Federal Aviation Administration

CHARTING AVIATION'S FUTURE:

OPERATIONS IN AN INFO-CENTRIC NATIONAL AIRSPACE SYSTEM

September 2022

Executive Summary

Exciting new opportunities are emerging in aviation and aerospace.

The world is experiencing an information revolution. We have become connected electronically through all kinds of devices, leading to large-scale growth in available data. Aviation is no different. Together with private industry, these increases in telecommunications, computational power, storage, and new technologies help us secure, leverage, and learn from accumulated data. Rapid growth has resulted in these technologies reaching a level of maturity that allows for their use in safety-centric industries, such as air traffic management (ATM). Embracing this information revolution within ATM provides opportunities for performance enhancements that support environ- mental objectives in aviation, just as it has for many other industries. With technology-neutral, well defined, and performance based requirements, the FAA will work in partnership with stakeholders to support new entrant traffic, providing complements to the traditional FAA delivered infrastructure, allowing Air Traffic Services (ATS) and airspace users to leverage the commercial infrastructure and information systems for resiliency and increased information performance.

This document reflects how that change can rapidly and easily bring us to all that the original Next Generation Air Transportation System (NextGen) envisioned as well as new airspace participants that this information evolution and accompanying technology advancements have brought us. This document should not be read as a replacement of the Future of the NAS Trajectory Based Operations (TBO). The TBO vision is still very much a major FAA focus for our existing passenger and cargo partners. A key element will be the continued focus on increasing performance of airspace operations based on enhanced capabilities of FAA systems and the resulting reduction in the spread of aircraft and crew performance in this mixed equipage environment. This document expands on that TBO vision by projecting that capabilities may be provided by performance based technology alternatives, such as connected aircraft information exchange for the future trajectory as an alternative to advance Data Communication (Data Comm). The use of alternatives will be proven by embracing the new entrants and the increasing adoption of modern information technologies.

While we still are committed to the NextGen path, exciting new opportunities are emerging in aviation and aerospace. In some cases the new vehicles and their manner of operation will allow them to be integrated into the Air Traffic Control (ATC) System and to participate in TBO. In other portions of the airspace, new equally performance-based approaches will support these operations within the airspace but not directly managed by ATC. Significant investments are advancing the research and development of autonomous vehicles, electric aircraft, high-speed and long-endurance aircraft, flying in the airspace above conventional fixed-wing aircraft, and new types of space vehicles. Success with these new technologies and vehicle types will not only introduce new ways to transport people and goods but will also expand aviation's role beyond transportation.

The future NAS must support the resulting changes in operations. These types of new vehicles include unmanned aircraft systems (UAS) delivering small packages on a large scale, highly automated urban air mobility (UAM) services transporting people and cargo in congested areas, and high-altitude platforms providing greater access to telecommunication services. The aviation system is in the discovery and rapid innovation phase for incorporating these new vehicles, modes of operation, and business models.

ATS automation systems will capitalize on innovation to migrate toward learning, adaptable, and lightweight interacting systems. With technology neutral well defined performance based requirements, partnerships will be established, providing supplemental services in addition to the traditional FAA delivered infrastructure allowing ATS and airspace users to leverage the commercial infrastructure and information systems for resiliency and increased information performance. Leveraging these evolving combinations of infrastructure services, the FAA will deliver ATM services that are ubiquitous (existing or being everywhere at the same time), scalable, resilient, and agile to respond to future user needs while we are improving the environmental sustainability of these operations.

These technologies are also key to ensuring that the growth in the number and types of aerial vehicles can occur without disrupting traditional ATS. New extensible traffic management (xTM) services, such as UAS Traffic Management (UTM) and UAM, will allow operations to coexist with conventional ATS by sharing fully integrated and interoperable information. Operations under xTM enable ATS to deliver tactical functions to those using its service without having to consider individual operations using xTM services. This independence will allow interoperation without each xTM operation imposing a burden on ATC services, enabling affordable scalability of xTM operations. These xTM services, approved by the FAA, will be supported by private entities applying new methods, new technologies, and rapidly evolving commercial infrastructure.

As always safety is paramount, and the move to a new information-centric environment increases the ability to move to increased safety opportunities. Just as NextGen moved safety analysis from the reactive to the proactive with increased levels of information sharing, moving that information environment to near-real time allows us to move beyond proactive to in-time support. Integrated safety management for traffic management will establish tailored standards, flight rules, and services to achieve safety acceptable for all types of operations. With big data, the NAS will assure in-time safety and security through continuous monitoring, modeling, and verification to detect anomalies, and notify participants using established procedures to correct for in-time spikes in risk. This transformed NAS will continue to rely on a layered approach to safety and security controls, with a greater reliance on data and emphasis on risks introduced by the integration of distributed and diverse systems.

Reaching this future state will require a regulatory framework and operating practices to create an environment for xTM service suppliers employing commercial infrastructure, all while accounting for their diverse operations. Performance-based standards will form a basis for regulatory compliance by providing the required levels of system and operator performance for specified operations. Cooperative operating practices will be developed for managing access to airspace and resources.

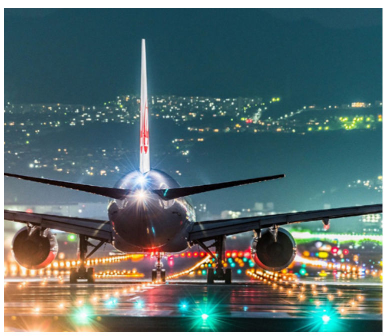
In the future, federated environment, interoperability, and clear standards, fueled by innovation and vigorous competition, will be essential to ensure a well-functioning system that meets future transportation needs. To promote competition for these emerging technologies, including access to airspace and operations in federated environments, the Department of Transportation (DOT) and the FAA will establish clear policies on equity and access supported by FAA rules, regulations, and approved standards along with methods for qualification of third-party services in these new environments.

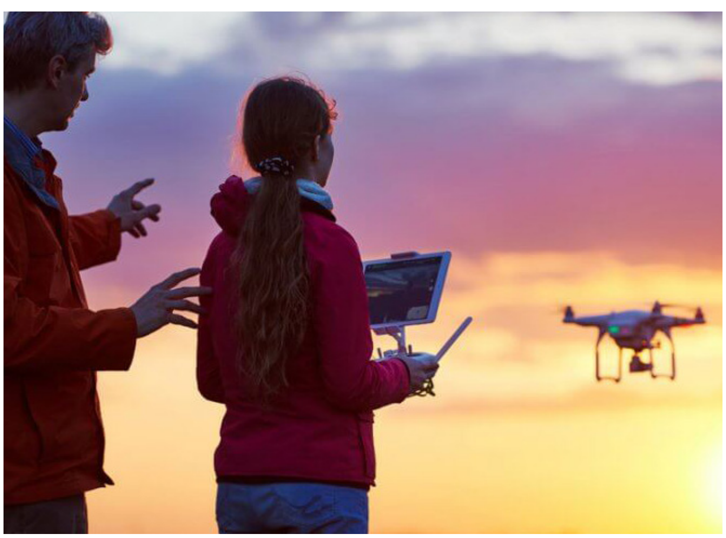
In keeping with those considerations, the vision provides a framework to develop service-level concepts and implementation plans to support the continued expansion of capabilities for more environmentally sensitive and efficient large passengers and cargo operations while meeting the challenges of the new entrants. It does not answer the "hows" but does identify challenge areas that need to be examined to define the specific operational methods and technical requirements to build systems and services that make the vision a reality.

The evolution of that concept and those implementation plans will need to proceed at the new industry's faster pace, directed by business requirements, and supported strongly by adherence to the safety risk management system framework. The role of this vision document and its principles is to guide the emerging architecture for all stakeholders, including a more diverse workforce to meet the new challenge and opportunities. The FAA as the existing ATS provider and safety authority must work together with all stakeholders to ensure concepts are compatible, access criteria are negotiated, available infrastructure is leveraged, and information standards are developed in a timely manner. Working together, all stakeholders can evolve to the vision and usher in a future era of growth in aviation.

This vision provides the foundation for full dialogue with all parts of the aviation community on assumptions, opportunities, and timelines to meet those opportunities. The need for that dialogue is evident in the myriad of new technologies, operations, and aviation community partners that have arrived since the beginning of NextGen implementation in 2008. This document is meant to be a basis to start that conversation.

Contents





Introduction

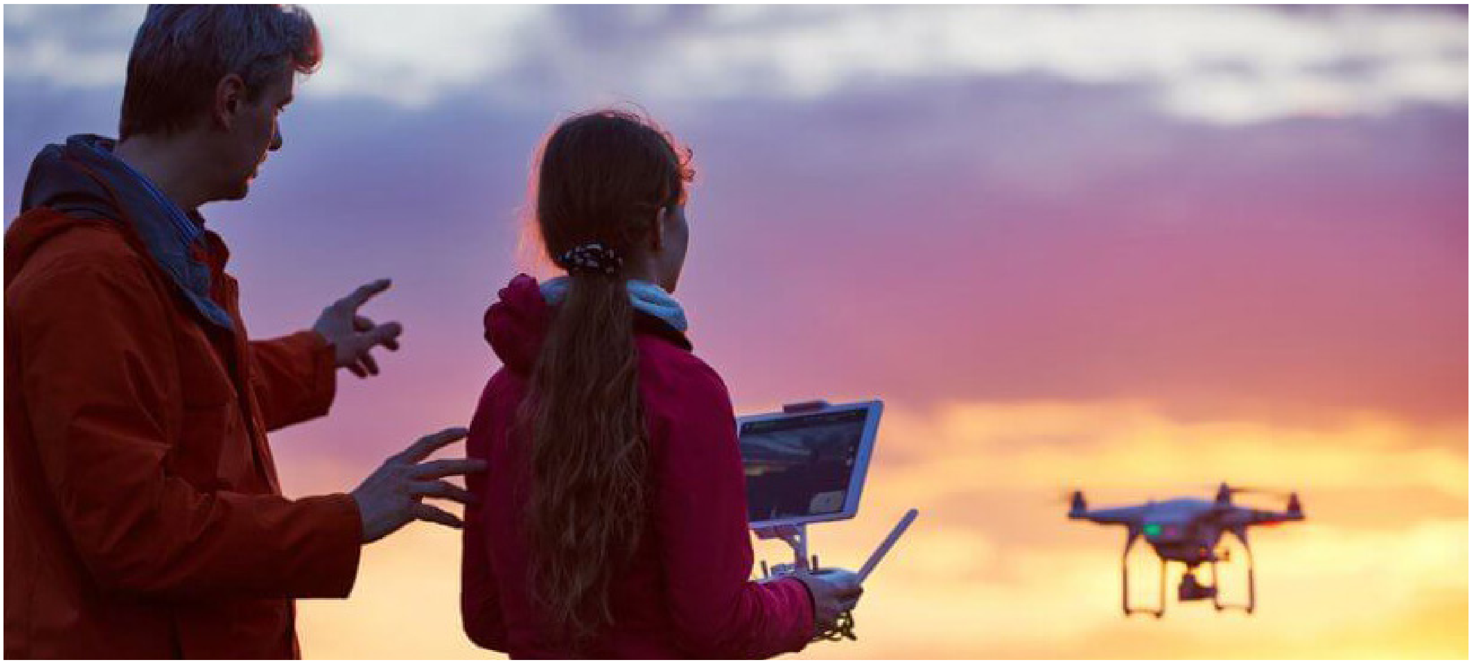
This document lays out a high-level vision for how new vehicle types and services can be sustainable, and cost-effectively integrated into the NAS through the use of modern software applications and infrastructure. The vision outlines how the FAA and user communities can work together to further define how new operations can work in a manner that continues to provide safe and more efficient services to aircraft while enabling new environmentally sustainable vehicle types to perform operations that meet their desired objectives. Central to the future is an integrated information environment that provides the data that drives future information services required for delivering interoperability and advanced predictive algorithms.

This document does not replace the Future of the NAS Trajectory Based Operations (TBO). The TBO vision is still very much a major FAA focus for our passenger and cargo partners. This document is complementary to and expands on the TBO vision's core concepts. A key element will be the continued focus on increasing performance of airspace operations based on enhanced capabilities of FAA systems and the reduction in the spread of aircraft and crew performance in this mixed equipage environment. This document expands the TBO vision by projecting that capabilities may be provided by performance based technology alternatives, such as connected aircraft information exchange for the future trajectory as an alternative to advance Data Comm, and the use of alternatives will be proven by embracing the new entrants and the increasing adoption of modern information technologies.

The vision provides a framework to develop a service-level concept and implementation plans. It helps to identify challenge areas that need to be examined to define the specific operational methods and technical requirements to build systems and services that make the vision a reality. This includes a move to heightened information integrity by applying new cyber security paradigms and leveraging this new information environment to provide increased in-time security. The expectation is that initial services that are built to deliver this vision will be operational in all segments starting now with our SWIM investment and UAS applications, and continuing through no later than 2035.

This document also references specific technologies and future operational concept components to better explain the intent of vision aspects. This should be considered a description of performance by analogy and not a particular conclusion on how that performance will be delivered.

Motivation And Opportunities



CHANGES IN AVIATION

As NextGen deploys the systems to complete the integration of trajectory operations into the NAS, what has been labeled "full TBO," there is the final phase (Dynamic TBO) where decisions and results are tailored to individual flights. This requires extensive information exchanges, which is an information hurdle for the limited bandwidth of our FAA-provided data communications services. This information hurdle is being swept aside by the connectedness that we see everywhere; the "Internet of Things" is not just a phrase, it is a reality. By leveraging the connectedness of the dispatcher and flight crew through Internet and, in some cases, mobile applications, individual trajectories can easily be negotiated and adjusted based on the richer information on the individual flight's intent and state that are now available. Dynamic TBO, as well as better understanding of each flight's safety state, is more readily achieved.

At the same time, new airborne vehicles are emerging which perform new missions and operate in new ways to execute those missions. This presents an opportunity for changing the NAS to provide access and offer alternative flight rules for future traffic management concepts operating outside of ATC. These new types of NAS users and their anticipated high number of operations require the adaptation to conventional ATM methods for sharing NAS resources.

Space commerce and national security missions, remotely piloted aircraft systems (RPAS), fully autonomous vehicles, and lighter-than-air aircraft (balloons) exhibit many different operational characteristics. Vehicle system advancements that reduce environmental impact in the areas of batteries, solar power, electric motors, efficient jet engines, low-boom supersonic aircraft, and reusable orbital and sub-orbital systems can enable new applications and corresponding missions.

While their safe operation and accommodation within current ATS can be provided today, current service accommodation will not scale to meet the expected growth in these operations. To be scalable, these new operations must be handled using a new model in which each new operation

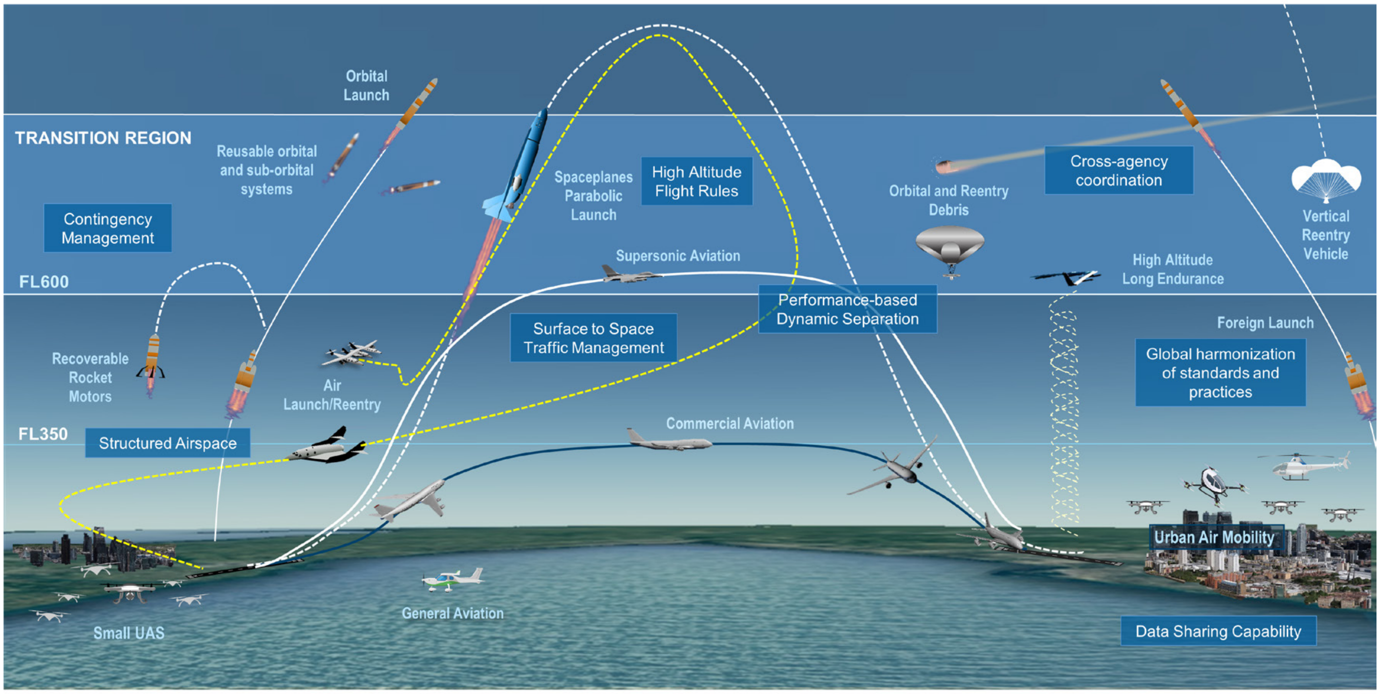


Figure 1 – Diverse aviation vehicles, missions, and business models drive the evolving vision.

does not impose additional demands on the current ATS system and reduce its operational efficiency. New traffic management services, tailored to new entrant characteristics, will be developed and able to coexist with traditional ATS. To deliver these new services, the FAA will lead and work with commercially available infrastructure. Methods and technologies from these new traffic management services could inform improvements to traditional ATS. As shown in Figure 1, new entrants include uncrewed vehicles of many sizes, a variety of high-altitude vehicles, and new vehicles providing access to space.

TECHNOLOGICAL OPPORTUNITY

State-of-the-art communication and information technologies provide an opportunity to develop a fully shared information environment between authorized participants. Advances in automation technology may use this information to address operational challenges introduced by new vehicle types and services. The information and data sharing structures and technologies developed as part of the FAA's Next Generation Air Transportation System (NextGen) will provide foundational elements for the environment. Other technologies will provide the necessary infrastructure, security, and analytics.

Full connectivity will come from infrastructure supporting NAS operations that enable all systems to share data. With all types of devices connected to the Internet (known as the Internet of Things [IoT]) and advances in wireless technology, nearly all operators and vehicles can be connected from nearly any location at any time. This ubiquitous system-to-system communication can be used to share location and intent information across vehicles, subsystems, and ATM stakeholders from airspace users to airports. We are already seeing this connectivity in aviation outside of ATC with the terabytes of information that individual aircraft downlink real-time to their operators and supporting industry. Not all this information needs to flow to all participants. By using data analytics at the connecting points to filter and reduce the volume of information, only actionable information will be shared to support human situational awareness through improved filtering and presentation methods. Derived from these information systems, this information will provide increasing support and situational awareness to the human operators through information and automation-based digital assistance. Autonomous systems can rely on this information, in concert with FAA-approved operating rules, to safely operate in the airspace.

As technology advances, information systems will operate with new heightened levels of information assurance. Advances in cybersecurity will assure information integrity between end systems across diverse infrastructure. Network diversity will help ensure reliability, continuity of operations, and sustainment of the advertised level of service. Cloud technologies (e.g., software-defined networking and network function virtualization) will enable dynamic configuration of applications and information resources to meet in-time demands of users and service suppliers.

Armed with large amounts of collected, shared, and stored operational data (e.g., on flights, weather, infrastructure status, and airspace), systems will be able to construct actionable in-time recommendations, and increasing flight efficiency. Augmented reality, such as head-up displays, will be leveraged to present actionable information to human decision-makers, allowing for greater understanding and better outcomes. With data driving analysis and decisions, operational system performance will be more effectively monitored, analyzed, and delivered. Virtual testing will enable rapid assessment of proposed changes by using digital replicas of operational systems. Operational solutions will be tailored to improve individual flight performance, and risk will be identified and reduced in vehicle operations. In-time safety monitoring and alerting will be enhanced by applying machine learning. Systems will use the data to continually improve decision support. By capturing cause-and-effect actions experienced in the environment, systems will optimize future decisions, and improve safety and performance.

As the existing NAS infrastructure ages, modernization plans must be developed to prevent obsolescence. New technologies that provide opportunities to more cost-effectively upgrade or replace capabilities using modern software-development environments and best practices should be considered. System development can then be fast, dynamic, and efficient in responding to changing needs and advancements. With these changes, new technological skills will be required with new and expanded opportunities for a more diverse, adaptive workforce.

New performance-based standards are developed to meet regulatory compliance.

ROLES AND RESPONSIBILITIES

Safety within a system requires good understanding of the roles and responsibilities of each component within that system. One key objective of this vision document is to start the conversation on who will be responsible for what in an info-centric, coordinated aviation future that features active, operational collaboration between government, the aviation industry, and potential non-aviation service suppliers.

While not every role is clearly established today, it will need to be as we move forward toward integrated operations. A machine cannot currently be held responsible for the safety of an aviation operation. In an increasingly automated future, the responsible person depends on the phase and the existing regulatory oversight construct.

LEVERAGING OPPORTUNITIES TOWARD A PERFORMANCE-BASED ENVIRONMENT

New technologies must be leveraged to address the required changes in demand for airspace access by new entrants. For new traffic management services to work under the larger ATM regulatory umbrella, the NAS must become performance-based in two areas:

- Performance-based standards will form a basis for regulatory compliance by providing the framework for required levels of system and operator performance for specified operations. Such standards make it possible to adopt diverse and evolving technologies as long as they meet the required performance.
- Performance-based outcomes relate to the relative value placed on different operational priorities, such as access, capacity, efficiency, and equity. By agreeing to these upfront, automation can make recommendations across multiple parties in a manner that

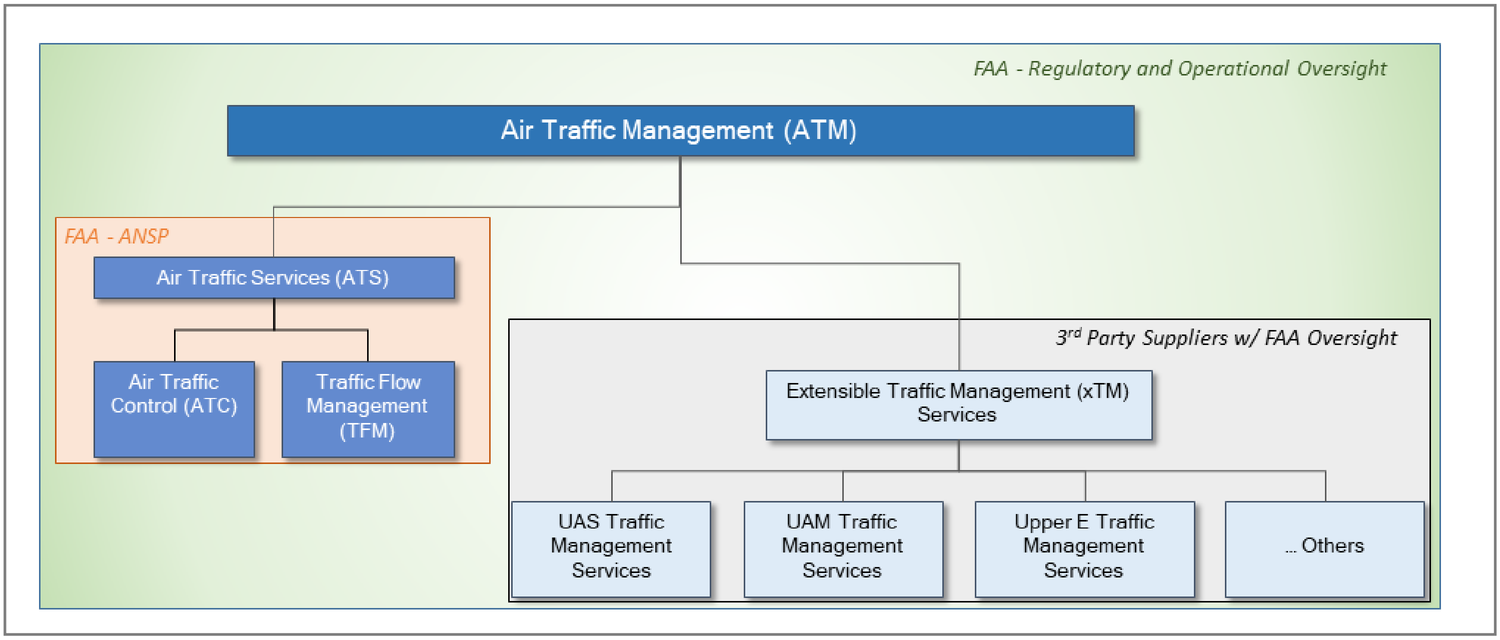


Figure 2 - Air Traffic Management in the evolving vision.

does not adversely impact system-level performance. With more accurate information and forecasts, technology can provide service suppliers and users with the ability to pursue performance-based outcomes.

Ultimately, services will be provided on a performance basis, in which the required performance is specified, decisions are made to achieve the required performance, and the performance is measured and monitored. Effective design will be required to ensure automation can successfully assist human operators with their required tasks. New entrants will drive the rapid adoption of advancements, providing an opportunity to leverage them as the NAS moves toward becoming performance-based.

Such an environment will provide for the following:

- **Rules of the Air:** A regulatory framework and operating practices will create the environment for diverse operations and distributed operational services provided by suppliers beyond traditional ATS.
- **Extensible Air Traffic Management Services:** Current ATM provides a variety of ATS, most notably air traffic control and traffic flow management. As shown in Figure 2, ATM will be gradually extended over time to include a variety of new extensible traffic management (xTM) services addressing the needs of new entrants such as UAS, UAM, or specialized high-altitude operations. The FAA will retain regulatory authority over all of ATM, including xTM services provided by approved entities.
- **Connected Participation:** All vehicles and service suppliers will be connected to an integrated information environment at all times.
- **Big Data:** Connected vehicles, with their onboard sensors, will provide significantly larger amounts of data, which will be used to better estimate the present state of the NAS and vehicles operating within it. Historical data and technological advances (such as machine learning) can then be leveraged to better predict future states used for operational planning.
- **In-time Safety Assurance:** Using measured or derived information for vehicles, automation will be able to monitor operations, detect safety risks, and provide in-time alerts when risks are detected.
- **In-time Security Monitoring:** *Enhanced* situational awareness is achieved using collected or derived information for vehicles and with modeled behaviors from historic data. As a result, automation will

be able to monitor vehicles for operational compliance as well as detecting anomalous behavior that may indicate security safety risks, and provide in-time alerts when compliance and security risks are detected.

- **Reduced Uncertainty:** Big data analysis will allow stakeholders to improve accuracy and estimate uncertainty. This ability will allow more precise decisions that manage the uncertainty and provide better knowledge of their impact on performance.
- **Trajectory Management:** With NextGen, the NAS is transitioning to TBO, an air traffic management method to strategically plan, manage, and optimize flights throughout the operation by using time-based management, information exchange between air and ground systems, and the aircraft's ability to fly precise paths in time and space. The uptake of new avionics through replacement with new aircraft over time and the alternatives provided by connected aircraft will increase the number of aircraft capable of the information requirements to participate in TBO. TBO improves the strategic planning of flights through improved estimates of the aircraft's four-dimensional trajectory (altitude, latitude, longitude, and time), which provides a common planning reference that can be shared across systems. Reduced uncertainty improves trajectories. With improved trajectories, the system state can also be better known, allowing decisions to deliver improved performance. Vehicles using xTM services in designated airspace will operate in an environment without direct ATC involvement, using their trajectories to cooperatively separate based on FAA rules, regulations, and approved standards that include consideration of equity, access, and competition. Data standards and processes established for TBO will be leveraged and extended as necessary.
- **Conflict Management:** Information exchange improves strategic planning which reduces the need for tactical intervention for conflict avoidance. In an environment relying on ATC services, this will reduce, but not eliminate, the need for tactical resolutions developed manually and delivered by voice. In other environments, cooperative separation will be applied in accordance with tailored flight rules (TaFR) and applicable performance-based standards.
- **Market Balancing:** Better and shared information on the present and forecast system status will allow all decision-makers to optimize their own performance while considering the state of the system. Decisions can be shifted to the stakeholders with the best knowledge of their performance objectives within established rules for the airspace. These rules, which ensure individual performance objectives are not to the detriment of the overall ATM system performance, need to be grounded in DOT competition policy and supported by FAA regulations, standards, means of compliance, and qualification of services for this more federated environment.

Building Upon A NextGen Foundation

Investments by the FAA and the aviation community in NextGen technologies deliver benefits to the NAS and operators. Investments in Performance-Based Navigation, Automatic Dependent Surveillance–Broadcast, air-ground data communications, automation infrastructure, decision support systems, and data sharing are steadily being deployed to form a mature ATM system that delivers benefits in efficiency, predictability, capacity, access, and for the environment, and contributes to the safest means of transport available.

New capabilities will continue to be deployed under NextGen. The transition to full TBO will further provide for efficient and predictable operations while maintaining operational flexibility. Additional improvements in information, precise satellite navigation, ground-based automation, and aircraft systems, among many others, provide the foundation for this transitional stage.

NextGen provides NAS users with access to improved information through System Wide Information Management (SWIM) and standardized information exchange models that improve interoperability. A common operational picture of the NAS will be available through shared weather, flight, traffic flow, aeronautical, and surveillance information. The connected aircraft allow full participation in SWIM while airborne and will provide a necessary starting point for ubiquitous information sharing with the flight deck. This shared information can then be used by either the flight deck or ground-based automation systems to improve planning.

Flight operators and traffic managers will collaborate on a common plan across multiple ground and airborne systems. NextGen will provide the ability to collaboratively plan, monitor, control, and deliver a precise trajectory by leveraging flight deck capabilities such as satellite navigation and controller pilot data link communications. These will provide an indispensable foundation for the integration of new operations using the trajectory as a basis.

Through NextGen, the FAA has been taking steps toward the initial accommodation of new entrants. Low-altitude UAS operations within the pilot's visual line of sight are currently permitted. UAS traffic predominantly remains segregated from manned flights. For airspace access, UAS operators are required to obtain an airspace authorization before operating beyond visual line of sight in Class B, C, and D airspace. Innovative methods will be needed to scale to the projected demand for these operations in the future.

A community-based traffic management system for low-altitude UAS, known as UTM, is evolving. With UTM, operators and entities are responsible for coordinating, executing, and managing operations under the FAA's regulatory framework. Early demonstrations of UTM support small package delivery operations. Building on the isolated new entrant operations depicted in Figure 3, the system is poised to integrate and adapt with an evolution of capabilities provided by operators and third parties. NextGen technologies, especially information exchange, provide a foundation to incorporate an increasing number of new entrants.

New automation, procedures, information sharing, sensors, and communication applications enable traffic managers, controllers, and operators to respond to off-nominal events in near real-time. Improvements in the timely management of special activity airspace in domestic and oceanic airspace will help protect aircraft from entering airspace where space launches or reentries would potentially pose a hazard.

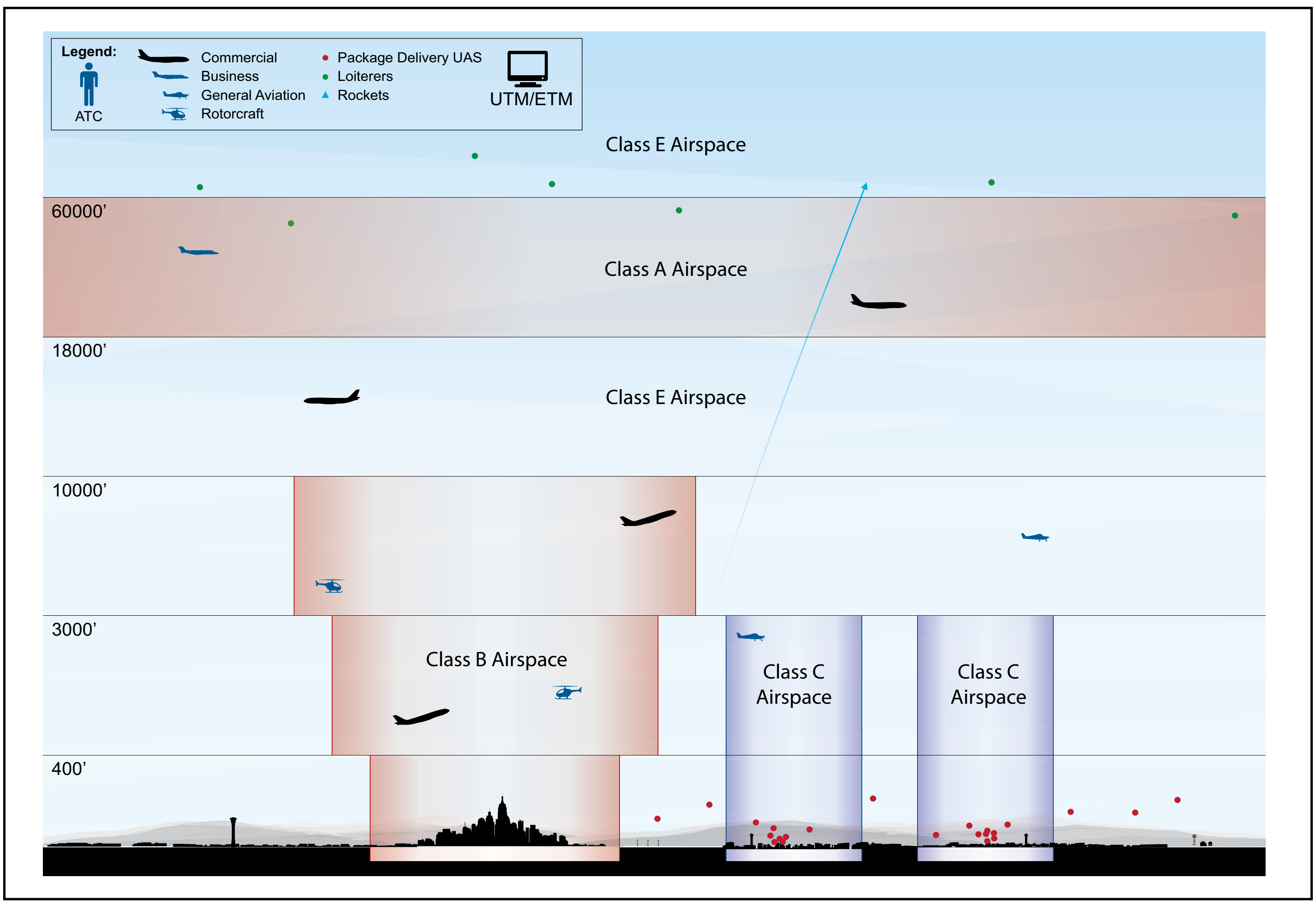


Figure 3 - The NextGen operational view with limited accommodation of new entrants.

Future Of Air Traffic Management

PRINCIPLES

The evolving NAS will be built around a combination of existing and modernized principles:

- Maintaining and improving safety, security, and resiliency
- Collaborating with affected stakeholders (e.g., operators and service suppliers) to develop:
  - Operating practices for interactions with and between new entrants, from strategic planning through tactical operation, balancing airspace user and system objectives
  - New methods to provide appropriate access to the NAS, enabling new and existing missions
- Distributing decision making to enable stakeholders to best meet their objectives
- Incorporating performance-based standards throughout the enterprise
- Leveraging partnerships with the private industry and their managed services to achieve economic viability and provide resiliency
- Building in scalability to rapidly expand capabilities to meet operational challenges
- Ensuring adaptability and agility to keep pace with unanticipated changes

OVERVIEW

The vision for the future NAS addresses the key drivers of change in a manner that respects the above aviation principles while taking advantage of opportunities presented by innovation and societal change. The vision is described through attributes of fundamental changes in three key areas: operations, supporting infrastructure, and integrated safety management.

1. **Operations** in this transformed NAS will be characterized by collaboration among and within diverse traffic management services, enabling the increased variety and number of new vehicles, missions, and operations. This collaboration will be made possible through a fully integrated information regime with interoperable sharing of information. This will be leveraged to accurately estimate the current state and confidently predict the future state of the NAS. This confidence can provide for precise individual operations supporting more fuel-efficient and noise-optimal execution. Increased agility in systems and services will allow the NAS to adapt as needs evolve in unanticipated ways.

2. **Infrastructure** will increasingly leverage commercial assets, services, and new technologies to support operations across diverse traffic management services. This public and private infrastructure will deliver traffic management services that are ubiquitous, resilient to unanticipated changes, and agile to respond to future user needs. With the help of machine learning and artificial intelligence techniques, the workforce will be more adaptable and flexible in off-nominal conditions, such as temporary facility shut-downs. Where necessary, public performance standards will be established to help ensure any unique government requirements can be met for any commercial services and technologies being used.

3. **Integrated safety management** for traffic management will establish tailored standards, flight rules, and services to achieve acceptable safety based on operational characteristics. With big data, the NAS will assure in-time safety through continuous monitoring, modeling, and verification to detect anomalies and notify participants using established procedures to correct real-time spikes in risk.

   A more robust, comprehensive, and data-driven safety management system (SMS) will incorporate quantitative elements and will require each operator, ATS, and xTM service supplier to account for interoperability across a variety of new interactions. These interactions will include public versus private services, air versus ground systems, and automated versus manual control functions, all supporting increased diversity of operations.

OPERATIONS

A significant increase in the variety of airborne vehicles, missions, and operations wishing to operate from surface to space is beginning to materialize. The FAA projects[1] that these diverse new entrants will represent substantial economic value. For the U.S. economy to realize the projected economic value, the NAS must affordably provide access to this variety while providing improved performance to conventional operations. Beyond economic value, these new airborne vehicles and technologies are being applied to fulfill changing national security missions.

Providing access involves being able to ensure new entrants can routinely operate in the NAS in large numbers without requiring unique dispensation. This does not imply full integration within ATS for all operations. Rather, planning will segregate operations to allow the simultaneous co-existence and interoperability of diverse collaborating traffic management services with conventional ATS. These new services are expected to cost-effectively enable these future operations. Achieving such interoperability will require common interactions made possible by a fully integrated information regime. Further, the amount of information provided in such an environment will require agile systems and services that are affordable and on pace with economic drivers to support decision-making for all ATM services.

Collaboration Among Diverse Service Providers

New traffic management services (referred to as xTM in this document) will address the operation of select new entrants within airspace that is flexibly allocated. Examples include services for UTM and Upper Class E Traffic Management (ETM) that

[1] Ref: The Economic Impact of Civil Aviation on the U.S. Economy, January 2020 (faa.gov/about/plans_reports/media/2020_jan_economic_impact_report.pdf)

provide for operations in certain volumes without the need to engage with traditional ATS. New xTM services will manage operations for entrants with differences in performance expectations compared to operations using traditional ATS. Highly automated and third party-managed xTM services will apply commercial practices to safely scale service growth in line with demand.

New traffic management services will address the operation of select new entrants.

Future air traffic services will continue to support the current base of airspace users and will interoperate with xTM services. Airspace will be allocated in accordance with established access criteria. These access criteria for shared resources (e.g., airspace and aerodromes) and associated airspace structures will be collaboratively defined across a diverse set of participants within an FAA-established regulatory framework. Methods and criteria for interactions between the xTM services also will be developed in a collaborative fashion, and supported and enforced through information, systems, services, and procedures. Operations will not be limited to the use of one xTM system, or infrastructure, for the entire duration of the flight (e.g., a flight may operate using ATS, switch to ETM, and back to ATS).

ATM suppliers will deliver services tailored to operator needs across a broad spectrum of users. The airspace will be joint-use where possible, employing flight rules, including new TaFR, that provide appropriate risk to each party. Flexibly allocated airspace structures (e.g., using a mesh of available routes and scheduling windows) will be applied only where needed to safely manage risk. Flight rules will account for a diversity of operations, environmental considerations, and vehicle attributes, such as the level of autonomy.

Planning functions will coordinate between ATM services to ensure well-organized operations. These will be organized to ensure operations under xTM allow ATS to deliver tactical functions without having to consider individual operations using xTM services. This independence will allow interoperation without imposing a burden on ATC services, enabling affordable scalability of xTM operations.

As depicted in Figure 4, the vision is a more adaptable future where different types of operations are more flexibly authorized across airspace classes. For example, large cargo RPAS will be operating in what is today Class A airspace. When operating using ATS, these vehicles will remain visible to ATC and follow applicable procedures. Control might also include various degrees of autonomy, from remotely piloted to fully autonomous with an interface to ATC.

Fully Integrated Information Environment

Collaboration among diverse traffic management services and the integration of their operations will be made possible through a fully integrated information environment. At a minimum, this will involve acquiring and sharing position data and some level of intent data for most vehicles. The full integration of information will allow decision-making to be shifted to the most appropriate participants.

Under the fully integrated information environment, decision making will be distributed optimally, not restricted by access to information.

This will enable interacting, distributed decisions to be made in real-time with better information. This integration will allow migration toward dynamic information services (e.g., aeronautical and flight), providing changes when needed for all operations. Consumers of shared information will be aware of the quality of the information being provided, including uncertainty. Information services will be provided with different, but known, performance attributes (e.g., latency and accuracy) appropriate to the given operation. Performance attributes of individual operations will also be known to ensure that performance standards for the desired operation are met.

The exchange of such information will inform a continuous planning process. During this process, operations using ATM services will be organized and dynamically segregated subject to established access and interaction criteria. With full TBO, a trajectory-based continuous planning process with extensive information exchange will already be in place for controlled flights using ATS. The trajectory-based ATS planning process will be extended to incorporate airspace organization and flow planning required to support xTM operations in accordance with established methods.

The integration of exchanged information will enable decisions to be made collaboratively, with full knowledge of the decisions made by other parties. The structure and allocation of decision-making will occur organizationally, spatially, and temporally, and will change dynamically to improve performance outcomes. Changes will be in response to operational circumstances, supported by ongoing data analytics and constrained by rules of engagement.

The information management approach will allow multiple parties conducting advanced data analytics to use voluminous amounts of historical data. These data and analytics will be applied toward continually learning and evolving systems and services, driving performance improvements across all systems and individual operations.

Agile Systems and Services

The monolithic automation systems of the past will migrate to be composed of learning, adaptable, and lightweight interacting systems delivering scalable, distributed applications, or microservices through a combination of private and public entities. In such an architecture, safety-critical services will be provided in a small, stable core, while all other services will be provided through a combined public-private microservices architecture that will evolve on pace with economic needs.

> *Gone will be the monolithic automation systems of the past.*

Advances in machine learning, artificial intelligence, and analytics, coupled with abundant observed data, will enable systems to continually refine predictive models supporting decision-making. With more and more data, these models will become increasingly tailored to the specific operation and circumstance being addressed. With increased information and advanced data analytics, the current state and predictions of the future state of

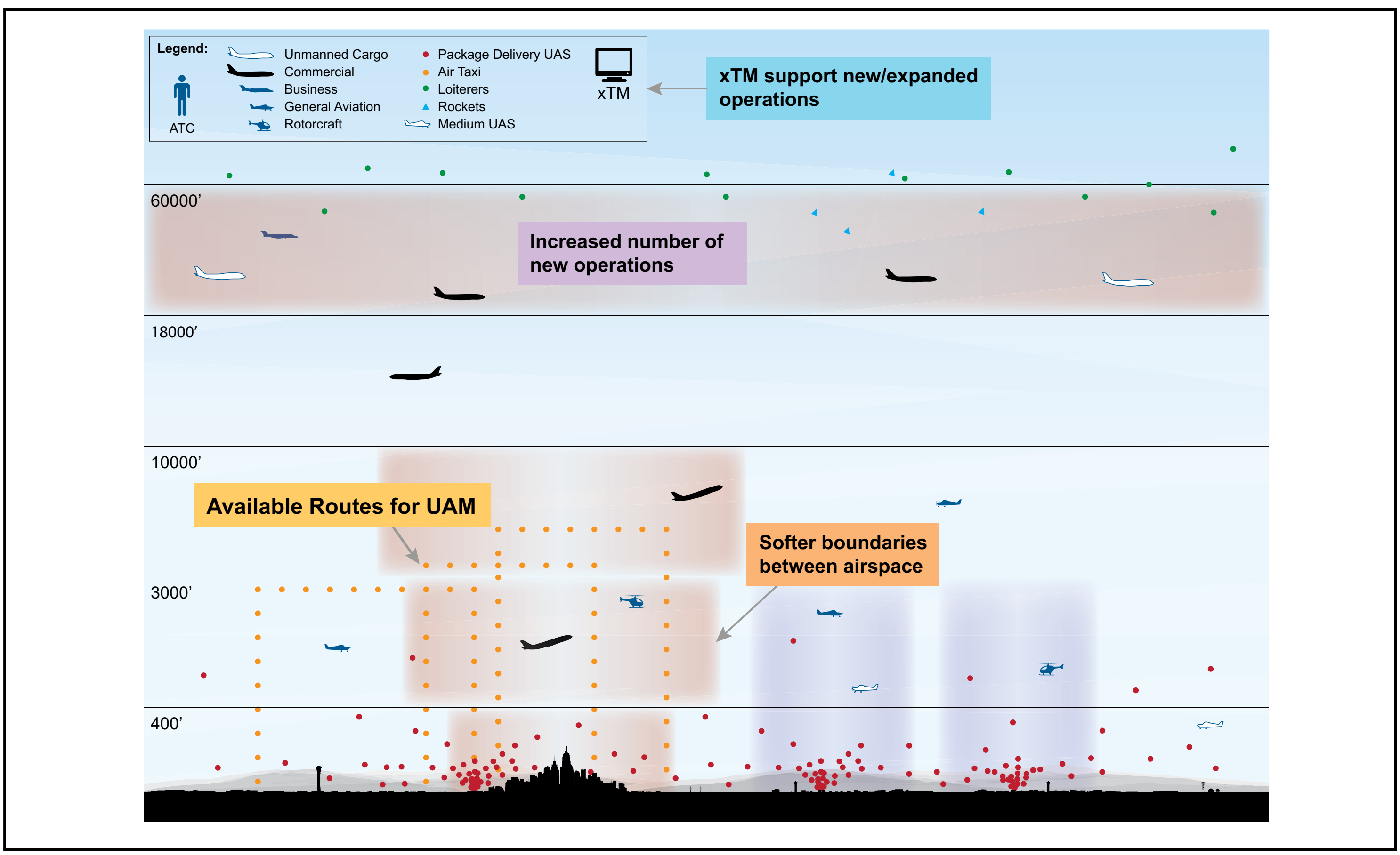


Figure 4 - Diverse collaborating traffic management services in joint use airspace with mature UAS operations.

the NAS will be more accurate. Decision-making will be able to apply interacting predictive models using this improved information to rapidly evaluate a variety of choices against performance objectives. Quality of information, including uncertainty, will be incorporated into predictive models, allowing performance outcomes to manage the effect of uncertainty and improved predictability.

The continuous planning process across ATM will occur through system-to-system interactions made possible through pre-defined operating rules and the fully integrated information environment. In such an environment, humans guide the objectives, while automation processes information and makes recommendations to assist in reaching solutions best meeting the objectives.

INFRASTRUCTURE

Today, advances in network infrastructure technologies are being deployed by industry and applied by commercial providers to deliver telecommunications services to a wide range of users, including aviation. This infrastructure already provides nearly ubiquitous coverage with enhanced reliability, availability, and security and evolves on pace with technology.

The transformed NAS will leverage this commercial infrastructure and applications that meet performance requirements to deliver services everywhere, always, and securely. Taking advantage of the diversity of offerings will allow the NAS to become more resilient. In doing so, shared infrastructure will evolve on pace with technology based on the commercial marketplace's requirements.

Ubiquitous Services

Advances in communications technology will offer the aviation community a broader range of alternatives for the next generation of aviation information exchange. The major telecommunications carriers will have completed their transition to the next-generation network, which will fully converge on the use of Internet protocol (IP) for supporting services at all performance levels. Another major aspect of the telecommunications revolution will be the move from wired access infrastructure to high-performance terrestrial wireless services when performance needs can be met. Increased use of software-defined networks will enable more provisioning and policy-based management of network resources. These advances will collectively enable secure, reliable, and ubiquitous information sharing with vehicles and service suppliers from anywhere.

No gaps: Infrastructure will deliver needed services everywhere, always, securely.

Terrestrial wireless services will have evolved to the Nth generation[2]. Most wireless access connections will be implemented with Nth-generation services. These wireless services will offer the bandwidth, reliability, and quality of service that today is delivered by wired access, enabling networks used for ATM applications to provide continuous connectivity to mobile aviation applications. These commercially available networks and associated services will provide service coverage across the continental United States (CONUS) for traditional and uncrewed aircraft altitudes.

Adding to the communications considerations for aviation will be the deployment of vast constellations of low-Earth orbit (LEO) satellites. Communications services offered by LEO satellite providers will rival terrestrial wireless and provide an entirely separate communications medium for aviation to consider. If these technologies meet required performance levels, they could provide an acceptably diverse medium to augment terrestrial wireless coverage in the CONUS while providing service to oceanic and other relevant domains in combination with other platforms.

Commercial services, infrastructure, and technologies will be leveraged to the maximum extent possible. Quality of service appropriate for the required performance level will enable the cost-effective use of this diverse infrastructure provision for aviation.

Customer network security will use a zero-trust model that will interoperate with an international trust framework to enable the use of fully defined information assurance controls and credential management for aviation, which will allow secure

[2] Nth generation represents whatever level wireless communications has evolved to in the subject timeframe.

information transfer across international and domestic security boundaries.

Data supporting operations and analysis will be available through scalable, access-managed common data services. As the industry evolves, the FAA-managed physical infrastructure will be introduced, expanded, or changed as needed to better align with information technology marketplace trends.

System Resiliency

The real-time management of diverse infrastructure, possibly delivered by different service suppliers, will allow for increased resiliency across communications, navigation, surveillance (CNS), and automation systems. While connected, native IP applications will reconfigure, as appropriate, in response to operational or infrastructure-related contingencies such as the loss of a major facility. In the case of the latter, it will be possible for adjacent or backup facilities to be readily connected to remote assets or service suppliers. That capability will allow the seamless handover of airspace control between facilities following established operational contingency plans. Traditional roadblocks to reconfigurability, such as dedicated hub-and-spoke voice communications architecture, will have been replaced by any-to-any connectivity with all voice communications assets and providers. This flexible connectivity will extend to data communications. Full information on communications services and infrastructure status will be immediately available to authorized personnel.

> *Leveraging multi-purpose commercial infrastructure will provide a more resilient, cost-effective NAS.*

Full network management and operations capabilities can be implemented in a distributed manner with the support of mobile devices, eliminating the need for costly, large-scale dedicated control centers. Each CNS component will have robust backup systems that allow for nearly seamless operation during outage events and provide safety mechanisms against cyber threats and misconfiguration.

High-accuracy positioning, navigation, and timing (PNT) is provided through a global navigation satellite system (GNSS). A second form of PNT allows for normal operations to continue when the GNSS is unavailable. A nationwide backup timing infrastructure allows for ground and airborne systems to remain fully synchronized. The exact performance standards required of a complementary PNT capability will depend on expectations of the targeted operations it supports. Policies and procedures will evolve to allow for these complementary PNT systems to be fully embraced by all parties.

Technologies that make automation services and network infrastructure more capable can also make those services more resilient and efficient. Network overlays allow data traffic to be reconfigured to respond to real-time changes in network status, demand, or security status. Cloud-related technologies allow automation services to scale dynamically in response to added workload or component failure. Advances in artificial intelligence will enable continuous monitoring of status, together with projections of response, to respond to failures or demand spikes with or without human intervention. Similarly, machine-learning approaches will enable effective prediction of potential failures, demand, and preventive maintenance application. Service overlaps will enable the required resilience and cost-effective application of operations and maintenance policies. In many circumstances, a specific outage will not diminish operational capability because of available redundancies, allowing maintenance to be scheduled for greater efficiency.

System Evolves On-Pace with Technology

Commercial services, infrastructure, and technologies will be leveraged in key industries. Public-private partnerships will make contracting possible for managed services in enterprise capabilities, such as communications, aeronautical information, and weather services. Beyond managed services, commercial services and infrastructure that meet necessary requirements may be fully leveraged for aviation applications. These evolving infrastructure needs include physical infrastructure, such as airport infrastructure, vertiports, heliports, and remote sites. The use of shared infrastructure and services will allow both to evolve on pace with technology and the commercial markets in accordance with the needs of the most demanding users or suppliers.

Shared infrastructure and services will evolve on pace with technology and the needs of the expanding list of users or providers.

Technology developments will enable the FAA to envision and pursue new automation architectures. A prominent element is the increasing integration of cloud services for automation and decision support. Methods to create secure zones that separate workloads and secure them individually are critical components of the network architecture. For example, micro-segmentation and edge security protect data that resides or moves through devices away from centralized data centers or cloud environments. These capabilities will support logical partitioning of information flows that will allow cloud implementation of non-safety-critical applications to meet the federal high-level security standards[3]. Cloud services and other shared-use infrastructure will enable the FAA to better keep pace with technology developments. An application framework and standardized infrastructure services will enable more discrete and competitive acquisition, as well as the development of applications and services that can be more readily integrated than today.

Initiatives, such as IoT and system solutions for autonomous vehicles, will fuel research into advanced concepts. One example is edge computing, which brings processing close to the data source to support timely decision-making and execution by the autonomous systems. Continued progress in reducing the size and increasing the density/complexity of electronic hardware will support these concepts. These technological developments will enable a shift to a distributed decision-making paradigm, with many decisions being made locally using the capabilities afforded by the new technologies, rather than the centrally based approach seen in the system today.

INTEGRATED SAFETY MANAGEMENT

This transformed NAS will continue to rely on a layered approach to safety controls with a greater reliance on data and emphasis on risks introduced by the integration of distributed and diverse systems. The FAA is accountable for establishing the performance expectations and operating rules for how separation and navigation services are designed and delivered by the xTM in each airspace class. The design assurance will address how ATS and the xTM service suppliers maintain interoperability. The SMS for each service supplier and major operator will detail how they integrate, adapt, and manage their operations and role, enabling the collective xTM air operations to work as designed.

Safety-critical performance indicators will be monitored to support airworthiness, detect operational emergencies, and evaluate information assurance. Operational safety analyses will identify trends or conditions for prognostic evaluations. These analyses will provide feedback, correct issues at system boundaries, and adapt the overall system to shifting risks or environments.

New entrants will introduce additional dimensions to the traditional role of ATM. They will employ user management and control information to:

- Determine and manage risk
- Enable interoperability across air vehicle operations with diverse performance and mission requirements

Beyond the enhancements for management of the integrated system, the three specific changes to integrated safety management are tailored safety processes, interoperability, and in-time safety assurance.

Tailored Safety Processes

Diversity in the future NAS will require accounting for differences in the safety performance expectations from all associated interacting elements (e.g., systems, services, and infrastructure). This will be achieved by tailoring standards, flight rules, and services to meet the needs of operations in all airspace.

[3] Standards under the Federal Information Security Management Act are already available in Amazon Web Services GovCloud U.S. Region, (aws.amazon.com/compliance/fedramp).

Performance-based standards will be defined to ensure suitable end-to-end performance across CNS applications delivered by public and private entities. Compliance with these standards will be assured through the FAA's regulatory framework with a certification, approval, and oversight process, and delegated authority where applicable.

Standards, flight rules, and services will be tailored to meet the needs of diverse operations in all airspace.

As the application of these standards will depend on operational circumstances, criteria must be defined for suitable performance levels meeting various operational needs. These criteria must consider that the end-to-end performance will be met through the combined use of multiple technologies and public-private infrastructure with varying performance levels. In the transformed NAS, much of the airspace will require position reporting from operations, and non-reporting visual flight rules (VFR) aircraft will require authorization to operate in high-density airspace where necessary to ensure safety is maintained. VFR will continue to place the responsibility for see/detect and avoid (DAA) on the operator. While nearly all users in the NAS will be connected, operations with aircraft that do not provide position information must be considered. VFR aircraft will monitor and execute avoidance maneuvers, if necessary, when they detect traffic for which intent and position are unknown.

At a minimum, collaboration between xTMs will involve sharing position data to enhance the ability to detect all traffic, including nearby VFR aircraft. This information may inform DAA systems, much like traffic advisories inform VFR pilots today. Other safety services, such as alerts, traffic advisories, and limited navigation assistance, can be provided by xTM when requested by the flight. Collaboration and safety services will be essential to adjusting flows in mixed-use airspace, such as UAS in the vicinity of airports serving traditional aircraft. These advanced traffic information services will improve conflict management over that of VFR aircraft alone.

Beyond VFR and instrument flight rules (IFR), new TaFR will be defined to account for the new operations and service delivery. TaFR will support cooperative separation possibly through shared intent data, performance envelopes, proposed resolutions, and constraints. This information will allow xTM suppliers to provide strategic traffic advisories with which flights can then tactically self-separate as a DAA procedure under TaFR. These concepts are like advanced collision avoidance systems with knowledge of the other aircraft's intent. ATC will continue to provide all traditional IFR separation services for traditional and uncrewed aircraft.

A variation of this is joint-use airspace (e.g., upper Class E airspace) where operations are sharing information at different levels, including those not sharing at all and operating via a "due regard"[4] principle. Those with service suppliers will have the benefit of strategic separation with all reporting traffic. However, tactical resolution will be left for the flight operators following flight rules applicable to their capability, the separation timing, and performance envelopes. The flights operating "due regard" will detect all other traffic directly or through their service supplier and follow TaFR procedures to remain separated. These advanced traffic information services will provide operators the means to self-assure separation. A variety of xTM service suppliers, DAA, navigation, and flight control systems will be used by flights to comply with defined flight rules. The system certification can then focus on meeting performance standards and ensuring service suppliers and systems comply with the relevant flight rules associated with separation assurance and other navigation services.

Interoperability

The service supplier SMS will ensure safe interoperability with its operators and other service suppliers, including any changes to their products and services. Each operation will follow specific flight rules that state how flights must respond to situations. How an operator complies with the rule (e.g., use of DAA or strategic conflict resolution) may differ from operator to operator or between xTM suppliers. However, these methods must be

[4] See FAA Order 7110.65Y, General Terms of Reference "o" for definition. (faa.gov/air_traffic/publications/atpubs/atc_html/chap1_section_2.html)

interoperable, with the key being the information sharing and information assurance that will support the flight rules. Interoperability depends on those information assurance standards, which must consider the many interactions of public and private services, air and ground systems, and automated and manual control functions that support the diversity of operations. Performance-based and interoperability standards are stated for common components.

Diverse services will interoperate safely.

Another level of interoperability is implied by the diversification of service delivery organizations. Each organization—operator, service supplier, and manufacturer—will address interoperability within its SMS. These processes must consider the implications for the effectiveness of assurance processes and interdependent system mitigations. Interoperability will be defined either in operational specifications for interdependent practices/procedures, or reliance on the conventional air traffic or xTM services. New standards for developmental assurance will help to detect incompatibility between interoperating systems early in the development and integration process. Such standards will include software development and update practices, regression practices, and system configuration management. Agile updates across applications will add compatibility checking, especially at the boundaries between systems. As an additional safety layer, health monitoring and in-time safety systems will find interoperability issues that escape other safety layers.

In-Time Safety Assurance

The NAS will promote in-time safety through continuous monitoring, modeling, and verification to detect anomalies and alerts for real-time changes in risk. Supported by models and live data, the risk in the system is continuously affected by airspace, service supplier, individual flight, or high-concern hazards. Prognostic models will project potential unsafe conditions and alert the aircraft operator, flight deck, or service suppliers, as appropriate. With health monitoring and real-time risk modeling for undesirable flight conditions, more operators will have advanced indications of state changes that would indicate the need to deviate from the intent before a situation becomes an emergency. Such models should work for risks that arise from nominal behavior pushing outside the safe operating envelope.

Continuous modeling, monitoring, and verification will provide in-time safety assurance and alerting.

Multiple systems and regimes will cooperate. Data will be available from multiple sources on board many aircraft, including surveillance of surrounding aircraft. This will be based on a continuous joint process of verifying live data from multiple sources. Monitoring of all means of independent information will be used to confirm data integrity in near real-time.

The other major risk that will be monitored in real-time is the complexity arising from anomalous operations (e.g., emergencies and non-compliant aircraft). In these cases, models can no longer extrapolate trajectories or assume flights behave according to flight rules. Monitoring must detect such anomalies and model the new range of risk (based on the likelihood of different flight behaviors going forward), predicting where other aircraft might be at greatest risk. Similarly, constant change in components and the use of learning systems and outside service data as extensions of the system mean real-time conditions will arise that could not have been planned for or tested. Information assurance monitoring must also detect these anomalous behaviors.

Post-operation modeling can reconstruct unsafe conditions or anomalies and support causal analysis. This type of continuous auditing and monitoring will inform emerging hazard identification and corrective actions. As an additional layer of in-time safety assurance, this continuous monitoring will highlight shifts in key performance areas that will allow an operational response to the current risk level. The results will be fed back into the system design assurance and standards for components and interoperability.

Guiding Aviation's Future Evolution

Attaining an outcome of collaborating traffic management across diverse participants requires a collaborative beginning. The projected diversity and its evolution must be understood through communication and coordination of plans, projections, and initial concepts by all stakeholders. These provide input to the airspace regulator to ensure timely readiness of required integrated safety management processes.

On its own, this process is not enough for convergence since vehicles, operations, infrastructure, or service delivery could potentially develop along different courses. The FAA will evolve the NAS along with industry's pace, directed by business requirements, and within a safety risk management system framework. In this process, the role of the human will not change, but the information evolution allows increased use of digital assistance to support enhanced performance. Therefore, the role of this vision document and its principles is to guide the emerging architecture, including its human components, and detect architecture and detect incompatibilities so that stakeholders can work to resolve issues. Stakeholders, including the FAA as the existing ATS provider and aviation safety authority, must work together to ensure concepts are compatible, access criteria are negotiated, available infrastructure is leveraged, and information standards are developed in a timely manner. Working together, all stakeholders can evolve to the vision and usher in a future era of growth in aviation. This vision is the first step and provides the objectives for a new unified concept across all types of operations and an expanded Enterprise Architecture, leveraging innovation and information to accelerate the evolution of the NAS.

Moving Forward

This vision focuses on enhancement rather than replacement of the current system by utilizing innovation to provide a national airspace system that leverages the innovation in information to both communications as well as the application layers of the aviation community. The existing system of voice and data will remain for both safety, and to support basic operations for the wide variety of participants in the airspace, which includes over 100,000 registered commercial and general aviation aircraft. There are great opportunities to augment the service to the existing operators and fleet, and to support the evolving and developing needs of new entrants. The realization of these improvements will require a real engagement of all parts of the nation's industrial base extending beyond the traditional aviation partners.

Information networks and communication

In keeping with the ICAO goal of a Globally Resilient Aviation Interoperable Network, the FAA will work with its internet providers including the satellite and broadband communication industry to work to achieve connectivity throughout the airspace, in all altitudes and regions, especially locations where there will be a high concentration of operations of the airspace. The aviation network needs to support zero-trust principles for information exchanges that include message security and integrity, especially for safety-related data. The performance of exchanges across the network needs to be tailored so that applications that require low latency safety-critical information exchanges can be supported. The zero-trust environment also ensures that authenticated users only gain access to the information for which they are authorized supporting role-based control on dissemination.

The aviation spectrum will still be the primary means of exchange of safety of flight information. With the rise of new entrants, an increased need for frequencies to meet their operational needs may be required. The community needs to work together to use the emergence of alternative paths of communication between air and ground for off-loading of more routine data exchanges from the already allocated aviation spectrum. This will allow more efficient interchanges and support the higher data needs for modern operations. The aviation community both domestic and international will need to work together to assure harmonized approaches to performance-based communication requirements for both aviation and shared spectrum uses.

Performance-Based Infrastructure

The introduction of federated air traffic management services and aircraft that operate with complete reliance on the quality of supplied communication, navigation and surveillance data will require levels of coordination and automation that are not seen in the NAS of today. How these systems come together and the safety, economic, environmental, and equitable responsibilities of the different participants will need to be well understood. Examples include:

- The system of system architecture requirements maintain separately managed but integrated air traffic management capabilities.
- An oversight system that correctly assigns safety of flight responsibilities and provides continual operational surveillance of those critical participants and components.
- Advanced, deterministic modeling and testing capabilities, operating off shared standards to ensure the validity of results, for the safe integration of systems.
- Agile certification standards for software development, updates, and system configuration.
- Distinction of safety-critical from ancillary services and the level of certification applied along this scale.
- Certification schemes that account for machine learning and context-based programming.
- Testing of automated processes designed to safely integrate air traffic while adhering to efficiency and equity/competition standards.
- Human/machine interfaces that allow for near-instant recognition of machine behavior and intended reactions.
- The need for redundancy and resiliency for safety-critical data.
- Communication protocols for any-to-any connected ATS.
- Development of reliable source(s) of PNT information to supplement GNSS.

Air Traffic Management

New airspace and procedural constructs will be needed to support advanced air traffic management operations. This will be established by working with the industry as UTM is developed to define methods and standards. This will lead to the determination of the need for new rules and new aircraft capabilities. It is clear that in all environments ATM will be based on the rapid exchange of information with FAA, but especially among operators. Facilitating the needed information exchanges for precision performance will include development of performance parameters and potential “equipage” for the fully integrated information environment complete with shared, dynamic position and intent data.

- This changing traffic management environment requires rules of the air that work for all airspaces, and all aircraft that may need access to that airspace.
- The FAA will not delegate the airspace to a third-party provider. Rather it will be based on a concept of operator shared cooperation similar to the concept we are currently developing for UTM rule by rule.
- New entrants operators will need to meet the requirements for the transit through

the current class of airspace and the existing VFR and IFR to reach these new structures and operations, or continue to engage with ATC to support the transit. The new operations must occur in a manner that allows easy discrimination from current operations to support pilots and controllers executing normal operations.

- There will be third-party service suppliers support for many of the operators. In the envisioned cooperative management environment, this may include direct support to operators' real-time decision making and may be coupled with establishing the required performance for, and regulation of, that third-party support.
- As with any change to the national airspace, safety management assessments associated with the new operations needs to be conducted and a safety management system needs to be established.
- Each potential cooperative airspace environment will include autonomous vehicles, so procedures and technologies need to be developed for the integration of autonomous aircraft operations with ATS.
- Finally, any of these cooperative traffic management environments will need to consider fuel efficiency, noise acceptability, and technology compatibility standards for automated, autonomous, and specialty class aircraft.

In-Time Safety

When developed, the automation of highly coordinated system-level safety assurance from each participating aircraft, along with ubiquitous data streams, have the potential to revolutionize aviation safety and efficiency. Through data analytics, nominal and off-nominal operational states can be developed allowing for expanded in-time safety alerts/actions in both aircraft operations and ATC. Consideration of the use of these AI/Ml capabilities as the advisory or automated response will require policies, standards, and a basis of certification for use to ensure the intended use meets the intended goals and does not introduce unforeseen safety risks.

Acronyms

ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
AWS	Amazon Web Services
CNS	Communication, Navigation, and Surveillance
CONUS	Continental United States
DAA	Detect and Avoid
Data Comm	Data Communications
ETM	Upper Class E Traffic Management
GNSS	Global Navigation Satellite System
IFR	Instrument Flight Rules
IoT	Internet of Things
IP	Internet Protocol
LEO	Low-Earth Orbit
NAS	National Airspace System
NextGen	Next Generation Air Transportation System
PNT	Positioning, Navigation, and Timing
RPAS	Remotely Piloted Aircraft Systems
SMS	Safety Management System
SWIM	System Wide Information Management
TaFR	Tailored Flight Rules
TBO	Trajectory Based Operations
TFM	Traffic Flow Management
UAM	Urban Air Mobility
UAS	Unmanned Aircraft Systems
UTM	UAS Traffic Management
VFR	Visual Flight Rules
xTM	Extensible Traffic Management

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