Real Options "In" a Micro Air Vehicle System

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What are Real Options?

- Real Options:
  - "Right, but not obligation" to act
  - Projects and systems vs. contracts
- Real Options "On" Projects
  - Flexibility that is emergent or coincidental in the development and operation of a system*
  - Example: whether or not to open a mine
- Real Options "In" Projects
  - Flexibility that has to be anticipated, designed and engineered into a system*
  - Example: Multi-story parking garage (Zhou &Tseng 2003)

*Kalligeros, 2002

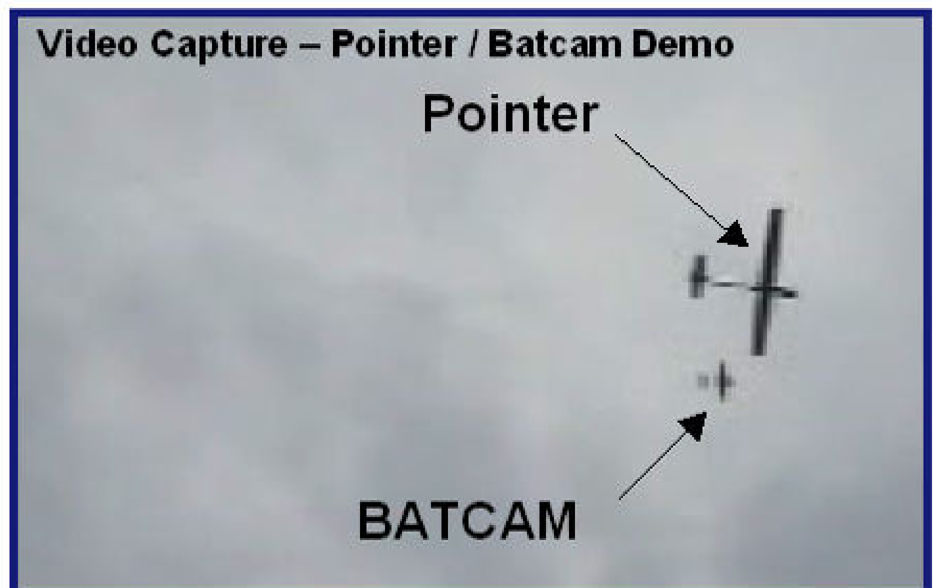
Real Options Analysis Methods

- Net Present Value with Uncertainty
  - Metric for comparing projects with uncertainty
- Two-Stage Decision Analysis
  - Technique for evaluating alternatives in uncertain situations
- Lattice Analysis
  - Analysis of time evolution of uncertainty

Choose method based on application and assumptions!

Applying Real Options Analysis

- Micro Air Vehicles (MAVs)
- Small Unmanned Aerial Vehicles (SUAVs)
- Challenges: Demand and Market Penetration



Case Study: Micro Air Vehicle

Desired Flexibility:

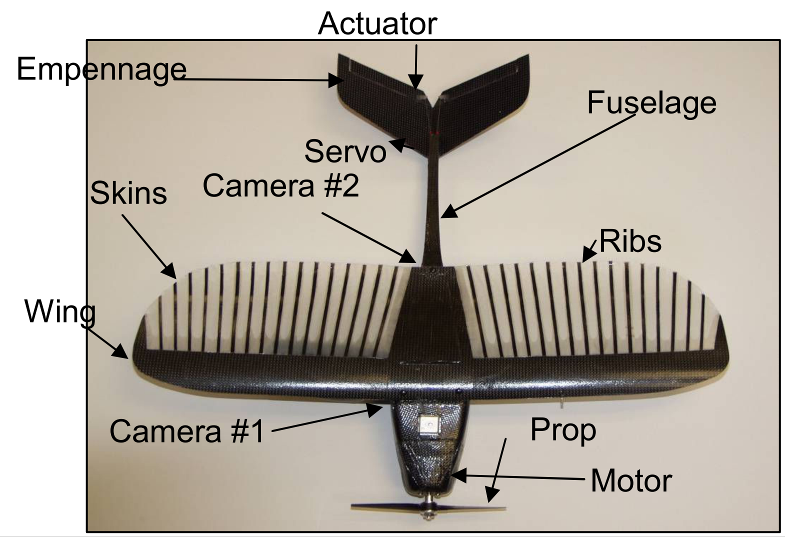
- **Endurance**

Flexible Options:

- Battery
- **Wing & Empennage Design**

Uncertainty:

- **Demand**
- Predicted Ratio of Micro Air Vehicles and Small Unmanned Air Vehicles
- Market Penetration



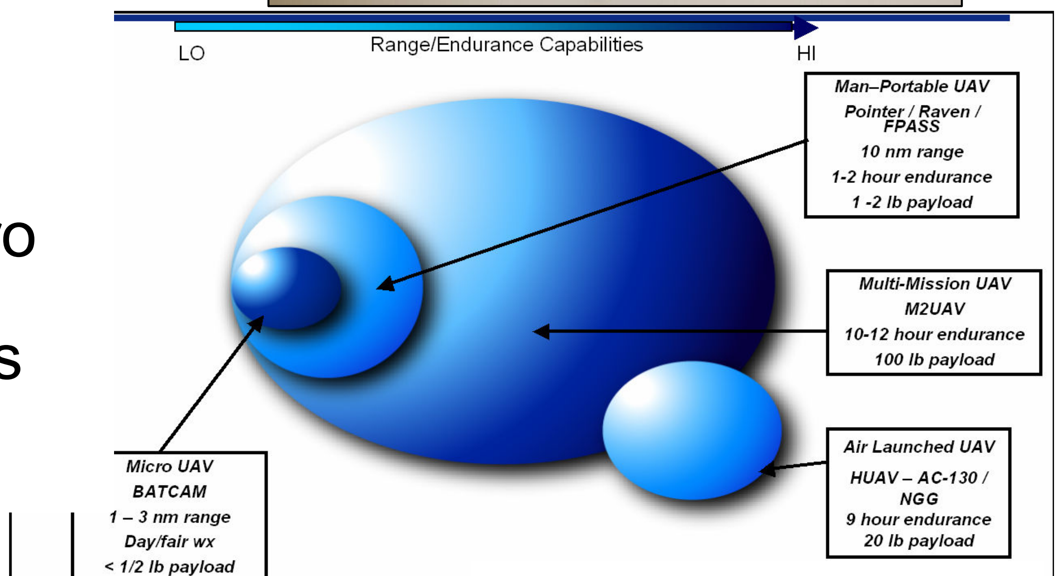


Figure Reference: Senseney, 2004

Designs for Real Options Analysis

- Fixed Design

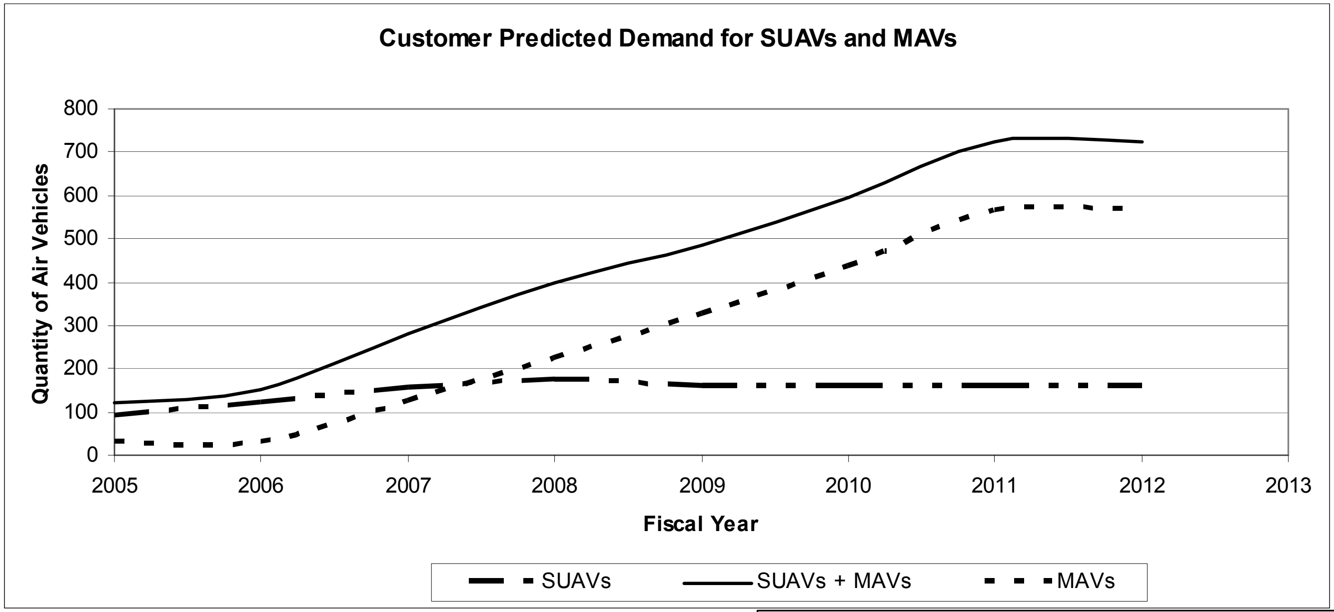
Target Market	MAVs (2007-2012)
Fixed Cost	$1.5M
Marginal Cost	$2000 per MAV
Price	$7000 per MAV
Discount Rate	12%

Consider a UAV manufacturer that will produce a fixed design capable of only performing the MAV mission or a flexible design that can do both SUAV and MAV missions.

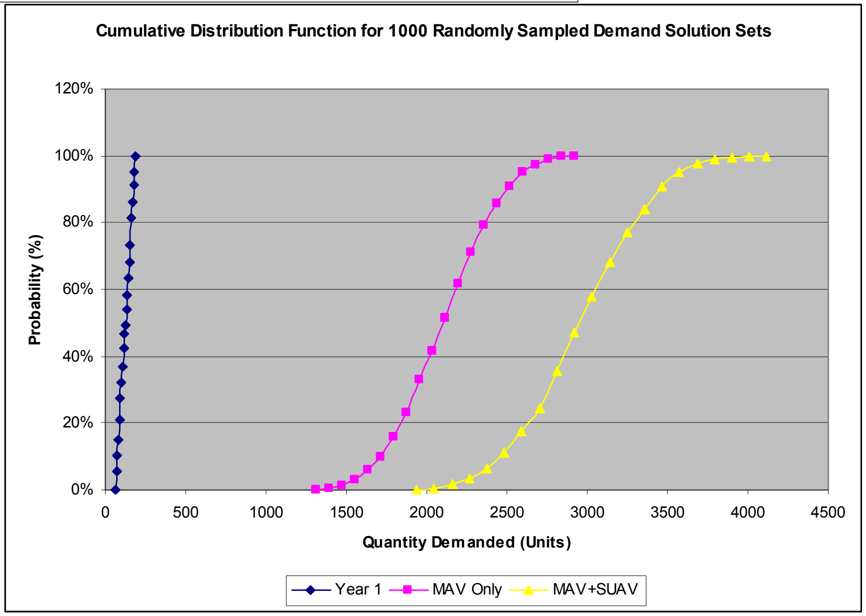
- Flexible Design

Target Market	MAVs (2007) MAVs + SUAVs (2008-2012)
Fixed Cost	$1.75M
Marginal Cost	$2500 per MAV
Price	$7000 per MAV without flexible option $10000 per MAV with flexible option
Discount Rate	12%

Uncertainty of Demand



SYSTEMS	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12
Micro Percentage	0.25	0.20	0.44	0.57	0.67	0.73	0.78	0.78
Small Percentage	0.75	0.80	0.56	0.43	0.33	0.27	0.22	0.22



ROA Method 1: Net Present Value

	2006	2007	2008	2009	2010
Period	0	1	2	3	4
Quantity Demanded		281	398	486	596
Capacity (Systems)		10,000	10,000	10,000	10,000
Market Penetration		0.445	0.565	0.669	0.730
Production		125	225	325	435
Revenue ($)		875,000	1,575,000	2,275,000	3,045,000
Costs ($)	1,500,000	250,000	450,000	650,000	870,000
Net Cash Flow ($)	-1,500,000	625,000	1,125,000	1,625,000	2,175,000
(1+r)^N	1	1.12	1.2544	1.404928	1.57351936
PV ($)	-1,500,000.00	558,035.71	896,843.11	1,156,642.90	1,382,251.82
NPV ($)	**5,527,987.33**				

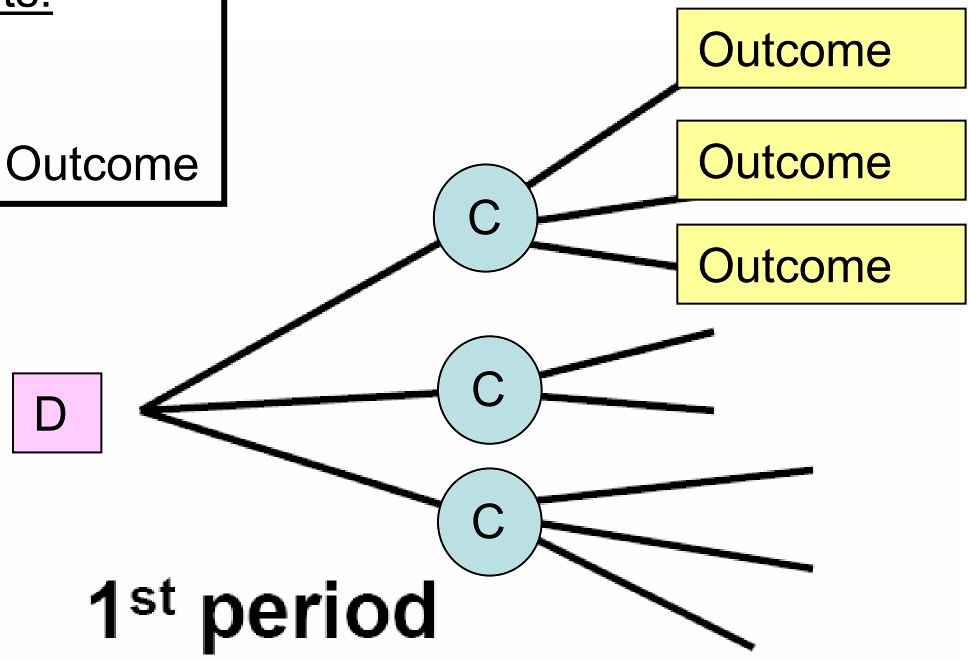
NPV = *Discounted* (Present Value) Total Benefits - *Discounted* Total Costs

	Predicted Demand	Demand w/ Uncertainty
Fixed	$5.53M	$6.46M
Flexible	$12.75M	$14.80M

ROA Method 2: Two-Stage Decision Analysis

Two Data Elements:

1. Probability
2. Value of Each Outcome



Objective: Identify the solution with the maximum Expected Value

ROA Method 2: Two-Stage Decision Analysis

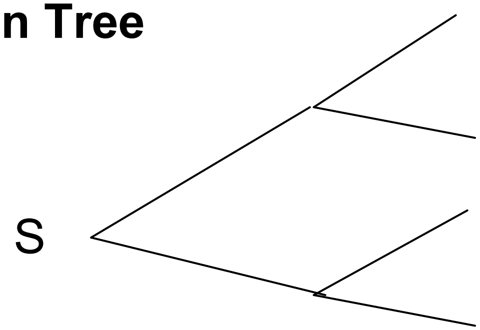
		Demand	Chance Event	Probability (%)
Year 1	MAVs Only	N > 141	High	41%
		104 < N < 141	Forecasted	27%
		N < 104	Low	32%
Year 2 – Year 6	MAVs Only	N > 2252	High	38%
		1955 < N < 2552	Forecasted	39%
		N < 1955	Low	23%
	MAVs + SUAVs	N > 3142	High	32%
		2765 < N < 3142	Forecasted	44%
		N < 2765	Low	24%

	Decision Analysis
Fixed	$5.90 M
Flexible	$13.07 M

ROA Method 3: Lattice Analysis

Implicit Assumption of Path Independence!

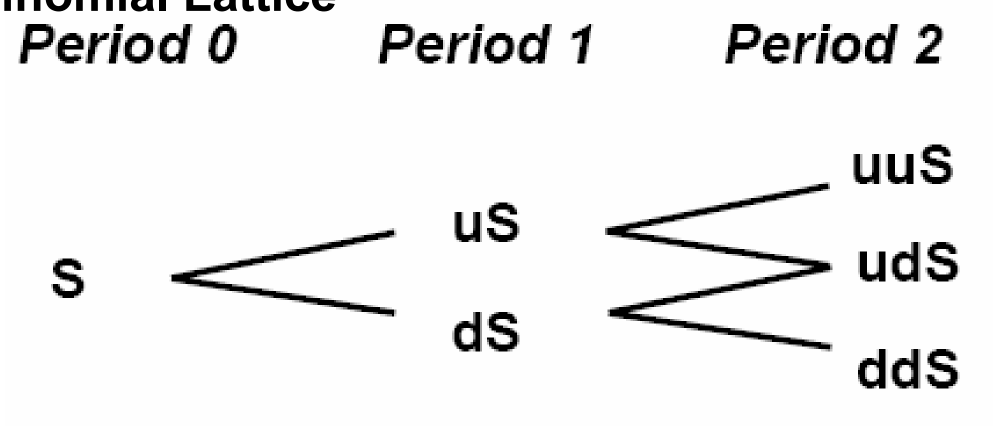
Decision Tree



The Lattice Method collapses the Decision Tree by assuming the states coincide: ie. the path

“up then down” = “down then up”

Binomial Lattice



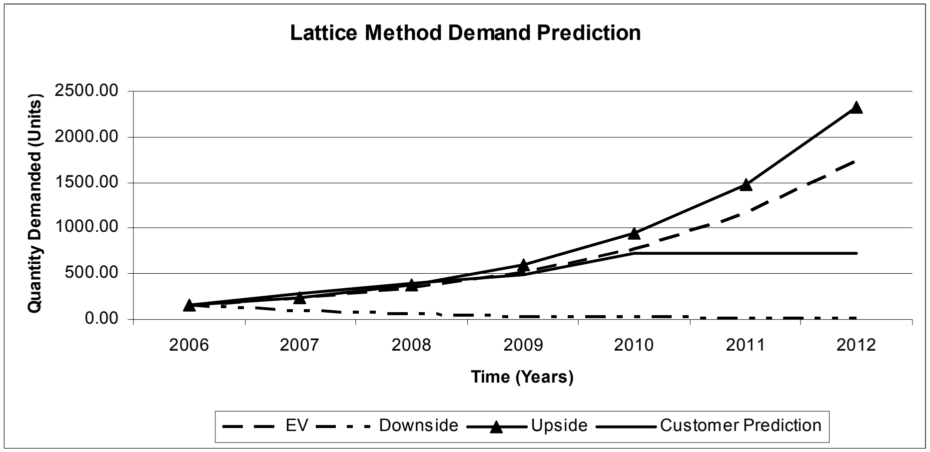
$$p = 0.5 + 0.5\left(\frac{v}{\sigma}\right)(\Delta t)^{0.5}$$

$$u = e^{\sigma \cdot \Delta t^{0.5}}$$

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

ROA Method 3: Lattice Analysis

Parameter		Value
Initial Demand	D_o	153 units
Time Step	Δt	0.5 years
Expected Growth	ν	39%
Volatility	σ	±32%
Probability Up	p	93%
Upside Factor	u	1.25
Downside Factor	d	0.80



	Lattice Analysis
Fixed	$13.89 M
Flexible	$28.94 M

Because MAVs and SUAVs are relatively new technology, the Expected Growth and Volatility parameters are difficult to estimate. In this case study, the assumptions for the Lattice Method do not accurately model the expected demand—leading to flawed results!

Summary Results for Analysis Methods

	NPV w/o Uncertainty	NPV w/ Uncertainty	Decision Analysis	Lattice Analysis
Fixed Design	$5.53 M	$6.46 M	$5.90 M	$13.89 M
Flexible Design	$12.75 M	$14.80M	$13.07 M	$28.94 M

Accounting for uncertainty is ALWAYS better, and in this case shows the value of the flexible design.

So what?

- **Considering uncertainty = recognize the greater upside potential value of the design**
- **Valuing the option provides important, decision making information about whether designers should *act* on flexibility**
- **Value of assessing the whole project, rather than individual time instantiations**

However

- **Beware of Assumptions--Lack of knowledge of the volatility and projected growth rate can cause model inaccuracies (for example: Lattice Analysis)**

Summary: Road Ahead

- Additional Case Study Applications
- Sensitivities to Assumptions
- Sensitivities to Uncertainties
- Variation of Multiple Uncertainties
- Integration of Physical Model and Multi-Design Optimization simulations into the ROA tool

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