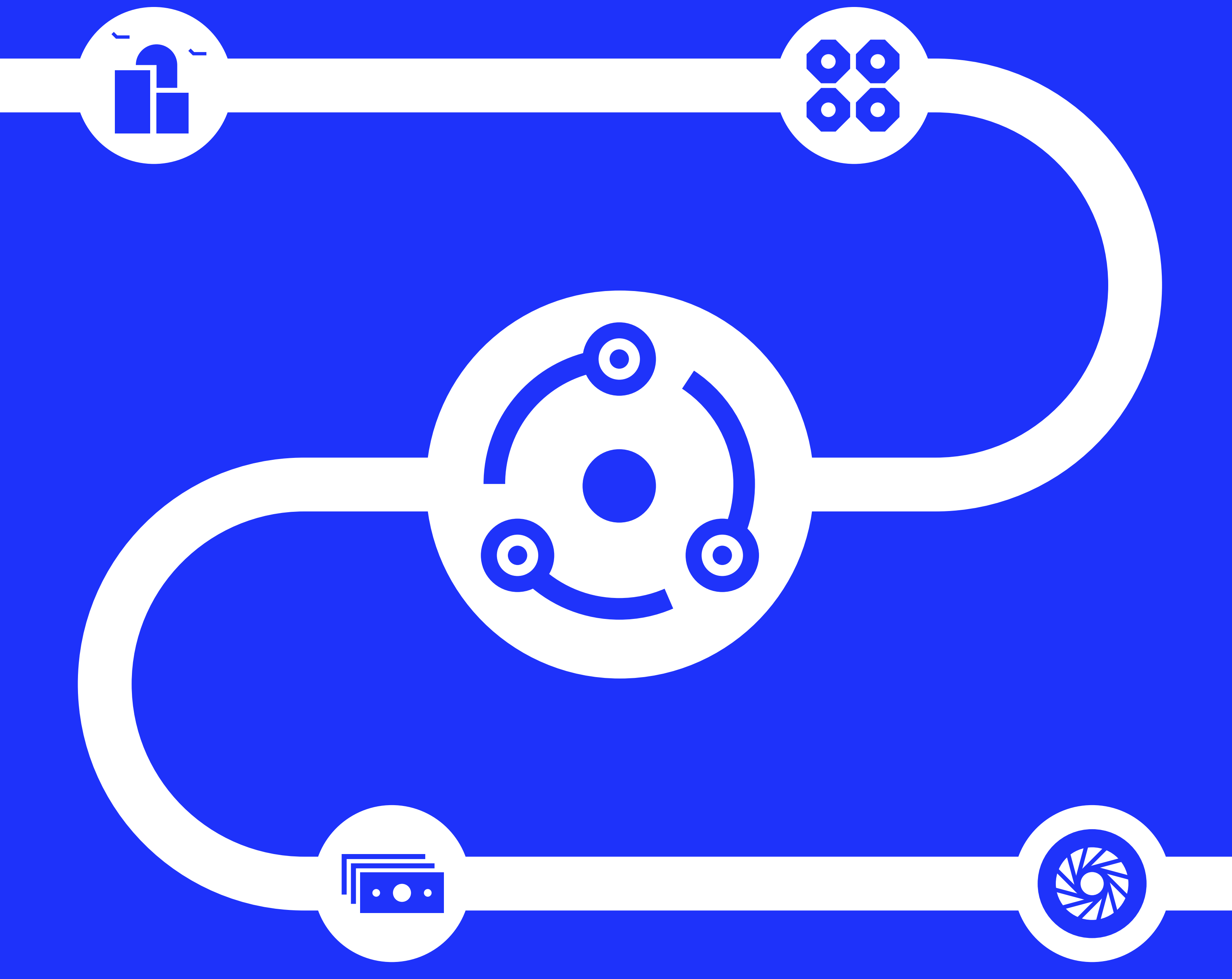
Operations
Net Zero Roadmap



Introduction

The global air transport industry is changing, motivated by the need for higher automation and greener infrastructure. Efficiency in Air Traffic Management (ATM) results in reduced fuel burn and for every tonne of fuel saved, 3.16 tonnes of CO_2 emissions are abated. It is imperative that all stakeholders find solutions to deliver these efficiencies, many of which are recognized as being achievable in the near term. This is particularly important while other net zero new technologies and solutions are matured and scaled up. This Operations Roadmap highlights operational concepts that can help steer the industry towards net zero and captures some of the anticipated technological advancements that will transform how air traffic is managed.

The roadmap presents the progressive implementation of improvements towards the desired operational set up. These improvements are expected to span across the entire operations and require the involvement buy-in of airlines, ground handlers, Air Navigation Service Providers (ANSPs) and various industry suppliers. The focus of this roadmap is on the collaboration required between the airlines and ANSPs, with industry suppliers being vital to ensure that ATM operational improvement are implemented where and when needed.

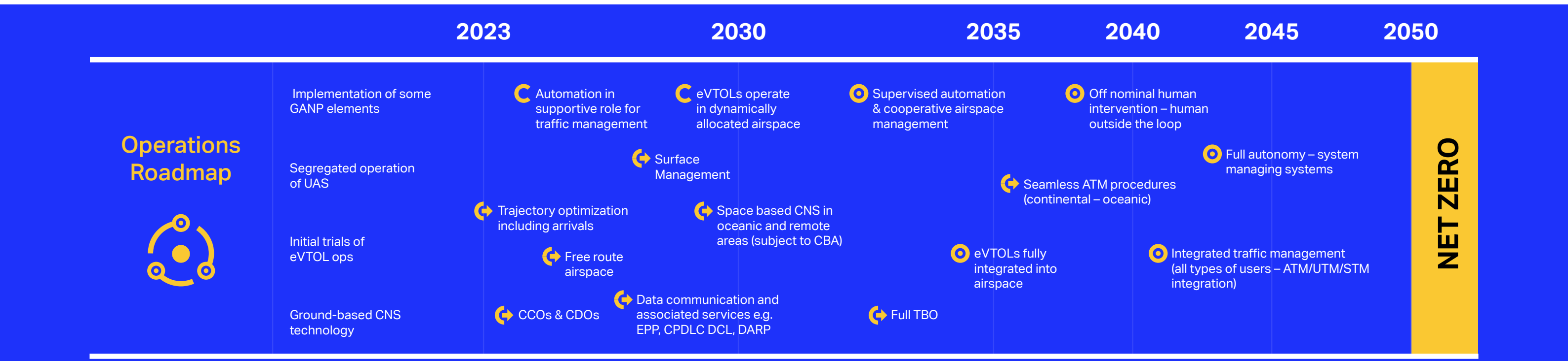
The short- and medium-term elements of the roadmap focus on existing operational concepts that will deliver the desired improvements to achieve safety and environmental targets. As such, most of these milestones are focused on further implementation of already existing procedures and technologies. The near and medium-term milestones are mostly classified as “developing concepts” which are being implemented today at a trial stage, but still need maturation and demonstration at a global scale. Long-term elements focus on the future end states of higher levels of automation on-board and in the ATM system. The need for new systems and technologies that will enable reduced human intervention are identified in the roadmap.

For example, for the last several years, advanced concepts such as Trajectory-Based Operations (TBO) have been put forward to improve efficiency in ATM and safety in the air. However, the achievement of full TBO environment still requires a series of enablers to be available.

It is also vital to note that while the roadmap is global, operational needs and the related improvement will vary across regions. For example, operations in the South Pacific oceanic airspace will differ from the more congested and structured operations in the North Atlantic. Similarly, while both the US and European airspace may seem comparable, the US has a significantly larger proportion of general aviation flying in accordance to instrument flight rules (19% in 2017 compared to 3.5% in Europe). Traffic in Europe is far more seasonal with a high peak in the June-September months, compared with the US where traffic is more equally distributed across the year. The sovereignty of airspace also plays a role, with larger fragmentation observed in e.g. Europe and South America than in North America.

To a certain extent, unifying operational standards and requirements could lead to increased flight efficiency, and hence improvement in the sustainability of aviation. However, there will be situations where specific solutions will not be required in some areas. Local investment must be driven by a local and network cost and benefit assessment, to ensure that ultimately there is a benefit to the end user and that the costs of service provision are managed. They should also take into account impacts on traffic flow and efficiencies beyond Flight Information Region (FIR) boundaries.

Chart 1: Operations Roadmap



Needs further implementation
New system
Developing concept

Acronyms

CCO: Continuous Climb Ops
CDO: Continued Descent Ops
EPP: Extended Projected Profile
CPDLC: Controller Pilot Data Link Communicatio
DARP: Dynamic Airborne Route Procedures
DCL: Departure Clearance
CNS: Communication, Navigation & Surveillance
EVTOL: Electric Vertical Take-Off and Landing
TBO: Trajectory Based Operations

Quick Wins

Implementation of Operational Concepts Under the GANP[1] (2023-2030)

The air transport industry plays a major role in global economic activity and remains one of the fastest growing sectors of the economy. In every region of the world, States depend on the aviation industry to maintain or stimulate economic growth and to assist in the provision of essential services to local communities. In the coming years, it is expected that aviation will see increased use of automation, robotics, Uncrewed Aircraft (UA), and Artificial Intelligence (AI). Air transport operations must evolve, not only to be ready for future operational environments, but also to enable concepts such as Trajectory Based Operations (TBO). However, challenges appear on the horizon, specifically due to uncoordinated investments in systems and infrastructure. Indeed, plans across airports, air navigation services providers (ANSP), and investment cycles are not always aligned and, historically, adoption of new technologies in the flight deck has happened at a much faster pace than adoption in ground systems.

The quick wins, or the short-term elements of the roadmap, are focused on implementation of operational concepts and use of Communications, Navigation, and Surveillance (CNS) technologies that can optimize operations and provide benefits today, without the need for major change in on-board aircraft technology.

Between 2023 and 2030, the industry would like to see progressive implementation of ATM operational concepts that can render environmental quick wins. Trajectory optimization allows aircraft to operate optimum profiles reducing fuel burn and CO_2 emissions. Continuous Descent Operations (CDO) and Continuous Climb Operations (CCO)[2] allow aircraft to follow a flexible, optimum flight profile while simultaneously cutting emissions and reducing noise. Free route airspace will allow air operators to fly their preferred routes without being constrained by fixed airspace structures, direct routings or fixed route networks. Surface management tools can provide more precise departure traffic planning and timely updates. Enhanced surface management will increase aerodrome throughput without compromising wake turbulence separation and other safety protocols, allowing for more optimum aerodrome operations.

SESAR, the technological pillar of the Single European Sky, promises a three-fold increase in capacity and a 10% reduction in CO_2 emissions per flight while reducing the unit cost of ATM services to airspace users by 50%. Several initiatives have been launched under the SESAR banner, yet airlines still face capacity constraints and high costs combined with inefficiency.

Perfect Flights

The aviation industry has often discussed the "perfect flight". However, beyond demonstrations and trials, we see little progress with implementation across different regions. For example, the Asia and South Pacific Initiative to Reduce Emissions (ASPIRE), links 19 transpacific flight routes where new fuel saving concepts are being trialled and refined for every phase of flight, beginning at the airport gate to User Preferred Routes (UPR) trials in Africa, Asia, and Latin America. Several ANSPs started implementing CCO/CDO at certain airports. Sustainability Ocean Tracks are being discussed for the North Atlantic. The main challenge is ensuring that trials result in a much-needed change in the system.

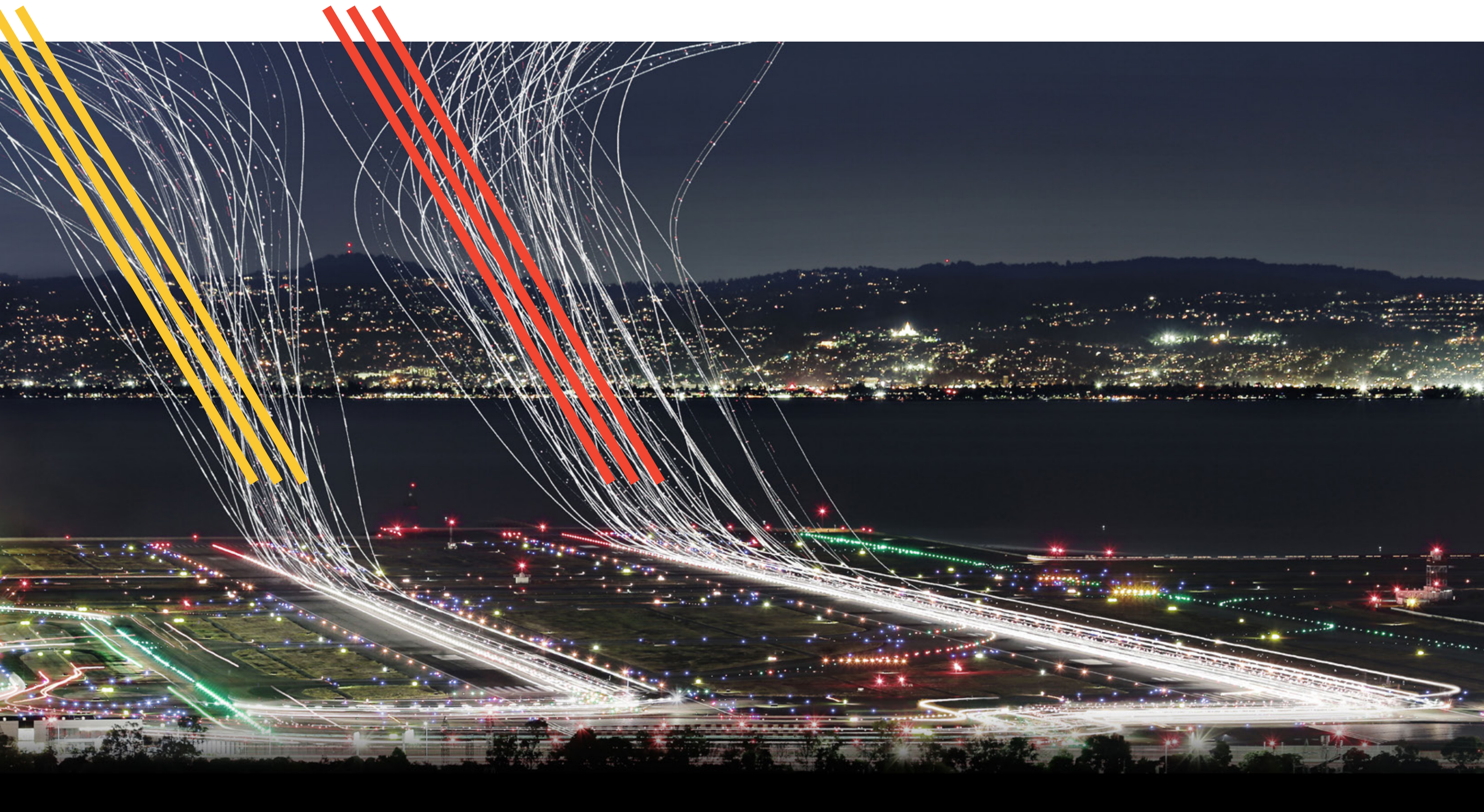
1 Global Air Navigation Plan.
2 CDO or CCO allows aircraft to make their approach or departure to an airport in a continuous manner from or to its cruising altitude. By avoiding levelling off at interim altitudes the aircraft is able to save fuel and reduce its noise footprint in the vicinity of the airfield.

CDOs/CCOs can only be flown when close collaboration between ATC and the pilots is achieved: the pilot knows best what the most optimum descent/climb trajectory is (given the aircraft type, payload, etc.) while the air traffic controller must carefully sequence all arriving/departing traffic. While CDO and CCO are well established procedures, more can be done to ensure a wider uptake. For example, EUROCONTROL data shows that in March 2023 approximately 31% of flights in the ECAC region completed a continuous descent from the top of descent [1]. While there will always be situations in which flying a CDO or CCO will not be appropriate (e.g. due to conflicting traffic), this data point shows that improvements can be made. This can be achieved through better prioritisation of the usage of the procedures and better education of the parties involved.

Trajectory optimisation both en-route and in the arrival phase of a flight can also provide relatively quick wins. Point Merge is a method of sequencing arrival flows without the use of holding stacks. At airports which operate Point Merge, arriving aircraft fly along parallel arcs from which they are cleared towards the runway. The solution was first developed by EUROCONTROL Experimental Centre in 2006 and implemented at Oslo (2011) and Dublin (2012). According to the Irish Aviation Authority, an average flight landing at Dublin airport in 2013 saved 11.3 track miles, 127 kg of fuel, 400 kg of CO_2, and reduced their fuel requirement by 19.1% per flight [2]. While Point Merge is now in operation at 38 airports globally (status April 2023) [3], it remains a potential solution for certain localities and not one that can be applied across the globe.

Several regional ATM programs have been initiated, such as NextGen and SESAR. However, the fundamental principles guiding such regional initiatives are not fully aligned and by extension, nor are the technological solutions. There are several technical incompatibilities between ATM technologies and aircraft equipage and performance requirements. ATM program implementations or modernization must be driven by a validated and agreed-upon operational benefit. Because many ANSPs have not implemented an Air Traffic Control (ATC) service that matches the capabilities of modern aircraft, ICAO developed the Aviation System Block Upgrade (ASBU) program which provides each Member State with information regarding the global approach towards advancing their Air Navigation capacity based on specific operational requirements. ASBUs enable ANSPs, Member States, and international organizations to work together to make the optimum use of new and existing technologies and to achieve operational improvements, moving all stakeholders towards a seamless airspace.

The benefits, impacts, and user perspectives on all ATM operational concepts are available in the IATA User Requirements for Air Traffic Services Vol I (URATS Vol I [6]). The different building blocks and additional explanations related to the ASBUs are accessible on ICAO's Global Air Navigation Plan resources page [7].



Preparation for the future generation of air traffic operations

To introduce significant, network wide operational improvements, a certain level of aircraft and ground equipage is required across the globe. Controller Pilot Data Link Communications (CPDLC) is a tool which allows to send text message communications between the pilots and air traffic control. This can reduce the risk of error and contribute to more efficient trajectories. In the same vein, airlines support a coordinated migration to data link for controller-pilot communication while continuing the provision of voice communications for tactical interventions and non-routine communications. However, data link standards are being implemented under various ATM programs, which are not interoperable. This results in airlines having to carry multiple systems, with increased costs and delayed realization of operational benefits and efficiencies. Addressing these interoperability challenges remains crucial for the achievement of long term operational goals.

Despite ICAO General Assembly resolution A37-11, we see only slow progress in the implementation of vertically guided approaches based on the Performance-Based Navigation (PBN) concept. Today we still have a significant number of non-precision Non-Directional Beacon (NDB) approaches. It is estimated that shorter PBN routes globally could cut CO_2 emissions by 13 million tonnes per year [4].

There have also been recent developments in space-based technology, e.g. space based ADS-B, which may provide efficiency benefits in certain locations, subject to a cost – benefit analysis.

For any current or future Communications, Navigation and Surveillance (CNS) technology, an operational improvement must be identified, and then an appropriate technology is chosen in consultation with the airlines, based on a positive cost-benefit analysis. Introduction of future CNS technologies should lead to rationalization in the system, to avoid unnecessary duplication of technologies.

When preparing for the future, efforts must also be made to improve airspace structures. The first priority is of course to address local hotspots. Going further, ANSPs and States must prioritize reducing fragmentation by implementing cross-border Free Route Airspace (FRA). This would allow airline operators to choose the most direct route, without being constrained by a pre-defined network of routes/airways. For example, NATS, the UK ANSP, implemented FRA in December 2021 and has estimated that this airspace change created a saving of up to 12,000 tonnes of CO_2 per year [12]. Simultaneously, flight planning software providers must work closely with ANSPs and aircraft operators to ensure that the best use of the available airspace is made.

Industry positions on various Communications, Navigation, and Surveillance (CNS) technologies are available in the IATA User Requirements for Air Traffic Services Vol II [5].

Future of air traffic operations

The COVID-19 pandemic may have fast-tracked certain future operational concepts. New consumer trends and behaviors are motivating new models for e-commerce from customer needs to get their purchases faster, to last mile delivery, micro-mobility, and new suppliers. At the same time, there is a growing demand for remote inspection and surveillance of critical infrastructure. With remote technology and remote working, there is an emphasized need for different services that are expected by the flying public.

Technologies such as big data, artificial intelligence, robotics, and the internet of things are slowly making their way in aviation to improve their efficacy and system optimization. At the same time, commercial aircraft today can provide enormous amounts of data. Access to timely, consistent, secure, and accurate information can enhance decision making across the aviation supply chain.

With the anticipated increase in the number and diversity of airspace users, we must ensure that the system is prepared to support the needed evolution. While technological solutions may be revolutionary, changes in the ATM system will be evolutionary due to the safety requirements and expectations of the flying public.

Future traffic management will require fewer human tactical interventions and will allow for the free flow of information between trusted operators, which will include new types of service providers and operators. By 2045, higher levels of automation and autonomy (uncrewed aircraft) in airspace management are expected. The evolution to the end state will include a progressive change from a human centric air traffic management system to an air traffic management system comprised of systems with a change in the role of the human.

Therefore, between the years of 2030 and 2045, there will be a change from human in the loop to human on the loop, whereby management will be by exception. Full autonomy is achieved when a state of human off the loop is reached.

The difference in automation levels is determined by the role of the human in authority over the execution of the function as well as how the human is engaged in the event of abnormal operation.

In the longer term, in addition to changes related to unmanned aviation, the number of commercial space operations above flight level 600 is expected to grow. Upper airspace operations will involve aircraft which have varying performance levels, from balloons with few manoeuvring capabilities to supersonic and commercial space aircraft that will cross the airspace much faster. There is a need to define global standards around the safety performance requirements for space vehicles and onboard equipage, to negate the necessity of closures of large portions of airspace while maintaining the required safety levels. While segregation of airspace users may work in the near term, it will have a negative impact on existing airspace users when operations are at scale. Therefore, all future airspace concepts are focused on integration of new aircraft technologies into airspace. The future traffic management system will be an integrated system of traditional Air Traffic Management (ATM), Uncrewed Traffic Management (UTM), and Space Traffic Management (STM).

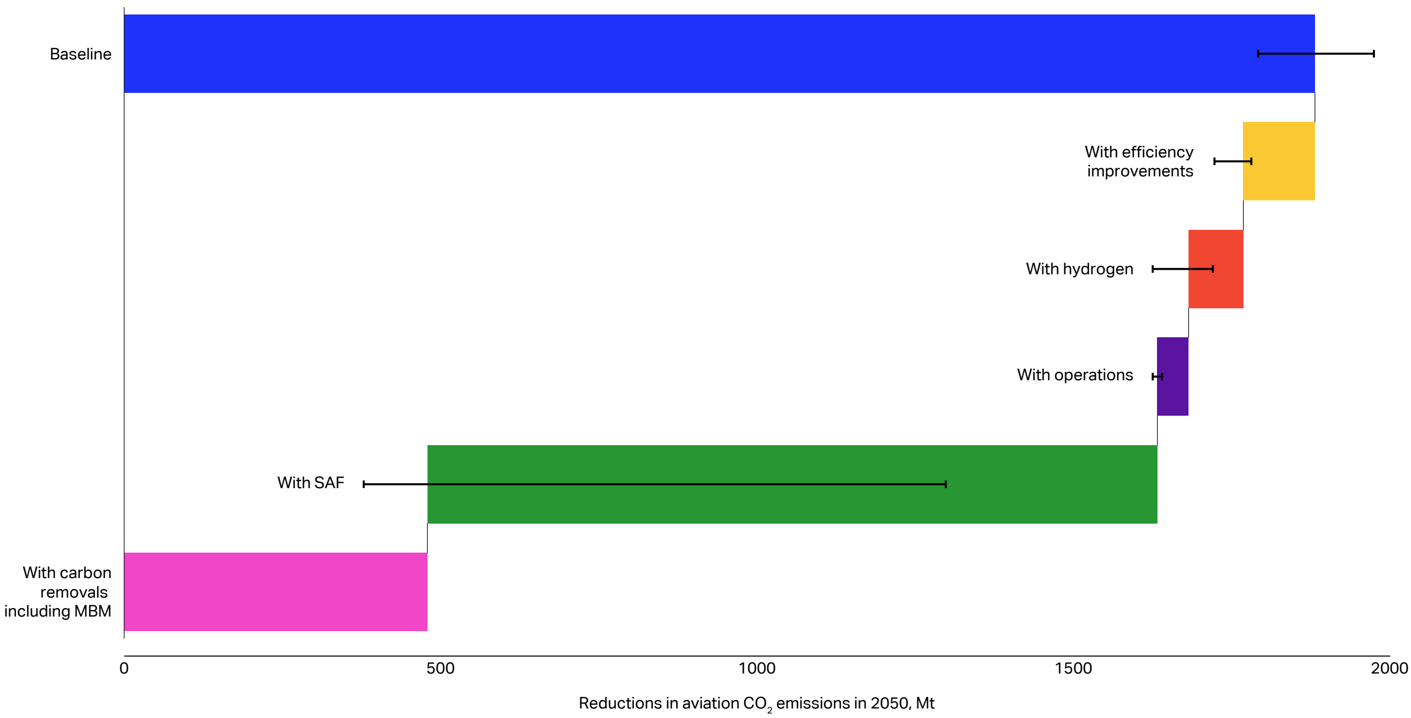
The Automation Working Group under the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) has been working on the concept of autonomy in airspace. Additionally, IATA has developed a High-Level Concept on New Operating Environment and impacts on flight rules [8].

The Complete Air Traffic System (CATS) Global Council, has launched a vision for a global airspace that is safe, fair, intelligent, and interoperable, leveraging revolutionized design, technology, and services to power global mobility and prosperity [9]. This forum includes different industry participants who are contributing to the development of the roadmap for the future airspace [10].

Different industry efforts, whether by IATA, JARUS or CANSO will feed into the different channels of ICAO to shape future standards and review provisions as needed. In 2023, ICAO will commence a revision of the GANP to incorporate new entrants and ensure that we can prepare for the future from now.

The Air Transport Action Group (ATAG) in *Waypoint 2050* identified three scenarios to illustrate potential pathways for operational efficiencies that result in 0%, 3%, and 6% reductions in emissions respectively by 2050 [13]. The operational improvements mentioned in this roadmap could be important enablers of those reductions. For example, a 3% improvement in operational efficiency by 2050 would translate into a reduction in emissions of close to 50 Mt by that year, with an in-flight energy saving of 0.5-1 EJ (see chart 2, below).

Chart 2: Reduction in aviation CO_2 emissions in 2050 achieved through the different levers of action. The solid bar indicates the central case and the black lines indicate maximum and minimum reductions based on the scenarios modeled.



Sources: IATA Sustainability and Economics, ICAO LTAG SAF availability scenarios

Conclusion

Decisions related to improvements and investments are often taken at the state level and are sometimes driven by non-aviation factors. In some cases, there is truncated awareness and support of Air Traffic Management requirements at the government level due to it being seen as an obscure and complex component of national infrastructure. Without alignment of the investments plans of airlines, airports, and ANSPs, operational benefits will remain elusive, and any new ATM program will not deliver its promised objectives.

As airspace becomes more of a scarce resource, states need to take a balanced and globally coordinated approach to airspace management in a way that harmonizes and meets the need of evolving airspace users. This will require integration of new entrants and a more effective relationship between civil and military authorities to allow for equitable access and ensure that airspace capacity meets current and future demands. However, the management of air traffic focusing on FIR or state boundaries rather than across a traffic flow does not achieve the full extent of efficiencies.

The ASBUs were designed to be a pragmatic framework that develops a set of air traffic management solutions or upgrades, takes advantage of current equipage, establishes a transition plan, and enables global interoperability. Yet there is still divergence with the implementation of air traffic management solutions and lack of interoperability across different regions.

The operational system is not, of course, just about technology. It is also an organizational network. Airspace users, airports, ANSPs, Civil Aviation Authorities (CAA), and other regulators and policymakers, and the industry's technology providers all have a stake in the future of air traffic management. The critical path to achieving the future end state also requires a regulatory framework and a skilled workforce to support the future system. Standard developing cycles need to be shorted and aligned with innovation cycles. To prepare the skilled workforce, up-skilling and re-skilling programs will be needed. More details on the policy enablers to the implementation of this roadmap can be found on the IATA Policy Roadmap.

Several approaches can be used to accelerate the implementation of the different elements included in the roadmap:

- Use of local and regional projects as proof of concept for the development of global standards and highlighting benefits and costs.
- Environment and performance benchmarking to measure progress and showcase best practices for implementation.
- Regional and local consortia for implementation which ensure that the needs of airspace users are considered in the planning and implementation phase.

The milestones identified in the Energy Infrastructure and Aircraft Technology Roadmaps will provide important (double digit) reductions in CO_2 by 2050, but will take time to be implemented and will be relatively costly, representing most of the investment needed to reach net zero carbon by 2050. The operational improvements, in contrast, provide modest reductions individually, but can be deployed much sooner and fleet-wide if the investments and policies happen now. Considering the Waypoint mid-operational scenario as a basis (O_2), a near 50 million tonnes of CO_2 could potentially be avoided by 2050 should all these levers be pulled. Today, the aviation system still has considerable inefficiencies which are resulting in unnecessary fuel burn and emissions, and which could be reduced in the very near term.

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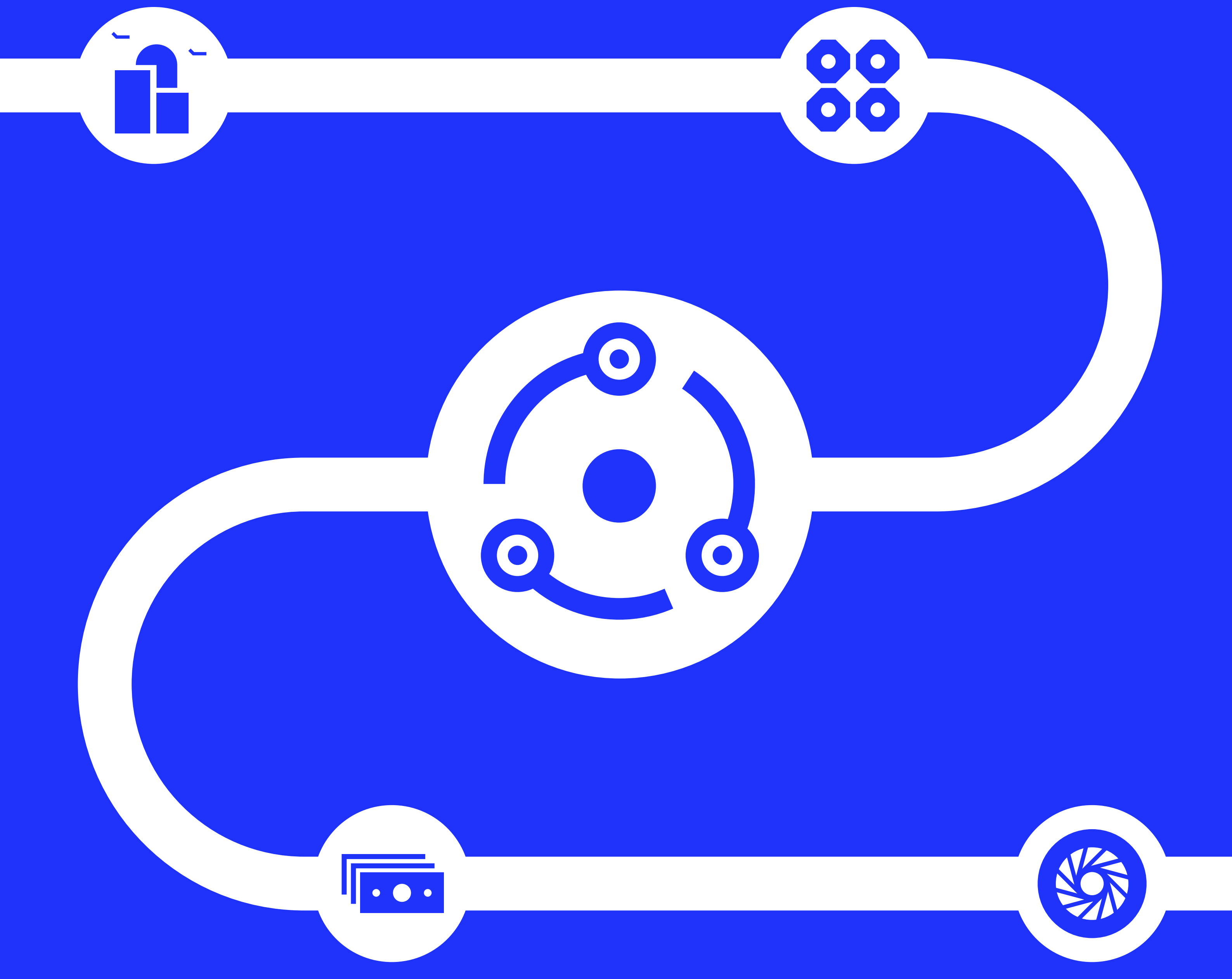

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