‘Please fasten your seatbelts, we’re in for a bumpy ride’

Fight for flight: Airlines tackle climate-change crash risk p52

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It’s time once again to jet off on holiday — but make sure you have your seatbelt fastened...

Are you reading this on a plane on your way to sunnier climes? Have you noticed the ride is a bit bumpier than it used to be? In this month’s cover story we hear how global warming is creating more turbulence on transatlantic flights. Does that matter? It sure matters to some passengers who don’t much like flying in the first place but it also matters to those who want to get their fast: more turbulence means longer journey times. It also means higher fuel consumption and more carbon emissions.

Of course, a few bumps in the air won’t bother E&T readers, who have the utmost faith in aeronautical engineers and a sound understanding of the statistics of risk. But perhaps you have a travelling companion who is of a more nervous disposition and, if you have just been told to return to your seats and fasten your seatbelts, you might like to show them the feature on p32 and in particular these reassuring words from Michelle Fitzgerald, Boeing’s deputy capability manager for structural testing: “We push every piece of every product to its limits — and beyond — to ensure the planes can easily handle any situation they are likely to encounter. I don’t stress when I fly. I’ve seen those wings bend 26 feet — I have supreme confidence in our products and I know that they will withstand anything they come across in flight.”

So sit back and relax. But wait, you didn’t have time to get any local currency? How will you pay for that first cocktail at sundown on the restaurant terrace you’ve been looking forward to so much? By card sure, but where you’re going they may be more likely to ask for a contactless card.

Don’t think you have one? Check the logos because the statistics show many people have them without even realising it.

Advocates say ‘wave and pay’ or ‘tap and go’ payments are more secure and efficient than pin cards or cash but the technology has yet to live up to the industry’s high hopes of a few years ago. Visa boss Peter Aylliffe predicted the end of cash by now. Do consumers have security fears? Or is it just not cool? Aasha Bodhani takes a look on p32.

While you’re soaking up the sun — let’s hope — the latest batch of graduates may well be more preoccupied with starting or still looking for their new jobs. The economic climate means it’s never been tougher for graduates. But, with industry reporting serious skills shortages, is this a good time to be a graduate in engineering? We talk to some recent graduates in our feature on p32. Graduates’ experiences vary but companies report they can’t get the engineers they need. Is that because the profession is failing to attract enough young people into it, and is a lack of role models to blame? When was the last time you saw a real engineer in a soap opera? Our readers have come up with some intriguing examples in this month’s letters on p42 — including one aeronautical engineer who knows all about life’s turbulence.

did you know...

First destinations of UK university graduates 2011-12 by subject
Turbulent times

Researchers at two UK universities have identified the likelihood of increased turbulence in aircraft over the coming half-century. But can we do anything to stop it? By Anne Harris
CLIMATE CHANGE HAS been blamed for a dizzying array of problems - melting ice caps, severe storms, species migration, death and destruction - but one of the more specific phenomena to be attributed to it is bumpier flights.

Turbulence is the dread of most air passengers. Despite endless reassurances that modern planes can withstand the wildest turbulence, the atmosphere has to offer, even the gentlest of bumps has some passengers grabbing their armrests in alarm.

The bad news for these nervous travellers is that by the middle of this century, according to research from the Universities of Reading and East Anglia, climate change will lead to bumpier transatlantic flights. Consequently, journey times could lengthen while fuel consumption and emissions look set to increase.

The modelling produced by the researchers suggests the average strength of transatlantic turbulence could increase by between 10 and 40 per cent, and the amount of airspace likely to contain significant turbulence by between 40 and 170 per cent, where the most likely outcome is around 100 per cent.

The research focused on clear-air turbulence in winter, which is particularly problematic to airlines, because clear-air turbulence is invisible to pilots and satellites, and winter is when it peaks. "It can be a problem because usually when you are flying through clouds it will be during take-off and descent so all the passengers should have their seatbelts on at that time," Dr Paul Williams from the University of Reading and an author of the report says.

"While it may not be pleasant for the passengers it is not particularly dangerous. However, when you are flying at 11km up through clear blue skies, the seatbelt sign is off and people are moving around the cabin when you suddenly hit turbulence and that is when people can suffer injuries."

Refining predictions

Williams has been researching the effects of turbulence for five years, refining an algorithm to make aviation turbulence predictions that are valid for a period from an hour to over a day. Williams admits that these predictions are certainly not perfect. "They do not get it right 100 per cent of the time, I think the success rate is about 70 per cent, and so I worked on developing a new method for this a few years ago," he said.

Williams has also worked on climate-change problems and he realised there was an opportunity to bring together these two independent strands of research. "The climate science community and the aeroplane turbulence community are two very different groups of people. They usually do not talk to each other data from a computer model output; the same sort of model that would predict the weather. "That is used as a data source," Williams adds. "There are ways of taking that data set and estimating from it where and when the turbulence would be. I should say the resolution and
TESTING TIME

BOEING AIRCRAFT TESTING

Engineers at Boeing put the aircraft through its paces to ensure that it can survive even the most severe turbulence. No aeroplane has been damaged by normal turbulence and the simple reason for that is they are designed to perform under the worst that nature can throw at them. Planes are designed to take stresses of up to 3.5 g before major damage occurs.

A team of 180 test and evaluation structural test engineers at Boeing’s Seattle base have a hand in making sure that all Boeing products can be operated safely. The team pushes structures to their physical limits, finding out where the breaking point is, often with an audible pop, snap or crack. Their efforts help ensure the safety of the company’s jets by verifying that the breaking point lies exceptionally far away from what a pilot may experience, even in extreme circumstances.

“Our job is to make sure that passengers and crew can trust the plane they’re in,” Marshall Short, lab test operations vice president, said. “We test and sometimes break things so people know they can trust the planes. It’s too bad the average traveller has no idea about all the work these teams do to keep them safe.”

Structural tests fall into two main categories: static and fatigue. Static testing determines an airframe’s ability to carry loads. Loads applied during the final phase of static testing are 80 per cent greater than loads that may be encountered in service. Photos and videos of static testing, with airplanes encased in large scaffold-like structures, show dramatic images of planes surviving seemingly impossible stresses, such as having their wings bent almost vertical.

Fatigue testing subjected airframes to the equivalent of up to three lifetimes of in-service wear and tear to help determine durability. This also helps set operator maintenance and repair schedules.

The basics behind these tests haven’t changed for almost a century, but the execution has, and in dramatic fashion. For instance, data-collection techniques have advanced significantly since the company started structural testing.

Originally, there were several “deflection men” responsible for manually recording data points. Today the static tests use a system that’s precise, sophisticated and the largest of its kind. Devices that capture any change in position to within 0.06mm allow more than 50 design engineers and stress analysts to remotely monitor airframe health, comparing their predictions to test data in real time.

The way loads are applied to the airframe has also evolved. Each structural test once required 29 employees, including 11 pump men who manually operated hydraulic controls to apply flight loads to a test article. Today, two engineers operate one computer that controls in excess of 166 servo-hydraulic load systems.

“Although the tools and instruments have advanced, our job still is as exciting as it ever was,” says Michelle Fitzgerald, deputy capability leader for structural testing. “We push every piece of every product to its limits and beyond – to ensure the planes can easily handle any situation they are likely to encounter. I don’t stress when I fly. I’ve seen those wings bend 26 feet – I have supreme confidence in our products and I know that they will withstand anything they come across in flight.”

< grid spacing of the data is really far too coarse to explicitly predict if there is any turbulence in it.”

Using a grid of tens of kilometres means that the data points are tens of kilometres apart, but now scientists have developed methods of taking data of this resolution and estimating where the turbulence will be using dozens of different measures to do these calculations. “In the paper we have used those exact same mathematical algorithms and instead of using data that corresponds to a weather forecast for tomorrow’s weather as being our input, we take two different climates in relations and have looked at different turbulence statistics from the pre-industrial to the double CO2.”

Trouble spots

Any location in which the wind speed changes with altitude – a wind shear effect – will always tend to be an unstable situation. There is a compensating, stabilising mechanism, which suppresses the instability – that is, the higher up you go in the atmosphere the less dense it gets – called stratification. In the same way that oil will rest on top of water in a stable situation, the stratification of the atmosphere is a stabilising effect that will try to inhibit the turbulence that is trying to be produced by the wind speed. The jet stream is a high wind-shear region, the wind is changing rapidly with the height, and that is why you tend to get this instability in the jet stream itself. “Certainly, if you fly over a mountain range there are ‘mountain waves’, which result from the interaction of the airflow of the mountain itself that creates a ‘gravity wave’ that propagates up into the atmosphere and eventually breaks up,” Williams adds. “It increases the shear locally; that is one reason you can get a lot of turbulence when you’re flying over a mountain.”

The effect that climate change is having on flying conditions boils down to warming by different amounts in different places. It is the difference the temperature between the North Pole and the equator at flight altitudes that drives the jet stream, and the difference is getting larger due to climate change. “At 10km up it is getting warmer more at the equator than it is at the North Pole,” Williams explains. “That makes the jet stream flow faster, which is a well-known climate phenomenon. What we have looked at is the particular consequences of that for clear-air turbulence because a stronger jet stream will give you more turbulence.

“We have looked at these two computer simulations and tried to estimate the turbulence in both cases and indeed we have found that the stronger jet stream does mean more turbulence and we are likely to be able to put some numbers to that to show exactly what the percentage increase is.”

The concept seems self-evident, but someone is still needed to do the actual work. “I think it is consistent with our understanding of climate science and changes to the jet stream, but the increases are not small,” Williams says. “We are looking at the most likely outcome as being a doubling of the amount of airspace containing significant clear-air turbulence – an enormous increase.”

Levels of turbulence (light, moderate, severe and extreme) are all measured in terms of G-force that is felt by the plane. Light turbulence is anything up to 0.5 g, moderate is 0.5 g to 1 g, severe is 1-2 g and extreme is anything above 2 g.

Whenever a pilot passes through turbulence he or she is supposed to report it. The TSSB database hold records of not only turbulence but other hazards such as icing of the wings.

Advanced algorithms

The research itself hasn’t helped the formulation of more accurate algorithms but has given extra motivation to the need to
develop them. "If the atmosphere is going to contain twice as much airspace containing turbulence, the only way planes are going to be able to avoid a 100 per cent increase in the amount of time with the seatbelt sign on is if they know where the turbulence will be," Williams says. "In order to get that we need to improve these algorithms that are used and so I think one consequence of this paper is to make it even more clear that we have got to develop better algorithms pretty urgently."

The major airlines are wary about discussing the subject, and Williams himself has had no formal contact with any of the airlines although he has given a talk at an aviation turbulence symposium in the US where pilots and aviation industry representatives were present and he had "informal chats" with them.

"I think from a pilot's perspective it is not an issue of safety, but an issue of comfort," Williams says. "It makes the passengers' flight more of a nuisance and one in which drinks will get spilt, but that is not a huge hazard. There are hundreds of injuries each year, mainly to crew as they are out of their seats trying to serve passengers as the turbulence hits. So, while this is not a safety issue primarily, it does stand to reason that an increase in turbulence will lead to an increase in injuries."*

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**FROM THE COCKPIT**

**BA PILOT TALKS TURBULENCE**

British Airways
Captain Steve
Allright, who runs
the BA Flying with
Confidence Course,
talks about his
experiences of
clear-air turbulence

"Many different things
may cause turbulence, but each and every
one of them is known and understood by
pilots. Every day I fly, I expect a small
amount of turbulence, just as I'd expect the
odd bump in the road on the drive to work.

"Different aspects of the weather cause
different types of turbulence. Clear-Air
Turbulence (CAT) is the most common
form you are likely to experience.

"Air tends to flow as a horizontal snaking
river called a jet stream. A jet stream can
sometimes be thousands of miles long but
is usually only a few miles wide and deep.
Depending on the direction of travel, our
flight planners either avoid (into a
headwind) or use (into a tailwind) these jet
streams to cut fuel costs, as they can flow up
to 250mph. Just like a fast-flowing river
swirling against the riverbank, where the
edge of the jet stream interacts with slower
moving air, there may be some mixing of the
air which causes turbulence.

"You cannot see CAT, you cannot detect
it on radar and you cannot accurately
forecast it, but there are other ways of
avoiding it. In the main we rely on reports
from other aircraft, which we hear either
directly or which are passed on by air
traffic control. We then consider
the options available to us. Our endeavour to
fly at an altitude that has been reported as
smooth may be prevented by several
constraints such another aircraft
occupying that level, or the weight of the
aircraft at that time. Whatever the
circumstances, a pilot will find the most
comfortable path to a destination
without compromising safety.

"Flight crews around the world share a
common classification of turbulence:
light, moderate and severe. The
definitions are laid down in our manuals and
help us to make an assessment as to what our
course of action should be. For the fearful flyer,
even light turbulence can be upsetting."

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**Events**

The Institution of Engineering and Technology

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A Structured Approach to Assessing and Controlling Your Own Risk

19 September 2013 | Strand Palace Hotel, London, UK

Registration to this event includes a copy of the Code of Practice for Electrical Safety Management (worth £130)

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Attend this event to learn the theory and then put it into practice

The morning seminar will examine why good electrical safety management matters, provide an introduction to the Code of Practice for Electrical Safety Management and how it will help to reduce dangers in the workplace. It will also introduce the self-assessment guidance to identify risks and work towards best practice in your own organisation.

The afternoon workshop will teach you how to use the structured approach to electrical safety management set out in the Code of Practice (included in the price), by applying the tools to a range of workplace scenarios, including your own.

Who you will hear from

- Bill Bates, Principal Electrical Inspector, Health and Safety Executive
- Malcolm Sarsteed, Group Process Safety Manager, Unilever
- Paul Bicheno, Portfolio Development Manager, IET Standards

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