# Project 85
# Strategies for Improving En-Route Fuel Efficiency

ASCENT

Georgia Tech
Aerospace Systems Design Laboratory

## Motivation

- Research focuses on near-term operational improvements and quantifies the impact on aviation, by investigating **en-route fuel efficiency**
- The outcome of this research is the identification of **operational strategies** to **improve en-route fuel burn** by **absorbing terminal delays** via lower cruise speeds

## Research Approach

**Data Exploration**

Exploration of historical flights to assess potential for delay absorption

**Task 1: Speed control event detection in FOQA data**

**Task 2: Holding pattern detection in FOQA and Threaded Track (TT) data**

- Holding pattern duration
- Look-ahead time for potential slow down

**Modeling**

Simulation of slowed-down flight trajectories and quantification of fuel burn

**Task 3: Development of surrogate models for fuel burn quantification**

**Task 4: Investigation of speed reduction on historical flight trajectories**

Single Flight Fuel Savings

**Task 5: Next Steps Architecting strategies for fleet wide delay absorption**

## Task 1: Speed Control Event Detection in FOQA Data

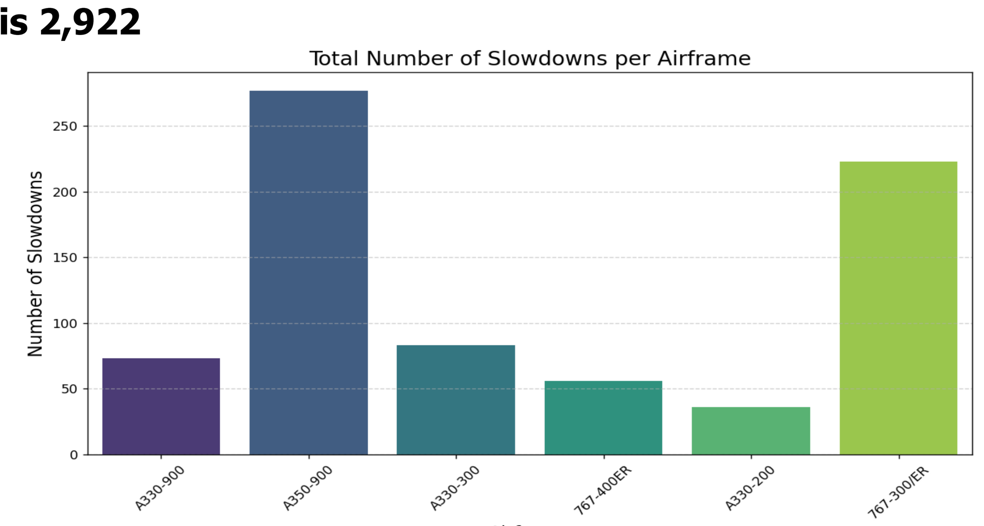
**Objective:** Use speed change analysis (changepoint analysis) to **uncover speed control events** within the 50,000-flight FOQA dataset

### Process

1) Changepoint algorithm **detects shifts in mean Mach number** along **constant altitude** cruise segments to identify speed change events
2) **Gradual shifts** (FMC driven) and speed changes concurrent with **turbulence events** are filtered out
3) Results find potential **intentional slow-downs** intended to manipulate the ETA

### Algorithm Results

Below are the results showing the total number of speed control events (slow-downs) for each widebody airframe. **The total number of medium and long-haul widebody flights considered is 2,922**



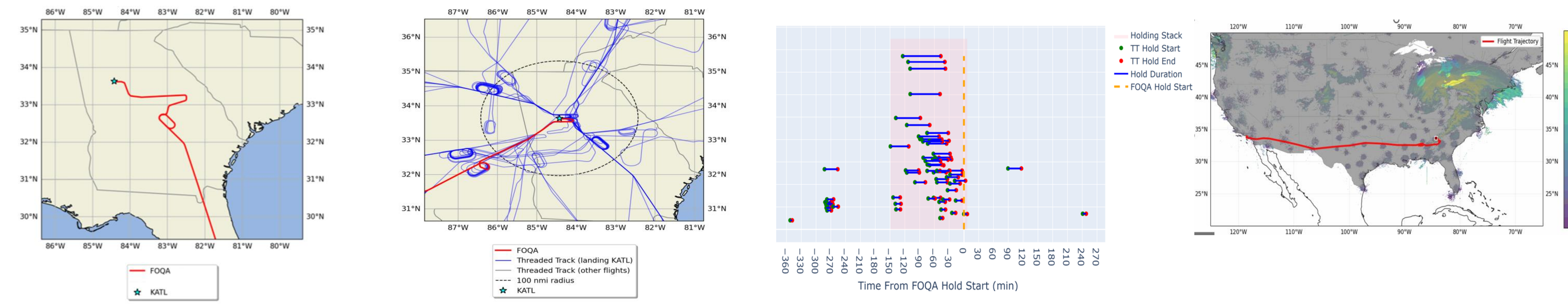

**Takeaway:** Speed control seems to be already practiced by some airlines. Absorbing terminal delays via lower cruise speeds is thus an operationally promising path to improve en-route fuel efficiency. System-wide implementation may yield significant benefits

## Task 2: Holding Patterns Detection in FOQA and TT Data

**Objective:** Assess **prevalence of holding patterns** and identify flights of interest for speed control simulation to estimate delay statistics (look-ahead time, holding duration)

### Process

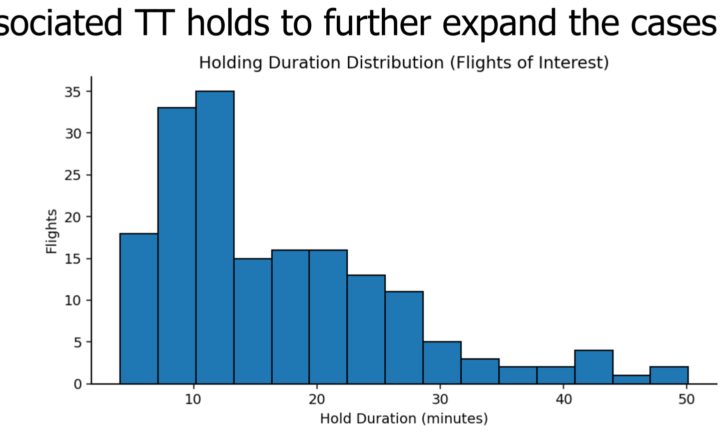
1. **Identify FOQA holds** — Identify FOQA holds using self-intersections and quantify fuel burn
2. **Identify associated TT holds** — Query flights within the FOQA hold window and 100 NM of the airport to identify TT holds
3. **Identify the holding stacks** — Identify the look-ahead time and holding stack statistics
4. **Identify potential holding causes** — Analyze the METAR data to identify the cause of the hold

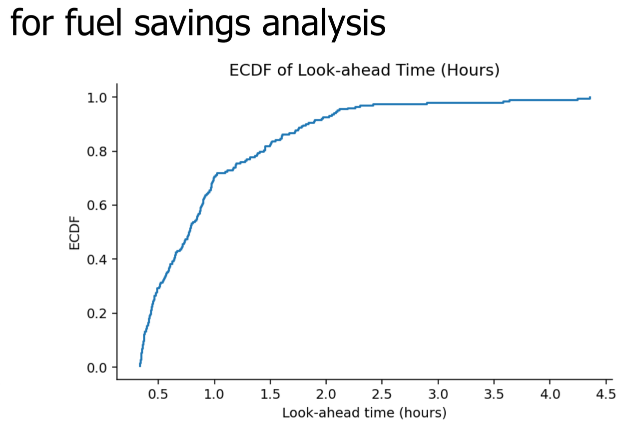


This analysis **quantifies FOQA fuel burn during holding patterns**, provides associated holding pattern statistics and **determines the look-ahead time**, which represents how early speed control can be applied in flight

### Results

- Identified and quantified the fuel burn during holding patterns in 988 of 50,000 FOQA flights across 15 aircraft types
- Identified 300 FOQA flights in a holding stack with a look-ahead time ≥ 20 minutes
- Identified 169 FOQA Flights of interest for speed control simulation, with the potential to leverage associated TT holds to further expand the cases for fuel savings analysis



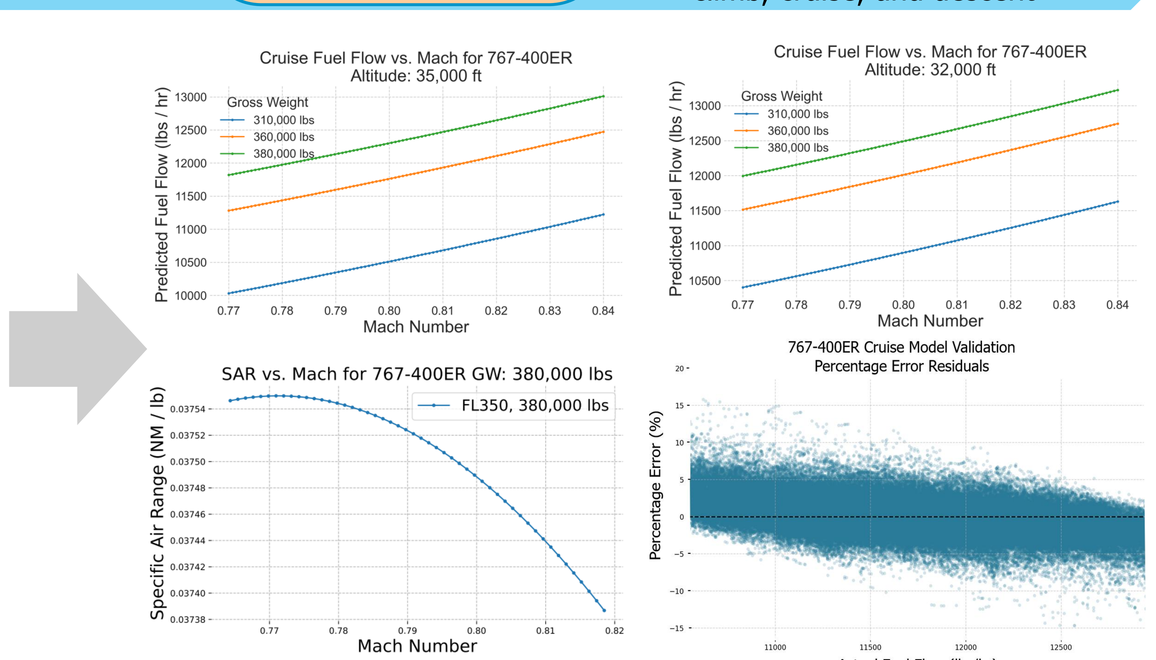

## Task 3: Surrogate Models for Fuel Burn Quantification

**Objective:** Generate surrogate models to **quantify fuel burn savings** during speed control simulations for all aircraft

**Inputs** — Gross weight, Mach, MSL altitude, temperature, acceleration, rate of climb → **Fuel Flow Prediction Surrogate Models** → **Outputs** — Predictions of fuel flow during climb, cruise, and descent

| Widebody Aircraft | | |
|---|---|---|
| A350-900 | A330-900 | A330-200 |
| A330-300 | 767-300ER | 767-400ER |

| Narrowbody Aircraft | | |
|---|---|---|
| A321-200 | A320-200 | A319-100 |
| A220-100 | A220-300 | 737-800 |
| 717-200 | 737-900 | 757-200 |
| 757-300 | | |




- Surrogate models generated for climb, cruise, cruise step-climb, and descent phases
- These models enable the quantification of fuel savings during the speed control simulations for promising scenarios identified by predictable holding with sufficient lookahead time

## Task 4: Investigation of Speed Control on Historical Flight Trajectories

**Objective:** Simulate flight trajectories to **quantify potential fuel savings** for aircraft implementing speed control strategies. **Exploration of speed control** using various speeds, various durations, and various amounts of delays to be absorbed

### Process

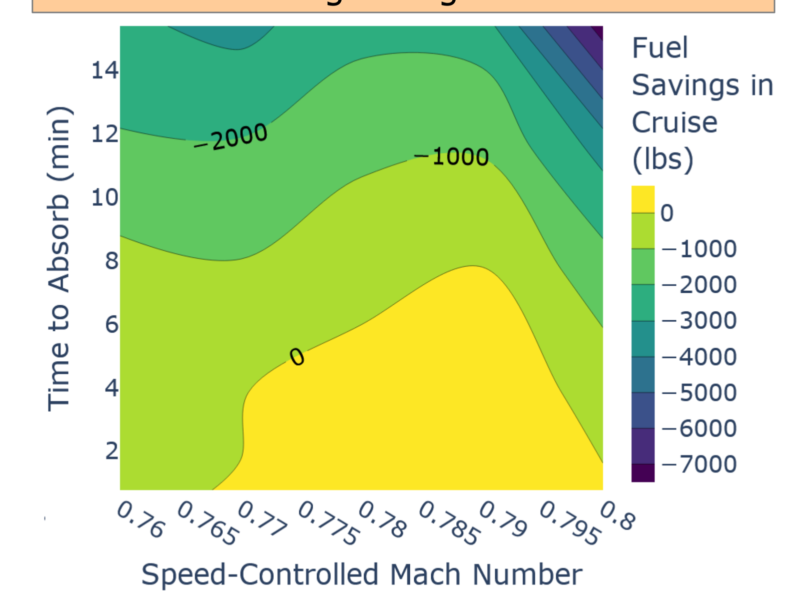
1) Calculate ground speed(s) at reduced cruise Mach numbers.
2) Compare original and revised speed(s) to determine when to start speed control
3) Leverage fuel burn surrogate models to quantify fuel burn at the new Mach number
4) Compare fuel burn to determine savings, factoring in fuel saved by avoiding part of the holds

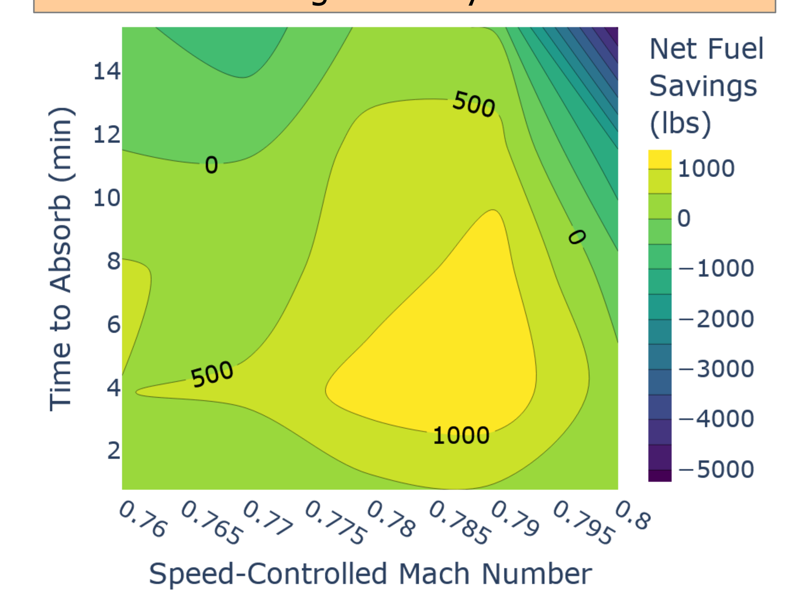
### Use Case Results

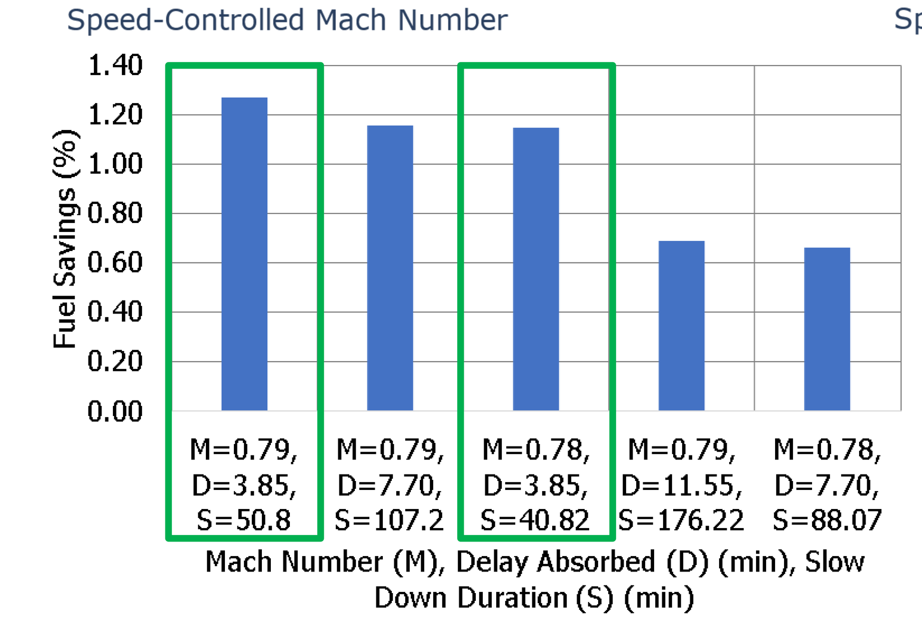
| Departure/Arrival | Aircraft | Average Mach Number | Cruise Duration | Total Hold Duration | Speed Control Mach Range |
|---|---|---|---|---|---|
| LFPG-KJFK | A330-300 | 0.819 | 7.5 hours | 15.4 minutes | 0.76-0.80 |

During cruise, the speed change causes most cases to use more fuel compared to the original flight...

...but this is offset by the fuel saved by avoiding the hold, which produces a net fuel savings in many cases




**Takeaway**: Of the five options with the most fuel savings, the options outlined in green are the most practical due to the relatively short required look-ahead time

## Next Step - Task 5: Architecting Strategies for Fleet-wide Terminal Delay Absorption

**Objective:** Develop **fleet-wide speed control strategies** to maximize total fuel savings while respecting some ATM considerations

- ATM considerations include maintaining sequencing, holding pattern exit times, airport arrival times

**System-wide fuel savings - Lower Bound -**

- All aircraft absorbing the same amount of delay enroute
- Limited by aircraft having shortest amount of look-ahead time

**Possible solutions to be investigated**

- Maintain sequencing with uneven delay absorption
- Prioritization of aircraft with higher fuel burn to improve system-wide benefits (sequencing not maintained)

**System-wide fuel savings - Upper Bound -**

- Speed control applied independently to all flights, maximizing savings for each flight
- Sequencing not maintained
- May cause arrival conflicts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