Greener by Design

Executive Committee

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GREENER BY DESIGN
ANNUAL REPORT 2017/18

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Front cover: The A-17 Zephyr, the 2017-18 Cranfield University 480 student-month MSc Group Design Project for a 200 seat short-medium range airliner with an ultra-high aspect ratio strut-braced wing, boundary-layer ingesting rear propulsor and many other novel technologies. In total about 81,000 staff and student hours were used. (For further information contact: howard.smith@cranfield.ac.uk)
(Rendering by H Goitia and L Bao)
Introduction

2017 was a big year for the environment. It ceased to be the preserve of the smaller political parties but became a mainstream political issue. Two events were significant in causing this seismic change: increasing concern at the poor air quality in our streets, and David Attenborough’s *Blue Planet* TV series showing in graphic detail what damage plastic waste is causing to our marine environment. This has catapulted the environment to near the top of the public’s conscience. It has also caused the Government to make the first significant environmental policy change since the present policy was set following the publication of the Stern Report ten years ago. No longer are the higher efficiency of diesel vehicles (producing less CO₂ than petrol vehicles) to be encouraged, recognising that the health impacts of higher levels of NOₓ and other airborne particulates from diesel vehicles outweigh the (relatively small but still significant) CO₂ advantage. Diesel vehicles are to be phased out, and the Government has also stated their intention to phase out all petrol cars too (although not hybrids – but zero emissions remains the Government’s aim). The UK has not been alone in this course of action: several other European states are also phasing out diesel cars, and some have also set dates to eliminate petrol vehicles, a significant step in the decarbonisation of road transport. And it doesn’t stop there. The Government has announced its intention to phase out rail diesel trains to a similar timescale, and the International Maritime Organisation is facing strong calls for shipping to produce plans to reduce its CO₂ emissions (which are a similar size to aviation’s).

There are two lessons here for aviation. First we cannot afford any let up in the speed with which our environmental footprint is shrinking. We must press on with all reasonable ways of minimising damage to the environment, whether it be through emissions from aircraft or airports, whether affecting air quality, noise or CO₂.

Second, if we fail to keep ahead of public opinion, or appear to be half-hearted, our industry will suffer through a perception we are damaging the environment. We will be seen as one of the ‘bad boys’ and legislation could force us to take action which is ill thought out, incur unnecessary cost on the industry, and be less effective than a well thought out ‘Greener by Design’. Greener by Design’s approach is as relevant as it was when we were founded 18 years ago.

Bearing this in mind, we have chosen as a theme for this year’s conference ‘Impact of Electric and Hybrid Propulsion in Aviation’. The conference will be held slightly later this year on Tuesday 20 November. After last year’s very successful conference on ‘Noise and the Community’ (a summary of which will be found later in this annual report), we are assembling an impressive group of speakers for this year’s conference. We hope you all will be able to join us, and look forward to welcoming old friends and new.

Geoff Maynard
Chairman
Greener by Design
INTRODUCTION

The Annual Conference for 2017 was held at the Society’s Headquarters in London on 12 October. This full-day conference was dedicated to addressing the thorny issue of aircraft noise and its impact on local communities.

Lord Callanan, Aviation Minister in the Department for Transport, gave the Keynote address. He started by commending the CAA on the exemplary way they had successfully repatriated 110,000 passengers stranded abroad the week before by the collapse of Monarch Airlines.

The CAA’s major long-term task is to implement airspace modernisation, thereby providing the air space capacity necessary to ensure the expansion of UK aviation could continue. In this task it was essential local communities were engaged, and the CAA needed to lead responsibly by analysing in detail the different options, including the frequency of use of the routes, to arrive at the best overall solution. The Government was taking powers to call in these proposals, if it was considered aspects had been overlooked or the scheme was not the best overall. The Government was establishing an independent Commission on civil aviation noise, and this will have a key role in ensuring the CAA is supported throughout this process.

The Government was part way through a major consultation process on a national aviation policy statement, and further consultation on Heathrow expansion following the revised air quality forecasts produced by the CAA. Everyone was encouraged to comment on these proposals to ensure the widest possible stakeholder involvement, and to ensure the best overall national solution was achieved while allowing for specific local issues.

SESSION 1: OPPORTUNITIES TO REDUCE NOISE IMPACTS AND TRADE OFFS.

Ian Jopson, Head of Environment & Community Affairs at NATS, outlined some of the ways air traffic control can help by changing approach and departure routes. These are aimed at allowing aircraft to climb more quickly and descend later, so aircraft are higher for longer and reduce noise on the ground. Displaced thresholds, continuous climb, continuous descent, steeper descents and segmented approach are all ways this can be achieved and are shown below.

Graph 1
much noise the aircraft actually makes at any time, with a lesser contribution from aircraft performance and configuration and the engine cycle. The engine and airframe component and that from the engine installation/acoustic liners will be of less significance, depending on aircraft configuration. There has been a steady reduction in engine noise, and the adjoining graph shows this clearly from 1985. (above left). It should be noted that a 20dB reduction equates to a 99% reduction in noise energy. Spliceless fan case liners and intake ducts, an advanced low-speed fan and optimised acoustic liners have all contributed to this reduction.

There is currently a great deal of work going on worldwide to better understand how the noise is generated, and how it can be minimised. It costs many millions of pounds to achieve 0.1dB reduction. Rolls-Royce have a dedicated test facility at NASA and are currently working on many different projects, some of which represent a step change in design. These include Ultrafan which could give a 20% improvement in efficiency, and the inclusion of a gearbox, which would enable slower fan rotation and a significant noise reduction. Finally, Nick reminded the audience of ICAO’s balanced approach, where besides aircraft improvements, land use planning, operational improvements and restrictions must contribute to reducing noise.

The third speaker was Steven le Moing, Airbus, who spoke on Aircraft Operations for Noise Mitigation and Trade Offs for Associated Aircraft Parameters.

He explored the significant difference in noise footprint between taking off using (near) full thrust, and so climbing rapidly away from the runway and high over the airport’s neighbours, and taking off on...
lower thrust, resulting in a reduced rate of climb and flying lower. Unsurprisingly the airport neighbours were the main beneficiaries of the reduced thrust take off (less noise) but at the expense of places further from the airport, where the aircraft was lower and still climbing. Stakeholders should be invited to comment on which they prefer, perhaps coupled with proposals to vary the route further from the airport. So although it will be noisier than before, by rotating routing the impact on individual communities could be reduced, albeit a greater area could be affected.

A similar principle could be used for approach, where a steeper approach could reduce noise due to the higher altitude, but noting that depending on the type of aircraft it may be necessary to deploy the flaps to maintain speed on a steeper approach, resulting in more noise. The nature of the terrain flown will have a key impact on determining where the balance of advantage lies. A key feature of the approach noise profile is when the undercarriage goes down, raising noise by around 5dB.

Revised navigational procedure allows the option of introducing new routes which can give additional opportunities to avoid densely populated areas, and permitting the resultant revised noise footprints to be modelled. The difference between the two footprints can be presented to stakeholders to determine which they prefer.

The final speaker of the first session was Andy Kershaw, Environmental Manager, British Airways, who spoke on noise abatement procedures and their benefits.

BA is very keen to reduce noise from its aircraft wherever they may be. Standard BA operating procedures is not to use reverse thrust, to minimise noise on the runway.

Increasing the angle of approach for landings from 3 degrees to 3.2 degrees does give some noise benefits, as does waiting to lower the undercarriage until the point speed control kicks in. A two-stage approach is also being investigated, using 4.5 and 3 degree approach angles. The key is to ensure the aircraft is stable at 1,000ft for the final approach, and that there are no unintended consequences. The challenge is to integrate this approach with current operations. A slower speed approach is also easier for some aircraft than others and may impact on the landing rate, a key consideration at Heathrow.

On departure, increasing the climb rate (to reduce noise further from the airport) has advantages but some bigger aircraft (A380) cannot meet much steeper climb rates than at present, and for some aircraft the increased climb rate increases noise substantially.

There are also advantages in reviewing procedures such as Noise Preferential Routes, which were designed many years ago for older types of aircraft. There is also a need to check that aircraft flown on auto pilot follow the correct route and an example was instanced where a turn was required when the computer assumed the aircraft had only reached 190kt, when the computer assumed the aircraft was doing 250kt.

The session concluded with a number of questions, some clarifying details of the steeper approach proposals.

SESSION 2: NOISE PERCEPTIONS AND RESEARCH

Research aimed at improving understanding the way that people react to aircraft noise was the focus of this session. The ability to determine effective policies and mitigation actions needs a
noise respite by communities. The reasons advanced for delivering respite relate to technical possibilities linked to airspace modernisation and community needs for a break from noise. A Heathrow Respite Working Group had been considering options, producing a report in 2016, since which time research had been undertaken into community attitudes. The 2016 report had found a lack of respite definition, no adequate metrics for describing respite, no universal formula for implementation and uncertainty over community value. Relief from or a reduction in aircraft noise was different from respite which involved a scheduling of that relief. Research was undertaken at a desktop level and looking at how attitudes varied according to spatial changes of route location and the scheduling of relief intervals. Experiments were carried out with volunteers in a sound lab environment comparing reaction to sound sequences and community group discussions were held to examine respite options. Respite was found to be valuable and the importance of quieter shoulder periods emphasised. Community dialogue emphasised the significance of what people see, feel and believe to levels of trust and engagement. Future work would need to address these non-acoustic factors that relate to social, personal and situational circumstances.

Dr Darren Rhodes, Head of Noise Analysis at the Civil Aviation Authority, set the scene with an explanation of the CAA’s 2014 Survey of Noise Attitudes (SONA) on aircraft which covered noise including effects on annoyance, wellbeing and health and was intended as a baseline for future survey work. Neighbourhood and road noise were also examined for context in the survey addressing nine airports in England. Surveys addressed various operational modes and averaging periods. Findings suggested that the mean annoyance score correlated well with the LAeq 16 hour metric and that other indicators were no better and the ‘summer day, average mode’ is still found to be the best for decision-making though ‘single-mode’ can be valuable for portraying exposure and changes to exposure. Perhaps, unsurprisingly, the likelihood of being highly annoyed was found to increase with increasing noise exposure. SONA found that for the most sensitive individuals, the odds of being highly annoyed were ten times higher but noise sensitivity was not found to be associated with noise exposure level suggesting that sensitive individuals do not move away from high noise areas. Interestingly, prior to moving to the area, those not aware of the possibility of hearing noise were less than half as likely to be highly annoyed as those who were previously aware of a noise issue but found it to be greater than expected. It was also found that an urban/rural classification distinction was found to be a poor descriptor of quiet locations and that a basic lack of information on ambient noise levels across a wide area was an influence upon annoyance.

Nicole Porter, Associate Director at Anderson Acoustics presented on the value placed on noise respite by communities. The reasons advanced for delivering respite relate to technical possibilities linked to airspace modernisation and community needs for a break from noise. A Heathrow Respite Working Group had been considering options, producing a report in 2016, since which time research had been undertaken into community attitudes. The 2016 report had found a lack of respite definition, no adequate metrics for describing respite, no universal formula for implementation and uncertainty over community value. Relief from or a reduction in aircraft noise was different from respite which involved a scheduling of that relief. Research was undertaken at a desktop level and looking at how attitudes varied according to spatial changes of route location and the scheduling of relief intervals. Experiments were carried out with volunteers in a sound lab environment comparing reaction to sound sequences and community group discussions were held to examine respite options. Respite was found to be valuable and the importance of quieter shoulder periods emphasised. Community dialogue emphasised the significance of what people see, feel and believe to levels of trust and engagement. Future work would need to address these non-acoustic factors that relate to social, personal and situational circumstances.
extraneous factors whether linked to airports or not. Among all the factors in a noise management strategy, many could not be modified but scope existed to engender change in communication, levels of trust and perceptions of fairness. Achieving a greater recognition of positives and negatives, making decision-making more transparent and airports taking a more proactive stance on engagement could all assist. Despite considerable airport resources being expended to build better communications, the complexity and opaqueness of metrics and contour representations create difficulties and fuel dissatisfaction. Suggestions are that residents want personalised information with information about numbers of events, loudness and timing that relates to experience. The use of maps and contours that reflect averaged modal operations only serve to add to frustrations whereas histograms are readily understood. It is clear that better information tools do offer potential to improve communication and give insights into decision-making processes. Used effectively, these could help to empower local communities, widen engagement, strengthen involvement in decision-making and thus build trust. The potential downside of new tools like illustrating the effects of PBN are that the visibility of ‘winners’ and losers’ becomes more clear. The conclusion is that supplementary metrics and proactive engagement offer the best prospects for greater levels of trust and tolerance.

Tim Johnson, Director of the Aviation Environment Federation provided a description of the AEF’s own 2016 survey to understand important issues reported by communities affected by air transport and by general aviation operations. Most respondents were concerned with air transport and airports in the South East. Lack of appropriate technical knowledge was found to be an issue and stakeholder engagement tended to be unproductive. Distrust was felt towards the industry and regulators felt to give too low priority towards environmental issues: communities were left to fight their own corner. The benefit of quieter noise levels of modern aircraft was eroded by greater frequencies or flight path concentration. Lack of effective controls was cited. The number of helicopter operations, an increase in business jet traffic noise levels in quiet spaces like AONBs was also mentioned. AEF respondents were increasingly aware of the effects of noise on health, both physical and mental and sought WHO and governmental health-based goals for aircraft noise.

The first panel question after the presentations was on the role and potential of social media. Evidence had shown that objective studies were influenced by the fact that social media sensitised communities to work in progress. The EU ANIMA project that had recently been set in train would be examining the effects of social media. Some tools now offer the ability to examine social media to extract data and
opinions and that can add to learning. Social media platforms may help with ‘inclusion’ for communities that are not particularly well connected. A question on SONA was about the nature of follow-up actions. The key point was that being commissioned by DfT, the study would be informing government policy and only then filtering through to actions for the CAA. A question on the respite study was about the variation in noise levels taken into account in sound lab studies. Both A320s and A380s were taken into account but practicality prevented using a full spread of types. Helicopter noise was questioned further as an increasing problem beyond the confines of London but it was noted that AEF data only related to the London area. Some areas did experience both air transport and helicopter noise. A question was posed about the trend towards lower noise levels advocated by the WHO; while there was a push in that direction and towards seeking quieter environments this must be evidence-based to balance interests.

On trust, a question was raised about the direction of policy change making trust harder to achieve. A suggested reduction in respite expected to the east of Heathrow was a concern as was the relative omission of government considering non-acoustic factors, social factors and noise metrics, e.g. by the Airports Commission. It was acknowledged that not having a user-friendly language for communication does not help but greater recognition of setting new noise metrics in place and shifting the power base towards communities is implicit in an emerging and better communication practice. There is a strong element of learning by experience at the research level that is opening up the debate in a positive direction.

SESSION 3: COMMUNITY AND INDUSTRY PERSPECTIVES AND TOOLS FOR BUILDING COMMUNITY TOLERANCE.

This session explored some new ways to improve industry/community understanding and three leading community representatives identified their key noise issues and how they should be addressed.

Tim May, Head of Airspace and Noise Policy at the Department for Transport (DfT), explained the Government’s proposal to establish an Independent Commission on Civil Aviation Noise (ICCAN). Such a body had been recommended by the Airports Commission during its work on future airport capacity in South East England but Tim stressed the national role for the new body. As part of its review of this proposal, the DfT had consulted with similar noise bodies operating in other countries including the Noise Ombudsman in Australia and ACNUSA in France. Both organisations presented at a previous Greener by Design conference.

There is a need to improve public confidence in both noise data and the airspace change process and ICCAN would be a credible and authoritative voice helping to improve processes and trust between industry and local communities.

ICCAN would have a formal role in the Airspace Change process, provide advice to local authorities and provide best practice guidance on noise management. It could propose ways to improve transparency on noise issues and would support or initiate research. The Commission would be independent of government and industry and would be publicly funded. The Government believes that it would be inappropriate to give the new body enforcement powers. The Secretary of State would still carry the necessary authority in this area.

The DfT consultation on this proposal had closed in May 2017 and the Department was considering the approximately 800 responses. The Government expect to respond to the consultation later in autumn 2017.

Post conference note: On 24 October 2017, the Government confirmed its intention to establish an Independent Commission on Civil Aircraft Noise.
The session then moved to presentations by speakers representing communities around airports. The first was Charles Lloyd, Chair of the Aviation Communities Forum. Charles is directly involved in community engagement with Gatwick Airport but focused his attention on the fundamental issues that, in his view, undermined the chances of positive engagement between industry and communities on the noise issue.

Aviation operates under an umbrella of legal and regulatory privilege. The lack of a clear, accessible, legal framework – of the type that applies to almost all other sectors that pollute – undermines the foundation of any tolerant relationship between polluter and polluted. This could be resolved by proper noise regulation but the Government and regulators have continued to allow aviation to operate with a virtual absence of noise regulation. Where the word ‘environment’ appears in regulations it is normally meant to cover emissions and climate change, not the effect on the local community environment.

Charles also pointed out that the industry had escaped from the responsibility of paying the full costs of its external impacts. One example he gave was that compensation is trivial compared to the industry’s impacts.

He said that growth in flights and airspace changes will continue to be held back while these building blocks of trust and engagement are absent. If the industry is serious about change they should work with communities and government to implement a comprehensive, independent system of regulation of aviation noise. They should also agree to much higher levels of compensation and taxation, accept noise reduction as a pre-condition of growth and get serious about the health impacts of their operations.

Harri Howells, Airspace Change Manager at NATS, then demonstrated a new tool from NATS designed to improve stakeholder engagement and the consultation process. The map-based sketching tool, named COMP-AIR, allows stakeholders to choose annoyance thresholds for noise levels and daily flight numbers and then compare the population impacted by different route options sketched with the tool. The tool is based on real operational data and ensures that the shape of routes selected is flyable. The outputs include both the total population affected and the number that are newly overflown.

The COMP-AIR version presented is still a demonstrator but NATS would like to see it rolled-out for use by stakeholders during airspace change consultations – enriching understanding of airspace planning trade-offs and providing a wider and clearer stakeholder feedback on the acceptability of various route options.

A few audience questions followed the demonstration and the main issue raised was a concern that the tool might be used by some communities already affected by noise to draw new routes that better ‘shared’ the impact with others. This could turn communities against each other and make the consultation process a ‘numbers game’ based on those who submitted a preferred route.

Harri acknowledged the importance of involving the community on the way it wants to engage and noted that the number of newly overflown was an important measure produced by the tool.
The next speaker was Dr Paul Grimley, Chairman of the Melbourne Civic Society. Melbourne is the small town three miles to the west of the East Midlands Airport (EMA) runway. EMA has about 60,000 aircraft movements each year with about 20,000 of them at night, making nights as busy as daytime.

EMA may be unique in the UK as it has no night curfew or ban on noisy aircraft. It does now have a noise limit applied by the local authority but this seems excessively high, perhaps to accommodate future growth. The airport’s policy is to encourage airlines to introduce new, quieter aircraft. This has happened but since 2004 night noise has increased. The noise benefits of less-noisy aircraft have been swallowed up by more movements and heavier aircraft.

The community feel badly let down by the local authority and they regard complaining to the airport as entirely futile – nothing will be done about it.

Paul then turned to the ‘Sustainable Aviation Noise Road Map’. He said this picture portrayed a bleak outlook for airport communities. Operational restrictions could bring rapid relief to those affected but the industry argues strongly against them. The noise benefits of new aircraft are not being shared with local communities and only used to justify growth. The longer-term benefits from more radical technologies seem highly speculative. The work on the ‘Silent Aircraft’ ten years ago has not led to radical redesigns.

Industry and regulators seem happy with this but, as seen from communities, such complacency just seems a product of the industry’s exemption from nuisance law and does nothing to build trust or encourage engagement.

Affected communities are not going to consider toleration until the industry and regulators take noise seriously and he suggested they start by doing away with night time aircraft noise, increasing ATMs only within a reducing noise envelope and develop a silent/ultra-quiet aircraft as soon as possible.

The final speaker was John Stewart from the Heathrow community group HACAN. He supported the points raised by the previous speakers and then focused on the long history of community engagement at Heathrow. 20 years ago some dialogue existed with the airport but little or no engagement took place between local communities and government or the regulator. In 2010, with the Coalition Government withdrawing support for a third runway, an opportunity arose to address longer-term quality of life issues and the level of engagement improved. The Heathrow Noise Forum was established with broad representation from local authorities, CAA and the industry. It was responsible for important research into noise effects which supported the long-held HACAN belief in respite.

Concern had been growing that PBN would lead to a concentration of noise over some residents and the Forum enabled people to work together to improve understanding. However, the airspace trials of 2014 placed new residents under flightpaths and concentrated disturbance for others. Local communities reacted strongly with several new noise groups being set up. This led to the formation of the Heathrow Communities Noise Forum, with the Heathrow Noise Forum becoming a more strategic advisory body.

It has taken time for trust to develop between communities and the airport and John feels that this foundation can be built on if we remember that local people are looking for action. The fundamental issue for each group of residents is the number of flights over them and their ability to get respite. Meaningful engagement is possible if industry is willing to discuss such limits and communities put aside their past suspicion, distrust and anger. John had sought to find common ground and he raised a final concern over the potential misuse of social media by local communities (eg myth-peddling) which could undermine attempts to make progress on these key issues.

SESSION 4: AIRPORTS AND COMMUNITIES.

The Conference concluded with a further session on airports and communities, with speakers from Manchester Airports Group, Heathrow, Gatwick and the Airport Operators Association. The presentations were followed by a panel session where the airport presenters were joined by community representatives.

The Airport Operators Association’s Peter O’Broin kicked off the session reporting on the focus that Sustainable Aviation has been putting on noise in
2017; reviewing and reporting back on progress made against the coalition’s 2013 Noise Roadmap, preparing for the CAA’s revised airspace change process and the DfT’s night noise and airspace and noise consultations. He reported that Sustainable Aviation’s noise group are also keenly awaiting the Government’s airspace strategy and World Health Organisation’s noise and health report in the coming year. During 2017 Peter reported that the group had run technology and community workshops, the latter being independently run by an external communications company. The outputs of those activities will result in a Sustainable Aviation position paper on noise in 2018. Peter reported that this position paper will be a valuable part of the industry’s input to the forthcoming consultations.

Matthew Gorman, Heathrow’s Corporate Responsibility Director, followed with his perspective on the noise debate, noting that different communities around airports show widely differing levels of noise tolerance. He cited studies showing 70% of people highly annoyed by aircraft noise in Korea at the 65dB DNL level; this compared with 35% highly annoyed around San Francisco airport, 10% around Seattle – all at the same noise level. Matthew reported on the airport’s Community Noise Forum, set up with membership from local boroughs, councillors, community groups, NATS, BA, CAA and DfT with a public gallery for observers. The purpose of the forum is to be a focal point for stakeholder involvement in planning, consultation and communication of modernisation of Heathrow’s airspace. It also forms a key channel for Heathrow to communicate on steps being taken to reduce noise and to take local community feedback on their noise concerns to airport.

Since the initiation of the forum, Matthew cited a number of lessons learnt. He noted that it is clear that we are still developing a common language to describe changes in noise, but that the use of independent analysis has been important to help build trust; the Dutch aerospace laboratory NLR had been commissioned by the group to validate the airport’s noise data. The forum has coalesced on the need for robust research into the concept of respite, to understand what respite means and that work is being taken forward by the airport, overseen by the community forum.

Manchester Airports Group, responsible for Manchester, East Midlands, Bournemouth and Stansted airports was represented on the panel by Neil Robinson who gave his perspective on the noise issues. According to Neil, the community response to noise is dynamic and can be unpredictable, but that communities are getting more sensitive to noise over time; this trend is evidenced through studies over the years such as ANIS, ANASE, SONA and NNAS. Neil noted that noise maps don’t always fit the pattern of complaints or annoyance and suggested that this is perhaps due, in part, to non-acoustic reactions to noise. In his view, core to community noise management is being open and honest to build trust, talking openly, clearly and often, a theme touched on by all speakers in the session.

Neil advanced that it is vital to consider mitigation for impacts, but also to attempt to be clear about the social and economic benefits that an airport can bring to its communities.

Andy Sinclair, Head Airspace Strategy and Engagement at Gatwick Airport, reported on the airport’s independent review of arrivals noise, a voluntary initiative driven by the aspiration to address noise issues around the airport. He reported that the review led to numerous immediate short-term actions to reduce noise impacts and further research to better understand the
impacts and drivers of noise annoyance. These short-term measures that the airport and other aviation stakeholders were actively pursuing were complimented by a number of longer-term actions, including airspace modernisation, aiming to further reduce noise impacts around the airport over the next decade.

The speakers on the panel session were then joined on the stage by Charles Lloyd, Dr Paul Grimley, John Stewart and Graham Lake, Principal, Aviation Management, for a question and answer session to review the day’s discussions and bring the conference to a close. In a lively session, with questions from both community and aviation industry conference participants, themes explored included what sustainability means in terms of noise, how the industry can engage meaningfully with communities and what the future holds for noise management. There appeared to be a consensus among community groups that aviation growth should be accompanied by reductions in noise impact; it was not clear, however, what metric should be used to measure this aspiration – there is clearly more work to do in this area. Industry stakeholders pointed out that airports, air traffic control, manufacturers and airlines had been working hard for decades to share the benefits of extensive research in noise reductions through improved operational procedures, encouraging best practice and designing and deploying new low noise aircraft. On community engagement the panel and audience seemed to agree that progress had been made but there is more to do – focusing on the future there is an on-going need for regular engagement underpinned by jointly agreed and simple noise metrics to demonstrate progress.
The last year has seen significant publicity given to electric aircraft projects. easyJet has formed a partnership with US firm Wright Electric, which is developing a battery-propelled aircraft for flights under two hours. In a separate venture, Airbus, Rolls-Royce and Siemens have signed an agreement to develop a hybrid-electric prototype, the E-Fan X. First flight of the aircraft, based upon a BAe 146 regional jet, is targeted for 2020. One of its four Honeywell turbofan engines will be swapped for an electric motor and fan, while a Rolls-Royce AE2100 gas turbine (normally used in the turboprop for the C-130 Hercules) will be installed in the rear fuselage to power a two-megawatt electrical generator to be developed by Siemens.

In time electricity can be expected to power short journeys, but the weight of the batteries rules out such aircraft for the bulk of the market. While hydrogen could play an intermediate range role, all medium and long-range aircraft for the foreseeable future would require low carbon drop-in fuels to minimise aviation’s carbon footprint. Increasingly, as the automotive industry shifts to electric solutions, sustainable alternative fuels will be channelled to power those transport sectors with no real alternative, namely shipping, long distance trucks and aviation.

CURRENT STATUS OF SUSTAINABLE ALTERNATIVE FUELS

It is now ten years since the first biofueled commercial flight by Virgin Atlantic in February 2008. Since that time great strides have been made in developing and certifying a wide variety of different feedstock and conversion pathways to drop-in fuels. Market penetration is currently low relative to some projections made ten years ago and indeed more recently. This reflects in part the fact that at the time (the first half of 2008) the price of oil was high – and therefore the potential price of sustainable alternative aviation fuel was relatively high. The collapse of the oil price made most feedstock / pathways uncompetitive, but the recent partial recovery of the oil price is helping the industry develop.

The approach by airlines has typically been to offer offtake agreements assuming that the alternative fuel is price competitive with kerosene. Indeed, a welcome convert to green aviation, Ryanair, spelt out such a policy only recently. An alternative approach is being taken by Braathens Regional Airlines who now offer biofuel flights for passengers, for a supplement. When the aircraft is refuelled, the appropriate amount of biofuel is added to reflect the purchases made by the passengers.
received RSB certification. Altair has now been acquired by World Energy.

Thus, while progress is being made, production is way below targets. Cost reduction with greater volumes will help, as will the possibility of any rise in the oil price. A significantly higher carbon price is badly needed. In the meantime, governments can help facilitate both supply and demand.

**REVISION OF THE EU RENEWABLE ENERGY DIRECTIVE (RED II)**


In the final vote, the European Parliament adopted the amendments tabled by industry proposing a multiplier of two for biofuels supplied to the aviation sector and rejected an amendment proposing a strict mandate for aviation biofuels. This multiplier should help to shift the biofuel feedstock towards

**easyJet and electric aircraft pioneer, Wright Electric, outline the electric future of aviation.**
Sustainable Alternative Fuels

the aviation sector and away from other sectors. A new recital has also been introduced to recognise the importance of advanced biofuels for reducing aviation’s emissions and to encourage fuel suppliers to meet the proposed targets also in the case of fuels supplied to aviation.

This is a positive outcome for the aviation industry as it sends a strong signal to Member States and the European Commission in advance of the final negotiations. In the coming months, the European Parliament, the Council and the European Commission will engage in the Trilogue negotiations, with the aim to reach a compromise on a final text. It will, therefore, remain important for advocacy efforts to continue, ensuring that both the Commission and the Council are supporting the European Parliament’s position.

Going in to the conference, the general stakeholder position was not in favour of the mid- and long-term goals for a number of reasons:

● The goals had been developed in an ad hoc manner and without the normally extensive input from experts in the Committee on Aviation Environmental Protection (CAEP).

● There was considerable uncertainty linked to the mid- and long-term goals and it was felt more appropriate to wait until additional modelling work had been done before committing to long-term quantitative targets. Thus, giving consideration to the longer-term goals would be more appropriate in 2025, the likely timing of a CAAF/3.

● There was a concern that, should governments decide on a quantitative goal, they may deploy economically blunt instruments (such as a mandate) in order to meet the goals.

Despite the ICAO Secretariat not receiving endorsement for a number of their proposals, they achieved a mandate to broaden their work on SAF beyond information sharing.

The CAAF/2 adopted a declaration which does not contain any specific goals but commits to do more work on this subject. The declaration contains an acknowledgement from governments that SAF will be a key component of the industry’s future. Industry pushed for language on sustainability to be added to the Vision which was also included. The final declaration was a successful outcome.

ATR and Sweden’s BRA perform first ATR biofuel flight.

Second ICAO Conference on Aviation and Alternative Fuels (CAAF/2)

CAAF/2 was held from 11–13 October 2017 in Mexico City. The Conference agreed an ICAO Vision for sustainable aviation fuels out to 2050 but fell short of recommending actual targets as part of the Vision.

The proposed Vision from the ICAO Secretariat originally put forward three goals for the deployment of SAF:

● A short-term goal of 5Mt of SAF (2% of fuel use) by 2025

● A mid-term goal of 128Mt of SAF by 2040

● A long-term goal of 285Mt of SAF (around 50% of forecast international jet fuel use) by 2050
NON-CARBON DIOXIDE EFFECTS

Since at least 2005 the level of scientific understanding (LOSU) of the climate impact of CO₂ emissions from aviation has been considered ‘high’, with the two other, less well understood main contributors being accepted as NOₓ and contrail-cirrus. Research has continued into both of these, with the aim of increasing their underlying scientific understanding but we are still some way from classifying the LOSU of either as ‘high’.

As noted in last year’s Annual Report, at the conclusion of the substantial FAA Aviation and Climate Change Initiative (ACCRI)[1], launched specifically to investigate the climate impact of non-CO₂ emissions, the authors offered only ranges for the radiative forcings from the eight main contributors. They declined to suggest mean or standard deviations for the contributions because of the wide variations in predictions, produced by a wide and disparate range of climate models. Over the last year there has been some limited progress to narrow the uncertainty in some areas.

NOₓ

One question that has been there since at least the first Greener by Design report in 2002 has been the possibility of reducing NOₓ emission at the expense of an increase in fuel burn and CO₂ emission by reducing engine overall pressure ratio (OPR). The ratio between NOₓ reduction and CO₂ increase is of the order of 10 to 1, while the net climate impact of NOₓ has been historically estimated as half that of CO₂, apparently making the case for some reduction in OPR.

In February 2018 Freeman et al of Manchester Metropolitan University[2] addressed this question, starting from the premise that there is indeed a 10 to 1 trade-off between NOₓ and CO₂ emission.
The study addressed the trade-off between short-lived climate forcers, such as the ozone generated by NO\textsubscript{X}, and the long-lived greenhouse gas CO\textsubscript{2}. It also accounted for the depletion of the long-lived gas methane by NO\textsubscript{X} and the long-term reduction in ozone as a consequence of the methane reduction. It used a simple climate model, modified to incorporate non-linearities parameterised from a complex chemistry model. Case studies showed that for a scenario of a 20% reduction in NO\textsubscript{X} emissions the consequential increase of 2% in CO\textsubscript{2} emissions needed to be reduced by 43% to realise an overall benefit. The case for reducing engine OPR in order to reduce climate impact appears not to be there. The authors argue that their results ‘provide important insights for industrial technology development and policy-making, regarding trade-offs between different aviation emissions species.’

The above work used an established climate model of the type associated with the conclusion in 2005 that the net RF caused by NO\textsubscript{X} emission is approximately half the RF due to the CO\textsubscript{2} from aviation. The case against reducing engine OPR is strengthened further by a study by Petari et al\textsuperscript{3} published in October 2016, which used two independent chemistry-transport models, one from the University of L’Aquila and one from the Centre for International Climate and Environmental Research, Oslo, to assess the climate impact of NO\textsubscript{X} emissions.

The authors claim that the results presented in the paper are ‘important to the aviation community by providing a more robust and complete estimate of the likely effects from aircraft NO\textsubscript{X} emissions which accounts for the short- and long-term gaseous and aerosol impacts, with explicit chemical transport model and radiative transfer model calculations.’ The study suggests that the net overall NO\textsubscript{X}-related RF is smaller than previous estimates and, if NO\textsubscript{X}-aerosol effects are included as well, then the net RF is negative. This has the wider implication that it may be the case that except for CO\textsubscript{2} and contrail/contrail-cirrus, which are known to produce significant globally-averaged warming effects, the other aircraft RFs may produce a very small warming or even a cooling effect. The authors point to uncertainties which need further investigation but consider a safe overall conclusion is that the net RF due to aviation NO\textsubscript{X} emissions, considering both short- and long-term effects might be very small and possibly on the negative side.

**REACT4C AND WE CARE**

These conclusions are not yet accepted as the last word on the subject. The European Union Framework 7 project REACT4C\textsuperscript{4} confirmed the strong compensation between the ozone and methane climate effects but nevertheless indicated a net warming effect of the present-day fleet of around one fifth the effect of CO\textsubscript{2}. To complicate matters, the study found that the radiative effect of two packets of NO\textsubscript{X} emitted three hours apart on a transatlantic flight, on a particular winter’s day, can differ by at least an order of magnitude as a result of one packet being carried to the north and the other south, into the tropics. Although both packets were emitted in the northern hemisphere, the one that went south and had by far the greatest radiative impact actually spending much of its active life in the southern hemisphere.

This finding led to the development in REACT4C of the concept of Climate Change Functions (CCF), for which 5D datasets were developed for eight representative winter and summers days, each with a distinctive but characteristic weather pattern, to describe the climate impact for a local emission. The first three dimensions represent the location of the emission, the fourth dimension the time of the emission and the fifth dimension the type of emission. The CCFs are calculated by modelling the effect of releasing unit emissions into air parcels which are advected by the simulated wind fields and experience chemical and micro-physical processes. The resulting atmospheric changes lead to imbalances in the radiation which are then used to estimate the climate impact using the ATR20 metric (average temperature response over 20 years). In the DLR WeCare project\textsuperscript{5}, which advances further the modelling in REACT4C, the area over which CCFs have been calculated has been enlarged as shown in the figure and the resolution of the 3D grid has been increased in a way which enables contrail-cirrus to be modelled.

![Areas of CCF calculation covered in REACT4C and WeCare.](image-url)
The CCF concept could be used on a daily basis to define climate optimised routing. In WeCare the studies suggest this could achieve a potential reduction of more than 10% for an operating cost penalty of less than 1% and possible ways of inducing the airlines to adopt it are considered. Two possibilities considered in WeCare are defining climate restricted airspace, to which ATM would deny access, and climate charged airspace which would attract a charge per unit distance depending on aircraft type.

The three charts show maps for the North Atlantic on a particular day, with three alternative trajectories for a flight from New York (JFK) to Frankfurt (FRA). Chart (a) shows the distribution of climate change function for that day, with low CCFs shown white and high CCFs dark red. Chart (b) shows restricted areas in grey and chart (c) shows areas with zero climate changes in white and large charges in dark blue. Trajectory 1 is optimised with regard to fuel and flight time, trajectory 2 is climate optimised and trajectory 3 is optimised to avoid climate-restricted airspace or expensive airspace regions. Reference (5) considers how in future the introduction of climate charged airspace for the non-CO\textsubscript{2} effects could be integrated naturally with market based measures designed initially to reduce only CO\textsubscript{2} emissions.

CONTRAIL-CIRRUS

Within WeCare, DLR made a series of flights with its HALO (High Altitude Long Range research aircraft) – a highly instrumented version of the Gulfstream G550 ultra long range business jet. Coupling the data from these flights with concurrent satellite observations and modelling using the CoCiP (Contrail Cirrus Prediction) tool provided evidence to support the tool and further insight into the physics of contrails and contrail cirrus.

The charts show contrail and cirrus optical depths calculated by CoCiP (left panel) and brightness temperatures from Meteosat Second Generation SEVIRI data (right panel). Contrail cirrus were measured along the flight track of HALO (red line at the western end of the blue track in the right panel), the position of the aircraft at the time of the satellite picture and the CoCiP calculation, 9 UTC on 29 March 2014. Contrails are shown as short black lines in the left panel.

The instrumentation on HALO enabled NO\textsubscript{x} and NO\textsubscript{y} concentrations to be used to distinguish between contrails, contrail-cirrus and natural cirrus. It also enabled the age of the contrails to be calculated and hence the variation with age to be determined of the distribution of ice particle size within the contrail/contrail-cirrus. Data such as these are used to support the development of more advanced modelling tools, including Large-Eddy-Simulation models which can be used to gain a deeper understanding of how contrails evolve and how they are affected by aircraft parameters and atmospheric conditions. An example below is from a prediction by Unterstrasser and Göschen\cite{4}, for one particular atmospheric condition, of the temporal evolution of contrail-cirrus total radiation extinction (product of mean optical depth and contrail width) for five different aircraft types.

It is found that differences in wake vortex properties and fuel flow affect the early contrail properties leaving a long-lasting mark over the simulated six-hour period.
The optical properties of contrails and contrail-cirrus were also addressed by Caiazzo et al.\(^\text{(7)}\) of MIT in considering the impact of biofuels on contrail warming. Given the up to 90% reduction in soot emissions from paraffinic biofuels, there has been some expectation that the transition to biofuels would not only reduce net CO\(_2\) emissions but also reduce contrail formation and its climate impact. The study simulated contrail formation and evolution to quantify RF over the United States under different emissions scenarios. It found two competing effects. First, the higher water content of biofuels compared to conventional jet fuels increases contrail occurrence by about 8%. On the other hand, these contrails are composed of larger diameter crystals (~ +58%) at lower number concentrations (~ -75%), reducing both contrail optical depth (~ -29%) and albedo (~ -32%). The conclusion is that the use of biofuels may either increase or decrease contrail warming, contrary to a previous expectation of a significant decrease in warming.

### AEROSOLS

In last year’s Annual Report, the possibility was noted that sulphate particles formed by the condensation of sulphate vapour in the engine exhaust could fall to lower altitudes where they can alter liquid clouds in a way that contributes to shortwave cloud brightening. The estimated cooling effect was powerful – a value of -46mW/m\(^2\) in 2005 – but this was only one result. In ref (5) the results of some calculations within WeCare are cited. These give values within the range -69.5 to +2.4mW/m\(^2\) in the year 2000. The uncertainty is large, with the high negative values depending on the sulphate being emitted in high numbers of ultrafine particles. There are other complexities associated with aerosol emissions but the large cooling from sulphates is the most striking one and evidently the one in most urgent need of clarification, particularly if there is the prospect of a substantial reduction in the sulphur content of aviation fuel in the coming years. The chart shows the RF of the main contributors to climate change in 2005 as reported in the EU 6th Framework project ATTICA\(^\text{([8])}\), to which has been added some more recent estimates on NO\(_x\), aerosols, contrails and contrail cirrus as noted in the caption.

### References


3. Giovanni Petari and 4 others, Radiative forcing from aircraft emissions of NO\(_x\): model calculations with CH4 surface flux boundary condition, Meteorol. Z., 26, (6), pp 663-687, October 2016.

4. Volker Grewe and 7 others, Reduction of the air traffic’s contribution to climate change: a REACT4C case study, Atmospheric Environment, 2014, (94), pp 616-625.

5. Volker Grewe and 30 others, Mitigating the climate impact from aviation: achievements and results of the DLR WeCare project, Aerospace, 2017, 4, (34), doi:10.3390/aerospace4030034.


Technology

CLEAN SKY 2

Clean Sky was launched in 2008 as a public private partnership between the European Commission and the European aeronautics industry. In September 2017, one of the most ambitious Clean Sky large demonstrators achieved it first flight. This was the ‘Breakthrough Laminar Aircraft Demonstration in Europe (BLADE), an A340-300 aircraft with its outer wing panels replaced with reduced sweep Natural Laminar Flow panels.

The Clean Sky 2 flight demonstrator programme also continues to take shape to support the broader research activities on three aircraft level platforms. In the ‘Large Passenger Aircraft’ category, Clean Sky 2 is co-funding an Airbus and Rolls-Royce collaborative flight test programme, announced in spring 2018, to optimise the integration of higher bypass ratio turbofan engines. Hybrid Laminar Flow Control flight demonstrations are also planned for late 2019/early 2020.

The ‘Regional Aircraft’ activity is performing additional design iterations on the Green Regional Aircraft while working towards two Flying Test Beds (FTBs) in support of related technology programmes for this category.

During 2017, the configuration for the Airbus ‘Racer’ compound helicopter was unveiled in the ‘Fast Rotorcraft’ category with flight tests planned for 2020.

These are complemented by three systems level demonstrators (Airframe, Engines and Systems), two cross-cutting activities (Eco-Design and Small Air Transport) to integrate the findings of the flight and systems level demonstrators plus a Technology Evaluator to assess the environmental and societal benefits.

Headline ATI Portfolio Statistics

Projects developed in the last 3 years...

- 120 INDIVIDUAL PROPOSALS
- 70% SUCCESS RATE AT 365
- 114 SMEs DIRECTLY CONTRACTED WITH MANY MORE SMEs SUBCONTRACTED
- 218 UNIQUE ORGANISATIONS
- £1.9BN GRANTS OF £1BN

Source: A analysis of Innovate UK Public Data (14 April 2018)
Note: SMEs are defined as having 250 or fewer employees in the UK
18.04.2018
Clean Sky 2 research activities continue to expand with the 7th call in late 2017/early 2108 and 8th Call in Spring 2018.

**THE AEROSPACE TECHNOLOGY INSTITUTE**

The UK ATI continues to grow its portfolio of research projects across the four value streams of ‘Aircraft of the Future’, ‘Propulsion of the Future’, ‘Smart, Connected and More Electric Aircraft’ and ‘Aerostructures of the Future’. Each of these contribute to aircraft level environmental and economic improvements. The total value of UK government research funding, managed and delivered through the ATI and Innovate UK, reached £1billion in spring 2018.

A wide range of research projects have received funding in 2017/2018 to develop technologies including (and not limited to) more electric aircraft systems, flight deck and cabin systems, integration of high bypass turbofan engines, electric propulsion systems as well as improved manufacturing processes.

Since 2016, the ATI has also been exploring the potential for collaborative research opportunities with international partners to gain mutual benefits for the UK and partner nations through access to capabilities and facilities only available in either the UK or the partnering nation. Discussions to date have included Sweden and Canada. This is in addition to raising awareness of EU funding opportunities and supporting UK companies’ applications.

**NASA**

NASA is emerging from a period of uncertainty with its future direction becoming clearer. Budgetary constraints and a focus on Space flight are likely to squeeze atmospheric flight research although expected deep cuts to environmental science research funding appear to have been avoided.

The Ultra Efficient Subsonic activities continue to look at novel aircraft configurations through to mid-2019 clarifying programme costs and schedule as well as to identify risk reduction potential.

**X-PLANES**

One flight test programme that has been fully funded is the $247.5 million contract awarded for the development of the Low-Boom Flight Demonstrator (LBFD) and the subsequent flight tests (first flight planned for 2022). The objective is to move from a sonic ‘boom’ to a sonic ‘thump’ to allow overland operation.

The X-57 Maxwell is an all-electric powered aircraft with distributed propulsion based on a Tecnam P2006T twin-engine light aircraft. It is scheduled to fly in 2018.

The NASA Low-Boom Flight Demonstration (LBFD).
BOEING ECODEMONSTRATOR

Boeing has announced the next step in their ecoDemonstrator programme, a collaboration with FedEx using a 777F aircraft to test ‘more than 35 technologies’ to address flight safety and environmental sustainability, e.g. increased biofuel usage, compact thrust reversers, clear air turbulence detection as well as numerous manufacturing improvements.

Progress towards ACARE Vision 2020 target for reduced CO₂ per seat km

The initial target date of 2020 set by ACARE for substantial aircraft improvements is approaching. One major element was a 50% reduction in the CO₂ emissions per seat km relative to a year 2000 baseline: 40-45% achieved by airframe and engine improvements with air traffic control delivering the remaining 5-10%. New aircraft are a critical component in driving toward this target.

Major programme milestones for several aircraft types have been achieved in 2017 and early 2018. First flights have been achieved by the Airbus A330-900neo, A319neo, A321neo, Boeing 787-10, 737 MAX-9, 737 MAX-7, Embraer 195-E2, COMAC 919 and Irkut MC21. These aircraft represent double digit block fuel improvements over the aircraft they are intended to replace.

It is noticeable that all except the 787-10, Comac 919 and MC21 are significant upgrades to successful aircraft types rather than the radical designs that perhaps were envisaged for 2020. These improvements have relied largely on improved engine efficiency. The associated larger fan diameters and weights have introduced new aerodynamic and structural integration challenges that have been addressed in combination with varying degrees of general wing aerodynamic improvement.

Further CO₂ per seat km benefits are being achieved through:

(i) ‘upscaling’ of single-aisle aircraft - the A321neo and 737 MAX-9/10 represent a greater proportion of the single aisle sales than in the previous variants with significant reductions in the proportion of the smaller family members sold, e.g. A319neo and 737 MAX-7.

This is particularly clear in several established low cost operators, e.g. SouthWest, easyJet and jetBlue, who have all increased the average size of the aircraft in their ‘neo’ and ‘MAX’ orders relative to their existing fleet.

(ii) ‘densification’ – increased seat counts on new and existing aircraft. There have been significant activities to increase the certified maximum passenger count on these aircraft, e.g. the 737 MAX200 and A321neo ‘Cabin Flex’.

In-service cabin changes have also been announced in the past year. Examples include British Airways and Cathay Pacific adding an extra seat abreast to their 777 economy class seating (9 abreast to 10). Emirates have also introduced some 2-class A380 cabins with 615 seats compared with their 489/517 seats 3-class cabins.

Both ‘upscaling’ and ‘densification’ offer a significant seat count increase for a proportionately smaller fuel burn penalty resulting in reduced fuel burn/CO₂ per seat km. These benefits can exceed 10% depending on details of the application.

The coming year should see the 777-9 and Airbus A330-800neo make their first flight. Again, these are developments of existing aircraft types with
new propulsion options and with a new wing for the 777-9 and a significantly modified wing for the A330-800.

**HYBRID-ELECTRIC AND ELECTRIC**

Over the past 12 months, there has been considerable interest in Hybrid-Electric and All Electric aircraft propulsion technology to substantially reduce aircraft emissions and reduce operating costs.

There have been many programme announcements from established major Original Equipment Manufacturers (OEMs) and Tier 1 suppliers as part of their technology development roadmaps. There have also been numerous start-up companies proposing aircraft ranging from small urban mobility vehicles through to 150 seat class main-line aircraft.

Even if the total aircraft energy requirement for a mission is increased, benefits can be derived where kerosene consumption in the upper atmosphere is replaced with ground-based electrical power generation. This is conditional on the ground-based electrical power source producing less environmentally damaging emissions than the in-flight use of kerosene.

**OEMS AND TIER 1**

E-FanX was launched in late 2017 by Airbus, Rolls-Royce and Siemens with the intent to develop a flight demonstrator for Hybrid-Electric technologies by 2020. This will involve replacing one of the inboard engines on a BAe146 with a 2MW electric motor driven fan assembly. This will be driven by either a battery or an AE2100 derived turboshaft/generator combination installed in the rear fuselage – it is not stated whether a blend of the two energy sources will be used.

Both GE and UTC were reported to have released white papers in 2017 describing activities on Hybrid Electric Propulsion and Systems.

GE experiments since 2015 have demonstrated the extraction of a combined 1MW of electrical power from both the high- and low-pressure turbines of a F110 engine. Although this is a military engine, the benefits are described as also being relevant to civil applications. GE were also reported to claim to have used a 1MW electric motor to drive a Dowty propeller – the motor demonstrated 98% efficiency.

UTC are also reported to have demonstrated power extraction from the low-pressure spool of a mid-size business jet engine permitting substantially greater power offtake than from just the high-pressure spool. They are also reported to have partnered with Lockheed Martin and the Air Force Research Lab on high energy storage module to improve specific power as well as to consider heat management.

**START UPS**

Numerous companies, many founded in recent years, are looking to develop a hybrid- or all-electric aircraft with a view to revolutionise air travel in several sectors from urban mobility through to 180-seat airliners.
The largest of these, in terms of aircraft size, is an all-electric 180-seat aircraft with ~300nm range. This is the largest of a range of aircraft being studied by Wright Electric, founded in 2016, with a partnership with easyJet, announced in 2017, to target this capability for 2027.

Zunum Aero are planning a range of aircraft (12-50 seat) Hybrid Electric aircraft, with all-electric potential at a later date. This activity has attracted backing from JetBlue Technologies and Boeing HorizonX. The 12-seat aircraft is planned for 2022 with the follow-on 50-seat variant. Range targets are >500nm towards 1,000nm.

Eviation Aircraft are planning a first flight for its all-electric Alice aircraft in late 2018 or early 2019. The initial version is expected to be an ‘air taxi’ for up to nine passengers with up to 650miles range.

An extended range version is planned as battery technology improves.

**e-VTOL**

Numerous high-profile e-VTOL concepts have emerged over the last couple of years. These are largely targeting urban mobility in roles essentially as light helicopters.

Perhaps two of the highest profile are the uber Elevate and Volocopter.

The Uber Elevate marketing video shows a four-seat tilt rotor configuration. A pilot is expected to initially occupy one of these seats although ultimately, an autonomous vehicle is planned. Cruise speed is about 150mph with a 200mph maximum with a capability to operate 2 × 50 mile flights at maximum speed.
or a single 200 mile flight at best flight speed. It is targeted at ‘super commuters’ (100 miles each way) wanting to minimise travel times.

In April 2017, Aurora Flight Sciences and Uber agreed to partner on vehicle development the Uber network. The demonstration vehicle with eight vertical lift rotors for take-off and landing with single propeller and conventional wing for forward flight. The first successful flight for the concept was completed in April 2017.

The Volocopter is a two-seat all-electric rotary wing aircraft optimised for shorter intra-city operations. It has an array of 18 rotors powered by nine battery packs with lower speed and range requirements (45mph and 17 mile range at best speed) relative to the Elevate. This vehicle was tested in autonomous flight for the first time in September 2017 in Dubai.

THE FUTURE

It is interesting to consider where Hybrid-Electric and All-Electric Propulsion technologies sit on the Gartner Hype Cycle and in the context of Amara’s Law, ie ‘We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run.’

Many of the signs suggest that this technology is moving up the initial ‘Technology Trigger’ curve and will be very interesting to see the height of the ‘peak’, the depth of the ‘trough’ and ultimately how high the ‘Plateau’ will be.

Many of the participants in this technology arena are eager to realise the potential benefits of Hybrid- and all-electric propulsion that could act as a major disrupter initially for smaller aircraft but maybe also for larger aircraft as technology improves. However, many also recognise the substantial challenges that must be overcome to achieve these benefits.

It is also possible that the knowledge gained in these activities may provide secondary benefits in the design of the systems for larger, longer range aircraft that are expected to have the greatest challenges for implementing electric propulsion systems.

To be continued …
FUEL EFFICIENCY

Dozens of different initiatives have appeared in the pages of GBD reports aimed at reducing fuel burn, and so minimising aviation CO₂ emissions. Worldwide aviation CO₂ emissions are, however, very substantial – estimated at a staggering 814 million tonnes in 2016 – and still rising. So how can we be certain the measures are having any effect?

One of the best ways is to record the emissions per passenger km. Many airlines now produce environmental reports which give this information, revealing both the scale of the challenge and some very substantial differences in performance.

One of the clear winners this year has been Virgin Atlantic. Its 2017 sustainability report records an 8% reduction in total CO₂ emissions (down from 4.43MT in 2016, to 4.08MT in 2017). This improvement is due to the introduction of the new Boeing 787, improving load factors and other operational efficiencies, including single-engine taxiing. More new 787s, replacing older A340-600s, will further improve efficiency next year, and in the years beyond with 12 Airbus A350s on order, further gains of around 30% are expected in fuel efficiency per aircraft replaced. CO₂ per passenger km was 76.9gm in 2016, with Virgin targeting a further 16% reduction by 2020. With a fleet of 39 aircraft at the end of 2016, on average only 6.9 years old, Virgin Atlantic is well placed to remain near the top.

A new convert to environmental performance is Ryanair’s Michael O’Leary. Just a few years ago he was denying the existence of man-made climate change, but Ryanair has now issued its first environmental report. This sets out Ryanair’s target of 61.4gm of CO₂ per passenger km by 2030. It also claims this represents a 66% reduction compared to performance in 2000.

Ryanair plan to achieve this by introducing the new Boeing 737MAX-200, which is expected to achieve a 16% reduction in emissions per seat. The report also highlights the contribution made by winglets (4% lower emissions), lightweight seats (1%), single engine taxiing (used by 79% of arriving aircraft) and increased use of ground power. Higher load factors (83%-94%) are also cited for improved performance over the last four years (13%).

Note however that introducing new aircraft is a ‘one-off’ efficiency improvement. It cannot be repeated the following year unless further new aircraft can be introduced. So major efficiency improvements tend to be spasmodic, reflecting the years where new aircraft were introduced.
At the other end of the scale lies Lufthansa, Europe’s largest airline. Here fuel efficiency has remained almost unchanged for the second year in a row. Lufthansa have cited falling load factors, changing passenger reservation patterns caused by strikes, and the negative effects of what are described as ‘geopolitical developments’. They quote fuel efficiency in litres per 100 passenger kilometres, their figure of 3.85 litres being marginally worse than the 3.84 recorded in both 2014 and 2015. This is more than twice Ryanair’s figure of 1.91 litres per 100pax km.

This poor performance comes despite the Lufthansa group setting itself a target back in 2006 to reduce emissions by 25% by 2020. It is, however, only half way to its target, and with only four years to go the target is very likely to be missed. Although new fuel efficient aircraft are on order (A320neo, A350-900, Bombardier C Series), and with some already delivered, they will make only a small improvement in fuel efficiency as there are around 600 aircraft in the current fleet. And this is despite the introduction of over 180 fuel efficiency projects being implemented during the year, ranging from engine modifications, improved flight planning and more direct routing to the introduction of lightweight trolleys weighing 35% less, and lighter weight cargo containers.

Two studies attempted to throw some light on the conspicuously different performances between airlines. The first, by the International Council on Clean Transportation (ICCT), ranked 20 airlines operating transpacific routes from the US to East Asia and Oceania destinations.

It found the gap between the most efficient (2.78 litres per 100 pax km) – Hainan Airlines and All Nippon Airways (ANA) – and the least efficient – Qantas - to be 64%. It assessed the key differences and found that they could be explained by:

1. Belly freight (a very significant amount on transpacific routes) (44%)
2. Seating Density (influenced by premium and first seating) (24%)
3. Aircraft fuel burn (16%)
4. Passenger Load factors (12%)

ICCT had previously analysed internal US and transatlantic operations, and found smaller, but still very significant differences between airlines, being 25% on internal flights and 51% on transatlantic flights. Unsurprisingly, performance was better from airlines with newer more fuel efficient aircraft, less premium seating, and higher passenger and freight load factors.

However, ICCT found that larger aircraft were less fuel efficient, with twin-engine aircraft outperforming four-engine aircraft. 747s and A380s are falling from favour now that twin-engine aircraft have the necessary range and payload for longer routes.

A study by the German organisation Atmosfair reported at the end of 2017 that aviation global CO₂ rose by 4% in 2016, but that passenger km rose by 7%. They ranked airlines according to their efficiency, not calculated on actual fuel consumed, but on modelled fuel consumption using aircraft type, engines, winglet fitted or not, seating and cargo capacity, and load factors. UK airline TUI again topped the index, with 80% of the technically feasible optimum.

A key conclusion of the study is that growth is outstripping efficiency improvements every year.

This reinforces the view that in the medium term alternative fuels must be developed in commercial quantities, so aviation’s carbon footprint can shrink. Electric and hybrid aircraft may in the longer term also provide a solution, and their prospects are discussed elsewhere in this report.
The Greener by Design Group

Greener by Design was formed in 1999 by the Royal Aeronautical Society and bodies representing airports, UK airlines and the aerospace industry, bringing together experts from every part of the aviation industry with Government bodies and research institutions. The initiative is sponsored by the Department for Business, Energy and Industrial Strategy and is supported by other bodies in the aviation sector but it is non-aligned, researching and advising independently of any interest.

Greener by Design

Researches, assesses and advises Government and industry on operational, technological, economic and regulatory options for limiting aviation’s environmental impact.

Promotes best practice across the aviation and aerospace sectors.

Promotes a balanced understanding of aviation’s true environmental impact and its environmental programmes, in liaison with other groups with similar objectives.

Issues an annual report and holds an annual conference and workshops on sustainable aviation.

The next annual Greener by Design Conference Impact of Electric and Hybrid propulsion in Aviation is scheduled to be held on 20 November 2018 at the Royal Aeronautical Society.
We are grateful for the support the Department for Business, Energy & Industrial Strategy gives the Greener by Design initiative.

Air Travel – Greener by Design draws on the expertise of industry and academia.
Any views expressed in this report are those of Greener by Design and do not necessarily represent the view of the Royal Aeronautical Society as a whole.

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