based on the number of paths that lead to final period outcomes. Values in the centre of the lattice have more paths leading to them, while values toward the ends of the lattice have fewer paths leading to them. The number of paths leading to outcomes in a binomial lattice can best be summarized through the illustration of Pascal's Triangle below.

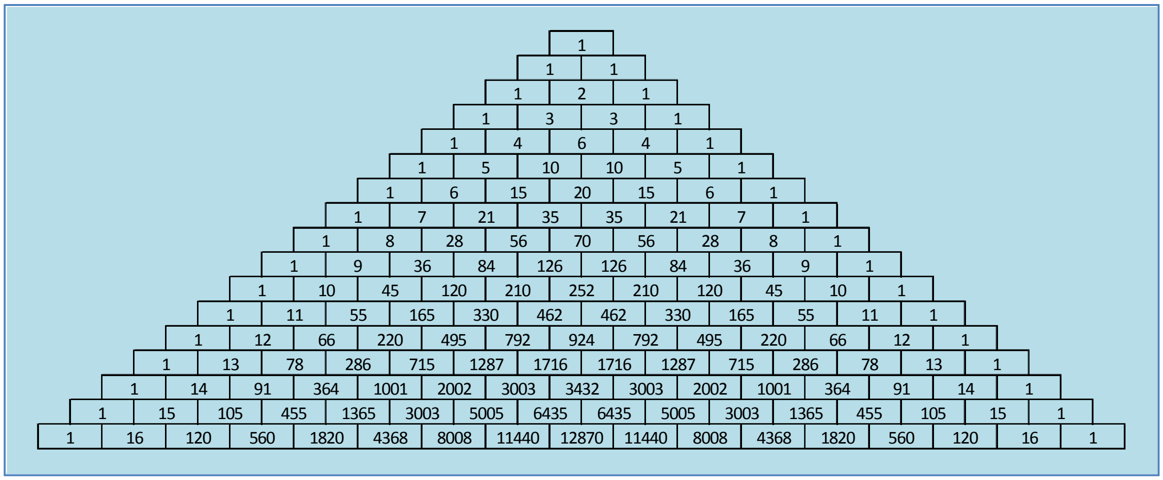

Figure 8: Pascal's Triangle (17 Row Lattice)

The value in each block of a Pascal Triangle represents the number of possible paths that can lead to the specific outcome located in the same location of the lattice. This leads to a normal distribution for objective probabilities as is illustrated in Figure 9: Distribution of Pascal's Triangle (17 Row Lattice).

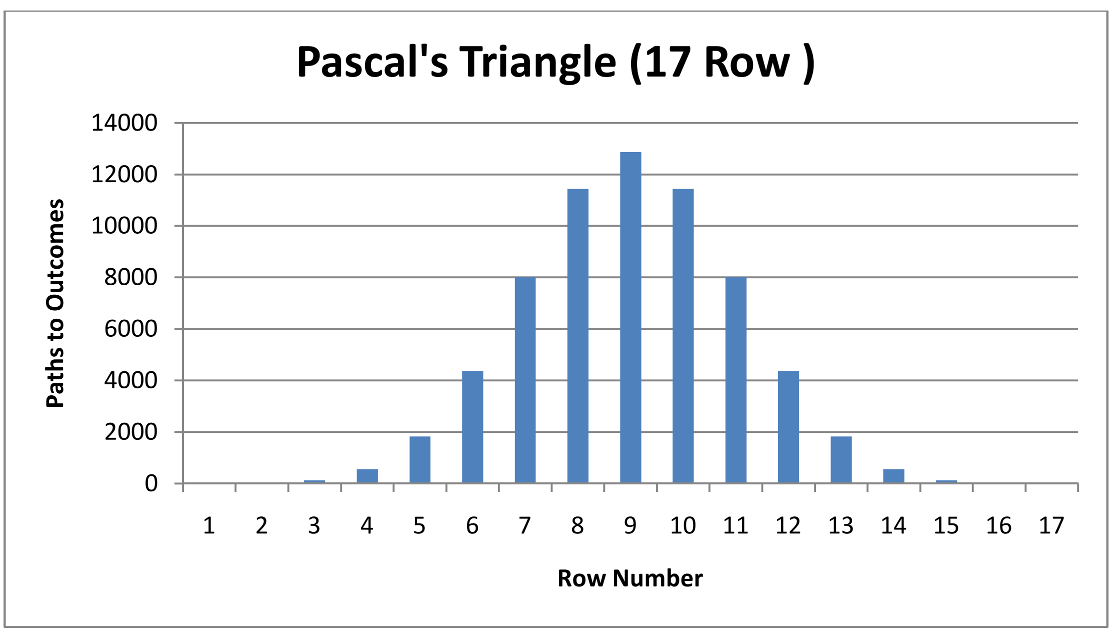

Figure 9: Distribution of Pascal's Triangle (17 Row Lattice)

To solve a binomial lattice, parameters must be calculated based on the option input variables of volatility (σ), risk-free rate (r), and the incremental time step (δt). These parameters are the upward move volatility factor (u), the downward move volatility factor (d), and the risk-neutral probability (p). The volatility factors are used for calculating future asset values while the risk-neutral probability is used to back calculate option values. It is important to note that the risk-neutral probability (p) is used for back calculating against the upward move, while it is the remaining probability (1-p) that is used for back calculating against the downward move.

$$u = \mathrm{e}^{(\sigma\sqrt{\delta t})}$$

Equation 11: Upward Move Volatility Factor

$$d = \mathrm{e}^{(-\sigma\sqrt{\delta t})}$$

$$d = \frac{1}{u}$$

Equation 12: Downward Move Volatility Factor

$$p = \frac{\mathrm{e}^{(r\delta \mathrm{t})} - \mathrm{d}}{\mathrm{u} - \mathrm{d}}$$

Equation 13: Risk-Neutral Probability

Firstly, asset values must be calculated from left to right, all the way to the final time period, giving each node an asset value. Each node's asset value is calculated by multiplying the previous node's asset value by an upward move volatility factor (u) and a downward move volatility factor (d), depending on the position of the previous period's node in the lattice.

Next, an option value is calculated for the final period of the lattice by subtracting the option cost from the asset value. The final time period is the option expiry period, hence there is no future option value. The option value of a prior period is equal to the weighted average of the future option values based on the risk-neutral probability of the asset values in those nodes occurring multiplied by the risk-free discount factor for one time increment. The option values are calculated all the way to the left side of the lattice, the first period and initial asset value.

When comparing to a DCF analysis, the additional value created by the real option is not the real option value, but the difference between the real option value and the NPV from the DCF approach.

Real options valuation is most advantageous when managerial flexibility is high, as well as uncertainty. When flexibility is low and there is certainty in model assumptions, ROA adds negligible value. Projects with high NPV based on conventional DCF show sufficient value creation for projects to move forward even though they are not accounting for value that other, more sophisticated, methods would.

The benefit to Teck Resources of using ROA is the more accurate valuations it provides in terms of uncertainty. Moreover, like DTA, ROA allows for the inclusion of options available to management, such as project expansion or deferral. The option of deferral in particular is interesting as ROA can quantify the value in marginal projects that are not slated for development due to current economic conditions, yet require accurate valuation for negotiations of sale or prioritization of future work.

3: Project Valuation Model.

The subsequent section will calculate the DCF NPV and a real options value (deferral option) of a mining project through two distinct models. The purpose being to calculate the discrepancy in value, illustrating how ROA can quantify the value inherent in the uncertainty associated with the project, and discuss the implications which arise through the use of valuation techniques that better reflect the realistic conditions present in a project.

An option inherent in all projects is the option to wait (deferral option). For mining companies, the optionality of waiting is very important and usually considered in a qualitative matter. However, attaching a quantitative value to the option is not always considered. The value of this option is important when determining what an appropriate selling price would be for the deposit/project.

When a mining company is fortunate enough to have several potential projects but only enough present resources to commission one of them at the current time, the option to wait can be applied to all projects so their respective values can be compared. Moreover, the way ROA applies uncertainty risk at the source as opposed to total cash flow, results can garner important information.

Unlike other options, the option to wait does not require a new cash flow model looking at potential scenarios, so it can be applied in a straightforward manner to conventional DCF information. This allows for a direct comparison of results from a more traditional method and ROA.

To add value to the study of real options and its practical applications, an ROA and accompanying sensitivity analysis will be conducted on one of Teck Resources' mineral prospects. First, a DCF analysis will be calculated using more current commodity price assumptions to see how the project fairs under the more traditional valuation methods that Teck implements. Second, an ROA will be completed using the inputs from the DCF (asset value and strike price) to see how the more complex approach values the project.

The following real options valuation model of the project will look at the option to wait. The option to wait, as many real options are, is not fixed with a specific exercise date. It is for this reason that the option will be calculated using the binomial method. As a result, the option values at each time increment will be available for analysis. The binomial method also provides the European option value (exercise at expiry). For this reason, the Black-Scholes option value will be calculated so the two mathematically unique solutions to the same problem can be compared.

3.1 Daedalus Project

Daedalus[14] is a sizable copper-nickel sulphide deposit that has been historically valued using the conventional DCF method. At current cost and commodity price estimates, set for the purpose of this paper, Daedalus' value has been estimated as slightly negative. It should be noted that though the technical aspects of the project are realistic, costs and commodity prices have been altered as to not reflect Teck Resources' estimates. An evaluation using a simplistic risk discounting method, which shows that a project is marginal, is an excellent candidate for ROA, as a more sophisticated method of risk discounting may show that when risk is accounted for appropriately, the projects value may in fact be in positive territory.

Daedalus is an open pit mine with a conventional truck and shovel mine fleet and mineral refining facility on site. The estimated cash flows for the project occur over 32 years, commencing with 5 years of capital cash outflows followed by 27 years of revenues. The jurisdiction that the project resides in is considered favourable for the mining industry. Because of the project's advantageous location, a low country-risk discount factor was incorporated into the discount rates.

DCF and ROA models were created for a base case scenario and other scenarios that illustrate the sensitivities of the models to certain variables. The scenarios not only allow for a comparison of how each of the models are sensitive to variability in their inputs, but also how the valuation model estimates compare when the same variables experience identical changes.

3.1.1 Discounted Cash Flow

The discounted cash flows of Daedalus are based on the line items in Table 2: Daedalus Project Cash Flow Line Items.

[14] For purposes of corporate confidentiality the project name in this study has been changed to Daedalus

Revenues	**US$M**
Operating Costs	**US$M**
Jurisdiction Royalty	**US$M**
EBITDA	**US$M**
Net Proceeds Tax	**US$M**
Cash Income Taxes	**US$M**
Cash Flow After Taxes	**US$M**
Capital Expenditures	**US$M**
Unlevered Free Cash Flow (before ∆ WC)	**US$M**

Table 2: Daedalus Project Cash Flow Line Items

The revenues of Daedalus are made up of the copper and nickel metal productions, as well as some minor metal by-products. Over the estimated 27 years of operation at the Daedalus mine, the average yearly metal productions are on the order of 292Mlbs of copper, and 81Mlbs of nickel. Of the major cash outflow components, the average yearly operating costs, royalty, taxes and sustaining capital expenditures are $354M, $34M, $48M and $41M respectively.

The revenues for the DCF method of valuation were calculated using the commodity prices listed in Table 3: Long Term Commodity Prices for Analysis. The calculations are also based on the assumption of zero inflation (constant unit revenues and costs). An evaluation in constant dollars allows for easier calculation and uses values that can be interpreted and understood in today's dollars, as a 15 year inflated value can lose its meaning quite quickly.[15] Though evaluations are not impartial to inflation even if commodity prices rise at the same rate as input costs, the financial evaluations in the Daedalus models do not look at taxes, depreciation, or working capital where inflation has its most significant affects.[16]

Commodity	Long Term Price ($US/lb)
Copper	2.30
Nickel	6.00
Cobalt	10.00

Table 3: Long Term Commodity Prices for Analysis

[15] (Torries, 1998)
[16] (Mills, 1996)

For base metal projects, a typical discount rate used for DCF project evaluation in a jurisdiction with low country risk and an average project risk is 8%. The rate itself is the aggregate of the risk-free rate, the project risk premium and the country risk premium. A rate for inflation is not included in the aggregate rate as the analysis is based on constant dollars. For lower risk countries this premium is in the 1-3% range.[17]

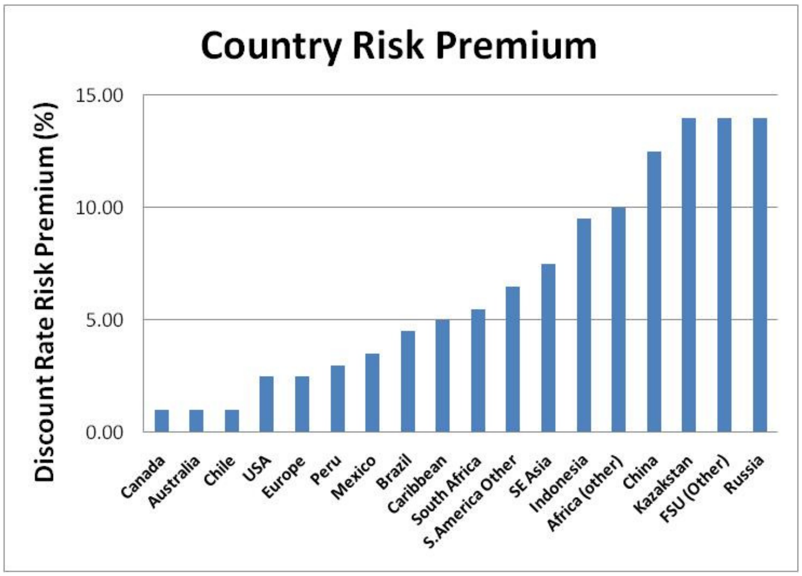

Figure 10: Country Risk Premium[18]

With the above economic variables and assumptions used, the cumulative discounted cash outflows for capital in the first 5 years is $2,668M, while the cumulative discounted cash inflows from the following 27 years of production is $2,559M, making for a negative project NPV of $109M.

The cash flows and cumulative cash flows, discounted and undiscounted, with respect to project year are illustrated in the graph below, Figure 11: Cash Flows vs. Time (Discount Rate = 8%).

[17] (Smith, 2011)
[18] (Smith, 2011)

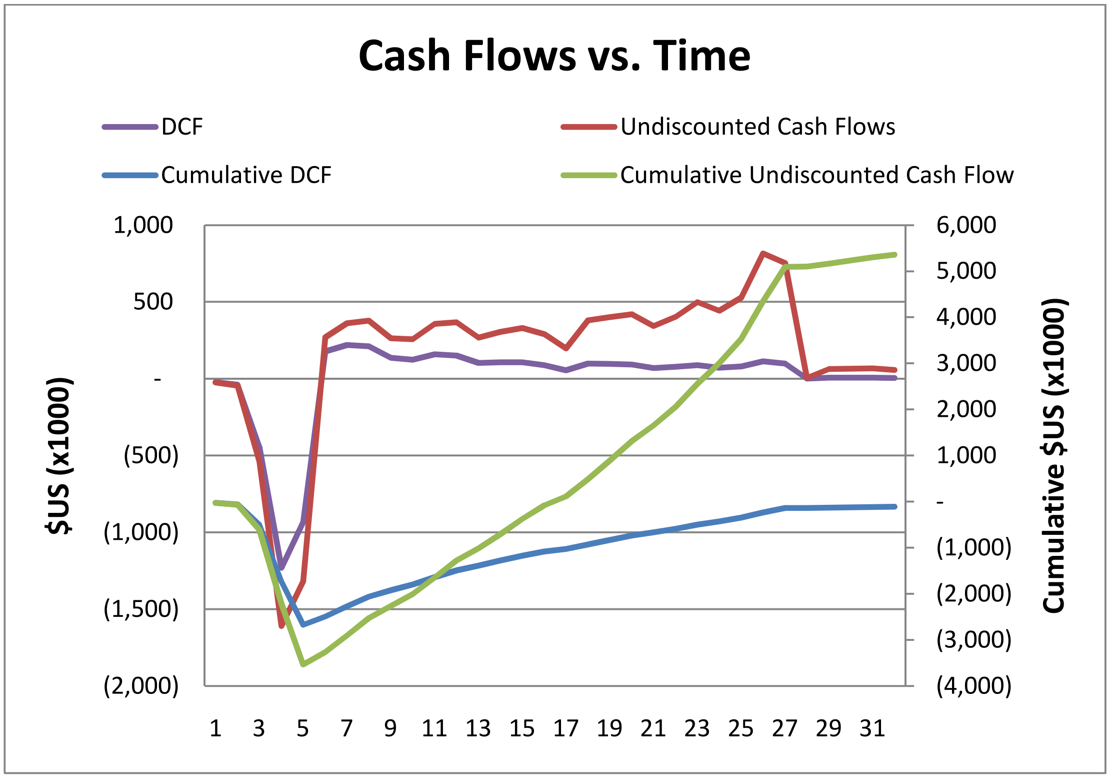

Figure 11: Cash Flows vs. Time (Discount Rate = 8%)

The high capital costs involved in the Daedalus project and the long duration of revenues provide a scenario where future revenues are discounted greatly in comparison to the large capital outlay at the beginning of the project. In a scenario such as this, future revenues are discounted quickly to a rate that adds little value to the present value of the project. Below, Table 4: Period Discount Factor (8% Discount Rate, Discounted Mid-Period) provides the discount factors applied to future cash flows at 8%.

Period	1	2	3	4	5	6	7	8
Discount Factor (@8%)	96.23%	89.10%	82.50%	76.39%	70.73%	65.49%	60.64%	56.15%
Period	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Discount Factor (@8%)	51.99%	48.14%	44.57%	41.27%	38.21%	35.38%	32.76%	30.33%
Period	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Discount Factor (@8%)	28.09%	26.01%	24.08%	22.30%	20.64%	19.12%	17.70%	16.39%
Period	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
Discount Factor (@8%)	15.17%	14.05%	13.01%	12.05%	11.15%	10.33%	9.56%	8.85%

Table 4: Period Discount Factor (8% Discount Rate, Discounted Mid-Period)

As can be seen from the discount factor table, the revenues past year 25 are contributing less than 15% of their future value to the project's present value. This illustrates well the issues that traditional DCF poses to long life project evaluation.

In comparison to the risk free rate, which will be used in the ROA to follow, the revenue contribution to present value is still at 51% in year 32, as can be seen in Table 5: Period Discount Factor (2.125% Risk-Free Rate, Discounted Mid-Period).

Period	1	2	3	4	5	6	7	8
Discount Factor (@2.125%)	98.95%	96.90%	94.88%	92.90%	90.97%	89.08%	87.23%	85.41%
Period	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Discount Factor (@2.125%)	83.63%	81.89%	80.19%	78.52%	76.89%	75.29%	73.72%	72.19%
Period	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Discount Factor (@2.125%)	70.68%	69.21%	67.77%	66.36%	64.98%	63.63%	62.31%	61.01%
Period	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
Discount Factor (@2.125%)	59.74%	58.50%	57.28%	56.09%	54.92%	53.78%	52.66%	51.56%

Table 5: Period Discount Factor (2.125% Risk-Free Rate, Discounted Mid-Period)

The drastic difference in discount factors based on the two discount rates is important to note as ROA uses the risk-free factors for discounting future option values, while accounting for the additional risk in a more sophisticated way, as opposed to putting a blanket factor on all future cash flows as DCF analysis does.

At an NPV of negative $109M, the Daedalus project would not move forward to commissioning but may show enough promise to move forward to a more detailed project study, or may be shelved until economic variables change enough to warrant an updated study and economic analysis. The option to shelve a project valuated by a conventional DCF analysis is interesting, as it is based on a qualitative understanding that as time moves forward, uncertainties in the economics of the project may clear up or the volatility of sensitive project variables may move into more favourable territory. Can these qualitative opinions be quantified? Further to analyzing Daedalus on a DCF basis, it is this paper's purpose to prove that, through the use of ROA, the decision to shelve the Daedalus project can be quantified. This option value has use for project postponement decision making but also for project sales, as this value would need to be incorporated into the sale price.

3.1.2 Real Options Analysis

To calculate the real option value of waiting to implement the project, a current asset value must first be calculated. As the DCF analysis provided, at a discount rate of 8% and commodity prices of $2.30US/lb, $6.00US/lb, and $10.00US/lb for copper, nickel and cobalt respectively, the asset value (S_O) for Daedalus is $2,559M. This asset value, of course, only looks at project revenues, operating/realization costs, and sustaining capital. The present value of capital cash outflows is equivalent to the project's strike price (the price to exercise the option of project commissioning); this value discounted to present dollars is $2,668M. The time duration for the option to wait is five years, at which time the option must be exercised or the project must be sold. The five-year time frame was chosen as it is approximately the same time period at which some jurisdictions allow companies to hold mineral rights before further investment is required to continue to hold the rights. Whether the investment is in an extended drilling program or full project commissioning is often irrelevant. The incremental time step (δt) for the binomial lattice calculation was chosen as 0.147 years, as a binomial model with 34 increments or time periods (35 Rows) was used for a option life of 5 years. The risk-free interest rate and volatility were converted to correspond with the time step used.

A risk-free discount rate equivalent to a five-year United States Treasury Bill was chosen for the ROA, as it represents a riskless investment over the same time period as the options life, 5 years. For risk-free rates, the practice professionals and academics use is to use short-dated government bonds of the currency in question. Though Teck Resources is a Canadian company, US T-Bills were used to determine the risk-free rate, as US dollars were used to calculate the project economics, and commodities sales contracts are usually negotiated in US dollars. This risk-free rate equates to 2.125%.

The cash flow volatility (σ) was assumed to be directly correlated to the historic volatility of copper price. The mine plan is optimized for the recovery of copper, and all other mineral revenue streams are from by-products associated with the concentrator's recovery of copper. This fact, along with the fact that copper revenue accounts for approximately 74% of net project revenue, made for a strong argument that future cash flow volatility would be correlated with the volatility of copper price. The volatility of copper price was calculated based on 25 years worth of monthly copper spot prices, as well as the respective CPI values, so a real (constant) dollar volatility could be calculate. Copper value does not compound as company assets would, it is this compounding that is the reason behind the lognormal distribution of expected asset values; recall Calculation 2: Proof of EV Lognormal Distribution. Therefore, the volatility of copper price was calculated as a regular standard deviation and not a standard deviation of the logs of the returns; this calculation can be found in Appendix 1: Historic Copper Volatility. Historic volatility for copper, from April 1986 to January 2011, was 28.54%.

With the previous variables known, the remaining can be calculated from equations, Equation 11: Upward Move Volatility Factor, Equation 12: Downward Move Volatility Factor, and Equation 13: Risk-Neutral Probability.

$$u = e^{\left(\sigma\sqrt{\delta t}\right)} = \mathrm{e}^{\left(0.2854\sqrt{0.147}\right)} = 1.116$$

$$d = e^{\left(-0.2854\sqrt{0.147}\right)} = 0.896$$

$$p = \frac{\mathrm{e}^{(2.125\%\times 0.147)} - 0.896}{1.115 - 0.896} = 0.487$$

Calculation 3: u, d, p Calculations for Binomial Lattice (Base Case)

Using all the above inputs, a binomial lattice was constructed (

Appendix 4: Binomial Method ROA (Base Case)). The lattice was constructed by projecting asset value (S_O) out 5 years over 34 discrete time steps based on the asset volatility (Upward and Downward move volatility factors). This created 35 probable asset values for Daedalus in the 5th year, which ranged from a minimum of \$62M to a maximum \$105,719M.

$$\$2{,}559M \times 1.116^{34} = \$105{,}719M$$

$$\$2{,}559M \times 1.116^{33} \times 0.896 = \$84{,}935M$$

$$\$2{,}559M \times 0.896^{34} = \$62M$$

Calculation 4: Highest, 2nd Highest, and Lowest Asset Values (Year 5)

Next, in the final year, an option value was calculated for each of the 35 cases by subtracting the strike price from the asset value, with the option value having a minimum of zero, as the option would not be taken if the outcome was negative.

$$\$105{,}719M - \$2{,}668M = \$103{,}051M$$

$$\$84{,}935M - \$2{,}668M = \$82{,}267M$$

$$\$62M - \$2{,}668M = 0$$

Calculation 5: Option Value of Highest, 2nd Highest and Lowest Asset Values (Year 5)

Using the risk-neutral probability and the time value discount factor of the risk-free rate, we can back calculate the 35 real option values in year 5 to time equals 0, one period at a time. An example for the option value of the highest asset value in the time period prior to the final period is shown below.

$$[(\$103{,}051M \times 0.487) + (\$84{,}935 \times (1 - 0.487))] \times (1 + 2.125\% * 0.147)^{-1} = \$92{,}099$$

Calculation 6: Option Value of Highest Asset Value in Period Prior to Final Period

Continuing this back calculation process for the entire lattice, we calculate a real option value of $704M. Compared to the DCF NPV of negative $109M, the real option valuation adds $813M to the project current value based on its valuation of the uncertainty. This difference in valuations is quite dramatic. It is hard to believe that a qualitative consideration of the uncertainty in the project would have consciously, or even subconsciously, been viewed to have so much worth. The real option analysis of the Daedalus project provides Teck Resources with an estimation of the value inherent in the project, which is not considered in more traditional project evaluation methods.

It should be noted that the probabilistic paths (35 row lattice) to these maximum and minimum values have 1 path leading to each of them and with approximately 1.72×10^{10} paths leading to the final year of the lattice, there is a 5.82×10^{-11} probability of each the maximum or minimum asset value outcomes occurring. The table below, Table 6: Outcome Probability of Row (35 Row Lattice) shows the objective probability of the outcomes in rows 1 to 18 of the 35 row lattice, with the objective probabilities of the outcomes in rows 18 to 35 being the exact same but in the reverse order (see section 2.2.4).

Row #	1	2	3	4	5	6	7	8	9
Outcome Probability	5.82E-11	1.98E-09	3.27E-08	3.48E-07	2.70E-06	1.62E-05	7.83E-05	3.13E-04	1.06E-03
Row #	10	11	12	13	14	15	16	17	18
Outcome Probability	3.05E-03	0.01	0.02	0.03	0.05	0.08	0.11	0.13	0.14

Table 6: Outcome Probability of Row (35 Row Lattice)

As upside and downside outcomes based on the volatility have the same probability of occurring, the value in the centre row of the lattice remains the same asset value as that in time zero, and the same strike price as well, in the case of Daedalus $2,559M and $2,669 respectively. What this means is that there is only a 0.14 probability of today's DCF NPV being calculated identically in 5 years due to an identical asset value. Likewise, there is a 43% chance that the value in 5 years time will be greater than today's NPV. The same holds true for the value being less than today's NPV. Though this may not seem surprising when one realizes that the asset value is volatile (in the case of Daedalus based on the historic volatility of copper), this belief of probable changing values is not quantified into the DCF analysis.

The Daedalus option value based on a Black-Scholes calculation should come out almost identical to the previously calculated value; hence, a Black-Scholes evaluation was conducted as a verification of the results of the previous binomial method calculation.

The Black-Scholes variables for Daedalus are the same as for the binomial method except for the Black-Scholes specific variables of d_1, d_2, $N(d_1)$, $N(d_2)$, and the annual risk-free rate from the binomial method must be converted to a continuous risk-free rate.

$$r = \ln(1.02125) = 2.10\%$$

$$d_1 = \frac{\ln\left(\frac{S_0}{X}\right) + \left(r + \frac{\sigma^2}{2}\right)5}{\sigma\sqrt{5}} = \frac{\ln\left(\frac{2559}{2668}\right) + \left(2.10\% + \frac{28.54\%^2}{2}\right)5}{0.2854\sqrt{5}} = 0.42$$

$$d_2 = \mathrm{d}_1 - \sigma\sqrt{\mathrm{T}} = 0.42 - 28.54\%\sqrt{5} = -0.22$$

$$N(0.42) = 0.66 \quad , \quad N(-0.22) = 0.41$$

Calculation 7: Black-Scholes Variables (Base Case)

Using the Black-Scholes formula to calculate the option value of Daedalus, we obtain a value of \$703M. The binomial and Black-Scholes real option values differ by only 0.23%, which can be attributed to one model using discrete time steps and the other assuming a continuous process.

What the ROA conveys in the case of the Daedalus project is that the uncertainty in the assets value equates to a 5 year deferral option value of approximately \$704M. This value provides a much different assertion of value as compared to a traditional DCF NPV of negative \$109M. Though management would still not go ahead with the commissioning of the project until much of this uncertainty cleared up, the ROA provides a value on Daedalus for management decision making whether it be regarding project sale, deferral or prioritization against other projects.

3.1.3 Model Sensitivity Analysis

The purpose of any model is to garner knowledge of the subject being modelled. This understanding comes from more than the end results of the model, such as a deterministic NPV or a European Black-Scholes option value. Some of the most important information to be understood about a project is how it reacts to changes in the model parameters and how sensitive it is to these variables. For this reason, some key sensitivities were looked at for the Daedalus project: copper price, discount rate, volatility and the risk-free rate.

The DCF and ROA are both sensitive to commodity prices, as these variables directly affect the future cash flows. Both the traditional DCF NPV and the ROA option value were plotted against copper price for a better understanding of the sensitivities in relation to each other.

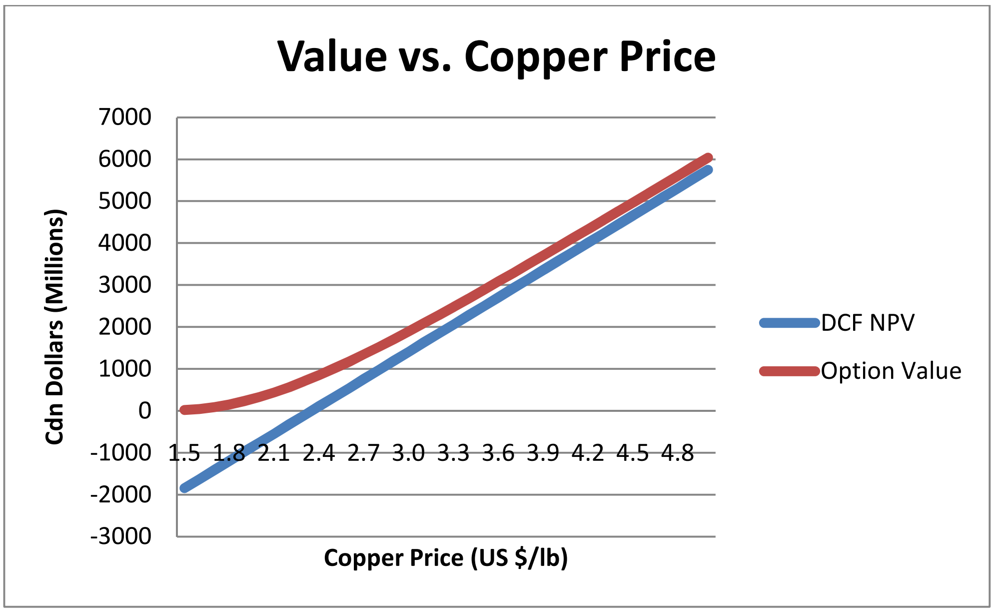

Figure 12: Sensitivity of Value vs. Copper Price

The graph in Figure 12: Sensitivity of Value vs. Copper Price shows that the value of an option is highest in relation to NPV when the NPV is generally lower. This is the case in marginal projects, and this is why ROA benefits marginal projects most in terms of evaluating the value present in the project. This is quite intuitive when one realizes that when an NPV is very high, high uncertainty within reason is a moot point. The value of a deferral option is minimal if the project has solid footing "in the money".

The project sensitivity to the discount rate can be seen in the value of the DCF NPV and the ROA option value, as the ROA utilizes the asset value and strike price discounted at the risk-adjusted discount rate.

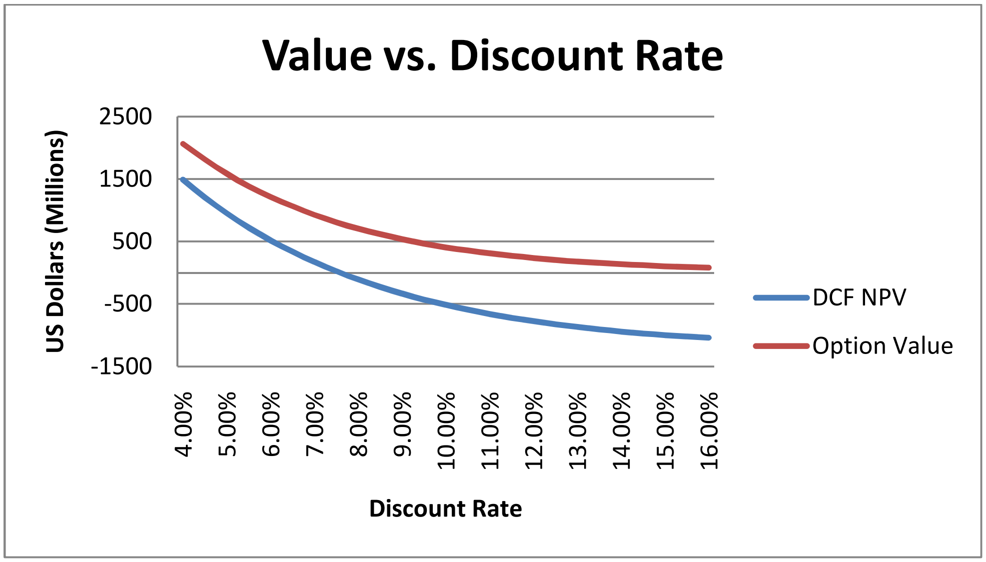

Figure 13: Sensitivity of Value vs. Discount Rate

The NPV decreases with an increasing discount rate faster than the option value whose value approaches zero. In other words, as the discount rate increases, the difference between the option value and DCF NPV increases. In effect, the DCF model is more sensitive to changes in the discount rate than the real options model. The option value always remains positive, as it is valuing the probability that the project will be "in the money" at some point in the future. The higher the discount rate, the less likely that outcome seems for the Daedalus project, and therefore, the option value continues to decrease.

As the option value is the value that can be attributed to the asset uncertainty (volatility), which has downside protection due to management flexibility, it is clear that as asset uncertainty increases, so does the option value. This is illustrated in Figure 14: Sensitivity of Value vs. Volatility.

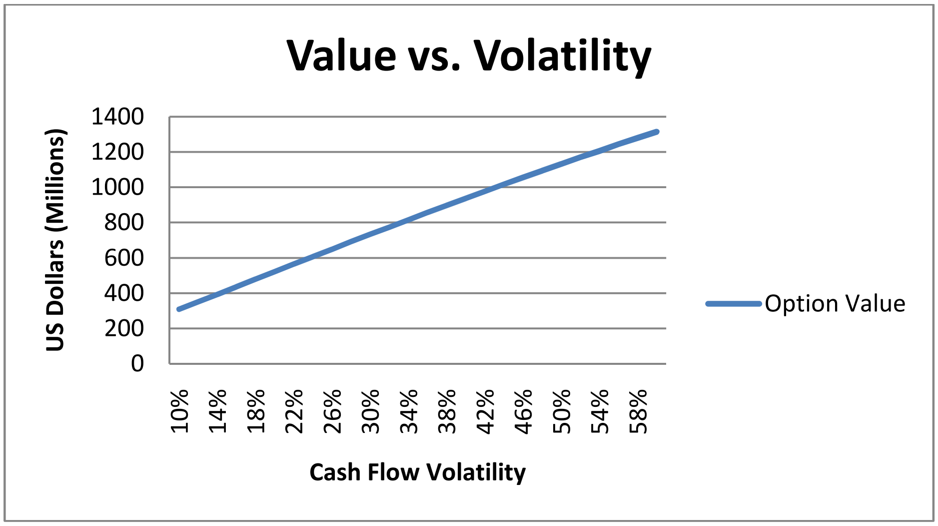

Figure 14: Sensitivity of Value vs. Volatility

The graph in Figure 15: Sensitivity of Value vs. RFR shows option value increasing in direct relation to an increase in the risk-free rate. This may seem counterintuitive, as the option values are discounted back at the risk-free rate, but at the same time, the risk-neutral probability increases with risk-free rate. The increase in risk-neutral probability outweighs the effects of the higher discount factor, which is why option value increases with risk-free rate. It should be noted that the discount rate for the asset value and strike price are held constant as the risk-free rate was increased for this sensitivity.

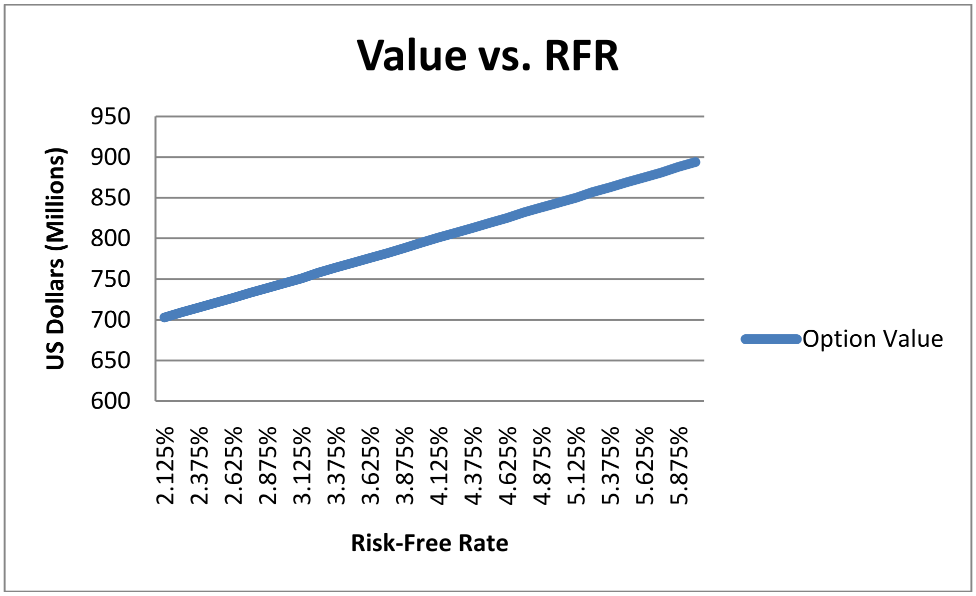

Figure 15: Sensitivity of Value vs. RFR

The results of the DCF and ROA valuation models illustrate that in the case of the Daedalus project, a higher valuation is achieved through an ROA due to the different way the method accounts for risk, as well as the optionality of the project that is being valued (commissioning in the next five year). Another key take away from the project analysis is the fact that option value differs more from the DCF project value when projects are marginal, which is the case for Daedalus, and how option value changes with key variables (sensitivity analysis). After all, the uncertainty exists in the project through the uncertainty of the variables that go into calculating the project value, so understanding how option value changes with input variables allows the project evaluator to understand how their valuation can change with respect to an incorrect assumption regarding inputs.

With respect to Teck Resources' the implications of this analysis show how valuing Daedalus using ROA can quantify value which is understood as inherent in the project but does not materialize through conventional DCF analysis.

4: Conclusion

In natural resource industries, such as base metal mining, project evaluation is critical to a company's success at choosing in which projects to invest and which to avoid. Natural resource extraction projects are often high initial investment long life endeavours, whose revenues are shrouded in uncertainty due to the long time frame over which they will be accruing. The most common method of evaluation is DCF analysis. One of the glaring issues with the conventional DCF method is that it punitively discounts these projects, as it does not account for managerial flexibility during the operation of the project. Other evaluation methods, such as complex DTA and ROA, incorporate this flexibility into the quantitative model, whereas flexibility is usually listed as qualitative factors for DCF analysis. With mining companies basing their resource purchase prices on their evaluations, there is no real concern if sellers are under estimating project value, as this will materialize as a lower expected sale price on their part. However, improper project evaluation puts a mining company at a disadvantage when companies are competing for resources, or when internal projects are competing against each other for capital dollars.

When potential buyers and sellers of mineral resources are all involved in negotiations, using a better method of evaluation becomes a competitive advantage. Assuming that more sophisticated methods of project evaluation do a better job of predicting project risk and revenues, as more companies begin to use these methods, competitive advantage will begin to disappear and the business playing field will level. This equates to a first mover advantage for companies who successfully implement the use of more accurate project evaluation methods. The comparison to make would be the advantage that companies who first implemented DCF analysis saw, and how after time DCF became a business standard.

One of the promising valuation techniques being used in business today is ROA, which allows one to financially model the real options available to management such as, expansion, contraction, abandonment and the option to wait for uncertainties to clear. An example was presented in this paper of the Daedalus base metal project and a deferral option. The projects DCF analysis projected an NPV of negative $109M, while an option to wait ROA calculated a value of $704M. The option value related to the uncertainty inherent in a long life project is an important value to quantify but perhaps more important than the quantitative value is the existence of the difference between valuation techniques and the importance of understanding why these differences exist. Without a method to quantify an option value, options are often left to a qualitative analysis of the project. Under qualitative analysis the true value of an option can easily be over or underestimated depending on the beliefs of those conducting the analysis.

All valuation methods can be looked at as tools, and tools work excellently when they are used on the jobs they were intended for. Likewise, the valuation methods only provide important information if they are used appropriately and if the people using the results understand how the calculations are being performed and what the results represent.

The comparative table below (Table 7: Valuation Method Comparative Table) provides a straightforward view of what is and what is not achieved through the use of the various valuation methods presented in this paper.

	Calculates Net Present Value	Risk Allocated at Source	Stochastic Method	Simplistic Method	Values Optionality
DCF	✓	✗	✗	✓	✗
DTA	✓	✗	✗	✗	✓
MCS	✓	✗	✓	✗	✗
ROA	✓	✓	✓	✗	✓

Table 7: Valuation Method Comparative Table

To use ROA, Teck does not require a paradigm shift in the way projects are currently being evaluated, as an ROA can be conducted in conjunction with other valuation methods, and the information gathered from it used as seen fit. For Teck Resources', a high level ROA of a project that suits its use (i.e. has identified optionality) would be a perfect proving ground to show the value that the method can add to the processes in place. Of course, the results from an ROA would be useless without decision makers understanding what a real option value is and what it is not. Therefore, an ROA learning session would be recommended for management involved in any decision-making based on the valuation. Not using ROA may or may not have great consequences for Teck, depending on which projects could benefit from an ROA, as adverse decisions may be made regarding them due to a lack of information. ROA's potential benefits far outweigh its cost and as such, should be considered for projects that are earmarked as benefiting from such an analysis.

In the world of project evaluation and capital budgeting, the best decisions will be the most informed decisions. This information can be garnered through thorough evaluation of a project, looking at different evaluation methods and project sensitivity, and the reasons for differences and sensitivities. This understanding of the project dynamics, the flexibility available to management, and the value inherent in the uncertainty of the project is what leads to more accurate project evaluations. ROA is another evaluation tool available to management and one that should not be overlooked, especially when projects are marginal, or in the negative, and option value is at its highest.

Appendices

Appendix 1: Historic Copper Volatility

The following spreadsheets calculate the copper volatility from LME historic copper prices and historic consumer price index data.[19]

Historical Copper Data		Historical CPI Data			Real Copper Price		Standard deviation of natural log of returns	0.08258016	
					1986 $US		Annualized Vol	0.28606608	
							Standard deviation of returns	0.08239788	
							Annualized Vol	0.28543462	
Source: Bloomberg		Source: Bloomberg							
LOCADY Index		CPI INDX Index						28.54%	
Copper LME official cash		US CPI Urban Consumers							
Date	PX_LAST	Date	PX_LAST		Real Price	Real Price $US/lb			
4/30/1986	1429.17	4/30/1986	108.7	0%	1429.17	$ 0.65	Return	1+return	ln(1+return)
5/30/1986	1393.93	5/31/1986	109	0.28%	1390.093	$ 0.63	-0.027342097	0.9726579	-0.027722848
6/30/1986	1395.35	6/30/1986	109.4	0.64%	1386.422	$ 0.63	-0.002641329	0.99735867	-0.002644824
7/31/1986	1305.74	7/31/1986	109.5	0.74%	1296.2	$ 0.59	-0.06507504	0.93492496	-0.067289009
8/29/1986	1306.7	8/31/1986	109.6	0.83%	1295.97	$ 0.59	-0.000177864	0.99982214	-0.00017788
9/30/1986	1351.39	9/30/1986	110	1.20%	1335.419	$ 0.61	0.030439928	1.03043993	0.029985826
10/31/1986	1295.57	10/31/1986	110.2	1.38%	1277.935	$ 0.58	-0.043045536	0.95695446	-0.043999471
11/28/1986	1321.28	11/30/1986	110.4	1.56%	1300.934	$ 0.59	0.017997003	1.017997	0.017836974
12/31/1986	1345.69	12/31/1986	110.8	1.93%	1320.185	$ 0.60	0.014797706	1.01479771	0.014689288
1/30/1987	1317.76	1/31/1987	111.4	2.48%	1285.821	$ 0.58	-0.026029361	0.97397064	-0.02637412
2/27/1987	1406.65	2/28/1987	111.8	2.85%	1367.646	$ 0.62	0.063636218	1.06363622	0.061693432
3/31/1987	1516.11	3/31/1987	112.2	3.22%	1468.816	$ 0.67	0.073973606	1.07397361	0.071365421
4/30/1987	1487.55	4/30/1987	112.7	3.68%	1434.753	$ 0.65	-0.023190666	0.97680933	-0.023463801
5/29/1987	1503.64	5/31/1987	113	3.96%	1446.422	$ 0.66	0.00813286	1.00813286	0.008099966
6/30/1987	1599.29	6/30/1987	113.5	4.42%	1531.655	$ 0.69	0.058926784	1.05892678	0.057255927
7/31/1987	1744.23	7/31/1987	113.8	4.69%	1666.062	$ 0.76	0.087752599	1.0877526	0.084113732
8/31/1987	1727.15	8/31/1987	114.3	5.15%	1642.53	$ 0.75	-0.014123904	0.9858761	-0.014224595
9/30/1987	1850.22	9/30/1987	114.7	5.52%	1753.434	$ 0.80	0.067520262	1.06752026	0.065338446
10/30/1987	2042.57	10/31/1987	115	5.80%	1930.673	$ 0.88	0.101080713	1.10108071	0.096292164
11/30/1987	2838.33	11/30/1987	115.4	6.16%	2673.54	$ 1.21	0.384771032	1.38477103	0.325534806
12/31/1987	3195.15	12/31/1987	115.6	6.35%	3004.436	$ 1.36	0.123767165	1.12376717	0.116686582
1/29/1988	2358.71	1/31/1988	116	6.72%	2210.274	$ 1.00	-0.264329838	0.73567016	-0.306973411
2/29/1988	2089.19	2/29/1988	116.2	6.90%	1954.346	$ 0.89	-0.115790348	0.88420965	-0.123061082
3/31/1988	2554.29	3/31/1988	116.5	7.18%	2383.273	$ 1.08	0.219473781	1.21947378	0.198419439
4/29/1988	2154.16	4/30/1988	117.2	7.82%	1997.928	$ 0.91	-0.161687257	0.83831274	-0.176364046
5/31/1988	2400.01	5/31/1988	117.5	8.10%	2220.265	$ 1.01	0.111283431	1.11128343	0.105515591
6/30/1988	2338.33	6/30/1988	118	8.56%	2154.038	$ 0.98	-0.029828283	0.97017172	-0.030282196
7/29/1988	2132.6	7/31/1988	118.5	9.02%	1956.233	$ 0.89	-0.091829773	0.90817023	-0.096323443
8/31/1988	2353.68	8/31/1988	119	9.48%	2149.958	$ 0.98	0.09902963	1.09902963	0.094427636
9/30/1988	2560.27	9/30/1988	119.5	9.94%	2328.882	$ 1.06	0.083221837	1.08322184	0.079939783
10/31/1988	3303.44	10/31/1988	119.9	10.30%	2994.862	$ 1.36	0.285965679	1.28596568	0.251509937
11/30/1988	3385.56	11/30/1988	120.3	10.67%	3059.105	$ 1.39	0.021451258	1.02145126	0.021224418
12/30/1988	3393.68	12/31/1988	120.7	11.04%	3056.28	$ 1.39	-0.000923528	0.99907647	-0.000923955
1/31/1989	3298.24	1/31/1989	121.2	11.50%	2958.075	$ 1.34	-0.032132258	0.96786774	-0.032659831
2/28/1989	3186.33	2/28/1989	121.6	11.87%	2848.307	$ 1.29	-0.037108078	0.96289192	-0.037814104
3/31/1989	3119.26	3/31/1989	122.2	12.42%	2774.661	$ 1.26	-0.025855927	0.97414407	-0.026196067
4/28/1989	3058.34	4/30/1989	123.1	13.25%	2700.581	$ 1.22	-0.026698614	0.97330139	-0.027061496
5/31/1989	2593.99	5/31/1989	123.7	13.80%	2279.44	$ 1.03	-0.15594473	0.84405527	-0.1695373
6/30/1989	2520.34	6/30/1989	124.1	14.17%	2207.582	$ 1.00	-0.031524246	0.96847575	-0.032031831
7/31/1989	2537.94	7/31/1989	124.5	14.54%	2215.856	$ 1.01	0.003747897	1.0037479	0.003740892
8/31/1989	2926.92	8/31/1989	124.5	14.54%	2555.472	$ 1.16	0.153266035	1.15326603	0.142597947
9/29/1989	2827.21	9/30/1989	124.8	14.81%	2462.482	$ 1.12	-0.036388483	0.96361152	-0.037067056
10/31/1989	2719.09	10/31/1989	125.4	15.36%	2356.978	$ 1.07	-0.042844359	0.95715564	-0.043789266

[19] Source Bloomberg

11/30/1989	2487.96	11/30/1989	125.9	15.82%	2148.064	$	0.97	-0.088636529	0.91136347	-0.092813481
12/29/1989	2439.76	12/31/1989	126.3	16.19%	2099.778	$	0.95	-0.022479008	0.97752099	-0.022735512
1/31/1990	2193.43	1/31/1990	127.5	17.30%	1870.007	$	0.85	-0.109426356	0.89057364	-0.11588948
2/28/1990	2460.64	2/28/1990	128	17.76%	2089.622	$	0.95	0.117440778	1.11744078	0.111041051
3/30/1990	2684.98	3/31/1990	128.6	18.31%	2269.497	$	1.03	0.086080401	1.0860804	0.082575253
4/30/1990	2587.25	4/30/1990	128.9	18.58%	2181.8	$	0.99	-0.038641453	0.96135855	-0.039407842
5/31/1990	2660.61	5/31/1990	129.1	18.77%	2240.188	$	1.02	0.026761317	1.02676132	0.026409496
6/29/1990	2623.97	6/30/1990	129.9	19.50%	2195.732	$	1.00	-0.01984505	0.98015495	-0.020044608
7/31/1990	2866.89	7/31/1990	130.5	20.06%	2387.977	$	1.08	0.087553934	1.08755393	0.083931077
8/31/1990	2961.31	8/31/1990	131.6	21.07%	2446.006	$	1.11	0.024300691	1.02430069	0.024010127
9/28/1990	2900.05	9/30/1990	132.5	21.90%	2379.135	$	1.08	-0.027338729	0.97266127	-0.027719386
10/31/1990	2657.45	10/31/1990	133.4	22.72%	2165.403	$	0.98	-0.089835976	0.91016402	-0.09413045
11/30/1990	2490.94	11/30/1990	133.7	23.00%	2025.17	$	0.92	-0.064761047	0.93523895	-0.066953218
12/31/1990	2552.32	12/31/1990	134.2	23.46%	2067.341	$	0.94	0.02082371	1.02082371	0.02060986
1/31/1991	2447.05	1/31/1991	134.7	23.92%	1974.717	$	0.90	-0.044803682	0.95519632	-0.045838391
2/28/1991	2515.4	2/28/1991	134.8	24.01%	2028.368	$	0.92	0.027169031	1.02716903	0.026806504
3/29/1991	2442.39	3/31/1991	134.8	24.01%	1969.494	$	0.89	-0.029025205	0.9709748	-0.029454769
4/30/1991	2492.7	4/30/1991	135.1	24.29%	2005.599	$	0.91	0.018332358	1.01833236	0.018166346
5/31/1991	2119.28	5/31/1991	135.6	24.75%	1698.862	$	0.77	-0.152940368	0.84705963	-0.165984183
6/28/1991	2231.22	6/30/1991	136	25.11%	1783.335	$	0.81	0.049723297	1.0497233	0.048526602
7/31/1991	2239.54	7/31/1991	136.2	25.30%	1787.357	$	0.81	0.002254997	1.002255	0.002252459
8/30/1991	2257.92	8/31/1991	136.6	25.67%	1796.749	$	0.81	0.005254752	1.00525475	0.005240994
9/30/1991	2360.28	9/30/1991	137	26.03%	1872.719	$	0.85	0.042281689	1.04228169	0.041412242
10/31/1991	2389.8	10/31/1991	137.2	26.22%	1893.377	$	0.86	0.011031033	1.01103103	0.010970635
11/29/1991	2321.87	11/30/1991	137.8	26.77%	1831.548	$	0.83	-0.032655343	0.96734466	-0.033200428
12/31/1991	2163.63	12/31/1991	138.2	27.14%	1701.784	$	0.77	-0.070849064	0.92915094	-0.073484082
1/31/1992	2216.77	1/31/1992	138.3	27.23%	1742.32	$	0.79	0.023819752	1.02381975	0.023540487
2/28/1992	2289.8	2/29/1992	138.6	27.51%	1795.824	$	0.81	0.030708519	1.03070852	0.030246448
3/31/1992	2215.29	3/31/1992	139.1	27.97%	1731.143	$	0.79	-0.03601753	0.96398247	-0.036682169
4/30/1992	2208.37	4/30/1992	139.4	28.24%	1722.022	$	0.78	-0.005269102	0.9947309	-0.005283033
5/29/1992	2227.11	5/31/1992	139.7	28.52%	1732.905	$	0.79	0.006320215	1.00632021	0.006300326
6/30/1992	2454.87	6/30/1992	140.1	28.89%	1904.671	$	0.86	0.099119977	1.09911998	0.094509839
7/31/1992	2533.91	7/31/1992	140.5	29.25%	1960.399	$	0.89	0.029258585	1.02925858	0.028838722
8/31/1992	2505.33	8/31/1992	140.8	29.53%	1934.157	$	0.88	-0.013385661	0.98661434	-0.013476057
9/30/1992	2321	9/30/1992	141.1	29.81%	1788.042	$	0.81	-0.075544858	0.92445514	-0.07855075
10/30/1992	2255.47	10/31/1992	141.7	30.36%	1730.202	$	0.78	-0.032348269	0.96765173	-0.032883038
11/30/1992	2213.49	11/30/1992	142.1	30.73%	1693.219	$	0.77	-0.021375055	0.97862495	-0.02160681
12/31/1992	2281.59	12/31/1992	142.3	30.91%	1742.859	$	0.79	0.029317172	1.02931717	0.028895643
1/29/1993	2200.77	1/31/1993	142.8	31.37%	1675.236	$	0.76	-0.038800037	0.96119996	-0.039572814
2/26/1993	2140.74	2/28/1993	143.1	31.65%	1626.125	$	0.74	-0.029316069	0.97068393	-0.029754372
3/31/1993	2144.7	3/31/1993	143.3	31.83%	1626.859	$	0.74	0.000451572	1.00045157	0.000451471
4/30/1993	1861.01	4/30/1993	143.8	32.29%	1406.758	$	0.64	-0.135292035	0.86470796	-0.145363442
5/31/1993	1782.66	5/31/1993	144.2	32.66%	1343.794	$	0.61	-0.044757935	0.95524206	-0.0457905
6/30/1993	1891.69	6/30/1993	144.3	32.75%	1424.994	$	0.65	0.060426025	1.06042602	0.058670738
7/30/1993	1969.7	7/31/1993	144.5	32.93%	1481.705	$	0.67	0.039797098	1.0397971	0.039025596
8/31/1993	1974.5	8/31/1993	144.8	33.21%	1482.239	$	0.67	0.000360047	1.00036005	0.000359982
9/30/1993	1657.5	9/30/1993	145	33.39%	1242.553	$	0.56	-0.16170484	0.83829516	-0.176385021
10/29/1993	1614.8	10/31/1993	145.6	33.95%	1205.555	$	0.55	-0.029776408	0.97022359	-0.030228726
11/30/1993	1624.8	11/30/1993	146	34.31%	1209.697	$	0.55	0.003436025	1.00343602	0.003430135
12/31/1993	1767.2	12/31/1993	146.3	34.59%	1313.019	$	0.60	0.085411259	1.08541126	0.081958956
1/31/1994	1842.7	1/31/1994	146.3	34.59%	1369.115	$	0.62	0.042722952	1.04272295	0.041835514

2/28/1994	1863.7	2/28/1994	146.7	34.96%	1380.942	$	0.63	0.008638594	1.00863859	0.008601495
3/31/1994	1890.5	3/31/1994	147.1	35.33%	1396.991	$	0.63	0.011621656	1.01162166	0.011554643
4/29/1994	1929.5	4/30/1994	147.2	35.42%	1424.841	$	0.65	0.019936101	1.0199361	0.019739979
5/31/1994	2238.3	5/31/1994	147.5	35.69%	1649.513	$	0.75	0.157682055	1.15768206	0.146419778
6/30/1994	2352.5	6/30/1994	147.9	36.06%	1728.984	$	0.78	0.048178346	1.04817835	0.047053749
7/29/1994	2438	7/31/1994	148.4	36.52%	1785.786	$	0.81	0.032852588	1.03285259	0.032324478
8/31/1994	2499	8/31/1994	149	37.07%	1823.096	$	0.83	0.020892909	1.02089291	0.020677646
9/30/1994	2486.5	9/30/1994	149.3	37.35%	1810.332	$	0.82	-0.007001327	0.99299867	-0.007025951
10/31/1994	2684	10/31/1994	149.4	37.44%	1952.817	$	0.89	0.078706407	1.07870641	0.075762552
11/30/1994	2975	11/30/1994	149.8	37.81%	2158.762	$	0.98	0.105460535	1.10546053	0.100262022
12/30/1994	3040	12/31/1994	150.1	38.09%	2201.519	$	1.00	0.019806404	1.0198064	0.019612809
1/31/1995	2998	1/31/1995	150.5	38.45%	2165.333	$	0.98	-0.016436877	0.98356312	-0.016573461
2/28/1995	2861.5	2/28/1995	150.9	38.82%	2061.266	$	0.93	-0.048060426	0.95193957	-0.049253718
3/31/1995	2986	3/31/1995	151.2	39.10%	2146.681	$	0.97	0.041438196	1.0414382	0.040602638
4/28/1995	2831	4/30/1995	151.8	39.65%	2027.205	$	0.92	-0.055656304	0.9443437	-0.057265094
5/31/1995	2851	5/31/1995	152.1	39.93%	2037.5	$	0.92	0.005078321	1.00507832	0.005065469
6/30/1995	3093	6/30/1995	152.4	40.20%	2206.096	$	1.00	0.082746902	1.0827469	0.07950124
7/31/1995	3005	7/31/1995	152.6	40.39%	2140.521	$	0.97	-0.029724669	0.97027533	-0.030175401
8/31/1995	2950	8/31/1995	152.9	40.66%	2097.22	$	0.95	-0.020228984	0.97977102	-0.020436392
9/29/1995	2944	9/30/1995	153.1	40.85%	2090.221	$	0.95	-0.003337577	0.99666242	-0.003343159
10/31/1995	2832	10/31/1995	153.5	41.21%	2005.462	$	0.91	-0.040550205	0.95944979	-0.041395289
11/30/1995	2920	11/30/1995	153.7	41.40%	2065.088	$	0.94	0.029731776	1.02973178	0.029298357
12/29/1995	2797	12/31/1995	153.9	41.58%	1975.529	$	0.90	-0.043368092	0.95663191	-0.044336592
1/31/1996	2571	1/31/1996	154.7	42.32%	1806.514	$	0.82	-0.085554312	0.91444569	-0.089437203
2/29/1996	2532	2/29/1996	155	42.59%	1775.667	$	0.81	-0.017075319	0.98292468	-0.017222783
3/29/1996	2547.5	3/31/1996	155.5	43.05%	1780.793	$	0.81	0.002886525	1.00288653	0.002882367
4/30/1996	2706	4/30/1996	156.1	43.61%	1884.319	$	0.85	0.058135025	1.05813502	0.056507948
5/31/1996	2544	5/31/1996	156.4	43.88%	1768.113	$	0.80	-0.061670287	0.93832971	-0.063653885
6/28/1996	1960	6/30/1996	156.7	44.16%	1359.617	$	0.62	-0.231034746	0.76896525	-0.262709493
7/31/1996	2039	7/31/1996	157	44.43%	1411.715	$	0.64	0.038318276	1.03831828	0.037602362
8/30/1996	2030	8/31/1996	157.2	44.62%	1403.696	$	0.64	-0.005680577	0.99431942	-0.005696773
9/30/1996	1938	9/30/1996	157.7	45.08%	1335.831	$	0.61	-0.048347083	0.95165292	-0.049554894
10/31/1996	2008.5	10/31/1996	158.2	45.54%	1380.05	$	0.63	0.033102179	1.03310218	0.0325661
11/29/1996	2497	11/30/1996	158.7	46.00%	1710.296	$	0.78	0.239299455	1.23929945	0.214546264
12/31/1996	2217.5	12/31/1996	159.1	46.37%	1515.036	$	0.69	-0.114167044	0.88583296	-0.121226884
1/31/1997	2384	1/31/1997	159.4	46.64%	1625.726	$	0.74	0.073061183	1.07306118	0.070515483
2/28/1997	2424	2/28/1997	159.7	46.92%	1649.899	$	0.75	0.014868482	1.01486848	0.01475903
3/31/1997	2412	3/31/1997	159.8	47.01%	1640.703	$	0.74	-0.005573179	0.99442682	-0.005588767
4/30/1997	2414	4/30/1997	159.9	47.10%	1641.037	$	0.74	0.000203278	1.00020328	0.000203257
5/30/1997	2605	5/31/1997	159.9	47.10%	1770.879	$	0.80	0.07912179	1.07912179	0.076147553
6/30/1997	2585.5	6/30/1997	160.2	47.38%	1754.331	$	0.80	-0.009344246	0.99065575	-0.009388177
7/31/1997	2330	7/31/1997	160.4	47.56%	1578.996	$	0.72	-0.09994401	0.90005599	-0.105298306
8/29/1997	2150	8/31/1997	160.8	47.93%	1453.389	$	0.66	-0.079548609	0.92045139	-0.082891087
9/30/1997	2148	9/30/1997	161.2	48.30%	1448.434	$	0.66	-0.003409314	0.99659069	-0.003415139
10/31/1997	1998	10/31/1997	161.5	48.57%	1344.784	$	0.61	-0.071560268	0.92843973	-0.074249809
11/28/1997	1861	11/30/1997	161.7	48.76%	1251.025	$	0.57	-0.069720617	0.93027938	-0.072270326
12/31/1997	1724	12/31/1997	161.8	48.85%	1158.213	$	0.53	-0.074188884	0.92581112	-0.077085043
1/30/1998	1740	1/31/1998	162	49.03%	1167.519	$	0.53	0.008034717	1.00803472	0.00800261
2/27/1998	1680	2/28/1998	162	49.03%	1127.259	$	0.51	-0.034482759	0.96551724	-0.03509132
3/31/1998	1745	3/31/1998	162	49.03%	1170.873	$	0.53	0.038690476	1.03869048	0.037960762
4/30/1998	1852.5	4/30/1998	162.2	49.22%	1241.472	$	0.56	0.060295578	1.06029558	0.058547716
5/29/1998	1685	5/31/1998	162.6	49.59%	1126.442	$	0.51	-0.092655947	0.90734405	-0.09723357

6/30/1998	1619	6/30/1998	162.8	49.77%	1080.991	$	0.49	-0.040349521	0.95965048	-0.041186146
7/31/1998	1697	7/31/1998	163.2	50.14%	1130.294	$	0.51	0.045608824	1.04560882	0.044599323
8/31/1998	1657	8/31/1998	163.4	50.32%	1102.3	$	0.50	-0.024766147	0.97523385	-0.025077988
9/30/1998	1634.5	9/30/1998	163.5	50.41%	1086.668	$	0.49	-0.014182073	0.98581793	-0.014283599
10/30/1998	1564	10/31/1998	163.9	50.78%	1037.259	$	0.47	-0.045467704	0.9545323	-0.0465338
11/30/1998	1557.5	11/30/1998	164.1	50.97%	1031.69	$	0.47	-0.005369714	0.99463029	-0.005384183
12/31/1998	1456	12/31/1998	164.4	51.24%	962.6959	$	0.44	-0.066874436	0.93312556	-0.069215506
1/29/1999	1399	1/31/1999	164.7	51.52%	923.323	$	0.42	-0.040898537	0.95910146	-0.041758409
2/26/1999	1380.5	2/28/1999	164.7	51.52%	911.1132	$	0.41	-0.013223731	0.98677627	-0.013311943
3/31/1999	1371.5	3/31/1999	164.8	51.61%	904.6241	$	0.41	-0.007122217	0.99287778	-0.007147701
4/30/1999	1568	4/30/1999	165.9	52.62%	1027.376	$	0.47	0.135693311	1.13569331	0.127243311
5/31/1999	1357	5/31/1999	166	52.71%	888.5898	$	0.40	-0.135087672	0.86491233	-0.145127132
6/30/1999	1536	6/30/1999	166	52.71%	1005.802	$	0.46	0.131908622	1.13190862	0.123905254
7/30/1999	1599	7/31/1999	166.7	53.36%	1042.659	$	0.47	0.036644234	1.03664423	0.035988798
8/31/1999	1652	8/31/1999	167.1	53.73%	1074.64	$	0.49	0.030672596	1.0306726	0.030211595
9/30/1999	1758	9/30/1999	167.8	54.37%	1138.824	$	0.52	0.059725345	1.05972534	0.058009766
10/29/1999	1752	10/31/1999	168.1	54.65%	1132.911	$	0.51	-0.00519153	0.99480847	-0.005205053
11/30/1999	1744.5	11/30/1999	168.4	54.92%	1126.052	$	0.51	-0.006054668	0.99394533	-0.006073072
12/31/1999	1846	12/31/1999	168.8	55.29%	1188.745	$	0.54	0.055675318	1.05567532	0.054180674
1/31/2000	1812	1/31/2000	169.3	55.75%	1163.405	$	0.53	-0.021317144	0.97868286	-0.021547635
2/29/2000	1726	2/29/2000	170	56.39%	1103.625	$	0.50	-0.051383587	0.94861641	-0.052750763
3/31/2000	1728.5	3/31/2000	171	57.31%	1098.76	$	0.50	-0.004407988	0.99559201	-0.004417732
4/28/2000	1715	4/30/2000	170.9	57.22%	1090.816	$	0.49	-0.007229673	0.99277033	-0.007255933
5/31/2000	1735.5	5/31/2000	171.2	57.50%	1101.921	$	0.50	0.01018007	1.01018007	0.010128602
6/30/2000	1773.5	6/30/2000	172.2	58.42%	1119.509	$	0.51	0.015961354	1.01596135	0.015835311
7/31/2000	1849.5	7/31/2000	172.7	58.88%	1164.103	$	0.53	0.039833853	1.03983385	0.039060944
8/31/2000	1900	8/31/2000	172.7	58.88%	1195.889	$	0.54	0.027304677	1.02730468	0.026938554
9/29/2000	1978	9/30/2000	173.6	59.71%	1238.529	$	0.56	0.035655469	1.03565547	0.03503453
10/31/2000	1839	10/31/2000	173.9	59.98%	1149.507	$	0.52	-0.071876902	0.9281231	-0.074590907
11/30/2000	1814.5	11/30/2000	174.2	60.26%	1132.24	$	0.51	-0.015021673	0.98497833	-0.015135641
12/29/2000	1808.5	12/31/2000	174.6	60.63%	1125.91	$	0.51	-0.005590071	0.99440993	-0.005605754
1/31/2001	1805.5	1/31/2001	175.6	61.55%	1117.642	$	0.51	-0.007344147	0.99265585	-0.007371248
2/28/2001	1738	2/28/2001	176	61.91%	1073.413	$	0.49	-0.039573525	0.96042647	-0.040377849
3/30/2001	1666	3/31/2001	176.1	62.01%	1028.36	$	0.47	-0.041971262	0.95802874	-0.042877504
4/30/2001	1660	4/30/2001	176.4	62.28%	1022.914	$	0.46	-0.005295996	0.994704	-0.005310069
5/31/2001	1666	5/31/2001	177.3	63.11%	1021.4	$	0.46	-0.001480032	0.99851997	-0.001481128
6/29/2001	1550.5	6/30/2001	177.7	63.48%	948.4488	$	0.43	-0.07142266	0.92857734	-0.074101606
7/31/2001	1469	7/31/2001	177.4	63.20%	900.1144	$	0.41	-0.050961486	0.94903851	-0.052305897
8/31/2001	1475	8/31/2001	177.4	63.20%	903.7909	$	0.41	0.004084411	1.00408441	0.004076093
9/28/2001	1424	9/30/2001	178.1	63.85%	869.1117	$	0.39	-0.03837075	0.96162925	-0.039126297
10/31/2001	1360.5	10/31/2001	177.6	63.39%	832.6934	$	0.38	-0.041902924	0.95809708	-0.042806174
11/30/2001	1532	11/30/2001	177.5	63.29%	938.1882	$	0.43	0.126690995	1.12669099	0.119285014
12/31/2001	1462	12/31/2001	177.4	63.20%	895.8253	$	0.41	-0.045153965	0.95484604	-0.046205171
1/31/2002	1515	1/31/2002	177.7	63.48%	926.7333	$	0.42	0.03450227	1.03450227	0.033920412
2/28/2002	1539	2/28/2002	178	63.75%	939.8275	$	0.43	0.014129492	1.01412949	0.014030601
3/29/2002	1623	3/31/2002	178.5	64.21%	988.3479	$	0.45	0.051626889	1.05162689	0.050338383
4/30/2002	1598.5	4/30/2002	179.3	64.95%	969.0851	$	0.44	-0.019489945	0.98051006	-0.019682378
5/31/2002	1629	5/31/2002	179.5	65.13%	986.4752	$	0.45	0.017944922	1.01794492	0.017785813
6/28/2002	1654	6/30/2002	179.6	65.23%	1001.057	$	0.45	0.014781501	1.0147815	0.014673319
7/31/2002	1510.5	7/31/2002	180	65.59%	912.1742	$	0.41	-0.088788795	0.91121121	-0.09298057
8/30/2002	1500	8/31/2002	180.5	66.05%	903.3241	$	0.41	-0.009702168	0.99029783	-0.009749541
9/30/2002	1434.5	9/30/2002	180.8	66.33%	862.4455	$	0.39	-0.045253503	0.9547465	-0.046309422

10/31/2002	1536	10/31/2002	181.2	66.70%	921.4305	$	0.42	0.068392661	1.06839266	0.066155333
11/29/2002	1626	11/30/2002	181.5	66.97%	973.8083	$	0.44	0.056844008	1.05684401	0.055287116
12/31/2002	1536	12/31/2002	181.8	67.25%	918.3894	$	0.42	-0.056909381	0.94309062	-0.058592904
1/31/2003	1713.5	1/31/2003	182.6	67.99%	1020.03	$	0.46	0.110672448	1.11067245	0.104965641
2/28/2003	1716	2/28/2003	183.6	68.91%	1015.954	$	0.46	-0.003995568	0.99600443	-0.004003571
3/31/2003	1587.5	3/31/2003	183.9	69.18%	938.3428	$	0.43	-0.076392612	0.92360739	-0.079468203
4/30/2003	1604	4/30/2003	183.2	68.54%	951.7183	$	0.43	0.014254375	1.01425438	0.014153737
5/30/2003	1683	5/31/2003	182.9	68.26%	1000.23	$	0.45	0.050972896	1.0509729	0.049716303
6/30/2003	1644	6/30/2003	183.1	68.45%	975.9847	$	0.44	-0.024239893	0.97576011	-0.024538515
7/31/2003	1769	7/31/2003	183.7	69.00%	1046.763	$	0.47	0.072519526	1.07251953	0.070010578
8/29/2003	1746	8/31/2003	184.5	69.73%	1028.673	$	0.47	-0.017281363	0.98271864	-0.017432429
9/30/2003	1794	9/30/2003	185.1	70.29%	1053.527	$	0.48	0.024160805	1.0241608	0.02387355
10/31/2003	2057	10/31/2003	184.9	70.10%	1209.28	$	0.55	0.147840015	1.14784001	0.137881928
11/28/2003	2073.5	11/30/2003	185	70.19%	1218.321	$	0.55	0.007476514	1.00747651	0.007448703
12/31/2003	2321	12/31/2003	185.5	70.65%	1360.068	$	0.62	0.116346243	1.11634624	0.11006107
1/30/2004	2489	1/31/2004	186.3	71.39%	1452.251	$	0.66	0.067777623	1.06777762	0.065579501
2/27/2004	2987	2/29/2004	186.7	71.76%	1739.084	$	0.79	0.197509212	1.19750921	0.180243743
3/31/2004	3067.5	3/31/2004	187.1	72.13%	1782.134	$	0.81	0.024754607	1.02475461	0.024453176
4/30/2004	2752	4/30/2004	187.4	72.40%	1596.277	$	0.72	-0.104288688	0.89571131	-0.110137114
5/31/2004	2830.5	5/31/2004	188.2	73.14%	1634.832	$	0.74	0.02415266	1.02415266	0.023865597
6/30/2004	2664.5	6/30/2004	188.9	73.78%	1533.251	$	0.70	-0.062135221	0.93786478	-0.064149499
7/30/2004	2900	7/31/2004	189.1	73.97%	1667.002	$	0.76	0.087233192	1.08723319	0.083636113
8/31/2004	2847	8/31/2004	189.2	74.06%	1635.671	$	0.74	-0.018794744	0.98120526	-0.01897361
9/30/2004	3140	9/30/2004	189.8	74.61%	1798.303	$	0.82	0.099428789	1.09942879	0.094790762
10/29/2004	2951	10/31/2004	190.8	75.53%	1681.204	$	0.76	-0.065116706	0.93488329	-0.067333577
11/30/2004	3262	11/30/2004	191.7	76.36%	1849.658	$	0.84	0.100198389	1.10019839	0.095490517
12/31/2004	3279.5	12/31/2004	191.7	76.36%	1859.581	$	0.84	0.005364807	1.00536481	0.005350468
1/31/2005	3275.5	1/31/2005	191.6	76.26%	1858.282	$	0.84	-0.000698414	0.99930159	-0.000698658
2/28/2005	3405	2/28/2005	192.4	77.00%	1923.719	$	0.87	0.035213554	1.03521355	0.034607738
3/31/2005	3408	3/31/2005	193.1	77.64%	1918.434	$	0.87	-0.002747201	0.9972528	-0.002750982
4/29/2005	3348.5	4/30/2005	193.7	78.20%	1879.101	$	0.85	-0.020502413	0.97949759	-0.020715506
5/31/2005	3214	5/31/2005	193.6	78.10%	1804.555	$	0.82	-0.039671458	0.96032854	-0.040479821
6/30/2005	3597	6/30/2005	193.7	78.20%	2018.554	$	0.92	0.118588365	1.11858836	0.112067502
7/29/2005	3775	7/31/2005	194.9	79.30%	2105.4	$	0.95	0.043023995	1.043024	0.042124182
8/31/2005	3915	8/31/2005	196.1	80.40%	2170.12	$	0.98	0.030739824	1.03073982	0.03027682
9/30/2005	3949	9/30/2005	198.8	82.89%	2159.237	$	0.98	-0.005014891	0.99498511	-0.005027508
10/31/2005	4091	10/31/2005	199.1	83.16%	2233.509	$	1.01	0.034397508	1.03439751	0.03381914
11/30/2005	4404.5	11/30/2005	198.1	82.24%	2416.805	$	1.10	0.082066419	1.08206642	0.078872564
12/30/2005	4584.5	12/31/2005	198.1	82.24%	2515.574	$	1.14	0.040867295	1.04086729	0.040054303
1/31/2006	4919.5	1/31/2006	199.3	83.35%	2683.139	$	1.22	0.066611261	1.06661126	0.064486577
2/28/2006	4839	2/28/2006	199.4	83.44%	2637.91	$	1.20	-0.01685675	0.98314325	-0.017000442
3/31/2006	5527.5	3/31/2006	199.7	83.72%	3008.709	$	1.36	0.140565467	1.14056547	0.131524163
4/28/2006	7230	4/30/2006	200.7	84.64%	3915.8	$	1.78	0.301488211	1.30148821	0.263508387
5/31/2006	8140	5/31/2006	201.3	85.19%	4395.519	$	1.99	0.122508673	1.12250867	0.115566067
6/30/2006	7501	6/30/2006	201.8	85.65%	4040.43	$	1.83	-0.080784427	0.91921557	-0.08423461
7/31/2006	7850.5	7/31/2006	202.9	86.66%	4205.763	$	1.91	0.040919795	1.04091979	0.04010474
8/31/2006	7647	8/31/2006	203.8	87.49%	4078.65	$	1.85	-0.030223536	0.96977646	-0.030689684
9/29/2006	7601	9/30/2006	202.8	86.57%	4074.106	$	1.85	-0.001114126	0.99888587	-0.001114747
10/31/2006	7410	10/31/2006	201.9	85.74%	3989.435	$	1.81	-0.020782633	0.97921737	-0.021001632
11/30/2006	6936	11/30/2006	202	85.83%	3732.392	$	1.69	-0.064430994	0.93556901	-0.066600372
12/29/2006	6290	12/31/2006	203.1	86.84%	3366.435	$	1.53	-0.09804887	0.90195113	-0.10319494
1/31/2007	5651	1/31/2007	203.379	87.10%	3020.291	$	1.37	-0.102822285	0.89717772	-0.108501315

2/28/2007	5980	2/28/2007	204.238	87.89%		3182.689	$	1.44	0.053769041	1.05376904	0.0523733
3/30/2007	6940	3/31/2007	205.247	88.82%		3675.464	$	1.67	0.154829894	1.15482989	0.143953055
4/30/2007	7824.5	4/30/2007	206.01	89.52%		4128.553	$	1.87	0.123273829	1.12327383	0.116247483
5/31/2007	7440.5	5/31/2007	206.813	90.26%		3910.694	$	1.77	-0.052768801	0.9472312	-0.054212078
6/29/2007	7650	6/30/2007	207.162	90.58%		4014.032	$	1.82	0.026424603	1.0264246	0.026081504
7/31/2007	8159	7/31/2007	207.655	91.03%		4270.946	$	1.94	0.064003853	1.06400385	0.062039012
8/31/2007	7580	8/31/2007	207.689	91.07%		3967.211	$	1.80	-0.071116668	0.92888333	-0.073772133
9/28/2007	8165	9/30/2007	208.467	91.78%		4257.439	$	1.93	0.073156751	1.07315675	0.07060454
10/31/2007	7761	10/31/2007	209.156	92.42%		4033.452	$	1.83	-0.052610683	0.94738932	-0.054045164
11/30/2007	6956	11/30/2007	210.81	93.94%		3586.724	$	1.63	-0.110755866	0.88924413	-0.117383464
12/31/2007	6676.5	12/31/2007	211.416	94.49%		3432.737	$	1.56	-0.042932351	0.95706765	-0.043881201
1/31/2008	7170.5	1/31/2008	212.18	95.20%		3673.453	$	1.67	0.070123727	1.07012373	0.067774274
2/29/2008	8540.5	2/29/2008	212.684	95.66%		4364.937	$	1.98	0.188238124	1.18823812	0.172471642
3/31/2008	8520	3/31/2008	213.464	96.38%		4338.549	$	1.97	-0.006045569	0.99395443	-0.006063917
4/30/2008	8655	4/30/2008	214.118	96.98%		4393.832	$	1.99	0.012742283	1.01274228	0.012661783
5/30/2008	8105	5/31/2008	215.304	98.07%		4091.951	$	1.86	-0.068705524	0.93129448	-0.071179751
6/30/2008	8775.5	6/30/2008	217.235	99.85%		4391.083	$	1.99	0.073102364	1.07310236	0.070553859
7/31/2008	8260.5	7/31/2008	219.133	101.59%		4097.586	$	1.86	-0.066839217	0.93316078	-0.069177764
8/29/2008	7510	8/31/2008	218.78	101.27%		3731.315	$	1.69	-0.089387164	0.91061284	-0.09363746
9/30/2008	6419	9/30/2008	218.852	101.34%		3188.206	$	1.45	-0.145554166	0.85444583	-0.157302167
10/31/2008	3995	10/31/2008	216.93	99.57%		2001.828	$	0.91	-0.372114706	0.62788529	-0.465397782
11/28/2008	3581	11/30/2008	213.002	95.95%		1827.47	$	0.83	-0.087099442	0.91290056	-0.091128323
12/31/2008	2902	12/31/2008	211.327	94.41%		1492.698	$	0.68	-0.183188619	0.81681138	-0.202347078
1/30/2009	3106	1/31/2009	211.903	94.94%		1593.287	$	0.72	0.067387041	1.06738704	0.065213644
2/27/2009	3390	2/28/2009	212.879	95.84%		1730.997	$	0.79	0.086431954	1.08643195	0.08289889
3/31/2009	4035	3/31/2009	212.572	95.56%		2063.322	$	0.94	0.191984488	1.19198449	0.175619555
4/30/2009	4515	4/30/2009	212.799	95.77%		2306.31	$	1.05	0.117765476	1.11776548	0.111331581
5/29/2009	4776	5/31/2009	213.078	96.02%		2436.437	$	1.11	0.056422238	1.05642224	0.054887952
6/30/2009	5108	6/30/2009	214.527	97.36%		2588.204	$	1.17	0.062290317	1.06229032	0.060427253
7/31/2009	5750	7/31/2009	214.782	97.59%		2910.044	$	1.32	0.12434873	1.12434873	0.117203961
8/31/2009	6490.5	8/31/2009	215.519	98.27%		3273.574	$	1.48	0.124922565	1.12492256	0.117714202
9/30/2009	6136	9/30/2009	215.956	98.67%		3088.514	$	1.40	-0.056531325	0.94346867	-0.058192116
10/30/2009	6575	10/31/2009	216.445	99.12%		3302.005	$	1.50	0.069124109	1.06912411	0.066839724
11/30/2009	6814.5	11/30/2009	216.956	99.59%		3414.223	$	1.55	0.033984745	1.03398474	0.033420022
12/31/2009	7346	12/31/2009	217.158	99.78%		3677.093	$	1.67	0.076992701	1.0769927	0.074172621
1/29/2010	6854	1/31/2010	217.458	100.05%		3426.086	$	1.55	-0.068262404	0.9317376	-0.070704053
2/26/2010	7072	2/28/2010	217.562	100.15%		3533.367	$	1.60	0.031313016	1.03131302	0.030832763
3/31/2010	7830	3/31/2010	217.611	100.19%		3911.204	$	1.77	0.106933951	1.10693395	0.101593987
4/30/2010	7365	4/30/2010	217.625	100.21%		3678.693	$	1.67	-0.059447484	0.94055252	-0.061287793
5/31/2010	6926	5/31/2010	217.32	99.93%		3464.275	$	1.57	-0.05828644	0.94171356	-0.060054128
6/30/2010	6515	6/30/2010	216.865	99.51%		3265.536	$	1.48	-0.057368035	0.94263196	-0.059079354
7/30/2010	7195	7/31/2010	217.621	100.20%		3593.847	$	1.63	0.100538001	1.100538	0.095799152
8/31/2010	7355.5	8/31/2010	218.068	100.61%		3666.484	$	1.66	0.020211613	1.02021161	0.020010069
9/30/2010	8053.5	9/30/2010	218.427	100.94%		4007.817	$	1.82	0.09309544	1.09309544	0.089013525
10/29/2010	8225	10/31/2010	218.97	101.44%		4083.014	$	1.85	0.01876249	1.01876249	0.018588646
11/30/2010	8375	11/30/2010	219.24	101.69%		4152.356	$	1.88	0.016983096	1.0169831	0.016840495
12/31/2010	9739.5	12/31/2010	220.186	102.56%		4808.133	$	2.18	0.157929018	1.15792902	0.14663308
1/31/2011	9720	1/31/2011	221.062	103.37%	103%	4779.492	$	2.17	-0.005956911	0.99404309	-0.005974725

Appendix 2: Discounted Cash Flow Model (Base Case)

Following are the spreadsheets that calculate the net present value of the Daedalus project based on conventional DCF analysis.

Global Variables		Value	
Copper		2.30	USD/lb
	23	23%	Copper Price Adjustment Factor
Nickel		6.00	USD/lb
	100	100%	Nickel Price Adjustment Factor
Cobalt		10.00	USD/lb
	100	100%	Cobalt Price Adjustment Factor
Discount Rate		8.00%	
	32	32%	
SMELTER TERMS			
Copper			
Cu Payable Intermediary		100%	
Nickel			
Ni Payable in Ni/Co Intermediary		70%	
Cobalt			
Co Payable in Ni/Co Intermediary		70%	
TRANSPORTATION			
Transportation Rates			
Metal		50.00	US$/t
Precipitate		165.00	US$/t

NPV	(109)

Daedalus Project

	Units	Base	2010	2011	2012	2013	2014	2015	2016	2017
			-5	-4	-3	-2	-1	1	2	3
PRODUCTION SUMMARY (MHP CASES)										
Copper										
Cu Metal Contained in Cu Cathode	t		0	0	0	0	0	96,141	128,798	139,544
Cu Metal Contained in Cu Cathode	M lbs		0.00	0.00	0.00	0.00	0.00	211.95	283.95	307.64
Nickel										
Ni Metal Contained in Ni/Co Intermediary	t		0	0	0	0	0	16,084	21,835	23,621
Ni Metal Contained in Ni/Co Intermediary	M lbs		0.00	0.00	0.00	0.00	0.00	35.46	48.14	52.07
Cobalt										
Co Metal Contained in Ni/Co Intermediary	t		0	0	0	0	0	689	923	1,000
Co Metal Contained in Ni/Co Intermediary	M lbs		0.00	0.00	0.00	0.00	0.00	1.52	2.03	2.20
REVENUES (MHP CASES)										
Gross Revenues										
Copper Cathode Sales - Gross	US$M		0.00	0.00	0.00	0.00	0.00	487.50	653.09	707.58
Nickel Contained in Ni/Co Intermediary - Gross	US$M		0.00	0.00	0.00	0.00	0.00	212.75	288.83	312.45
Cobalt Contained in Ni/Co Intermediary - Gross	US$M		0.00	0.00	0.00	0.00	0.00	15.19	20.35	22.04
Total Gross Revenues	**US$M**	27,003.4	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**715.43**	**962.27**	**1,042.07**
Physical Deductions										
Copper Cathode	US$M		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ni in Ni/Co Intermendiary	US$M		0.00	0.00	0.00	0.00	0.00	(63.82)	(86.65)	(93.73)
Co in Ni/Co Intermediary	US$M		0.00	0.00	0.00	0.00	0.00	(4.56)	(6.10)	(6.61)
Total Physical Deductions	**US$M**	-2,671.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**(68.38)**	**(92.75)**	**(100.35)**
Net Revenues										
Copper Cathode Sales - Net	US$M		0.00	0.00	0.00	0.00	0.00	487.50	653.09	707.58
Nickel Contained in Ni/Co Intermediary - Net	US$M		0.00	0.00	0.00	0.00	0.00	148.92	202.18	218.71
Cobalt Contained in Ni/Co Intermediary - Net	US$M		0.00	0.00	0.00	0.00	0.00	10.63	14.24	15.43
Total Net Revenues	**US$M**	24,332.5	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**647.05**	**869.51**	**941.72**
Transportation Costs	**US$M**		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**10.58**	**14.27**	**15.45**
TOTAL NET REVENUES FOB MINE GATE (MODEL F	**US$M**		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**636.47**	**855.24**	**926.27**
SITE OPERATING COSTS										
Opex (MHP Cases)										
Mine Operating Cost	US$M		0.00	0.00	0.00	0.00	0.00	98.49	106.96	131.45
Mill Operating Cost - Variable	US$M		0.00	0.00	0.00	0.00	0.00	79.78	108.02	120.08
Mill Operating Cost - Fixed	US$M		0.00	0.00	0.00	0.00	0.00	56.58	56.58	56.58
CESL Operating Cost - Variable	US$M		0.00	0.00	0.00	0.00	0.00	39.13	52.43	56.80
CESL Operating Cost - Fixed	US$M		0.00	0.00	0.00	0.00	0.00	24.61	24.61	24.61
G&A Cost	US$M		0.00	0.00	0.00	0.00	0.00	32.00	32.00	32.00
SITE OPERATING COSTS (MODEL FEED)	**US$M**	11,314.20	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**330.60**	**380.59**	**421.52**

	Units	Base		2010	2011	2012	2013	2014	2015	2016	2017
				-5	-4	-3	-2	-1	1	2	3
ROYALTIES											
Total Ore Milled	kt			0	0	0	0	0	29,100	39,400	43,799
STATE ROYALTY (MHP CASES)											
Net Return Value - Copper	JS$/t Milled			0.00	0.00	0.00	0.00	0.00	16.75	16.58	16.16
Net Return Value - Nickel	JS$/t Milled			0.00	0.00	0.00	0.00	0.00	5.12	5.13	4.99
Net Return Value - Cobalt	JS$/t Milled			0.00	0.00	0.00	0.00	0.00	0.37	0.36	0.35
Total Net Return Value	**IS$/t Milled**			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**22.24**	**22.07**	**21.50**
Applicable Rates:											
Base Rate	%			0.00%	0.00%	0.00%	0.00%	0.00%	3.95%	3.95%	3.95%
Bid Rate	%			0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	0.55%	0.55%
State Royalty Payable	**US$M**			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**29.12**	**39.13**	**42.38**
CAPITAL EXPENDITURES											
Development Capital											
Mine - Development	US$M	438.817		0.00	0.00	21.94	329.11	87.76	0.00	0.00	0.00
Mill & Infrastructure - Development	US$M	1,890.233		0.00	0.00	378.05	756.09	756.09	0.00	0.00	0.00
CESL - Development	US$M	798.872		0.00	0.00	79.89	399.44	319.55	0.00	0.00	0.00
Owners Cost - Development	US$M	406.000		23.82	43.91	57.62	125.35	155.30	0.00	0.00	0.00
Total Development Capital		3,533.921		23.82	43.91	537.50	1,609.99	1,318.71	0.00	0.00	0.00
Sustaining Capital											
Mine - Sustaining	US$M	374.739		0.00	0.00	0.00	0.00	0.00	6.34	63.82	66.26
Mill - Sustaining	US$M	279.688		0.00	0.00	0.00	0.00	0.00	0.00	6.25	12.50
CESL - Sustaining	US$M	134.250		0.00	0.00	0.00	0.00	0.00	0.00	3.00	6.00
Tailings Raise - Sustaining	US$M	329.485		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Sustaining Capital		1,118.161		0.00	0.00	0.00	0.00	0.00	6.34	73.07	84.76
Total Capital Expenditures	**US$M**	4,652.083		**23.82**	**43.91**	**537.50**	**1,609.99**	**1,318.71**	**6.34**	**73.07**	**84.76**
VALUATION DATE TIMING											
				-5	-4	-3	-2	-1	1	2	3
Year				2010	2011	2012	2013	2014	2015	2016	2017
Last Day of Year	d/m/y			12/31/2010	12/31/2011	12/31/2012	12/31/2013	12/31/2014	12/31/2015	12/31/2016	12/31/2017
Valuation Date		1-Jan-10									
Fraction of FCF Remaining in Valuation Date Year	-			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Intermediate Calculation	-			0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Discounting Period	Years			0.50	1.50	2.50	3.50	4.50	5.50	6.50	7.50
Discount Rate		8.00%		1-Jan-00	2-Jan-00	3-Jan-00	4-Jan-00	5-Jan-00	6-Jan-00	7-Jan-00	8-Jan-00
Discounting Factor				0.9623	0.8910	0.8250	0.7639	0.7073	0.6549	0.6064	0.5615
VALUATION											
			Average								
Revenues	US$M	23,928	748	0	0	0	0	0	636	855	926
Operating Costs	US$M	(11,314)	(354)	0	0	0	0	0	-331	-381	-422
Jurisdiction Royalty	US$M	(1,095)	(34)	0	0	0	0	0	-29	-39	-42
EBITDA	US$M	11,519	360	0	0	0	0	0	277	436	462
Net Proceeds Tax	US$M	(117)	(4)	-	-	-	-	-	-	-	-
Cash Income Taxes	US$M	(1,394)	(44)	-	-	-	-	-	-	-	-
Cash Flow After Taxes	US$M	10,008	313	-	-	-	-	-	277	436	462
Capital Expenditures	US$M	(4,652)	(145)	(24)	(44)	(537)	(1,610)	(1,319)	(6)	(73)	(85)
Unlevered Free Cash Flow (before Δ WC)	US$M	5,356	167	(24)	(44)	(537)	(1,610)	(1,319)	270	362	378
Cumulative Free Cash Flow	US$M			(24)	(68)	(605)	(2,215)	(3,534)	(3,264)	(2,901)	(2,523)
PV of Unlevered Free Cash Flow (before Δ WC)	US$M	(109)		(23)	(39)	(443)	(1,230)	(933)	177	220	212
Cumulative PV of Unlevered Free Cash Flow	US$M			(23)	(62)	(505)	(1,735)	(2,668)	(2,491)	(2,271)	(2,059)
NPV	8.00%	US$M		(109)							
IRR	%			7.64%							
PV Future Cash Flow (After Tax)	US$M	2,935		-	-	-	-	-	181	264	260
PV Sustaining Capital	US$M	(376)		-	-	-	-	-	(4)	(44)	(48)
PV Net Cash Flow	US$M	2,559		-	-	-	-	-	177	220	212
PV of Capital (Strike Price)	US$M	(2,668)		(23)	(39)	(443)	(1,230)	(933)	-		

Global Variables	Value	
Copper	2.30	USD/lb
23	23%	Copper Price Adjustment Factor
Nickel	6.00	USD/lb
100	100%	Nickel Price Adjustment Factor
Cobalt	10.00	USD/lb
100	100%	Cobalt Price Adjustment Factor
Discount Rate	8.00%	
32	32%	
SMELTER TERMS		
Copper		
Cu Payable Intermediary	100%	
Nickel		
Ni Payable in Ni/Co Intermediary	70%	
Cobalt		
Co Payable in Ni/Co Intermediary	70%	
TRANSPORTATION		
Transportation Rates		
Metal	50.00	US$/t
Precipitate	165.00	US$/t

Daedalus Project

	Units	Base	2018	2019	2020	2021	2022	2023	2024	2025
			4	5	6	7	8	9	10	11
PRODUCTION SUMMARY (MHP CASES)										
Copper										
Cu Metal Contained in Cu Cathode	t		128,505	127,418	136,616	138,329	128,967	130,502	136,468	136,203
Cu Metal Contained in Cu Cathode	M lbs		283.31	280.91	301.19	304.96	284.32	287.71	300.86	300.28
Nickel										
Ni Metal Contained in Ni/Co Intermediary	t		21,939	21,836	22,745	23,718	22,543	21,998	23,576	23,668
Ni Metal Contained in Ni/Co Intermediary	M lbs		48.37	48.14	50.14	52.29	49.70	48.50	51.98	52.18
Cobalt										
Co Metal Contained in Ni/Co Intermediary	t		921	913	979	991	924	935	978	976
Co Metal Contained in Ni/Co Intermediary	M lbs		2.03	2.01	2.16	2.19	2.04	2.06	2.16	2.15
REVENUES (MHP CASES)										
Gross Revenues										
Copper Cathode Sales - Gross	US$M		651.60	646.09	692.73	701.42	653.94	661.73	691.98	690.63
Nickel Contained in Ni/Co Intermediary - Gross	US$M		290.20	288.84	300.86	313.73	298.19	290.98	311.86	313.08
Cobalt Contained in Ni/Co Intermediary - Gross	US$M		20.30	20.13	21.58	21.85	20.37	20.62	21.56	21.52
Total Gross Revenues	**US$M**	27,003.4	**962.10**	**955.06**	**1,015.17**	**1,037.00**	**972.51**	**973.33**	**1,025.40**	**1,025.23**
Physical Deductions										
Copper Cathode	US$M		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ni in Ni/Co Intermendiary	US$M		(87.06)	(86.65)	(90.26)	(94.12)	(89.46)	(87.29)	(93.56)	(93.92)
Co in Ni/Co Intermediary	US$M		(6.09)	(6.04)	(6.47)	(6.56)	(6.11)	(6.18)	(6.47)	(6.45)
Total Physical Deductions	**US$M**	-2,671.0	**(93.15)**	**(92.69)**	**(96.73)**	**(100.67)**	**(95.57)**	**(93.48)**	**(100.02)**	**(100.38)**
Net Revenues										
Copper Cathode Sales - Net	US$M		651.60	646.09	692.73	701.42	653.94	661.73	691.98	690.63
Nickel Contained in Ni/Co Intermediary - Net	US$M		203.14	202.19	210.60	219.61	208.73	203.69	218.30	219.15
Cobalt Contained in Ni/Co Intermediary - Net	US$M		14.21	14.09	15.11	15.30	14.26	14.43	15.09	15.06
Total Net Revenues	**US$M**	24,332.5	**868.95**	**862.37**	**918.44**	**936.32**	**876.94**	**879.85**	**925.37**	**924.85**
Transportation Costs	**US$M**		**14.29**	**14.20**	**14.99**	**15.42**	**14.53**	**14.42**	**15.28**	**15.30**
TOTAL NET REVENUES FOB MINE GATE (MODEL I	**US$M**		**854.66**	**848.16**	**903.45**	**920.90**	**862.40**	**865.43**	**910.09**	**909.55**
SITE OPERATING COSTS										
Opex (MHP Cases)										
Mine Operating Cost	US$M		168.31	196.07	196.90	197.75	200.49	200.66	204.42	206.39
Mill Operating Cost - Variable	US$M		120.08	120.04	120.08	120.07	120.03	120.05	120.01	119.99
Mill Operating Cost - Fixed	US$M		56.58	56.58	56.58	56.58	56.58	56.58	56.58	56.58
CESL Operating Cost - Variable	US$M		52.31	51.87	55.61	56.31	52.50	53.12	55.55	55.44
CESL Operating Cost - Fixed	US$M		24.61	24.61	24.61	24.61	24.61	24.61	24.61	24.61
G&A Cost	US$M		32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
SITE OPERATING COSTS (MODEL FEED)	**US$M**	11,314.20	**453.88**	**481.17**	**485.78**	**487.32**	**486.21**	**487.02**	**493.18**	**495.01**

	Units	Base		2018	2019	2020	2021	2022	2023	2024	2025
				4	5	6	7	8	9	10	11
ROYALTIES											
Total Ore Milled	kt			43,799	43,787	43,799	43,798	43,784	43,789	43,777	43,766
STATE ROYALTY (MHP CASES)											
Net Return Value - Copper	JS$/t Milled			14.88	14.76	15.82	16.01	14.94	15.11	15.81	15.78
Net Return Value - Nickel	JS$/t Milled			4.64	4.62	4.81	5.01	4.77	4.65	4.99	5.01
Net Return Value - Cobalt	JS$/t Milled			0.32	0.32	0.34	0.35	0.33	0.33	0.34	0.34
Total Net Return Value	**JS$/t Milled**			**19.84**	**19.69**	**20.97**	**21.38**	**20.03**	**20.09**	**21.14**	**21.13**
Applicable Rates:											
Base Rate	%			3.95%	3.95%	3.95%	3.95%	3.95%	3.95%	3.95%	3.95%
Bid Rate	%			0.55%	0.55%	0.55%	0.55%	0.55%	0.55%	0.55%	0.55%
State Royalty Payable	**US$M**			**39.10**	**38.81**	**41.33**	**42.13**	**39.46**	**39.59**	**41.64**	**41.62**
CAPITAL EXPENDITURES											
Development Capital											
Mine - Development	US$M	438.817		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mill & Infrastructure - Development	US$M	1,890.233		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CESL - Development	US$M	798.872		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Owners Cost - Development	US$M	406.000		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Development Capital		3,533.921		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustaining Capital											
Mine - Sustaining	US$M	374.739		79.52	6.18	0.00	6.18	0.00	6.18	16.59	6.18
Mill - Sustaining	US$M	279.688		12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50
CESL - Sustaining	US$M	134.250		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Tailings Raise - Sustaining	US$M	329.485		0.00	45.72	0.00	0.00	47.30	0.00	0.00	47.29
Total Sustaining Capital		1,118.161		98.02	70.40	18.50	24.68	65.80	24.68	35.09	71.96
Total Capital Expenditures	**US$M**	4,652.083		**98.02**	**70.40**	**18.50**	**24.68**	**65.80**	**24.68**	**35.09**	**71.96**
VALUATION DATE TIMING											
				4	5	6	7	8	9	10	11
Year				2018	2019	2020	2021	2022	2023	2024	2025
Last Day of Year	d/m/y			12/31/2018	12/31/2019	12/31/2020	12/31/2021	12/31/2022	12/31/2023	12/31/2024	12/31/2025
Valuation Date		1-Jan-10									
Fraction of FCF Remaining in Valuation Date Year	-			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Intermediate Calculation	-			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Discounting Period	Years			8.50	9.50	10.50	11.50	12.50	13.50	14.50	15.50
Discount Rate		8.00%		9-Jan-00	10-Jan-00	11-Jan-00	12-Jan-00	13-Jan-00	14-Jan-00	15-Jan-00	16-Jan-00
Discounting Factor				0.5199	0.4814	0.4457	0.4127	0.3821	0.3538	0.3276	0.3033
VALUATION											
			Average								
Revenues	US$M	23,928	748	855	848	903	921	862	865	910	910
Operating Costs	US$M	(11,314)	(354)	-454	-481	-486	-487	-486	-487	-493	-495
Jurisdiction Royalty	US$M	(1,095)	(34)	-39	-39	-41	-42	-39	-40	-42	-42
EBITDA	US$M	11,519	360	362	328	376	391	337	339	375	373
Net Proceeds Tax	US$M	(117)	(4)	-	-	-	-	(2)	(5)	(6)	(6)
Cash Income Taxes	US$M	(1,394)	(44)	-	-	-	-	(1)	(4)	(5)	(5)
Cash Flow After Taxes	US$M	10,008	313	362	328	376	391	334	330	365	363
Capital Expenditures	US$M	(4,652)	(145)	(98)	(70)	(19)	(25)	(66)	(25)	(35)	(72)
Unlevered Free Cash Flow (before Δ WC)	US$M	5,356	167	264	258	358	367	268	305	330	291
Cumulative Free Cash Flow	US$M			(2,260)	(2,002)	(1,644)	(1,277)	(1,009)	(704)	(374)	(84)
PV of Unlevered Free Cash Flow (before Δ WC)	US$M	(109)		137	124	159	151	102	108	108	88
Cumulative PV of Unlevered Free Cash Flow	US$M			(1,922)	(1,798)	(1,638)	(1,487)	(1,385)	(1,277)	(1,169)	(1,080)
NPV	8.00%	US$M									
IRR	%										
PV Future Cash Flow (After Tax)	US$M	2,935		188	158	168	162	128	117	120	110
PV Sustaining Capital	US$M	(376)		(51)	(34)	(8)	(10)	(25)	(9)	(11)	(22)
PV Net Cash Flow	US$M	2,559		137	124	159	151	102	108	108	88
PV of Capital (Strike Price)	US$M	(2,668)									

Global Variables	Value	
Copper	2.30	USD/lb
23	23%	Copper Price Adjustment Factor
Nickel	6.00	USD/lb
100	100%	Nickel Price Adjustment Factor
Cobalt	10.00	USD/lb
100	100%	Cobalt Price Adjustment Factor
Discount Rate	8.00%	
32	32%	
SMELTER TERMS		
Copper		
Cu Payable Intermediary	100%	
Nickel		
Ni Payable in Ni/Co Intermediary	70%	
Cobalt		
Co Payable in Ni/Co Intermediary	70%	
TRANSPORTATION		
Transportation Rates		
Metal	50.00	US$/t
Precipitate	165.00	US$/t

Daedalus Project

	Units	Base		2026	2027	2028	2029	2030	2031	2032	2033
				12	13	14	15	16	17	18	19
PRODUCTION SUMMARY (MHP CASES)											
Copper											
Cu Metal Contained in Cu Cathode	t			128,913	150,691	158,846	156,374	147,677	162,458	169,141	157,630
Cu Metal Contained in Cu Cathode	M lbs			284.20	332.22	350.20	344.75	325.57	358.16	372.89	347.51
Nickel											
Ni Metal Contained in Ni/Co Intermediary	t			20,860	23,004	25,257	24,928	23,621	27,176	27,844	24,208
Ni Metal Contained in Ni/Co Intermediary	M lbs			45.99	50.71	55.68	54.96	52.07	59.91	61.38	53.37
Cobalt											
Co Metal Contained in Ni/Co Intermediary	t			924	1,080	1,138	1,120	1,058	1,144	1,144	1,129
Co Metal Contained in Ni/Co Intermediary	M lbs			2.04	2.38	2.51	2.47	2.33	2.52	2.52	2.49
REVENUES (MHP CASES)											
Gross Revenues											
Copper Cathode Sales - Gross	US$M			653.67	764.10	805.45	792.92	748.81	823.76	857.65	799.28
Nickel Contained in Ni/Co Intermediary - Gross	US$M			275.92	304.29	334.09	329.74	312.45	359.48	368.31	320.21
Cobalt Contained in Ni/Co Intermediary - Gross	US$M			20.36	23.80	25.09	24.70	23.33	25.21	25.21	24.90
Total Gross Revenues	**US$M**	27,003.4		**949.96**	**1,092.19**	**1,164.63**	**1,147.36**	**1,084.59**	**1,208.46**	**1,251.17**	**1,144.39**
Physical Deductions											
Copper Cathode	US$M			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ni in Ni/Co Intermendiary	US$M			(82.78)	(91.29)	(100.23)	(98.92)	(93.73)	(107.84)	(110.49)	(96.06)
Co in Ni/Co Intermediary	US$M			(6.11)	(7.14)	(7.53)	(7.41)	(7.00)	(7.56)	(7.56)	(7.47)
Total Physical Deductions	**US$M**	-2,671.0		**(88.89)**	**(98.43)**	**(107.75)**	**(106.33)**	**(100.73)**	**(115.41)**	**(118.06)**	**(103.53)**
Net Revenues											
Copper Cathode Sales - Net	US$M			653.67	764.10	805.45	792.92	748.81	823.76	857.65	799.28
Nickel Contained in Ni/Co Intermediary - Net	US$M			193.15	213.00	233.86	230.82	218.71	251.64	257.81	224.15
Cobalt Contained in Ni/Co Intermediary - Net	US$M			14.26	16.66	17.57	17.29	16.33	17.65	17.65	17.43
Total Net Revenues	**US$M**	24,332.5		**861.07**	**993.76**	**1,056.88**	**1,041.03**	**983.86**	**1,093.05**	**1,133.11**	**1,040.86**
Transportation Costs	**US$M**			**13.93**	**15.79**	**17.00**	**16.76**	**15.86**	**17.87**	**18.44**	**16.56**
TOTAL NET REVENUES FOB MINE GATE (MODEL	**US$M**			**847.14**	**977.98**	**1,039.88**	**1,024.27**	**968.00**	**1,075.18**	**1,114.67**	**1,024.30**
SITE OPERATING COSTS											
Opex (MHP Cases)											
Mine Operating Cost	US$M			207.93	207.53	213.57	212.80	210.14	137.27	98.39	88.84
Mill Operating Cost - Variable	US$M			119.95	120.08	120.08	120.08	120.08	120.08	120.08	120.08
Mill Operating Cost - Fixed	US$M			56.58	56.58	56.58	56.58	56.58	56.58	56.58	56.58
CESL Operating Cost - Variable	US$M			52.47	61.34	64.66	63.65	60.11	66.13	68.85	64.16
CESL Operating Cost - Fixed	US$M			24.61	24.61	24.61	24.61	24.61	24.61	24.61	24.61
G&A Cost	US$M			32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
SITE OPERATING COSTS (MODEL FEED)	**US$M**	11,314.20		**493.54**	**502.14**	**511.50**	**509.72**	**503.52**	**436.67**	**400.50**	**386.27**

	Units	Base		2026	2027	2028	2029	2030	2031	2032	2033
				12	13	14	15	16	17	18	19
ROYALTIES											
Total Ore Milled	kt			43,752	43,799	43,799	43,799	43,799	43,799	43,799	43,799
STATE ROYALTY (MHP CASES)											
Net Return Value - Copper	JS$/t Milled			14.94	17.45	18.39	18.10	17.10	18.81	19.58	18.25
Net Return Value - Nickel	JS$/t Milled			4.41	4.86	5.34	5.27	4.99	5.75	5.89	5.12
Net Return Value - Cobalt	JS$/t Milled			0.33	0.38	0.40	0.39	0.37	0.40	0.40	0.40
Total Net Return Value	**JS$/t Milled**			**19.68**	**22.69**	**24.13**	**23.77**	**22.46**	**24.96**	**25.87**	**23.76**
Applicable Rates:											
Base Rate	%			3.95%	3.95%	3.95%	3.95%	3.95%	3.95%	3.95%	3.95%
Bid Rate	%			0.55%	0.55%	0.55%	0.55%	0.55%	0.55%	0.55%	0.55%
State Royalty Payable	**US$M**			**38.75**	**44.72**	**47.56**	**46.85**	**44.27**	**49.19**	**50.99**	**46.84**
CAPITAL EXPENDITURES											
Development Capital											
Mine - Development	US$M	438.817		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mill & Infrastructure - Development	US$M	1,890.233		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CESL - Development	US$M	798.872		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Owners Cost - Development	US$M	406.000		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Development Capital		3,533.921		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustaining Capital											
Mine - Sustaining	US$M	374.739		92.66	20.67	0.00	0.00	0.00	0.00	0.00	0.00
Mill - Sustaining	US$M	279.688		12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50
CESL - Sustaining	US$M	134.250		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Tailings Raise - Sustaining	US$M	329.485		0.00	0.00	47.27	0.00	0.00	47.30	0.00	0.00
Total Sustaining Capital		1,118.161		111.16	39.17	65.77	18.50	18.50	65.80	18.50	18.50
Total Capital Expenditures	**US$M**	4,652.083		**111.16**	**39.17**	**65.77**	**18.50**	**18.50**	**65.80**	**18.50**	**18.50**
VALUATION DATE TIMING											
				12	13	14	15	16	17	18	19
Year				2026	2027	2028	2029	2030	2031	2032	2033
Last Day of Year	d/m/y			12/31/2026	12/31/2027	12/31/2028	12/31/2029	12/31/2030	12/31/2031	12/31/2032	12/31/2033
Valuation Date		1-Jan-10									
Fraction of FCF Remaining in Valuation Date Year	-			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Intermediate Calculation	-			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Discounting Period	Years			16.50	17.50	18.50	19.50	20.50	21.50	22.50	23.50
Discount Rate		8.00%		17-Jan-00	18-Jan-00	19-Jan-00	20-Jan-00	21-Jan-00	22-Jan-00	23-Jan-00	24-Jan-00
Discounting Factor				0.2809	0.2601	0.2408	0.2230	0.2064	0.1912	0.1770	0.1639
VALUATION											
			Average								
Revenues	US$M	23,928	748	847	978	1,040	1,024	968	1,075	1,115	1,024
Operating Costs	US$M	(11,314)	(354)	-494	-502	-511	-510	-504	-437	-401	-386
Jurisdiction Royalty	US$M	(1,095)	(34)	-39	-45	-48	-47	-44	-49	-51	-47
EBITDA	US$M	11,519	360	315	431	481	468	420	589	663	591
Net Proceeds Tax	US$M	(117)	(4)	(4)	(7)	(8)	(7)	(6)	(8)	(9)	(8)
Cash Income Taxes	US$M	(1,394)	(44)	(3)	(5)	(6)	(23)	(53)	(113)	(137)	(122)
Cash Flow After Taxes	US$M	10,008	313	307	419	467	437	361	469	517	462
Capital Expenditures	US$M	(4,652)	(145)	(111)	(39)	(66)	(19)	(19)	(66)	(19)	(19)
Unlevered Free Cash Flow (before Δ WC)	US$M	5,356	167	196	380	402	419	343	403	499	443
Cumulative Free Cash Flow	US$M			112	492	894	1,313	1,656	2,058	2,557	3,001
PV of Unlevered Free Cash Flow (before Δ WC)	US$M	(109)		55	99	97	93	71	77	88	73
Cumulative PV of Unlevered Free Cash Flow	US$M			(1,025)	(927)	(830)	(736)	(666)	(589)	(500)	(428)
NPV	8.00%	US$M									
IRR	%										
PV Future Cash Flow (After Tax)	US$M	2,935		86	109	113	98	75	90	92	76
PV Sustaining Capital	US$M	(376)		(31)	(10)	(16)	(4)	(4)	(13)	(3)	(3)
PV Net Cash Flow	US$M	2,559		55	99	97	93	71	77	88	73
PV of Capital (Strike Price)	US$M	(2,668)									

Global Variables	Value	
Copper	2.30	USD/lb
23	23%	Copper Price Adjustment Factor
Nickel	6.00	USD/lb
100	100%	Nickel Price Adjustment Factor
Cobalt	10.00	USD/lb
100	100%	Cobalt Price Adjustment Factor
Discount Rate	8.00%	
32	32%	
SMELTER TERMS		
Copper		
Cu Payable Intermediary	100%	
Nickel		
Ni Payable in Ni/Co Intermediary	70%	
Cobalt		
Co Payable in Ni/Co Intermediary	70%	
TRANSPORTATION		
Transportation Rates		
Metal	50.00	US$/t
Precipitate	165.00	US$/t

Daedalus Project

	Units	Base		2034	2035	2036	2037	2038	2039	2040	2041
				20	21	22	23	24	25	26	27
PRODUCTION SUMMARY (MHP CASES)											
Copper											
Cu Metal Contained in Cu Cathode	t			183,091	232,368	220,384	55,438	55,788	55,788	55,788	51,761
Cu Metal Contained in Cu Cathode	M lbs			403.65	512.28	485.86	122.22	122.99	122.99	122.99	114.11
Nickel											
Ni Metal Contained in Ni/Co Intermediary	t			32,826	55,829	50,696	10,334	10,301	10,301	10,301	9,558
Ni Metal Contained in Ni/Co Intermediary	M lbs			72.37	123.08	111.77	22.78	22.71	22.71	22.71	21.07
Cobalt											
Co Metal Contained in Ni/Co Intermediary	t			1,312	1,665	1,579	397	397	397	397	369
Co Metal Contained in Ni/Co Intermediary	M lbs			2.89	3.67	3.48	0.88	0.88	0.88	0.88	0.81
REVENUES (MHP CASES)											
Gross Revenues											
Copper Cathode Sales - Gross	US$M			928.39	1,178.25	1,117.49	281.10	282.88	282.88	282.88	262.46
Nickel Contained in Ni/Co Intermediary - Gross	US$M			434.21	738.49	670.60	136.69	136.26	136.26	136.26	126.42
Cobalt Contained in Ni/Co Intermediary - Gross	US$M			28.92	36.71	34.81	8.76	8.76	8.76	8.76	8.13
Total Gross Revenues	**US$M**	27,003.4		**1,391.52**	**1,953.44**	**1,822.90**	**426.55**	**427.90**	**427.90**	**427.90**	**397.01**
Physical Deductions											
Copper Cathode	US$M			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ni in Ni/Co Intermendiary	US$M			(130.26)	(221.55)	(201.18)	(41.01)	(40.88)	(40.88)	(40.88)	(37.93)
Co in Ni/Co Intermediary	US$M			(8.68)	(11.01)	(10.44)	(2.63)	(2.63)	(2.63)	(2.63)	(2.44)
Total Physical Deductions	**US$M**	-2,671.0		**(138.94)**	**(232.56)**	**(211.62)**	**(43.63)**	**(43.51)**	**(43.51)**	**(43.51)**	**(40.37)**
Net Revenues											
Copper Cathode Sales - Net	US$M			928.39	1,178.25	1,117.49	281.10	282.88	282.88	282.88	262.46
Nickel Contained in Ni/Co Intermediary - Net	US$M			303.95	516.94	469.42	95.68	95.38	95.38	95.38	88.50
Cobalt Contained in Ni/Co Intermediary - Net	US$M			20.25	25.70	24.37	6.13	6.13	6.13	6.13	5.69
Total Net Revenues	**US$M**	24,332.5		**1,252.58**	**1,720.89**	**1,611.28**	**382.92**	**384.39**	**384.39**	**384.39**	**356.64**
Transportation Costs	**US$M**			**20.93**	**31.64**	**29.20**	**6.48**	**6.48**	**6.48**	**6.48**	**6.02**
TOTAL NET REVENUES FOB MINE GATE (MODEL F	**US$M**			**1,231.65**	**1,689.24**	**1,582.07**	**376.44**	**377.91**	**377.91**	**377.91**	**350.63**
SITE OPERATING COSTS											
Opex (MHP Cases)											
Mine Operating Cost	US$M			71.74	63.26	60.82	29.15	29.15	29.15	29.15	27.57
Mill Operating Cost - Variable	US$M			120.08	120.08	120.08	120.08	120.08	120.08	120.08	111.41
Mill Operating Cost - Fixed	US$M			56.58	56.58	56.58	56.58	56.58	56.58	56.58	56.58
CESL Operating Cost - Variable	US$M			74.53	94.59	89.71	22.57	22.71	22.71	22.71	21.07
CESL Operating Cost - Fixed	US$M			24.61	24.61	24.61	24.61	24.61	24.61	24.61	24.61
G&A Cost	US$M			32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
SITE OPERATING COSTS (MODEL FEED)	**US$M**	11,314.20		**379.53**	**391.12**	**383.80**	**284.98**	**285.12**	**285.12**	**285.12**	**273.24**

	Units	Base		2034	2035	2036	2037	2038	2039	2040	2041
				20	21	22	23	24	25	26	27
ROYALTIES											
Total Ore Milled	kt			43,799	43,799	43,799	43,799	43,799	43,799	43,799	40,637
STATE ROYALTY (MHP CASES)											
Net Return Value - Copper	JS$/t Milled			21.20	26.90	25.51	6.42	6.46	6.46	6.46	6.46
Net Return Value - Nickel	JS$/t Milled			6.94	11.80	10.72	2.18	2.18	2.18	2.18	2.18
Net Return Value - Cobalt	JS$/t Milled			0.46	0.59	0.56	0.14	0.14	0.14	0.14	0.14
Total Net Return Value	**IS$/t Milled**			**28.60**	**39.29**	**36.79**	**8.74**	**8.78**	**8.78**	**8.78**	**8.78**
Applicable Rates:											
Base Rate	%			3.95%	3.95%	3.95%	3.95%	3.95%	3.95%	3.95%	3.95%
Bid Rate	%			0.55%	0.55%	0.55%	0.55%	0.55%	0.55%	0.55%	0.55%
State Royalty Payable	**US$M**			**56.37**	**77.44**	**72.51**	**17.23**	**17.30**	**17.30**	**17.30**	**16.05**
CAPITAL EXPENDITURES											
Development Capital											
Mine - Development	US$M	438.817		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mill & Infrastructure - Development	US$M	1,890.233		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CESL - Development	US$M	798.872		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Owners Cost - Development	US$M	406.000		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Development Capital		3,533.921		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustaining Capital											
Mine - Sustaining	US$M	374.739		2.09	2.09	0.00	0.00	0.00	0.00	0.00	0.00
Mill - Sustaining	US$M	279.688		12.50	12.50	12.50	12.50	6.25	3.13	1.56	0.00
CESL - Sustaining	US$M	134.250		6.00	6.00	6.00	6.00	3.00	1.50	0.75	0.00
Tailings Raise - Sustaining	US$M	329.485		47.30	0.00	0.00	47.30	0.00	0.00	0.00	0.00
Total Sustaining Capital		1,118.161		67.89	20.59	18.50	65.80	9.25	4.63	2.31	0.00
Total Capital Expenditures	**US$M**	4,652.083		**67.89**	**20.59**	**18.50**	**65.80**	**9.25**	**4.63**	**2.31**	**0.00**
VALUATION DATE TIMING											
				20	21	22	23	24	25	26	27
Year				2034	2035	2036	2037	2038	2039	2040	2041
Last Day of Year	d/m/y			12/31/2034	12/31/2035	12/31/2036	12/31/2037	12/31/2038	12/31/2039	12/31/2040	12/31/2041
Valuation Date		1-Jan-10									
Fraction of FCF Remaining in Valuation Date Year	-			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Intermediate Calculation	-			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Discounting Period	Years			24.50	25.50	26.50	27.50	28.50	29.50	30.50	31.50
Discount Rate		8.00%		25-Jan-00	26-Jan-00	27-Jan-00	28-Jan-00	29-Jan-00	30-Jan-00	31-Jan-00	1-Feb-00
Discounting Factor				0.1517	0.1405	0.1301	0.1205	0.1115	0.1033	0.0956	0.0885
VALUATION											
			Average								
Revenues	US$M	23,928	748	1,232	1,689	1,582	376	378	378	378	351
Operating Costs	US$M	(11,314)	(354)	-380	-391	-384	-285	-285	-285	-285	-273
Jurisdiction Royalty	US$M	(1,095)	(34)	-56	-77	-73	-17	-17	-17	-17	-16
EBITDA	US$M	11,519	360	796	1,221	1,126	74	75	75	75	61
Net Proceeds Tax	US$M	(117)	(4)	(10)	(15)	(14)	(0)	(0)	(1)	(1)	(1)
Cash Income Taxes	US$M	(1,394)	(44)	(190)	(370)	(339)	(2)	(2)	(4)	(5)	(4)
Cash Flow After Taxes	US$M	10,008	313	595	835	772	72	73	71	69	57
Capital Expenditures	US$M	(4,652)	(145)	(68)	(21)	(19)	(66)	(9)	(5)	(2)	-
Unlevered Free Cash Flow (before Δ WC)	US$M	5,356	167	527	815	754	6	63	66	67	57
Cumulative Free Cash Flow	US$M			3,528	4,343	5,097	5,103	5,166	5,232	5,299	5,356
PV of Unlevered Free Cash Flow (before Δ WC)	US$M	(109)		80	114	98	1	7	7	6	5
Cumulative PV of Unlevered Free Cash Flow	US$M			(348)	(233)	(135)	(134)	(127)	(121)	(114)	(109)
NPV	8.00%	US$M									
IRR	%										
PV Future Cash Flow (After Tax)	US$M	2,935		90	117	100	9	8	7	7	5
PV Sustaining Capital	US$M	(376)		(10)	(3)	(2)	(8)	(1)	(0)	(0)	-
PV Net Cash Flow	US$M	2,559		80	114	98	1	7	7	6	5
PV of Capital (Strike Price)	US$M	(2,668)									

Appendix 3: Black-Scholes ROA (Base Case)

The following spreadsheet calculates the real option value of Daedalus based on the Black-Scholes formula. Notice how the risk-free rate used in the formula is the continuous rate as opposed to the discrete rate of 2.125%.

Daedalus

Asset Value	S	2,558.85		DCF of Asset Value	8.00%
Strike price	K	2,667.98		DCF Cu Price ($/lb)	2.30
Risk free rate	Rf	2.103%	2.125%		
Volatility	Vol	28.54%			
Time to exercise	T	5			
	Done	0.42	=(LN(S/K)+(Rf+(Vol^2)/2)*T)/(Vol*SQRT(T))		
	Dtwo	-0.22	=(LN(S/K)+(Rf-(Vol^2)/2)*T)/(Vol*SQRT(T))		
	ND1	0.662	=NORMSDIST(Done)		
	ND2	0.413	=NORMSDIST(Dtwo)		
	Revenue	1,694	=S*ND1		
	Cost	(992)	=-K*ND2*(EXP(-Rf*T))		
	Option price	703			

Difference from Binomial Model

0.23%

Appendix 4: Binomial Method ROA (Base Case)

The following spreadsheets are the binomial lattice for the Daedalus Project which are used to calculate the real options value of the project.

		Time Increment	0	1	2	3	4	5	6	7	8	9	10	11
		Row												
		1												
		2												
Real Option Value	**704**													
DCF NPV	**(109)**	3												
Asset Value	**2,558.85**	4												
Exercise price	**2,668.00**													
Nominal annual interest rate	**2.125%**	5												
Number of months	**60.00**													
Month per step	**1.7647059**	6												
Effective interest rate for period	0.3125%													
Volatility		7												
standard deviation	**0.285**													
e	2.718	8												
Interval as fraction of year	0.147													
Working	1.116	9												
Expected rise	11.57%													
Expected fall	10.37%	10												
u	1.116	11												
d	0.896													
p	0.487	12												8,529
Risk-Free Discount Factor	0.997												7,645	6,053
		13										6,852	5,184	6,852
											6,142	4,411	6,142	4,390
		14								5,505	3,726	5,505	3,704	5,505
									4,934	3,124	4,934	3,100	4,934	3,075
		15						4,423	2,597	4,423	2,571	4,423	2,545	4,423
							3,964	2,140	3,964	2,113	3,964	2,085	3,964	2,057
		16				3,553	1,747	3,553	1,719	3,553	1,691	3,553	1,662	3,553
					3,185	1,413	3,185	1,385	3,185	1,356	3,185	1,327	3,185	1,296
		17		2,855	1,132	2,855	1,104	2,855	1,076	2,855	1,047	2,855	1,017	2,855
Asset Value =			2,559	897	2,559	871	2,559	845	2,559	817	2,559	788	2,559	759
Option Value =		18	704	2,294	680	2,294	655	2,294	630	2,294	603	2,294	576	2,294
				526	2,056	503	2,056	480	2,056	456	2,056	431	2,056	406
		19			382	1,843	362	1,843	341	1,843	319	1,843	297	1,843
						269	1,652	251	1,652	233	1,652	214	1,652	195
		20					183	1,480	168	1,480	153	1,480	137	1,480
								120	1,327	108	1,327	95	1,327	83
		21							75	1,189	66	1,189	56	1,189
										44	1,066	37	1,066	31
		22									25	956	20	956
												13	856	10
		23											6	768
														3
		24												
		25												
		26												
		27												
		28												
		29												
		30												
		31												
		32												
		33												
		34												
		35												

		Time Increment	12	13	14	15	16	17	18	19	20	21	22	23
		Row												
		1												
		2												
Real Option Value	**704**													
DCF NPV	**(109)**	3												
Stock price now	**2,558.85**	4												
Exercise price	**2,668.00**													
Nominal annual interest rate	**2.125%**	5												
Number of months	**60.00**													
Month per step	**1.7647059**	6												31,717
Effective interest rate for period	0.3125%												28,429	29,139
Volatility		7										25,482	25,859	25,482
standard deviation	**0.285**										22,840	22,920	22,840	22,904
e	2.718	8								20,472	20,286	20,472	20,270	20,472
Interval as fraction of year	0.147								18,350	17,926	18,350	17,910	18,350	17,894
Working	1.116	9						16,447	15,812	16,447	15,796	16,447	15,780	16,447
Expected rise	11.57%						14,742	13,918	14,742	13,902	14,742	13,886	14,742	13,870
Expected fall	10.37%	10				13,214	12,220	13,214	12,205	13,214	12,189	13,214	12,173	13,214
					11,844	10,700	11,844	10,684	11,844	10,668	11,844	10,652	11,844	10,636
u	1.116	11		10,616	9,338	10,616	9,322	10,616	9,306	10,616	9,290	10,616	9,274	10,616
d	0.896		9,516	8,119	9,516	8,103	9,516	8,087	9,516	8,071	9,516	8,054	9,516	8,038
p	0.487	12	7,028	8,529	7,011	8,529	6,995	8,529	6,978	8,529	6,962	8,529	6,946	8,529
Risk-Free Discount Factor	0.997		7,645	6,035	7,645	6,018	7,645	6,001	7,645	5,984	7,645	5,968	7,645	5,951
		13	5,165	6,852	5,146	6,852	5,128	6,852	5,110	6,852	5,093	6,852	5,076	6,852
			6,142	4,370	6,142	4,350	6,142	4,330	6,142	4,312	6,142	4,293	6,142	4,276
		14	3,682	5,505	3,660	5,505	3,638	5,505	3,617	5,505	3,596	5,505	3,577	5,505
			4,934	3,051	4,934	3,027	4,934	3,003	4,934	2,980	4,934	2,957	4,934	2,935
		15	2,518	4,423	2,492	4,423	2,465	4,423	2,439	4,423	2,413	4,423	2,387	4,423
			3,964	2,028	3,964	1,999	3,964	1,970	3,964	1,940	3,964	1,911	3,964	1,881
		16	1,632	3,553	1,601	3,553	1,569	3,553	1,537	3,553	1,504	3,553	1,470	3,553
			3,185	1,265	3,185	1,232	3,185	1,199	3,185	1,164	3,185	1,127	3,185	1,089
		17	986	2,855	954	2,855	920	2,855	885	2,855	848	2,855	809	2,855
			2,559	728	2,559	695	2,559	661	2,559	626	2,559	588	2,559	547
		18	547	2,294	517	2,294	486	2,294	453	2,294	419	2,294	382	2,294
			2,056	379	2,056	352	2,056	323	2,056	293	2,056	261	2,056	227
		19	274	1,843	251	1,843	226	1,843	201	1,843	175	1,843	148	1,843
			1,652	176	1,652	156	1,652	136	1,652	115	1,652	95	1,652	74
		20	122	1,480	106	1,480	90	1,480	75	1,480	59	1,480	45	1,480
			1,327	71	1,327	59	1,327	48	1,327	37	1,327	27	1,327	17
		21	47	1,189	38	1,189	30	1,189	23	1,189	16	1,189	10	1,189
			1,066	25	1,066	19	1,066	14	1,066	9	1,066	5	1,066	3
		22	16	956	12	956	8	956	5	956	3	956	1	956
			856	7	856	5	856	3	856	2	856	1	856	0
		23	4	768	3	768	2	768	1	768	0	768	0	768
			688	2	688	1	688	0	688	0	688	0	688	-
		24	1	617	1	617	0	617	0	617	0	617	-	617
				0	553	0	553	0	553	0	553	-	553	-
		25			0	496	0	496	0	496	-	496	-	496
						0	444	0	444	-	444	-	444	-
		26					0	398	-	398	-	398	-	398
								-	357	-	357	-	357	-
		27							-	320	-	320	-	320
										-	287	-	287	-
		28									-	257	-	257
												-	230	-
		29											-	206
														-
		30												
		31												
		32												
		33												
		34												
		35												

		Time Increment	24	25	26	27	28	29	30	31	32	33	34	
		Row											105,719	
		1										94,759	103,051	1
											84,935	92,099	84,935	
		2								76,130	82,284	76,130	82,267	2
Real Option Value	**704**								68,237	73,487	68,237	73,470	68,237	
DCF NPV	**(109)**	3						61,163	65,603	61,163	65,586	61,163	65,569	3
							54,822	58,537	54,822	58,520	54,822	58,504	54,822	
Stock price now	**2,558.85**	4				49,139	52,204	49,139	52,188	49,139	52,171	49,139	52,154	4
Exercise price	**2,668.00**				44,045	46,529	44,045	46,512	44,045	46,496	44,045	46,479	44,045	
Nominal annual interest rate	**2.125%**	5		39,478	41,443	39,478	41,426	39,478	41,410	39,478	41,393	39,478	41,377	5
Number of months	**60.00**		35,386	36,885	35,386	36,868	35,386	36,852	35,386	36,835	35,386	36,819	35,386	
Month per step	**1.7647059**	6	32,800	31,717	32,784	31,717	32,767	31,717	32,751	31,717	32,734	31,717	32,718	6
Effective interest rate for period	0.3125%		28,429	29,123	28,429	29,107	28,429	29,091	28,429	29,074	28,429	29,058	28,429	
Volatility		7	25,843	25,482	25,827	25,482	25,811	25,482	25,794	25,482	25,778	25,482	25,761	7
standard deviation	**0.285**		22,840	22,888	22,840	22,872	22,840	22,855	22,840	22,839	22,840	22,822	22,840	
e	2.718	8	20,254	20,472	20,238	20,472	20,222	20,472	20,205	20,472	20,189	20,472	20,172	8
Interval as fraction of year	0.147		18,350	17,878	18,350	17,862	18,350	17,846	18,350	17,829	18,350	17,813	18,350	
Working	1.116	9	15,764	16,447	15,748	16,447	15,731	16,447	15,715	16,447	15,698	16,447	15,682	9
Expected rise	11.57%		14,742	13,854	14,742	13,837	14,742	13,821	14,742	13,804	14,742	13,788	14,742	
Expected fall	10.37%	10	12,156	13,214	12,140	13,214	12,124	13,214	12,108	13,214	12,091	13,214	12,074	10
			11,844	10,620	11,844	10,604	11,844	10,587	11,844	10,571	11,844	10,554	11,844	
u	1.116	11	9,258	10,616	9,242	10,616	9,226	10,616	9,209	10,616	9,193	10,616	9,176	11
d	0.896		9,516	8,022	9,516	8,006	9,516	7,990	9,516	7,973	9,516	7,957	9,516	
p	0.487	12	6,930	8,529	6,913	8,529	6,897	8,529	6,881	8,529	6,864	8,529	6,848	12
Risk-Free Discount Factor	0.997		7,645	5,935	7,645	5,919	7,645	5,902	7,645	5,886	7,645	5,869	7,645	
		13	5,059	6,852	5,043	6,852	5,026	6,852	5,010	6,852	4,994	6,852	4,977	13
			6,142	4,259	6,142	4,242	6,142	4,226	6,142	4,209	6,142	4,193	6,142	
		14	3,558	5,505	3,540	5,505	3,524	5,505	3,507	5,505	3,491	5,505	3,474	14
			4,934	2,915	4,934	2,896	4,934	2,879	4,934	2,862	4,934	2,846	4,934	
		15	2,362	4,423	2,339	4,423	2,318	4,423	2,300	4,423	2,283	4,423	2,266	15
			3,964	1,852	3,964	1,825	3,964	1,800	3,964	1,780	3,964	1,763	3,964	
		16	1,436	3,553	1,402	3,553	1,368	3,553	1,337	3,553	1,313	3,553	1,296	16
			3,185	1,050	3,185	1,009	3,185	966	3,185	925	3,185	894	3,185	
		17	767	2,855	722	2,855	674	2,855	620	2,855	562	2,855	517	17
			2,559	503	2,559	455	2,559	400	2,559	335	2,559	251	2,559	
		18	342	2,294	298	2,294	250	2,294	193	2,294	122	2,294	-	18
			2,056	191	2,056	152	2,056	108	2,056	59	2,056	-	2,056	
		19	120	1,843	90	1,843	60	1,843	29	1,843	-	1,843	-	19
			1,652	53	1,652	32	1,652	14	1,652	-	1,652	-	1,652	
		20	30	1,480	17	1,480	7	1,480	-	1,480	-	1,480	-	20
			1,327	9	1,327	3	1,327	-	1,327	-	1,327	-	1,327	
		21	5	1,189	2	1,189	-	1,189	-	1,189	-	1,189	-	21
			1,066	1	1,066	-	1,066	-	1,066	-	1,066	-	1,066	
		22	0	956	-	956	-	956	-	956	-	956	-	22
			856	-	856	-	856	-	856	-	856	-	856	
		23	-	768	-	768	-	768	-	768	-	768	-	23
			688	-	688	-	688	-	688	-	688	-	688	
		24	-	617	-	617	-	617	-	617	-	617	-	24
			553	-	553	-	553	-	553	-	553	-	553	
		25	-	496	-	496	-	496	-	496	-	496	-	25
			444	-	444	-	444	-	444	-	444	-	444	
		26	-	398	-	398	-	398	-	398	-	398	-	26
			357	-	357	-	357	-	357	-	357	-	357	
		27	-	320	-	320	-	320	-	320	-	320	-	27
			287	-	287	-	287	-	287	-	287	-	287	
		28	-	257	-	257	-	257	-	257	-	257	-	28
			230	-	230	-	230	-	230	-	230	-	230	
		29	-	206	-	206	-	206	-	206	-	206	-	29
			185	-	185	-	185	-	185	-	185	-	185	
		30	-	166	-	166	-	166	-	166	-	166	-	30
				-	149	-	149	-	149	-	149	-	149	
		31			-	133	-	133	-	133	-	133	-	31
						-	119	-	119	-	119	-	119	
		32					-	107	-	107	-	107	-	32
								-	96	-	96	-	96	
		33							-	86	-	86	-	33
										-	77	-	77	
		34									-	69	-	34
												-	62	
		35											-	35

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