Market Your Systems Engineering With Business Skills

Tracy J. Farwell
Space and Communications Group
The Boeing Company
tracy.j.farwell@boeing .com

Abstract. Several indirect methods for quantifying the economic value of Systems Engineering practices are described. All are easily recognized as conventional valuations. Systems Engineers are more effective when marketing their core skills in a business context. This paper supports those SEs who participate in the marketing of Systems Engineering as Engineering.

INTRODUCTION

Engineering. As engineers we employ knowledge of physics and mathematics as well as current engineering standards to design and develop products and services that have viable economic value in a particular market. When one chooses a branch of engineering such as software, civil, mechanical, power, etc. there is a corresponding market which is distinct from other engineering markets. Although the authority for economic decisions is reserved for those with engineering management responsibility, every engineer knows why the end product or service is marketable.

Systems Engineering. Cost is a variable parameter for the engineer to consider among other parameters and cost efficiencies cannot be achieved without considering all costs. The value of Systems Engineering stems from the end-to-end scope of knowledge accumulated from regarding the whole system as a total product. The System Engineer is uniquely positioned to discover leveraged cost strategies and identify key inputs for economic decision making.

Moreover, the legacy of product development principles, methods, tools and processes that Systems Engineers bring to any project inherently acts to preclude problems during product integration and installation. SE practices which rely on early discussion of customer needs and objectives, analysis of alternatives, formal requirements definition with test criteria, all act to preclude latent design flaws.

THE RIDDLE

Virtual Value. It's not just the Systems Engineers who have difficulty trying to identify the costs saved due to problems that were obviated by Systems Engineering practices (Repenning 2001). What would have been the cost of a problem that didn't happen? Every problem that is precluded by an effective process is obviously one for which no cost is incurred. How do we determine the "would have" costs?

This situation poses an important distinction between costs obviated and costs incurred. Conventional accounting practices deal effectively with "costs incurred." The Financial Accounting Standards Board (FASB) sets accounting standards for costs incurred that are backed by the American Institute of Certified Public Accountants. Engineers too deal effectively with costs incurred.

Without metrics for accurate quantification of "costs obviated" and therefore saved, a direct valuation of Systems Engineering achievements, and even their attribution to Systems Engineering, appears to be both indeterminate and undeterminable.

All is not lost. We know of many other domains of knowledge typically associated with an intrinsic value that is not directly quantifiable. What is the value of law and order, of literacy, science, art, or accounting itself? What is the value of engineering? The value is in the discipline and System Engineering practitioners and advocates know this. So neither Engineering nor System Engineering can be reduced to a measurable commodity, nor is engineering unique in this regard.

Nevertheless, every Systems Engineer knows that the "value" of Systems Engineering is frequently challenged, discussed, debated and easily "refuted" by those who apparently do not accept the virtual value. One must recognise of course that any undeterminable value is easily "debated." The larger question is "Why debate at all when any discipline, by its very nature, cannot be metricized?"

THE MARKETPLACE

Business Skills. All the dialectics aside, we promote the intrinsic value of Systems Engineering more effectively when we become conversant with the terms and principles used in the business community to make sound decisions. Three approaches are addressed -

Engineering Economic Analysis, Return on Investment, and Real Option Modelling.

NOTE: Dollar values have been assigned in the following examples to establish a business perspective for each case presented. These values are entirely arbitrary and do not in any way represent any business case known to the author. Unless noted otherwise, all \$ units are 10^6.

Engineering Economic Analysis. Undergraduate engineering curricula typically include core or elective coursework treating engineering economics. Linear relationships between future and present values are defined. For example, consider the cash flow diagram in Figure 1. A series of receipts is equivalent to an initial principal expense.

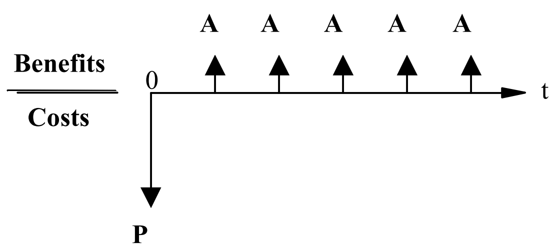

Figure 1. Cash Flow Diagram

Where P is the present value, A is an annual payment amount in a series of payments, "i" is the interest rate and "n" is the number of years the payments are made,

$$P = A\left[\frac{(1+i)^n - 1}{i\,(1+i)^n}\right]$$

This computation allows direct comparison of the net present value of a series annual license payments (A) over "n" years for a Systems Engineering tool application as opposed to outright purchase at year zero. This approach is generally termed "Discounted Cash Flow" (DCF) in the business community (Cox 2001).

Return on Investment (ROI). After falling out of favor in the late 1980's, ROI is still used as a valuation standard. This approach offers an indirect valuation of Systems Engineering if one postulates that costs are incurred when Systems Engineering is not employed during product development.

Consider a development contract with a budget of 10M per year for 5.5 years. Assume that this plan has been patterned after a similar project that did not employ Systems Engineering methods or tools. The cash flow model for this case is shown in Figure 2.

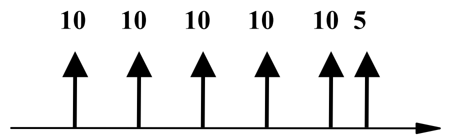

Figure 2. Project Plan

A saving in integration and test of 6 months is anticipated as a result of the decision to replan and add Systems Engineers. This is represented in Figure 3

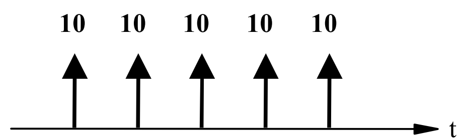

Figure 3. Project Replan

Under the replan, 5M in project expense is eliminated. The present value of this amount is represented in Figure 4.

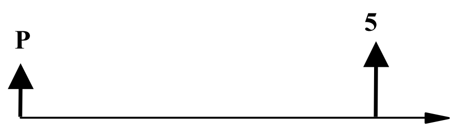

Figure 4. Present Value of Estimated Savings

A present value for the single amount that would have been expended at year 5.5 is evaluated from the following expression:

$$P = \left[\frac{A}{(1+i)^n}\right]$$

With i = 7% this yields a present value of P_{ES} = 3.5M for the "estimated savings." This is an example of DCF.

To determine the Return on Investment, the cost of Systems Engineering must be determined. The following assumptions are made.

SE Tool Cost at year 0: 30k

Systems Engineers per year (3) 60k ea

The resulting cash flow is given in Figure 5.

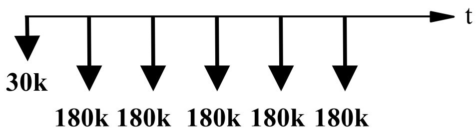

Figure 5. Estimated SE Costs

Computing the present value of SE costs, C_{SE} is determined from the payment series equation and is found to be 760K.

$ROI = P_{ES} – C_{SE} = 3.5M – 0.8M = 2.7M$

This would be considered a strong indicator in favor of deciding to apply Systems Engineering for this project.

Consider the outcome for an expected budget of 1M per year rather than 10M.

$ROI = P_{ES} – C_{SE} = 0.35M – 0.8M = – 0.45M.$

The replan is not effective in this case since the estimated savings do not offset the corresponding costs.

Difficulties for Systems Engineers posed by the ROI approach have been thoroughly discussed in the literature (Sheard 1998). One of the most serious is the need to quantify any estimated savings without an accepted industry standard for such estimates.

Call Option Modelling. To provide an alternative valuation that considers the potential future market value of a given product development project, the Real Option Model is proposed. Originally suggested for evaluating candidate concepts for research and development funding (Mitchell 1988), this method readily relates to the valuation of project development options to choose among candidate development projects.

The concept is taken from the "Call Option" where the investor who owns a certain stock offers to sell this stock at a future date for a fixed amount (K), in exchange for a fee. The fee represents the value of the option, and is independent of the idea to sell the stock for a price that is higher or lower than the current market value. If the wrong "fix" is chosen, the option will not be purchased.

Once the option is sold, the value of the option to the owner will increase if the market value of the stock happens to exceed "K." If the market value for the stock happens to decrease below "K," the value (premium) of the option is zero since there would be no buyer willing to pay more than the market value for the stock. The value of the option as a function of stock value is shown graphically in Figure 6.

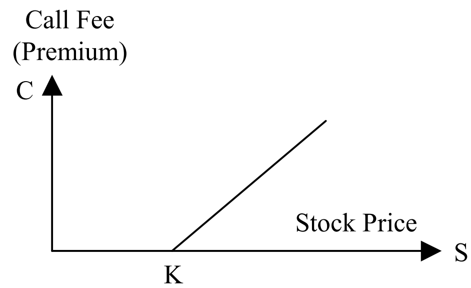

Figure 6. Option Value Characteristic

A model that identifies the value of any call option for any market conditions has become a common tool in the business community. The model consists of a curve fit derived from years of data recorded by the Chicago Board Options Exchange (CBOE).

The Black-Scholes Model (Nobel, 1997) requires the following inputs in order to produce an estimated premium:

S = current stock price
t = time until option expiration
K = option striking price
r = risk free interest rate
N = cumulative standard normal distribution
e = exponential function (2.7183)

$$d_1 = \frac{\ln(S/K) + (r + \sigma^2/2)^t}{\sigma \sqrt{t}}$$

$$d_2 = d_1 – \sigma \sqrt{t}$$

σ = standard deviation of stock prices
ln = natural logarithm

To estimate the value that the market would impart to an option, Black-Scholes approach subtracts the present value of the predicted exercise price on the expiration date from the value of the stock if purchased directly without the option.

C = Theoretical Call Premium

C = [Stock value (direct)] – [Present value of K at expiration]

$$C= SN(d_1) – Ke^{(-rt)} N(d_2)$$

This model has been validated by comparing predicted and actual call premiums recorded by CBOE. The call options and the corresponding "puts" are exchanged in the open market as shown in Figure 7.

The purchaser of the call option is the investor who offers to buy the stock by writing a "put" option (Jarrow 1983).

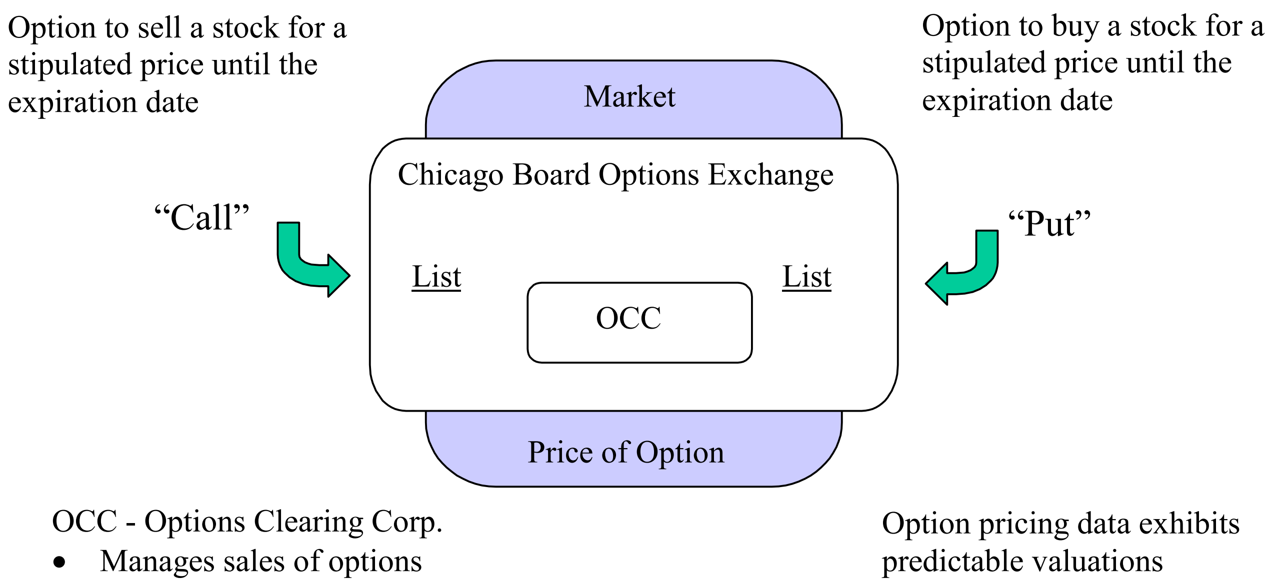

Figure 7. The Market Determines Call Option Value

Other Options. It is common practice in the business community to apply the Black-Scholes model to investment options that do not involve stock trades at all. Typically only five inputs are needed to produce a valuation – the generalized use of the five parameters to evaluate a business case is noted below (Luehrman, 1998):

Call Option	Parameter	Business Opportunity
Stock Price	S	Present value of business assets to be acquired
Exercise Price	K	Expenditure required to acquire the assets
Time to expiration	t	Length of time the decision may be deferred
Risk-free interest rate	r	Time value of money
Variance of returns on stock	σ^2	Riskiness of project assets

For example, consider the case of a modification to an existing product. The cost to develop the modification is 10M. The present value of future cash flow attributable to the modified product is 9M.

Net Present Value = – 1M.

Now obtain the Call Option valuation. The investment can proceed any time in the next 2 years due to an advantage gained by intellectual property (patents, know-how). The average cost of capital is 7% and the volatility in market value has been 30% for several years.

Paramet	Produc Modificati
S	9M
K	10M
t	2
r	7%
σ^2	30%

Using Black-Scholes, the Option Value = 1.6M. Software to compute Black-Scholes valuations is available for internet download. Look-up tables are also available (Luehrman 1998).

This result factors in the prospect of a better outcome from fortuitous market conditions that have been observed in the past. Although Black-Scholes was validated for the CBOE market, it is used as a yardstick for business opportunities in general.

Why Different Approaches. Recognizing that owning a stock is different from owning an option, it is important to use the option value method when it provides a better insight. The risk that circumstances will change is something that we understand intuitively. When an investment has already been made (the stock case), circumstances are evaluated as shown in Figure 8.

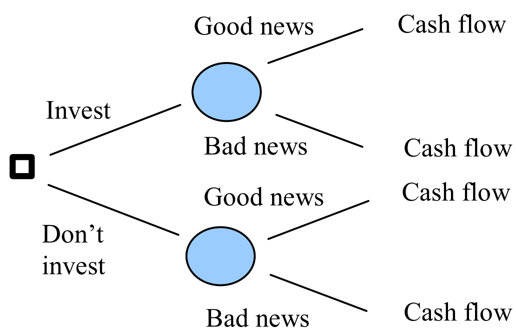

Figure 8. Assets–in-place

For this situation DCF methods are found very useful.

When the principal investment has not been made (the option case), circumstances are evaluated as shown in Figure 9. Although there is a cost in owning an option, the option allows favorable situations to develop and become evident, providing more information to the investor prior to making a decision. Traditional DCF methods are not as effective in identifying value in this case (Luehrman, 1997).

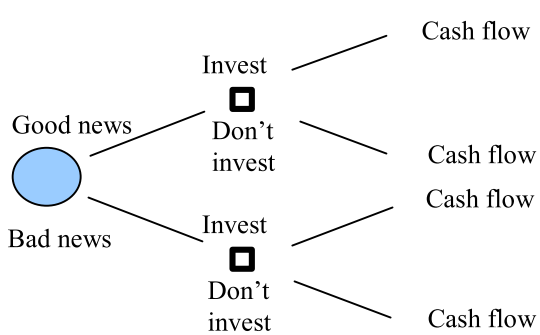

Figure 9. Evident Opportunity

SE As An Option. Although Systems Engineers find little comfort in the prospect, Systems Engineering is an option when project development decisions are taken. Few investors can afford a deployment cycle that applies a full-up Systems Engineering enterprise process model. Few SEs are employed solely to tailor an enterprise model to a given development project.

Even so, various SE process elements can be and often are selected for deployment on a given project, and are decided in terms of perceived value. The values perceived are typically those of marketing managers, project managers and business planners, not SEs.

Can Systems Engineering be characterized as an investment option? By now we should conclude "yes".

The option analogy in the engineering domain is the value of the opportunity to develop a product with confidence in the predicted cost of development. When taken as an effective product development methodology, Systems Engineering provides assurance that a product can be developed with lower development risk than otherwise.

Using the same parameters as the product modification business case example, Black-Scholes can provide a valuation for SE. Consider the case of a production contract involving the delivery of 9 units in 2 years with P = 1M ea. The customer assures a generous follow-on contract if the project succeeds with unit cost.

S = 9 M.

Assume that the finance estimating team predicts that the total cost of design, integration, production and test is 10M.

K = 10M.

Assume now that the likelihood of succeeding within a 10M cost cap is estimated as 70%, giving a risk of failure of 30%.

$\sigma^2 = 30\%$

Taking the prevailing interest rate as 7%, the Option Value is (again) 1.6M. This is the fraction of the 10M total cost to commit to System Engineering in order to assure that the overall design, integration and test costs do not cause an overrun of the 10M estimate.

Higher risk estimates (interpreted as σ^2 volatility in this example) produce a higher option value using Black-Scholes. This approach yields a higher valuation for SE when project risk is high. The 1.6M for SE assures that the cost cap of 10M is not exceeded. In this scenario, the cost of the option to assure customer satisfaction for the first 9 units and to capitalize on the follow on opportunity is 1.6M.

Systems Engineering encompasses a legacy of built-in lessons learned so that costly "surprises" are obviated by skilful incorporation of the legacy processes. When utilized, it assures that the given development project remains viable despite "conditions" that can occur. These conditions constitute a significant dimension of the market.

Characterizing the Market. Consider some of the qualitative conditions that influence our market. The "market conditions" that can increase the perceived value of SE are

1) Concept changes that occur during development, impacting the intended use of the product, resulting in a reconsideration of performance requirements,
2) New standards levied on a project during

development that must be quickly incorporated into the requirements management tools,

3) Changes to performance requirements that impact on-going design effort by adding or deleting required capabilities and modifying test conditions,

4) Advances in new technology that must be exploited quickly by rapid assessment of compatibility with existing concepts, requirements and test plans,

5) Validation or discovery of intellectual property that builds on current concepts/analyses to establish a new follow-on product or capability.

"Market conditions" that erode the value of SE are

1) A reduction in the expected quality of the end product which occurs when project standards are rescinded or interpreted loosely by the customer,

2) A shift of budget away from analysis in favor of test which emphasizes the discovery of problems rather than obviating them,

3) Exclusive reliance on "risk management" methods that react to "known" problems by tracking and mitigating, rather than utilizing the SE processes to systematically ferret out and resolve the latent unknowns before they emerge as "problems,"

4) Open ended or highly flexible marketing strategies that rely on poorly framed contract requirements or exempt engineering from producing baselined designs,

5) The absence of an acceptable standard as a basis for agreement in estimating obviated costs,

6) Preference for reactive strategies that respond to emergent cost issues, rather than proactive project planning.

CONCLUSION

A Systems Engineering cost model has been posed as an extension of the call option method employed in conventional business case analysis. A better understanding of this and other business case methods will enable the Systems Engineer to convey the intrinsic value of Systems Engineering to the business community in business terms as a proven product development discipline. This prepares the System Engineer to offer a prospectus of our knowledge base in any market. A context-based summary of the cost estimation methods is provided in Table 1.

Paradoxes encountered in the effort to quantify a commodity value for Systems Engineering have been discussed. Even so, there should be no need to demand a higher standard of economic justification for SE than for engineering in general.

Methods	Context	Comment
Engineering Economic Analysis	Engineering	Universally accepted
ROI	Business	Universally accepted
	Systems Engineering	Needs a recognized business valuation standard for obviated costs
Call Option Modelling	Stock Trades	Validated; Nobel 1997
	R&D Decisions	Factors-in estimated market volatility
	Systems Engineering*	The value of the option increases with project risk
* The precision of the estimates produced from this model would not be as rigorous as, for example, finite element stress modelling for bridge design.		

Table 1: Summary of Valuation Methods

The best course of action is to advocate for development cost containment in building a particular business case for SE. This would seem far more fruitful than trying to build a generalized business case for Systems Engineering from direct study of certain case histories with their inevitable controversies that cause disagreement over ROI. Engineering credibility stems from mathematically justified principles that guide engineering design – so too for Systems Engineering. This paper offers several ways for the Systems Engineering practitioner to present domain knowledge as intellectual capital from which to assert a convincing, conventional value proposition.

REFERENCES

Cox, L., "Overview of Basic Concepts in Engineering Economic Analysis," Industry Workshop, Boeing, 2000

Jarrow, R.A., Rudd, A., *Option Pricing*, Dow Jones-Irwin, Homewood, Illinois, 1983

Luehrman, T. A., "What's It Worth – A General Manager's Guide to Valuation", Harvard Business Review, May-June 1997

Luehrman, T. A., "Investment Opportunities as Real Options: Getting Started on the Numbers," Harvard Business Review, July-August 1998

Mitchell, Graham R., "Options for the Strategic Management of Technology," Proceedings of the first International Conference on Technology Management, Miami Florida, Feb 1988

Repenning, N. P., Sterman, J. D., "Nobody Ever Gets Credit for Fixing Problems that Never Happen," California Management Review, Summer 2001

Sheard, S. A., Miller, C. L., "The Shangri La of ROI," Proceedings of INCOSE, 2000

BIOGRAPHY

Tracy J. Farwell has thirty years' experience in systems engineering of hardware and software systems for aircraft, defense and space products including US and UK assignments. Currently he is a principal systems engineer for a major technology demonstration program. Mr. Farwell has served as an INCOSE Seattle Chapter board member and president. He has participated in the SE Principles Working group.