Real Options and Flexibility Approach to Systems Engineering Enterprise Wide Satellite Communications

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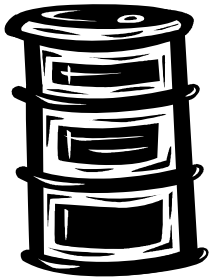
Purpose

- This briefing discusses the possible relationship of Real Options and Flexibility to engineering an enterprise wide satellite system.
- The briefing also discusses possible techniques for identifying Real Options and a method to invest in a basket of options

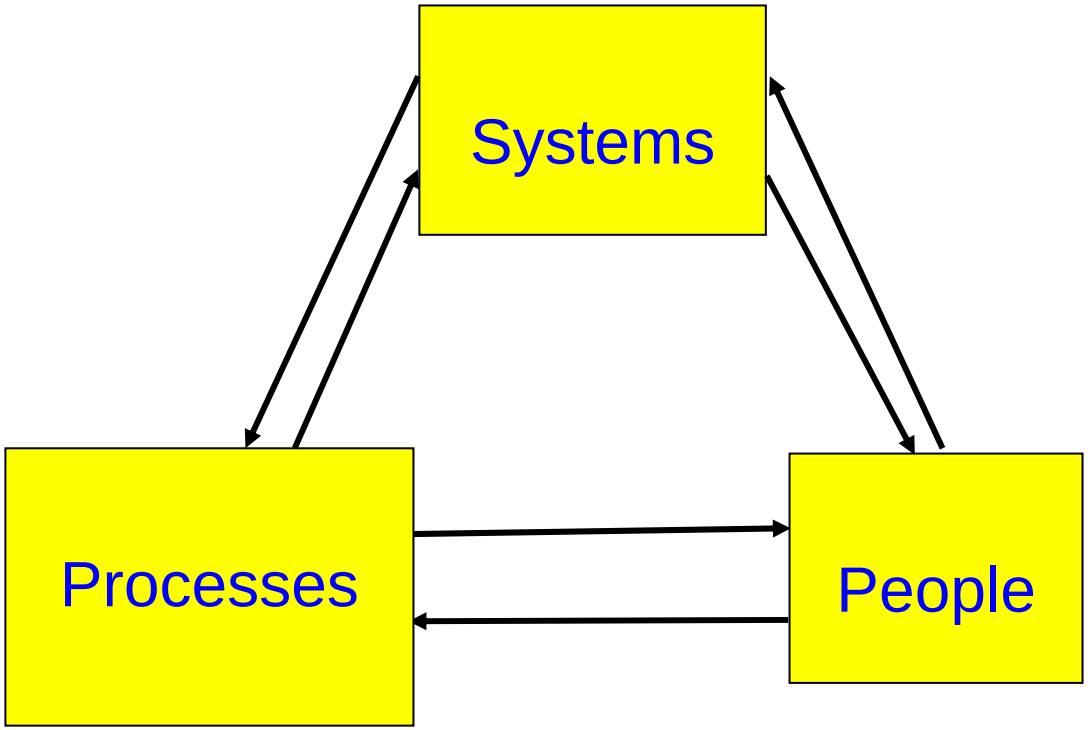
What Are Real Options?



- Options are a ***right***, but not a ***responsibility***, to take some ***action*** in the future, if you decide this action is to your advantage
- A financial option could include purchasing a call on 100 barrels of oil at $2/option with a strike price of $65/barrel within 3 months
  - Investor has paid $200 for the right, but not the obligation, to buy 100 barrels of oil in that timeframe.
  - Would only exercise the option if the price of oil climbs above $65/barrel
  - Could sell the option to someone else, or take delivery of the oil
  - If oil stays below $65/barrel, then the option expires
- Options evolved to include buy/sell ***On*** real estate
- Real Options as discussed here are options built ***Into*** a system that can be ***exercised*** at a future date ***if*** the right conditions present themselves
  - Real Options can often have a very long lifetime, whereas financial options often have a short lifetime
  - A challenge for many people is that Real Options may never be exercised

Real Options Impact Areas

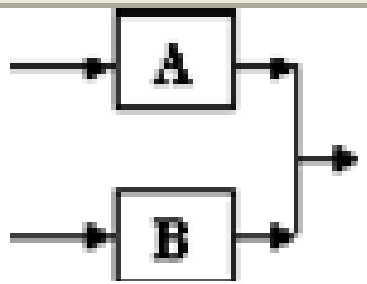
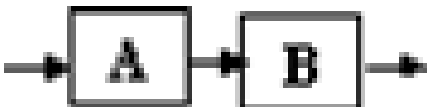
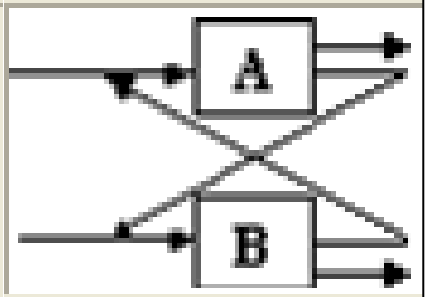
- Real Options can be used separately or together in each of the below areas
- Extra fuel on a satellite can provide for future orbital maneuvers that enable service to areas with increased demand



Design Structure Matrix (DSM)

- **DSMs identify dependencies and aid in understanding complexity**
- **Start in a column and ask the question, "How does a change in the component from this column impact the component in the row?"**

Three Configurations that Characterize a System

Relationship	**Parallel**	**Sequential**	**Coupled**
Graph Representation			
DSM Representation			

	A	B
A		
B		

	A	B
A		
B	X	

	A	B
A		X
B	X	

DSM Component Relationships (DSM Web Site 2006)

Medium Detail, Terminal-Satellite-Terminal DSM

	Baseband -- User 1	Input Port -- User 1	Terminal -- User 1	Encoder -- Terminal 1	Interleaver -- Terminal 1	Modulator -- Terminal 1	Uplink Channel -- User 1	Antenna -- Terminal 1	Satellite Receive Antenna	Satellite Demodulator	Satellite Communications Payloa	Satellite Modulator	Satellite Transmit Antenna	Antenna -- User 2	Downlink Channel -- User 2	Demodulator -- Terminal 2	De-Interleaver -- Terminal 2	Decoder -- Terminal 2	Terminal -- User 2	Output Port -- User 2	Baseband -- User 2
Baseband -- User 1		L	H																		H
Input Port -- User 1			H																		
Terminal -- User 1	H	H					M				H				L						
Encoder -- Terminal 1										M								H			
Interleaver -- Terminal 1																	H				
Modulator -- Terminal 1				M						H						M					
Uplink Channel -- User 1			H	H	L						H				M						
Antenna -- Terminal 1									M				L	M							
Satellite Receive Antenna								M													
Satellite Demodulator				L		M															
Satellite Communications Payload			M				L								L						
Satellite Modulator																H					
Satellite Transmit Antenna									L			L									
Antenna -- Terminal 2								L	L				H								
Downlink Channel -- User 2			M				M				H						L	M			
Demodulator -- Terminal 2				L								H									
De-Interleaver -- Terminal 2					H																
Decoder -- Terminal 2				H								L									
Terminal -- User 2			H				L				H				M					H	H
Output Port -- User 2																			H		
Baseband -- User 2	H		M																H	L	

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Identifying Real Options in Satellites and Constellations

- The proposed method works in concert with the concepts of using DSMs to identify Real Options opportunities
- Similar to Risk Management process, only Impact of Risk is substituted with Positive Impact of Exercising Real Option
  - Upper right corner is now green as impacts are positive
- Probabilities of a Real Option linked to technology development are assigned by adding a “0” to the Technology Readiness Level (TRL)
- Systems Engineers should use TRLs and DSMs to identify those areas most likely to change (hot spots) and those areas not likely to change (cold spots)
  - Some cold spots require overdesign to support hot spot changes

Real Options Opportunity Chart

Probability of Technology Improvement	Positive Impact of inserting a new technology and Exercising a Real Option				
	Negligible	Minor	Moderate	Serious	Critical
Very Likely (VL) 81-100%	Low	Medium	High	High	High
Somewhat Likely (SL) 61-80%	Low	Medium	Medium	High	High
About Even (AE) 41-60%	Low	Low	Medium	Medium	High
Somewhat Unlikely (SU) 21-40%	Low	Low	Medium	Medium	Medium
Very Unlikely (VU) 0-20%	Low	Low	Low	Low	Medium

Opportunity Rating: Low (L) | Medium (M) | High (H)

Technology Maturity
(Technology Readiness Levels)

- System Test, Flight and Operations
- System/Subsystem Development
- Technology Demonstration
- Technology Development
- Research to Prove Feasibility
- Basic Technology Research

9 - Actual System "Flight Proven" Through Successful Mission Operations

8 - Actual System Completed and "Flight Qualified" Through Test and Demonstration

7 - System Prototype Demonstration in an Operational Environment

6 - System/Subsystem Model or Prototype Demonstration in a Relevant Environment

5 - Component and/or Breadboard Validation in Relevant Environment

4 - Component and/or Breadboard Validation in Laboratory Environment

3 - Analytical and Experimental Critical Function and/or Characteristic Proof-of-Concept

2 - Technology Concept and/or Application Formulated

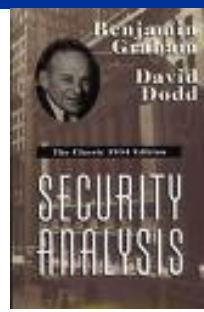
1 - Basic Principles Observed and Reported

Target Level of Technology Forecast

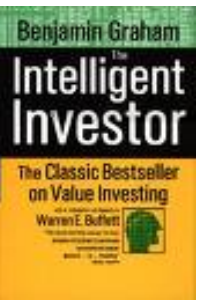
Possible Real Options for a Satellite Constellation

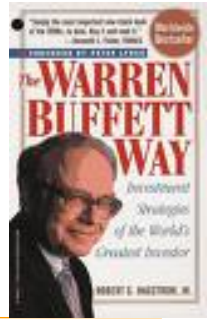
- Reliable, relatively inexpensive launch capability could enable ready replenishment of constellation with upgraded capabilities
- Increased memory and processing power enable software upgrades to a satellite and constellation
- Multi-band terminals have the options to use satellites providing, for instance, high throughput but in different frequency bands
  - This provides a given terminal operator the option to use multiple bands to support their mission
  - Inserting too many options into a terminal can cause the terminal to do nothing well
- Use of commercial SATCOM capabilities can be an option to exercise multiple times as needed
- Can use extra SWaP on commercial satellites to include experimental packages as a way to mature technology before basing a constellation on that technology

Value Investing



- Value Investing was developed by Ben Graham as a reliable method to purchase stocks and bonds with a positive return on investment
  - Detailed in *Security Analysis*, developed after the Great Depression
- Value Investing relies on purchasing a stock or a bond below its Intrinsic Value
  - Intrinsic value for a stock depends on earnings, debt, sales growth, and expenses – difficult to predict
  - Intrinsic value is important not for precision but for a way to compare potential investments
- Such a purchase provides the buyer with a Margin of Safety
  - For bond holders, this means company income can easily cover the interest payments and service debt
  - Diversification also key to providing a Margin of Safety
- The are well discussed in *The Intelligent Investor* and *The Warren Buffett Way*





Value Investing in Real Options

- Author believes Intrinsic Value, Margin of Safety, and Diversification can all be applied to purchasing Real Options
- Options with higher TRLs would provide a Margin of Safety
- Options should be compared by the area of the Real Options Opportunity chart they fall in
- Systems Engineers would price out all options in the green area
- Options in the green area would be ranked from least expensive to most expensive
- Program Managers would then purchase a basket of options according to the funding available
- For some diversification, Program Managers should purchase at least 5 options

Value of a Real Option

- This area requires more research
- Many researchers rely on calculations of items such as Expected Net Present Value
  - This author feels the such a calculation can be very precise, but may lack accuracy
- Author believes value of an option relates to the combination of operational value added and cost savings
- In many instances, it might not be possible to monetize operational value
- This is analogous to Graham and Buffett determining an Intrinsic Value and a Margin of Safety
  - While not precise, it offers a good chance to compare investments

Summary

- Real Options can be used not only as a Traditional Systems Engineering tool but also as an Enterprise Systems Engineering tool
- DSMs are a valuable tool to help understand interdependencies
- A key challenge for applying Real Options to programs will be developing a method to value the options so Program Managers can justify an investment
- The combination of DSMs, TRLs, Real Options Opportunity Chart, and Value Investing provide a framework for identifying and investing in Real Options for a system or an enterprise
- We hope to do more research on applying Real Options to satellites and constellations

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