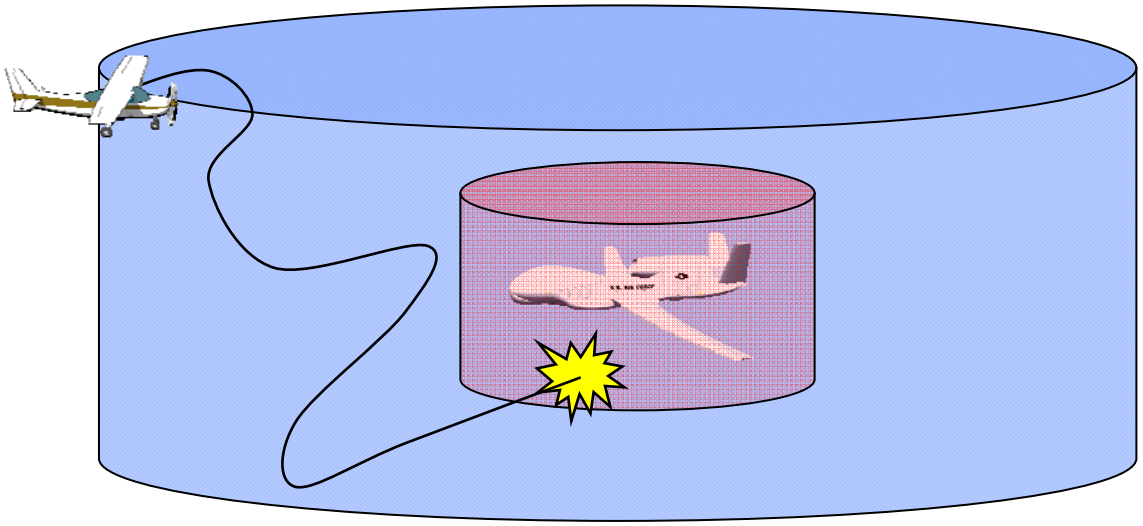
ESD.71 Engineering Systems for Analysis



Luke Cropsey

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Real Options for Integrating Unmanned Aircraft into the National Airspace System

Graphic from MIT/LL briefing provided to 303 AESW/XR, May 2007.

Background

- Growing need for Department of Defense to fly unmanned aircraft for training and operations within the national airspace system
- Unmanned aircraft need to be further developed to meet regulatory requirements for integrated flight
- Significant uncertainty exists in both the cost and performance needed to achieve integrated operations
- This analysis seeks to address the impact of this uncertainty on the system design

Options Development

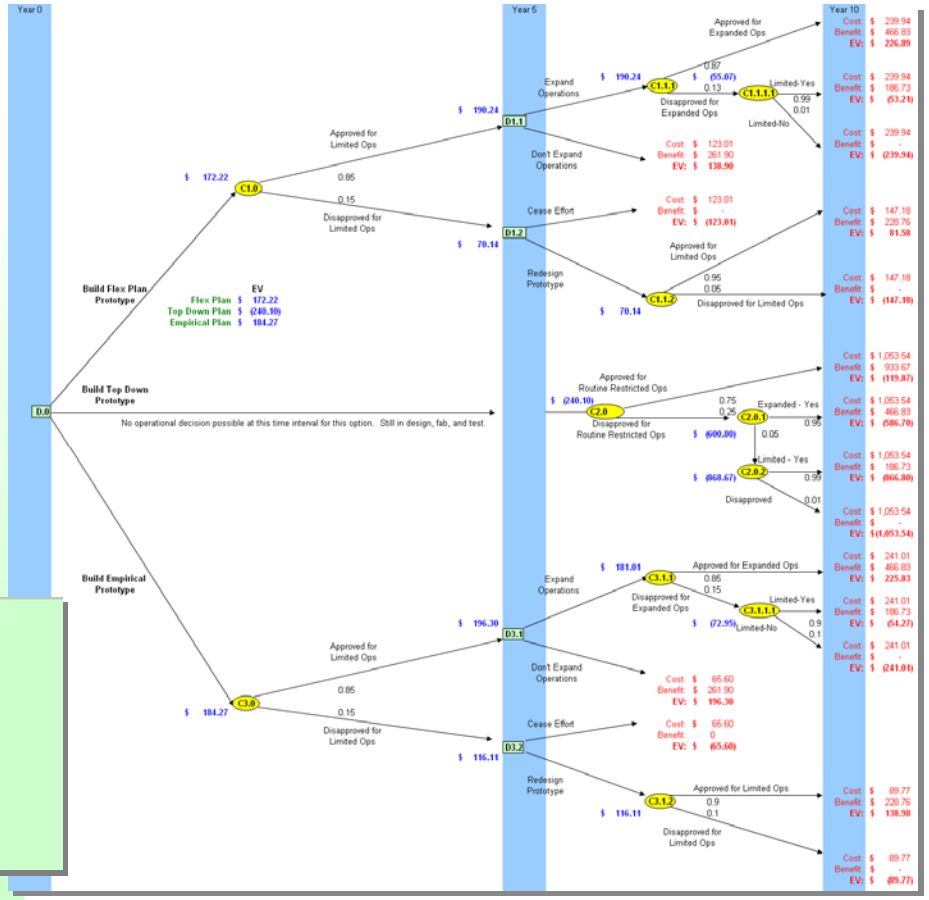
- Option 1: Pursue a top-down engineering design with significant upfront effort
  - Intensive requirements definition phase
  - Attempt to proceed directly from no access to significant access
- Option 2: Employ an empirical approach by fielding as rapidly as possible
  - Puts out the current state-of-the-engineering as quickly as possible
  - Iterates on the design as quickly as possible, feeding results from previous interation into the next
- Option 3: Flexible framework that seeks to field system quickly, but with foresight towards later requirements
  - Seeks to integrate a design for immediate employment with an approach for future extensibility to minimize “switching” costs

Uncertainty Development

- Probability of FAA approval for unmanned aircraft operations
  - Treated as an exogenous system variable
  - Is path dependent: the way you get there matters
  - Will use decision tree analysis to evaluate impact
- Uncertainty in potential revenue base
  - Manned aircraft operations serve as the mission unmanned aircraft will “replace” with corresponding revenue swap
  - Cost of manned operations is not constant, and may vary dramatically over the develop phase of the unmanned aircraft capability

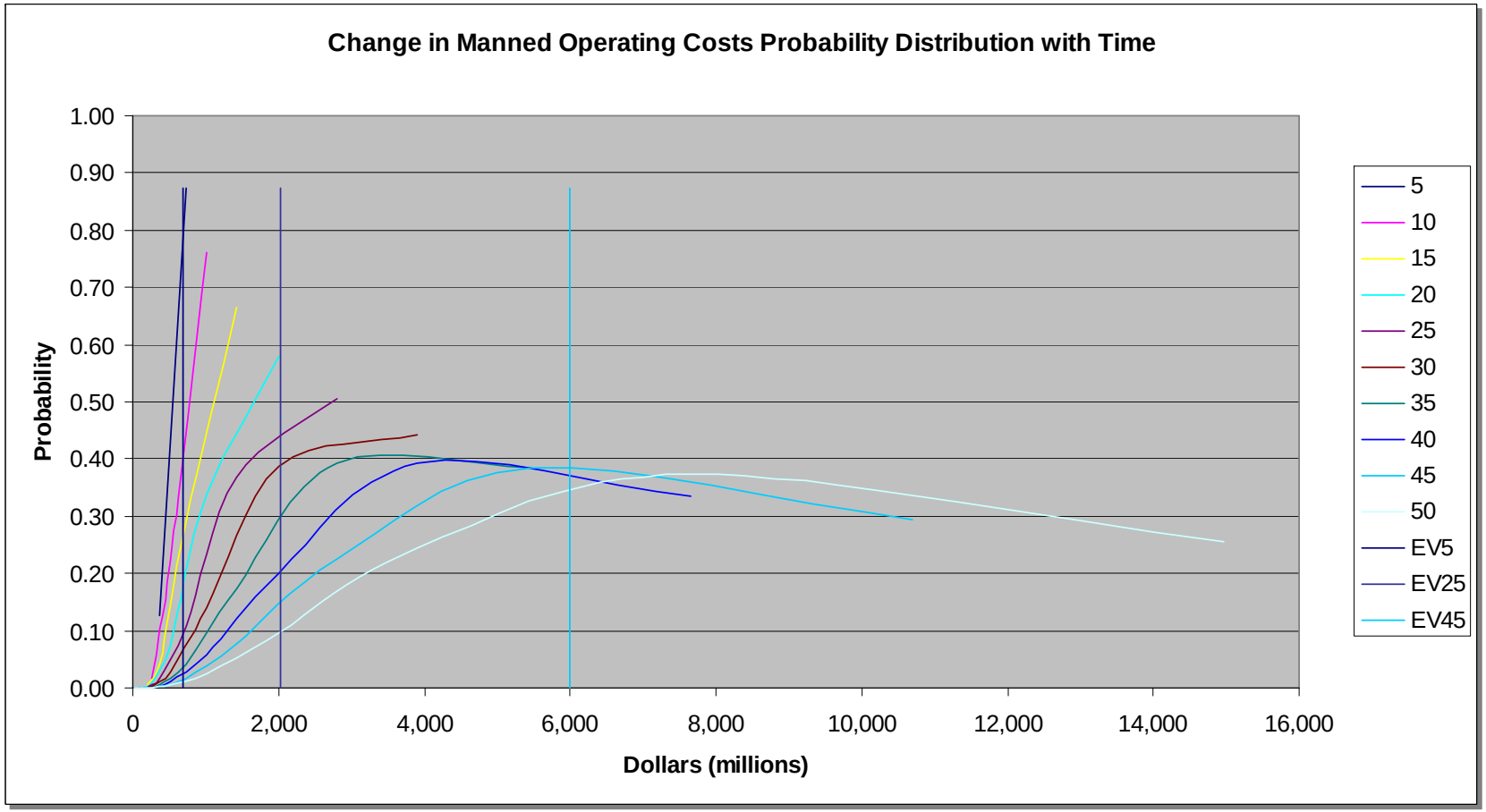
Decision Tree Analysis

- Each option evaluated over two decision periods
- Decision period equal to 5 years cycle time
- UAS NRE costs only



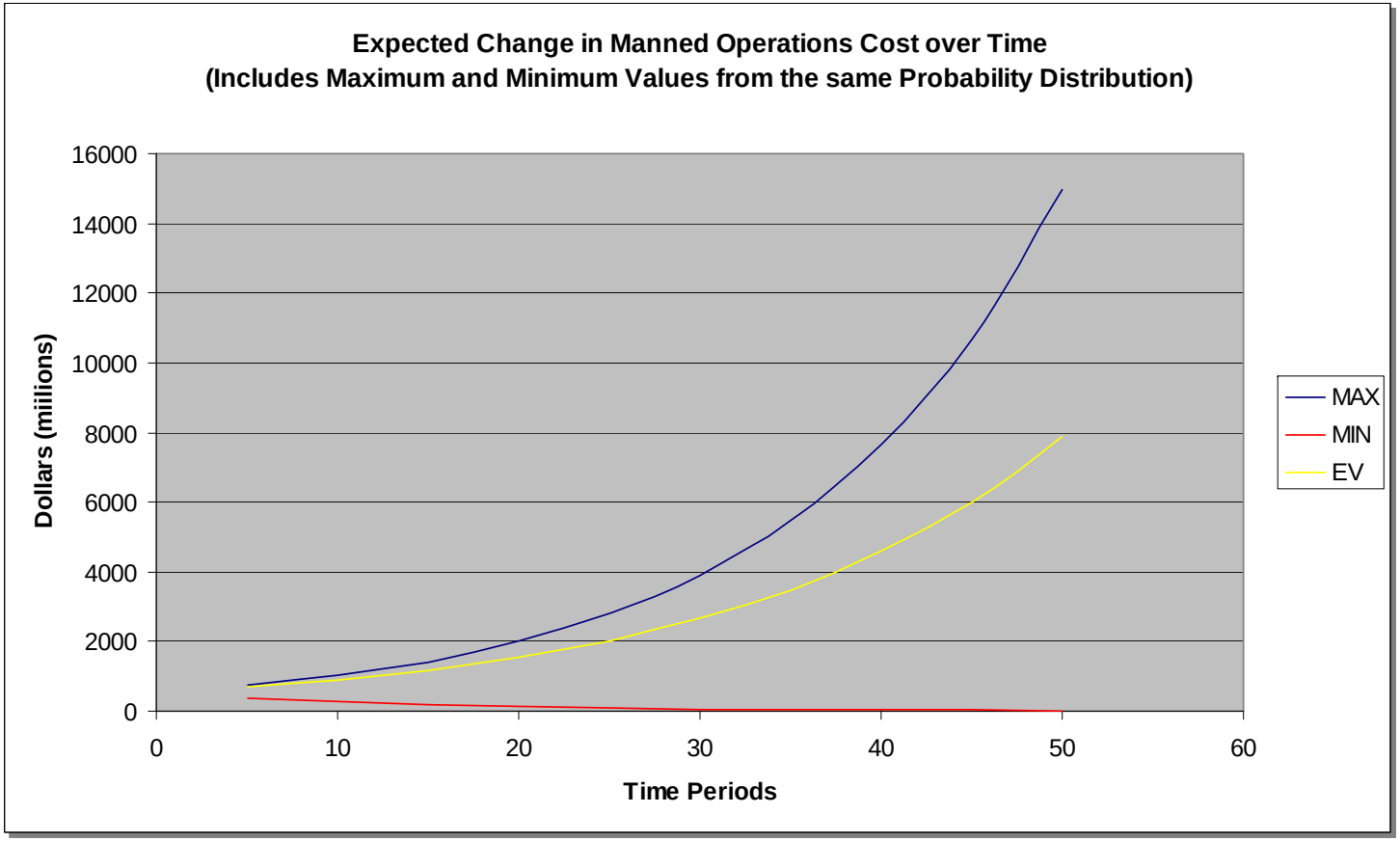
Expected NPV		
Flex Plan	$	172.22
Top Down Plan	$	(240.10)
Empirical Plan	$	184.27

Uncertainty Development



Probability Distribution of Manned Operating Costs over Time

Uncertainty Development



Expected Value over Time

NPV with Uncertainty

	0	5	10	15	20	25	30	35	40	45	50
Captial Costs:	150.00	200.00	400.00	600.00	600.00						
Recurring Costs:		500	500	500	500	500	500	500	500	500	500
Approval Status:		LO App	EO App	RR App	ER App	FI App					
% Mission Capable:	0.00	0.10	0.25	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00
Net Revenue:	150	291	1,339	6,402	18,456	42,318	76,031	119,190	186,689	292,254	457,353
		533	15	1,967	6,895	17,006	30,789	48,434	76,031	119,190	186,689
			526	154	2,169	6,657	12,292	19,506	30,789	48,434	76,031
				587	236	2,426	4,730	7,679	12,292	19,506	30,789
					554	696	1,638	2,844	4,730	7,679	12,292
						11	374	867	1,638	2,844	4,730
							143	59	374	867	1,638
								271	143	59	374
									354	271	143
										407	354
											440

	0	5	10	15	20	25	30	35	40	45	50
Probability	150	218	753	2,701	5,839	10,042	13,532	15,910	18,690	21,944	25,755
Weighted		133	6	830	2,909	6,726	10,960	15,085	20,298	26,848	35,044
Net Revenue			33	22	457	1,755	3,646	6,076	9,590	14,547	21,408
				9	11	213	624	1,329	2,552	4,557	7,706
					2	10	54	164	409	897	1,795
						0	2	10	38	111	276
							0	0	1	8	27
								0	0	0	1
									0	0	0
										0	0
											0

	0	5	10	15	20	25	30	35	40	45	50
E [Revenues]	150	351	726	3,543	9,215	18,747	28,817	38,574	51,578	68,910	92,011
PV(E[Revenues])	150	251	369	1,284	2,381	3,454	3,786	3,613	3,444	3,281	3,124

NPV over 25 years	**7,088**	Current Year $$s over 25 years	**31,729**
NPV over 50 years	24,336	Current Year $$s over 50 years	311,620

NPV with Uncertainty and Flexibility

	0	5	10	15	20	25	30	35	40	45	50
PV(Net Revenue)	180,943	228,300	287,872	360,514	445,212	536,260	620,554	683,995	709,389	656,447	457,353
WITH OPTIONS		90,179	114,756	144,818	179,962	217,738	252,412	278,574	289,198	267,811	186,689
(check next year)			43,979	56,633	71,517	87,513	101,900	112,822	117,406	108,921	76,031
				20,580	27,180	34,271	40,364	45,055	47,171	43,959	30,789
					9,057	12,505	15,206	17,349	18,455	17,401	12,292
						3,621	4,922	6,022	6,715	6,542	4,730
							776	1,401	1,916	2,103	1,638
								271	4	288	374
									354	271	143
										407	354
											440

Shut Down?	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
WITH OPTIONS		**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
(check next year)			**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
				NO	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
					NO	**NO**	**NO**	**NO**	**NO**	**NO**
						NO	**NO**	**NO**	**NO**	**NO**
							NO	**NO**	**NO**	**NO**
								YES	NO	NO
									YES	YES
										YES

Value of option =	180,943
	- 24,336
	156,608

Conclusions – UAS Specific Findings

- The potential value of addressing uncertainty in key design factors is substantial
- The AF should approach the problem in a parametric sense--which set of options provides the best investment over what range of values
- The AF should give specific thought to the utility gained from less than total access and quantify the operational utility of additional flexibility

Conclusions – UAS Specific Findings

- A sensitivity analysis should be performed to focus on a subset of high impact variables to investigate
  - The high complexity of the effort suggests the analysis would benefit from applying Wang's option identification process to narrow the trade space
  - Analysis on R&D costs and utility of partial access should be done to determine how well they need to be characterized for a reasonable answer
- Discussions with the FAA on how this approach could impact flight authorization should be accomplished as soon as possible

Conclusions – General Observations

- Different types of uncertainties require different approaches and tools
- Even a small amount of information with reasonable assumptions about the uncertainty can provide significant insights into design values
- A synthesis of the decision tree and the binomial lattice approaches into a single analysis tool would provide significant benefit for this kind of option analysis