# Incorporating New Technologies into the Aviation Integrated Modeling (AIM) Project

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**UTIAS-MITACS International Workshop on Aviation and Climate Change**

**29-30 May 2008**

# Background IAE

- University expertise in topics related to impact of aviation on the environment brought together by formation of IAE in 2004

Centre *for* **Atmospheric Science**

Department of Chemistry
Department for Applied Mathematics and Theoretical Physics (DAMTP)
Department of Geography

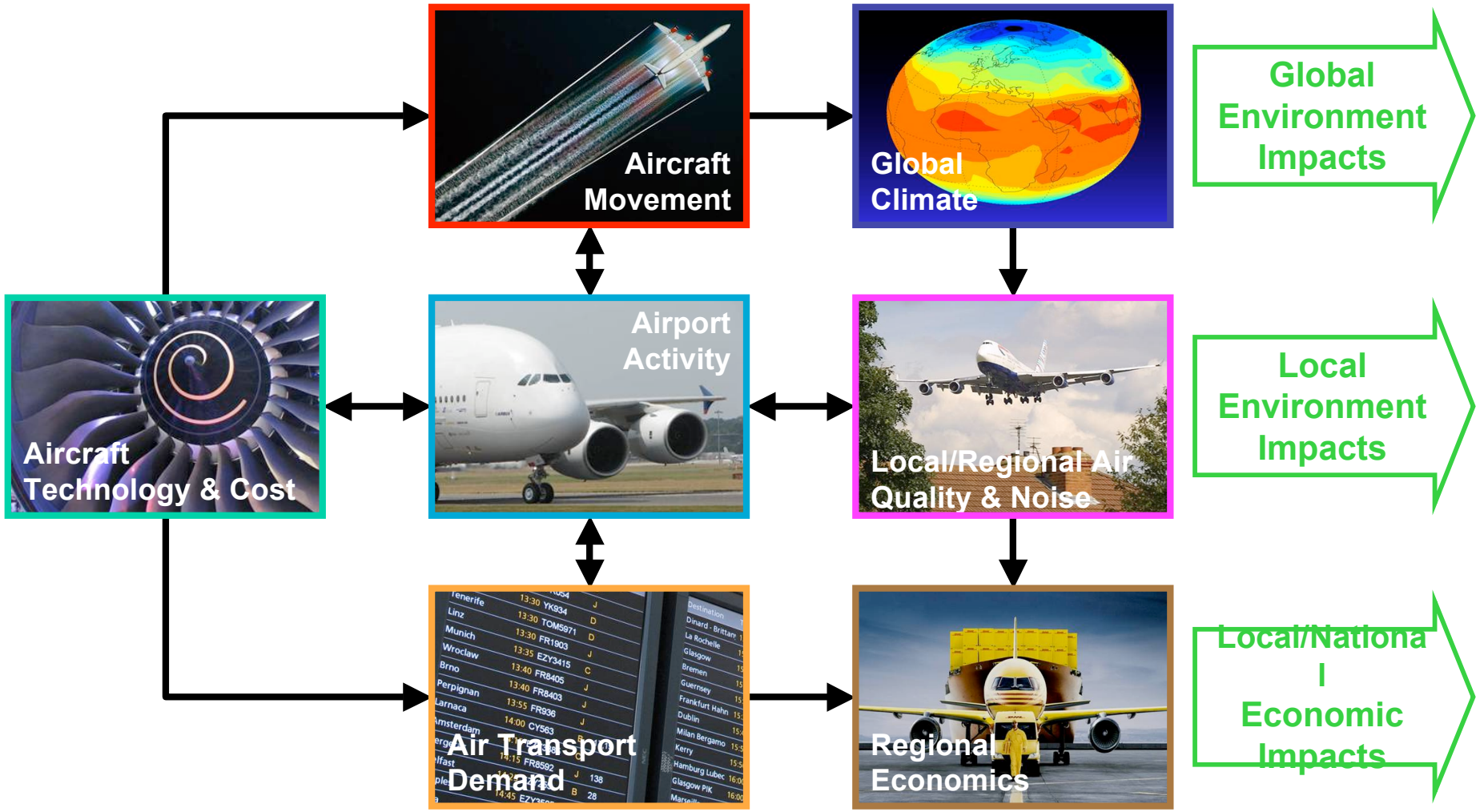
The Martin Centre for Architectural and Urban Studies

Department of Architecture


DEPARTMENT OF ENGINEERING

The Department of Land Economy

# AIM Architecture



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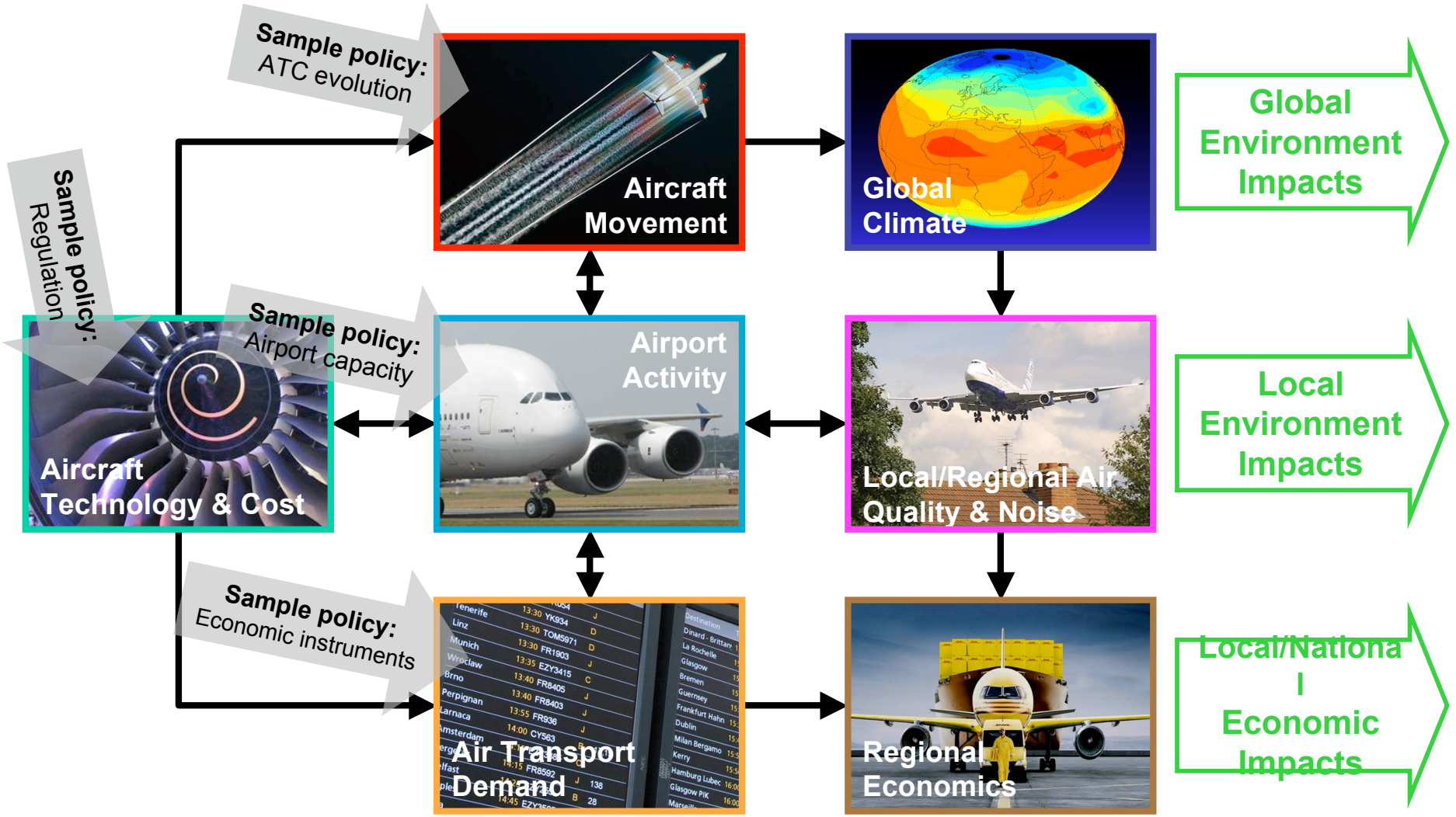


# AIM Team

**Core team:**

- Dr. Andreas Schäfer *(Principal Investigator)*
- Steven Barrett *(Local Air Quality & Noise)*
- Dr. Lynnette Dray *(Air Transport Demand)*
- Antony Evans *(Airport Activity)*
- Dr. Marcus Köhler *(Global Climate)*
- Dr. Tom Reynolds *(Project Manager & Aircraft Movement)*
- Dr. Maria Vera Morales *(Aircraft Technology and Cost)*
- Dr. Zia Wadud *(Regional Economics)*

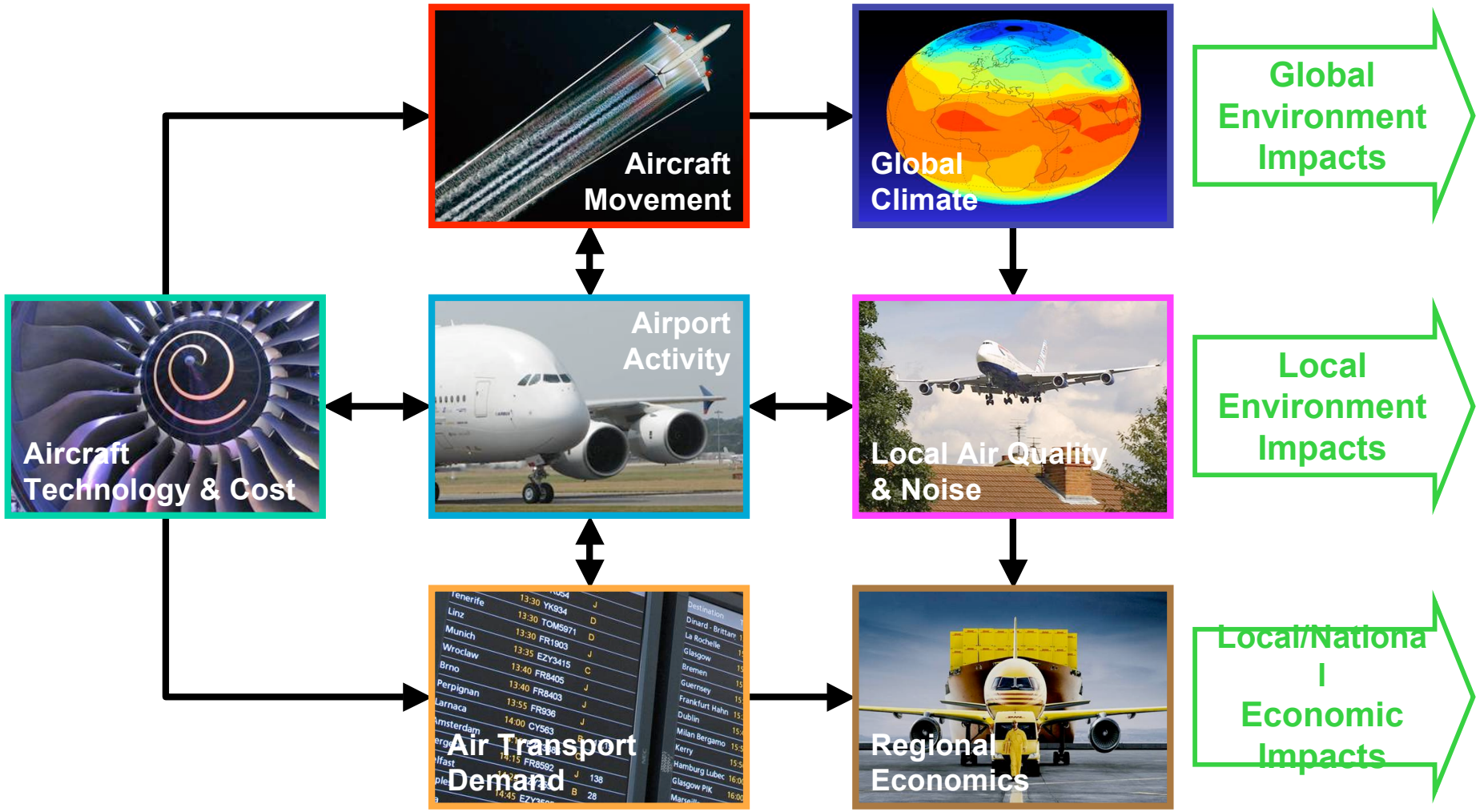
**IAE co-investigators:**

- Prof. Rex Britter *(Engineering)*
- Prof. Bill Dawes *(Engineering)*
- Dr. Chez Hall *(Engineering)*
- Prof. Peter Haynes *(DAMTP)*
- Prof. Roderic Jones *(Chemistry)*
- Dr. Matthew Juniper *(Engineering)*
- Prof. John Pyle *(Chemistry)*
- Dr. Helen Rogers *(DAMTP)*

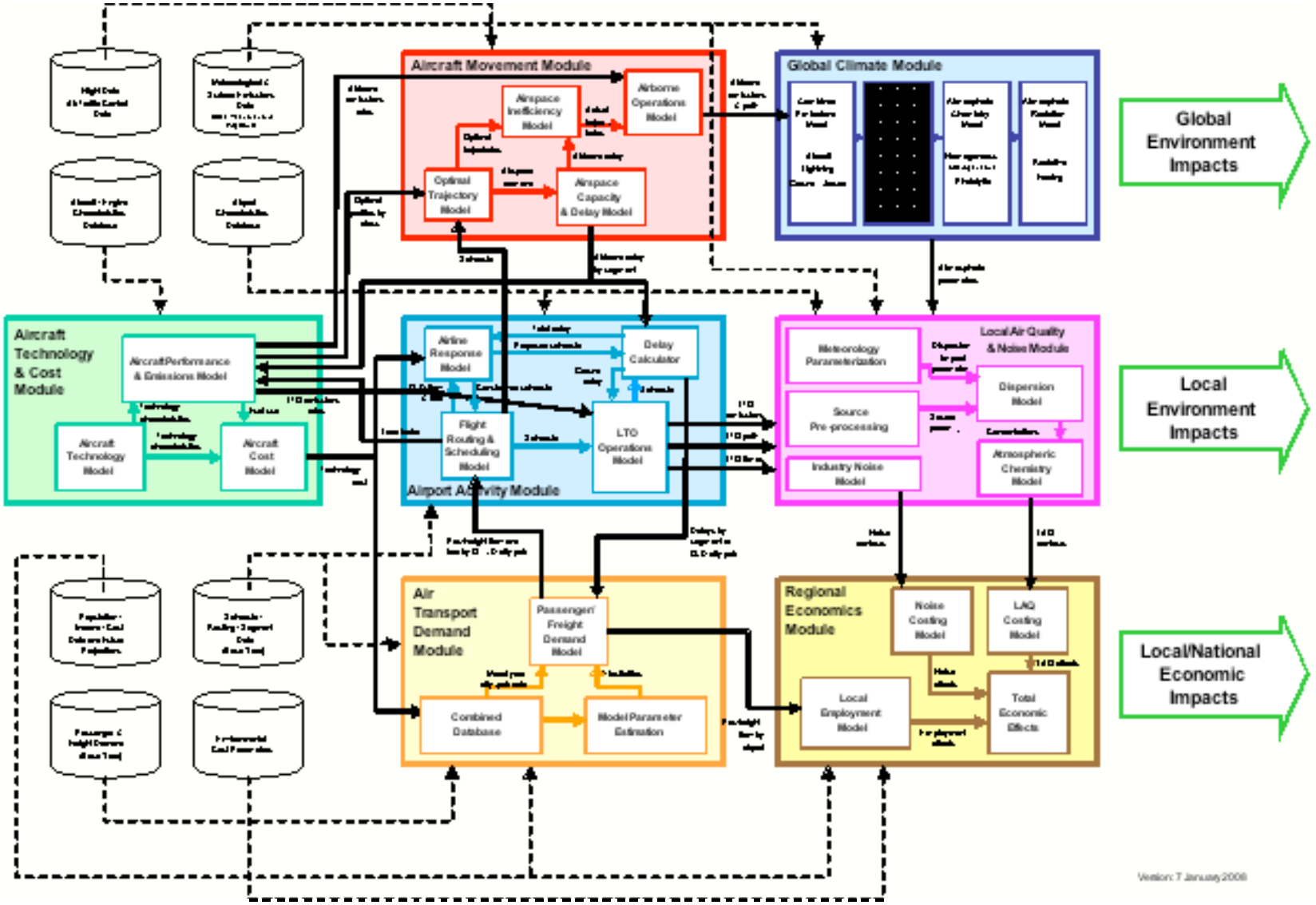
**Affiliated students:**

- Pablo Bolgeri *(Politecnico di Milano)*
- Henry Hallam *(Engineering)*
- Richard Hunsley *(Engineering)*

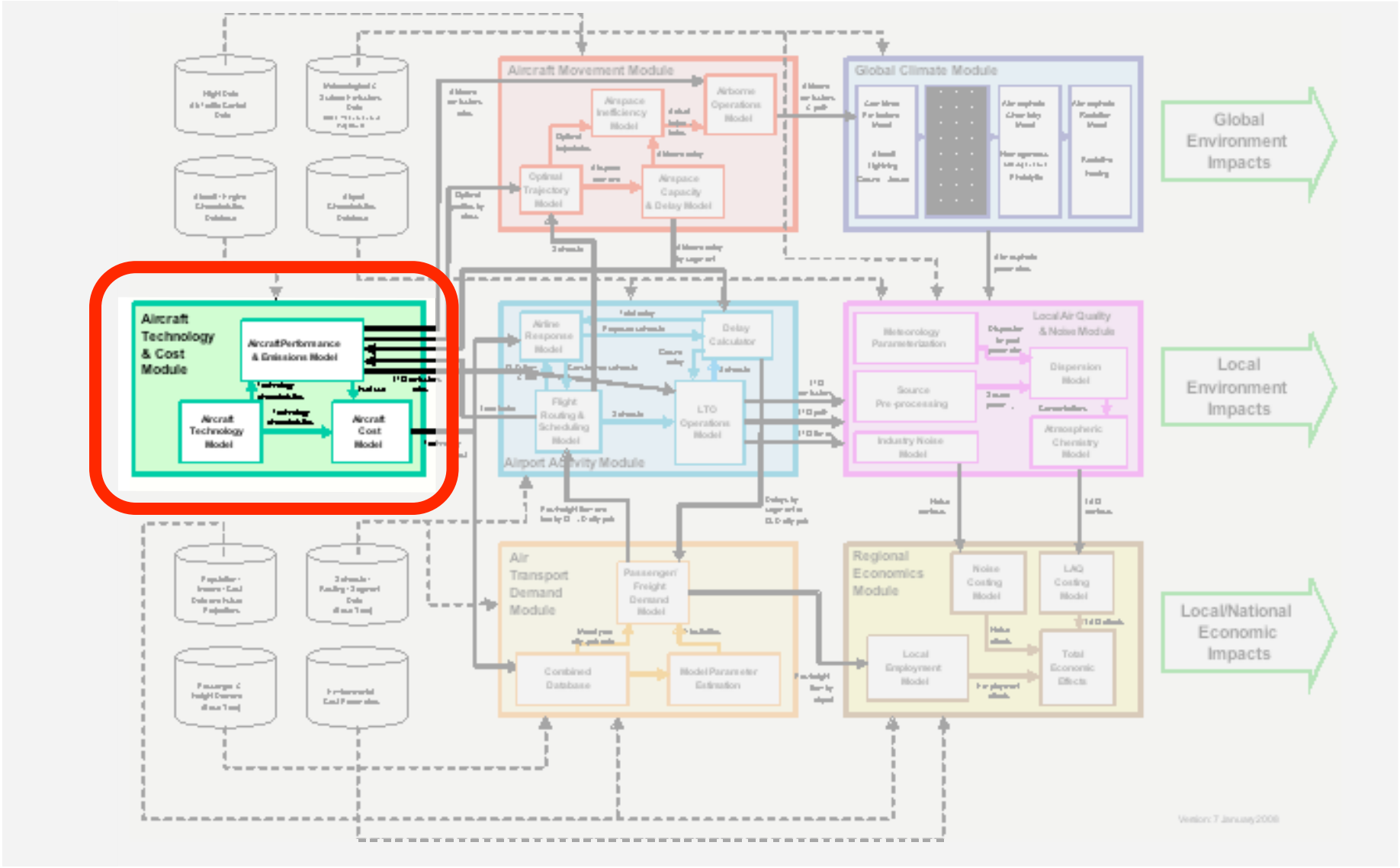
# AIM Architecture



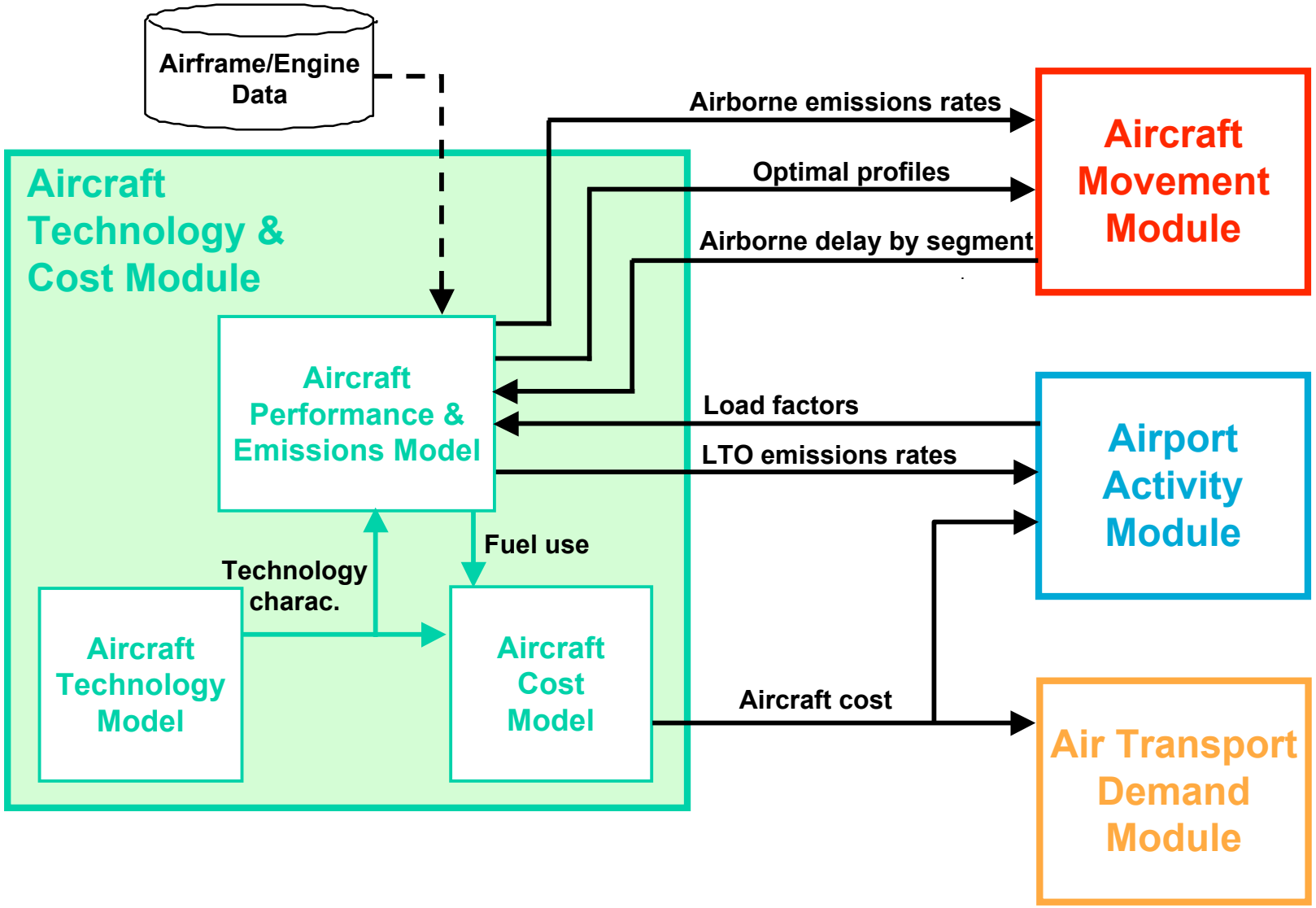
# AIM Detailed Architecture



# AIM Detailed Architecture



# Aircraft Technology & Cost Module



# Goals

- Model aircraft performance and emissions
- Implement new aircraft technology paths
- Model the cost associated with ownership/operation

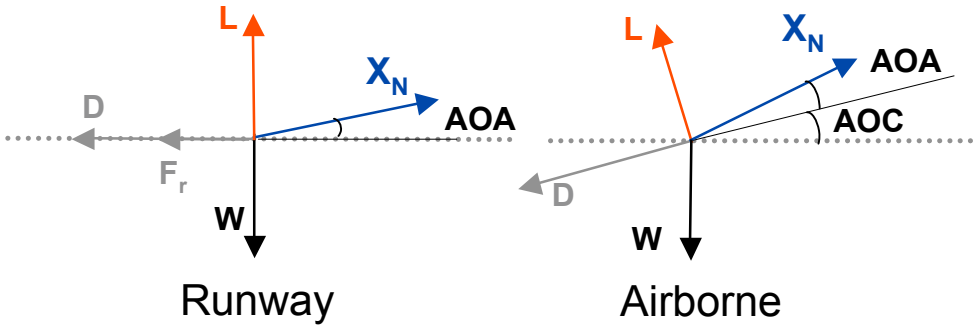
# Methodology

- Model aircraft performance and emissions
  - Eurocontrol: Base of Aircraft Data (BADA)
    - Performance and operating procedure coefficients
  - AIM: Performance and Emission Simulations of flight Operations (PESO)
    - Main forces resolved at different points along the flight mission
    - Forces derived from:
      - Aircraft aerodynamic characteristics
      - Aircraft mass
      - Engine performance

# PESO: Modelling

- Solving the main forces on the aircraft

- Flight phases
  - Taxi in/out
  - Take off
  - Climb
    - Max Thrust/Thrust Cut Back
    - Climb to initial Cruise Altitude
  - Cruise
    - Constant Flight Level/Continuous Climb…
  - Descent
    - Initial Descent
    - Continuous Descent Approach/Stepped Approach…
  - Landing



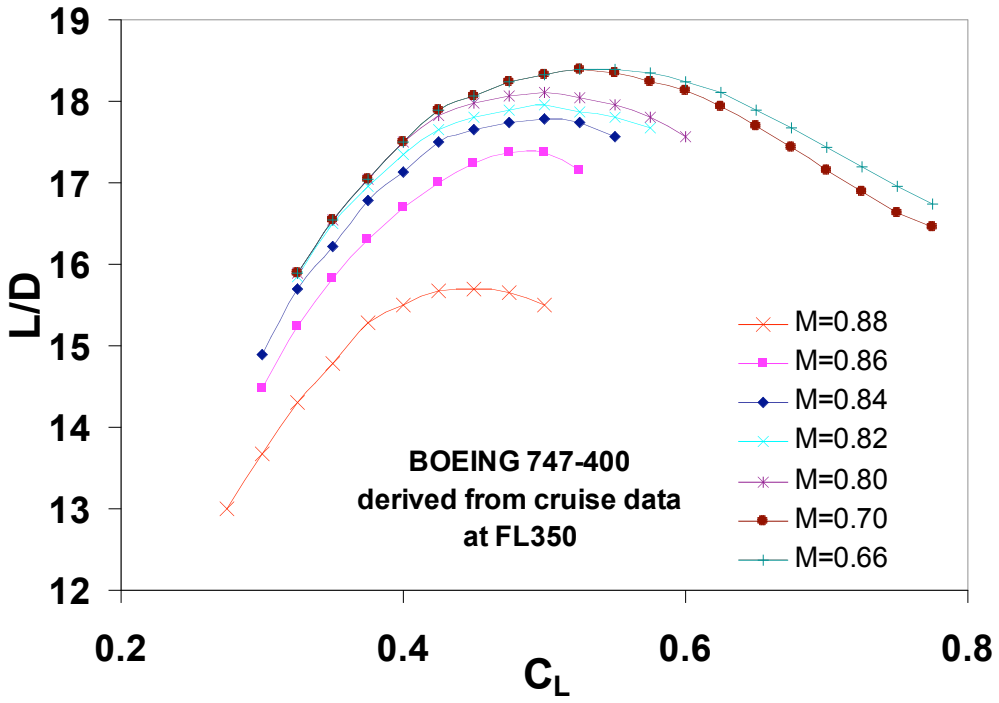
# PESO: Modelling

- Input
  - Flight phases: Standard procedures/Operation strategies
  - Airframe/Engine aerodynamics
  - Engine performance: GasTurb

- Output
  - Flight trajectory, Mach number, fuel consumption…
  - $EI_i$ =f(engine cycle)

# PESO: Modelling

- PESO version 0.1: preliminary model
  - Aircraft aerodynamics: from Cumpsty's Jet Propulsion



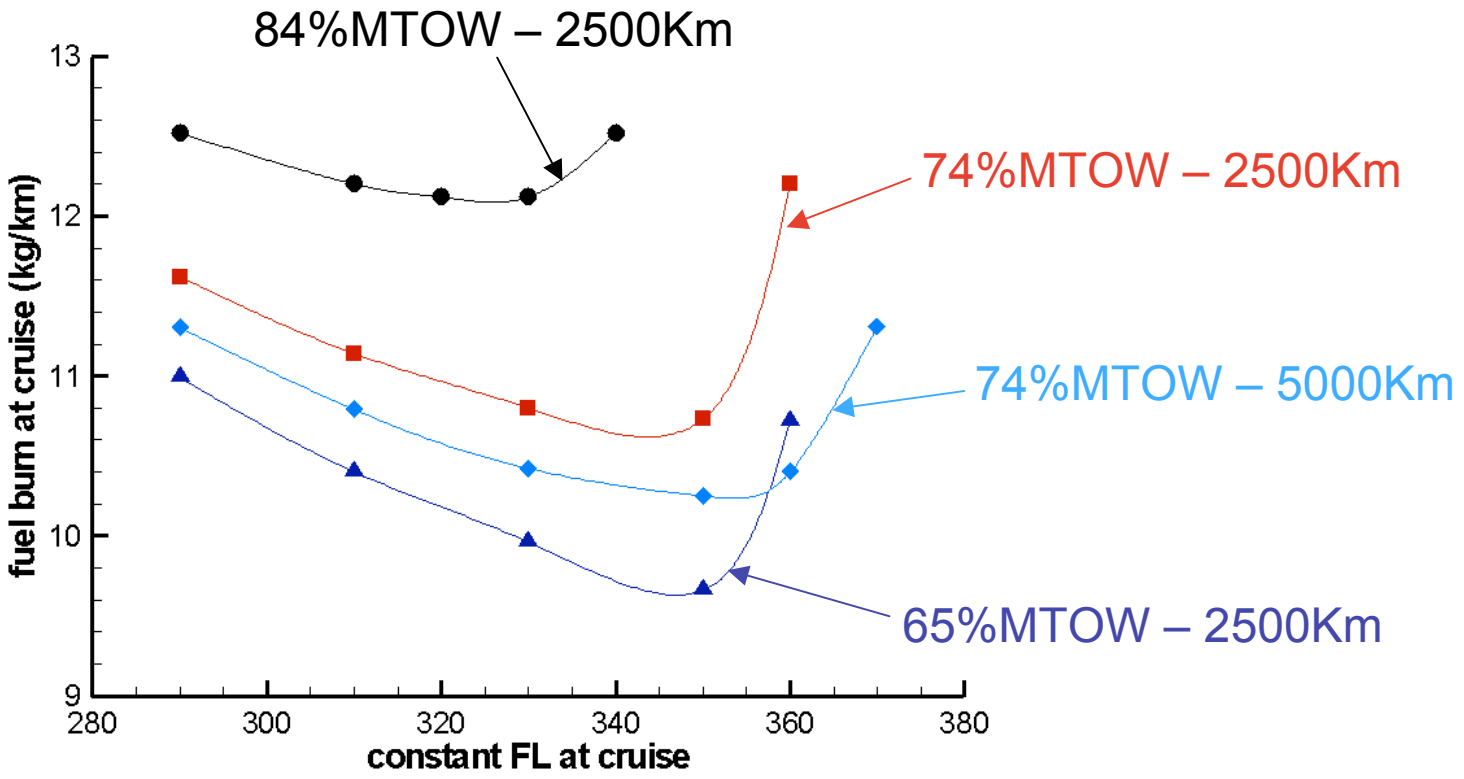

  - $C_L$ is obtained assuming that at cruise the aircraft is flying at $L/D_{max}$ and at conventional angle of attack

# PESO: Modelling

- Engine performance simulation: The working line of the engine at cruise altitude and Mach number is used in non-dimensional form throughout the flight mission
  - Engine is simulated for any thrust, altitude and Mach number
  - Requires few calculations in GasTurb
  - Results can be scaled to any engine with similar technology level
  - Inaccurate when the exhaust nozzle unchokes

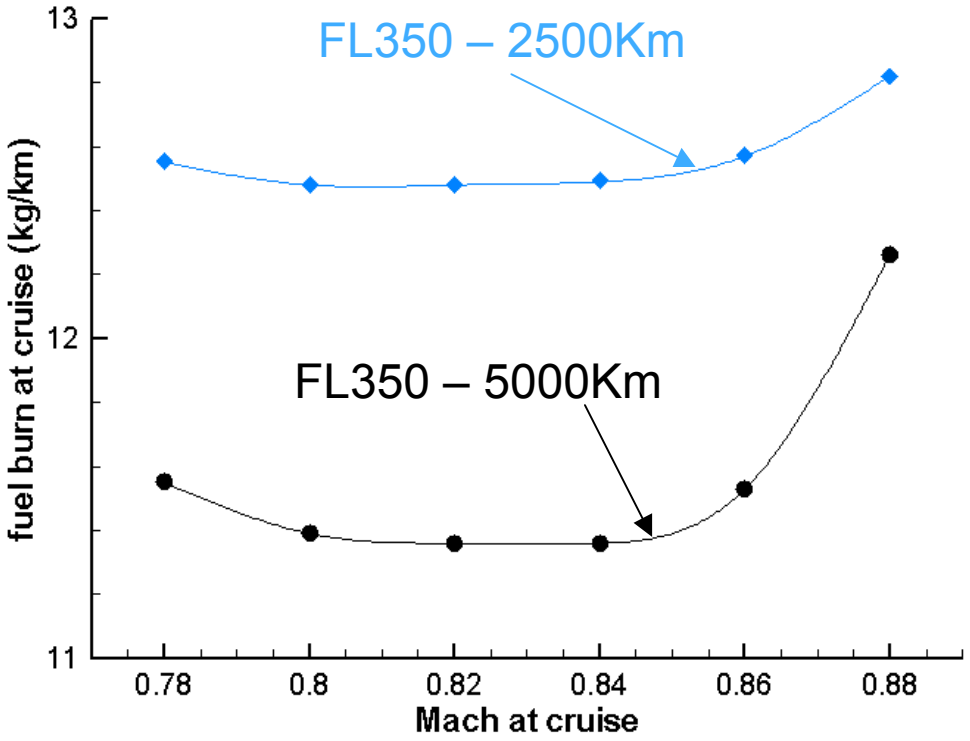
# PESO: Sample Result

- B747-400
- The RB211-524G  engines that power the B747-400 have been scaled from a model of the Trent-892



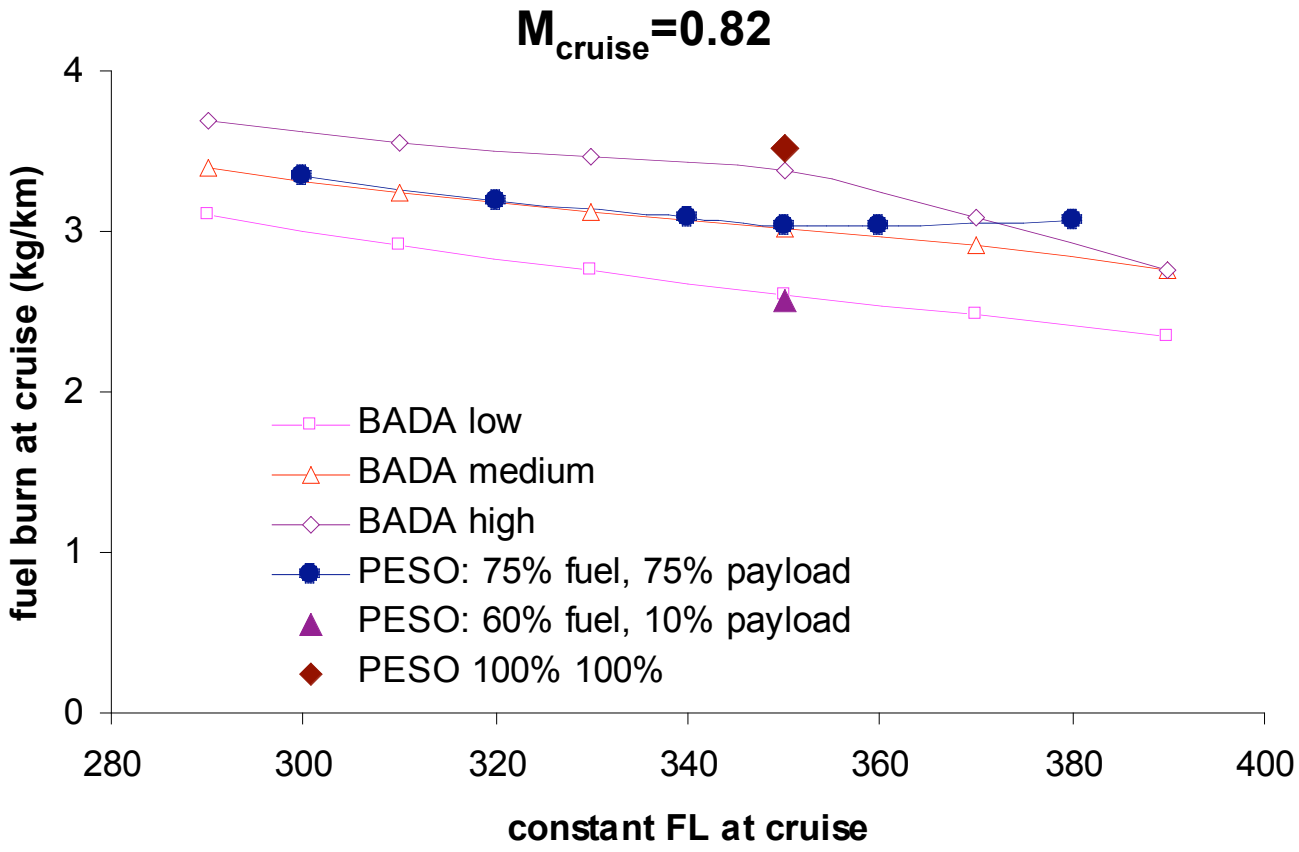
# PESO: Sample Result

At Take Off: Payload=75%, Fuel=75%



# PESO: Sample Result

- A320-200
- CFM56 two spool unmixed flow turbofan

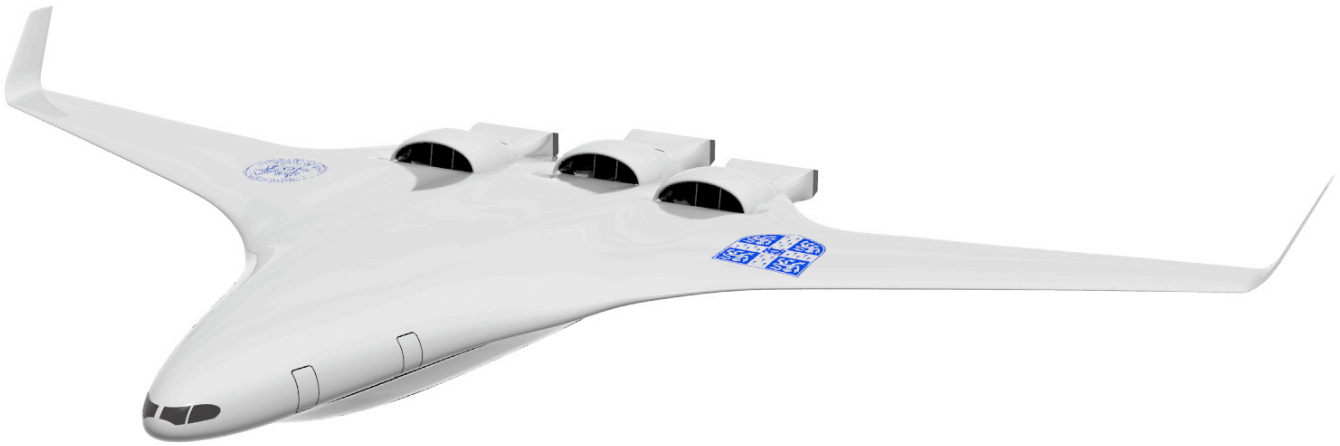


# PESO: Strengths/Weaknesses

- Strengths
  - Simple and Flexible
  - Engine modelled for Thrust, Altitude and Mach number
  - Could be run as an optimizer
- Weaknesses
  - Highly dependent on the quality of the input data

# New Technologies

- Variable Nozzle systems
- Boundary Layer Ingestion
- Open Rotor Propulsion
- Distributed Propulsion
- BWB…



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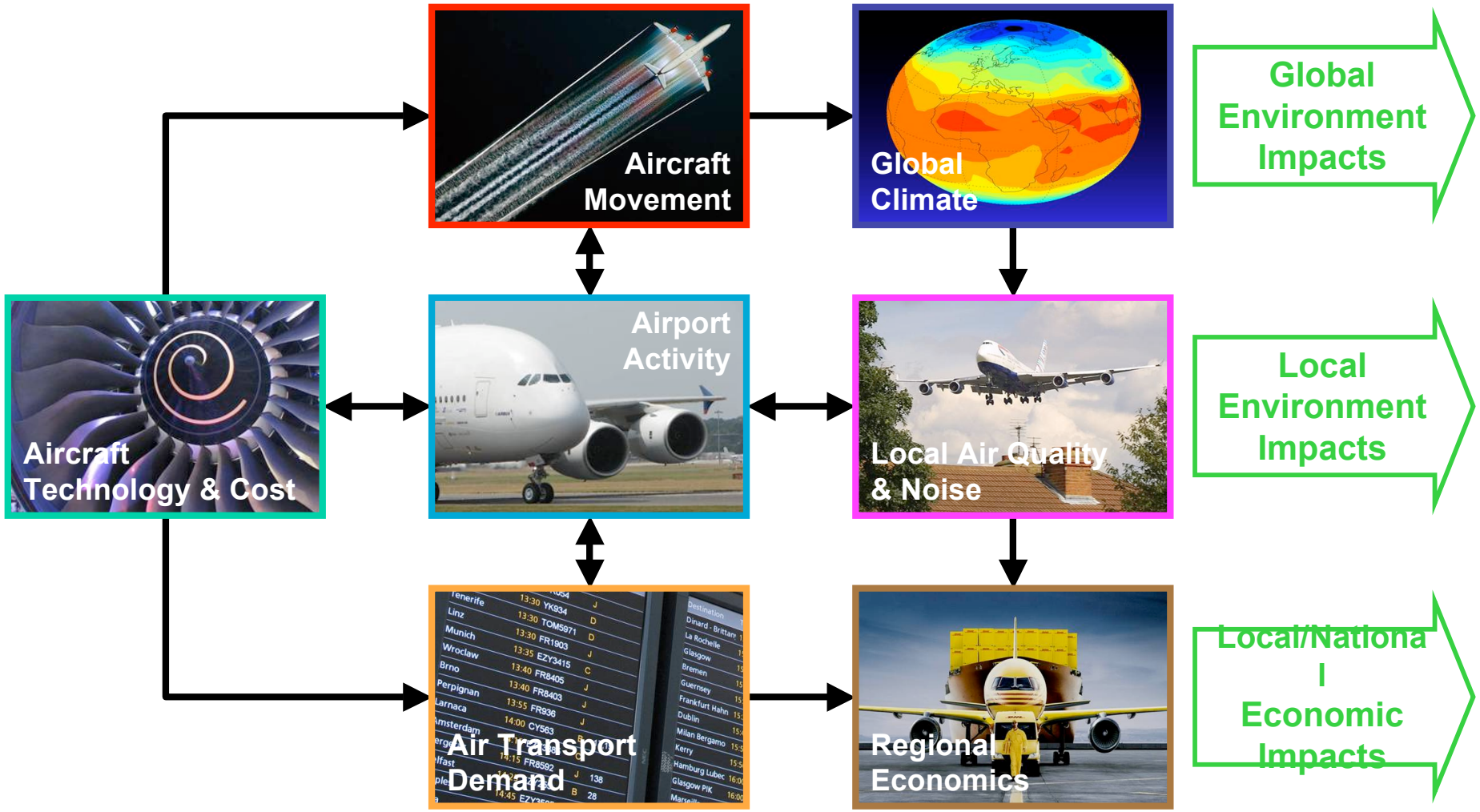
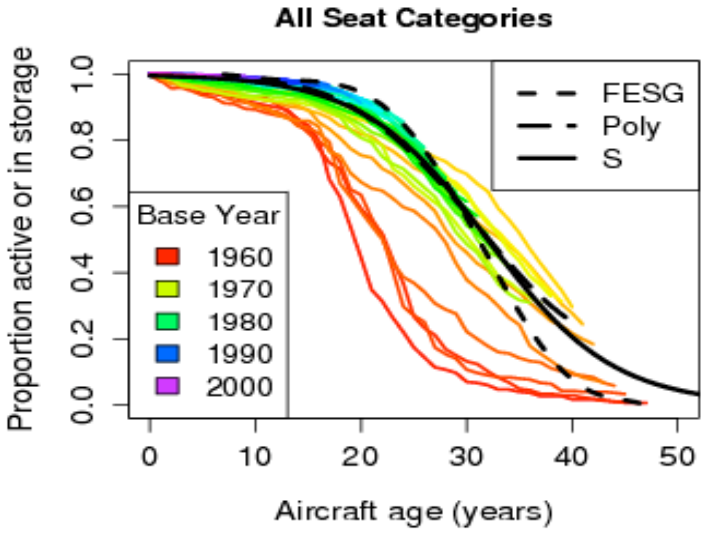
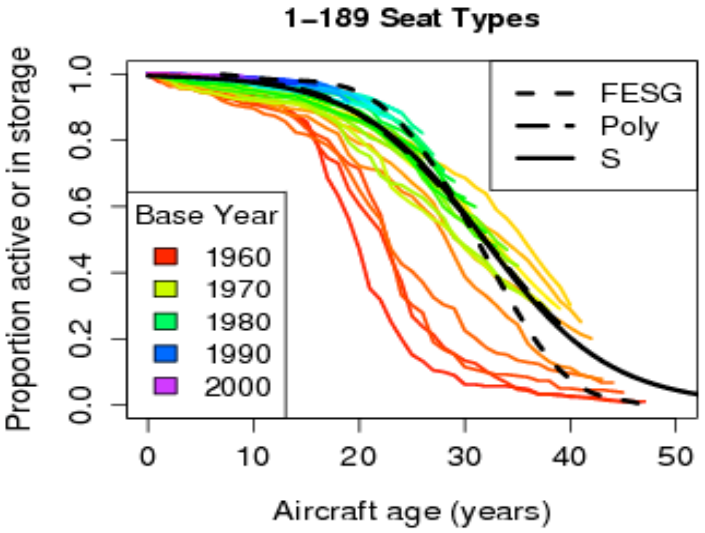
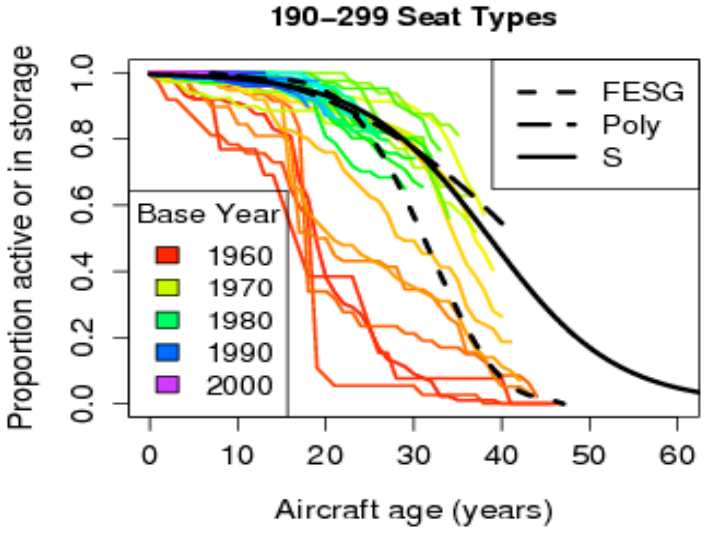
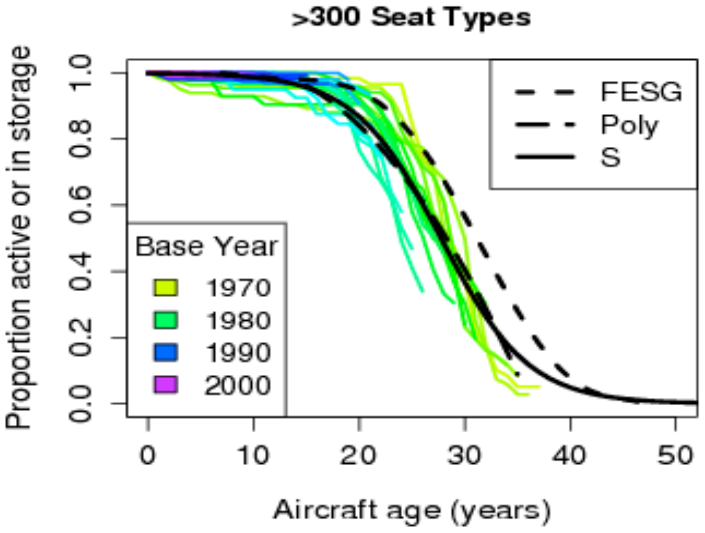


# Retirement Curves




[Data: Back Aviation Fleet Database]