Identifying the Requirements and Design Variables for New Aircraft Considering Fleet-Level Objectives Under Uncertainties

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Research Task / Overview

- Can we identify a quantitative approach to determine the "right requirements" for a new system?
- Can we concurrently optimize multiple systems?
- Can this approach address multi-domain uncertainties?

Goals & Objectives

Develop decision support framework that:

- Assists decision-maker or acquisition practitioner to identify new system requirements that improve (maximize) system-level objective
- Allows new system to operate along with the existing system
- Addresses multi-domain uncertainties and uncertainty propagation

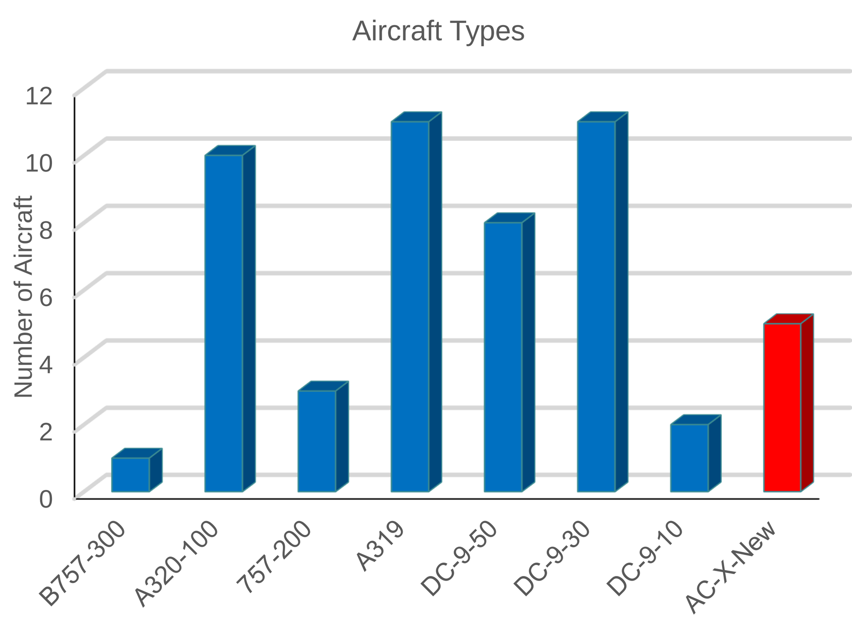
Data & Analysis

Case - Study

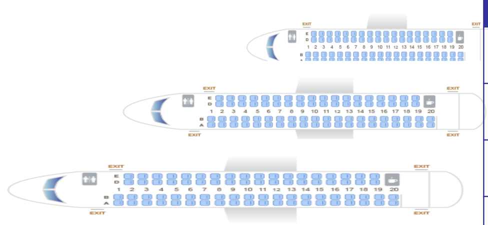
- A notional 31-route network airline with hub at Memphis

Source: Great Circle Mapper (www.gcmap.com)

- Airline has 7 different aircraft types currently in its fleet (blue bars)
- User-determined 5 new aircraft to be acquired (red bar)

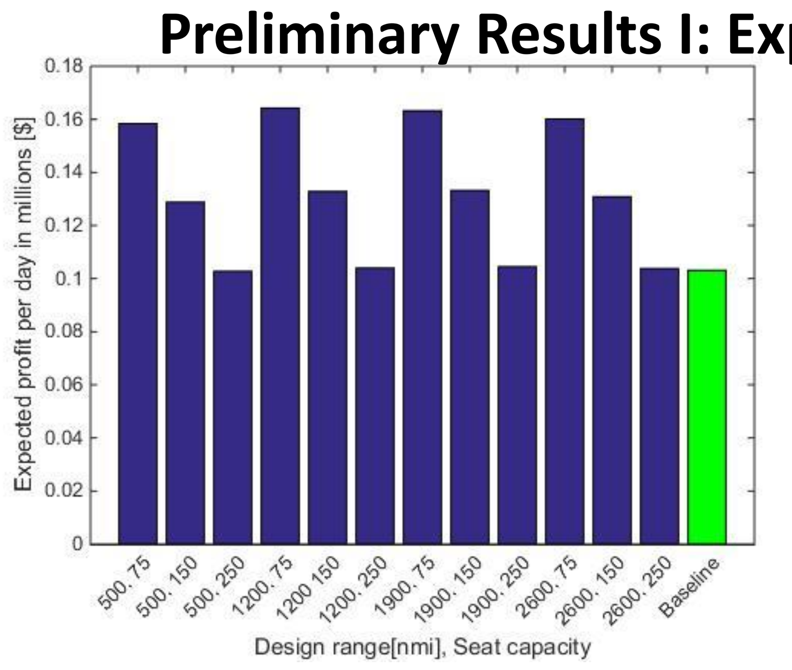


Design variables at top level problem for enumeration



Seat Capacity	Design Range [nautical miles]
75	2600
150	1900
250	1200
	500

Preliminary Results I: Expected Fleet Profit



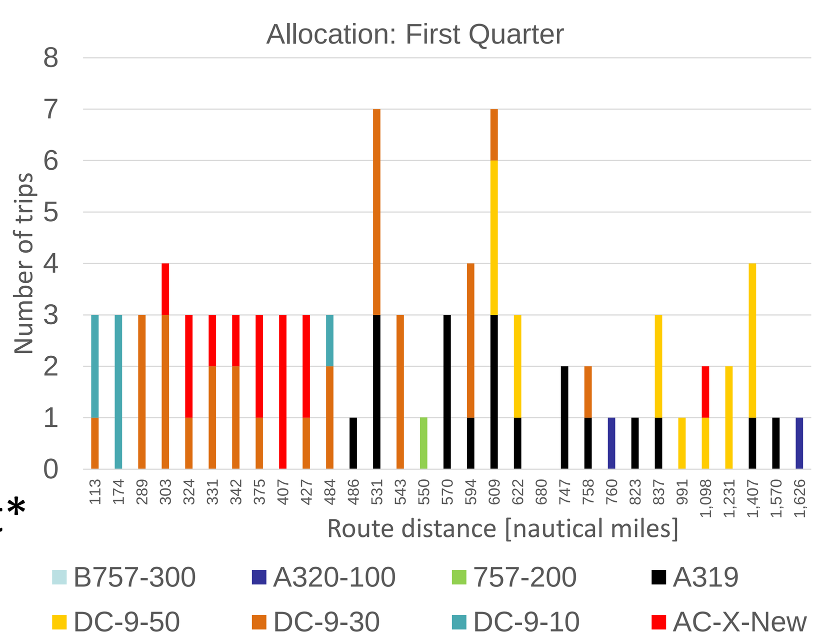
- Green bar denotes baseline fleet with no new aircraft type-X in use
- 75 seats has higher expected profit
- 75 seats with 1200nmi design range leads to highest fleet expected profit

Preliminary Results II: Design-Allocation Subspace

Optimal Design Variables

Top Level (aircraft requirements)	
Design Range [nautical miles]	1200
Seat Capacity	75
Aircraft Design Subspace	
Aspect ratio	12.0
Taper ratio	0.3
Thickness to chord ratio	0.095
Wing area [sq. ft]	664.76
Wing sweep (LE) [deg]	13.22
Thrust per engine [lbs]	9351

Source: Delta Cargo



- Result resembles Embraer 175 type aircraft*
- Optimized w.r.t. this airline network

- Acquisition practitioner seeks customized aircraft tailored towards their operational behavior
- Aircraft manufacturer wants to sell aircraft to multiple customers – Changing to a multi-objective approach at the top level would facilitate this

* Limited by the fidelity of the aircraft sizing tool used in the study

Methodology

Objective

Maximize fleet level expected profit

Variables

New aircraft requirements (design range, seat capacity)

New aircraft design variables (NLP: Nonlinear Programming)

Aspect ratio, taper ratio, wing sweep, engine thrust etc.

Allocation variables (MIP: Mixed integer programming)

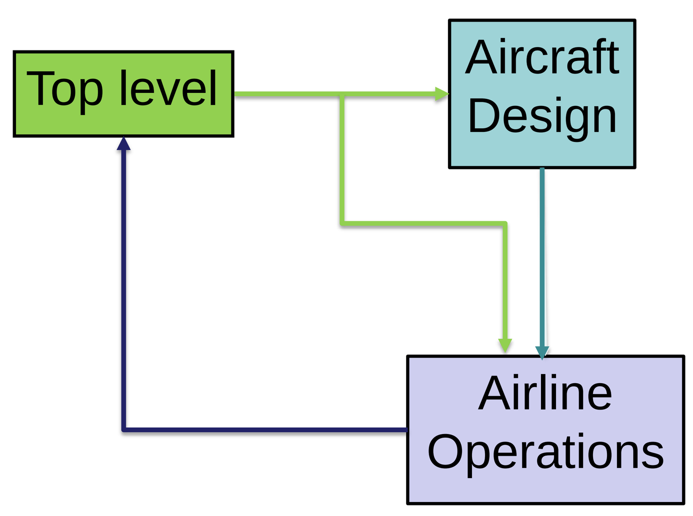
Trips, passengers carried on a particular route

Constraints

Passenger demand

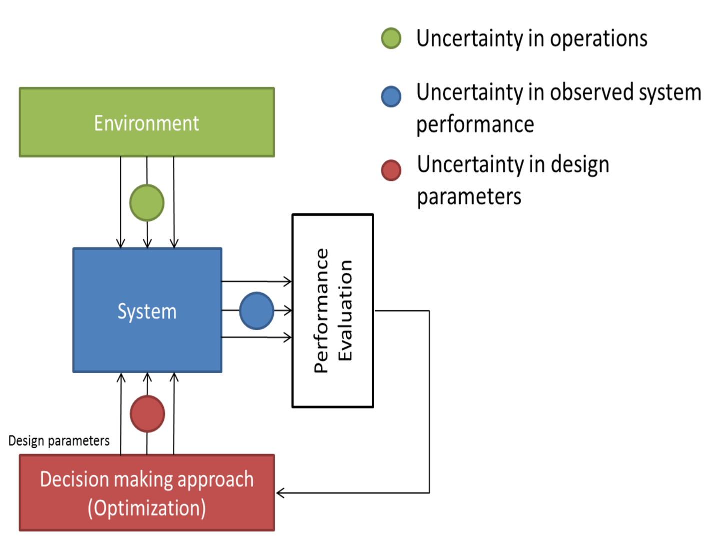
Aircraft performance (takeoff distance, landing distance etc.)

Fleet operations (maximum operational hours, number of each aircraft types etc.)



Sequential Decomposition Approach

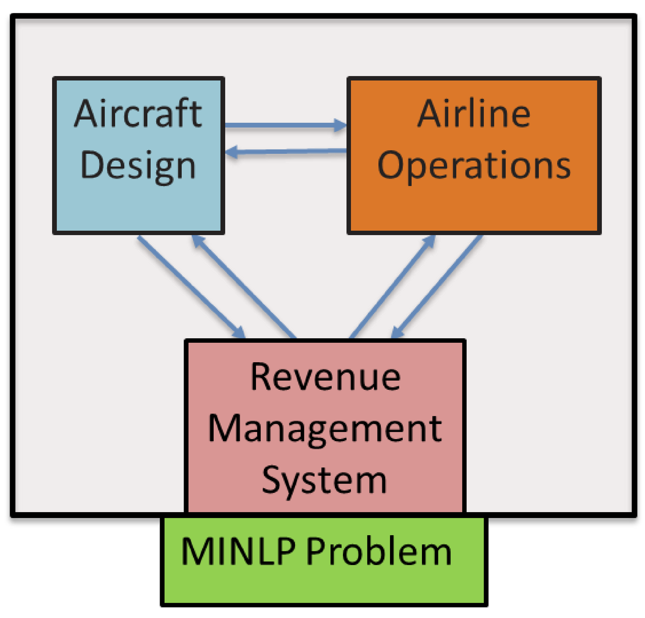
Addressing Uncertainty



- Reliability-based design optimization (RBDO) formulation to handle *uncertainty in new system design*
- Descriptive sampling approach to handle *uncertainty in passenger demand*
- Propagation of uncertainty from aircraft sizing subspace
  - Performance of new aircraft is uncertain
  - Coefficients in allocation problem have distributions
- Used a 'Robust Optimization' approach
  - Interval Robust Counterpart (IRC) formulation: Optimize considering the nominal and worst-case values of uncertain parameters within a pre-defined tolerance limit

Future Research

- Alternate approach to address multi-domain problems as Mixed-Integer Non-Linear Programming (MINLP) problem
  - Requires a new MINLP solving approach to address complex tightly coupled systems
  - **AMIEGO** (**A M**ixed **I**nteger **E**fficient **G**lobal **O**ptimization) - A MINLP solver to address Aircraft design and Airline allocation as MINLP problem (under development)
  - Would enable to integrate other complex systems
  - For example, an integrated Revenue Management System will enable to decide the ticket prices under uncertain demand (under development)



Contacts/References

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