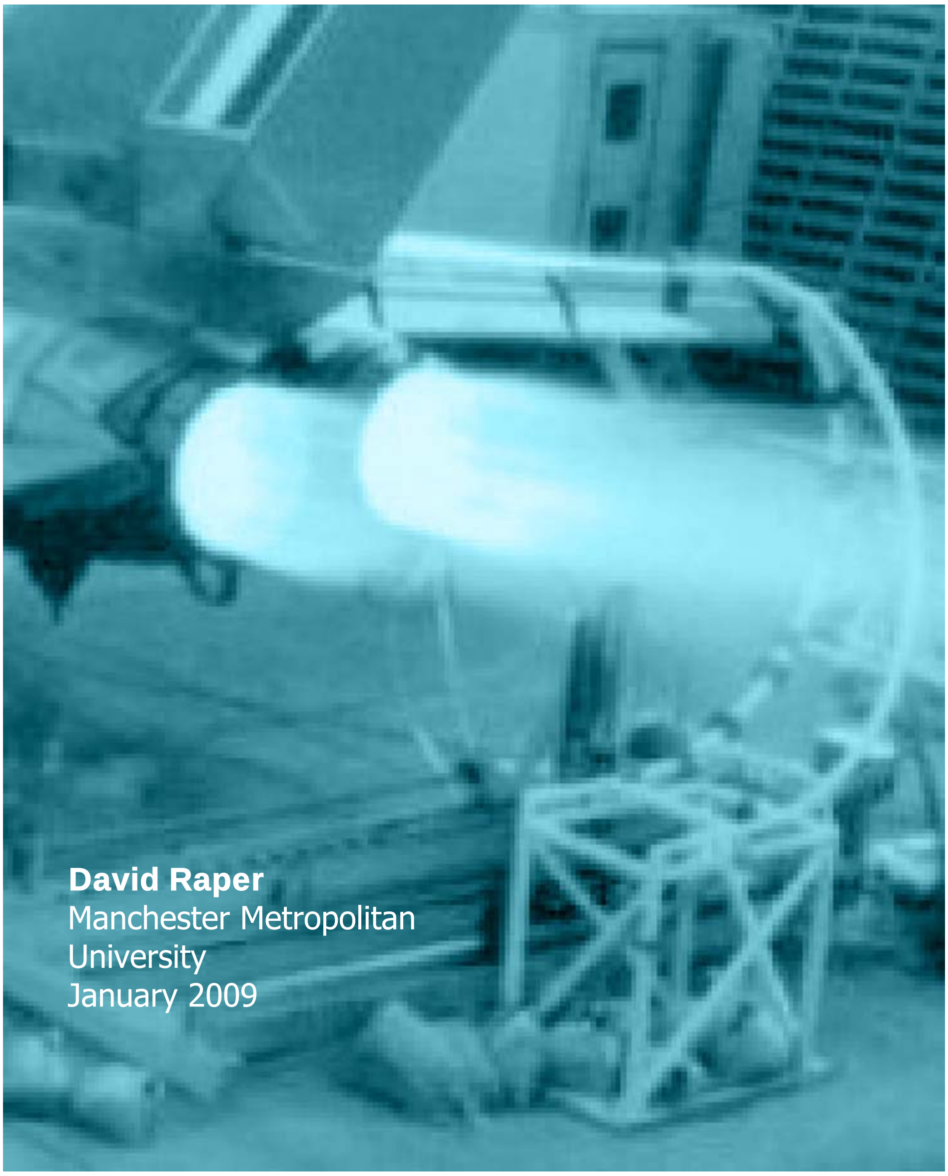
Omega

Aviation in a sustainable world

Local Air Quality

Project Aircraft Plume Analyses Facility (ALFA)



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About Omega

Omega is a one-stop-shop providing impartial world-class academic expertise on the environmental issues facing aviation to the wider aviation sector, Government, NGO's and society as a whole. Its aim is independent knowledge transfer work and innovative solutions for a greener aviation future. Omega's areas of expertise include climate change, local air quality, noise, aircraft systems, aircraft operations, alternative fuels, demand and mitigation policies.

Omega draws together world-class research from nine major UK universities. It is led by Manchester Metropolitan University with Cambridge and Cranfield. Other partners are Leeds, Loughborough, Oxford, Reading, Sheffield and Southampton.

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Executive Summary

Omega has facilitated the secondment of Professor Andreas Petzold to MMU for three short term secondments. The secondments were timed to assist the development of the Science City / Northern Way funded Alfa project. Alfa (Aircraft Plume Analysis Facility) is an emerging capability of MMU, Sheffield and Manchester Universities to measure the composition of aircraft engine exhaust emission in situ. The assembled equipment includes a traversing rake and probe assembly, aerodyne mass spectrometer and a mobile lidar.

Professor Petzold has been able to use his knowledge of particulate measurements, instrument calibration and testing to assist in the integration of the Alfa equipment. He has also formed valuable links between Omega and the international community.

1 Introduction

Aviation is a major enabler for global wealth creation, benefiting developed and developing countries alike and supports 8% of global economic activity. It is also a critical part of the UK economy, currently delivering more than 2% of GDP (£>25 billion). The UK has the second largest aerospace and aviation economy in the World and has been a global leader in the sector for over 60 years. Over the last 30 years there has been a six fold increase in air travel demand. At the same time there has been a 60% improvement in fuel efficency and more than 20 dB reduction in aircraft noise. These improvements have been delivered through fundamental aeronautical research focused primarily on technological and operational developments to improve efficency and cost effectiveness. However, predictions show that global air transport demand could grow by a factor of four over the next 30 years. Whilst it is widely agreed that the consequences of this would bring significant economic and social benefits the associated enviromental impact of local air quality will provide significant challenges for all.

Local air quality will constrain the growth of airports and the aviation sector. Indeed the Secretary of State for Transport has made it clear that UK airports will not be allowed to develop unless air quality standards are met. Indeed this message is reinforced in the Secretary of State for Transport's policy decision on the 15th of January 2009 where it is stated *'..any expansion at Heathrow airport must be accompanied by a firm commitmment to ensure that the strict local environmental conditions that have been set will not be exceeded'* (http://www.dft.gov.uk/pgr/aviation/heathrowconsultations/heathrowdecision/)

There are a number of uncertainties associated with the future prediction of air quality impacts at an airport. One of the largest being non aircraft related emissions and in particular those from road transportation. However, the composition of aircraft exhausts in particular – gaseous and particulate emissions is still not fully understood.

Aircraft engine manufacturers such as Rolls Royce are only required to measure NO_X, soot and un-burnt hydrocarbons at point of certification . Unfortunately this is not sufficient information for atmoshpheric scientists (or legislators) wishing to understand the impact of emissions on the environment. Recent work funded by the USFAA has started to develop a better understanding of gaseous and particulate emissons from aircraft engines (see: http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?all/TM-2006-214382.html) but there is a distinct lack of UK or European effort within this area.

Under separate funding, Manchester Metropolitan University was awarded £500,000 to develop a UK capability along with Sheffield and Manchester Universities to facilitate the measurement , on-wing, of aircraft exhaust emissions. Omega has helped to develop the potential of the capability and enhance its deployment.

The capability comprises:

1) A traversing sampling rake

   The probe has two co-located sampling orifices for both diluted and undiluted exhaust gas samples. The flow rates for the sampling probes can be set based upon the requirements of the instruments to be used. The undiluted flow capacity will be such that it can provide 25 l/min of undiluted sample for use with the CO_2, CO, UHC and NOx instrumentation. The diluted line is capable of being diluted with particle free dry air at a position as close as physically possible to the sampling orifice.

2) High resolution time of flight Mass Spectrometer (WToFMS) system for incorporation into an existing Aerodyne Aerosol Mass Spectrometer (AMS). The Aerodyne AMS provides quantitative real-time size-resolved composition analysis of non refractory particulate matter. Aerosol particles in the size range 0.04 to ~1.0 micrometers are sampled into a high vacuum system where they are aerodynamically focused into a narrow beam (~1 mm diameter). The particle beam is directed onto a resistively heated surface where volatile and semi-volatile chemical components are thermally vaporized and detected via standard 70 eV electron impact ionization quadruple mass spectrometry. Particle aerodynamic diameter is determined from particle time-of-flight (velocity) measurements using a beam chopping technique.

   This approach provides universal detection of chemical species that vaporize (in <1 sec) at 200 to 900C (typically 600C). This "non-refractory" fraction includes the majority of atmospheric components, with the notable exception of elemental carbon and crustal oxides (dust). Some inorganic components (e.g. seasalt) require vaporization at higher temperature (900C). The combination of quantitative size and chemical analysis of sub-micron aerosol mass loadings with fast time resolution makes the Aerodyne AMS unique.

3) Upgrade to an existing mobile Lidar system. Lidar is the optical equivalent of radar: scattering of laser light from atmospheric aerosol permits measurement of the dispersion of pollution in the atmosphere. The Rapid-scanning Lidar at MMU was originally developed at the Central Electricity Research Laboratories, Leatherhead, for studying dispersion of atmospheric emissions from power stations. It is built around a Nd:YAG laser. Originally this operated in the green (λ=532 nm), but for eye-safety reasons this has now been converted to the UV-A (λ=355 nm). Recent investment under the Alfa project has now allowed the upgrade of the system in particular: the noise of the system has been reduced with the purchase of narrower optical filters on the return signal path.

The collection of equipment that is being developed at Manchester Metropolitan University (MMU) and collocated at the Universities of Sheffield and Manchester will be the first of its kind in Europe. In particular it will facilitate the improved understanding of plume composition and local dispersion. It is expected to be used to:

- build a database of operational aircraft emissions
- provide a better understand the complex physics and chemistry within the plume
- develop insights into the environmental impacts of operational controls such as reduced thrust, and fuel modifications including bio-fuels.

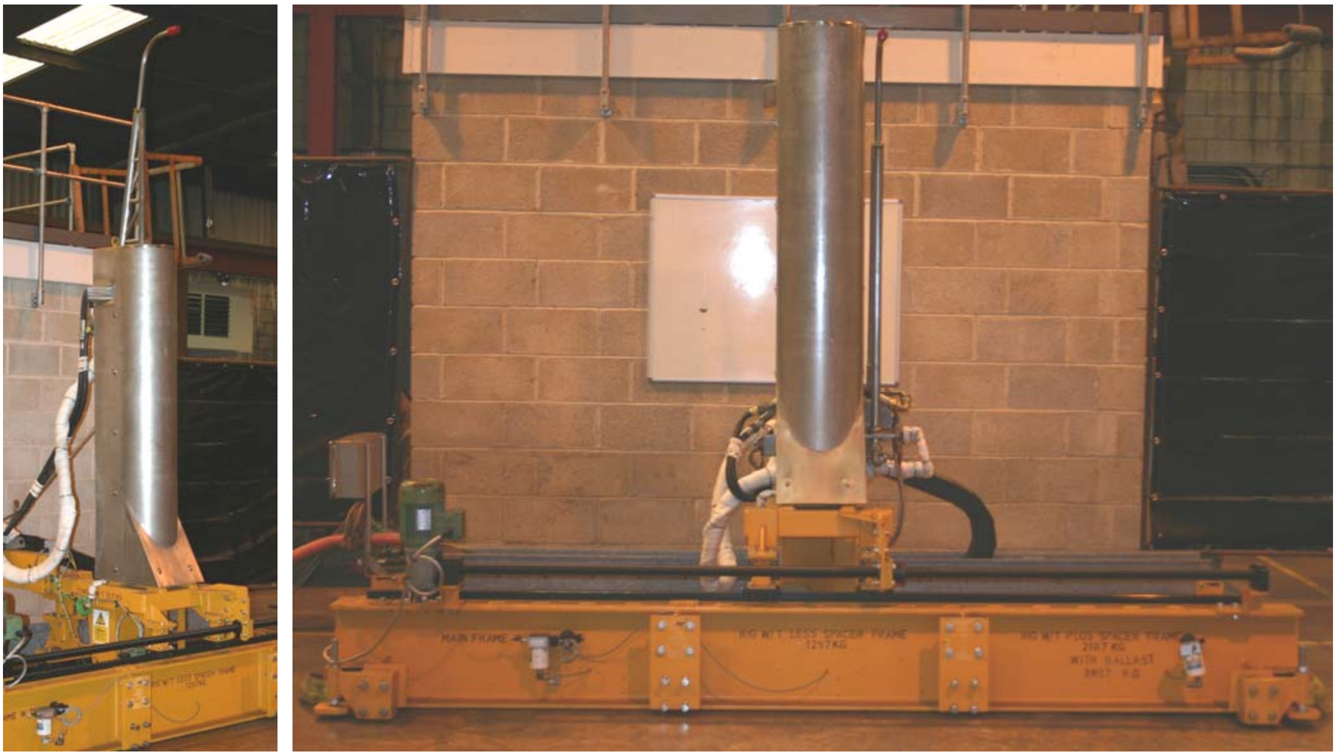

Figure 1 Sampling Rake

Figure 2 High resolution time of flight Mass Spectrometer (WToFMS)

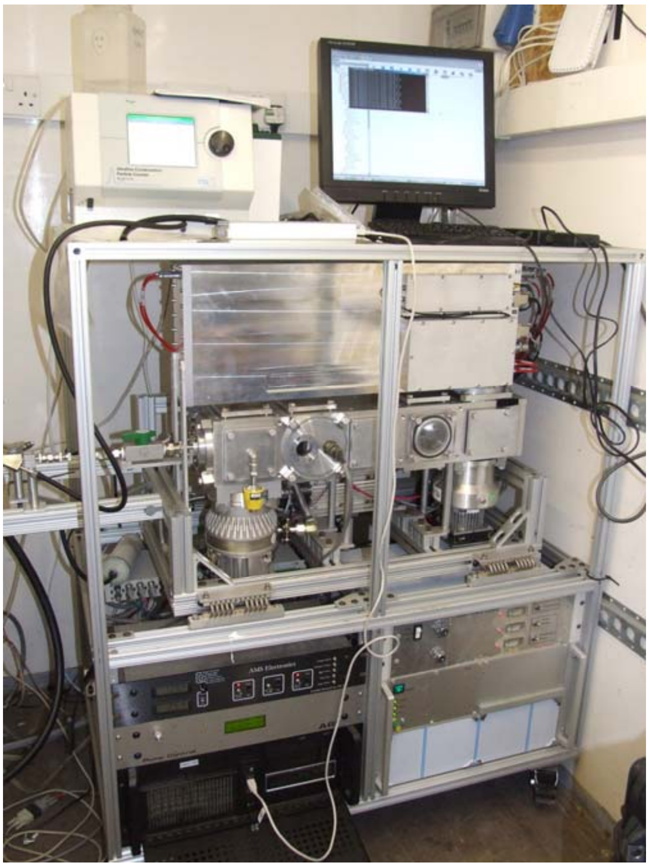

Figure 3 Mobile Lidar

In order to maximise the benefits from this developing capability Omega provided funding to support the short term secondment of Professor Andreas Petzold from Deutsches Zentrum für Luft- und Raumfahrt; DLR.

Professor Petzold was specifically tasked to work with the combustion and environmental teams at MMU and Sheffield to help ensure the successful development and setup of the Alfa rake. Dr Petzold also acted as a key reference point to international forums such as Society for Automotive Engineers and ICAO. Importantly Professor Petzold also helped to bridge the gap between the European funded ECATS Network of Excellence and Omega.

The Alfa capability is near to finalisation, with only a sample line conditionining system (hot water trolley) yet to be commissioned. Both the Lidar and Mass Spectrometer are fully functioning and have been used in a number of seperate measurement campaigns.

2 Secondments

Two short term secondment periods involving Professor Petzold have been funded by Omega:

October 2007 – 4 weeks
October 2008 – 4 weeks

During these three periods Professor Petzold has provided the technical link between Manchester University Atmospheric Science Centre, MMU and DLR. Through assuming a hands-on role he now more fully understands the ALFA capability and has been able to include parts of the facility in a recently successful proposal to EASA. This project will use the Alfa Aerodyne mass spectrometer to standardized instrumentation and better understand the effect of sample lines. A second phase of the project, if funded, will use the Alfa rake for sampling directly behind an aircraft.

An Important output from these secondment periods was a report to the Society of Automotive Engineers (SAE) which detailed the characteristic properties of particles emitted from aircraft engines and their relationship to current measurement approaches.

3 Conclusion

The expertise acquired through these secondments significantly strengthens the technical capability available through the ALFA rig. Future deployment of the rig will help characterize 'actual' emissions from aircraft engines in airport environments as opposed to nominal test conditions required by ICAO certification processes. The ability to take such 'on wing' measurements makes it possible to account for a wide range of operational power settings beyond those required for certification testing. It also permits examination of any installation effects, potential alternative fuels and engine deterioration effects on emission performance. Improved understanding in these areas is crucial to more robust modeling of aircraft emissions in the near airport environment.