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The Value of R&D– A Real Options Analysis Approach.

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Background

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The Question asked

"The CSA Research Programme has been challenged recently to justify the value it delivers at the portfolio level. Most of the methods in use (case studies and feedback surveys) operate at the project level and cannot be aggregated. They are also retrospective when what is also needed is a tool that enables the current portfolio to be valued in order that decisions can be taken about future additions to the portfolio and thus optimise the commitment of further public money.

An internal Dstl study has identified Real Options Analysis (ROA) as providing a viable econometric component of an evaluation method that has the potential to allow research options to be valued and aggregated. The approach is novel within the MOD and to reduce risk, a pilot study is proposed using a large segment of the Research Programme to test the viability of the approach."

Hence our overall objective is using ROA to quantify the benefit of individual Research Projects and, ultimately, overall Programme for Justification and prioritisation.

The MoD R&D Programme

- The MOD's Science and Technology (S&T) programme, is owned by the MOD's Chief Scientific Advisor (CSA), and is funded with an annual budget of approximately £450m.
- The S&T programme is underpinned by a Defence S&T Plan that ensures MOD's research provides a breadth of support for all MOD's strategic objectives and Military Tasks, these are listed below*.

  - Defending the UK and its overseas territories,
  - Providing strategic intelligence,
  - Providing nuclear deterrence,
  - Supporting civil emergency organisations in times of crisis,
  - Defending our interests by projecting power strategically and through expeditionary interventions,
  - Providing a defence contribution to UK influence,
  - Providing security for stabilisation.

*MOD Defence Science & Technology Plan 2014 – 2015

MoD Research Aims

- Within the plan are a number of objectives that the S&T programme must achieve:
  - To continue essential investment in S&T as a key element of MOD's overall capability, maintaining operational advantage and freedom of action in critical areas, including the Strategic Deterrent, Chemical and Biological Defence, countermeasures for counter-terrorism and sustain levels of investment to maintain credibility in critical international research collaboration.
  - Ensure the technical means to counter evolving threats.
  - Ensure an effective balance between research focused on long-term needs of capability and immediate application of expertise on today's battlefield.
  - Achieve an effective balance in programmes and maintain flexibility to adapt to the unexpected.

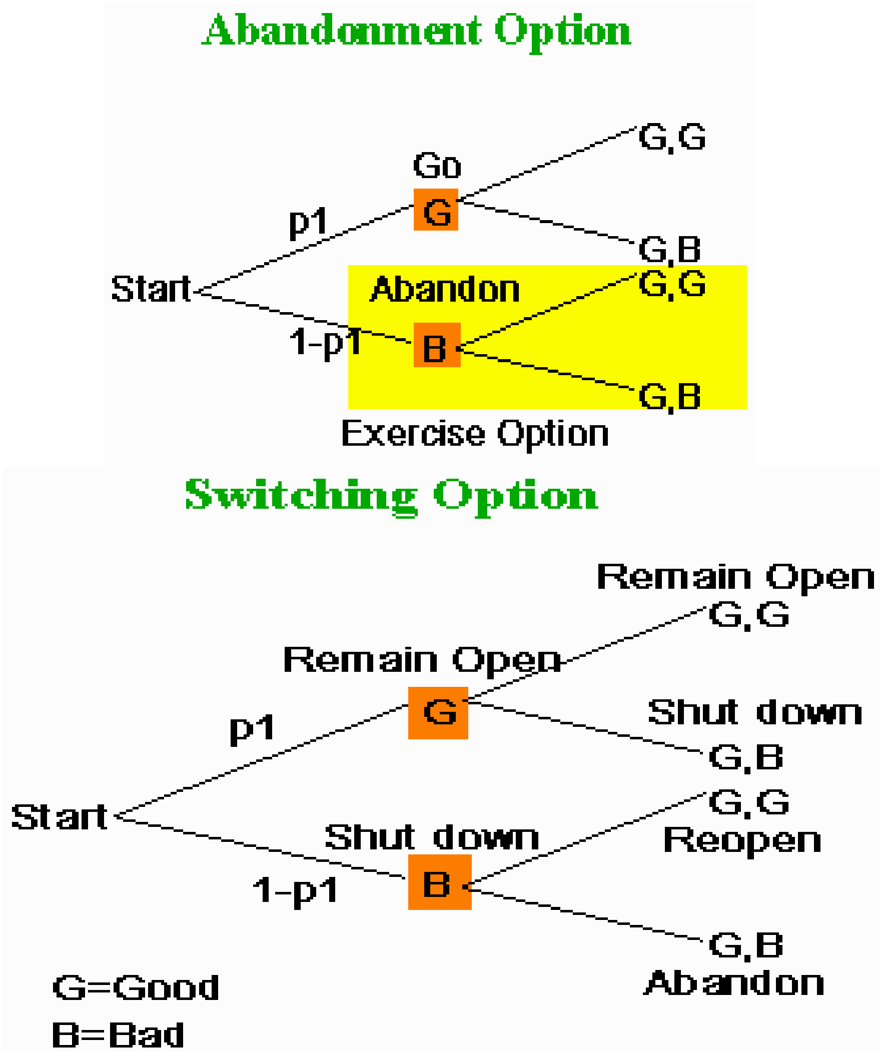
*MOD Defence Science & Technology Plan 2014 – 2015

What is Real Options Analysis (ROA)?

- Focuses on “Real” physical assets rather than financial assets
- The right to take a decision at one or more points in the future unlike traditional discounted cash flow approaches (NPV)
- Important in projects sequential in nature where uncertainty is resolved over time
- NOT an equation or set of equations
- Practical application to real life projects presents some serious difficulties that have hindered its success.

Options available in real analysis:

- Abandon
- Defer
- Switch
- Expand/Contract
- Upgrade
- Acquire incrementally



ROA Methods/Models

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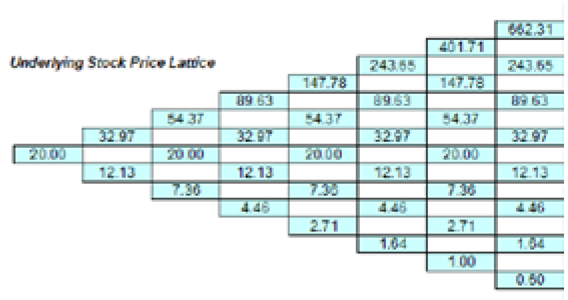
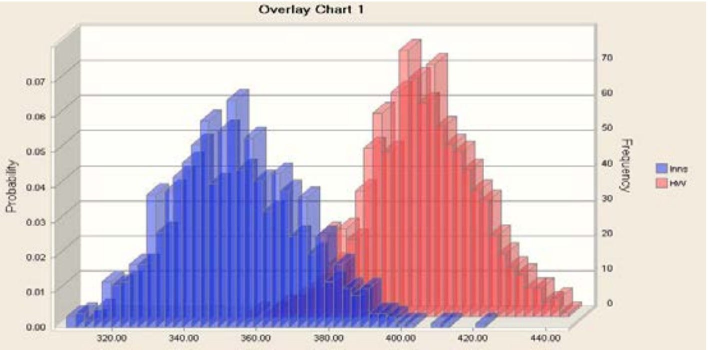
- Black & Scholes formula

$$V=St\Phi(d1)-Xe^{-rT}\,\Phi\,(d2)$$

- Lattice/Decision Trees



- Adaption of Monte Carlo simulation



Outcome of Literature Review

- Most examples of use of ROA have been in the Pharmaceutical Industry.
- In most studies the value of the option reflects the profit from successful commercial exploitation
- The value of the underlying asset is equal to the overall profit expected from a contract to develop an end product.
- The greater is the volatility in the value of the underlying asset, the greater the value of the option.
- For financial options where the underlying asset is traded on the market on a continuous basis, there is no problem with availability of data.
- For real options a proxy measure of volatility is the variance in the share price.
- For defence this is not appropriate

What determines the project's option value?

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- Risk free interest rate **(r_f) -** *Need to determine the correct rate. Use HMT Discount rate?*

- Time until expiration **(t)** – *Maturity date and type of option. Deadline for research or time until another company has similar products/ideas?*

- Value of the underlying asset **(S)** – *This is the crux of the matter. Present value of the cash flows of the project excluding initial investment?*

- Project volatility **(σ)** – *this is the volatility of the asset value- this is usually determined through the performance of previous projects or in financial terms a sample of a particular type of stock and then calculating their standard deviation through monte carlo simulation for example.*

- Exercise (strike) Price **(X)** – *this is complex when there is no market for the option or its underlying asset. What capital investment is to be made?*

Calculating the option value using Black-Scholes

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Each number in the table gives the value of a European call for specified values of NPVq and $\sigma\sqrt{t}$, as a percentage of S, the value of project assets.

Example:

Suppose $S = \$100$

$X = \$105$

$t = 1$ year

$r_f = 5\%$

$\sigma = 50\%$ per year

then NPVq = 1.0

and $\sigma\sqrt{t} = 0.50$.

The table gives a value of 19.7%.

Interpretation:

Viewed as a call option, the project has a value of:

Call value = 0.197 × \$100 = \$19.70.

Compare this to its conventional NPV:

$$NPV = S - X = \$100 - \$105 = \$-5.$$

Black-Scholes value of a European call option, expressed as a percentage of underlying asset value.

NPVq

$\sigma\sqrt{t}$	0.80	0.82	0.84	0.86	0.88	0.90	0.92	0.94	0.96	0.98	**1.00**	1.02	1.04	1.06	1.08
0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.6	1.2	**2.0**	3.1	4.5	6.0	7.5
0.10	0.0	0.1	0.2	0.3	0.5	0.8	1.2	1.7	2.3	3.1	**4.0**	5.0	6.1	7.3	8.6
0.15	0.5	0.7	1.0	1.3	1.7	2.2	2.8	3.5	4.2	5.1	**6.0**	7.0	8.0	9.1	10.2
0.20	1.5	1.9	2.3	2.8	3.4	4.0	4.7	5.4	6.2	7.1	**8.0**	8.9	9.9	10.9	11.9
0.25	2.8	3.3	3.9	4.5	5.2	5.9	6.6	7.4	8.2	9.1	**9.9**	10.9	11.8	12.8	13.7
0.30	4.4	5.0	5.7	6.3	7.0	7.8	8.6	9.4	10.2	11.1	**11.9**	12.8	13.7	14.6	15.6
0.35	6.2	6.8	7.5	8.2	9.0	9.8	10.6	11.4	12.2	13.0	**13.9**	14.8	15.6	16.5	17.4
0.40	8.0	8.7	9.4	10.2	11.0	11.7	12.5	13.4	14.2	15.0	**15.9**	16.7	17.5	18.4	19.2
0.45	9.9	10.6	11.4	12.2	12.9	13.7	14.5	15.3	16.2	17.0	**17.8**	18.6	19.4	20.3	21.1
0.50	**11.8**	**12.6**	**13.4**	**14.2**	**14.9**	**15.7**	**16.5**	**17.3**	**18.1**	**18.9**	**19.7**	20.5	21.3	22.1	22.9
0.55	13.8	14.6	15.4	16.1	16.9	17.7	18.5	19.3	20.1	20.9	21.7	22.4	23.2	24.0	24.8
0.60	15.8	16.6	17.4	18.1	18.9	19.7	20.5	21.3	22.0	22.8	23.6	24.3	25.1	25.8	26.6
0.65	17.8	18.6	19.3	20.1	20.9	21.7	22.5	23.2	24.0	24.7	25.3	26.2	27.0	27.7	28.4
0.70	19.8	20.6	21.3	22.1	22.9	23.6	24.4	25.2	25.9	26.6	27.4	28.1	28.8	29.5	30.2
0.75	21.8	22.5	23.3	24.1	24.8	25.6	26.3	27.1	27.8	28.5	29.2	29.9	30.6	31.3	32.0
0.80	23.7	24.5	25.3	26.0	26.8	27.5	28.3	29.0	29.7	30.4	31.1	31.8	32.4	33.1	33.8
0.85	25.7	26.5	27.2	28.0	28.7	29.4	30.2	30.9	31.6	32.2	32.9	33.6	34.2	34.9	35.5
0.90	27.7	28.4	29.2	29.9	30.6	31.3	32.0	32.7	33.4	34.1	34.7	35.4	36.0	36.6	37.3

Assumptions: Volatility and option price are fixed

Lattice method example

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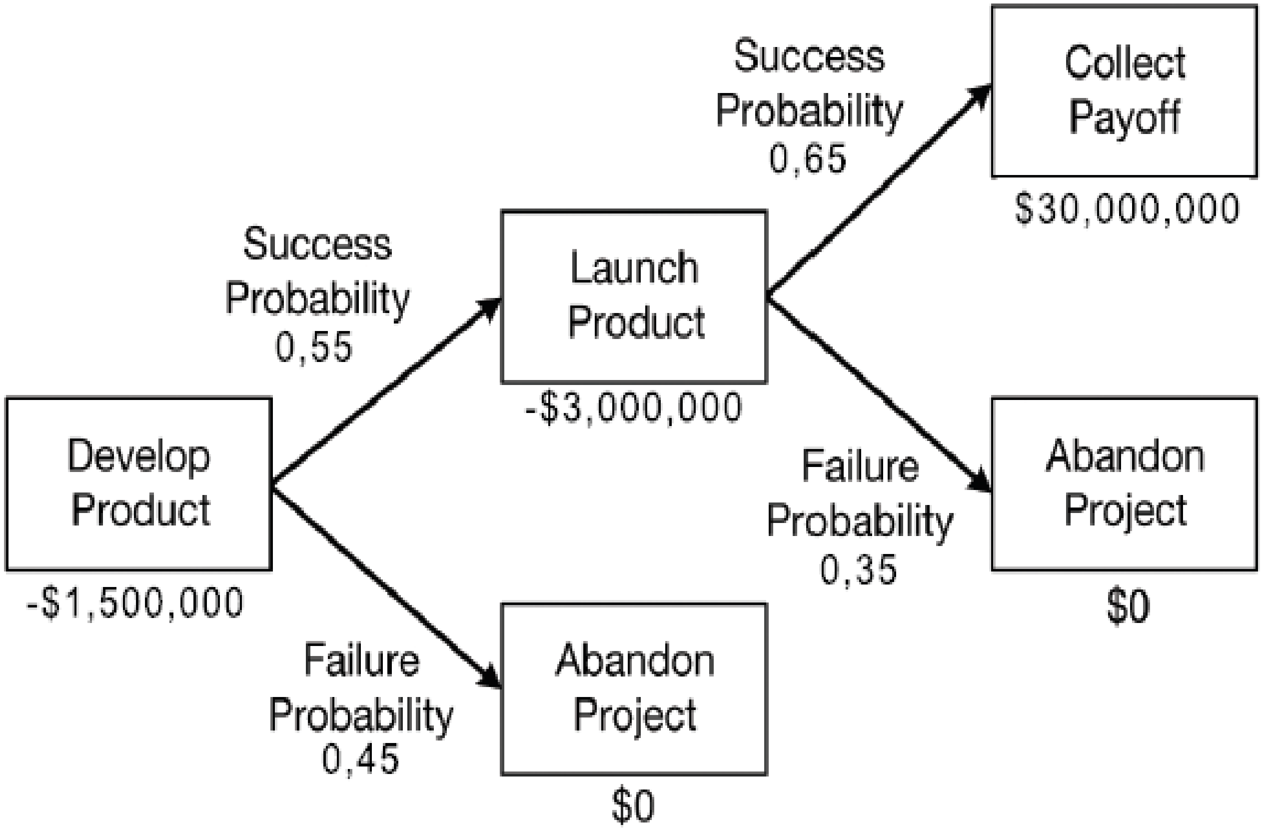
Magnitude of rise or fall depends on volatility



Monte Carlo (Probability) Simulation

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- Used to understand the impact of risk and uncertainty in project management
- The model itself contains uncertainty due to future estimates
- Can tell you how likely the possible outcomes are
- A random value is selected for each of the tasks, based on the range of estimates.
- The result of the model is recorded and the process is repeated thousands of times using different random values.

Monte Carlo Simulation Example

Total time estimate is 14 months based on three estimates only in table below:

Task	Time Estimate			
Job 1	5 Months			
Job 2	4 Months			
Job 3	5 Months			
Total	14 Months			

Based on experience, expertise or historical information estimate minimum and maximum expected

Task	Minimum	Most Likely	Maximum	
Job 1	4 Months	5 Months	7 Months	
Job 2	3 Months	4 Months	6 Months	
Job 3	4 Months	5 Months	6 Months	
Total	11 Months	14 Months	19 Months	

Results of Monte Carlo Simulation Example

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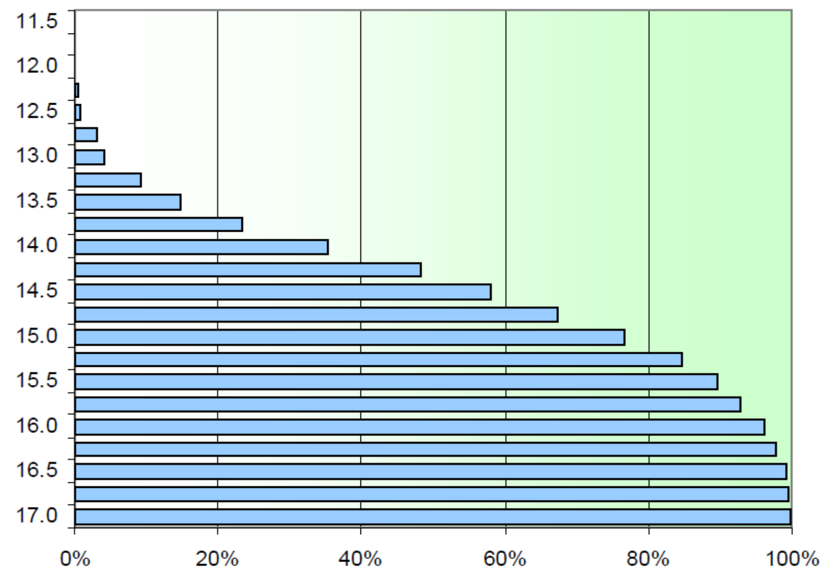
Simulation run 500 times

Shows the likelihood of a particular result

Initial estimate was 14 months results indicate 18 months

Time	Number of Times (Out of 500)	Percent of Total (Rounded)
12 Months	1	0%
13 Months	31	6%
14 Months	171	34%
15 Months	394	79%
16 Months	482	96%
17 Months	499	100%
18 Months	500	100%



Some Possible Approaches to measuring Value of the Underlying Asset

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- Stakeholder Perspective- aggregated through Multi Criteria Decision Analysis
- Econometric – based on value of the contract +throughlife costs
- Mitigation of Threat – value the threat (probability X consequence)
- Meeting the requirement – value the requirement
- Utility function e.g. some defence equivalent of QALYs

This remains the most challenging element of using ROA

Quantitative Assessment

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- **Testing increasing volatility -the higher is volatility the greater the ROA measure of benefit (though with Boundary Value approach increased uncertainty surrounding whole life cost of the capability means higher ROA value- ROA value of research inversely related to the precision of CAAS's forecasting estimates.)**
- **Varying the length of time to maturity reduces the present value of the benefits and also (by a much smaller amount) the present value of the costs. Impact on the ROA measure more complex: same impact on the NPV of benefits and costs but offsetting gain through having the option to commit or not to commit.**
- **Changing the Risk Free Rate from 3.5% to 5% in real terms halves the NPV measure whilst reducing the Real Options value by only two sevenths by altering the alternative investment in a risk free return.**
- **ROA measure is substantially larger than NPV measure of value because it depends upon the level of volatility, the greater the volatility the bigger the ROA value.**

Software Assessment

Three alternative software packages were identified and analysed.

- Super Lattice Solver (SLS)- flexible and easy to use but too restrictive for valuing defence research programs
- Crystal Ball (CB) - not explicitly intended for ROA and any model would have to be created within the program to do this
- Foresight Real Options Model (FROM)- specifically deals with ROA applied to multi-phase research projects of the kind outlined in the statement of requirements and could be adapted for defence

Recommendation was made to adapt the FROM tool. This recommendation was taken up and Polaris made the relevant updates, including adding a Monte-Carlo module to estimate R&D costs and timings.

Conclusions

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- **The Real Options measure higher than the NPV calculation due to scope to avoid commitment to later stages of R&D & acquisition of the capability.**
- **It presumes R&D gives you the right, but not the commitment, to acquire future defence capabilities. (For commercial R&D this does apply; less clear with defence R&D.)**
- **Need for an objective measure of defence output (paradoxical results in the quantitative assessment from use of the "Boundary Value" approach.**

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