Thursday 19 September 2023

Today's Schedule:

- Call Roll
- Service/Outreach Sign-Ups:

  Mon. 10/23 Eisenhower Middle School, Abilene

  Mon. 10/30 Wamego Middle School

  Sat. 12/2 Flint Hills Discovery Center, Manhattan

  Sat. 12/9 Flint Hills Discovery Center, Manhattan

  ? Farley Elementary visit to KU Campus
- Mid-Semester Jeopardy/Quiz Questionnaire
- Competitions
- Small Report 6

AEROSPACE JEOPARDY!

Fall 2023 Outreach Activities Driver/Rider signups

	Mon. 10/23	Mon. 10/30	Sat. 12/2	Sat. 12/9
Ativie,Joseph			x	
Bailey,Lucy M				
Barland,Jack A	x		x	
Bonham,Maggie E		x		
Braaten,Niels C		x		
Caulfield,Camden Lee				
Coppens,Ryan				
Dargahi,Alex			x	
Denault,Carson Robert		x		
Deng,Keyu			x	
Dillon,Peter				
Dodge,Andrew				
Dunlay,Joshua P	x			
Dutta,Sap				
Foster,Dean C	x		x	x
Gillies,Gunnar			x	x
Goudschaal-Frazier,Gracyn Jane				
Guzman,Jonathan Alan		x		
Harder,Samuel A			x	x
Heide,Rhett Gile	x		x	
Horst,Evelyn			x	
Hunt,Wesley Afra	x			
Junnare,Nupoor	x	x		
Keathley,Liliana Gabriel				
King,Kathryn M				
Kuligowski,Payton M			x	x
Larsen,Isaac		x		x

	Mon. 10/23	Mon. 10/30	Sat. 12/2	Sat. 12/9
Linthavong,Cherry			x	
Lofland,Chris C	x	x		
Marshall,Jeb O	x		x	x
Mays,Benjamin S		x		
Mcmichael,Barrett			x	x
Mcnulty,Jack B		x		
Mistretta,Anthony J		x		
Olson,Kadin Lee	x		x	
Platt,Charlie M		x		
Poznanski,Joshua	x	x	x	x
Reida,Reanne N			x	x
Reidy,Macoy M		x	x	
Relan,Jennifer	x	x	x	x
Richardson,Jake	x		x	x
Russell,Lucas S	x		x	x
Schneider,Cade W	x		x	x
Shah,Dhairya	x	x		
Sullivan,Tim Michael				
Sutton,Joshua T				x
Svoboda,Benjamin C		x		
Thorson,Johnathan A		x		
To,Hoang Minh			x	
Torok,Jackson P				x
Torres Leon,Hector	x		x	
Waggoner,Alex				x
Wall,James Edgar			x	
Wegiel,Jeremy L				

Abilene Elementary School 10/23 Drivers & Riders

- Meet in W. Learned Lot ~ 1:20pm, Dr. B. cell: (785) 760-4614
- 721 stayers – go to 1182 for fabrication
- Drive to Abilene, 1101 N Vine Abilene, KS 67410

	Driver	Rider
Barland,Jack A		
Braaten, Niels		y
Dunlay,Joshua P	y 3	
Foster,Dean C	y 4	
Heide,Rhett Gile		
Hunt,Wesley Afra		y
Junnare,Nupoor		y
Lofland,Chris C		y
Marshall,Jeb O		y
Olson,Kadin Lee		y
Poznanski,Joshua		y
Relan,Jennifer	y 3	
Richardson,Jake		
Russell,Lucas S		y
Schneider,Cade W		
Shah,Dhairya		
Torres Leon,Hector		

AE 521 Small Report 6 Required Contents

Due Monday October 23am to: kuaerodesign@gmail.com

Total Points: 50

Notes on Team Assignment:

Note that the work to be performed for this report is to be done by a team of students numbering up to 5 individuals.

AE521_Report6_TeamName.docx *example: AE521_Report6_SkyHawks.docx*

Report Title: AE 521 Report 6 Objective Function Development

1. Introduction:

Choose a competition design to analyze the rest of the semester and possibly in the Spring. Describe why your team likes this design better than the others. If you choose a design of your own construction, tell the reader why you want to work on this particular kind of aircraft.

2. Abbreviated Operating Statement (AOS)

Generate an AOS for your team's chosen design. Make it good and put some thought in it.

3. Concept of Operations (ConOps)

Generate a ConOps for your team's chosen design as was covered in class. Show all principal mission phases and interactions

4. Mission Specification

Generate a Mission Specification for your team's chosen design as was covered in class. Include all information in tabular form, taken straight from your chosen AIAA or VFS specification.

5. Mission Profile

Generate a Mission Profile for your team's chosen design as was covered in class. Make SURE to do it in 3 dimensions with a CAD ribbon as was covered.

6. Objective Function (OF)

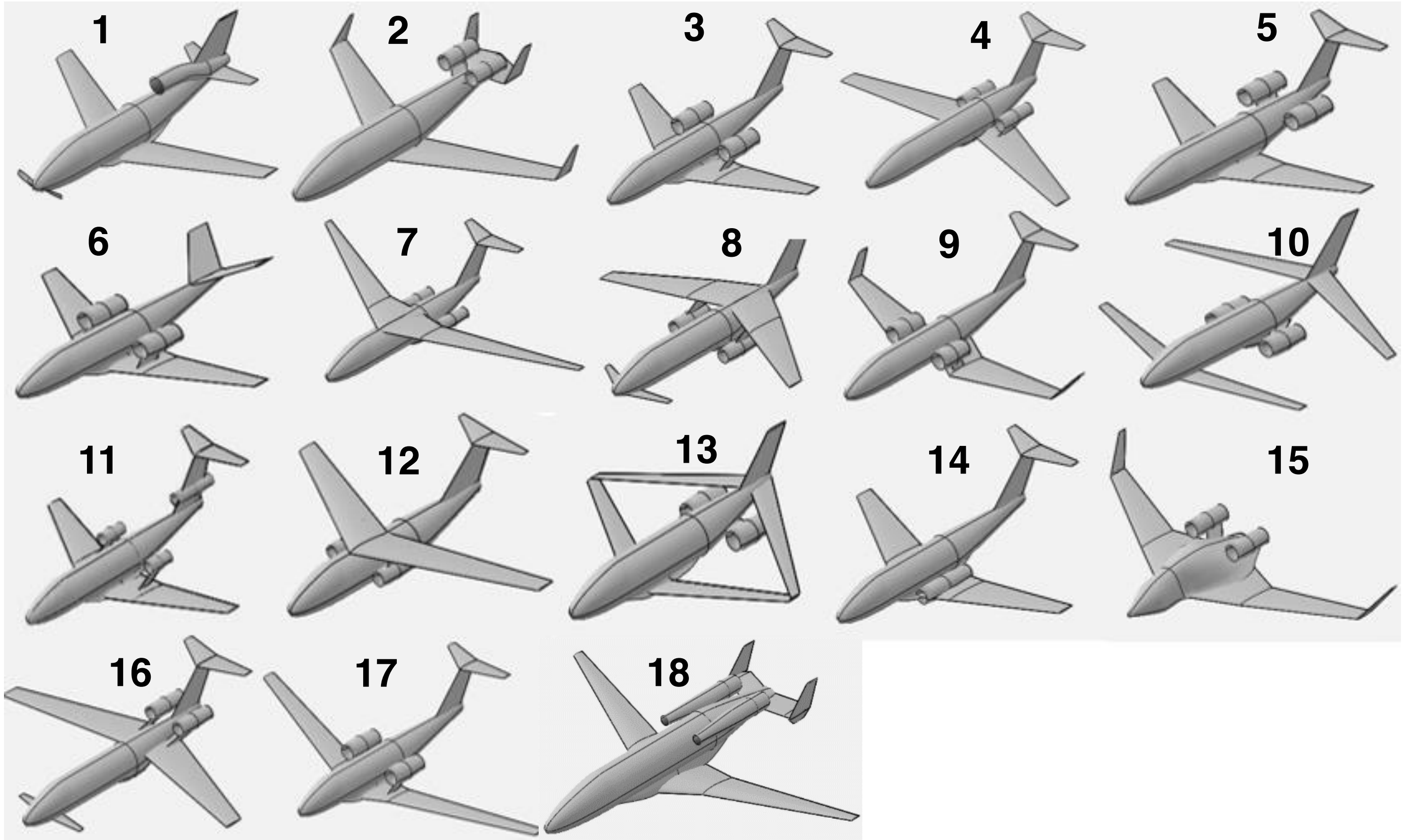
Following all of the steps presented in class, generate an objective function for your aircraft design. Include all requirements and objectives as well as at least five ancillary objectives. Define all terms, requirements and objectives and present a final mathematical expression for the objective function and all of its components.

7. Summary and Recommendations

Step 3: Objective Function

Configuration Sweep:

Choosing the configuration that best suits the mission



Step 3: Objective Function

From coming efforts, many configurations with pros and cons

Wing Podded Engines	
+ Lower Interference Drag	– Spar Discontinuity – Adds Weight
+ Blown Flaps	– Engine Accessibility
	– Less Wing Fuel Volume
	– No Room for Engine Growth

Figure 6-3: Wing Podded Engines

Delta Wing	
+ Delayed Stall	– Engine Accessibility
+ Transonic Performance	– Passenger Visibility Low
	– High Landing Angle of Attack
	– Low L/D
	– "Are you trying to go to space?" – Dr. Willam Anemaat

Figure 6-4: Delta Wing

Tandem Wing	
+ High AR	– Landing Gear Integration
+ Low Trim Drag	– Engine Placement
	– Cabin Noise/Vibration
	– Pitch Break Characteristics
	– Certification Cost

Figure 6-5: Tandem

Step 3: Objective Function

From coming efforts, many configurations with pros and cons

Joined Wing			
+	High L/D	−	Requires Composites
+	Less Trim Drag	−	Certification Cost
		−	EIS

Figure 6-6: Joined Wing

Strut-Braced			
+	High AR	−	Landing Gear Integration
+	Lower Structural Weight	−	Low Fuel Volume
+	Lower Span Loading	−	Interference Drag
		−	Certification Cost
		−	EIS

Figure 6-7: Strut-Braced

High Wing			
+	Easy Engine Access	−	Interference Drag
+	Good Passenger Visibility	−	Landing Gear Integration
+	Lateral Ground Clearance	−	Jet Noise Radiated Down
		−	Engine Exhaust Washes Cabin
		−	Market Appeal

Figure 6-8: High Wing

Step 3: Objective Function

From coming efforts, many configurations with pros and cons

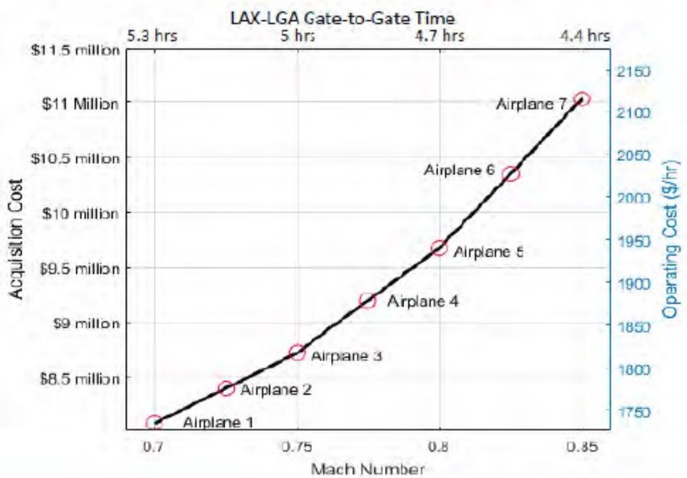
BUSINESS JET OWNERS & OPERATORS

Help KU win AIAA's aircraft design competition by filling out this brief survey

1 When buying a business jet, how important are the following criteria to you?

	How Important? (1=Low, 10=High)
Acquisition Cost	
Direct Operating Cost	
Appearance	
Average Cruise Speed	

2 The following chart shows a trade-off between cruise speed and cost. If you were to buy a business jet in the next 4 years, what airplane would you prefer? (Circle your preference)



3 Rank the following in terms of appeal (1=best, 5=worst)

4 Please, fold and mail.

(Stamp included on envelope!)

Step 3: Objective Function

Use survey information, experience & market data to generate an Objective Function.

Concept 1: Requirements, R_i (i = 1…n)

A performance or physical characteristic below which and/or above which, the design will be considered nonviable.

Concept 2: Objectives, O_j (j = 1… m)

A performance or physical characteristic that is desirable to attain.

Step 3: Objective Function

Recall from Systems Engineering:

1. Mandatory requirements (Requirements) insure that the system satisfies the customer's operational need. Mandatory requirements (1) specify the necessary and sufficient conditions that a minimal system must have in order to be acceptable (2) must be passed or failed, there is no middle ground, and (3) must not be susceptible to trade-offs between requirements. Typical mandatory requirements might be of the following form: The system shall not violate federal, state or local laws. Mandatory requirements state the minimal requirements necessary to satisfy the customer's need.

2. Tradeable Requirements (Objectives) are evaluated to determine the preferred designs. Tradeoff requirements (1) should state conditions that would make the customer happier (2) should use scoring functions to evaluate the criteria, and (3) should be evaluated with multicriterion decision aiding techniques because there will be trade-offs between these requirements.

Sometimes there is a relationship between mandatory and tradeoff requirements, e.g. a mandatory requirement might be a lower threshold value for a tradeoff requirement. The words optimize, maximize, minimize and simultaneous should not be used in stating a hard and fast requirement.

Verify and validate requirements
Each requirement should be verified by logical argument, inspection, modeling, simulation, analysis, test or demonstration. Validating requirements means ensuring that

1) the recommended solution satisfies the actual needs of the customer
2) the description of the requirements is consist and complete
3) a system model can satisfy the requirements
4) a real-world solution can be tested to prove that it satisfies the requirements.

Requirements are often validated by reference to an existing system that meets most of the requirements.

Step 3: Objective Function

Use survey information, experience & market data to generate Objective Function.

Concept 1: Requirement

A performance or physical characteristic below which and/or above which, the design will be considered nonviable.

Typical values: $R_1 = 0/1$, $R_2 = 0/1$, $R_3 = 0/1$

Example: Required Ferry Range: 1800nmi

Step 3: Objective Function

Use survey information, experience & market data to generate Objective Function.

Concept 1: Requirement

A performance or physical characteristic below which and/or above which, the design will be considered nonviable.

Typical values: $R_1 = 0/1$, $R_2 = 0/1$, $R_3 = 0/1$

Example: Required Ferry Range: 1800nmi

Concept 2: Objective

A performance or physical characteristic that is desirable to attain, typically within given bounds.

Typical values: $O_1 = 50kts$, $O_2 = 0.10$, $O_3 = 1500ft$

Example: Objective Ferry Range: 2100nmi

Step 3: Objective Function

Concept 3: Multiplicative Weighting

Typically done to provide a "switch" to null designs that can't meet threshold values

$$OF = R_1 R_2 R_3 R_4 R_5$$

Concept 4 Additive Weighting

Typically done to assess objectives relative to each other

$$OF = O_1 + 3O_2 + 2O_3 + 10O_4 + 2O_5$$

Concept 5 Exponentially Additive Weighting

Typically done to assess objectives relative to each other and more strongly weight high or low performance.

$$OF = 2O_1^2 + 5O_2^{-1} + O_3^1 - 3O_4^2$$

Step 3: Objective Function

Combined Objective Functions:

Example

$$R_1 = \begin{cases} 1 \;\; if\, V_{cr} \geq 250kts \\ 0 \;\; if\, V_{cr} < 250kts \end{cases}$$

$$O_1 = \begin{cases} \dfrac{V_{cr} - 250kts}{100kts} \;\; if\, 250kts < V_{cr} < 350kts \\ 1 \;\; if\, V_{cr} > 350kts \end{cases}$$

Step 3: Objective Function

Combined Objective Functions:

Example

$$R_1 = \begin{cases} 1 \;\; if\; V_{cr} \geq 250kts \\ 0 \;\; if\; V_{cr} < 250kts \end{cases}$$

$$O_1 = \begin{cases} \dfrac{V_{cr} - 250kts}{100kts} \;\; if\; 250kts < V_{cr} < 350kts \\ 1 \;\; if\; V_{cr} > 350kts \end{cases}$$

$$R_2 = \begin{cases} 1 \;\; if\; W_{pl} \geq 1800lbf \\ 0 \;\; if\; W_{pl} < 1800lbf \end{cases}$$

$$O_2 = \begin{cases} \dfrac{W_{pl} - 1800lbf}{1200lbf} \;\; if\; 1800lbf < W_{pl} < 3000lbf \\ 1 \;\; if\; W_{pl} > 3000lbf \end{cases}$$

Step 3: Objective Function

Combined Objective Functions:

Example

$$R_1 = \begin{cases} 1 \ \ if\ V_{cr} \geq 250kts \\ 0 \ \ if\ V_{cr} < 250kts \end{cases}$$

$$O_1 = \begin{cases} \dfrac{V_{cr} - 250kts}{100kts} \ \ if\ 250kts < V_{cr} < 350kts \\ 1 \ \ if\ V_{cr} > 350kts \end{cases}$$

$$R_2 = \begin{cases} 1 \ \ if\ W_{pl} \geq 1800lbf \\ 0 \ \ if\ W_{pl} < 1800lbf \end{cases}$$

$$O_2 = \begin{cases} \dfrac{W_{pl} - 1800lbf}{1200lbf} \ \ if\ 1800lbf < W_{pl} < 3000lbf \\ 1 \ \ if\ W_{pl} > 3000lbf \end{cases}$$

$$R_3 = \begin{cases} 1 \ \ if\ BFL \leq 2500ft \\ 0 \ \ if\ BFL > 2500ft \end{cases}$$

$$O_3 = \begin{cases} \dfrac{1000ft}{BFL - 1500ft} \ \ if\ \ 1500ft < BFL < 2500ft \\ 1 \ \ if\ BFL < 1500ft \end{cases}$$

Step 3: Objective Function

Combined Objective Functions:

Example

$$R_1 = \begin{cases} 1 & if\ V_{cr} \geq 250kts \\ 0 & if\ V_{cr} < 250kts \end{cases}$$

$$O_1 = \begin{cases} \dfrac{V_{cr} - 250kts}{100kts} & if\ 250kts < V_{cr} < 350kts \\ 1\ if\ V_{cr} > 350kts \end{cases}$$

$$R_2 = \begin{cases} 1 & if\ W_{pl} \geq 1800lbf \\ 0 & if\ W_{pl} < 1800lbf \end{cases}$$

$$O_2 = \begin{cases} \dfrac{W_{pl} - 1800lbf}{1200lbf} & if\ 1800lbf < W_{pl} < 3000lbf \\ 1\ if\ W_{pl} > 3000lbf \end{cases}$$

$$R_3 = \begin{cases} 1 & if\ BFL \leq 2500ft \\ 0 & if\ BFL > 2500ft \end{cases}$$

$$O_3 = \begin{cases} \dfrac{1000ft}{BFL - 1500ft} & if\ \ 1500ft < BFL < 2500ft \\ 1\ if\ BFL < 1500ft \end{cases}$$

Caution! Ill-posed OF!

Step 3: Objective Function

Combined Objective Functions:

Example

$$R_1 = \begin{cases} 1 \ \ if\ V_{cr} \geq 250kts \\ 0 \ \ if\ V_{cr} < 250kts \end{cases}$$

$$O_1 = \begin{cases} \dfrac{V_{cr} - 250kts}{100kts} \ \ if\ 250kts < V_{cr} < 350kts \\ 1 \ \ if\ V_{cr} > 350kts \end{cases}$$

$$R_2 = \begin{cases} 1 \ \ if\ W_{pl} \geq 1800lbf \\ 0 \ \ if\ W_{pl} < 1800lbf \end{cases}$$

$$O_2 = \begin{cases} \dfrac{W_{pl} - 1800lbf}{1200lbf} \ \ if\ 1800lbf < W_{pl} < 3000lbf \\ 1 \ \ if\ W_{pl} > 3000lbf \end{cases}$$

$$R_3 = \begin{cases} 1 \ \ if\ BFL \leq 2500ft \\ 0 \ \ if\ BFL > 2500ft \end{cases}$$

$$O_3 = \begin{cases} \dfrac{1000ft}{BFL - 1500ft} \ \ if\ \ 2000ft < BFL < 2500ft \\ 1 \ \ if\ BFL < 2000ft \end{cases}$$

Better…

Step 3: Objective Function

Combined Objective Functions:

Example

$$R_1 = \begin{cases} 1 \;\; if \; V_{cr} \geq 250kts \\ 0 \;\; if \; V_{cr} < 250kts \end{cases}$$

$$O_1 = \begin{cases} \dfrac{V_{cr} - 250kts}{100kts} \;\; if \; 250kts < V_{cr} < 350kts \\ 1 \;\; if \; V_{cr} > 350kts \end{cases}$$

$$R_2 = \begin{cases} 1 \;\; if \; W_{pl} \geq 1800lbf \\ 0 \;\; if \; W_{pl} < 1800lbf \end{cases}$$

$$O_2 = \begin{cases} \dfrac{W_{pl} - 1800lbf}{1200lbf} \;\; if \; 1800lbf < W_{pl} < 3000lbf \\ 1 \;\; if \; W_{pl} > 3000lbf \end{cases}$$

$$R_3 = \begin{cases} 1 \;\; if \; BFL \leq 2500ft \\ 0 \;\; if \; BFL > 2500ft \end{cases}$$

$$O_3 = \begin{cases} \dfrac{1000ft}{BFL - 1500ft} \;\; if \; 2000ft < BFL < 2500ft \\ 1 \;\; if \; BFL < 2000ft \end{cases}$$

$$R_4 = \begin{cases} 1 \;\; if \; Cacq \leq \$8.5M \\ 0 \;\; if Cacq > \$8.5M \end{cases}$$

$$O_4 = \begin{cases} \dfrac{\$7.5M}{\$8.5M - Cacq} \;\; if \; \$1M < Cacq < \$8.5M \\ 10 \;\; if \; \$500k < C_{acq} < \$1M \\ 100 \;\; if \; Cacq < \$500k \end{cases}$$

Step 3: Objective Function

Combined Objective Functions:

Example

$$R_1 = \begin{cases} 1 \ \ if\ V_{cr} \geq 250kts \\ 0 \ \ if\ V_{cr} < 250kts \end{cases}$$

$$O_1 = \begin{cases} \dfrac{V_{cr} - 250kts}{100kts} \ \ if\ 250kts < V_{cr} < 350kts \\ 1 \ \ if\ V_{cr} > 350kts \end{cases}$$

$$R_2 = \begin{cases} 1 \ \ if\ W_{pl} \geq 1800lbf \\ 0 \ \ if\ W_{pl} < 1800lbf \end{cases}$$

$$O_2 = \begin{cases} \dfrac{W_{pl} - 1800lbf}{1200lbf} \ \ if\ 1800lbf < W_{pl} < 3000lbf \\ 1 \ \ if\ W_{pl} > 3000lbf \end{cases}$$

$$R_3 = \begin{cases} 1 \ \ if\ BFL \leq 2500ft \\ 0 \ \ if\ BFL > 2500ft \end{cases}$$

$$O_3 = \begin{cases} \dfrac{1000ft}{BFL - 1500ft} \ \ if\ \ 2000ft < BFL < 2500ft \\ 1 \ \ if\ BFL < 2000ft \end{cases}$$

$$R_4 = \begin{cases} 1 \ \ if\ Cacq \leq \$8.5M \\ 0 \ \ if Cacq > \$8.5M \end{cases}$$

$$O_4 = \begin{cases} \dfrac{\$7.5M}{\$8.5M - Cacq} \ \ if\ \ \$1M < Cacq < \$8.5M \\ 10 \ \ if\ \$500k < C_{acq} < \$1M \\ 100 \ \ if\ Cacq < \$500k \end{cases}$$

$$R_5 = \begin{cases} 1 \ \ if\ Pk \geq 90\% \\ 0 \ \ if Pk < 90\% \end{cases}$$

$$O_5 = \begin{cases} \left(\dfrac{P_k - 90\%}{10\%}\right)^2 \ \ if\ \ 90\% < Pk < 100\% \\ 1 \ \ if Pk = 100\% \end{cases}$$

Step 3: Objective Function

Combined Objective Functions: Example

$$R_1 = \begin{cases} 1 \ if\ V_{cr} > 250kts \\ 0 \ if\ V_{cr} < 250kts \end{cases} \quad R_2 = \begin{cases} 1 \ if\ W_{pl} > 1800lbf \\ 0 \ if\ W_{pl} < 1800lbf \end{cases} \quad R_3 = \begin{cases} 1 \ if\ BFL < 2500ft \\ 0 \ if\ BFL > 2500ft \end{cases} \quad R_4 = \begin{cases} 1 \ if\ Cacq \leq \$8.5M \\ 0 \ if Cacq > \$8.5M \end{cases} \quad R_5 = \begin{cases} 1 \ if\ Pk \geq 90\% \\ 0 \ if Pk < 90\% \end{cases}$$

$$O_1 = \begin{cases} \dfrac{V_{cr} - 250kts}{100kts} \ if\ 250kts < V_{cr} < 350kts \\ 1 \ if\ V_{cr} > 350kts \end{cases} \quad O_2 = \begin{cases} \dfrac{W_{pl} - 1800lbf}{1200lbf} \ if\ 1800lbf < W_{pl} < 3000lbf \\ 1 \ if\ W_{pl} > 3000lbf \end{cases}$$

$$O_3 = \begin{cases} \dfrac{1000ft}{BFL - 1500ft} \ if\ 2000ft < BFL < 2500ft \\ 1 \ if\ BFL < 2000ft \end{cases} \quad O_4 = \begin{cases} \dfrac{\$7.5M}{\$8.5M - Cacq} \ if\ \$1M < Cacq < \$8.5M \\ 10 \ if\ \$500k < C_{acq} < \$1M \\ 100 \ if\ Cacq < \$500k \end{cases}$$

$$O_5 = \begin{cases} \left(\dfrac{P_k - 90\%}{10\%}\right)^2 \ if\ 90\% < Pk < 100\% \\ 1 \ if Pk = 100\% \end{cases}$$

Inclusion of overall design drivers like W_{TO} & DOC

$$OF = R_1 R_2 R_3 R_4 R_5 \frac{\left(5O_1^1 + O_2^3 + 2O_3^2 + 2O_4^{-2} + 2O_5^1\right)}{DOC * W_{to}}$$

Step 3: Objective Function

Combined Objective Functions:

Example

$$R_1 = \begin{cases} 1 \ \ if\ V_{cr} > 250kts \\ 0 \ \ if\ V_{cr} < 250kts \end{cases} \quad R_2 = \begin{cases} 1 \ \ if\ W_{pl} > 1800lbf \\ 0 \ \ if\ W_{pl} < 1800lbf \end{cases} \quad R_3 = \begin{cases} 1 \ \ if\ BFL < 2500ft \\ 0 \ \ if\ BFL > 2500ft \end{cases} \quad R_4 = \begin{cases} 1 \ \ if\ Cacq \leq \$8.5M \\ 0 \ \ if Cacq > \$8.5M \end{cases} \quad R_5 = \begin{cases} 1 \ \ if\ Pk \geq 90\% \\ 0 \ \ if Pk < 90\% \end{cases}$$

$$O_1 = \begin{cases} \frac{V_{cr} - 250kts}{100kts} \ \ if\ 250kts < V_{cr} < 350kts \\ 1 \ \ if\ V_{cr} > 350kts \end{cases} \qquad O_2 = \begin{cases} \frac{W_{pl} - 1800lbf}{1200lbf} \ \ if\ 1800lbf < W_{pl} < 3000lbf \\ 1 \ \ if\ W_{pl} > 3000lbf \end{cases}$$

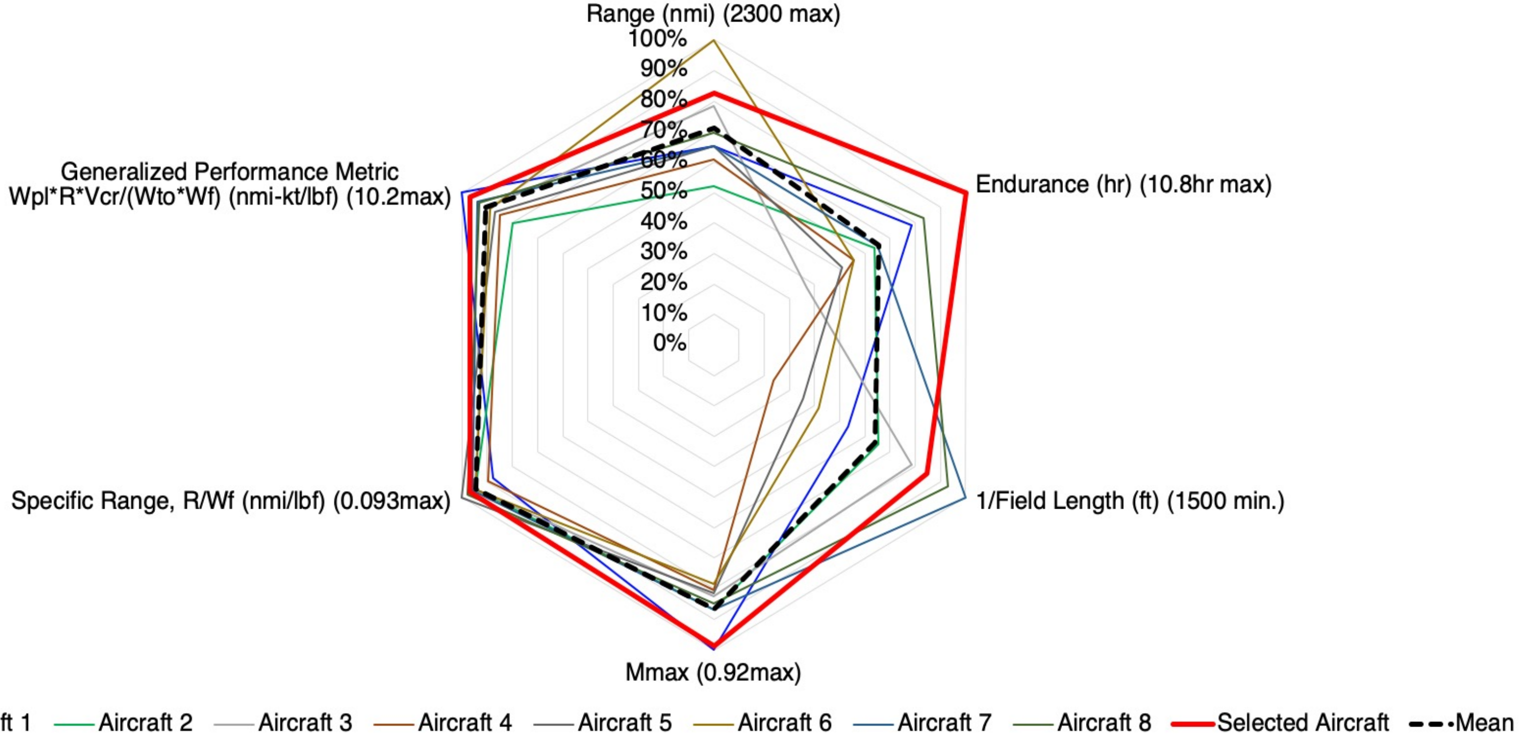
$$O_3 = \begin{cases} \frac{1000ft}{BFL - 1500ft} \ \ if\ \ 2000ft < BFL < 2500ft \\ 1 \ \ if\ BFL < 2000ft \end{cases} \qquad O_4 = \begin{cases} \frac{\$7.5M}{\$8.5M - Cacq} \ \ if\ \ \$1M < Cacq < \$8.5M \\ 10 \ \ if\ \$500k < C_{acq} < \$1M \\ 100 \ \ if\ Cacq < \$500k \end{cases}$$

$$O_5 = \begin{cases} \left(\frac{P_k - 90\%}{10\%}\right)^2 \ \ if\ \ 90\% < Pk < 100\% \\ 1 \ \ if Pk = 100\% \end{cases} \qquad O_6 = \frac{DOC_{A-10} - DOC}{DOC_{A-10}} \qquad O_7 = \frac{W_{TOA-10} - W_{TO}}{W_{TOA-10}}$$

$$OF = R_1 R_2 R_3 R_4 R_5 \left(5O_1 + O_2^3 + 2O_3^2 + 2O_4^{1.5} + 2O_5\right) O_6^1 \sqrt{O_7}$$

Step 3: Objective Function

Visualization of Multi-Point Aircraft Performance



General Performance of Maritime Patrol Jet Market 2020 with 1.2*Endurance for Selected Aircraft

Step 3: Objective Function

Visualization of Multi-Point Aircraft Performance

Breguet Range

Propeller planes

$$R(nmi) = 325.9\left(\frac{nmi-lbf}{hp-hr}\right)\left(\frac{\eta_p}{c_p\left(\frac{lbf}{hp-hr}\right)}\right)\left(\frac{L}{D}\right)Ln\left(W_i/W_{i+1}\right)$$

Jets

$$R(nmi) = \left(\frac{V(kts)}{c_j\left(lbf/lbf-hr\right)}\right)\left(\frac{L}{D}\right)Ln\left(W_i/W_{i+1}\right)$$

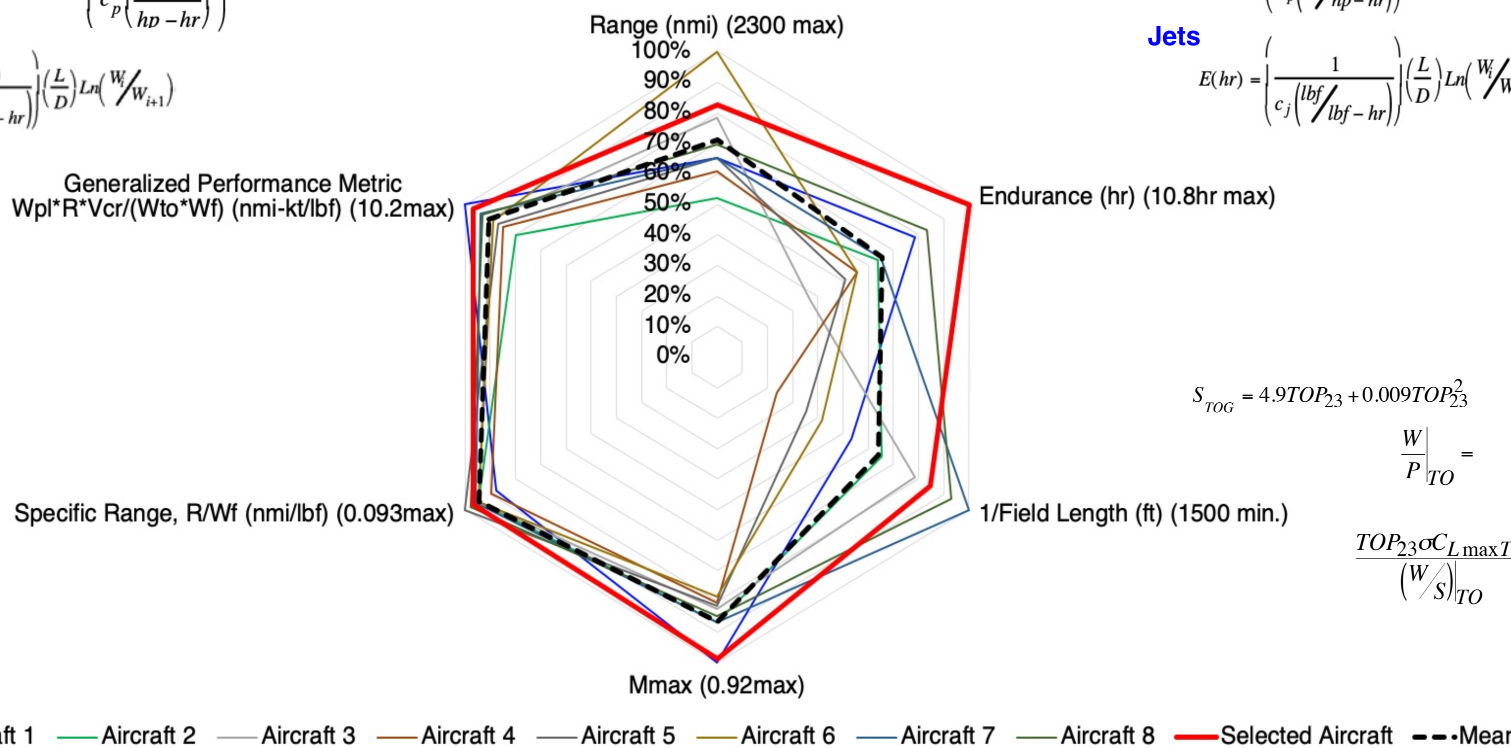
Breguet Endurance

Propeller planes

$$E(hr) = 325.9\left(\frac{nmi-lbf}{hp-hr}\right)\left(\frac{1}{V(kts)}\right)\left(\frac{\eta_p}{c_p\left(lbf/hp-hr\right)}\right)\left(\frac{L}{D}\right)Ln\left(W_i/W_{i+1}\right)$$

Jets

$$E(hr) = \left(\frac{1}{c_j\left(lbf/lbf-hr\right)}\right)\left(\frac{L}{D}\right)Ln\left(W_i/W_{i+1}\right)$$



$$S_{TOG} = 4.9TOP_{23} + 0.009TOP_{23}^2$$

$$\left.\frac{W}{P}\right|_{TO} = \frac{TOP_{23}\sigma C_{L\,max\,TO}}{\left.\left(W/S\right)\right|_{TO}}$$

General Performance of Maritime Patrol Jet Market 2020 with 1.2*Endurance for Selected Aircraft

Step 3: Objective Function

Visualization of Multi-Point Aircraft Performance

Breguet Range

Propeller planes

$$R(nmi) = 325.9\left(\frac{nmi-lbf}{hp-hr}\right)\left(\frac{\eta_p}{c_p\left(\frac{lbf}{hp-hr}\right)}\right)\left(\frac{L}{D}\right)Ln\left(\frac{W_i}{W_{i+1}}\right)$$

Jets

$$R(nmi) = \left(\frac{V(kts)}{c_j\left(\frac{lbf}{lbf-hr}\right)}\right)\left(\frac{L}{D}\right)Ln\left(\frac{W_i}{W_{i+1}}\right)$$

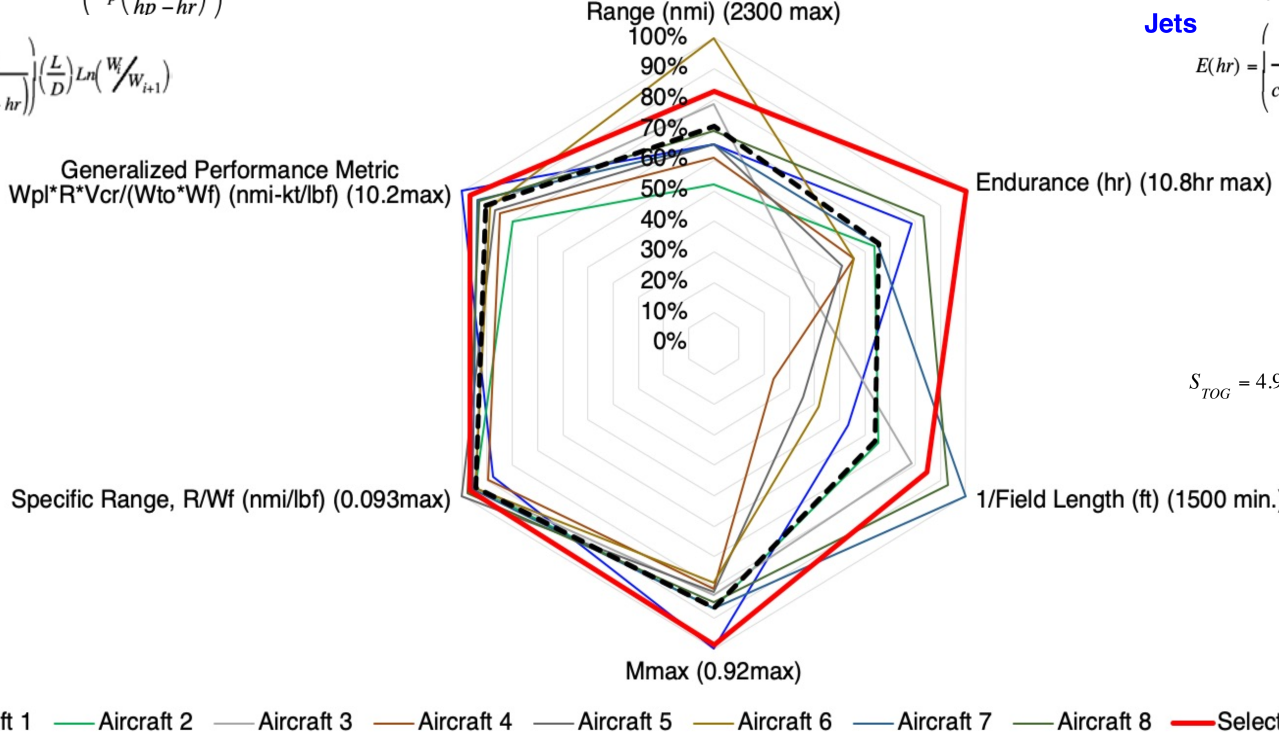
Breguet Endurance

Propeller planes

$$E(hr) = 325.9\left(\frac{nmi-lbf}{hp-hr}\right)\left(\frac{1}{V(kts)}\right)\left(\frac{\eta_p}{c_p\left(\frac{lbf}{hp-hr}\right)}\right)\left(\frac{L}{D}\right)Ln\left(\frac{W_i}{W_{i+1}}\right)$$

Jets

$$E(hr) = \left(\frac{1}{c_j\left(\frac{lbf}{lbf-hr}\right)}\right)\left(\frac{L}{D}\right)Ln\left(\frac{W_i}{W_{i+1}}\right)$$



$$S_{TOG} = 4.9TOP_{23} + 0.009TOP_{23}^2$$

$$\left.\frac{W}{P}\right|_{TO} = \frac{TOP_{23}\sigma C_{L\max TO}}{\left.\left(W/S\right)\right|_{TO}}$$

General Performance of Maritime Patrol Jet Market 2020 with 1.2*Endurance for Selected Aircraft

$$\uparrow \left.\frac{L}{D}\right|_{max} \quad \uparrow C_{LmaxTO} \quad \uparrow \frac{W_f}{W_{to}} \quad \uparrow \frac{W_{pl}}{W_{to}} \quad \uparrow V_{max} \quad \uparrow \eta_p \quad \downarrow c_p \quad \downarrow c_j$$

$$\left.\frac{L}{D}\right|_{max} = \sqrt{\frac{\pi A e}{4C_{Do}}}$$

Step 3: Objective Function

Visualization of Multi-Point Aircraft Performance

Breguet Range

Propeller planes

$$R(nmi) = 325.9\left(\frac{nmi-lbf}{hp-hr}\right)\left(\frac{\eta_p}{c_p\left(\frac{lbf}{hp-hr}\right)}\right)\left(\frac{L}{D}\right)Ln\left(\frac{W_i}{W_{i+1}}\right)$$

Jets

$$R(nmi) = \left(\frac{V(kts)}{c_j\left(\frac{lbf}{lbf-hr}\right)}\right)\left(\frac{L}{D}\right)Ln\left(\frac{W_i}{W_{i+1}}\right)$$

Breguet Endurance

Propeller planes

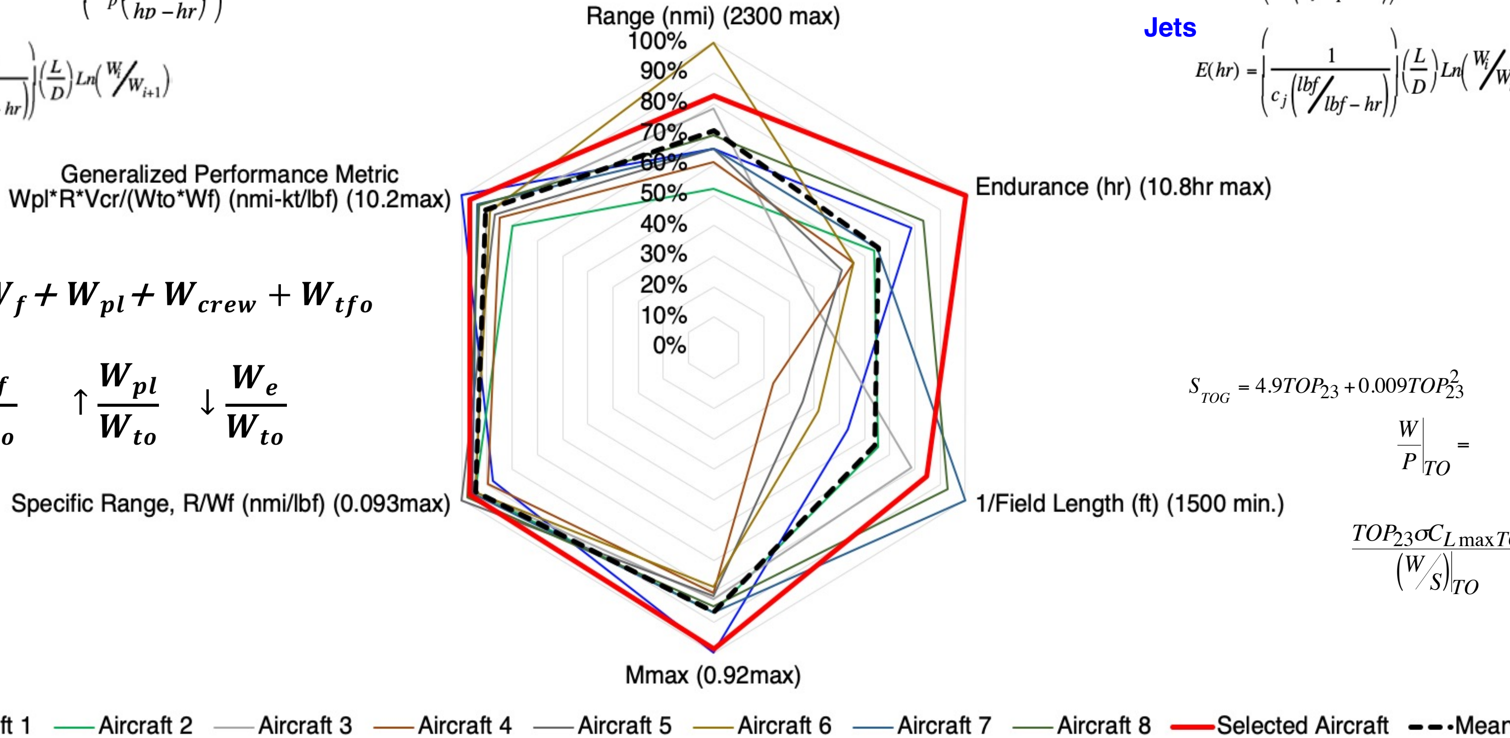
$$E(hr) = 325.9\left(\frac{nmi-lbf}{hp-hr}\right)\left(\frac{1}{V(kts)}\right)\left(\frac{\eta_p}{c_p\left(\frac{lbf}{hp-hr}\right)}\right)\left(\frac{L}{D}\right)Ln\left(\frac{W_i}{W_{i+1}}\right)$$

Jets

$$E(hr) = \left(\frac{1}{c_j\left(\frac{lbf}{lbf-hr}\right)}\right)\left(\frac{L}{D}\right)Ln\left(\frac{W_i}{W_{i+1}}\right)$$

$$W_{to} = W_e + W_f + W_{pl} + W_{crew} + W_{tfo}$$

$$\uparrow\frac{W_f}{W_{to}} \quad \uparrow\frac{W_{pl}}{W_{to}} \quad \downarrow\frac{W_e}{W_{to}}$$



General Performance of Maritime Patrol Jet Market 2020 with 1.2*Endurance for Selected Aircraft

$$S_{TOG} = 4.9TOP_{23} + 0.009TOP_{23}^2$$

$$\left.\frac{W}{P}\right|_{TO} = \frac{TOP_{23}\sigma C_{L\max TO}}{\left.\left(W/S\right)\right|_{TO}}$$

$$\uparrow\left.\frac{L}{D}\right|_{max} \quad \uparrow C_{LmaxTO} \quad \uparrow\frac{W_f}{W_{to}} \quad \uparrow\frac{W_{pl}}{W_{to}} \quad \uparrow V_{max} \quad \uparrow \eta_p \quad \downarrow c_p \quad \downarrow c_j$$

$$\left.\frac{L}{D}\right|_{max} = \sqrt{\frac{\pi Ae}{4C_{Do}}}$$

Step 3: Objective Function

Combined Objective Functions:

Apply OF to evaluate designs

$$OF = R_1 R_2 R_3 R_4 R_5 \left(5O_1 + O_2^3 + 2O_3^2 + 2O_4^{1.5} + 2O_5 \right) O_6^1 \sqrt{O_7}$$

Wing Mounted Engines			
+	Reduced Cabin Noise	–	Engine Maintenance
+	Low CG excursion	–	Engine Placement w/ respect to Engine Non-Containment Event
+	Co-Locate Landing Gear & Engine Pylon Structure		
+	Reduced Risk of Engine FOD		

Figure 6-14: Wing Mounted Engines

Three Surface			
+	Co-Locate Wing Spar & Rear Bulkhead	–	Landing Gear Integration
		–	Not Widely Accepted
+	Low Trim Drag		
+	Passenger Ground View		
+	High L/D		

Figure 6-15: Three Surface

Step 3: Objective Function

Combined Objective Functions:

Apply OF to evaluate designs

$$OF = R_1 R_2 R_3 R_4 R_5 \left(5O_1 + O_2^3 + 2O_3^2 + 2O_4^{1.5} + 2O_5 \right) O_6^1 \sqrt{O_7}$$

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Figure 6-14: Wing Mounted Engines

$$OF = 3.62$$

Three Surface			
+	Co-Locate Wing Spar & Rear Bulkhead	–	Landing Gear Integration
+	Low Trim Drag	–	Not Widely Accepted
+	Passenger Ground View		
+	High L/D		

Figure 6-15: Three Surface

$$OF = 2.91$$

Step 3: Objective Function

Combined Objective Functions:

Apply OF to evaluate designs

$$OF = R_1 R_2 R_3 R_4 R_5 \left(5O_1 + O_2^3 + 2O_3^2 + 2O_4^{1.5} + 2O_5\right) O_6^1 \sqrt{O_7}$$

Wing Mounted Engines	
+ Reduced Cabin Noise	– Engine Maintenance
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Figure 6-14: Wing Mounted Engines

$OF = 3.62$ ✓

Three Surface	
+ Co-Locate Wing Spar & Rear Bulkhead	– Landing Gear Integration
+ Low Trim Drag	– Not Widely Accepted
+ Passenger Ground View	
+ High L/D	

Figure 6-15: Three Surface

$OF = 2.91$

Step 3: Objective Function

Design Characteristics List:

Certification Base: FAR-25

Entry into Service:
EIS 2030 -100, EIS 2031 -200

Passengers:
30" pitch, 50 pax -100, 76 -200

Range:
2,000nmi -100, 1,500nmi -200

Cruise Mach: 0.78 (R), 0.80 (O)

Seat Width: 17.2" (R), 18" (O)

Wingspan: < 24m (O), < 36m (R)

Approach Speed: V_A < 141kts

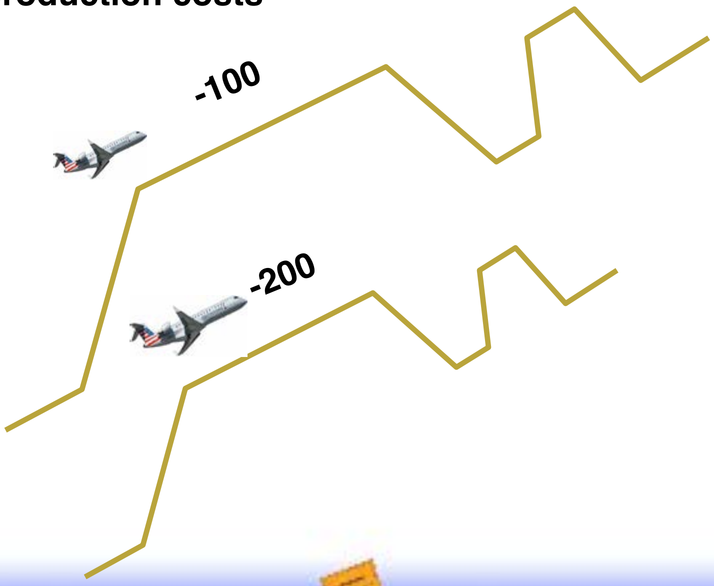
Takeoff Field Length:
5kft MSL, ISA+18, 4,000/50ft -100 6,000/50ft -200

Landing Field Length:
5kft MSL, ISA+18, 4,000/50ft -100 6,000/50ft -200

Crew: Pilot, Copilot, 1 F/A -100, 2 F/A's -200

Specified Design Objectives:

1. Maximize structural commonality between -100 & -200
2. Good aesthetics
3. Enhanced Reliability WRT SOTA
4. Reduced MRO load WRT SOTA
5. Minimize DOC
6. Minimize production costs



Step 3: Objective Function

Objective Function with Anciliary Objectives:

Ancillary Design Considerations

1. Reduce total fuel burn to most efficient in class
2. Minimize Time on Ground per Turn
3. Under FAA 90 sec. Evacuation requirement
4. Rapid Cabin Sterilization
5. Exceed most stringent EASA noise regulations for RJ's
6. Special accommodations for business travelers
7. Allow pax to have ready access to all luggage without wait
8. Allow for growth of the physical dimensions of the traveling public
9. Operate from austere airports with neither jetways nor air-stairs
10. Allow for rapid powerplant inspection, LRU replacement, drop
11. Enable all normal ground operations with engines running
12. Minimal to no de-icing dispatch delays
13. Powerplants reachable without special equipment
14. Minimize number of engine start cycles per operational day
15. Allow for powerplant diameter growth with time without significant aircraft changes
16. ADA compliant cabin section, ingress and egress from ground w/o special equipment

Step 3: Objective Function

11 Requirements Weighting Functions from the Design Characteristics:

R_1: Certification Base: FAR-25
R_2: Entry into Service: EIS 2030 -100, EIS 2031 -200
R_3: Passengers: 30" pitch, 50 pax -100, 76 -200
R_4: Range: 2,000nmi -100, 1,500nmi -200
R_5: Cruise Mach: ≥0.80
R_6: Seat Width: ≥18"
R_7:(Folded) Wingspan: ≤ 24m
R_8: Approach Speed: V_A < 141kts
R_9: Takeoff Field Length: 5kft MSL, ISA+18, 4,000/50ft -100 6,000/50ft -200
R_{10}: Landing Field Length: 5kft MSL, ISA+18, 4,000/50ft -100 6,000/50ft -200
R_{11}: Crew: Pilot, Copilot, 1 F/A -100, 2 F/A's -200

6 Objectives Weighting Functions from the Specified Design Objectives:

O_1: Maximize structural commonality between -100 & -200
O_2: Good aesthetics
O_3: Enhanced Reliability WRT SOTA
O_4: Reduced MRO load WRT SOTA
O_5: Minimize DOC
O_6: Minimize production costs

16 Objectives Weighting Functions from Anciliary Objectives:

AO_1: Reduce total fuel burn to most efficient in class
AO_2: Minimize Time on Ground per Turn
AO_3: Under FAA 90 sec. Evacuation requirement
AO_4: Rapid Cabin Sterilization
AO_5: Exceed most stringent EASA noise regulations for RJ's
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Step 3: Objective Function

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Step 3: Objective Function

How to Handle Requirements Weighting Functions:

11 Requirements Weighting Functions from the Design Characteristics:

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R_{11}: Crew: Pilot, Copilot, 1 F/A -100, 2 F/A's -200

Step 3: Objective Function

How to Handle Requirements Weighting Functions:

11 Requirements Weighting Functions from the Design Characteristics:

R_1: Certification Base: FAO-25
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R_{10}: Landing Field Length: 5kft MSL, ISA+18, 4,000/50ft -100 6,000/50ft -200
R_{11}: Crew: Pilot, Copilot, 1 F/A -100, 2 F/A's -200

Just meet them all...

Step 3: Objective Function

How to Handle Specificed Objectives Weighting Functions:

6 Objectives Weighting Functions from the Specified Design Objectives:

O_1: Maximize structural commonality between -100 & -200
O_2: Good aesthetics
O_3: Enhanced Reliability WRT SOTA
O_4: Reduced MRO load WRT SOTA
O_5: Minimize DOC... Or is it Maximize DOP?
O_6: Minimize production costs

Step 3: Objective Function

How to Handle Specificed Objectives Weighting Functions:

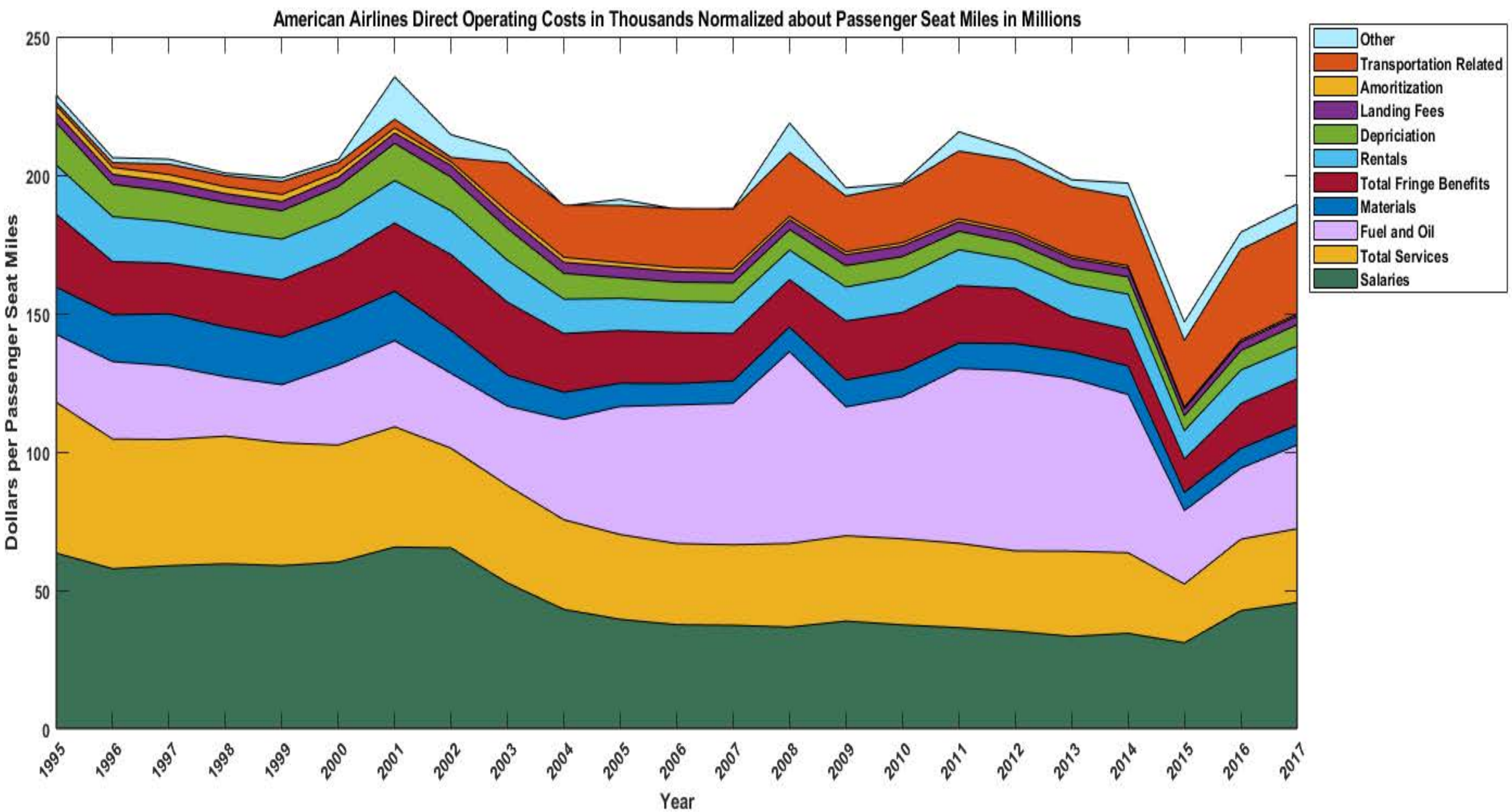
6 Objectives Weighting Functions from the Specified Design Objectives:

O_1: Maximize structural commonality between -100 & -200
O_2: Good aesthetics
O_3: Enhanced Reliability WRT SOTA
O_4: Reduced MRO load WRT SOTA
O_5: Minimize DOC ... Or is it Maximize DOP?
O_6: Minimize production costs

Develop methods to weight each value from 0 to 1. If guidance is given on their relative importance with respect to each other, apply such weighting.

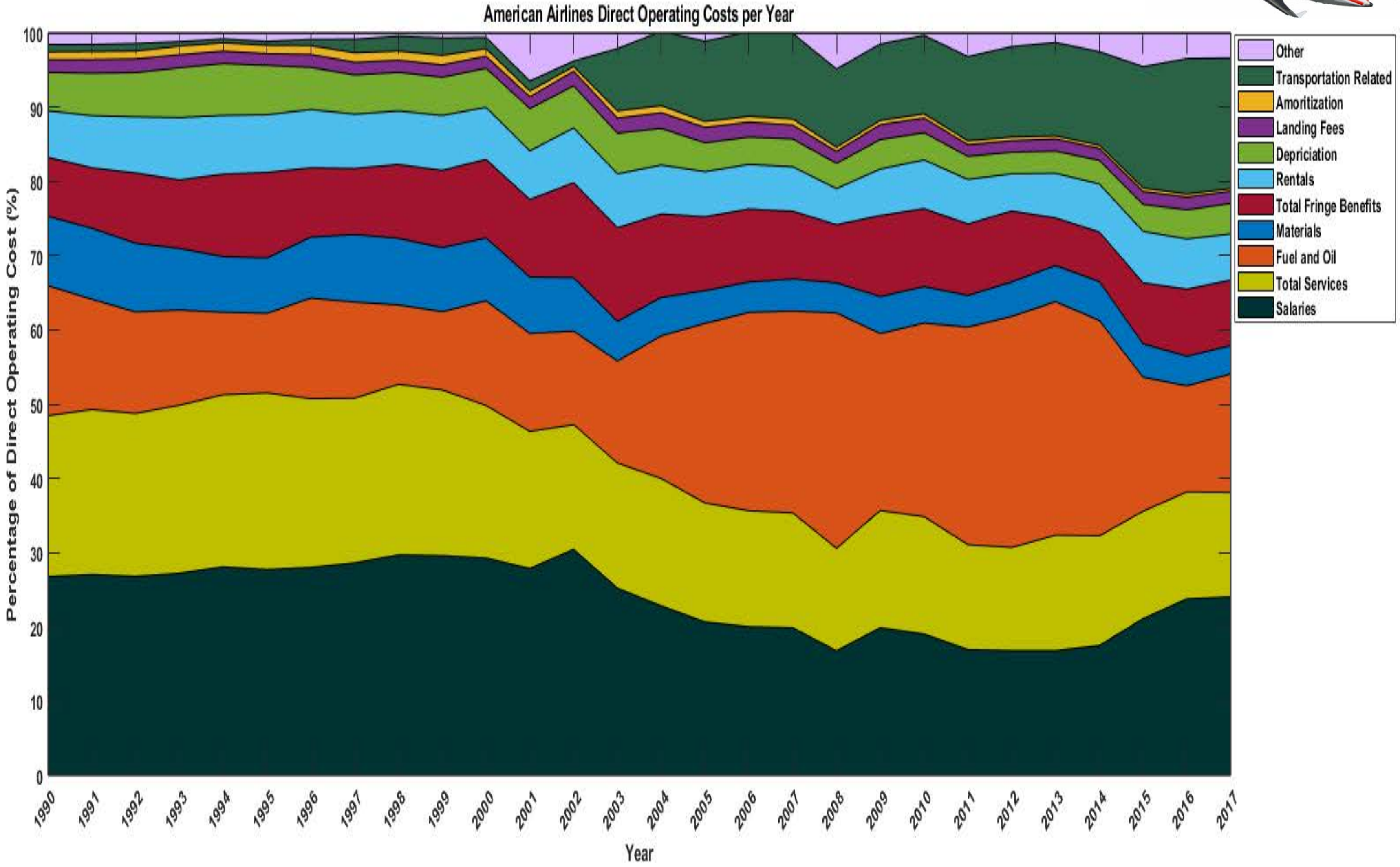
Step 3: Objective Function

Recall...



Step 3: Objective Function

Recall...



Step 3: Objective Function

How to Handle Specificed Objectives Weighting Functions:

6 Objectives Weighting Functions from the Specified Design Objectives:

O_1: Maximize structural commonality between -100 & -200

0 if no part by weight is common between the two, 1 if all parts can be made with the same tooling jigs, procedures and processes

$$O_1 = \left| \frac{weight\ of\ items\ that\ use\ the\ same\ tooling, jigs\ and\ processes\ between\ the\ -100\ and\ -200\ aircraft}{W_{e-100} + W_{e-200}} \right|$$

O_2: Good aesthetics

O_2 = 0 if ranked the worst aircraft among surveyed candidates, 1 if best among candidates, rank ordered in between

O_3: Enhanced Reliability WRT SOTA

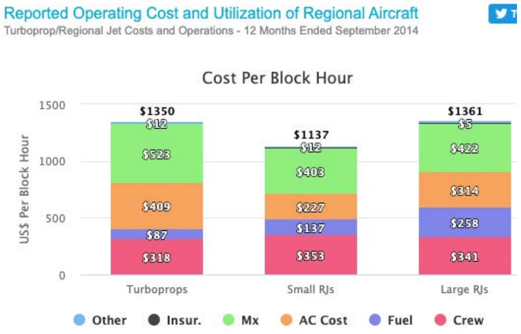
O_3 = 0 if < SOTA 99.7% Dispatch Reliability (Brooks, Robert, "Embraer Draws Regional Jet Order Worth Up to $1 B," 2014.)

O_3 = 333(DR – 0.997) if > SOTA 99.7% Dispatch Reliability

O_4: Reduced MRO load WRT SOTA

O_4 = 0 if T_O < 18,000hrs (14,400cycles) MTBO (GE Aviation, "CF34-10E Engines Outperforming Expectations," May 2014, https://www.aerocontact.com/en/virtual-aviation-exhibition/product/545-cf34-8e-ge-aviation, 1.25 flt hrs/cycle)

$O_4 = \frac{T_O}{42{,}000} - \frac{3}{7}$ **if T_O > 18,000hrs MTBO (considering maximum airframe life of 60,00**



O_5: Minimize DOC ... Or is it Maximize DOP?

O_5 = 0 if DOC > $1,361 ($2014) (https://www.planestats.com/bhsr_2014sep)

$$O_5 = 4\frac{\$1{,}361 - DOC}{\$1{,}361}\ if\ DOC < 1{,}361$$

O_6: Minimize production costs, $C_{pro} \propto C_{acq} \propto W_{TO}$

O_6 = 0 if $W_{TO} > W_{TOref}$

$$O_6 = 4\frac{W_{TOref} - W_{TO}}{W_{TOref}}\ if\ \ W_{TO} < W_{TOref}$$

Step 3: Objective Function

How to Handle Anciliary Objectives Weighting Functions:

16 Objectives Weighting Functions from Anciliary Objectives:

AO_1: Reduce total fuel burn to most efficient in class
AO_2: Minimize Time on Ground per Turn
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AO_{16}: ADA compliant cabin section, ingress and egress from ground without special equipment

Develop methods to weight each value from 0 to 1. If guidance is given on their relative importance with respect to each other, apply such weighting.

Step 3: Objective Function

How to Handle Anciliary Objectives Weighting Functions:

	Configuration 1 Scores	Configuration 2 Scores	Configuration 3 Scores
O_1: Maximize structural commonality between -100 & -200	1	1	0.9
O_2: Good aesthetics	0.9	0.8	0.6
O_3: Enhanced Reliability WRT SOTA	0	0	0
O_4: Reduced MRO load WRT SOTA	0.5	0.4	0.4
O_5: Minimize DOC	0.1	0.05	0.05
O_6: Minimize production costs	0.1	0.1	0.05
Sum:	2.6	2.35	2
Weighted Sum (ROWF = 2):	0.87	0.78	0.67
AO_1: Reduce total fuel burn to most efficient in class	1	0	0
AO_2: Minimize Time on Ground per Turn	1	0	0
AO_3: Under FAA 90 sec. Evacuation requirement	1	1	1
AO_4: Rapid Cabin Sterilization	1	1	1
AO_5: Exceed most stringent EASA noise regulations for RJ's	1	1	0
AO_6: Special accommodations for business travelers	1	1	1
AO_7: Allow pax to have ready access to all luggage without wait	1	1	1
AO_8: Allow for growth of the physical dimensions of the traveling public	1	1	1
AO_9: Operate from austere airports with neither jetways nor air-stairs	1	1	1
AO_{10}: Allow for rapid powerplant inspection, LRU replacement, drop	1	1	1
AO_{11}: Enable all normal ground operations with engines running	1	1	1
AO_{12}: Minimal to no de-icing dispatch delays	1	1	1
AO_{13}: Powerplants reachable without special equipment	1	1	1
AO_{14}: Minimize number of engine start cycles per operational day	1	1	1
AO_{15}: Allow for powerplant diameter growth with time without significant aircraft changes	1	1	1
AO_{16}: ADA compliant cabin section, ingress and egress from ground without special equipment	1	1	1
Sum:	16	14	13
Weighted Sum:	1	0.875	0.8125
Total Score:	1.87	1.66	1.48

Step 3: Objective Function

Objective Function with Financial Analysis:

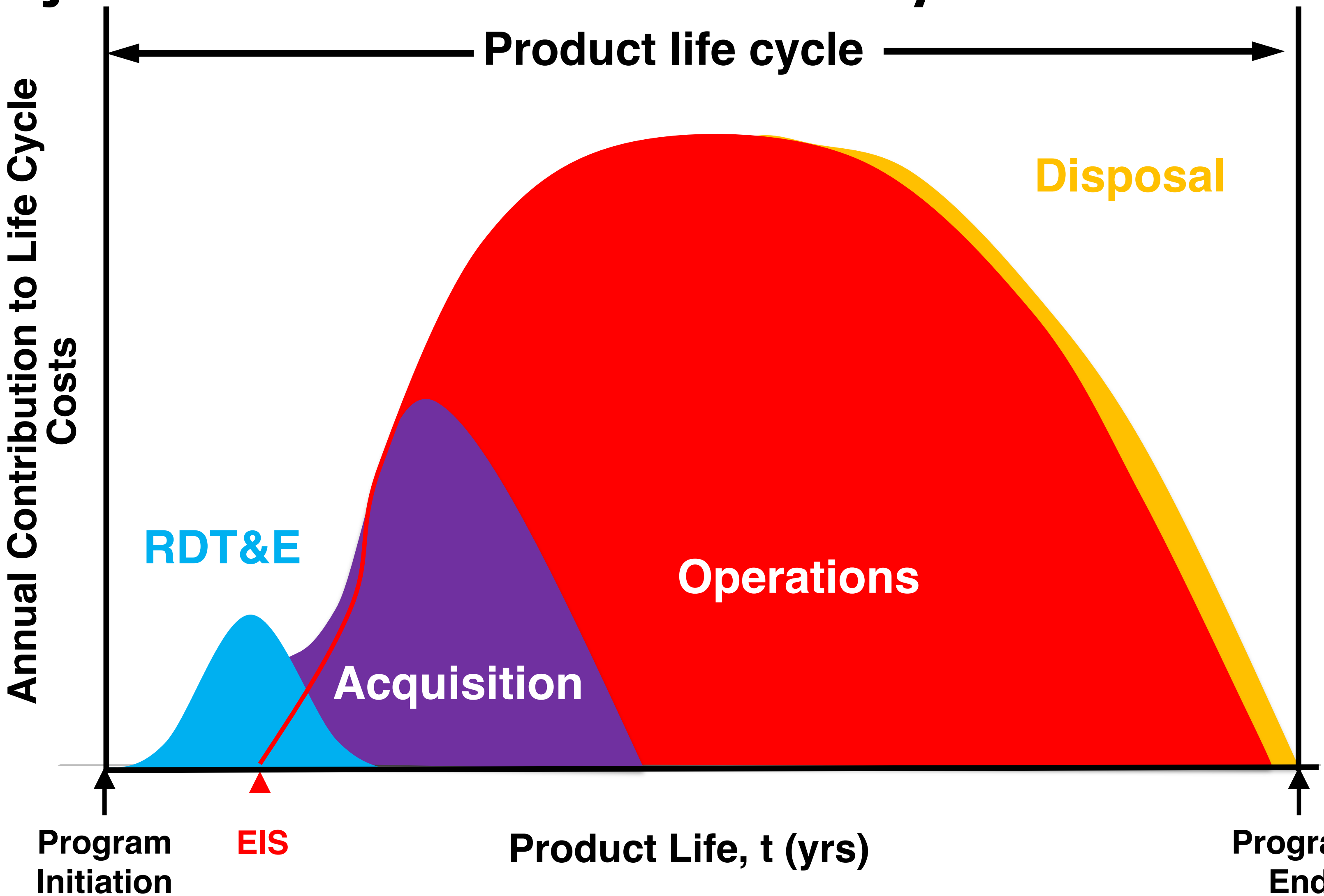
Example Weighting Exercise:

Profit = Earnings - Costs

Life Cycle Profit = Life Cycle Earnings – Life Cycle Costs

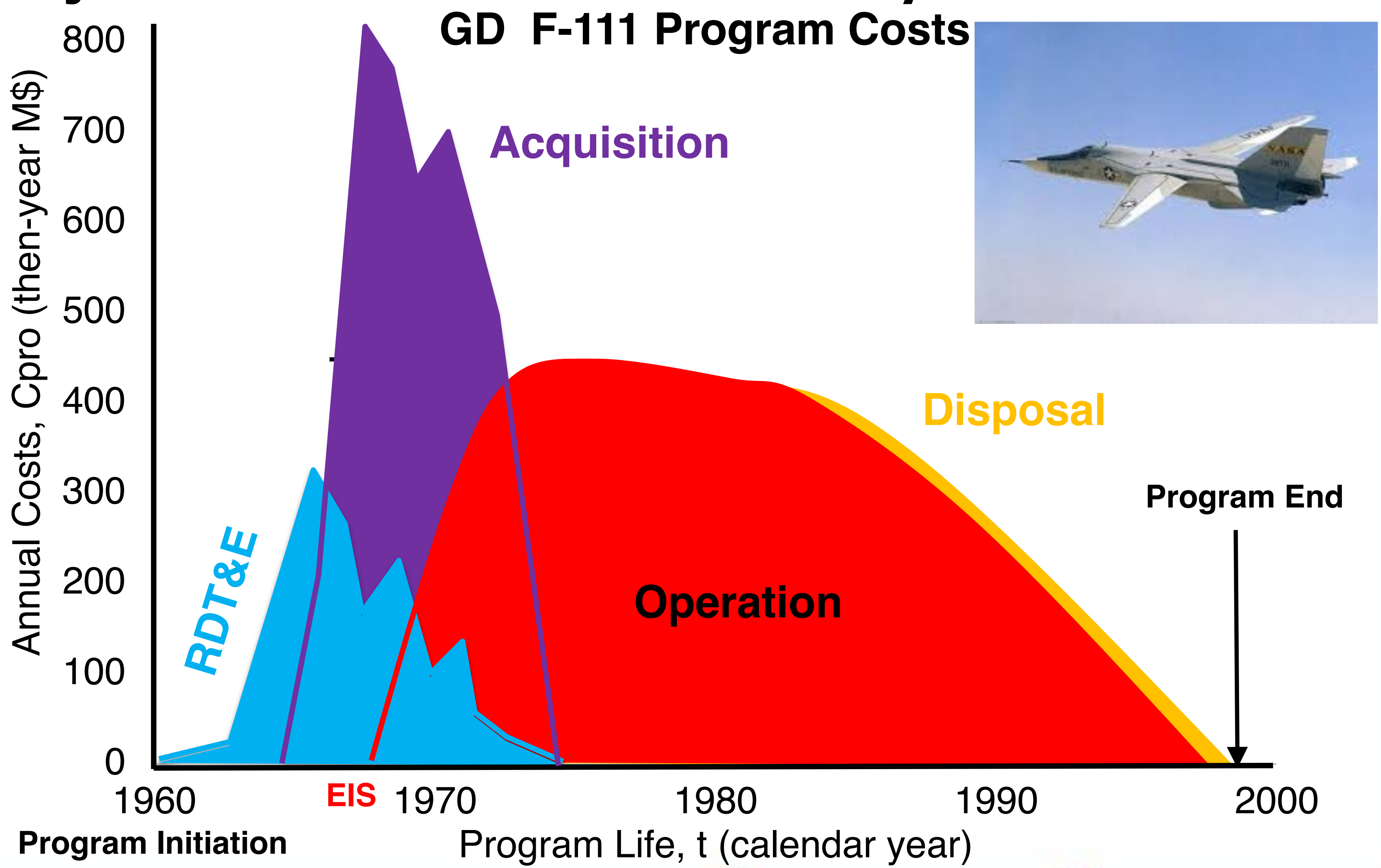
Step 3: Objective Function

Objective Function with Financial Analysis:



Step 3: Objective Function

Objective Function with Financial Analysis:



Step 3: Objective Function

Objective Function with Financial Analysis:

Example Weighting Exercise -- airliners

1. Examine the many cost categories for that product

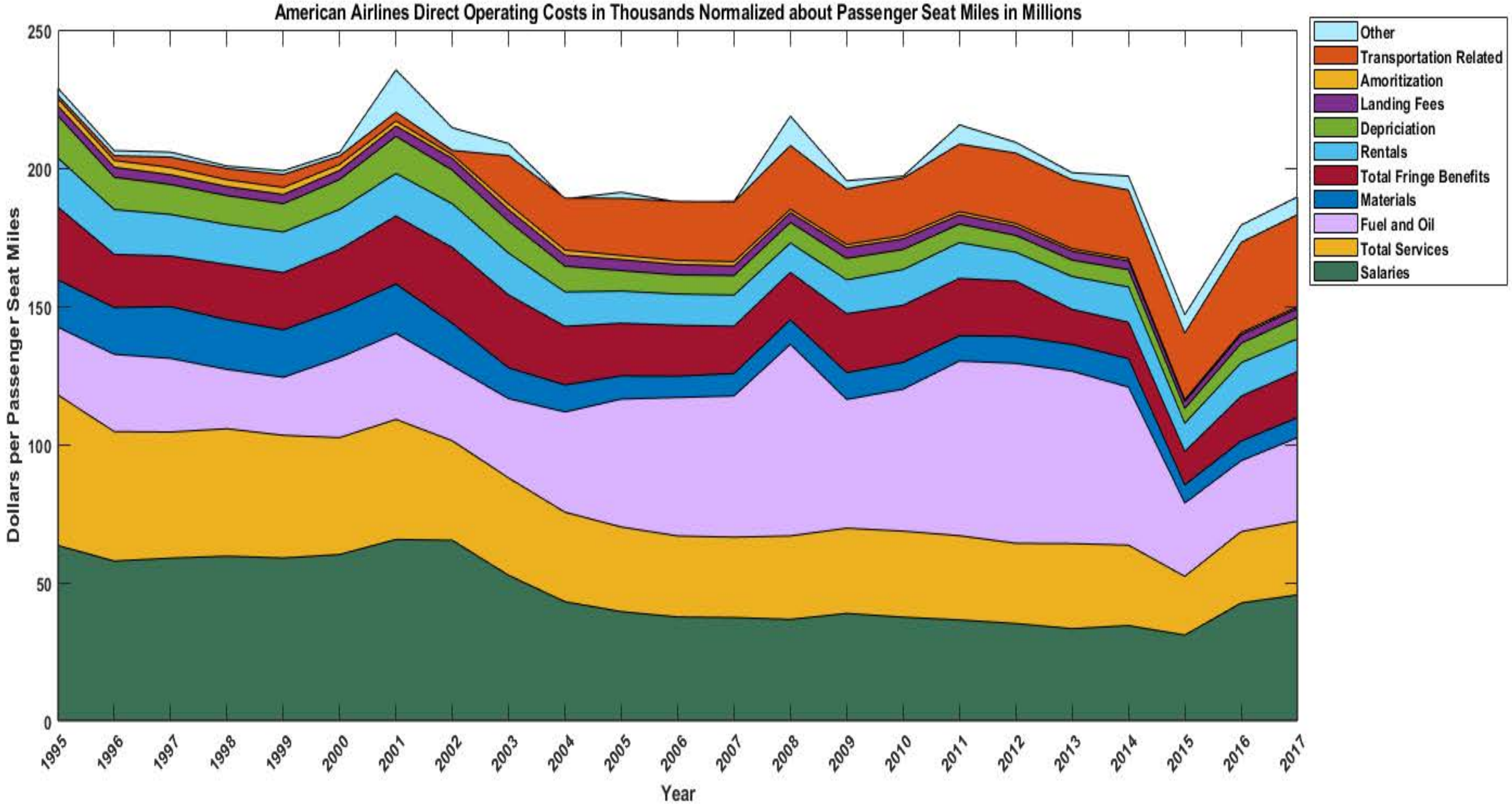
Component	Build Up
Salaries	Management Salaries, Flight Personnel Salaries, Maintenance Salaries, Aircraft and Traffic Handling Salaries, Other Salaries
Total Fringe Benefits	Personnel Expenses, Employee Benefits and Pensions, Payroll Taxes
Fuel and Oil	Fuel and Oil
Materials	Maintenance Materials, Passenger Food, Other Materials
Total Services	Advertising, Communication, Insurance, Outside Flight Equipment Maintenance, Passenger Traffic Commissions, Cargo Traffic Commissions, Other Services
Landing Fees	Landing Fees
Rentals	Rentals
Depreciation	Depreciation
Amortization	Amortization
Other	Other
Transportation Related Expenses	Transportation Related Expenses (AOG spares, shipping components, weather delay fees, passenger accommodations)

Step 3: Objective Function

Objective Function with Financial Analysis:

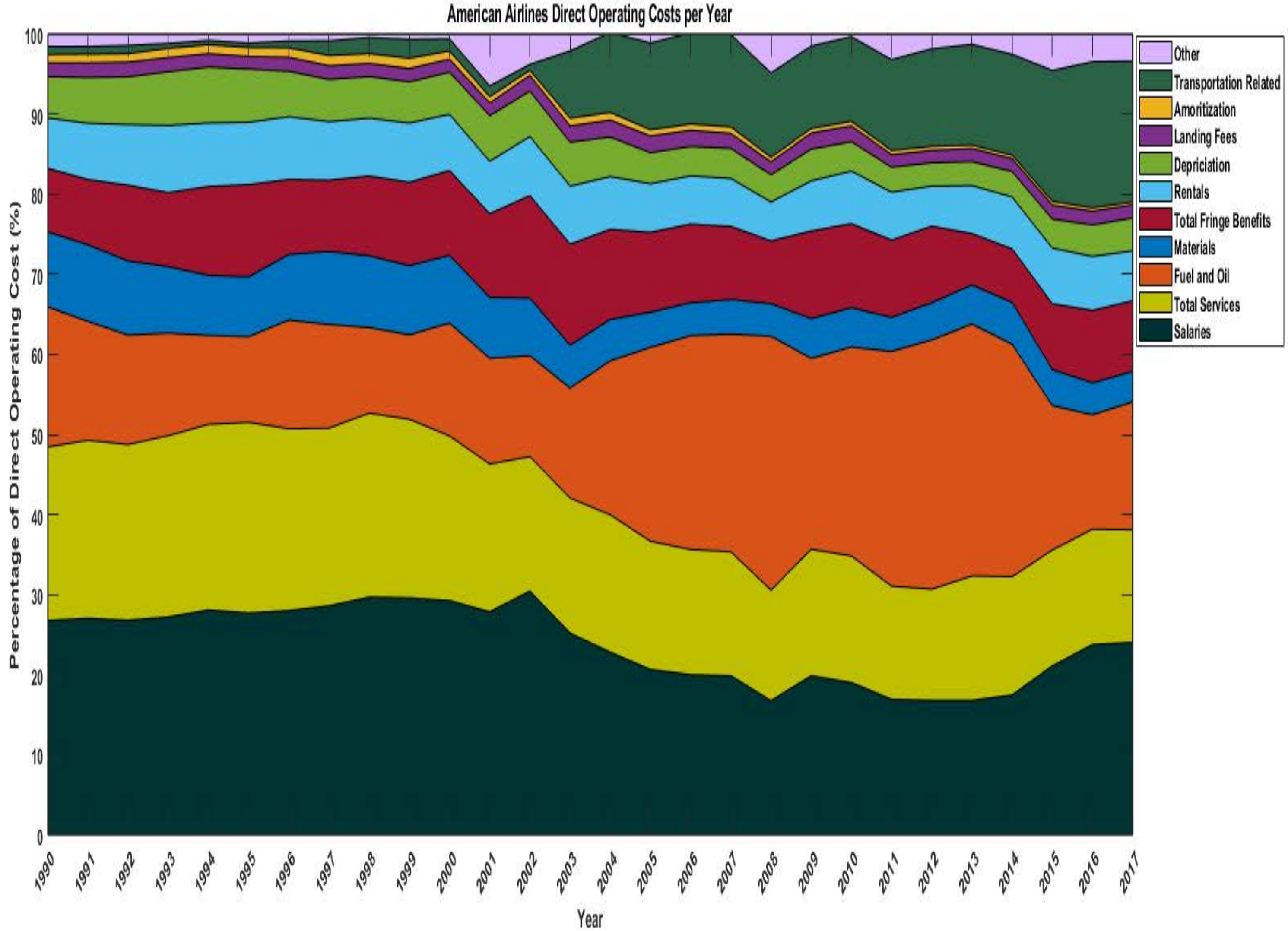
Example Weighting Exercise -- airliners

Determine the statistical distributions of the affected cost components



Step 3: Objective Function

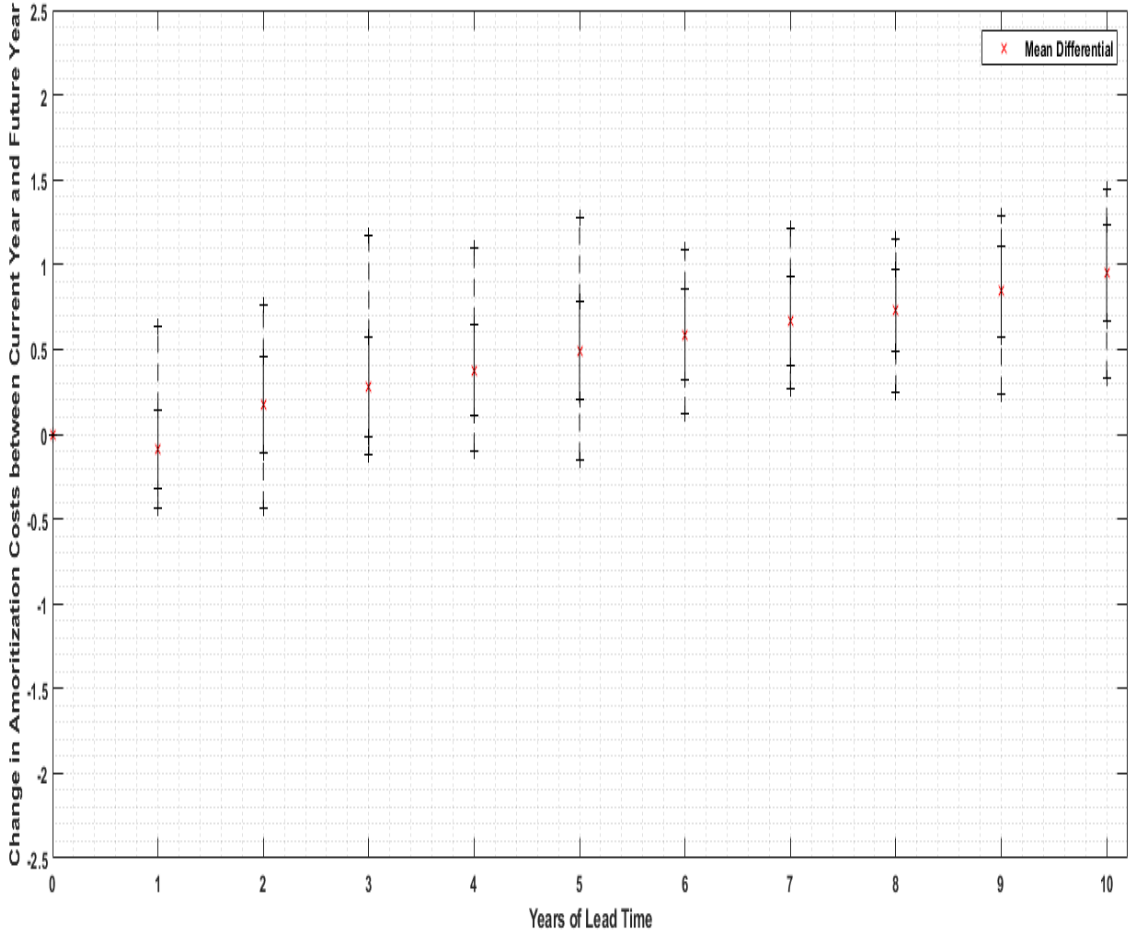
Objective Function with Financial Analysis:



Step 3: Objective Function

Objective Function with Financial Analysis:

Get statistical distributions of each cost component and track with time



Step 3: Objective Function

Objective Function with Financial Analysis:

Example Weighting Exercise -- airliners

Estimate % of DOC for each category over expected lifetime:

$$OF = R_1R_2R_3R_4R_5\begin{pmatrix} 0.26O_{1sal} + 0.04O_{2frn} + 0.18O_{3fuel} + 0.11O_{4mat} + 0.11O_{4mat} + 0.08O_{5svc} + \\ +0.03O_{6lfees} + 0.05O_{7rent} + 0.09O_{8dep} + 0.03O_{9amr} + 0.06O_{10otr} + 0.07O_{11Xprt} \end{pmatrix}$$

Component	Build Up
O1 = Salaries (26%)	Management Salaries, Flight Personnel Salaries, Maintenance Salaries, Aircraft and Traffic Handling Salaries, Other Salaries
O2 = Total Fringe Benefits (4%)	Personnel Expenses, Employee Benefits and Pensions, Payroll Taxes
O3 = Fuel and Oil (18%)	Fuel and Oil
O4 = Materials (11%)	Maintenance Materials, Passenger Food, Other Materials
O5 = Total Services (8%)	Advertising, Communication, Insurance, Outside Flight Equipment Maintenance, Passenger Traffic Commissions, Cargo Traffic Commissions, Other Services
O6 = Landing Fees (3%)	Landing Fees
O7 = Rentals (5%)	Rentals
O8 = Depreciation (9%)	Depreciation
O9 = Amortization (3%)	Amortization
O10 = Other (6%)	Other
O11 = Transportation Related Expenses (7%)	Transportation Related Expenses (AOG spares, shipping components, weather delay fees, passenger accommodations)