The future of flying

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Aircraft that work together to solve complicated mathematical problems and airports with more flexibly used runways could be the future of flying, according to studies by the Department of Engineering and its industrial and academic partners.

Air traffic across Europe is likely to double by 2020 according to current forecasts. This estimated increase represents a remarkable number of flights when you consider that last year in the UK alone almost 2.2 million flights carrying 200 million passengers were handled by the National Air Traffic Services.

It also represents a massive challenge for UK aviation policy, which is faced with airports operating at near full capacity such as Heathrow - the busiest in the UK and one of the busiest in the world. Increased air traffic, rising fuel prices and tight security all combine to increase the vulnerability to system-wide breakdowns, delayed flights, long queues and rising costs.

Efforts to reduce pressure on overstretched airport facilities are being aided by research projects involving University of Cambridge engineers working with industrial and academic partners. Each project is aimed at tackling some of the uncertainties associated with air traffic, and the risks these pose to heavily loaded airports, when even a short delay finding a wheelchair for a passenger with reduced mobility can affect the tight workings of the airport.

One limiting factor in dealing with a vastly increased air traffic density is the workload falling on air traffic management (ATM). "Some of the technologies assisting ATM date from the 1950s," explained Professor Jan Maciejowski, who led the Department of Engineering component of a recently completed pan-European study, iFly. "We've been looking at how we can modernise and automate ATM to improve safety at the same time as reducing workload, costs and environmental impact."

The project, funded by the European Commission and coordinated by the National Aerospace Laboratory in the Netherlands, brought together 17 partners from academia and aerospace industries across Europe. Their mission was to develop an advanced airborne flight information system so that processes normally carried out on the ground by air traffic controllers can be carried out mid-flight by multiple aircraft requiring the same airspace.

"Essentially the idea is for the aircraft to use onboard computers to predict future positions of other aircraft and to dynamically share information," explained Professor Maciejowski, who worked on the project with PhD student Ellie Siva and colleagues at the Swiss Federal Institute of Technology Zürich and the National Technical University of Athens. "The computers communicate with each other, negotiating how best to use the airspace with least cost in terms of fuel and time, while respecting the priorities of other aircraft and the comfort of passengers, and of course maintaining safe separation from each other."

The automated system enables different aircraft to solve complex mathematical optimisation problems between them - each one solving the problem for itself and then passing on its current solution and intentions to the next aircraft, which then responds, and so on. In a simulation of about 1,000 flights, the researchers found that this cooperative activity resulted in only a very small extra distance being flown (less than 1%) per aircraft. Ultimately, the hope is that if such a system came into operation, it would accommodate a three-to-six fold increase in current en-route traffic levels and be part of a System Wide Information Management 'database in the sky' proposed across Europe.

At the heart of the project is the discipline of control engineering. A recent programme grant awarded to the University of Cambridge and Imperial College London by the Engineering and Physical Sciences Research Council has assembled a team to push the boundaries of control engineering in relation to power systems and transportation. As part of this programme, Professor Maciejowski is looking at another aspect of air traffic control - the terminal manoeuvring area between the airport and 10,000 feet up.

Here, a very different scenario is in operation: many aircraft in a small space require coordination to land using the least amount of fuel, a situation too complicated to solve by aircraft communicating with each other. Professor Maciejowski and colleague Dr Alison Eele are creating a new mathematical system to optimise the landing trajectories of each plane. Their formulae use thousands of processors, now economically available as graphical processor units, to combine location measurements by radar, work out the flight plan for landing, give instructions and then recalculate every few seconds.

Although both projects are a long way from implementation - they would first need to go through rigorous safety checks in collaboration with airlines and authorities - Professor Maciejowski said that each has now reached a proof-of-concept stage and initial talks have begun: "I've been delighted by how positively airport operators have reacted already. It's a sign of the times - airports are running at capacity and it's becoming a matter of urgency to look at how systems can be improved."

Meanwhile, the focus of Professor Duncan McFarlane's research is what happens on the ground. Working with Alan Thorne and other colleagues at the Department of Engineering's Institute for Manufacturing (IfM), the team is involved in trials conducted by BAA at Heathrow Airport on measures to increase punctuality, reduce delays and strengthen resilience at the UK's hub airport. The trials are centred on making the best use of the airport's two runways, which are in heavy demand.

In the first phase of the Operational Freedoms trial Heathrow explored how its runways and airspace can be better used to recover quickly following airport disruption, such as that caused by bad weather. One strategy was to use both runways for either arrivals or for departures, instead of one for each. Initial results indicated improvements in punctuality, reduced emissions and fewer planes having to taxi across runways. A second phase is now ongoing until March 2013 to carry out a more-detailed analysis.

"The Civil Aviation Authority is overseeing the tests. Our role has been to independently audit the trial and ensure its objectives are met," explained Professor McFarlane. "We measure everything to do with the impact of changes on the performance of the airport, from how long the aircraft are in overhead 'circulation stacks', to take-off delays, to emissions and noise, and then we generate what we think are appropriate recommendations."

A further study has also just started, this time examining the order of aircraft landing on runways. "A big aircraft creates a huge air turbulence behind it and small aircraft have to wait proportionally longer before landing," said McFarlane. "Flexible use of runways could mean landing larger aircraft on one and smaller on another, or ordering planes in overhead circulation stacks into optimal landing sequences. Using runways effectively could go a long way towards helping airport operations recover quickly and efficiently from unwanted variability."

The current studies build on a major aerospace programme at the IfM driven by the end users of the research - the aircraft manufacturers, airlines and airports. For instance, the researchers have previously examined how radio-frequency identification (RFID) technology and better data sharing in airports can reduce costs and achieve greater business efficiencies.

Many of the delays in airports occur as a result of bottlenecks in the sequence of activities that take place when an aircraft is at a gate between flights. Referred to as the turnaround process, the operation involves the coordination of activities such as baggage handling, refuelling, maintenance tasks and passenger transfer. Because the companies carrying out these tasks don't always share information, a breakdown somewhere along the line can cause a system-wide snarl-up.

Tiny electronic RFID tags can be used to provide visibility for different assets used in airport operations, such as bags, baggage containers and catering trolleys, which can then be fed back to computers used by the different service teams on the ground, allowing them to recognise and share problems quickly.

Working with airlines such as Easyjet and FlyBe, and Manchester, Luton and Heathrow Airports, the researchers looked at what causes delays and whether better information usage can improve aircraft turnaround time. "For example, one cause of aircraft delay can be the unavailability of a wheelchair to take a passenger to a flight. Something as simple as a strategy for locating and ensuring wheelchairs are in the right place at the right time can make a considerable difference to guarding against delays," commented Professor McFarlane. "What our aerospace programme is trying to do is quantify the risk and uncertainty associated with different disruptions, and then redesign and pilot robust practices that will eliminate unexpected delays or increased costs."

Provided by University of Cambridge