Engineering Systems Analysis for Design

US Air Force
KC-X Tanker Replacement Program: Value of Flexibility

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Motivation

To determine the value of imbedding flexibility in the production buy schedule of the proposed US Air Force KC-X tanker aircraft by using the principles of Real Options

- The current arrangement locks the United States Government (USG) into a long-term, deterministic financial agreement which fails to account for future uncertainty.
- The forces of uncertainty may prevent USG from acting upon future opportunities or responding to unforeseen demands and requirements.
- Flexibility may be added to this agreement by either delaying the purchase decision and/or allowing the USG to modify the production quantity.

Background: KC-X Tanker Program

- KC-X program is the first of three acquisition programs needed to replace the entire fleet of aging USAF KC-135 Stratotankers.
- Primary mission of the KC-X will be to provide aerial refueling to United States military and coalition aircraft

Deterministic Production Schedule

- Effort Contracted to produce 179 aircraft
  – Worth $40B
  – Procured over a 15-20 year period

Production Buy Schedule (excluding 4 retrofit aircraft)

	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	Total
Buy Qty	7	12	15	15	15	15	15	15	15	15	15	15	6	175

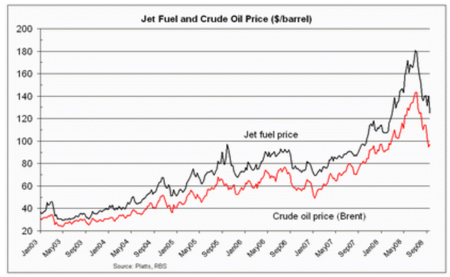
Note: Schedule should be predicated on bidders IMS and entrance criteria for LRIP

Retrofit Schedule

	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	FYXX	Total
Buy Qty			4											4

Sources of Uncertainty

- Demand uncertainty
  - Dubious forecast of how many aircraft are needed
- Uncertainty in the price of jet fuel
  - Seismic shifts in the price of jet fuel
  - Affects long-term cost of operations

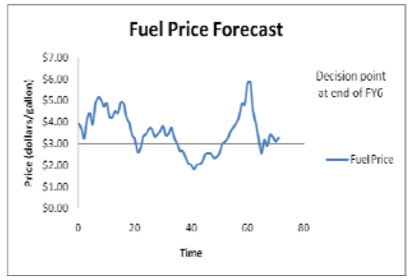


Exercising Options

- ***Inflexible***: Purchase full lot of 179 aircraft at the given production rate
- ***Flexible***: Purchase 79 Boeing 767 aircraft at the given production rate.
  - Re-evaluate decision to purchase remaining 99 based on oil prices and US government update to actual demand during the sixth fiscal year of production.
  - Following outcomes are possible in this scenario:
    - ➢Continue with purchase of 99 aircraft
    - ➢Purchase more than 99 aircraft
    - ➢Purchase less than 99 aircraft

Models

- Aircraft Cost Model
  - DAPCA IV computer model based on industry data
  - $C_M = 11W_e^{0.921} * V^{0.621} * Q^{0.799}$
- Fuel Cost Model
  - Geometric Brownian Motion (Stochastic process)
  - $dS = \mu S dt + \sigma S dz$
  - Regression analysis performed
- Demand Model
  - Affected by fuel cost
  - Conditional probabilities



Conditional Probability of Demand in Light of Fuel Cost			
Fuel Cost	P(HD/FC)	P(MD/FC)	P(LD/FC)
High	1/6	1/3	1/2
Med	1/3	1/3	1/3
Low	1/2	1/3	1/6

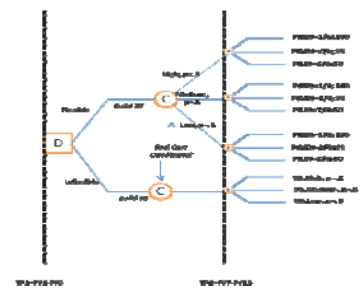
149	High Demand= Original requirement +50%
99	Medium Demand= original demand
50	Low Demand=original demand-50%
99	= Original Demand

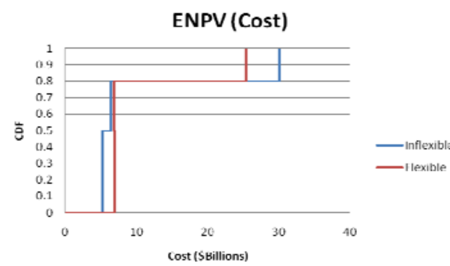
Operational Considerations

- Each aircraft will operate for 750 hours per year
- Each aircraft consumes 1722 gallons of jet fuel per hour

Decision Analysis

- Two-stage decision analysis
  - Fuel price at end of period 1 drives stage 2 decisions
- Results (Cost)
  - No option: $41.7B
  - Flexible: $39.2B
  - Savings: $1.5B





Lattice Analysis

•Binomial lattice framework
•Models the change in jet fuel price over time by considering the movement of the price at each time node

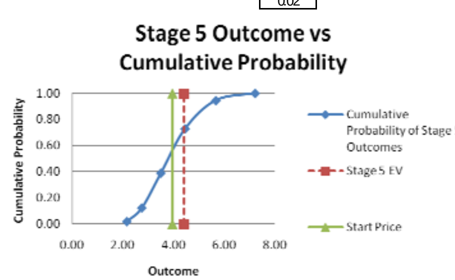
OUTCOME LATTICE (Jet Fuel Price, $ per Gallon)

3.96	4.46	5.03	5.68	6.40	7.22
	3.51	3.96	4.46	5.03	5.68
		3.11	3.51	3.96	4.46
			2.76	3.11	3.51
				2.44	2.76
					2.17

PROBABILITY LATTICE

1.00	0.56	0.31	0.18	0.10	0.06
	0.44	0.49	0.41	0.31	0.22
		0.19	0.33	0.36	0.34
			0.09	0.19	0.27
				0.04	0.10
					0.02

Starting Fuel Price ($ per gallon)	Growth Rate	Volatility	"Up" step (u)	"Down" step (d)	Probability of "Up" (p)	Probability of "down" (1-p)
3.96	1.45%	[illegible]	1.13	[illegible]	[illegible]	0.44



Lattice Valuation

Price Range	Price	Build Level	Build
LOW	$2.71≤	HIGH	149
MED	$6.27	MED	99
HIGH	≥ $6.28	LOW	50

OUTCOME LATTICE (Jet Fuel Price, $ per Gallon)

3.96	4.46	[illegible]	[illegible]	6.40	7.22
	3.51	[illegible]	[illegible]	5.03	5.68
		[illegible]	[illegible]	3.96	4.46
			[illegible]	3.11	3.51
				2.44	2.76
					2.17

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BUILD LEVEL

0	1	2	3	4	5
MED	MED	MED	MED	LOW	LOW
	MED	MED	MED	MED	MED
		MED	MED	MED	MED
			MED	MED	MED
				MED	MED
					HIGH

Probability Weighted, Fuel Cost, $M (FLEXIBLE CASE)

0	1	2	3	4	5
0	$ 319.54	$ 201.91	$ 127.59	$ 40.72	$ 25.73
	$ 197.16	$ 249.17	$ 236.18	$ 198.99	$ 157.17
		$ 76.87	$ 145.73	$ 184.17	$ 193.96
			$ 29.97	$ 114.02	$ 119.68
				$ 17.59	$ 36.92
					$ 6.86

Discount Rate = 27%

EV (Cost)	$0.00	$516.70	$527.96	$539.47	$555.49	$540.33
PV (Cost)	$0.00	$406.85	$327.34	$263.36	$213.53	$163.54
NPV (Cost)	$1,374.63					

Probability Weighted, Fuel Cost, $M (NO FLEXIBILITY)

0	1	2	3	4	5
0	$ 319.54	$ 201.91	$ 127.59	$ 80.62	$ 50.95
	$ 197.16	$ 249.17	$ 236.18	$ 198.99	$ 157.17
		$ 76.87	$ 145.73	$ 184.17	$ 193.96
			$ 29.97	$ 75.76	$ 119.68
				$ 11.69	$ 36.92
					$ 4.56

Discount Rate = 27%

EV (Cost)	$0.00	$516.70	$527.96	$539.47	$551.23	$563.24
PV (Cost)	$0.00	$406.85	$327.34	$263.36	$211.89	$170.48
NPV (Cost)	$1,379.93					

Value of flexibility = $5.3M cost savings

Conclusion

- The flexible options produced procurement and operational cost savings
  - On the order of 1 to 6%
  - For a system price tag near $40B, the potential savings are noteworthy
- Flexibility option merits greater consideration
  - Consider other units of measure (contractor profit, capability gained, etc)
  - Structured for mutual benefit (military, taxpayer, industry)