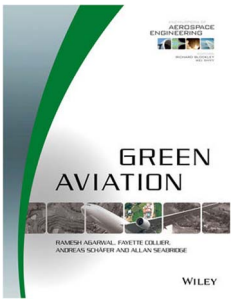

Green Aviation – Encyclopedia of Aerospace Engineering

R. Agarwal *et al.*

John Wiley and Sons, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK. 2016. 514pp. Illustrated. £160. ISBN 978-1-118-86635-1.

Green Aviation is Volume 9 of the *Encyclopedia of Aerospace Engineering*, an ambitious joint venture between the AIAA and the RAeS 'to meet the challenge of distilling the body of aerospace engineering knowledge into a single cohesive reference framework'. This is easier said than done when, as in the case of the impact of aviation on the environment, the science and technology are steadily evolving.

Nevertheless, the book makes a heroic and comprehensive effort to meet its goal. It is divided into nine parts containing in total 38 chapters, each written by specialists in their field, and offers something to a reader interested in almost any aspect of the interaction between aircraft and the environment.

The greater part of the book is concerned with the impact of aviation on climate, and the technological possibilities for reducing it. There is a chapter by Shine near the end of the book discussing the climate impact of the non-CO_2 effects of aviation, mainly the increase in cirrus cloud formed from contrails and the effect of the emission of oxides of nitrogen, which together have at least as great an impact as CO_2. Nevertheless, for the rest of the book, the discussion of climate impact and its mitigation focuses almost entirely on CO_2 emission and its reduction by reducing fuel burn.

The first chapter, by Bows-Larkin, stands out from the rest of the book by developing further the arguments in her paper in the August 2010 issue of *The Aeronautical Journal* that technological advance will not be sufficient to offset unrestrained growth in world aviation. She ends, 'The headline conclusion is clear and unequivocal……. the demand for aviation will need to be constrained if the global community is not to renege on its 2°C commitments'. Although it is difficult to rebut her arguments, the remaining chapters largely avoid this issue.

There follow three chapters setting out the key facts about atmospheric chemistry and the impact on the atmosphere of emissions from aviation. There is some overlap between these, as there is with the final six chapters which make up Part 9 of the book, but each chapter has its own perspective and makes interesting reading in its own right. The fifth chapter, concluding Part 1 of the book, is entitled 'Avoiding the Predictable Surprise…'. It is by Rachel Burbridge, reporting on a study by EUROCONTROL that concludes that there is a need for the aviation sector to build resilience to the predictable impacts of climate change; some

actions are already being taken in Europe but there is a need for action to be taken globally, and now rather than later.

Part 2 of the book contains three chapters on advances in aerodynamics and aircraft design that have the potential to reduce fuel burn. The first, by US authors, discusses drag reduction by various methods of flow control. It begins with a survey of the different mechanisms for transition from laminar to turbulent boundary layer flow and reviews US experience since 1939 with flight tests of laminar flow on wings. This culminates in the incorporation of natural laminar flow (NLF) control, achieved solely by shaping the surface, on the nacelles of the Boeing 787-8 and the winglets of the 737 MAX, followed by hybrid laminar flow control (HLFC), by a combination of surface shaping and leading-edge suction, applied to the empennage of the 787-9. There is reference to the flight tests of HLFC on a Boeing aircraft in 1990-91 but no fuller discussion of the application of laminar flow control to the wings of future aircraft, where the potential reduction in fuel burn is the greatest, nor is there any reference to the European project under Clean Sky to test an Airbus A340 with laminar flow outer wings. This aircraft is now in flight test, but it came too late to warrant a mention. The final part of the chapter reports on the application of flow control by laterally sweeping miniature jets at the knuckle between fin and rudder, demonstrated by tests on a full-scale Boeing 757 fin in the NASA 40ft × 80ft wind tunnel. By delaying flow separation to higher lift coefficients, these would enable the fin size in future designs to be reduced, thereby reducing drag, weight and fuel burn.

The next chapter, by Torenbeek, reviews the history of the evolution of the flying wing concept into the blended wing-body (BWB – the NASA preferred term is hybrid wing-body HWB) as now developed by Boeing and NASA. This configuration has been the pin-up model of an environmentally friendly aircraft since the RAeS published the first Greener by Design technology report in 2001. Torenbeek envisages fuel savings of 30–40% for the next generation of large transport aircraft, combining the BWB configuration with the most advanced future engines. In Chapter 20 of the book, there is a complementary article by NASA and Boeing on the development, under the NASA Environmentally Responsible Aircraft (ERA) project, of the concept of pultruded rod stitched efficient unitised structure (PRSEUS) for composite panels. These are damage arresting panels aimed at the structural design problems of the non-circular, pressurised passenger cabins of the BWB.

The final chapter in Part 2 by Joaquim Martins reviews the possibilities of fuel burn reduction by wing morphing, which is taken as the in-flight variation in wing sweep, planform, twist and aerofoil shape. The author's conclusion is a cautious one – when all factors are taken into account many proposed systems 'do not buy themselves into the aircraft'. In the longer term, however, he sees real potential in adaptive trailing edge morphing as a means of optimising cruise performance and, in combination with active control, of reducing gust sensitivity, thereby enabling increases in wing span and reductions in weight, drag and fuel burn.

Part 3 consists of five chapters on combustion-based propulsion. Three of

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these, from NASA Glenn, Rolls-Royce and Pratt and Whitney, deal with current and future turbofan engines, including the geared turbofan that has entered service on the A320neo and the larger potential geared turbofan engines that are currently envisaged. The fourth and fifth chapters, both from NASA Glenn, discuss advanced design concepts beyond the geared turbofan and the substantial progress that has been made in developing contra-rotating open rotors that achieve the potential increases in propulsion efficiency while at the same time meeting current noise targets. Inevitably, there is some overlap in the first three papers but the picture that emerges overall is one of a significant further reduction in CO_2 emission from the continued evolution of the kerosene-fuelled gas turbine.

Part 4 deals with alternative propulsion, the first chapter of which is an interesting paper on energy optimisation for solar powered aircraft which, I suggest, has nothing whatsoever to do with the environmental impact of aviation. The titles of the other first chapters in Part 4 are the following: Hydrogen-Powered Aviation; Biofuels for Green Aviation; Hydrogen Fuel Cells for Auxiliary Power Units; Electric Drives for Propulsion System of Transport Aircraft and finally Lithium-Ion Batteries: Thermodynamics, Performance and Design Optimisation. Between them, these chapters cover the potential applications and challenges that face the candidate technologies to replace kerosene-fuelled propulsion in the longer term. I was particularly taken by the eXtreme Green concept advanced by NASA Glenn, which requires biofuels not only to be sustainable and renewable alternatives to petroleum-derived fuels but also to use no fresh water, food crops or arable land in their production. The only biomass sources that meet these criteria are marine algae/bacteria and halophytes (salt-tolerant plants) and the authors urge large-scale research and development into these as future renewable energy sources.

Part 5 contains two chapters, the already mentioned one on damage arresting composites and one from NASA Ames, Langley and Glenn on Greener Helicopters. The latter recognises, slightly enviously, the Green Rotorcraft Integrated Technology Demonstrators proceeding within the European Clean Sky program, which aim to reduce CO_2, noise and chemically harmful emissions from rotorcraft. It then discusses US research aimed at these objectives, with advances in propulsion systems and noise reduction as the priorities; the possibility of a metropolitan/regional transport system using battery/hybrid power (the Hopper Bay Area Network, envisaged for California around 2040) is one subject highlighted.

Part 6 considers noise. The first chapter discusses the problem of the continued and spreading public hostility to aircraft noise as air traffic grows, despite the progressive reduction of the noise of individual aircraft. Developing greater public understanding and tolerance of aircraft noise, through better communication with affected communities, is now seen as important as technological and operational advances to reduce noise. The second chapter reviews some of the current modelling methods used in noise prediction, both by airframe and engine designers and by regulatory bodies. The third chapter deals with emissions trading for CO_2

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with a shorter, speculative discussion on noise trading. The CO_2 trading discussion focuses on the EU scheme which has now been superseded for international flights by the ICAO carbon offset scheme CORSIA, which differs from a trading scheme but had not been formulated at the time of publication of this book.

The eight chapters of Parts 7 and 8 cover systems and operations. Four of these, Chapters 25, 26, 27 and 30, address energy usage and its minimisation by optimising and integrating on-board systems, advances in avionics and ATM and by trajectory optimisation both in cruise and in the departure from and approach to airports. There is inevitably some overlap between the four chapters but each provides a good account of its main subject. The other four chapters are more individually distinct. Chapter 28, by Dray and Evans of University College London, gives a limited account of the development of integrated assessment modelling, which projects the long-term behaviour of and interaction between the key stakeholders in civil aviation – passengers and shippers, airlines, airports and their regions, aircraft and engine manufacturers, air navigation service providers, governments and regulators. The purpose of the model is to enable the long-term impacts of alternative policies to be evaluated. Chapter 29 describes a cost analysis method, developed within the NASA ERA project that can be used during the conceptual design process to assess critically the business case for adopting particular environmental technologies. Chapter 31, by Bennett and Raper of Manchester Metropolitan University, is the only one in the book addressing the impact of airports on local air quality. It discusses the tools now available for monitoring and modelling air quality around airports. Although the great majority of local pollution comes from motor vehicle emissions, the local impact of aviation emissions remains an important subject for research. Chapter 32 'A Roadmap for Aviation Research in Australia' touches on environmental impact, but only within the wider framework of the economic and social needs for the growth of aviation in Australia. It seems a little out of place in a book on Green Aviation.

The final part of the book – Part 9 – consists of six chapters on Atmosphere and Climate. Chapter 37 on atmospheric composition and Chapter 33 on atmospheric modelling are suitable companions to Chapters 2–4 on emissions. Chapter 34 on in-plume physics and chemistry, precedes a chapter by Gierens on contrails and contrail cirrus. As by far the largest contributor to the current imbalance in the Earth's radiation budget, this aviation-induced cloudiness, its underlying science and the limited but promising options for mitigating its impact need to be more widely understood, particularly by the operating community and regulators. The following chapter by Shine on radiative forcing and alternative metrics for climate impact also contains important material for future regulators. The final chapter is on meteorology and the risks to aircraft of a wide range of adverse weather conditions. It is interesting but, like a couple of other chapters in the book, makes no real connection with climate change.

In summary, this is a substantial book in which 38 authors have contributed authoritative

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essays that, mostly, address a topic of great importance in all its aspects. Although green aviation is a field in which both the science and technology are steadily advancing, it should serve as an important source for workers in the field for years to come.

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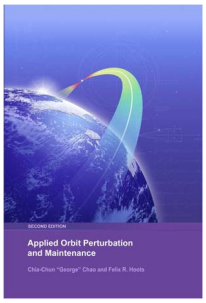

Applied Orbit Perturbation and Maintenance – Second edition

C-C. Chao and F. R. Hoots

American Institute of Aeronautics and Astronautics, Reston, VA, 2017. Distributed by Transatlantic Publishers Group, 97 Greenham Road London N10 1LN, UK. xviii; 411pp. Illustrated. £97. ISBN 978-1-88498-927-8.

This second edition of *Applied Orbit Perturbation and Maintenance* by Chia-Chun (George) Chao with new inputs from Felix Hoots is a welcome update to an already established astrodynamics text by the primary author.

Building from the fundamental theory of orbit motion through the development of classical elements and complex perturbed trajectories to application to mission analysis problems, the text provides a comprehensive treatise and consideration of appropriate approaches to orbit representation and modelling solutions. The chapters on orbit maintenance of different classical orbits ranging from low-Earth up to higher altitude orbits are particularly useful, most notably

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