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AVIATION

Plotting the route to a greener future

Presented in partnership between Inmarsat and aviation journalist Elan Head

About the Author

Elan Head is an award-winning reporter and editor who specialises in coverage of the aviation industry and emerging technologies.
In addition to her work as a journalist, she is a commercially rated helicopter pilot and FAA Gold Seal flight instructor.

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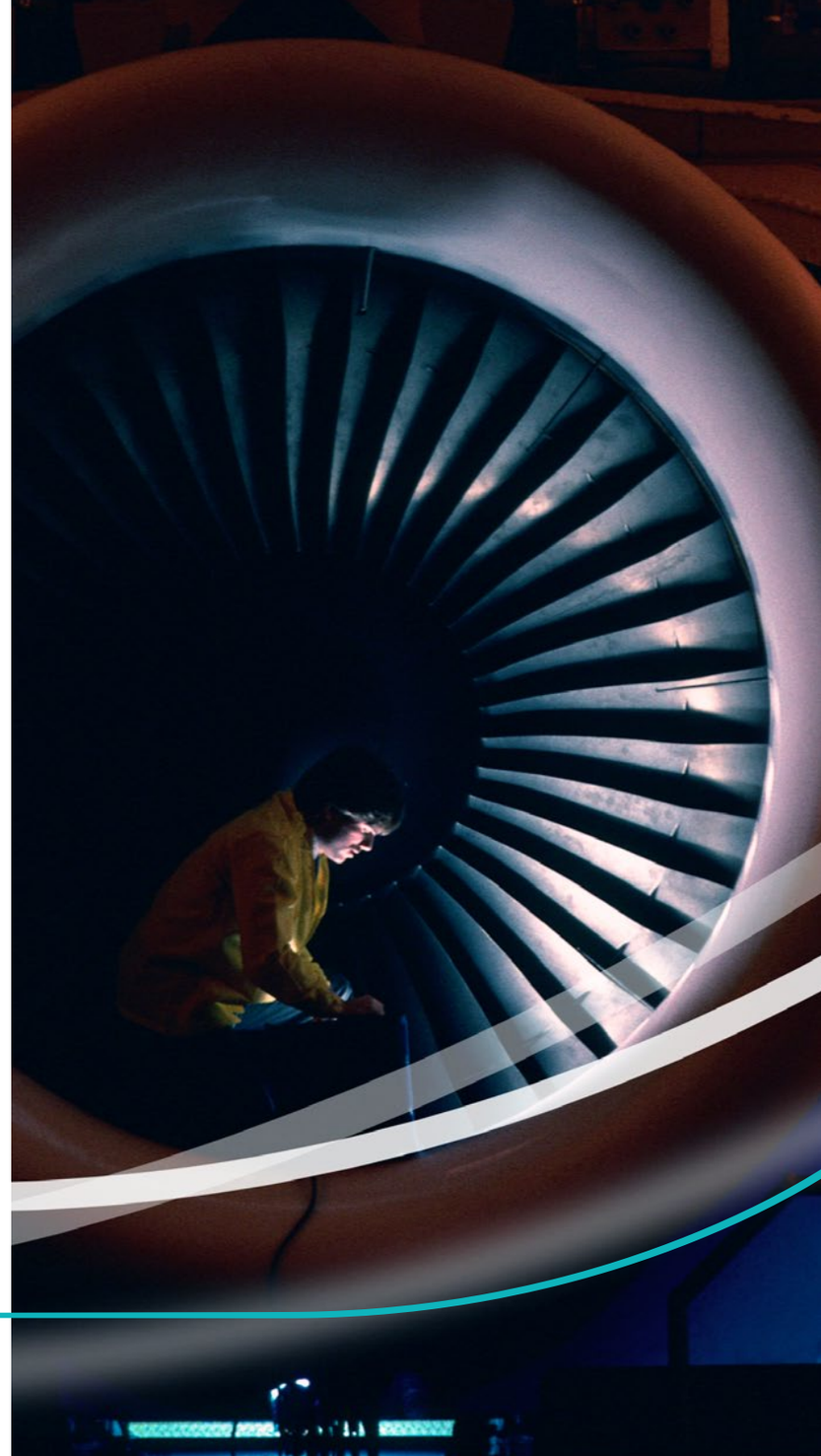
Introduction

In October 2021, members of the International Air Transport Association (IATA) approved an ambitious resolution, committing to achieving net-zero carbon emissions by 2050.[1] The commitment aligns with the Paris Agreement goal to keep global warming below 1.5°C, but the scale of the challenge is enormous. Reaching net-zero implies that a cumulative total of 21.2 gigatonnes of carbon will be abated between now and 2050, equivalent to around three-fifths of global carbon emissions from all sources in 2019.[2]

IATA's commitment is a proactive response to the growing environmental pressures facing the air transport industry, including activist campaigns for demand reduction and sustainability mandates tied to some COVID-19 relief packages. It also acknowledges an uncomfortable truth: that time is running out to avert the worst impacts of global temperature rise. The Intergovernmental Panel on Climate Change (IPCC) underscored this point in April 2022, when it released its latest report on mitigation prospects.[3]

> **"It's now or never, if we want to limit global warming to 1.5°C. Without immediate and deep emissions reductions across all sectors, it will be impossible."**
>
> said Jim Skea, a professor at Imperial College London and co-chair of an IPCC working group.



[1] https://www.iata.org/en/pressroom/2021-releases/2021-10-04-03/
[2] https://www.weforum.org/agenda/2021/11/global-co2-emissions-fossil-fuels-new-data-reveals/
[3] https://www.ipcc.ch/report/ar6/wg3/

Aviation has long been recognised as an especially difficult sector to decarbonise due to the lack of suitable substitutes for fossil jet fuel. Sustainable aviation fuel (SAF), hydrogen, and batteries are promising solutions for achieving "deep" emissions reductions in the long term, but they won't arrive at scale overnight. As for "immediate" reductions, the industry has only two practical options: fly less, and/or make current flight operations more efficient.

This paper focuses on the latter, and specifically on how satellite communications can enhance the efficiency of individual operations and the air traffic system as a whole. The upshot: Satcom can enable marginal emissions reductions today, while laying the groundwork for significant reductions in the future. If aviation is to meet its climate goals while continuing to deliver broad benefits to the global economy, connectivity will be essential.

[4] https://news.un.org/en/story/2022/04/1115452

Room for improvement

"Operational improvements" factor into every roadmap for moving aviation to net-zero, but the term is not always clearly or consistently defined. Depending on the context, it could include anything from using electric tugs for moving airplanes around the airport, to optimising climbs and descents to minimise fuel burn. While the cumulative effects of these actions can be substantial, they're also difficult to measure, and often obscured by gains associated with more fuel-efficient aircraft and engines.

"Operational efficiency is one of those things that when we talk about fuel efficiency, everything gets lumped together and it's just, hey, look how [much] less fuel we're using per passenger kilometre," said Brandon Graver, a senior aviation researcher at the International Council on Clean Transportation (ICCT) who has studied the role of improved fuel efficiency in moderating the growth of aircraft emissions.

In a recent blog post, Graver explored how these factors break down for U.S. commercial airlines, whose fuel efficiency per revenue passenger kilometre improved by 23% between 2005 and 2019, or 1.5% per year.[5] He determined that payload efficiency — carrying more passengers per flight — accounted for two-thirds of this gain, or a 1% annual fuel efficiency improvement.

[5] https://theicct.org/aviation-fuel-efficiency-jan22/

Lower aircraft fuel burn due to technology enhancements translated to a 0.4% annual improvement, while traffic efficiency improvements including upgraded navigation and air/ground traffic management could account for the remaining 0.1%.

That may not sound like a lot, but steady improvements on the order of 0.1% per year could make a significant contribution by 2050. Worldwide, the Air Transport Action Group (ATAG) estimates that substantial investments in operations and infrastructure could result in net CO_2 reductions of 0.1% to 0.2% per year, which would combine to reduce aviation carbon emissions by 3% to 6% in 2050.[6] In its 2021 Aviation Climate Action Plan, the U.S. Federal Aviation Administration (FAA) predicts that operational improvements will contribute up to 4% of emissions reductions in 2050.[7] "[Operational efficiency] is really hard to measure due to many things, Graver noted. "But there's definitely a lot of improvements that need to be made operationally, and the biggest ones are improved air traffic management."

The potential for enhanced air traffic management (ATM) is particularly pronounced in Europe, which has highly congested airspace, fragmented ATM, and a patchwork system of route charges that does not always incentivise the most fuel-efficient flight paths. A 2020 environmental assessment by Eurocontrol found that in 2019, flights within Europe had an average fuel inefficiency of between 8.6% to 11.2%, with flights between some airport pairs — such as Dusseldorf and Zurich — showing an average excess fuel burn of greater than 20%.[8]

Notably, when Eurocontrol analysed flights during the height of the COVID-19 pandemic in 2020, it found that average excess fuel burn dropped to just 3.5% thanks to the easing of airspace restrictions enabled by the sharp drop in traffic. The comparison illustrates not only the significant potential for fuel savings from more efficient routing, but also how critical ATM modernisation will be for avoiding even more wasted emissions as flight volumes increase in the future.

The Eurocontrol study supports the potential for ATM modernisation to influence roughly 10% of aviation emissions in Europe. That's consistent with the long-term goal of the Single European Sky (SES) regulatory framework to reduce air transport emissions in Europe by 5% to 10%. One important component of SES is Iris, a satellite-based data-link service promoted by the European Space Agency (ESA) and powered by Inmarsat SwiftBroadband-Safety (SB-S), which will enable new approaches to ATM discussed later in this paper.

[6] https://aviationbenefits.org/environmental-efficiency/climate-action/waypoint-2050/
[7] https://www.faa.gov/sustainability/aviation-climate-action-plan
[8] https://www.eurocontrol.int/publication/environmental-assessment-european-atm-network-fuel-inefficiency-study

Clearly, operations and infrastructure improvements alone won't push aviation all or even most of the way to net-zero. Nevertheless, these measures can often be implemented at scale faster than advancements in airframe and engine technologies, which take many years to develop and certify. That makes them low-hanging fruit for an industry that is under pressure to reduce its emissions.

For Graver, the near-term focus on efficiency improvements over demand reduction makes sense, as the limited alternatives to air travel on many routes would complicate a "cap-and-reduction" approach. "There are certain times you just have to fly," he said, pointing out that North America and Africa, for example, lack the high-speed rail options that are available in Europe and some parts of Asia. But he emphasised the importance of the aviation industry taking immediate steps to reduce its carbon footprint, even if some investments will take time to pay dividends."The important thing is that we need to start dealing with it now, and not start dealing with it in 2040, because then it's kind of too late," he said.

Tangible benefits

As Graver's analysis indicates, airlines and air navigation service providers (ANSPs) have already been making progress in enhancing operational efficiency as flight volume has grown in recent decades. Satellite communications have played an important role in this, enabling more optimised flight paths and increasing the data that can be transmitted between the ground and aircraft in flight.

Some of the most striking improvements have been in remote oceanic regions, notably in the congested flight tracks over the North Atlantic, where flight paths were previously highly constrained due to the lack of radar coverage and delays in high frequency (HF) radio communication. Inmarsat has been providing safety satcom services to flights in this region since 2001.

"I think using satcom in oceanic airspace has almost solely facilitated how that airspace is managed today,"

said Euan Mitchell, a senior product manager at SITA, a leading specialist in air transport communications and information technology. Because pilots remain in contact with air traffic control (ATC) throughout their flights, they can fly shorter, more efficient routes with less separation from other traffic, compared to the more conservative routings that were used to ensure safe separation in the past.

A 2017 study prepared for Inmarsat by the aviation consultancy Helios estimated that satcom-enabled ATC and airline operational control (AOC) improvements generated a $3 billion benefit in oceanic regions between 2001 and 2016, with about 4% of that related to a reduced environmental impact.[9] Up until 2012, most of satcom's benefits were relatively modest and associated with classic AOC communications, which airlines have long used to improve delay management and scheduling, among other things. But the benefits grew rapidly after 2012, when reduced separation unlocked a host of new opportunities to optimise flight paths.

In recent years, airlines have been benefitting from new applications that provide pilots with more and better information about how to fly more efficiently. These include graphical weather applications such as SITA's eWAS, which provide pilots with a more comprehensive understanding of weather than they can obtain through onboard radar. While many of these apps can be used offline, connectivity enhances their benefits. "The new thing that connecting it in flight enables is [access to] the latest and greatest forecast," Mitchell explained.

"Typically the weather forecast has a validity period which in many cases for a short-haul sector of one or two hours is perfectly OK. But if you're flying on a long-haul sector of multiple hours, ideally you want to get that update when it's available. And that's really what this dedicated IP connection is enabling: a higher data volume real-time update, which has not been possible previously."

A 2018 report commissioned by Inmarsat from the London School of Economics estimated that live weather and environment updates streamed to pilots' electronic flight bags (EFBs) could deliver global annual cost savings of US$1.3 billion per year thanks to improved navigation and adverse weather avoidance.[10] The benefits of avoiding turbulence could be even higher, with an estimated range of annual global fuel savings of $1.3 billion to $2.6 billion, in addition to savings on airframe inspections and follow-on repairs.

The report also observed that around 10% of flights depart without winds uplink in their flight management computer due to ground communication issues such as radio congestion and 4G blind spots. As a consequence, they often carry additional contingency fuel that increases their overall fuel burn. The report estimated that providing winds uplink to all flights could result in annual global fuel savings of around 850 million litres (250 million gallons) and a corresponding reduction in CO_2 emissions of two million tonnes.

[9] https://www.inmarsat.com/en/insights/aviation/2017/the-3bn-boost-how-satcom-has-helped-the-aviation-industry.html
[10] https://www.inmarsat.com/en/insights/aviation/2018/the-skys-the-limit-2-the-future-of-airline-operational-cost-savings-revealed.html

There are also less obvious opportunities for weight savings that translate to decreased fuel burn. Even small weight reductions — such as those achieved by replacing paper manuals with EFBs — have been credited with significant cumulative fuel savings.[11] The London School of Economics report notes that a typical wide-body aircraft departs with onboard inventory weighing about six tonnes, including meals, beverages, duty-free goods, and more. Dynamic, real-time adjustments in onboard inventory to match passenger numbers and preferences, enabled by connectivity, can save around 400 kilograms per flight, and satcom-powered online ordering can eliminate the need to carry duty-free merchandise on aircraft altogether.

In the past few years, sophisticated data science applications enabled by machine learning have presented airlines with new opportunities to reduce fuel burn by optimising flight paths. Alaska Airlines is using the Flyways AI platform from Airspace Intelligence to help its dispatchers identify more fuel-efficient routes. The airline estimated that it saved 480,000 gallons of fuel and 4,600 tons of carbon emissions during a six-month trial period, even with significantly depressed flying due to COVID-19.[12]

Other artificial intelligence-powered apps provide direct guidance to pilots in the cockpit about how to reduce fuel burn in flight. For example, SITA's OptiClimb uses machine learning to optimise an aircraft's climb-out phase to initial cruise level, minimising fuel burn and CO_2 emissions in the process. "It's really quite amazing the level of fuel that can be saved if you optimise that flight profile during the climb," said Euan Mitchell.

He pointed out, however, while OptiClimb may tell a pilot exactly how to fly to optimise fuel burn, this flight profile still needs to be cleared by ATC. And that points to the next frontier for operational improvements: maximising the efficiency of the overall air traffic system so that every aircraft can fly as near as possible to its optimal trajectory, almost all the time.

[11] https://www.cnbc.com/2014/09/11/american-airlines-scraps-paper-manuals-for-tablets-to-cut-fuel-costs.html
[12] https://news.alaskaair.com/newsroom/alaska-airlines-and-airspace-intelligence-announce-first-of-its-kind-partnership-to-optimize-air-traffic-flow-with-artificial-intelligence-and-machine-learning/

Time-based management

Aircraft operating in congested airspace form a complex and interconnected system, and we've all witnessed how sensitive that system is to disruptions. Weather delays, for example, tend to have a cascading effect, impacting not just the flights that are directly affected by the weather, but every flight that happens downstream. The more aircraft that are operating in the system, the more challenging it is to recover from any disturbance.

With demand for air travel expected to double over the next 20 years, the world will need new tools for managing that volume of flights safely and efficiently. Even if demand is capped, there is a compelling need to eliminate inefficiencies in the current ATM system, as illustrated by Eurocontrol's estimates of excess fuel burn for flights in Europe.

Today, industry is converging around the concept of trajectory-based operations (TBO), which integrates a time element into the management of an aircraft's three-dimensional flight path for 4D trajectory optimisation. TBO assumes constant information sharing between airlines and air traffic control, starting with the flight planning stage, and continuing through every segment of a flight, from pre-departure to the arrival gate.

Aircraft will share detailed information about their desired and actual trajectories, allowing ATC to factor that data into its planning. Time-based automation capabilities will assist controllers with spacing and speed control to allow each aircraft to fly its optimal trajectory. Automation will also assist with tactical flight rerouting around weather while maintaining the smooth functioning of the overall system.

According to the FAA's Aviation Climate Action Plan, "TBO is expected to provide efficiency benefits by allowing flights to absorb delays caused by merging and sequencing in a more fuel-efficient manner over the full trajectory." Additionally, the plan states,

"TBO is necessary for accommodating anticipated growth in demand for aviation, which could result in increased congestion and excess fuel burn per flight if these capabilities are not developed and implemented."

TBO will demand a multi-link environment, with satcom playing a valuable role in enhancing the capacity, security, and resilience of the overall system. In Europe, that role is being played by Iris, the satellite-based data-link service promoted by the European Space Agency and powered by Inmarsat SB-S. In development since 2014 and now poised for commercial deployment, Iris is immediately complementary to Europe's VHF Data Link (VDL) Mode 2 system, which is expected to face a capacity shortage before the anticipated roll-out of TBO in 2027.

"This is really what connectivity is bringing, real-time data for an increased resilience of the network to disruptions; a way to increase the predictability of operations on a daily basis for reduced operating cost,"

said Sylvie Sureda-Perez, director of Datalink Solutions for Inmarsat Aviation. Antonio Garutti, head of the Telecommunication System Project Office at ESA, emphasised that "Iris is ready. We concluded the development, verification, and standardisation phases." Now, the platform is moving into extended pre-commercial flights with Airbus, easyJet, and 13 European ANSPs before entering pre-operational service by Q2 2023.

In a recent "green paper", ESA estimated that ATM modernisation could, on average, reduce Europe's CO_2 emissions by 15 million tonnes per year from 2024 to 2040, reaching up to 16 million tonnes in 2040.[13] That's comparable to the 2019 emissions of a smaller European nation like Lithuania or Luxembourg. The cumulative CO_2 savings during that time period could reach up to 284 million tonnes.

[13] https://artes.esa.int/iris-green-value-how-esa-harnessing-satellite-technology-reduce-aviation-emissions

ESA also calculated how much of these projected savings could be attributed to Iris, assuming that the savings will contribute to 50% of the benefits (complementing terrestrial technologies 50% of the time). Assuming a gradual ramp-up in which Iris is on just 2.5% of aircraft in 2024, a third in 2030, and nearly all airliners in 2038, Iris is credited with average annual CO_2 savings of 1.5 to 3 million tonnes over the time period. In 2040, Iris could save up to 6.5 million tonnes of CO_2, equivalent to the current yearly emissions of cities like Seville or Florence.

Garutti pointed to the aircraft equipage rate as one of the key challenges for achieving the full potential of Iris. Here, airlines have the possibility to optimise their efficiency by combining satcom equipage with a shift to more fuel-efficient aircraft and engines. The COVID-19 pandemic has already accelerated fleet renewals for a variety of reasons, and Eurocontrol estimates that bringing fleet renewal forward by three to seven years could provide additional fuel and CO_2 savings of 1.7% to 5.3% annually between 2028 and 2030.[14] Airlines that line fit their new, fuel-efficient aircraft with satcom will be fully prepared to take advantage of TBO, as well as current and future operational apps.

Although Iris was developed in a European context, the next phase of the program, Iris Global, will see it evolve into a global system. Inmarsat provides worldwide capacity via its ELERA satellites, and the company sees potential for Iris to help improve the efficiency of ATM in the U.S., Asia, and other regions as they move toward TBO.

[14] https://www.eurocontrol.int/publication/eurocontrol-think-paper-16-reducing-aviation-emissions-55-by-2030

Creative solutions

Just as smartphones enabled a universe of apps that dramatically transformed how and why we use mobile phones, the existence of high-capacity, secure data links for the cockpit is spurring new and creative approaches to reducing aviation's environmental impact.

"When you have a data link that is stable, safe, secure, there will be a number of applications that the airlines, the users, the air traffic management, stakeholders will develop … to extend the advantages we see today to a different level,"

said Garutti. Sureda-Perez added, "If you think about communication, we always think about the pilot talking to a controller … but in the future there will also be increased machine-to-machine exchanges. And this will really foster some automation that is going to facilitate and improve the way flights operate and airspace is managed."

Some of these future innovations may incorporate ideas that haven't occurred to us yet. But two more advanced concepts are already being explored: contrail avoidance and formation flying, both of which will require the type of robust connectivity provided by satcom.

Contrail avoidance would address some non-CO_2 climate impacts of aviation, which are still an active area of research. Some studies have suggested that the net warming effect of contrail-cirrus cloud coverage could be even greater than the impact from aviation's CO_2 emissions, although the question is far from settled.

Because contrails only form in relatively shallow layers of ice-supersaturated air below a critical temperature threshold, flight trajectories could theoretically be adjusted to avoid areas conducive to contrail formation. According to a 2020 report from the European Union Aviation Safety Agency (EASA), most of the warming associated with contrails comes from a few "big hits" where the accompanying cloud formation is especially large and long-lasting.[15] Rerouting only those flights that are likely to generate big hits could yield significant environmental gains at a relatively low cost.

Although the concept is promising, our current ability to predict regions of ice-supersaturation is limited. Operationalising contrail avoidance would require advancements in meteorology, as well as a better understanding of the actual climate impact of the contrail cirrus effect. Once those advancements are realised, the ability to transmit real-time weather updates to the cockpit and dynamically adjust flight routing will be critical to achieving the desired goals.

[15] https://www.easa.europa.eu/document-library/research-reports/report-commission-european-parliament-and-council

Formation flying takes inspiration from the V-shaped flight pattern of migrating birds, who realise intuitively that the wake vortices that trail from wingtips contain a large amount of kinetic energy. This principle of wake energy retrieval can be used to reduce fuel burn for trailing aircraft that "surf" in the wake of the leader.

Airbus has been exploring commercial formation flight through its high-profile "fello'fly" program, in collaboration with partner airlines SAS Scandinavian Airlines and Frenchbee, along with multiple civil aviation authorities and ANSPs. In November 2021, two A350 test aircraft performed the first long-haul fello'fly demonstration, flying at a separation of three kilometres from Toulouse, France to Montreal, Canada. Airbus reported that over six tonnes of CO_2 emissions were saved on the trip, confirming the potential for fuel savings of more than 5% on long-haul flights.[16]

Safely maintaining the reduced separation necessary for commercial formation flight will require new procedures and pilot assistance functions within the aircraft systems. Secure, reliable connectivity will be necessary to safely accomplish the rendezvous of the leading and trailing aircraft and to maintain communications with ATC throughout the flight. In the longer term, the addition of an aircraft-to-aircraft data link could support more efficient management of wake energy retrieval operations and enable more of them to be managed simultaneously.[17]

The potential for reducing aviation carbon emissions through formation flight is substantial. A 2021 study by researchers at the University of Bristol suggests that formation flying could be used in up to 95% of transatlantic flights, 75% of other long-haul routes, and 35% of short-haul flights.[18] The average overall fuel savings for each category were estimated at around 9%, 6%, and 2%, respectively, "showing that there is real potential even for the short-haul flights," the authors concluded.

[16] https://www.airbus.com/en/newsroom/press-releases/2021-11-airbus-and-its-partners-demonstrate-how-sharing-the-skies-can-save
[17] https://flipbook.mms-airbus.com/fellofly/index.html#/page/22
[18] https://arc.aiaa.org/doi/10.2514/1.C035954

A sustainable future

While SAF and hydrogen combustion are, for the time being, the only practical alternatives to Jet A for large commercial airliners, smaller aircraft are much better suited to battery electric and hydrogen fuel cell solutions. At this lower end of the market, recent advancements in electrification and autonomy have combined with investor enthusiasm for green technology to power an explosion of disruptive innovation.

In recent years, billions of dollars of investment have flowed into the development of small uncrewed aircraft, electric air taxis, and electric and hydrogen-powered regional aircraft. While most of these projects are still in their early stages, they have the potential to bring the benefits of aviation to a much larger share of the world's population at a much lower financial and environmental cost.

One of the leaders of this movement is Slovenia-based Pipistrel, which was acquired by Textron in April 2022 as part of Textron's long-term strategy to offer a family of sustainable aircraft for urban air mobility, general aviation, cargo, and special mission roles. Pipistrel is notable as the first (and so far only) company to type certify an electric aircraft with EASA, the Velis Electro. The company is actively developing other hybrid and fully electric aircraft, including a hybrid-electric cargo drone, the Nuuva V300.

According to Pipistrel's global head of business development, Bryan Wood, almost all of Nuuva's prospective customers are interested in operating beyond visual line of sight (BVLOS). That, he said, would be almost impossible to do without the satellite connectivity being provided by Inmarsat, especially given the many remote locations where the aircraft is expected to operate.

Additionally, satcom will enable Nuuva aircraft to fly directly from their originating point to their destination, rather than having to follow an indirect path dictated by line-of-sight ground stations.

"So you end up with much less energy expenditure and much less carbon emission output, whether it's local emissions or not,"

he said. These benefits are some of the reasons why Inmarsat's ELERA network was recently recognised with a Hall of Fame trophy by the Association for Uncrewed Vehicle Systems International (AUVSI).[19] ELERA powers Inmarsat's new uncrewed aerial vehicle connectivity offering, Velaris, which provides reliable uptime links for applications such as high-definition video, as well as fast and precise positioning data for ANSPs.

Aircraft like Nuuva are a reminder that even as ATM is modernising to handle higher volumes of airline traffic, it will need to evolve to accommodate a host of new airspace entrants, too. Traditional ATM will need to merge with uncrewed traffic management (UTM) as well as urban air traffic management (UATM), the system envisioned for large numbers of future urban air taxis. A secure, robust multi-link environment will be essential as the system becomes increasingly reliant on data and communication between machines.

The present moment is a challenging one for the aviation industry in many ways, but also one that is rich in opportunity. When IATA announced its net-zero ambition last year, Director-General Willie Walsh said,

"There will be those who say that we face impossible numbers and technical challenges. Aviation has a history of realizing what was thought to be impossible — and doing so quickly."

As we wait for SAF to scale up, and the development of "impossible" technologies like hydrogen and battery electric aircraft, there are nevertheless tangible steps that the industry can take to reduce its climate impact today. Operational improvements can amplify the impact of more fuel-efficient aircraft and engines, moderating

[19] https://www.inmarsat.com/en/news/latest-news/aviation/2022/inmarsat-elera-wins-prestigious-auvsi-xcellence-award.html

carbon emissions as air transport demand rebounds in the wake of COVID-19. Equipping with satcom now will allow airlines to maximise fuel-saving opportunities in the near term, while preparing for the advent of trajectory-based operations later in the decade. Down the road, connectivity could enable radical new approaches to fuel savings, such as wake energy retrieval.

Satcom on its own will not accomplish emissions reductions, but it's a powerful enabler for operational improvements and will be increasingly central to the airspace of the future. And the evidence is clear that decarbonisation needs to start now, using all of the tools at the industry's disposal.

"In the long term, obviously the impact from green aircraft and sustainable fuel on reduced CO_2 emissions is big, But today this is not available. It is as simple as that. So if you want to start addressing the problem, you have to start with the available solution."

Said Sylvie Sureda-Perez, director of Datalink Solutions for Inmarsat Aviation.

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