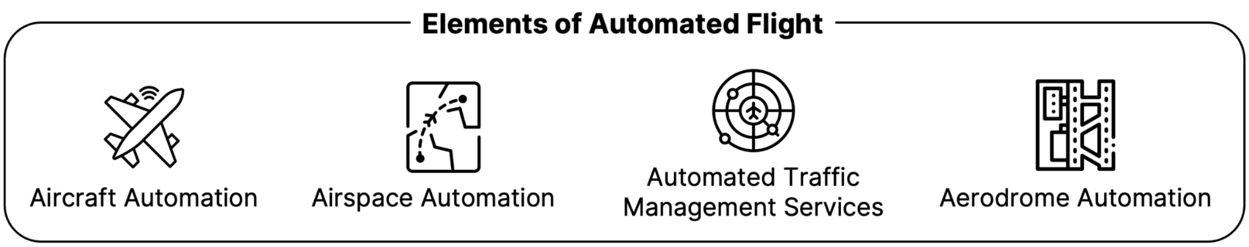
Concept of Operations for Automated Flight Rules

Abstract

This document proposes a new Concept of Operations for Automated Flight Rules (AFR) for both crewed and uncrewed aircraft operations. As the aviation industry continually evolves in the context of an increasingly digital and data enabled world, it is critical to outline an overall vision for the future of aircraft operations. This vision must ensure safety, public acceptance and be inclusive of all airspace users, current or emerging.

The following Concept of Operations (ConOps) document addresses that vision in the context of flight rules; the internationally agreed procedures and operating conditions that govern the conduct of a flight. At the highest level, these are captured in International Civil Aviation Organization's (ICAO) Annex 2 and enacted through the aviation authorities in the member States. Flight Rules serve to manage aircraft proximity and traffic conflict, as well as to ensure the expeditious flow of traffic and efficient use of airspace.

The evolution of flight rules is not unprecedented, as it has previously happened with Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). As the industry further matures, the adoption and integration of innovative aviation products and services indicates the need for the development of a new ruleset, a third operating paradigm, that leverages aircraft and airspace automation at its core — **Automated Flight Rules (AFR)**. While not intended to impose new requirements on visual and instrument flight operations, the new mode offers a third operating paradigm. This paradigm equally leverages deployed and emerging technologies, as well as capabilities from existing aviation stakeholders of today and those of newer highly automated aircraft and traffic management solutions that unlock efficiency, cost, and safety benefits to the entire community.



Key Elements of Automated Flight

AFR will promote system automation, including digitized communication and information exchange, across the entire industry: airspace, aircraft, and aerodromes. Airspace and air traffic management elements seek foundation in alternative air traffic management strategies and solutions, including new separation standards that leverage aircraft performance, novel procedures, airspace design, and modern information networks. Aircraft automation that supports autonomy will leverage flight and mission management systems with integrated detect-and-avoid (DAA) systems, information sharing, and aeronautical decision-making capabilities. Aerodrome automation will provide decision support tools for towered aerodromes and integrated automation features for non-towered aerodromes in support of slot management, terminal spacing and sequencing, as well as surface resource metering.

Ecosystem development and proper integration of system automation in the operating environments of today will enable all varieties of AFR operations - from free flight concepts to high-density operations in dedicated airspace environments. While each domain is served, depending on system architecture, AFR operations will utilize uniquely catered automated services that deliver the enabling capabilities amongst the stakeholders.

There remains ongoing debate on the meaning of automation, autonomy, and autonomous. It is not the intent of this document to enter that debate or to pick a global definition. For the sake of clarity and to remain consistent with terminology accepted by regulatory authorities, in this document, we adopt the context that autonomy is achieved through automation.[1] The complexity of the task (function) being performed or the nature of the environment it is performed in (e.g., complex, dynamic) has no relevancy in determining the level of autonomy. Instead, distinction is based on the nature of the interaction taking place between the human and machine in performing the function.

AFR will benefit the broad aviation community in many ways, where examples range from: unlocking underutilized airspace, increasing airspace and aerodrome capacity, enable and support innovative aviation products and services, support long range mission to utilize flight paths that better address sustainability or business objectives in lieu of Air Traffic Service Provider (ATSP)-preferred routes, and provide access to ATSP-like services in environments that previously lack them. Additionally, AFR will ensure that innovative aviation products and services would avoid any unnecessary compliance, equipage, or procedural burden of compatibility with today's operations that would detract from, or diminish, its benefits.

AFR will play a critical role in the emergence and enabling of innovative aviation products and services, overcoming the constraints of airspace and aerodromes that are approaching fundamental limits based on human capability, and addressing the evolving needs of aerospace and airspace systems worldwide. Crucially, AFR is inclusive of existing users and operations, enables innovative aviation products and services, and doesn't compromise safety and public acceptance.

Why Now?

Over the years, many concepts have been presented by the FAA, NASA, RTCA, ASTM, GAMA, SESAR, CASA, and other jurisdictions that speak to new flight rules: their definition, needs, and benefits. As the FAA and other international regulators have begun exploring new flight rules, industry and other stakeholders must proactively contribute to this exploration to ensure that their expectations can be included within this concept.

As governments around the world continue to stand up research studies, testing opportunities, and other influential efforts[2] to achieve the new flight rules paradigm, Boeing is in a unique position to provide a holistic worldwide appraisal. This ConOps will serve as the foundation for exploration and testing of architecture, simulation, standards, and regulatory work.

[1] With reference to Boeing's work on Modes of Autonomy.
[2] An example of such effort is the FAA Reauthorization Bill that solidified the necessary initial steps toward understanding the requirements and scope of work that will unlock new flight rules in the US.

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1 Introduction

The aviation industry faces a critical challenge in its pace of evolution in contrast to other transportation sectors, such as automotive and rail, which have embraced significant technological advancements to redefine operational paradigms. On the other hand, aviation has experienced a comparatively stagnant developmental trajectory over recent decades. Despite the introduction of highly sophisticated aircraft, the efficiencies and capabilities these modern platforms can offer are constrained by the flight rules originally conceived using technologies and for flight operations introduced many decades ago. The challenge is to support and enable all existing users and operations along with the new, innovative, and emerging technologies and operations, all while maintaining and enhancing the levels of safety and public trust.

Aircraft today are managed within volumes of airspace that envelop their missions to ensure safety and efficiency without being overly burdensome. In some airspace classes, where the number of passengers per aircraft or the complexity[3] is high, aircraft participation is compulsory and is managed by a singular overseeing Air Traffic Service Provider (ATSP) authority. In other general controlled airspace, the ATSP's responsibility is mission specific: they may manage traffic directly, provide traffic advisory service, or may have no specific role. In uncontrolled airspace, where complexity is low, flights are generally self-managed, though ATC may still provide advisory services. Flight rules apportion traffic management roles and responsibilities between aircraft self-management and ATSPs dependent on mission needs (e.g., airspace complexity, speeds, meteorologic conditions). As such, regulatory policies ensure that current airspace users are served by an intersection of flight rules and airspace classes in the context of rules of the air to receive appropriate services that meet their mission purpose.

The case for a new operating mode is motivated by a technology push – specifically, the potential to improve the efficiency of existing aircraft operations using digital data exchanges, and new aircraft and ground automation technologies that leverage high-quality surveillance and other data. Concurrently, a new operating mode is also motivated by a technology pull – namely, the need to address the evolving demands of existing and novel operations (e.g., dynamic sustainability driven routing, noise abatement, reduced separation, and uncrewed aircraft operations) which aim to leverage new traffic management technologies for their intended scale without overloading the current air traffic control system. These push and pull objectives can be simultaneously realized via Automated Flight Rules (AFR) integrated with and complementary to operations exercised under legacy VFR and IFR.

The concept for AFR implies the introduction of digital information exchanges and availability of novel automation technologies for managing and controlling aircraft, airspace, and aerodrome systems. A high level of digitization and automation across the operating environment will promote new operations that emulate the structure and accessibility of IFR operations while maintaining the flexibility of VFR in both constrained and unconstrained airspace.

AFR is intended to support, or be complimentary to, all existing airspace users, as well as enabling new, innovative, and emerging technologies and operations which include a variety of use cases: Long-Haul Flight Operations (i.e., Oceanic and Transcontinental), Urban Air Mobility (UAM), Regional Air Mobility (RAM), Uncrewed Air Systems (UAS), General Aviation (GA), etc.

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[3] Airspace complexity is determined by air traffic controller and crew task loads and response times, which is a function of the number of proximity pairs and clusters. Density is one consideration of airspace complexity, but high density in conjunction with conformity and flow structure may not be sufficient to be considered complex.

As the concept evolves over time, AFR application will vary between these users and the airspace designations in support of their missions.

1.1 Purpose

This document aims to solidify a comprehensive vision for a future aerospace environment that supports and includes not only existing aerospace users and participants, but emerging integrated automated flight operations that leverage high levels of automation for managing aircraft, airspace, and aerodrome systems. It addresses the function of these operations and is not intended to fully define an implementation path.

Many have acknowledged that AFR will bring many benefits to the aviation industry; one of the themes is the flexibility of VFR and accessibility of IFR. This ConOps focuses on how to achieve those benefits and bring them to life as part of a holistic and integrated approach for users and system stakeholders.

1.2 Scope

This document establishes a high-level common framework for new flight rules that could be applied and implemented with minimal regional variations. Automated flight allows the industry to introduce and leverage novel systems and system automation that increases efficiency, access, and flexibility in the environment while minimizing the impact on the existing systems and stakeholders. All aircraft and associated enabling elements could leverage the operational implementation of automated flight and integrate it into the operational environments.

While this document acknowledges that there will need to be considerable effort by the stakeholders identified hereinafter (i.e., ATSPs, aerodromes, regulators, etc.) to work together, it is not within the scope to identify or impose the detailed requirements for participation and accommodation of AFR for those stakeholders.

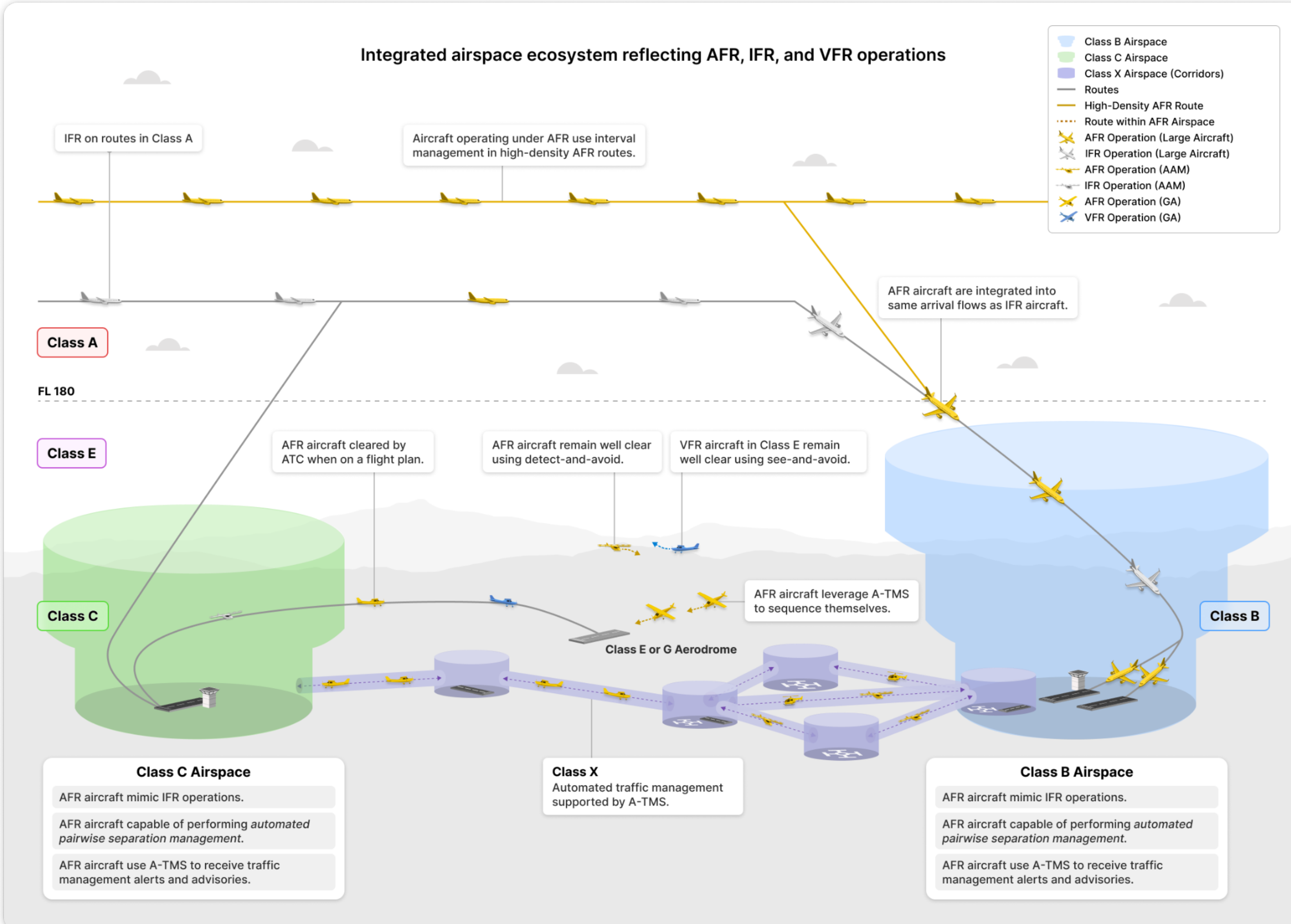
2 Concept

This section outlines the core concept of AFR, detailing the enabling technologies and capabilities that underpin this new operational paradigm. It explores how AFR leverages advancements in automation across airspace, aircraft, and aerodrome systems to enhance safety, efficiency, and scalability in aviation. From fundamental enablers like Performance Based Navigation and Surveillance (PBN and PBS respectively) to novel Automated Traffic Management Services (A-TMS) and advanced aircraft automation, this section provides a comprehensive overview of the technological framework that makes AFR possible.

At the highest level, AFR can be described as a set of flight rules specifically designed to support highly automated operations, which rely on digital information exchanges and greater levels of aircraft automation, automation of conflict management, ground automation, aircraft-aircraft connectivity, and aircraft-ground connectivity.

Shown below is an operational view of the AFR concept, which illustrates the integration of AFR aircraft across all airspace classes, their operation within Class X[4], and the use of A-TMS for supporting traffic management.

[4] Class X airspace is a newly proposed airspace class within which aircraft will operate under AFR.



Integrated airspace ecosystem reflecting AFR, IFR, and VFR operations

2.1 Enablers of Automated Flight

AFR leverages enabling technologies, such as ubiquitous communication, surveillance capabilities, highly repeatable navigation, and advances in system automation, where some can be allotted as required or supplemental. These technologies and systems may be apportioned to either on the aircraft, on the ground, or a combination of both.

The following enablers are required for **all AFR operations**:

- **Performance-Based Navigation (PBN)**: navigation capability with sufficient precision and availability to ensure mission success depending on the definition of navigation specification and leg types used for the flight profile.
- **Performance-Based Surveillance (PBS) or Electronic Conspicuity**: reliable cooperative and non-cooperative traffic surveillance means capable of collecting and integrating extended surveillance information from a variety of sensors and other sources to provide necessary situational awareness about the operations.
- **Short-term Intent Sharing:** strategic and tactical services benefit from understanding when an extrapolation of past and present position is not reflective of near-term intent (e.g., leveling, entering a traffic pattern, or changing altitude or speed).
- **Detect and Avoid (DAA)**: capability to detect and avoid in-flight hazards that enable an aircraft to satisfy the requirement of remaining well clear (RWC) and provides collision detection with generation and execution of collision avoidance (CA) maneuvers.
- **Conformance Monitoring:** assurance of conformance with the short-term intent that reduces uncertainty around discrepancy between aircraft intent and short-term intent.

The following enablers are required for **AFR operations at higher complexities**:

- **Performance-Based Separation**: separation criteria that are codified based on aircraft performance accounting for aircraft systems and their capabilities, as well as specific combinations of PBN specifications that yield appropriate separation minima.
- **Trajectory Intent Sharing:** submission of operational intent that can be processed into trajectory-based flight plans with dynamic updates (enabling flow management and efficient airspace/resource use through sequencing and setting spacing targets).
- **Aerodrome[5] Automation:** aerodrome automation will support the aerodrome demand and capacity balancing, facilitate strategic flow management through the management of takeoff and landing slots, allocate real-time landing zone availability, provide guidance for take-off and landing, and initiate terminal spacing and sequencing.
- **Integrated Operating Picture:** situational awareness will support optimized flight planning and execution (including advanced Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Infrastructure to Infrastructure (I2I) capabilities) accounting for weather, CNS performance, traffic congestion and surveillance, airspace and aeronautical information, obstacle and terrain constraints, etc.
- **Advanced Communication and Navigation capabilities:**
    - **Communications** - reliable V2V (data and voice relay), V2I, and I2I communications (including reliable and deterministic ground-to-air C2 capabilities and internet protocols[6]).

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[5] The term "aerodrome," as referred under this ConOps, is inclusive of airports, heliports, helipads, and any kind of vertiport infrastructure.

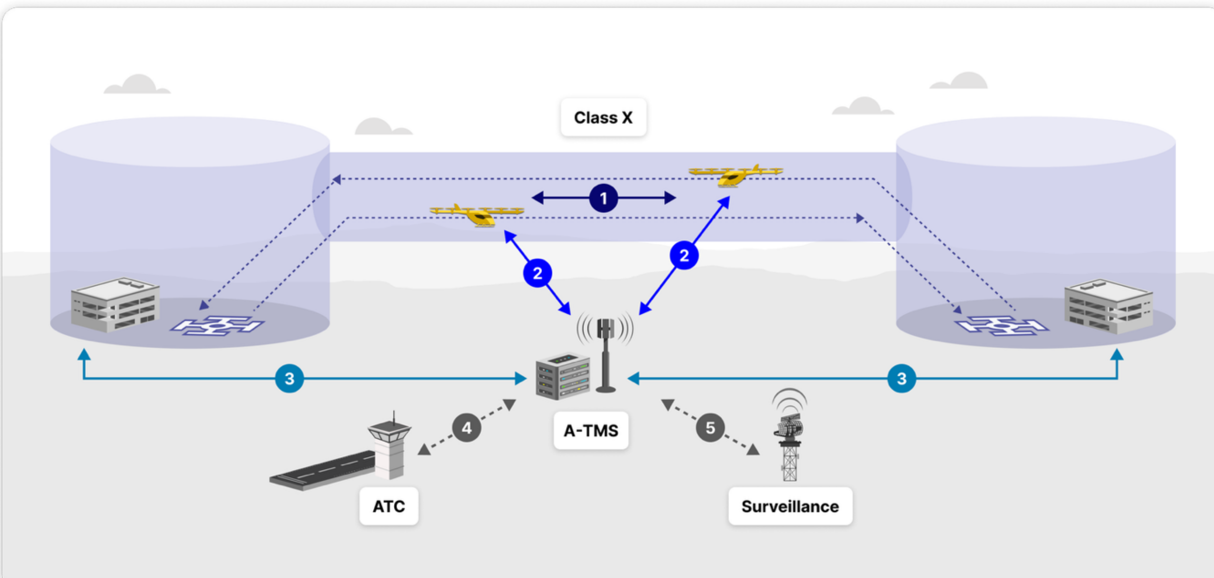
[6] Internet Protocol-based communications will enable constant flight conformance monitoring of aircraft as well as automated communications transfer as the aircraft cross sector boundaries.

- **Navigation** - reliable navigation capabilities beyond currently certified navigation means enabling automatic takeoff and landing.

2.2 Capabilities of Automated Flight

AFR adopts automation at the core of the concept. Automation of systems across aircraft, operator, ATSP, and aerodrome domains enable both AFR participation and the concept ecosystem. Each of these stakeholders will utilize their respective dedicated automation pieces that include:

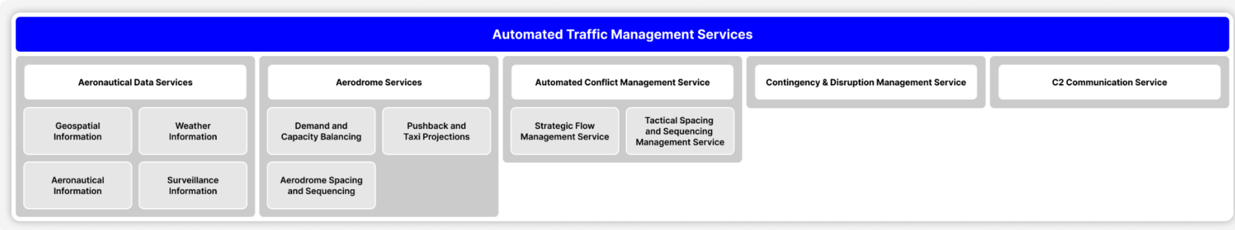
- **Automated Traffic Management Services (A-TMS) modules:**
    - **Airspace Services**: advanced traffic awareness and codified ATM principles and strategies, providing flow management and in-flight tactical services.
    - **Aerodrome Services**: replicates ground and airspace traffic management functions for dedicated aerodromes.
    - **Flight Data Exchange (FDX):** establishes an interface between ATSP and A-TMS for data sharing and governing the logic and criteria for traffic flow management (e.g., DCB for airspace and aerodromes, tactical spacing logic, traffic acceptance rate, etc.).
- **Aircraft Mission Management System (MMS)**: extends aircraft's traditional FMS capabilities to plan, evaluate, and execute end-to-end trajectories, optimize mission profile, avoid hazards (e.g., terrain, inoperable weather, DAA, or traffic advisories), etc.



Automation distribution in UAM AFR Operations with (1) integrated MMS-enabled aircraft, (2) A-TMS airspace services, (3) A-TMS aerodrome services, and (4) A-TMS FDX connection.

2.2.1 Automated Traffic Management Services

A-TMS is a framework of services and infrastructure supporting the integration of AFR operations in various environments across airspace systems. The services and framework can be offered through legacy ATSP, novel Third-Party Service Providers, or as a combination of both. A-TMS can extend human-centric ATSP functions through the automated principles and strategies and offer strategic and tactical services for intent management, strategic planning and conflict management, as well as provide tactical spacing and sequencing service in advisory and responsible roles depending on the airspace. A-TMS will be centered around operational information necessary to enable operations under AFR, which includes basic intent conformance monitoring as a standard service.



A-TMS modules enabled through a service-oriented architecture

Operators may use A-TMS for key airspace integration and coordination functions that safely enable AFR. The services will aid operators to 1) be integrated into the airspace and traffic flow, 2) apply proper spacing between AFR participants, and 3) be able to utilize digital means to maintain appropriate spacing from other IFR and VFR traffic, as applicable.

As part of the A-TMS integration with legacy ATSP systems, **Flight Data Exchange (FDX)** will offer effective management and integration of higher-complexity AFR operations from the ATSP perspective, enabling them to:

- Set and send airspace constraints for AFR operations;
- Update strategic and tactical flow management logic for AFR where necessary;
- Adjust Class X capacities;
- Distribute airspace restrictions that may affect Class X[7].
- Receive or retain AFR intent and interact with live tracks of AFR aircraft, including access to historical data if needed.

The following is a list of common attributes that may be applied to A-TMS:

- **Universal Applicability**
  - Services will be available to all operators.
  - All AFR operations will have access to A-TMS under a set of standard services, with additional services available to the operators if they choose to enroll.
- **Operational Data and Information**
  - Maintain multiple layers of relevant information and validated, high-integrity data that support safe operations aggregated from a variety of sources, including ATSP, weather SDSPs, etc.
  - Databases include:
    - Aeronautical Information: Instrument Flight Procedures (IFPs), airspace structures and codified routes, aerodromes, NOTAMs, temporary flight restrictions etc.
    - Geospatial Information: obstacles, terrain, etc.
    - Weather information: large real-time weather surveillance systems, forecasting services, and micro-weather systems.
  - Maintain cooperative traffic surveillance information (e.g., ID, position, intent).

[7] ATSPs can reduce or increase codified separation standards between the aircraft as well as the codified capacity of corridors, over time as data collected on the performance of the ecosystem is proven.

    - Maintain non-cooperative traffic surveillance information that validates cooperative surveillance information and identities non-cooperative targets[8].
- **Conflict Management**
    - Flow Management maintains the acceptance rate for airspace based on known conditions (e.g., weather, traffic demand, and ATSP service availability, etc.).
    - Interconnection with aerodrome slot reservations will aid in strategic planning and Demand and Capacity Balancing (DCB) (e.g., gate-to-gate planning, arrival and departure slots, gate slots, and taxi paths).
    - Airspace DCB and Synchronization:
        - Airspace DCB: A-TMS will alert operators if their initial operational intent submission is not valid from a capacity perspective.
        - Pre-Departure Traffic Synchronization: ensures that the intent of the aircraft is free of strategic conflict[9] immediately prior to takeoff.
    - Tactical spacing and sequencing services are provided in supporting capacity outside of Class X or in a responsible capacity within Class X[10].
        - Right-of-way logic will be used during overtaking, network intrusion, and crossing aircraft scenarios.
        - A-TMS will predict and detect conflicts and offer the necessary measures for AFR aircraft deconfliction.
        - Delay absorption and speed adjustments offer airspace awareness and sequencing & spacing capabilities necessary for traffic flow conditioning.
        - In-flight re-routes and closed loop heading/altitude changes provide re-route options to the operators.
        - A-TMS may be used to keep track of Law Enforcement and Medical Evacuation aircraft to deconflict AFR operators.
- **Contingency and Disruption Management[11]**:
    - Incurred due:
        - Non-conformity in the execution of an operational intent (e.g., unacceptable deviations).
        - Change or disruption in the aircraft's required interaction with the operator (e.g., loss of C2 link).
        - Change or disruption in the availability of aerodrome services.
        - Change or disruption in the availability of A-TMS.
    - Implemented in either a supporting role to the operators' and ATSPs' decision-making or in a responsible role for determining an appropriate contingency response in Class X.
    - A-TMS may be used to coordinate amendments to in-progress operations or propose adjustments to those that remain in the strategic timeframe.

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[8] Due to the national security sensitivity around access to air traffic surveillance (based in national security), it is expected that A-TMS will be able to leverage filtered feeds from government-owned and third-party surveillance systems.

[9] RTA tolerances may overlap to prevent over constraining and give flexibility for in-flight adjustments.

[10] Automated conflict management services will be required for participation within Class X and can be used in the supporting role in other classes of airspace. In high-complexity Class X, A-TMS will be responsible for providing safety-critical tactical services, similar to ATSP services provided today. In less demanding environments, A-TMS services may reduce in responsibility and criticality, allowing operators to apply less stringent decision-making and spacing criteria.

[11] Abnormalities occurring during normal operations imply the existence of a contingency. Any disruption management intervention will imply the modification of at least one flight plan, and it is likely that multiple flight plans may be affected.

    - Requires a previously secured[12] plan, including coordination with ATSP.
- **Modular Architecture:** should be easily connected and upgradable via a modular approach.
- **Agnostic to Architecture Type**: could be centralized, federated, fully decentralized or a variation of each.
- **Datalink**: A-TMS can offer brokered C2 datalink services[13] to AFR operators.

2.2.2 Aerodrome Management

Aerodrome Management for AFR lies within two domains - ground and air - and will be part of the A-TMS framework under the modular nature. A-TMS automation may enhance traffic management in the airspace and on the surface of enabled aerodromes through the use of proper infrastructure. The airspace management component can be used for traffic monitoring in the vicinity[14] of the aerodrome and for automated spacing and sequencing of traffic, as necessary. Surface management could address surface movement instructions and delivery, slot allocations for arrivals, departures, and gate management, as well as management of vehicle towing, as applicable.

NOTE: The level of system responsibility may vary from assistive to responsible based on the operational needs, airspace, infrastructure availability and deployment, and the level of automation desired at the aerodrome.

A-TMS aerodrome airspace management component may be represented as an automated system that replicates some spacing and sequencing functions of ATSP Tower Local Control. Aerodromes that do not have sufficient (if any) surveillance and do not provision ATSP services may benefit from being a part of A-TMS network to provision services and infrastructure. Aerodromes that already have sufficient surveillance infrastructure may benefit from integrating A-TMS to enable higher-density operations as well as integrate more decision-making and decision-support tools in their suite.

The airspace management component would include handling of contingency scenarios like go-around, missed approach, and aerodrome closures, response to changes in resource availability, and other relevant scenarios that affect a continuous safe flight and landing.

A-TMS aerodrome surface management component augments coordination of aerodrome surface movements, efficiently matching these with scheduled arrival and departure times. Operators may use A-TMS aerodrome services to coordinate slot reservation requests as necessary and available. When the operator adjusts their operational intent due to an airspace constraint, A-TMS will be able to appropriately coordinate that adjustment with Aerodrome Management.

A-TMS aerodrome surface management functions include guidance and control of surface movements of aircraft, managing the corresponding surface movement instructions, support to DCB, strategic flow management, support of contingency management (e.g., absorption of emergency landings, forcing missed approaches because of runway/FATO occupancy), etc. A-

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[12] Some parameters in that plan may not be predicted until the specific situation has occurred (i.e., specific take-off and landing zone selection, emergency landing maneuver, etc.).
[13] C2 may be provided and maintained separately of A-TMS through external C2 providers and maintained by the operators themselves.
[14] A-TMS aerodrome services are more localized than a standard Terminal Area, applicable only to the area of responsibility similar to an ATSP Tower Local Controller area of responsibility.

TMS can be complimentary to already existing ATSP systems but is also capable of fully automating certain legacy ATSP services, as outlined below.

- **Surface and Airspace Guidance:**
    - Surface control via taxi trajectories between the parking stand and runway.
    - Untowered aerodromes can be served by A-TMS with zoning criteria protecting aerodrome surfaces and the airspace surrounding that aerodrome.

      NOTE: For closely spaced or coupled aerodromes with conflicting procedures, A-TMS could maximize efficiency for the surface and airspace resources.

- **Operational Awareness[15]:** Broad awareness of the terminal airspace to understand traffic flow in support of the surface management process.
- **Traffic Spacing and Sequencing:**
    - Assurance of the appropriate spacing between the aircraft on arrival and approach, as well as appropriate departure spacing for the traffic flow.
    - Application of traffic sequencing into the aerodromes using existing techniques for arbitration of traffic flow management.
- **Strategic Slot Assignment Management**:
    - Slot assignment[16] will be similar to current runway slot negotiation, which allows for DCB well ahead of time prior to actual traffic synchronization on the surface.
    - Slot allocation is not necessary for all AFR operations but will likely be required at high-demand aerodromes in support of spacing and sequencing for aerodrome arrival coordination.
- **Tactical Slot Management:**
    - Provide movement area safety assurance during taxi-in and landing phases using surface movement authorizations via automated messages.
    - Adjust slots for takeoff/landing times starting at the pushback phase, with the aim to intelligently integrate aircraft into the terminal and overhead flow of traffic.
- **Level of Automation:** Gradual shift from human-centric to over the loop decision support with functions increasingly allocated to A-TMS, as it proves effectiveness.

2.2.3 ATSP Capabilities Supporting Automated Flight

As A-TMS provides a backbone for AFR-supporting automation of airspace, air traffic management principles and technology are expected to continue evolving as well, providing a platform for integration. A few fundamental airspace and air traffic management (ATM) principles and assumptions are listed below:

- **ATM Automation**:
    - Continuous ATM automation to allow scalability and diversity of operations.
    - Shift in ATM paradigm to enable human-over-the-loop solutions (e.g., airspace automation and A-TMS).
    - Selective management of AFR operations by legacy ATSP depending on the operating environment.
- **Performance Based Separation Criteria**: Separation standards guided by the aircraft's performance-based capabilities and intent sharing with defined RWC boundaries.

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[15] Operational awareness is not solely AFR-centric but also extends to IFR and VFR operations that are planned or active in the airspace via surveillance means.

[16] Slot assignment establishes slot times or temporal slot windows that become associated with trajectory's final initial takeoff window and final at-fix times (IATA Slot Guidelines).

- **Architecture Agnostic**: centralized, federated, decentralized service architectures could all be applicable.

  NOTE: Digital information sharing is a critical enabler for AFR, focusing on key considerations (which data, who needs to exchange, with whom, and for what) and data requirements rather than prescribing a particular technology for implementation.

- **Layered Approach**: Layered approach to building out AFR-specific capabilities (incl. advanced data collection and analysis for trajectory modeling and strategic flow management), as well as data accessibility, availability, and sharing for all airspace users enabling information exchange[17] and supporting decision-making mechanisms.
- **Airspace Design**:
  - May follow the same altitude requirements as IFR or VFR.
  - Can use both fixed route structures and dynamic route/free flight concepts.
  - Performance-based CNS requirements will be defined for participation.
- **Advanced Off-Nominal Planning**: Advanced and dynamic off-nominal planning and tactical handling using predictable playbooks (including uncertainty of aircraft position, traffic restrictions, timing, and fuel/energy consumption).

2.2.4 Aircraft Automation

Legacy onboard Flight Management Systems (FMS) may be substantively sufficient to operationally support AFR. Newer aircraft with higher levels of automation aiming to operate under AFR will likely be equipped with more advanced versions of the aircraft avionics suite like mission management systems (MMS). MMS will be responsible for management of the aircraft's operational intent[18] execution, C2, aircraft flight behaviors, aircraft state recording, maintenance data capture, etc. MMS will utilize PBN requirements in all phases of flight to be able to reach operational performance with a high level of predictability in support of higher-density traffic flows (e.g., 4D RNP NavSpecs). These PBN requirements will likely be used for conformance monitoring and tactical spacing of AFR aircraft.

MMS could be used to maintain proper spacing based on the assigned "target" traffic aircraft and interval based on spacing requirements. As AFR matures further, V2V and V2I exchanges will enable tighter spacing and better data exchanges between the participating aircraft.

The following is the list of attributes that describe AFR aircraft.

- **Crewed and Uncrewed Operations**:
  - AFR aircraft may be either crewed (onboard PIC), remotely piloted (remote 1:1 PIC to aircraft), and remotely supervised aircraft (remote M:N supervisor).
  - All AFR operations will be able to switch to IFR or VFR[19].

    NOTE: AFR is aimed at addressing interoperability issues associated with the implementations of the PIC role within factors like aircraft configurations,

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[17] Technical implications for the data exchange (incl. cybersecurity) will require significant consideration.

[18] Operational intent is a mission-specific data file that comprises a flight plan, contingency & emergency procedures, environmental and operational constraints (e.g., aerodrome availability), service constraints, assigned resource constraints, expected gate occupancy time, etc. It will also have a record of any (if any) changes that happened within either of the elements outlined herein.

[19] Further explained in Transitioning Operating Modes.

performances, capabilities (e.g., levels of automation/autonomy), and subsequent operational limitations (e.g., energy limitations).

- **Various Levels of Control and Automation**: Aircraft may have different levels of automation and system control (ranging from supervision control to simplified control to increasing levels of automation).
- **Various Aircraft Types**: Configurations may vary from turbine-powered fixed-wing aircraft to rotorcraft to electrically powered aircraft with or without VTOL capability.
- **Performance-Based Limitations:** Achievable climb/descent gradients, speeds and accelerations in different configurations.

NOTE: AFR operations will be based on Performance-Based Reserves to tailor reserve requirements to the level of predictability of energy/fuel consumption and uncertainties (e.g., wind, alternate aerodrome locations) specific to the mission in lieu of a fixed fuel/energy reserve budget.

3 Integration

This section delves into the integration of AFR within the existing and evolving airspace structure. It details how AFR operations will interact with current VFR and IFR within various airspace classes (A through G). Furthermore, it introduces the concept of a dedicated Class X, designed to support high-complexity AFR operations, and outlines the principles for transitioning between different operating modes.

NOTE: Class X is a proposed naming convention for an airspace class dedicated to AFR operations. It is not in scope of this document to propose any specific naming convention for a class of airspace that subsumes the requirements for operations under the concept of AFR.

3.1 Automated Flight per Airspace Classes

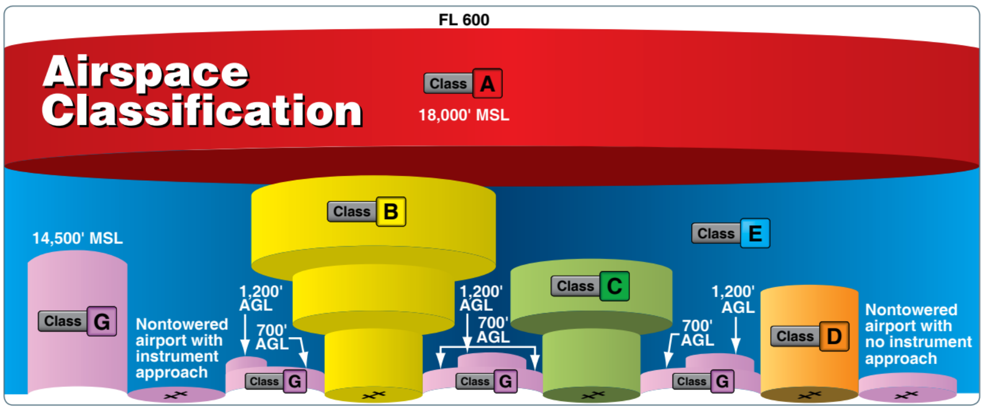
Like VFR and IFR today, AFR requirements for operation in different airspace classes will vary based on the complexity and density of aircraft movements, nature of the operations conducted in that airspace, required level of safety, and interest of the operating stakeholders.

Integration of AFR aircraft into the airspace system follows the following principles:

- Any aircraft may operate under AFR if it is AFR-certificated and has the appropriate onboard equipment.
- AFR will exist in all existing classes of airspace.
- No new requirements will be imposed on VFR and IFR operations.
- Each airspace class shall have a single default authority responsible for providing separation services. That authority may elect to delegate responsibility for separation to another party when operationally desirable.
- Integrated Operating Picture is assumed to be a common good that supports the continuous safe flight and is required within Class X for all AFR aircraft. In all other classes of airspace, maintenance and use of Integrated Operating Picture is strongly suggested for AFR aircraft but is not required for operation.

The most restricted airspace, Class A, supports IFR flights, requires mandated communication, surveillance equipment, and ATSP clearance. Similarly, Class B, C, and D airspace define controlled airspace enveloping airports, which requires mandatory ATSP coordination, even though each airspace class in succession has generally reduced requirements and fewer operational restrictions. Class E is also controlled airspace and may contain both IFR and VFR traffic that may or may not be utilizing ATSP services (though with the exception of surface areas around airports when the weather is poor, requiring IFR operations and a clearance).

Uncontrolled airspace, Class G, has the lowest set of required equipment and pilot capabilities, as well as a commensurate lack of ATSP services, regardless of the flight rules. ATSP has no authority, and often no capability, to offer separation services in Class G; though, they may offer traffic advisories when able to both VFR and IFR operations.



U.S. Airspace Classification (PHAK Chapter 15)

High-complexity AFR operations may get allocated a dedicated airspace class unique to their operational needs (e.g., corridors) in the short term used solely for AFR operations. It is labeled as Class X throughout this document. Class X and its airspace structures may come in the form of published routes and procedures within the existing airspace, akin to VFR corridors, helicopter routes, and military training routes. Unique AFR procedures may be created within Class B, C, D to effectively allow procedural integration with other airspace users.

The following table outlines a set of minimum requirements required to enter existing classes of airspace and the AFR environment, as well as the services that are available to each operation.

			VFR	IFR	AFR
Class X	**Minimum to enter**	Weather			None
		Equipage			Navigation, Surveillance, DAA
		Intent Sharing			Operational Intent
		Authorization			A-TMS
	ATSP Service Provided				None
	ATSP Service Available				None
	Automated Traffic Management Services				Strategic and Tactical Services
Class A	**Minimum to enter**	Weather		None	None
		Equipage		VHF, Navigation, Surveillance	VHF, Navigation, Surveillance, DAA
		Intent Sharing		Flight Plan and Authorization Limit	Flight Plan and Authorization Limit
		Authorization		ATSP	ATSP
	ATSP Service Provided			Sequencing and Separation	Sequencing and Separation
	ATSP Service Available			Traffic Advisories, Safety Alerts	Traffic Advisories, Safety Alerts

			VFR	IFR	AFR
	Automated Traffic Management Services			None	Strategic Services, Traffic Advisories and Safety Alerts (supporting role)
Class B	Minimum to enter	Weather	VMC	None	None
		Equipage	VHF, Surveillance	VHF, Navigation, Surveillance	VHF, Navigation, Surveillance, DAA
		Intent Sharing	Tactical Intent	Flight Plan and Clearance Limit	Tactical Intent
		Authorization	ATSP	ATSP	ATSP
	ATSP Service Provided		Sequencing and Separation	Sequencing and Separation	Sequencing and Separation
	ATSP Service Available		Traffic Advisories, Safety Alerts	Traffic Advisories, Safety Alerts	Traffic Advisories, Safety Alerts
	Automated Traffic Management Services		None	None	Strategic Services, Traffic Advisories and Safety Alerts (supporting role)
Class C	Minimum to enter	Weather	VMC	None	None
		Equipage	VHF, Surveillance	VHF, Navigation, Surveillance	VHF, Navigation, Surveillance, DAA
		Intent Sharing	Tactical Intent	Flight Plan and Clearance Limit	Tactical Intent
		Authorization	Two-way Radio Communications	ATSP	ATSP
	ATSP Service Provided		Sequencing and Separation from IFR	Sequencing and Separation	Sequencing and Separation
	ATSP Service Available		Traffic Advisories, Safety Alerts	Traffic Advisories, Safety Alerts	None
	Automated Traffic Management Services		None	None	Strategic Services, Traffic Advisories and Safety Alerts (supporting role)
Class D	Minimum to enter	Weather	VMC	None	None
		Equipage	VHF	VHF, Navigation, Surveillance	VHF, Navigation, Surveillance, DAA
		Intent Sharing	Tactical Intent	Flight Plan and Clearance Limit	Tactical Intent
		Authorization	Two-way Radio Communications	ATSP	ATSP
	ATSP Service Provided		None	Sequencing and Separation between IFR	Sequencing and Separation from IFR
	ATSP Service Available		Sequencing, Traffic Advisories, Safety Alerts	Traffic Advisories, Safety Alerts	None
	Automated Traffic Management Services		None	None	Strategic Services, Traffic Advisories and Safety Alerts (supporting role)
Class E Surface	Minimum to enter	Weather	Under VMC	None	None
		Equipage	VHF	VHF, Navigation, Surveillance	VHF, Navigation, Surveillance, DAA
		Intent Sharing	Tactical Intent	Flight Plan and Clearance Limit	Tactical Intent
		Authorization	None (unless Special VFR)	ATSP	ATSP
	ATSP Service Provided		None	Sequencing and Separation between IFR and from AFR	Sequencing and Separation from IFR
	ATSP Service Available		Traffic Advisories, Safety Alerts	Traffic Advisories, Safety Alerts	None
	Automated Traffic Management Services		None	None	Strategic Services, Traffic Advisories and Safety Alerts (supporting role)
Class E	Minimum to enter	Weather	VMC	None	None
		Equipage	None (unless in Mode C Veil)	VHF, Navigation, Surveillance	VHF, Navigation, Surveillance, DAA
		Intent Sharing	None	Flight Plan and Clearance Limit	Tactical Intent
		Authorization	None	ATSP	None
	ATSP Service Provided		None	Separation between IFR	None
	ATSP Service Available		Traffic Advisories, Safety Alerts	Traffic Advisories, Safety Alerts	None
	Automated Traffic Management Services		None	None	Tactical Services, Traffic Advisories and Safety Alerts (supporting role)
Class G	Minimum to enter	Weather	VMC	None	None
		Equipage	None (unless in Mode C Veil)	VHF, Navigation, Surveillance	VHF, Navigation, Surveillance, DAA
		Intent Sharing	None	Flight Plan and Clearance Limit	Tactical Intent

		VFR	IFR	AFR
	Authorization	None	ATSP	None
	ATSP Service Provided	None	None	None
	ATSP Service Available	Traffic Advisories, Safety Alerts (upon availability)	Traffic Advisories, Safety Alerts (upon availability)	None
	Automated Traffic Management Services	None	None	Tactical Services, Traffic Advisories and Safety Alerts (supporting role)

The table highlights most differences between airspace requirements and how they compare between legacy VFR, IFR, and novel AFR operations. There are many operational caveats to all operations (even VFR and IFR today). This table, however, covers main points of contention that can guide further explanation and decomposition of operational requirements for interactions between different types of operations in all environments.

The following sections provide a high-level technical description of how AFR will take place in both existing classes of airspace (Class A-G) and in the newly proposed Class X.

3.1.1 Class X

Class X is a new class of airspace proposed to support higher-density and predictable AFR operations, with all aircraft within that airspace operating under AFR. Traffic management in that environment will be provided solely through A-TMS without direct ATSP involvement, where operations will be uniquely limited to AFR aircraft. Two distinct ways of airspace organization have emerged are:

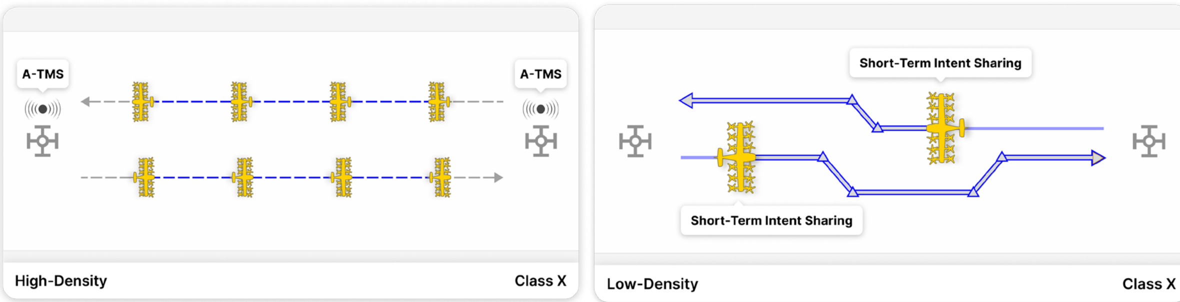
- **Corridors** are often attributed to UAM operations as part of alleviating unnecessary workload from the high tempo of operations in already busy ATSP environments.
- **High Density Tracks** can be attributed to many use cases to accommodate the characteristics of AFR-specific variables.

NOTE: AFR operators do not have to conduct flights only in Class X but also may conduct flights on different types of routes and airways, as well as arrival, approach, and departure procedures outside of Class X. However, new criteria, behavior patterns, and ATSP interfaces may be necessary to support holistic AFR integration.

Class X structures may be designed for both low- and high-altitude airspaces. In low altitude environments, they may be used to serve high-density AAM routes and aerodromes, where the airspace may extend to the aerodrome surface. In high altitude environments, they may be used to designate high-density enroute airspace or routes, in which greater routing flexibility and/or lower in-trail separation may be achieved by leveraging AFR capabilities. In either configuration, these airspace structures must not be viewed as segregated but rather porous, allowing other IFR and VFR traffic to be able to cross these airspaces easily. Because the actual density of operations experienced within this environment may vary, different methods of traffic management may apply:

- **Low-density**: Aircraft-centric “self-separation” may provide a sufficient level of safety and efficiency for AFR operations (e.g., aircraft self-organizing around untowered aerodromes). AFR aircraft will share short-term intent information (e.g., next few waypoints and associated altitudes) and assume responsibility for tactical deconfliction using “rules of air.” A-TMS may supplement ground automation systems data for onboard capabilities, like traffic surveillance data and sequencing instructions.

- **High-density**: A centralized traffic management entity and high-level of airspace organization become necessary to maintain the robustness and predictability of AFR operations. Responsibility for conflict management is assigned to ground-based automation systems, which provide safety-critical strategic and tactical services to all operations. A-TMS would be functionally similar to existing ATSP services; though, the greater use of automation will refine airspace efficiency and capacity benefits by reducing dependence on human performance for conflict detection and resolution.



Examples of the application of low- and high-density Class X airspace

A-TMS providing traffic management services within Class X may include both air and ground components. Key envisioned operational criteria include:

- Operational intents must be submitted to the A-TMS and consequently validated before aircraft can enter Class X airspace. As part of this validation:
  - Automated DCB service verifies that the specified capacity of ground and airspace resources is not exceeded.
  - Automated Tactical Spacing and Sequencing service issues individual times for entering the airspace at an airborne entry fix.
  - Automated Tactical Spacing and Sequencing service issues individual times for entering the airspace from the aerodrome in Class X.
- Operators must conform to routes and procedures with defined lateral and vertical conformance thresholds (e.g., based on RNP values).
- A-TMS will alert airspace users and stakeholders of potential aircraft conflicts.
  - Automated Conformance Monitoring service will identify aircraft that have exceeded the lateral or vertical conformance threshold of their assigned RNP route or procedure.
  - Automated Conflict Probe will identify conflicts not related to lateral and vertical deviations, such as overtaking aircraft on the same RNP route.
- A-TMS system will communicate with operators through digital communications link.
- A-TMS may issue a Required Time of Arrival (RTA) for flow management to aircraft operating in Class X. An RTA may be assigned at any airspace or ground resource, including waypoints and aerodromes.
  - A-TMS will exchange data with the ATM system to enable resource management, flight handoffs, and contingency management.
  - Airspace management: the ATSP will be able to set availability, capacity limits and conditions for operation in Class X.
  - Flight handoffs: in cases where a flight transitions between Class X and Class A, B, C or D airspace, a hand-off between the A-TMS and the ATSP system will allow for the exchange of flight information, authorizations, and operational intents.

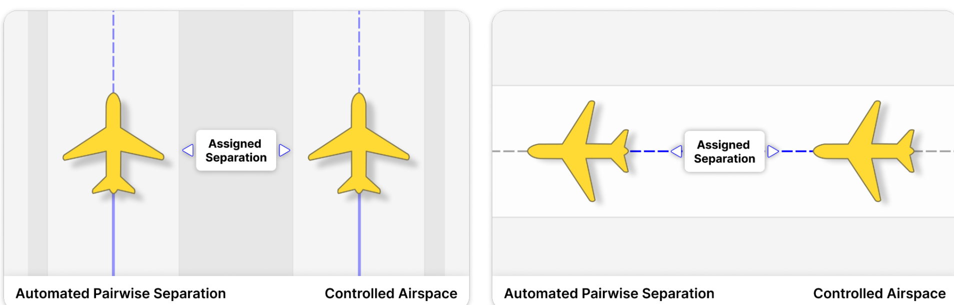
- Contingency management: information about emergency aircraft, nonconforming flights, and detected conflicts within Class X will be shared with the ATM system in case these scenarios require ATSP handling outside of Class X.

3.1.2 Airspace Classes A, B, C, and D

Classes A, B, C, and D require all aircraft to have some level of coordination with the ATSP, either through explicit authorizations or establishing and maintaining two-way communication.

AFR aircraft flying in these classes of airspace will be handled by the ATSP similarly to IFR aircraft: they will be required to share operational intent (e.g., through a flight plan), receive airspace authorizations, and maintain two-way communications. They will receive the same ATSP services as IFR aircraft, being separated from other aircraft by radar and non-radar ATC separation rules as applicable. They will also be authorized to fly in Instrument Meteorological Conditions (IMC) and will be capable of using new and existing Instrument Flight Procedures (IFPs) and instrument routes.

In these classes of airspace, new AFR capabilities will inherently enable AFR aircraft to conduct advanced pairwise procedures, such as in-trail interval management, self-metering at merge points, and separation monitoring on closely spaced instrument approaches. In these operational scenarios, the ATSP will be able to delegate responsibility for pairwise separation to AFR aircraft, similar to how aircraft may be delegated responsibility for pilot-applied visual separation today – though without the need for the target aircraft to be visually identified (e.g., conspicuity acquisition). While these AFR capabilities may also be available to equipped IFR aircraft, their inclusion as minimum AFR equipment will unambiguously communicate to the ATSP and other airspace users the ability of an AFR aircraft to automatically execute more advanced procedures.



Example of performance-based separation applied in a controlled airspace

A-TMS services may be leveraged by AFR and other aircraft in Class A, B, C and D in a decision support or advisory capacity, wherever such are available. In these classes of airspace, these automated services may be used to support operator flight planning, provide digital in-flight advisories, and aid in coordinating appropriate routing with ATSP, among other tactical and strategic services. Integration with ATSP will play a key role for coordination of data and information exchange between operators, aircraft, ATSPs, and all other involved stakeholders.

3.1.3 Airspace Class E

In Class E airspace, only IFR aircraft are required to operate in coordination with the ATSP. Like VFR traffic today, AFR aircraft will be able to operate in this type of airspace without an explicit clearance or two-way communications. ATSP flight following services may be available to AFR aircraft controller workload permitting, as is the case with VFR flights today.

AFR aircraft flying in Class E will be handled by the ATSP similarly to VFR aircraft; they will not receive separation services. VFR in Class E today rely on see-and-avoid to remain well clear of other VFR and IFR traffic. Similarly, AFR aircraft will primarily rely on DAA capabilities and supporting A-TMS services to remain well clear of all other traffic. AFR aircraft will at minimum share their short-term operational intent with other AFR aircraft for efficient trajectory planning when maneuvering is needed to maintain remain-well-clear.

Separation between IFR and VFR aircraft in Class E today is the responsibility of both aircraft - each is required to apply see-and-avoid to remain well clear. AFR aircraft will be capable of operating in both Visual Meteorological Conditions (VMC) and IMC, but the use of see-and-avoid by IFR aircraft in IMC cannot be expected. As a result, the AFR aircraft in IMC will have an upper hand for assurance of appropriate separation between AFR and IFR aircraft relying on their DAA capability to remain well clear of IFR traffic (Figure 2). In VMC, both aircraft will be capable of appropriately remaining well clear.

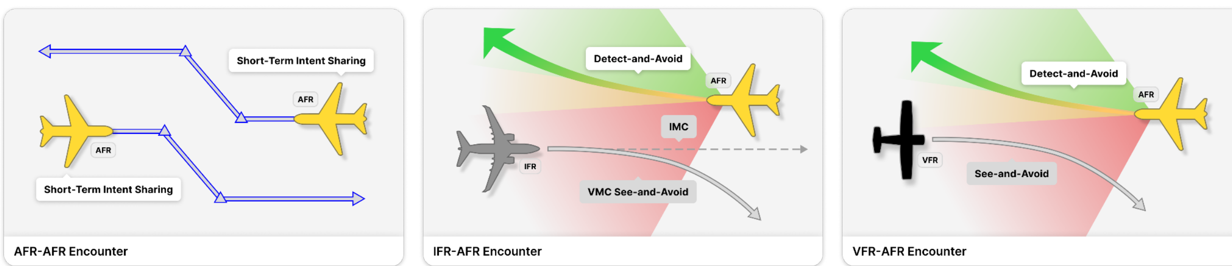


Illustration of remain-well-clear maneuvering in Class E airspace

As flight trajectories in Class E airspace will be determined by the AFR operator, with or without A-TMS involvement, they will be able to operate with similar trajectory flexibility as current VFR traffic, though having airspace access in all weather conditions.

On departure and approach, AFR aircraft may fly instrument procedures in Class E airspace without the need for an ATSP authorization. In that case, AFR aircraft will be able to self-sequence with IFR aircraft on the same instrument procedure[20]. AFR aircraft will not be subject to the constraint of one-in-one-out ATSP procedures that are used to separate IFR aircraft operating at uncontrolled airports. Instead, they will reduce the interference to the best extent possible between them and the IFR operations managed by the ATSP.

When transitioning from Class E to Class A or B airspace, AFR aircraft will be expected to coordinate an authorization from the ATSP prior to entering the new airspace either pre-departure or in-flight. This coordination could be done either through A-TMS or legacy means. During this process, ATC will be able to assign the AFR aircraft an RTA with a respective tolerance over an entry fix as part of traffic flow management. In this scenario, the AFR aircraft will leverage the automation capabilities to meet that assigned RTA.

As in other classes of airspace, A-TMS services may be leveraged in Class E to help operators plan, optimize, and adjust flight trajectories for strategic flow management or through digital in-flight advisories for tactical spacing and sequencing. AFR aircraft may use those services to increase the integrity of their onboard systems with ground-based solutions. Aerodrome

[20] The self-sequence of AFR aircraft might require coordination with ATSP if Class E is designed all the way to the ground and the need for coordination and clarity of sequence exists.

services could also be integrated for surface Class E airspace, where ATSP is able to delegate the responsibility for sequencing and arbitration in lieu of them providing this service with a lack of the necessary means to do so.

3.1.4 Airspace Class G

In Class G, aircraft will not, by definition, receive services from the ATSP, require airspace authorizations, or be in two-way communication with the ATSP[21]. Responsibilities for remaining well clear in Class G airspace will be similar to Class E airspace. When operating in the vicinity of an uncontrolled airfield in IMC, both IFR[22] and AFR aircraft will be responsible for deconfliction. That being said, to maintain higher safety margins, AFR aircraft will have better situational awareness in those conditions and may take on the responsibility for remaining well clear of the IFR aircraft established on an instrument flight procedure.

As in other classes of airspace, A-TMS services may be leveraged in Class G to help operators plan, optimize, and adjust flight trajectories for strategic flow management or through digital in-flight advisories for tactical spacing and sequencing. Supporting aerodrome services specifically could be integrated in untowered Class G aerodromes to extend ATSP or ATSP-like services of sequencing and arbitration.

3.2 Transitioning Operating Modes

During certain scenarios or when intending to operate in areas that do not adequately support AFR, operational advantage or convenience may require switching from AFR to VFR or IFR. If the switch is strategically planned, a composite flight plan submitted through A-TMS will be transmitted to the traditional ATFCM and ATSP. It will give ATSP awareness about the location where the aircraft will enter the ATSP-controlled airspace as well as the operational intent for that operation as pertinent to their airspace.

If the switch was not planned but rather became a tactical decision, the following applies:

- To switch from AFR to IFR, an IFR Clearance will be obtained in-flight from the respective ATSP, superseding any other authorizations. Any updates to the flight plan will be uploaded into the FMS or MMS, and the squawk code will be obtained from the ATSP to properly integrate into the airspace and pop up on the radar scope.
- To switch from AFR to VFR, current flight authorization will be canceled upon leaving Class X and, if necessary or desired, a VFR clearance is obtained. The aircraft will squawk VFR (or an assigned squawk code) and comply with the VFR requirements.
- To switch from VFR or IFR to AFR, coordination through A-TMS will be initiated to ensure no impact on existing traffic flow management. Upon securing a viable AFR authorization, any current authorization will be canceled with ATSP, and proper related details will be communicated to the legacy ATSP either through A-TMS or manually.

A-TMS may be used to coordinate any changes and other relevant information with ATSP before the operation enters the ATSP-controlled airspace or after it has left that airspace, just like any VFR or IFR operation today.

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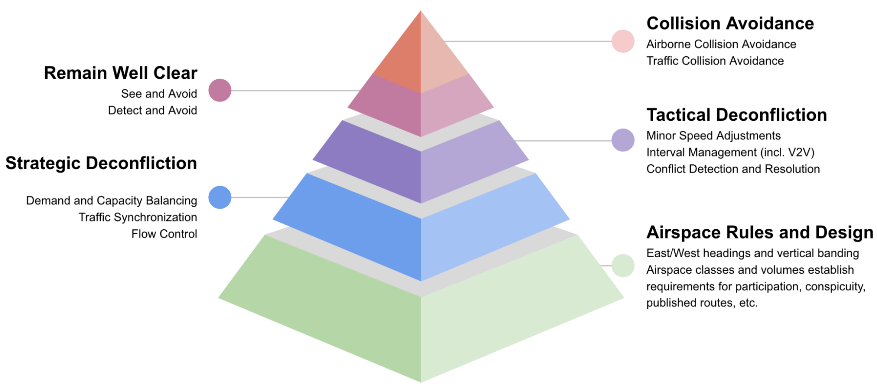
[21] With the exception of an IFR departure receiving a departure authorization, departure instructions, and a void time to safely depart a Class G aerodrome and enter a controlled airspace shortly after.
[22] Operating IFR in Class G is deemed an unsafe practice. However, it is permitted to do so for the approach and departure segments of an IFR flight when applying the one-in-one-out rule.

4 Technical Considerations

This section addresses the foundational technical considerations for the successful implementation and operation of AFR. It delves into critical aspects, such as the conflict management framework, detailing the hierarchy from strategic flow management to tactical spacing, Remain-Well-Clear (RWC), and Collision Avoidance (CA). The section also explores the role of Performance Based Navigation (PBN) procedures in ensuring precise and predictable flight paths, the essential communication and intent sharing mechanisms, and the crucial cybersecurity measures required to safeguard the integrity of automated aviation systems.

4.1 Conflict Management Framework

Air traffic management objectives are centered around identifying and addressing traffic conflicts, ensuring appropriate separation, and maintaining efficient flow of air traffic. The following figure notionally shows the hierarchy and associated elements of the ICAO's conflict management framework combined with the associated functions from this ConOps.



Conflict Management Framework Hierarchy

The table below describes the timeline and allocation throughout different layers of the conflict management framework - strategic, tactical, RWC (in the form of see and avoid and detect and avoid), as well as CA.

	Deconfliction Methods and Responsibilities [RACI]		
Time to CPA Time are rough approximations	**Strategic Conflict Management**	**Separation Provision**	**DAA (RWC/CA)**
Many Hours (T < - 2)	Capacity-Based Planning [RA]	Nothing	Nothing
Many Minutes (-120 < T < - 30$_3$)	4D Route Planning [RA]	Nothing	Nothing
Several Minutes (-10 < T < -2)	Provide 4D Route Planning If Requested by Separation Provision [C]	Adjust Vertical/Lateral Path and/or Speed Change [RA]	Receive Changes from Separation Provision [I]*
Many Seconds (-120 < T < -30)	1. Provide 4D Route Planning If Requested by DAA [C] 2. Nothing	1. Adjust Along-Path Timing and/or Lane Changes [RA] 2. Coordinate avoidance action	1. Receive Changes from Separation Authority [I]* 2. Maintain Well Clear [RA]
Tens of Seconds (-30 < T < 0)	1. Provide 4D Route Planning If Requested by DAA [C] 2. Nothing	1. Adjust Along-Path Timing and/or Lane Changes [RA] 2. Nothing	1. Receive Changes from Separation Authority [I]* 2. Regain Well Clear [RA]
Post CPA	Two conflict management strategies executing in parallel (like ATC and 'see and avoid' do traditionally)		
Several Seconds (0 < T < 10)	Nothing	Nothing	Increase spacing until clear of conflict [RA]
Tens of Seconds (10 < T < 60)	Provide 4D Route Planning If Requested by DAA [C]	Coordinate Return to Course [C]	Return to Course [RA]

* The operator retains the authority to accept/reject the changes from Strategic and/or Separation Provision.

Conflict Timeline with Conflict Management

Proposed values for the separation minima related to AFR are beyond the scope of this document but are fundamentally related to the aircraft's capabilities, designated system reliability, and bounding uncertainties[23]. Establishing those separation criteria is dependent on a multi-step process: conflict detection and conflict resolution (CD&R), which will be the outcome of robust CNS requirement application as part of traffic flow management. The future positions of the aircraft are predicted based on their current positions, flight path, and intent, per the active flight plan (direction, speed, and climb/descent gradient) if one is filed.

4.1.1 Strategic Flow Management

Strategic Flow Management uses defined AFR resources (airspace, aerodromes, routes, procedures, etc.) and associated capabilities, aircraft performance, predicted weather, and filed external flight plans to build AFR operational intents that are:

- designed to be free of flow constraints.
- optimized for as many of the variables as feasible given the planning horizon.
- agreeable by the relevant stakeholders.

A-TMS may offer strategic flow management services, assessing operational intents against the established set of constraints, and, once free of known conflict, distilling into flight authorizations or coordination items with ATSP, and sending them back to operators.

4.1.1.1 Airspace Organization

AFR aircraft may operate in all the same airspace that today's VFR and IFR operations with minor differences, while also designed compatible with multiple control paradigms. Airspace organization for AFR operations may come as a "free flight" approach with short-term intent to a fully structured operation weaving through complex airspace alongside other procedures and airspace.

To minimize mission variance impact, some AFR-specific procedures may be designed to avoid encounters with other traffic flows, including those supporting legacy IFR and VFR traffic, to the extent possible. Wake vortex protection and encounters with VFR traffic should also be considered through design as critical elements of safe operational integration.

4.1.1.2 Demand and Capacity Balancing

DCB for aerodromes begins weeks in advance per emerging scheduling processes[24]. Following slot and operational requests, the DCB output determines if an aerodrome should be categorized as a Level 1, 2, or 3[25]. DCB for airspace complements aerodrome DCB, as multiple missions may plan to utilize airspace coincidentally. The airspace and route capacity will depend on the design, size, complexity and the 4D navigation performance of participating aircraft.

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[23] Building from the concept of Established-on-RNP (EOR) for reduced separation based on design and performance of proximate operations. This will be specifically lucrative to AAM implementation in tighter terminal airspaces to use in lieu of legacy separation standards.

[24] The contracting process for aerodromes should be similar to the processes outlined in the IATA Worldwide Airport Slot Guidance, in which DCB (and slot administration) is done on a seasonal basis.

[25] A Level 3 Aerodrome is one in which demand exceeds capacity, and a negotiation process is required among respective operators. Level 2 and 1 Aerodromes have less demand than capacity, and they are able to be managed with more flexibility on shorter time horizons.

Weather is a crucial example of forecasting uncertainty in the strategic timeframe, specifically wind speed and direction influencing aerodrome configurations. Far in advance, the details of weather are unknown and unaccounted for. Closer to the departure time, real-time and near-term forecast data should afford finer resource allocation through traffic synchronization.

4.1.1.3 Traffic Synchronization

Aerodrome traffic synchronization involves the allocation of slot times, and adjusting those slots as needed (to align with any RTAs and last-minute intent changes). Airspace synchronization involves 4D trajectory planning to reduce en-route congestion. The behavior is mostly executed pre-flight but may be initiated in-flight with a time horizon looking out over several minutes in more congested areas. When used in-flight, this behavior may be triggered by A-TMS tactical functions (and coordinated with ATSP where necessary). Final RTA and RTA tolerances[26] will dovetail with the strategically administered or planned aerodrome arrival time for slotted aerodromes.

Time dimension used for tactical spacing and sequencing will aid in (e.g., via combination of DCB and Traffic Synchronization) ensuring the viability of the arrival traffic sequence. Moreover, strategic flow management will reduce potential traffic disruptions by conditioning flows to balance the demand with available capacity for the forecasted conditions and most current known status of concerned resources.

By design, strategic flow management will facilitate a largely unrestricted flight maintaining end-to-end traffic flow and reducing delay and congestion. AFR operations should require minimal in-flight adjustments (unless there are changes in the intent), especially as trajectory and weather[27] predictions improve within the modular architecture of AFR.

4.1.2 Tactical Spacing and Sequencing Management

Tactical spacing and sequencing management layer uses real-time surveillance information, trajectory and intent updates, and operational intents to continually monitor for and address trajectory-based conflicts among participating and, in some instances, non-participating aircraft. The goal is also to minimize the global knock-on effects of those changes. When required due to an identified conflict, prescribed revisions for one or more participating flights will be communicated to the operator and will include along-path speed adjustments, vertical adjustments, lateral changes, or rerouting.

This function is already performed by a centralized ATSP controller per airspace sector using high-integrity airspace awareness and procedural and decision support tools. Advances in technology will allow integration of automation features in many tactical spacing and sequencing management behaviors, with the same access to high-integrity information. This leads to automation of tactical flow management within Class X but also introduction of automation tools for legacy ATSP use.

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[26] An optimal RTA Tolerance window will be the result of balancing throughput needs with flexibility needs.

[27] Weather predictions for longer AFR missions is a more challenging aspect of flight planning. Thus, any major inflight weather impacts will be mitigated via trajectory amendments or mission adjustments.

The concept could be further decentralized to the aircraft. However, to fully authorize the aircraft for a completely self-provisioned tactical spacing and sequencing management, advances in V2V[28], V2I, I2I, and spectrum allocation are required.

4.1.3 Remain-Well Clear & Collision Avoidance

While philosophically aligned with the ICAO conflict management layer of collision avoidance, the evolution in common terminology makes this layer most easily understood as the "see and avoid" layer technologically augmented through Traffic Collision Avoidance System (TCAS) and DAA that follow DO-365 standard. For the purposes of this ConOps, the focus is on a DAA behavior that encodes the RWC criteria and respective CA maneuvers.

In essence, RWC is a variety of maneuvers to maintain well clear of nearby traffic and resolve traffic conflicts based on situational awareness (i.e., from the pilot, ATSP, aircraft sensors, ground-based surveillance, etc.), whereas CA is a variety of maneuvers that allow the aircraft to regain well clear. RWC and CA have historically been placed onboard the aircraft and remained dependent on aircraft-centric surveillance. However, as an enhancement of airborne-based DAA, ground-based DAA option is also available via DO-365. To help distinguish between tactical spacing, RWC, and CA, the following comparison is offered:

- Tactical spacing strives to maintain a specified distance or time between flights already in execution to avoid an anticipated unsafe traffic encounter.
    - It works on a time horizon of several minutes.
- RWC is a general requirement of all operators to manage and maintain a sufficient distance or time between flights to avoid an anticipated unsafe traffic encounter.
    - It works on a time horizon on the order of minutes.
- CA is no longer about ensuring predicted spacing in a particular dimension, but rather about sensing and recovering from an imminent threat of collision.
    - It works on a time horizon of several seconds.

NOTE: DAA in the capacity of **RWC** and **CA** resides with the operator of the AFR aircraft. Aircraft that rely on or complement an onboard DAA with a ground-based DAA solution in any capacity will require a data feed for the operator or the aircraft to act upon from the radar or sensors. DAA's **RWC** function overlaps with Tactical Spacing and Sequencing Management and should only be counted upon situation-required, especially when operating in close lateral proximity (assuming healthy cooperative surveillance). DAA's **CA** will serve as the last measure of conflict management, initiated once the aircraft has lost well clear. **RWC and CA together provide the ultimate safety net in the conflict management process.**

4.2 PBN Procedures

Performance-Based Navigation (PBN)[29] procedures and requirements will be essential for AFR as navigational performance is paramount to traffic separation. PBN NavSpecs will primarily

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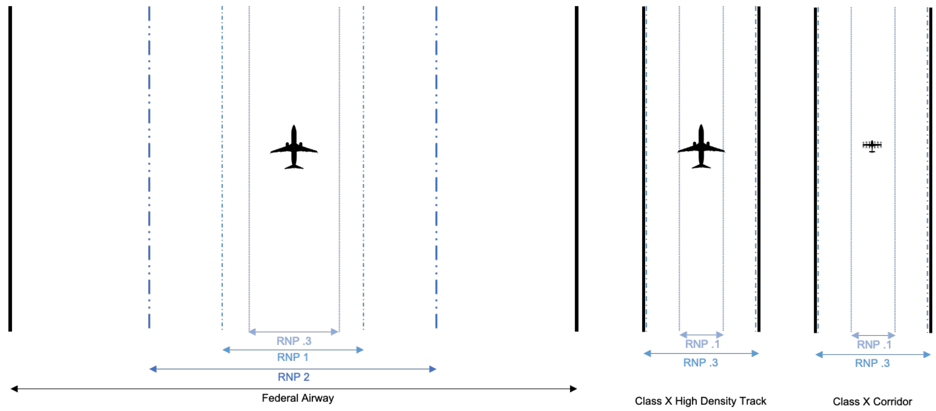
[28] In the U.S, there is significant momentum toward V2V to enable this paradigm of full decentralization of separation authority of the aircraft (RTCA V2V White Paper).

[29] PBN procedures utilize either RNP or RNAV specifications. Since RNAV navigational precision is lower (i.e., it does not go lower than 1 NM), RNP values are ultimately used to describe that variable. RNP values may go as low as 0.1 NM or even lower if the aircraft's avionics suite is advanced enough to support it and navigational signals in the operating environment permit.

drive the separation requirements of the AFR operations, support interoperability, and help define spacing thresholds for interval management, spacing and sequencing, and V2V.



Comparison of RNP NavSpecs for Airways, High Density Tracks, and AFR Corridors

Aircraft RNP capabilities are fundamental to airspace planning. These capabilities coupled with the RNP criteria can be applied to AFR-specific departure, en-route, approach, and missed approach procedures. Terminal IFPs for AFR operators provide 3D (lateral and vertical) guidance during landing and takeoff. They will include specifically designed approach and departure procedures that may be unique to AFR but interoperable between various flight operations (e.g., suitable for AFR and IFR). These procedures will be associated with existing and new PBN NavSpecs that apply to AFR and will be fileable[30] as part of a flight route for flight planning purposes.

4.3 Communication and Intent

Agnostic to specific implementation details, all automation systems will primarily communicate with each other via data sharing and digital messaging (machine-to-machine interfaces with human operators over the loop or out of the loop). While, ideally, all AFR participants should communicate via data, human-to-human communication using VoIP and aircraft-to-human V2V voice relay will be designed to support interactions with legacy aircraft with limited data communication capabilities, external actors (e.g., ATSP), external crewed traffic and airport management operators, etc.

Pre-flight communications are concerned with all data exchanges related to operations planning up to sufficient time before the aircraft begins movement from the gate. **In-flight** communications are concerned with all data and voice exchanges related to operations in execution. That includes the exchange of approved intent and any modification to that intent resulting from tactical interventions or RWC and CA actions. Although non-safety-critical, **post-flight** communications may be subject to specific verification and authentication requirements for the sake of audit trail, law enforcement, incident or accident investigation, and analytics.

4.4 Cybersecurity

The development of AFR must consider the cybersecurity risks associated with the exchange of safety-critical information between ground and airborne systems, and between aircraft in flight

[30] Flight Plan filing requirements do not include Instrument Approach Procedures as part of the route, as only Standard Instrument Departures (SIDs) and Standard Instrument Arrivals (STARs) fall within the flight route intentions.

via digital datalinks. For instance, enabling an aircraft to use surveillance data from ground systems for traffic avoidance will require that the entire surveillance chain – in this case composed of sensors, data processors, and data links – meet the required integrity and availability for safety-critical use. Similarly, the use of V2V, V2I, and I2I communications for short- and long-term intent sharing and trajectory deconfliction must consider hazards such as signal spoofing and jamming. Given their greater levels of connectivity compared to current aircraft systems, involved AFR systems will need to be designed with robust security measures and mitigation mechanisms to meet the integrity and availability targets needed for safe operations.

5 Working Together

This ConOps is a step toward the future of the aviation industry that lies in Automated Flight Operations. It serves multiple purposes - stakeholder engagement, concept maturation, and understanding of technical/regulatory gaps and required milestones - where all can prompt the industry to collaborate on the consensus regarding how to reach high-scale operations under Automated Flight Rules. As AFR is intended to be a utilitarian operating mode for all aviation stakeholders, it is critical to use this document as a foundation for engagement and collaboration between the industry, regulatory, workforce, and community stakeholders involved in industry development and evolution.

5.1 Regulatory Engagement

There is a distinct need for regulatory changes that will take the aviation industry from the initial or existing rulemaking of today to the establishment of Automated Flight Rules. The introduction of the concepts described in this document would require significant amendments to VFR and IFR regulatory material which would be incompatible with the notion of maintaining compatibility with today's operations. This supports development of regulatory materials for a new set of rules governing AFR, enclosing many, if not all, notions outlined in this ConOps.

While the process of evolution will slowly move forward with amendments and means of compliance that cater to AFR, novel regulations and standards must be developed. Many civil aviation authorities worldwide, like in the US, Australia, and EU, have already begun the modernization work toward "future skies" and new flight rules. This ConOps further solidifies and supports these efforts.

Some areas advancements include new ATSP- and automated traffic management related regulations, guidance for new Instrument Flight Procedure criteria (ex., vertical landing accommodating unique flight profiles, RNP-based separation in tight urban environments, etc.), AFR-specific routing implementation, autonomy in flight inclusion (i.e., M:N, landing hazard avoidance), and PNT solutions.

The industry, alongside regulatory bodies and many other aviation stakeholders, must focus on the following critical actions that aim to successfully integrate AFR and advance the future of aviation:

- **Implement a Phased Automation Transition:** Introduce certification pathways for automated traffic management solutions to begin operating assistive to ATSP. Successfully demonstrate the safety and reliability of these solutions before fully integrating them in existing ATSPs systems. Establish necessary regulatory foundation for aerodrome evolution and new airspace classification and AFR airspace structures through further rulemaking and amendments to federal regulations. In the US, these are, respectively, 14 CFR Part 139 and Part 71.

- **Drive Substantial Rulemaking and System Planning:** Initiate and actively engage in the rulemaking process required for seamless airspace integration of AFR operations. Develop and execute careful systems planning to ensure a safe and efficient addition of new automated traffic management solutions alongside legacy, human-centric ATSP management paradigms.
- **Invest in and Develop Robust Infrastructure and Standards:** Acknowledge the critical reliance of AFR on robust CNS and data sharing solutions. Prioritize and invest in technical advances for PNT, on-board and off-board hazard assessment, aerodrome surveillance infrastructure, and more precise RNP capabilities.
- **Accelerate New Standards Development:** Require specific standards development through Standards Development Organizations (SDOs) that contribute to hardware and software enhancement and operational compliance for operational efficiency and robust solutions that support AFR needs. Establish and maintain critical engagement with SDOs, including the ASTM, RTCA, and EUROCAE. Utilize these organizations to translate industry needs and visions into formal requirements and suggestions for rulemaking authorities.
- **Ensure Universal Enhancement of Flight Operations:** Commit to developing and implementing new flight rules that enhance all flight operations—on-demand, scheduled air taxi, and large transport aircraft—across all relevant regulations (i.e., US 14 CFR Part 91, 121, Part 135, etc.).
- **Support Operational Validation Programs:** Proactively support and leverage existing industry engagement programs, such as the 4-Dimensional Trajectory Live Flight Demonstration (4DT LFD) and Urban Air Mobility (UAM) Demonstration, to validate and verify all key AFR elements outlined in this Concept of Operations (ConOps).

On the global level, regulatory engagement shall secure harmonization for the direction toward automated flight while keeping safety in the already established airspace systems in different regions. Engagement with the International Civil Aviation Organization (ICAO) will be pivotal for smoothing out the differences in applicability for different regions and specific countries as it pertains to consistency and compatibility. In addition, the European Union Aviation Safety Agency (EASA), Civil Aviation Safety Authority (CASA) in Australia, and other worldwide Civil Aviation Agencies shall work with ICAO to ensure compatibility of AFR with their aerospace and aviation-related operational structures.

5.2 Workforce Engagement

Some AFR operations will require a unique workforce of individuals to support the rapid industry growth (i.e., UAM). As AFR will expedite the elimination of the constraint of constant human-in-the-loop or human-on-the-loop and improve the scalability of operations, it will create career paths unique to the AFR fleet. The industry will need to take intentional actions to ensure that the workforce supporting AFR has the right training and skill sets. These new skill sets will combine traditional aviation, akin to pilot, dispatcher, and ATSP training, with additional autonomy and electric propulsion extensions.

Targeted public and private investment in training and education will be needed to prepare the workforce to support the emerging operations under AFR. For example, just like Aircraft

Dispatcher certification requires a training course that encompasses broad aeronautical knowledge, training of personnel engaged in the daily AFR necessitates understanding, where the training requirements are based on the broad knowledge of the daily area of operation.

5.3 Community Engagement

Continuing the industry's efforts towards public acceptance of higher levels of automation and autonomy in aircraft, it is paramount to demonstrate that traveling on an aircraft flying AFR will be safe and reliable - no different than what they have come to expect.

Industry stakeholders shall work with local authorities and economic development organizations to effectively evaluate, plan, and implement the changes to safely integrate AFR in all airspaces. It shall be acknowledged that with airspace integration being pivotal in the utility of AFR, tight collaboration with specific stakeholders that utilize or have jurisdiction over the affected airspace will be fundamental to keeping the airspace safe and the community satisfied. There are ongoing efforts in certain locations to prepare for future AFR integration via working groups involving the business, government, and community organizations for proper collaboration patterns and understanding of each other's needs.

5.4 Industry Work and Operational Validation

At the time of writing this document, many ongoing efforts have been conceived that will support the concepts outlined and highlighted here. Some of the efforts are put forth through standards engagement in RTCA DO-365 for detect and avoid capabilities, while others are focusing on the data and information exchange through ASTM PSU Interoperability Standard and Vertiport Supplemental Data Service Provider Standard. Future development of standards that support the continuation of this effort will be required and shall be supported through industry engagement.

On the other side, many of the research studies and operational testing and validation efforts have been put in motion that will be focused on tailoring and building a proper foundation for integration of AFR enablers and key assumptions into the existing airspaces. Some of these include work done by NASA and MIT Lincoln Laboratories, as well as through Boeing partnerships in Europe and Australia. With that in mind, solidifying the concept for new flight rules and propelling forward the work done through many organizations worldwide should be an industry priority in support of the growth of aviation as a whole.

6 Acronyms

A-TMS	Automated Traffic Management Services
AAM	Advanced Air Mobility
AFR	Automated Flight Rules
ATM	Air Traffic Management
ATSP	Air Traffic Service Provider
CA	Collision Avoidance
CASA	Civil Aviation Safety Authority (Australia)
C2	Command and Control
CNS	Communication, Navigation, and Surveillance
ConOps	Concept of Operations
DAA	Detect and Avoid
DCB	Demand and Capacity Balancing
EU	European Union
FAA	Federal Aviation Administration
FMS	Flight Management System
FDX	Flight Data Exchange
GA	General Aviation
GAMA	General Aviation Manufacturers Association
I2I	Infrastructure to Infrastructure
IFP	Instrument Flight Procedures
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
MMS	Mission Management System
NASA	National Aeronautics and Space Administration
NOTAM	Notice to Air Missions
PBN	Performance Based Navigation
PBS	Performance Based Surveillance
PHAK	Pilot's Handbook of Aeronautical Knowledge
PIC	Pilot in Command
RAM	Regional Air Mobility
RCP	Required Communication Performance
RNP	Required Navigation Performance
RSP	Required Surveillance Performance
RTCA	RTCA, Inc. (formerly Radio Technical Commission for Aeronautics)
RWC	Remain-Well Clear
SESAR	Single European Sky ATM Research
SDSPs	Service Delivery Service Providers
UAM	Urban Air Mobility
UAS	Uncrewed Air Systems
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VTOL	Vertical Takeoff and Landing
VoIP	Voice over Internet Protocol

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