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Institute for Aviation
and the Environment 

Modelling Sustainable Aviation with AIM

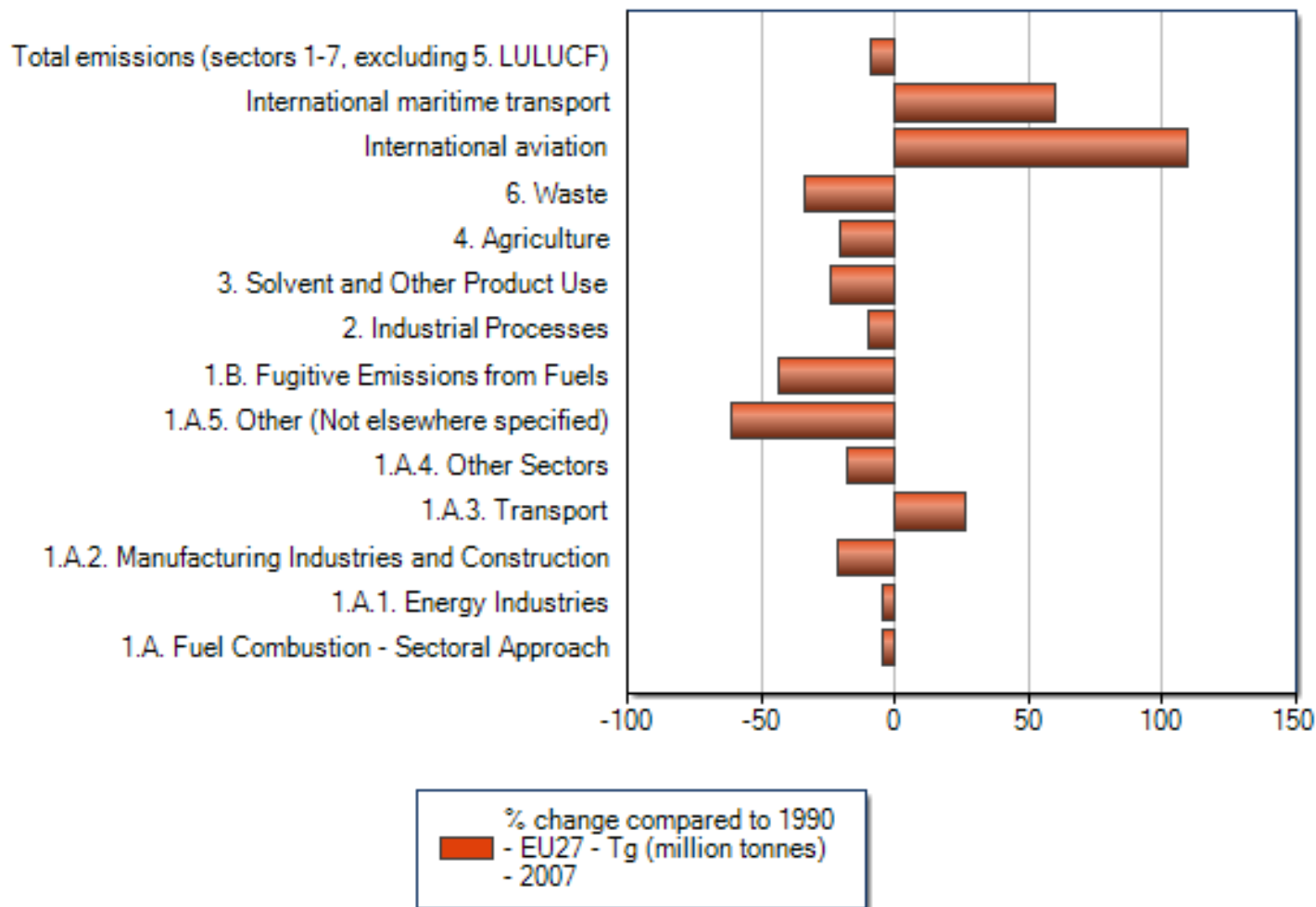
Lynnette Dray

Institute for Aviation and the Environment, University of
Cambridge



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- Contributes to about 4.5% of global GDP (IATA 2000)
- About 3% of global energy-use-related emissions (IEA 2008)
- Global RPK growth of ~5%/year forecast (Airbus, Boeing 2009)
 - Even with optimistic reductions in carbon intensity, aviation emissions are likely to grow
- Emissions from other sectors have been decreasing in some regions (e.g. the EU)
 - Aviation potentially a target for emissions reduction policies



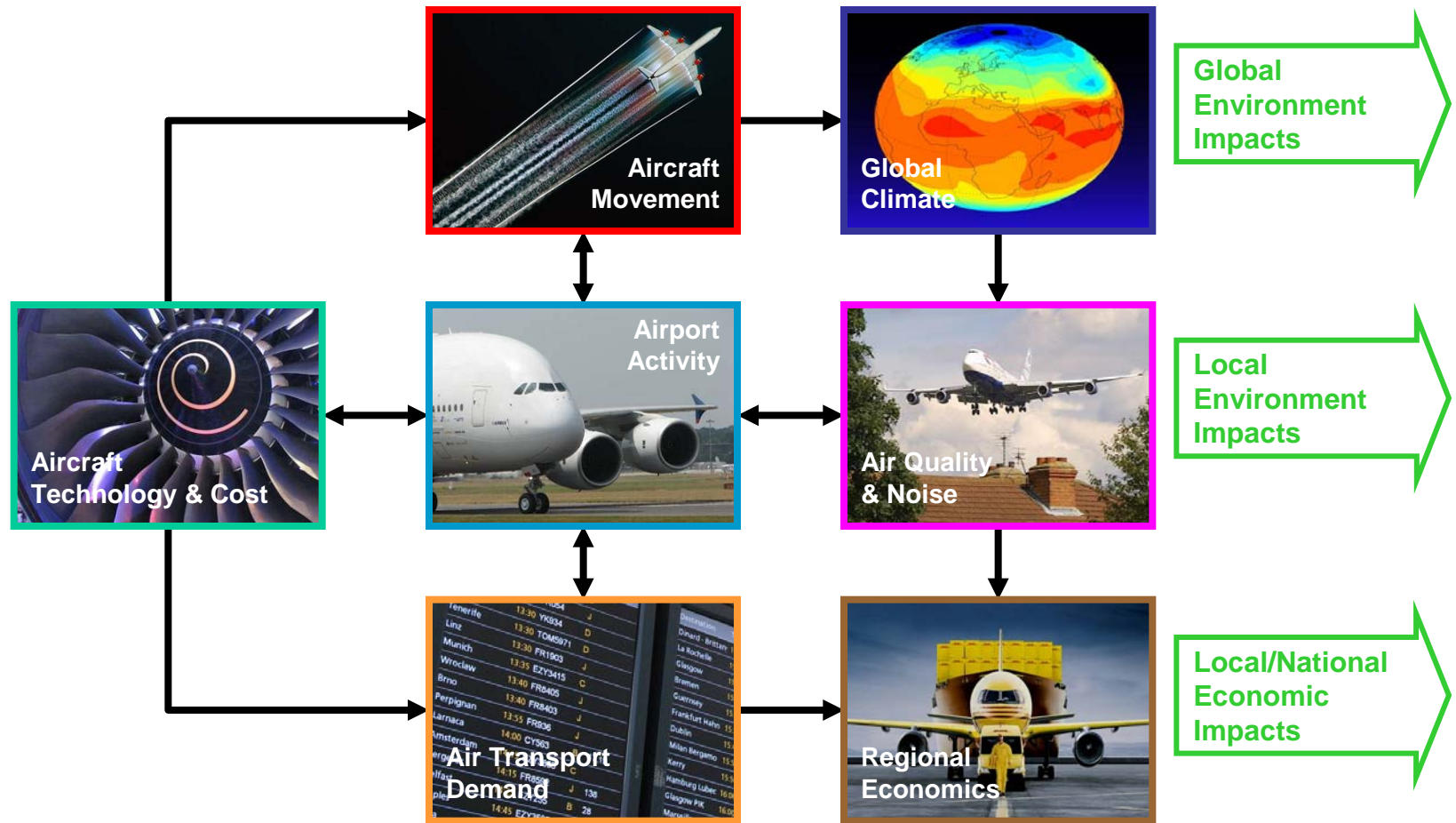
[Source: EEA]

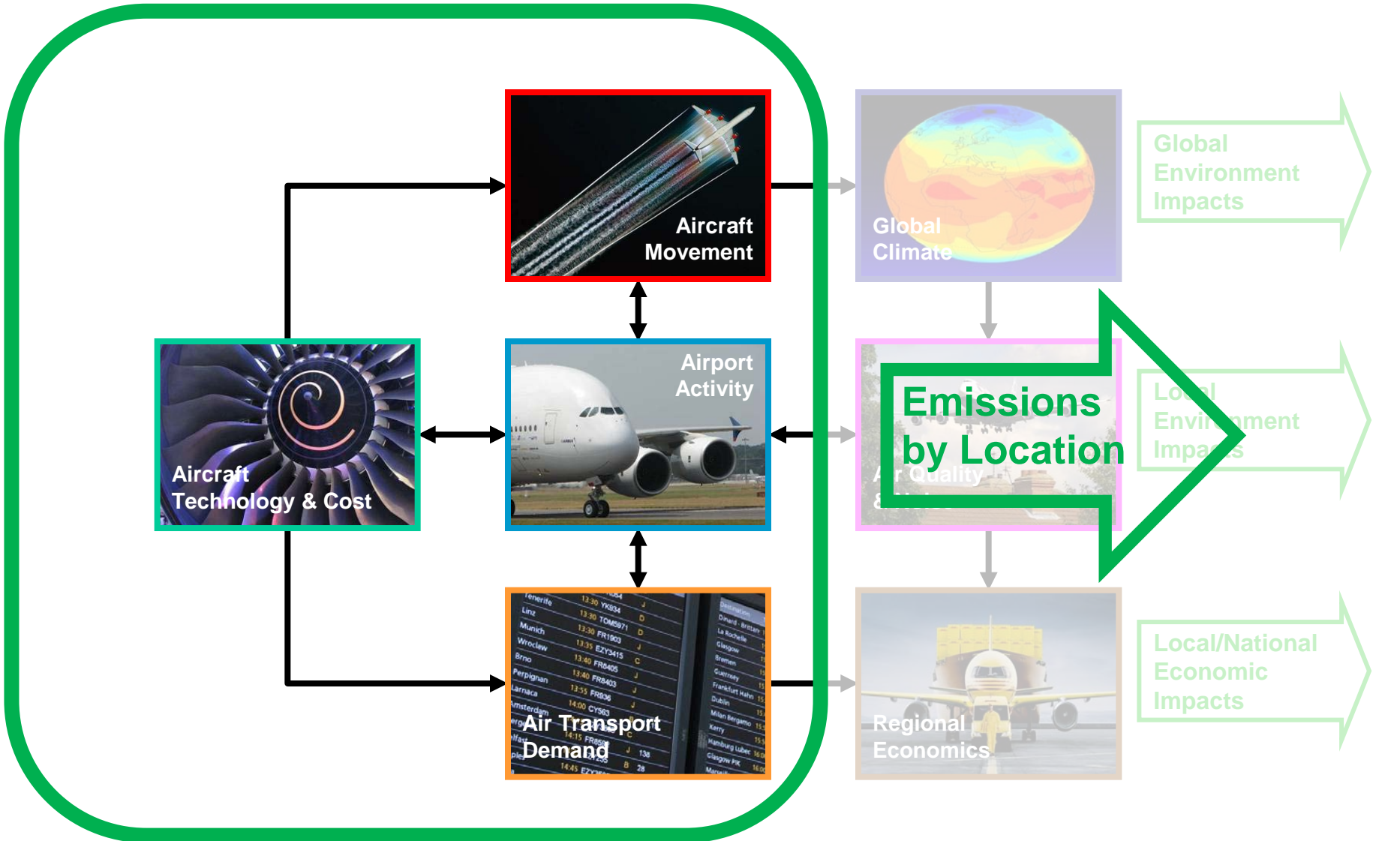
- Goal: Develop integrated assessment tool for aviation, environment & economic interactions at local & global levels, now and into the future
 - Assess policies to strike appropriate balances between economic benefits and environmental impact mitigation
 - Independent & transparent tool for mediating between stakeholders

- Funding from:



- Considerable input from UK OMEGA projects for this study



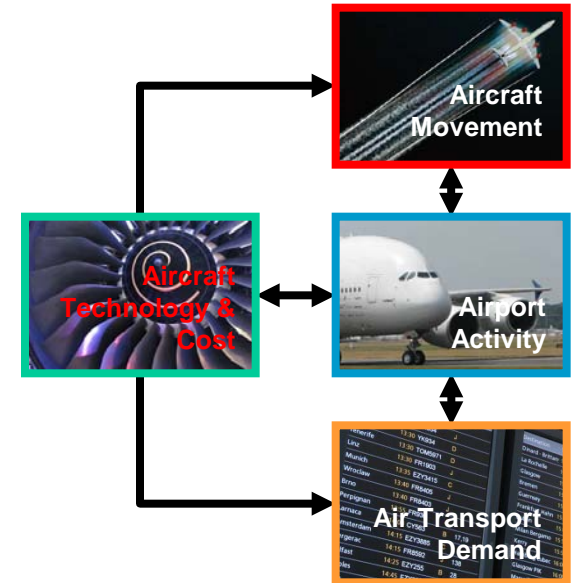


Goal

- Simulate emission rates by aircraft type, and the associated direct operating costs

Methodology

- Below 3000 feet: ICAO Exhaust Emission Data, Reference LTO Cycle
- Above 3000 feet: Eurocontrol Base of Aircraft Data (BADA)
- Three size categories
- Simple fleet turnover model for introduction of new technology

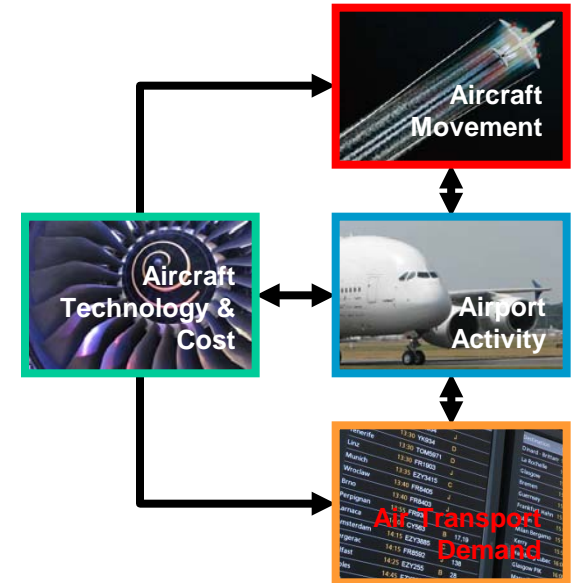


Goal

- Forecast true origin-ultimate destination demand for air travel
- Global set of 700 cities, 95% of scheduled RPK

Methodology

- Simple gravity-type model
- Demand is a function of population, income, fare, travel time, road/high-speed rail links etc.
- Estimate separately for short-, medium-, long-haul and different world regions
- Modular – can plug in other projections if required

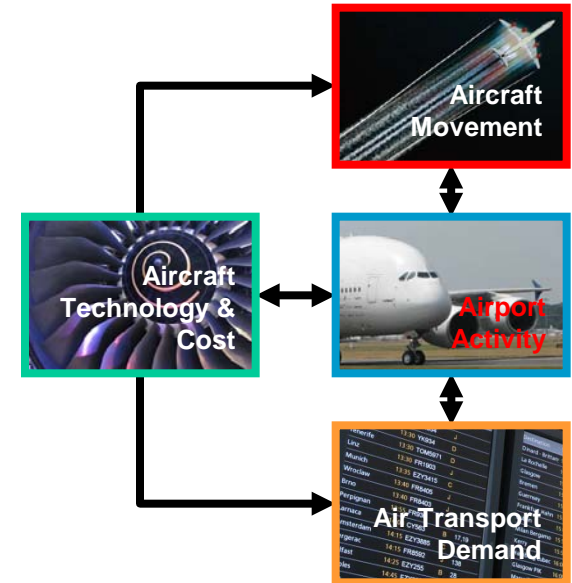


Goal

- Generate flight schedules
- Predict delay and LTO emissions

Methodology

- Flight routing and scheduling modeled according to forecast passenger demand
 - Routing network scaled from base year
 - Proportion of flights of each aircraft size estimated using a multinomial logit regression
 - Flight frequencies applying estimated base year load factors
- Flight delay modeled using queuing theory
- LTO emissions estimated according to schedule, delays, and engine emission rates

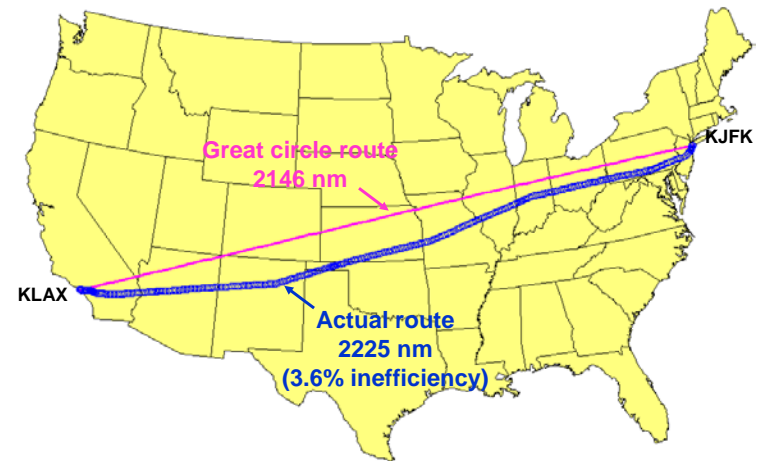
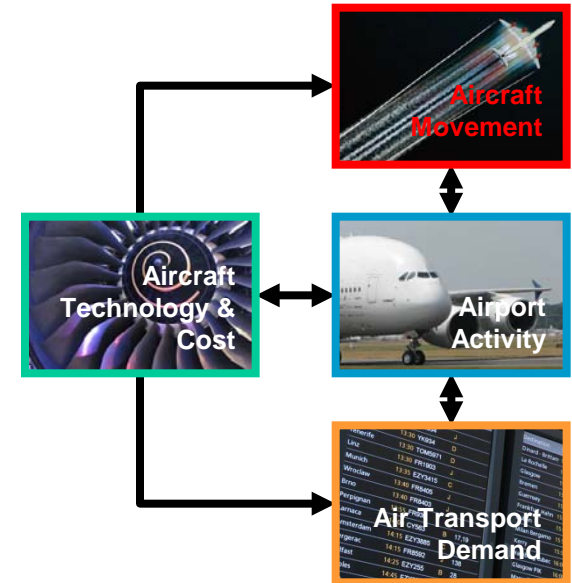


Goal

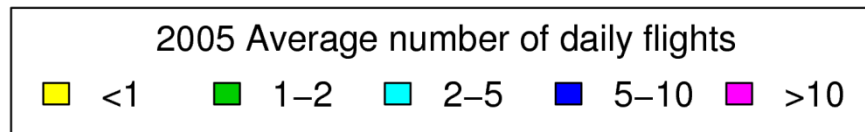
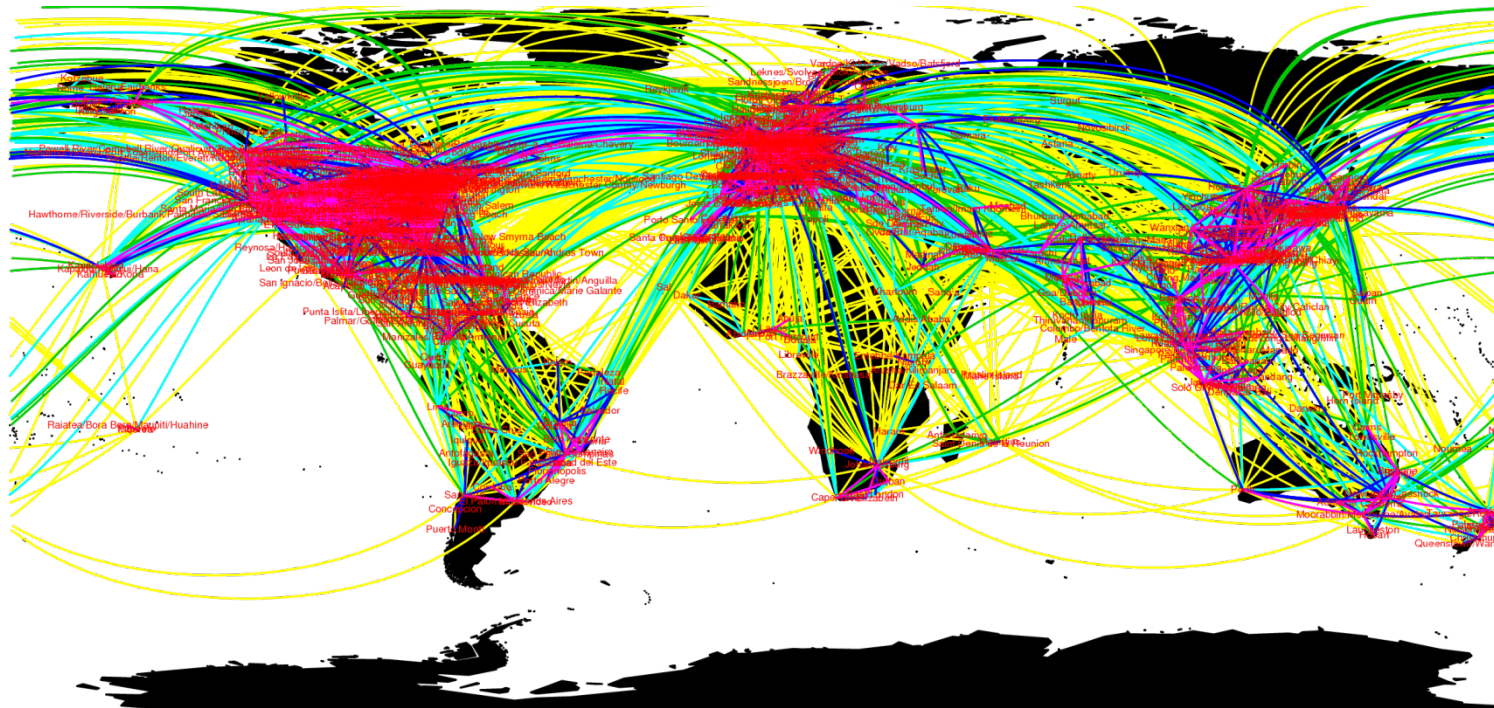
- Simulate the location of emissions release from aircraft in flight, accounting for ATM inefficiencies

Methodology

- Calculate optimal routes between given city pairs, e.g. great circle
- Add “inefficiency factors” to account for air traffic control



- Global model – 95% of scheduled RPK



[Data: OAG(2005)]

- Economic
 - Taxes, subsidies for lower-emission technologies, emissions trading
 - Increases in airline costs may increase fares/reduce demand and/or induce other emissions-saving measures
 - Demand reduction also possible through mode shift – e.g. to high-speed rail
- Technological
 - Retrofits to existing aircraft – e.g. winglets
 - Radical new technology – e.g. open rotor engines, BWBs
 - New fuels
- Operational
 - Improved air traffic management
 - CDAs

Potentially complex interactions between different measures

- Basic principle: “Cap and Trade”
 - Set a cap on emissions for a given year (e.g. 10,000 tonnes of CO₂)
 - The number of available allowances adds up to this amount (e.g. 10,000 permits for 1 tonne of CO₂)
 - Allocate these allowances to emitters by some method (often based on past emissions)
 - Allow trading in allowances to account for difference in ease/cost of reducing emissions
 - Emissions > Number of allowances → Buy allowances
 - Emissions < Number of allowances → Sell allowances
- Should theoretically result in lowest-cost pollution reduction solution

- Main existing CO₂ emissions trading scheme is the EU ETS
 - Sets cap on CO₂ from included sectors only
 - Cap for aviation = 97% of average 2004-2006 emissions, from 2012
 - Airlines can also buy allowances from other sectors
- Some proposed US GHG emissions trading schemes include aviation indirectly
- Global emissions trading has been proposed (e.g. CCSP 2007)
 - Significant political challenges
 - Allows direct (if uncertain) link between global temperature rise and emissions cap

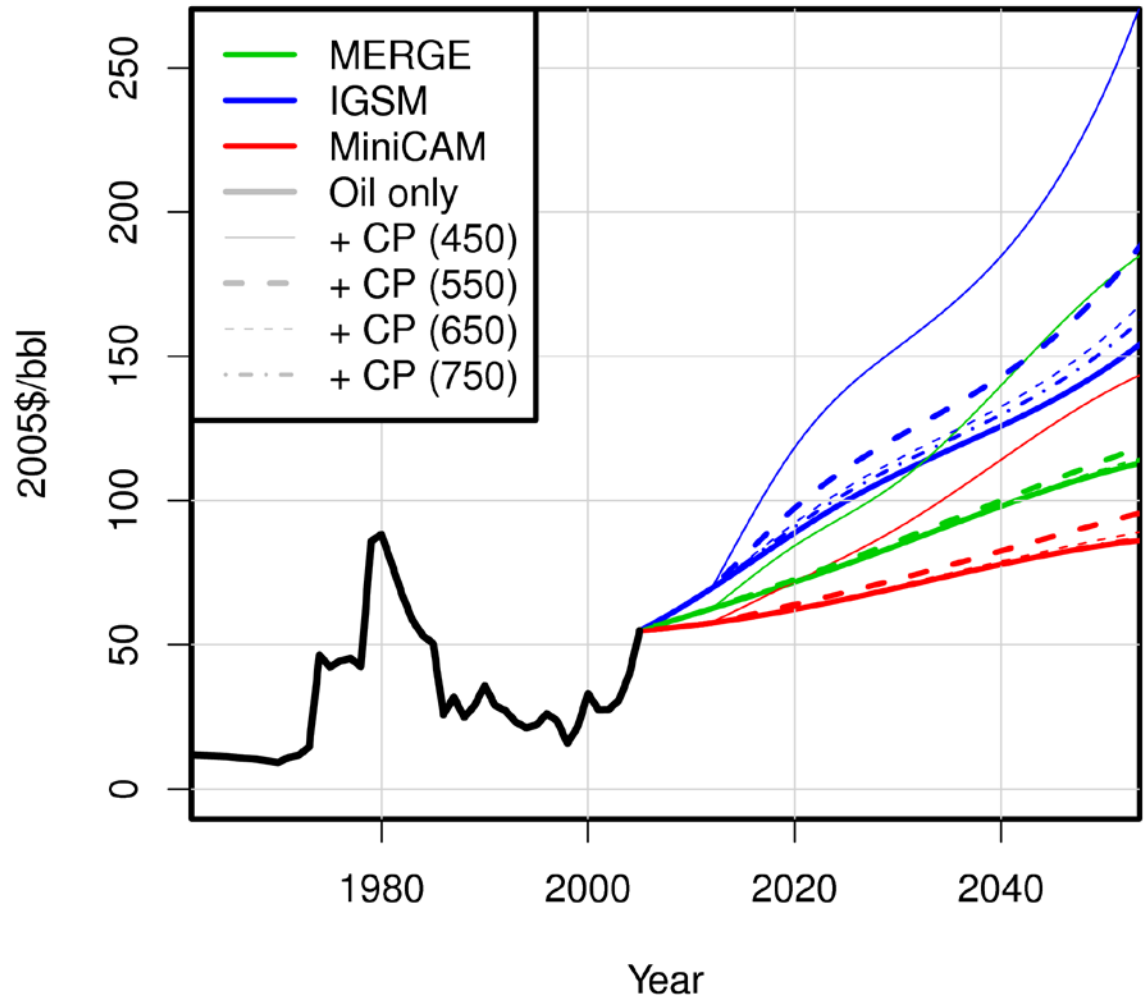
- Stern (2007) – link between chance of temperature rise and atmospheric GHG stabilisation level:

Stabilisation level (CO ₂ e)	Risk of exceeding 2°C	Risk of Exceeding 3°C	Most likely temperature rise
750ppm	90-100%	60-99%	3-4°C
650ppm	82-100%	44-94%	2-3°C
550ppm	63-99%	21-69%	2-3°C
450ppm	26-78%	4-50%	1-2°C

- 550 ppm CO₂e is equivalent to around 440-500 ppm CO₂
- EU goal is to limit emissions rise to 2°C
- In this study we use CCSP (2007) global emissions trading scenarios for carbon price and other variables by stringency level

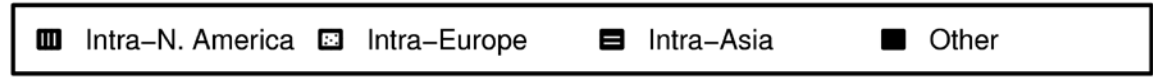
- Main differences between scenarios:
 - Fuel price
 - Higher at greater stringency
 - Carbon price
 - Higher at greater stringency
 - GDP
 - Slightly lower at greater stringency
 - Population
 - Small variation
- Emissions trading is applied from 2012

Forecast Oil + Carbon Prices

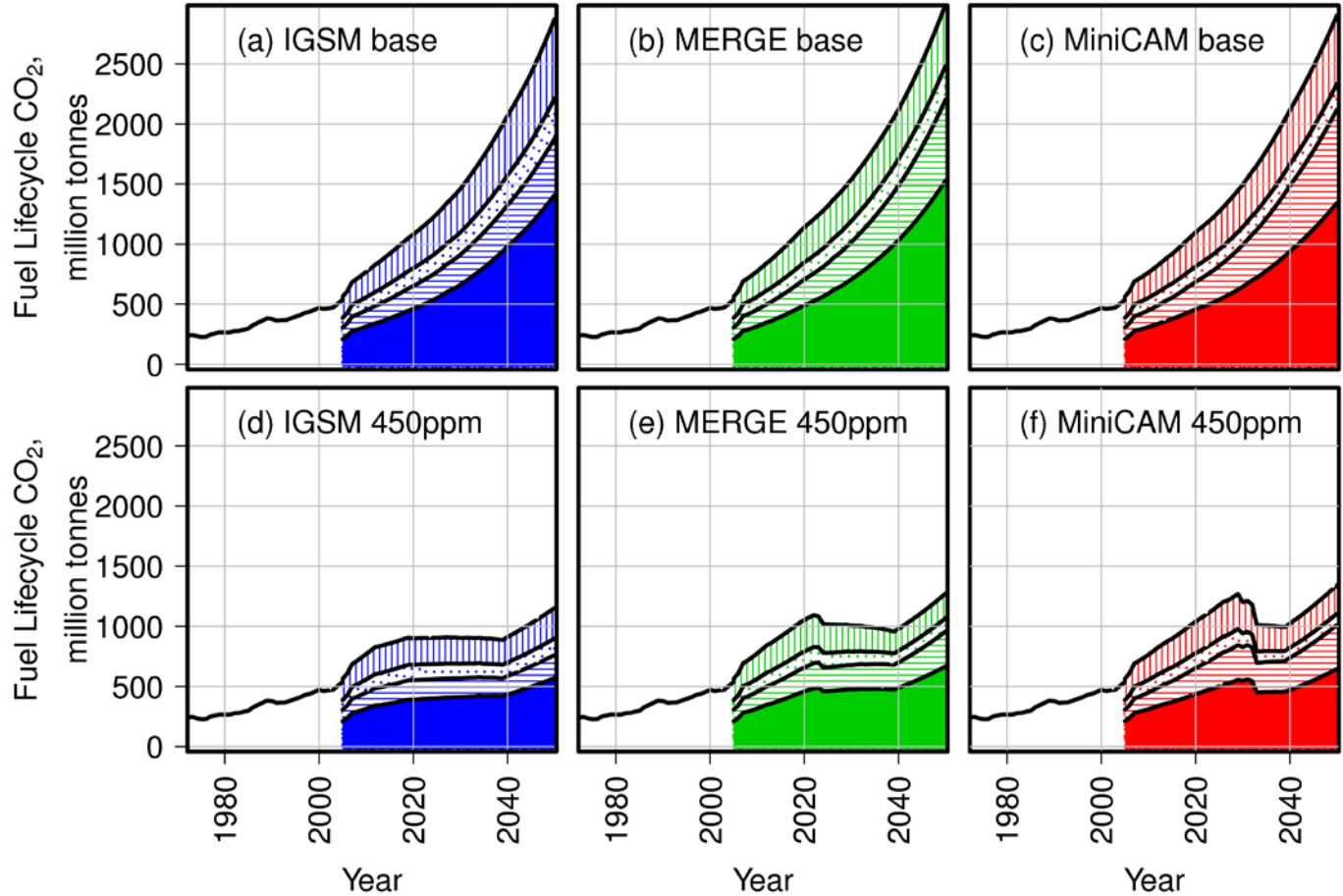


[Data: CCSP(2007)]

- Use AIM to identify the effects of CCSP global emissions trading on aviation RPK, emissions and technology uptake
 - E.g., How is the fleet affected by emissions trading?
 - How much are emissions reduced by demand decreases, and how much by alternative technologies?
 - What is the relationship between stringency level and system changes?
- Assume a range of available technology options for emissions reduction
 - Retrofits (e.g. Winglets, engine upgrade kits)
 - Improved ATM – non-optional
 - Increased maintenance (engine, aerodynamic)
 - 20% cellulosic biomass fuel blend – from 2020
 - Open rotor short-haul aircraft – from 2020



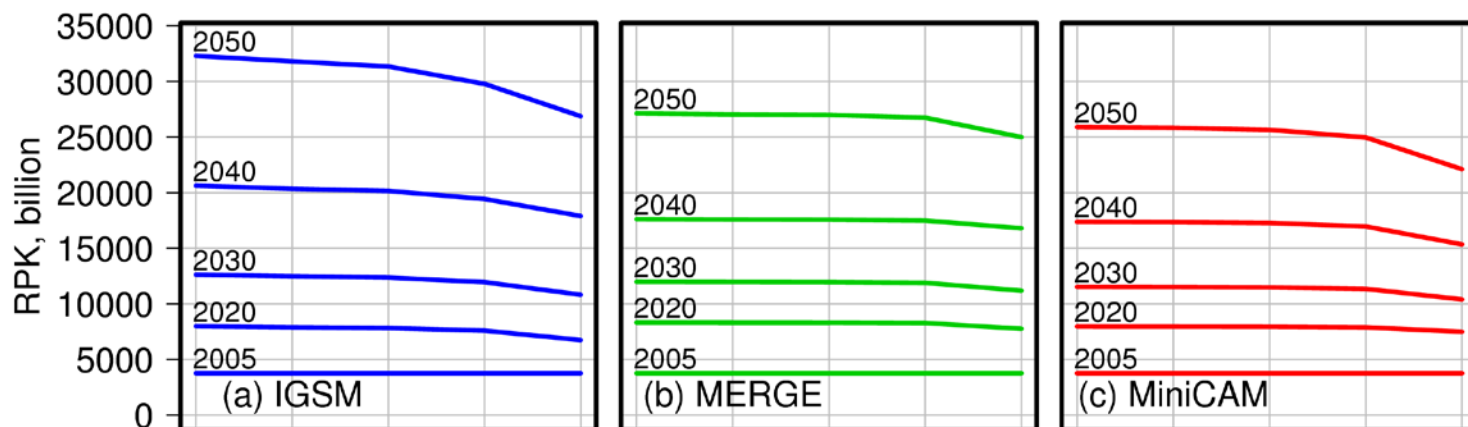
No Emissions Trading



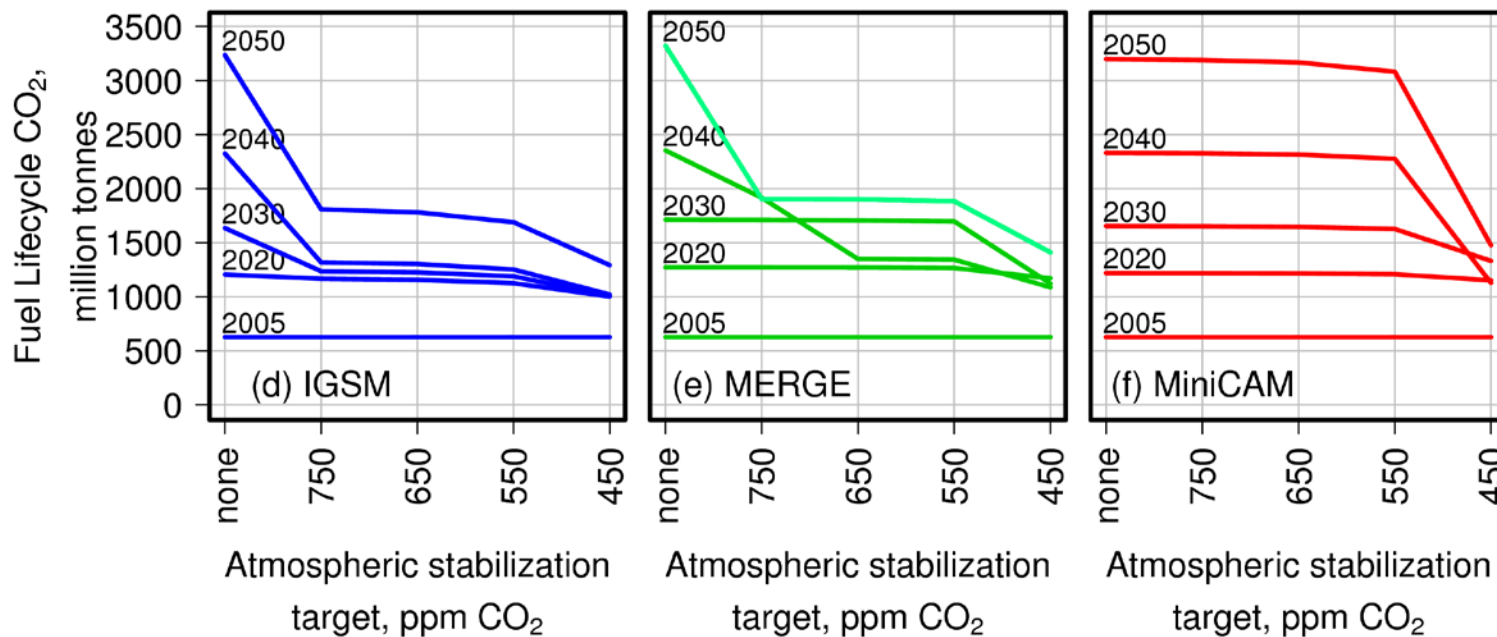
Global Emissions Trading with 450 ppm Stringency

[Past data: IEA]

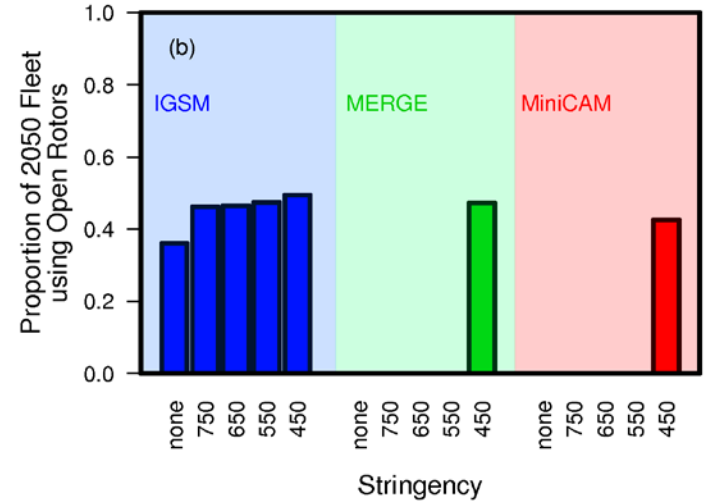
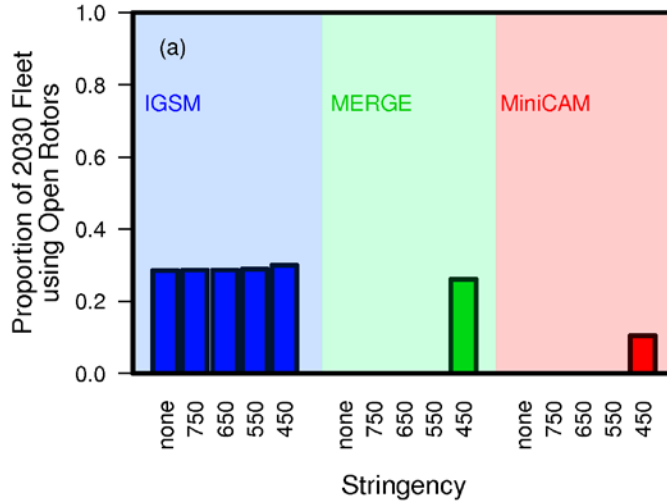
RPK



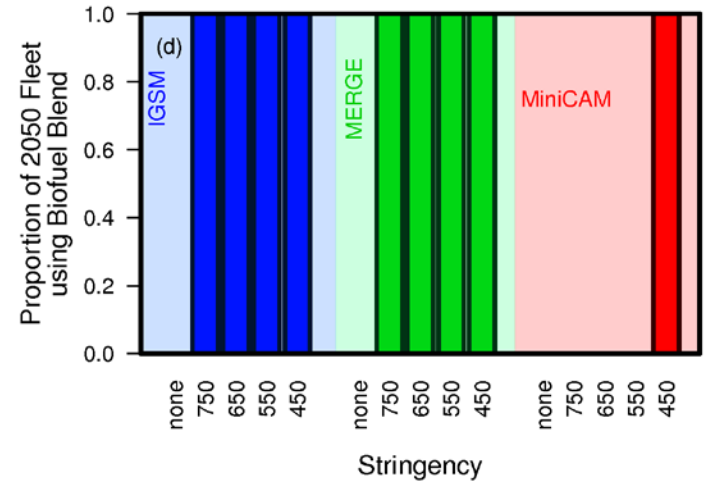
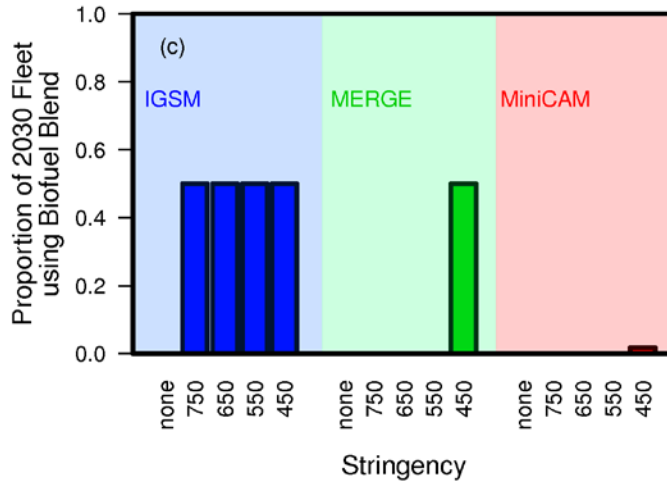
Fuel Lifecycle CO₂



Open Rotor
Engine Aircraft



20%
Biofuel
Blend



- Global aviation emissions grow in all scenarios
 - However, emissions will decrease in other sectors due to emissions trading
 - Geographic location of growth varies
- Largest reduction in 2050 emissions relative to no-trading case in these scenarios: ~60% (450 ppm, IGSM)
 - 1/3 of reduction due to demand reduction, 2/3 due to technology adoption
 - Greatest new-technology adoption for narrowbody open rotor engine aircraft and cellulosic biomass aviation fuel
- Low stringencies (750-550ppm) vary in effect based on how oil price compares to biofuel price

Core team:

- Dr. Andreas Schäfer
(Principal Investigator)
- Dr. Lynnette Dray
(Air Transport Demand)
- Dr. Antony Evans
(Airport Activity)
- Dr. Helen Rogers
(Global Climate)
- Dr. Maria Vera Morales
(Aircraft Technology and Cost)

IAE co-investigators:

- Prof. Bill Dawes *(Engineering)*
- Dr. Chez Hall *(Engineering)*
- Prof. Peter Haynes *(Applied Maths)*
- Prof. Roderic Jones *(Chemistry)*
- Prof. John Pyle *(Chemistry)*

Affiliated researchers:

- Prof. Rex Britter *(Air Quality, MIT)*
- Dr. Marcus Köhler *(Global Climate, King's College London)*
- Dr. Tom Reynolds *(Air Traffic Control/Management, MIT/Lincoln Labs)*
- Dr. Zia Wadud *(Regional Economics, Bangladesh University of Engineering and Technology)*
- Dr. Steven Barrett *(Air Quality, MIT)*