

Managing Operational Uncertainty with Real Options

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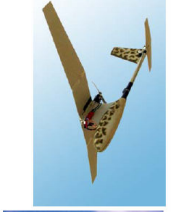
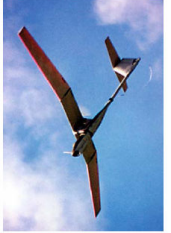
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Mini Air Vehicles



2.4.1 Mini UA

Manufacturer	Dragon Eye	FPASS	Pointer	Raven	BUSTER	BATCAM
User Service	Aero Vironment Marine Corps	Lockheed Martin Air Force	AeroVironment SOCOM, AF	AeroVironment Army, SOCOM, AF	Mission Technologies, Inc. Night Vision Labs, US Army	ARA SOCOM
Weight	4.5 lb	7 lb	8.3 lb	4 lb	10 lb	0.84 lb
Length	2.4 ft	2.7 ft	6 ft	3.4 ft	41 inches	24 in
Wingspan	3.8 ft	4.3 ft	9 ft	4.3 ft	49.5 inches	21 in
Payload Capacity	1 lb	1 lb	1 lb	2 lb	3.0 lb	0.09 lb
Engine Type	Battery	Battery	Battery	Battery	Gasoline/JP-5& JP-8	Battery
Ceiling	1,000 ft	1,000 ft	1,000 ft	1,000 ft	10,000 ft	1,000 ft
Radius	2.5 nm 45-60 min	6 nm 1 hr	6 nm 2 hr	6 nm 1.5 hr	10 km 4 + hr	1.6 nm 18 min
Number Planned	467 systems*	21 systems	50 systems	300+ systems	9 systems	23 systems
Number of UA/System	3	6	2	3	4	2

* Does not include 4 Dragon Eye, 6 Swift, and 15 Evolution systems (58 UA total) for SOCOM.

Operational Uncertainty

- **What are operational uncertainties?**
 - factors that may change during the operational life of the system, such that they have a potential impact on the requirements, capabilities or performance of the system.
 - directly concern the end user of a system.
- **Why manage operational uncertainties?**
 - minimize risk and take advantage of opportunities.
- **How to manage operational uncertainties?**
 - operational option as a real option for managing operational uncertainty by the end user, through the opportunity, but not the obligation, to execute the option during the operational life of the system.

Approach

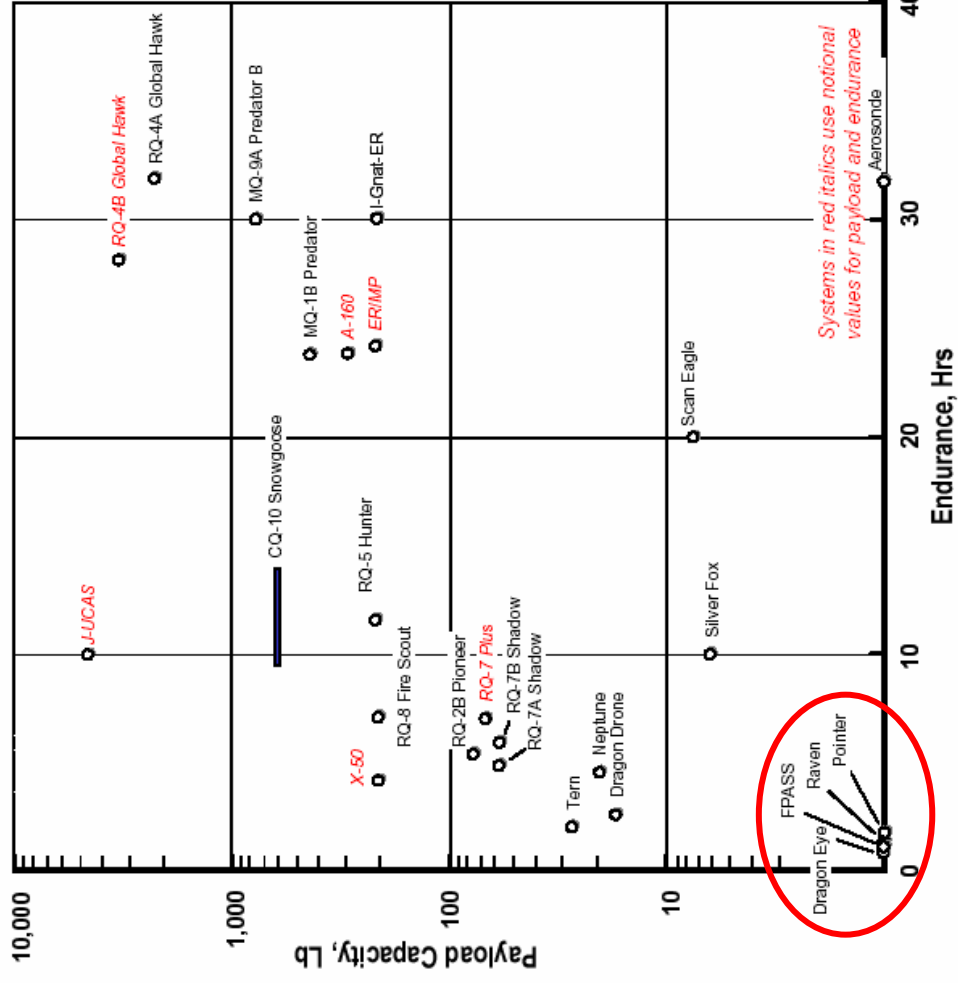
Incorporate operational options in design:

- Identify performance/value metrics important to end user
- Identify major operational uncertainties that may affect the metrics; model these uncertainties
- Identify designs (some with operational options)
- Value the alternative designs (and options)

Micro Air Vehicles

- Typically weigh up to few pounds
- Up to 1200 ft altitude
- Flight durations from few minutes to 2 hours

- Performance metric: Endurance
- Value metric: Profit



Operational uncertainties

- Terrain properties
- Types of hazards
- Types of missions
- Internal faults

- Uncertainty in flight duration
 - Historical data?
 - Categorized flight duration into “short” and “long” durations
 - Short: < 1 hour
 - Long: 1->2 hours
 - Uncertainty metric: percentage of long duration missions in a given period of operation

Designs considered

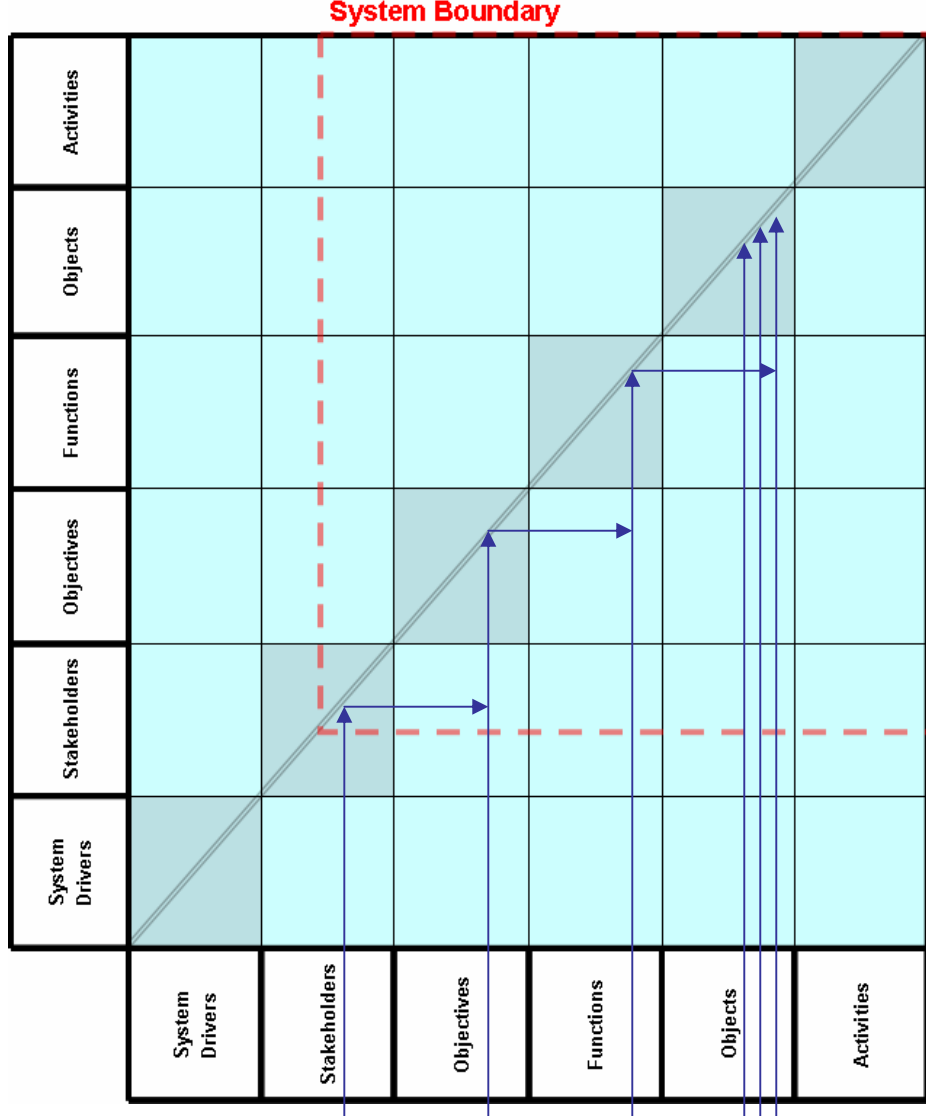
- Many alternatives, design variables that affect endurance

End user / operator

Mission types

Flight duration

Design



Designs considered

- Consider battery mass budget

Optimized for:

Short duration

Long duration

Design	Battery Mass (gm)	Total Mass (gm)	Endurance (hr)	Cost/MAV
Fixed S	88	504	1.005	\$1,234.96
Fixed L	219	635	2.004	\$1,271.64
Flexible	88	507	0.999	\$1,244.88
	extra 132	639	2.001	\$1,281.84

Option to insert extra battery

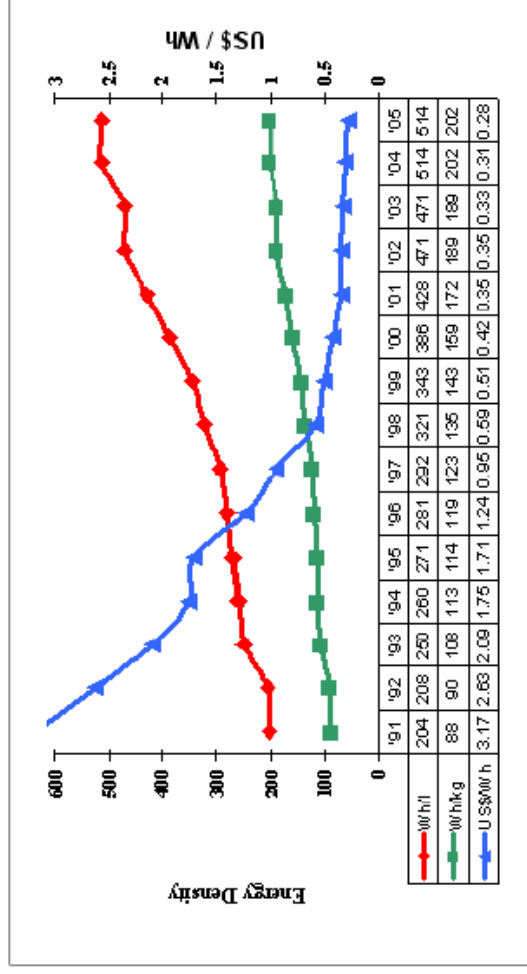


Figure 1: Historical data for Li-ion battery prices and energy density. (Source: <http://www.batteryuniversity.com/parttwo-55.htm>)

Cost and profit

Design	Cost	Revenue/S	Revenue/L	Profit/S	Profit/L
Fixed S	\$6,174,785	\$10,000,000	\$10,000,000	\$3,825,215	\$3,825,215
Fixed L	\$6,358,185	\$10,000,000	\$20,000,000	\$3,641,815	\$13,641,815
Flexible	\$6,224,390	\$10,000,000	\$20,000,000	\$3,775,610	\$13,590,810
	\$6,409,190				

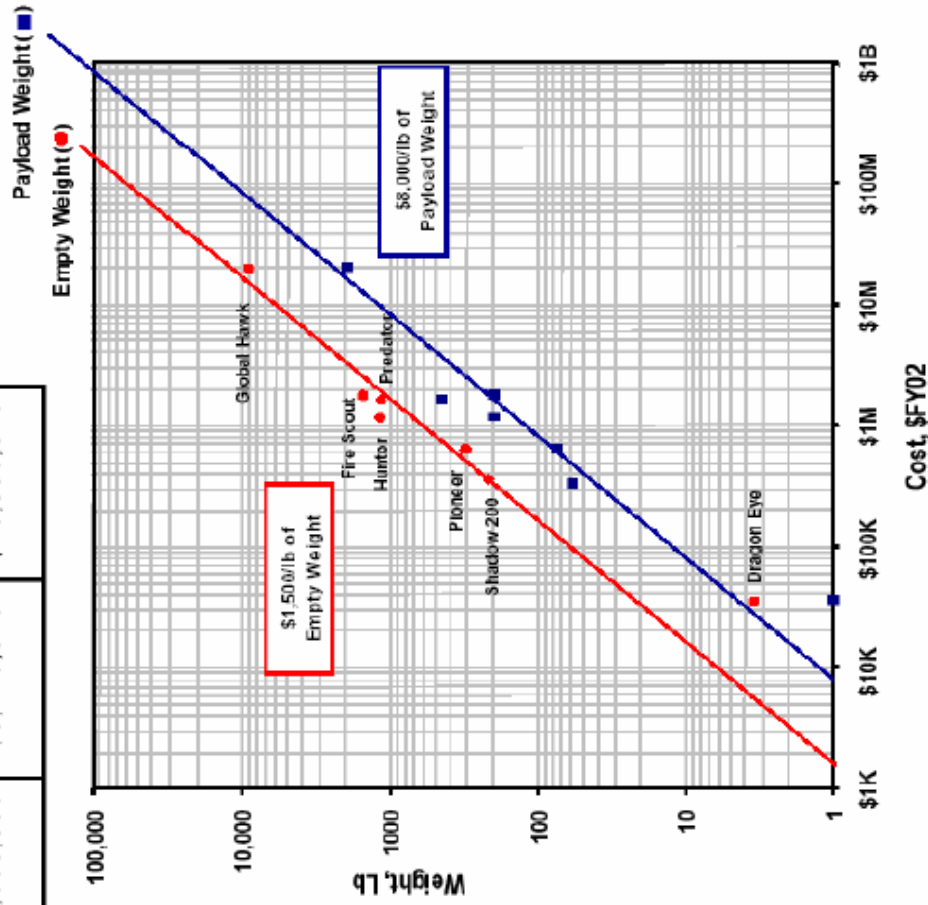


Figure 2: Cost versus weight of uninhabited air vehicles.
 (Source: http://www.uavforum.com/library/uav_roadmap_2005.pdf)

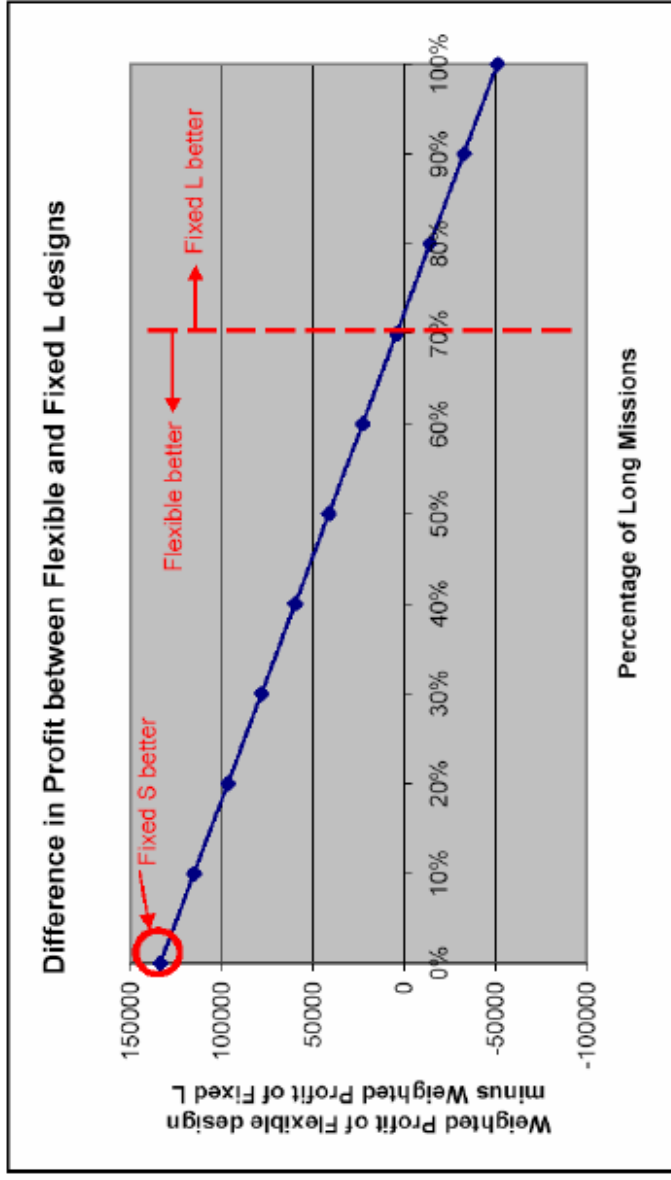


Value metric: weighted profit

% Long Missions	Average Profit	
	Fixed S	Flexible
0%	\$3,825,215.00	\$3,641,815.00
10%	\$3,825,215.00	\$4,641,815.00
20%	\$3,825,215.00	\$5,641,815.00
30%	\$3,825,215.00	\$6,641,815.00
40%	\$3,825,215.00	\$7,641,815.00
50%	\$3,825,215.00	\$8,641,815.00
60%	\$3,825,215.00	\$9,641,815.00
70%	\$3,825,215.00	\$10,641,815.00
80%	\$3,825,215.00	\$11,627,770.00
90%	\$3,825,215.00	\$12,609,290.00
100%	\$3,825,215.00	\$13,590,810.00

uncertainty

Limits
Upside
Opportunity



Uncertainty modeling using lattice

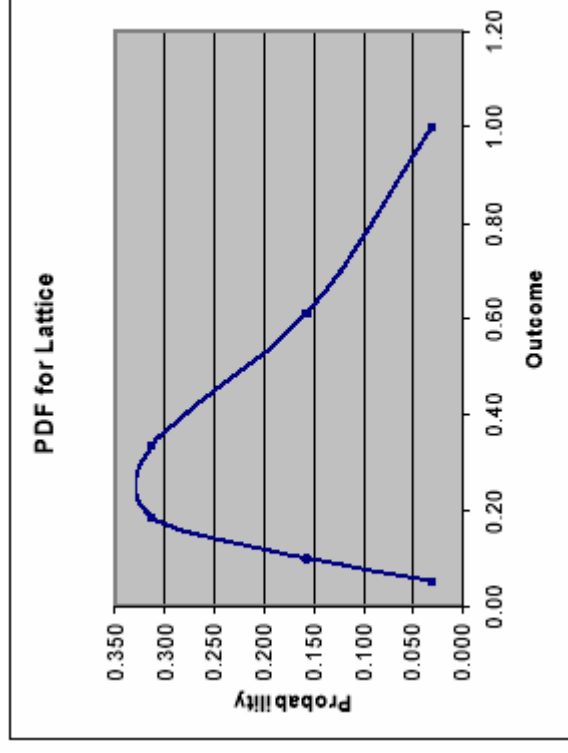
% long duration missions

OUTCOME LATTICE

0.250	0.338	0.456	0.615	0.830	1.000
	0.185	0.250	0.337	0.455	0.614
		0.137	0.185	0.250	0.337
			0.101	0.137	0.185
				0.075	0.101
					0.055

PROBABILITY LATTICE

1.000	0.500	0.250	0.125	0.063	0.031
	0.500	0.500	0.375	0.250	0.156
		0.250	0.375	0.375	0.313
			0.125	0.250	0.313
				0.063	0.156
					0.031



Decision analysis using lattice

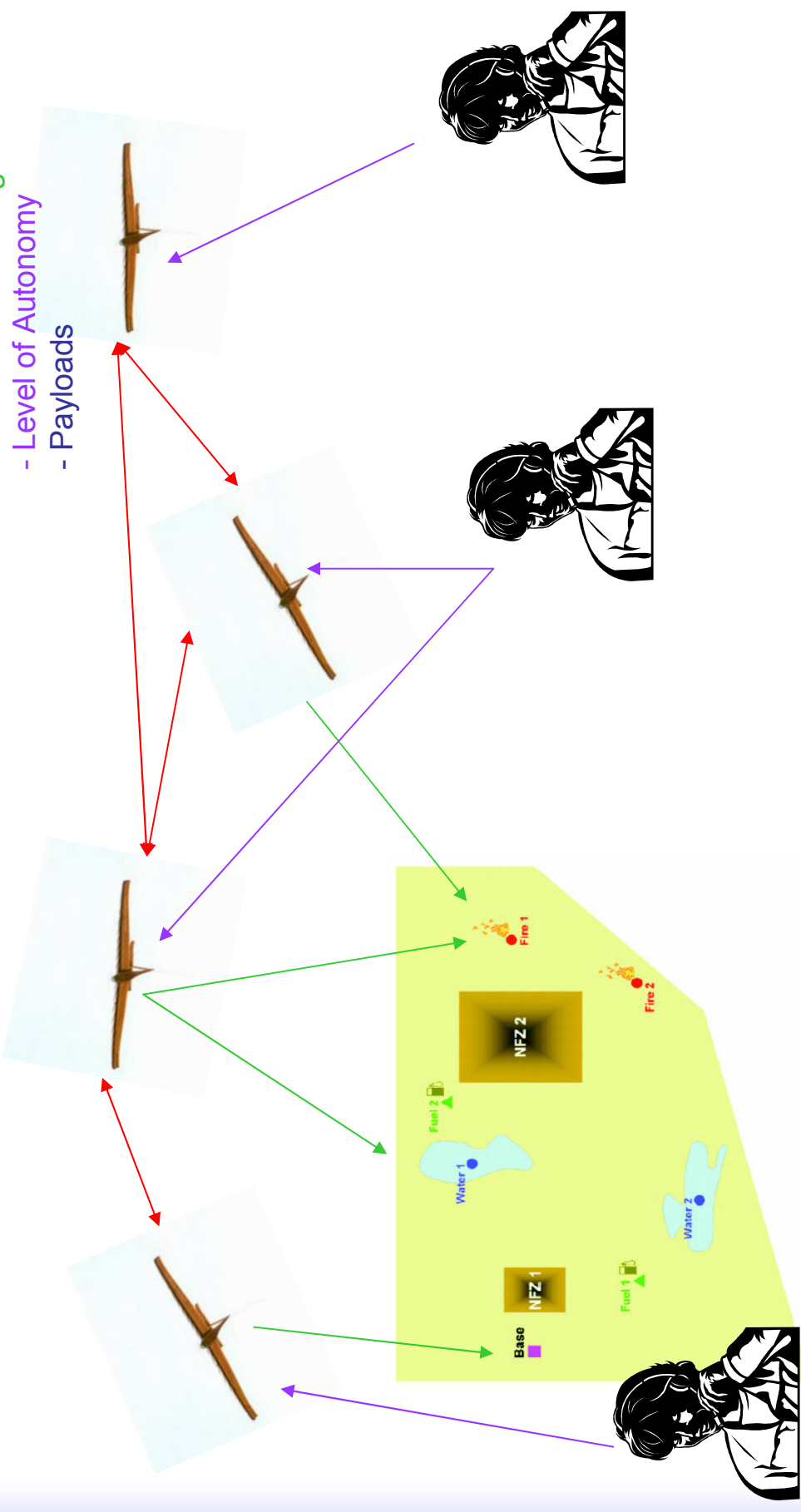
NPV lattice for each design.

NPV for Fixed S:	0	1	2	3	4	5
	17,614,259	15,443,729	13,012,736	10,290,024	7,240,586	3,825,215
		15,443,729	13,012,736	10,290,024	7,240,586	3,825,215
			13,012,736	10,290,024	7,240,586	3,825,215
				10,290,024	7,240,586	3,825,215
					7,240,586	3,825,215
NPV for Fixed L:	0	1	2	3	4	5
	29,450,373	29,416,513	28,755,896	26,800,216	22,404,695	13,641,815
		22,794,658	21,419,428	19,249,327	15,692,022	9,786,602
			17,338,940	14,978,126	11,716,364	7,010,068
				12,636,874	9,537,115	5,488,117
					8,342,564	4,653,862
NPV for Flexible:	0	1	2	3	4	5
	29,832,131	29,684,790	28,908,581	26,845,905	22,371,302	13,590,810
		23,185,306	21,707,690	19,434,557	15,782,679	9,806,841
			17,702,610	15,242,288	11,880,492	7,081,618
				12,944,303	9,741,515	5,587,792
					8,569,039	4,768,954
					4,320,110	

The value of the flexible option to add/remove an extra battery compared to the Fixed L design is \$29,832,131 - \$29,450,373 = **\$381,758**

Future work

- Case Study: MAV Network



- Considering multiple operational options in design

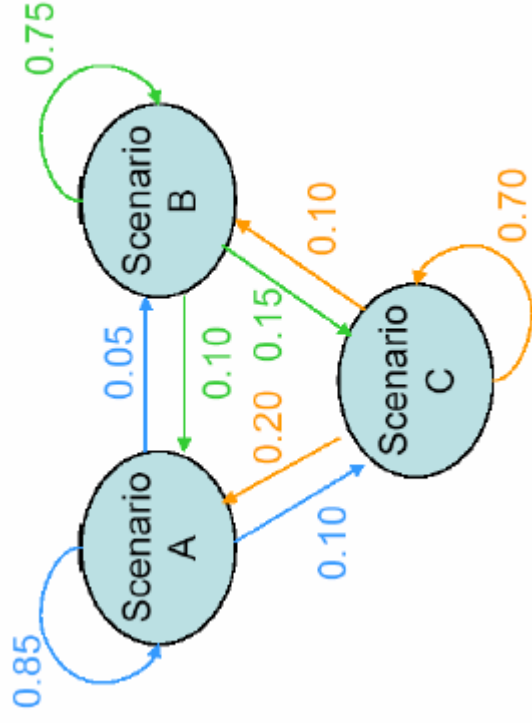
Backup Slides

Decision analysis using lattice

Table 4 Weighted average profit per mission for each design.

	0	1	2	3	4	5
Profit for Fixed S:	3,825,215	3,825,215	3,825,215	3,825,215	3,825,215	3,825,215
		3,825,215	3,825,215	3,825,215	3,825,215	3,825,215
			3,825,215	3,825,215	3,825,215	3,825,215
				3,825,215	3,825,215	3,825,215
					3,825,215	3,825,215
						3,825,215
Profit for Fixed L:	6,141,815	7,016,815	8,198,065	9,792,753	11,945,581	13,641,815
		5,491,815	6,139,315	7,013,440	8,193,509	9,786,602
			5,010,815	5,489,965	6,136,818	7,010,068
				4,654,875	5,009,446	5,488,117
					4,391,479	4,653,862
						4,196,567
Profit for Flexible:	6,229,410	7,088,240	8,247,661	9,812,878	11,925,922	13,590,810
		5,591,422	6,226,956	7,084,927	8,243,188	9,806,841
			5,119,311	5,589,606	6,224,505	7,081,618
				4,769,949	5,117,967	5,587,792
					4,511,421	4,768,954
						4,320,110

Scenarios for decision analysis



Scenario	% Long Missions	Initial Probability
Scenario A: Short	30%	0.5
Scenario B: Long	70%	0.3
Scenario C: Avg	50%	0.2

Scenario	% Long Missions	Average Profit		
		Fixed S	Fixed L	Flexible-
Scenario A: Short	30%	\$3,825,215.00	\$6,641,815.00	\$6,720,170.00
Scenario B: Long	70%	\$3,825,215.00	\$10,641,815.00	\$10,646,250.00
Scenario C: Avg	50%	\$3,825,215.00	\$8,641,815.00	\$8,683,210.00

Summary of outcomes for each scenario and design

Decision analysis

Rank	Strategy	Expected Value
1	Flexible+ extra batteries	\$ 16,532,128
2	Fixed L	\$ 16,433,630
3	Flexible- extra batteries	\$ 12,017,136
4	Fixed S	\$ 7,650,430

