Airborne Atmospheric Measurement – An Interview with Alan Woolley, Acting Head of FAAM

The emissions scandal in Europe, forest fires in Indonesia, increasing levels of air pollution in Asia – perhaps now more than ever the need for understanding our atmosphere is of paramount importance. To this end, Cranfield University in Bedfordshire recently hosted the Natural Environment Research Council's (NERC) first Atmospheric Science Showcase, attracting the UK's foremost atmospheric researchers and scientists, the BBC, and related media representatives including International Environmental Technology editor Rachael Simpson.

Rachael Simpson

Originally known as the Cranfield Institute of Technology, renamed Cranfield University in 1993, the campus our group strolls through has evolved from a College of Aeronautics which was present on the site from 1946 until 1969, when it was granted university status. Before 1946, the site was an RAF base used during WW2 to house bomber squadrons, and the subject of several aerial attacks. You could say that planes and air travel are in Cranfield's blood. It may also explain the campus' unusual building numbers. Walking from the main showcase reception to the air hangar I ask Dr Alex Pryce, Cranfield's Communications Manager, why the buildings aren't numbered with any semblance of order. "Rumour has it that it was to confuse the Germans if they landed here during the war," she tells us. "They would have just got lost."

> *"When the Icelandic volcano (Eyjafjallajökull) erupted in 2010 and airspace was closed we built a safety case in which to operate the aircraft based on our abilities, and the measurements we had made of the ash. We then used the aircraft to go up and survey UK airspace to ensure there was no ash left. Over the next month, when the ash cloud was sweeping across the country, we were able to help decide which airports were safe to use and which were not - this could not have been done very easily any other way."*

The aircraft at the centre of the showcase has its own tale of evolution from original purpose to present-day state. Dwarfing all the other planes in the hanger, the 31 meter long BAe 146-301, boasting a 26 meter wingspan, was built in 1981 as a "high-density" passenger aircraft for short-haul regional flights. Now it is owned by the Natural Environmental Research Council (NERC), and, through a joint venture with the Met Office, the Facility for Airborne Atmospheric Measurement (FAAM) was born.

The plane has been heavily modified to conduct airborne atmospheric measurements with a team of 18 scientists and 3 crew (2 pilots and 1 cabin crew) on board. Designed and built to cater only to short flights, extra fuel tanks have been retrofitted to increase the fuel capacity by 12,000 litres extending the flight range to 2000 miles, essential for travelling across the globe. The overhead luggage compartments and most of the seats have been stripped out, providing much needed space for the 50-100 instruments carried on each flight (up to 4000 kilos of instrumentation payload). "It gets hot in here, and very noisy", says Alan Wooley, acting head of FAAM and our guide around the aircraft. There is extra noise associated with the science instrumentation on board, due to powering it all and the physically noisy items such as pumps etc. Heat management from the instruments can be a problem as the power from the instrumentation is ultimately dispersed as heat, and the increased attitude of the aircraft (pitch ~7 degrees) associated with flying at a slightly slower standard speed (200kts IAS) results in an appreciable temperature gradient from front to back.

No one said that flying on this plane was a job for the faint-of-heart scientist. Despite its imposing size the aircraft is capable of dropping to a height of only 50 feet above water - lower than the Dambusters flew - and can go up to a maximum altitude of 35,000 feet, covering most of the Troposhere, at least around the UK. Walking around the outside of the plane, it's easy to spot the modifications that have been made – shiny metallic pylons for cloud physics measurements hang from beneath the wings, sensors protrude from the fuselage to monitor the air temperature, ports embedded in the nose cone gather information on turbulence. Small, disposable radiosondes attached to parachutes can be dropped down a chute from the inside of the plane, to descend slowly through the atmosphere and send back real-time measurements. Two cargo holds offer additional space for spare instruments, luggage, and other supplies. Ready for loading stands a shipping crate full of gas canisters used to store samples for testing back at the lab, once the wheels have touched back down on terra firma.

The BAe 146-301 FAAM aircraft

Overall, it's a very impressive sight.

The new FAAM calibration laboratory is worth a mention too. Still filled with the unmistakable aroma of fresh paint, the lab opened in May 2015 to allow for the onsite calibration of instruments before they are loaded straight onto the plane.

Read on for IET's exclusive interview with Alan Woolley to learn more about FAAM, the challenges of airborne atmospheric measurement, and why calibration is so vitally important.

1. When was FAAM established and what are its main aims and goals?

A: FAAM was established in 2004, to provide an airborne platform to make in-situ measurements of the atmosphere.

2. What makes the use of aircraft such an effective tool in atmospheric research?

A: A lot of work has gone into making sure the measurements on the aircraft are as good as they can be. It's a relatively unique facility, and without it there are remote parts of the atmosphere that you simply couldn't access via any other means. It's the only way of getting data from inside clouds or from smoke plumes, for example.

The FAAM CORE 5-hole turbulence probe, measuring incident airflow and 3D wind components

3. Can you give any examples of projects that could not have been achieved without the use of the FAAM aircraft?

A: There are a lot of different examples of this. When the Icelandic volcano (Eyjafjallajökull) erupted in 2010 and airspace was closed we built a safety case in which to operate the aircraft based on our abilities, and the measurements we had made of the ash. We then used the aircraft to go up and survey UK airspace to ensure there was no ash left. Over the next month, when the ash cloud was sweeping across the country, we were able to help decide which airports were safe to use and which were not - this could not have been done very easily any other way.

We also flew in Brazil in 2012 looking at biomass burning; again, it was a very remote area, conditions we see with a lot of the projects we do. In 2014 we were based in Guam, looking at chemical transport in tropical convection, and we were out in the middle of the Pacific Ocean off the coast of Guam. There is no other way of doing that (research) than with the FAAM aircraft.

Gas canisters for sampling

4. Your website mentions FAAM core instruments – what are these core instruments, and what are their main applications?

A: We maintain a suite of instrumentation at FAAM, which tend to be the things that are easier to look after; instruments that are off the shelf, don't require very much modification, and instruments that the user community want on pretty much every flight, such as air motion, temperature sensors, hygrometers for measuring humidity, ozone measurements, basic not-too-reactive gases – things at the simpler end of the instrumentation spectrum that run all the time and don't need too much in the way of "handholding". At the other end are the non-core instruments, where you might have a University research group specialising in measuring particular cloud particles or a specific reactive gas molecule. You can't just go and buy them off the shelf so easily – it takes such an effort to make instruments such as these and we don't tend to support them as our main intention is to supply the plane and fly it around the world for projects. Therefore we are happy to provide a certain base level of instrumentation to the researchers and scientists that use our services.

Logos on the rear show the institutions affiliated with the aircraft

Banks of computers and monitors inside the plane

5. Your website also states that FAAM is involved in "Managing the introduction of instruments on behalf of the scientific community" – what does this entail?

A: This applies mostly to the non-core instruments. For example, when a university wants to fly an instrument on the aircraft we liaise between them and the certifying body, BAE Systems, to make sure that those instruments are up to our safety specifications and to flying on the plane. There are a vast amount of ground rules whereby special racks (to hold the equipment) have to be designed, and to be mechanically safe, and FAAM helps with that process.

In addition, having flown with the aircraft for many years, we have personally encountered a lot of the most common problems with things like environmental vibration, changes in temperature and humidity. Thanks to our experience we are able to help the groups that want to fly their instruments with the decision making process at the design stage.

6. You've recently moved into your new lab which allows onsite instrument calibration – why is this calibration so important?

A: To put it simply, you need the right answers when you are going out flying. Flying is an expensive enterprise - you've seen the size of the jet we are taking around the world - and when we are collaborating on projects with other agencies and other research groups, everyone needs to know that their instruments, under the same conditions, will give the same readings. That's why precise calibration is so important. If we are measuring at a low level, and someone else is measuring at a high level, and there is a difference in results we need to know that the difference is real, and not a result of a problem with the measurement equipment – this is what calibration does for us.

7. When working at altitude, what main problems do you face?

A: Inside the plane it is very noisy. At a low level you would be strapped into your seat for safety reasons. It can get extremely hot and the temperature can fluctuate, which is obviously unpleasant for the scientists but also for the instruments – they don't like such changes in those sorts of things. Temperature, pressure and humidity changes, as I discussed earlier, often affect the instruments we are using.

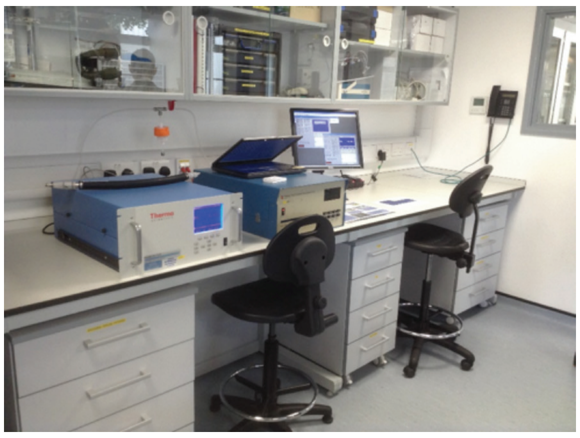
Sometimes it can be very difficult to communicate; you're not face to face with other people, you're communicating via a headset. Vibration, motion sickness, all of that. It can be very challenging at times.

Wing mounted imaging probe (bottom right) and three "blanks"

The inside of the plane has been stripped right back to allow more space for instrumentation

8. Do you see the way in which we carry out airborne atmospheric research changing much in the years to come? And if so, how?

A: The rise of UAV's means you can cheaply get a lot of sensors airborne, so that will probably change the way things happen, but for a lot of large scale "flying laboratory" experiments like ours you won't be able to fly those as UAV's in general airspace for a long time to come. That would be the main kind of change that I would expect to see – for many many years there hasn't been any other way of doing this kind of data acquisition. Models can give you so much, satellite data can give you so much, and satellite instrumentation is getting more sophisticated, but ultimately you still need in-situ measurements to support, constrain and optimise both of these.



The recently opened lab allows on-site calibration