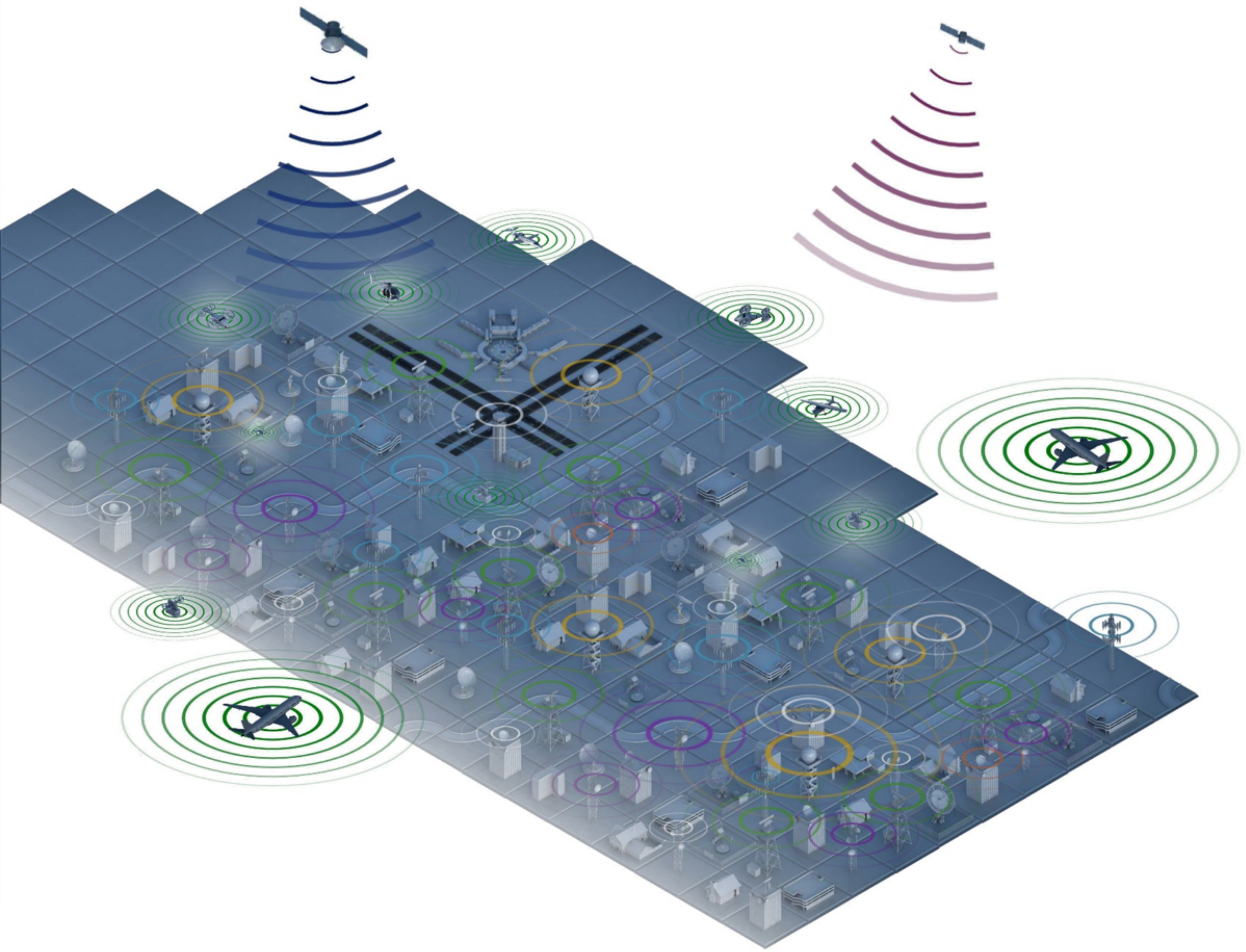
Initial Concept of Operations for an Info-Centric National Airspace System



FAA Office of NextGen

ICN INFO-CENTRIC NATIONAL AIRSPACE SYSTEM

December 2022

Acknowledgments

Mitre CAASD was responsible for the development of earlier drafts of this documents as well as the scenarios contained in this document.

The development of this document was enhanced thanks to collaboration with various organizations and individuals within the Federal Aviation Administration (FAA). Within ANG, inputs from groups working on lower level concepts for UAS Traffic Management, Urban Air Mobility, Upper Class E Traffic management, and Performance Based Flow Management were instrumental in developing and reviewing material that contributed to the development of this document.

Major concept elements and scenarios were vetted with key individuals from organizations across the FAA during discussions held in November and December 2020. The feedback received during these review sessions are incorporated into this document. The following FAA organizations participated in these sessions and their feedback was instrumental in the development of this document:

- Office of NextGen (ANG-2/3/B/C/E)
- Unmanned Aircraft Systems (AUS)
- Air Traffic Services (AJT)
- System Operations (AJR)
- Flight Standards Services (AFS)
- Airports (ARP)
- Mission Support Strategy (AJV-S)
- ATO Program Management Organization (AJM)
- Office of Air Traffic Oversight (AOV)
- Safety and Technical Training (AJI)

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1 Introduction

1.1 Document Scope and Intended Use

This *Initial Concept of Operations for an Info-Centric National Airspace System (NAS)* is informed by the Federal Aviation Administration's (FAA) draft vision document, *Charting Aviation's Future: Operations in an Info-Centric National Airspace System* [1]. This concept describes future operations in the NAS, with initial capabilities expected to be operational by approximately 2035. It provides a high level description of the integrated future environment.

The Info-Centric NAS Concept of Operations (ConOps) is the Level 1 concept for the enterprise in accordance with the FAA's Operational Concept Hierarchy [2]. As such, it is broad in scope and describes NAS operations in general terms, serving as the frame of reference for lower-level concepts. As an enterprise level concept, this document provides a description of future operations that aims to be neutral regarding specific technologies and solutions.

This document is expected to be used by NAS stakeholders as a framework to use for the development of lower level ConOps that provide more specific details regarding services, solutions, and capabilities as well as research and development planning. As they are developed, lower level ConOps will trace to this *Initial Concept of Operations for an Info-Centric NAS* to ensure that they account for future interactions between other new services and capabilities. Readers both internal and external to the FAA, particularly researchers and concept developers, will use this document to understand future NAS operations and the enterprise context of the future environment, operations, participants, and their interactions. The ConOps will facilitate alignment, consistency, interoperability, and technology integration across the NAS.

1.2 Background

The future Info-Centric NAS seeks to address anticipated changes in aviation and aerospace while taking advantage of opportunities presenting themselves in business practices and technology. This includes accommodating increased diversity and number of operations within the NAS by the introduction of new extensible traffic management services while simultaneously bringing improvements to traditional Air Traffic Services (ATS). These changes will build upon the present-day NAS, and enhance current capabilities while providing novel approaches for faster delivery of new capabilities. As new operations emerge, services and the infrastructure supporting these services must be agile and able to scale up for equitable access.

The Info-Centric NAS will leverage opportunities across technology and business practices with availability of information serving as a lynchpin for change. Other industries are broadly taking advantage of the digital transformation to improve their business operations with great success. The Info-Centric NAS will apply these practices. People and systems are connected everywhere and always, sharing data and information using more resilient infrastructure and automation including modern cybersecurity architectures and structures that can respond to future needs. Improvements made through the deployment of the Next Generation Air Transportation System (NextGen) by the FAA and the aviation community provide the foundation for the future with the addition of new planned capabilities and services taking advantage of modern info-centric technology.

1.3 Current NAS Operations

Scheduled air transport and general aviation (GA) flights compose the vast majority of operations in the NAS today. These flights operate under Instrument Flight Rules (IFR) or Visual Flight Rules (VFR). Figure 1-1. NextGen Operational View with Limited Accommodation of New Entrants shows that flight rules pertaining to airspace access vary depending on the airspace class. The FAA provides those flying under IFR with ATS that include air traffic control (ATC) services to ensure safety and traffic flow management (TFM) services to balance demand and capacity when needed.

In the past decade, the FAA has been modernizing the NAS through its NextGen program. Among many improvements, NextGen enables digital information and data sharing, more precise and efficient navigation enabling more optimal flight paths, and enhanced surveillance of aircraft. NextGen continues to be implemented and deploy new capabilities including enhancements to existing systems.

These automation capabilities are important elements of the move towards Trajectory Based Operations (TBO). For example, a new system called Terminal Flight Data Manager (TFDM) will provide automation for the tower that includes electronic flight data and capabilities that support traffic flow management and collaborative decision making for the surface. Automation enhancements to Time-Based Flow Management (TBFM) are providing the ability to do time-based scheduling of flights to additional key points in the airspace based on four-dimensional trajectory predictions. The FAA is in the process of implementing and integrating these systems and other TBO enablers into the NAS based on a roll-out strategy that is focused on geographically defined operating areas. The implementation is based on a system-of-systems approach to change management which includes the technology, procedures, policies, and operator and workforce education and training.

As NextGen capabilities that will further improve services to traditional aviation users continue to be rolled out across the NAS, new types of vehicles are emerging, such as small, unmanned aircraft systems (i.e., drones), high-altitude and long-endurance vehicles flying above conventional air traffic, and various types of space launch and reentry vehicles. Some of these vehicles will be able to operate routinely under current flight rules, while other vehicles will need modified flight rules to operate. In collaboration with NAS stakeholders, the FAA is taking steps toward the initial accommodation of these new entrants.

Low-altitude unmanned aircraft systems (UAS) operations comprise most of today's new entrant operations. Recreational users and licensed commercial UAS operators can operate at low altitudes within the pilot's visual line of sight in uncontrolled airspace. New flight rules have been established for unmanned aircraft to operate in the NAS: the final rule for Remote Identification of Unmanned Aircraft and the final rule for Operation of Small Unmanned Aircraft Systems Over People. UAS aircraft operating in the NAS are subject to the Remote Identification rule. The Operations Over People rule allows expanded routine operations of small UAS (sUAS) over people without a waiver or exemption under certain conditions. This rule also allows routine operations of sUAS at night under specific conditions. Some UAS operations that are not permitted under the Part 107 rules require a waiver from the FAA to operate.

The system for safely operating UAS in the NAS is beginning to adapt and evolve through the integration of capabilities provided by operators and third parties. The UAS Low Altitude Authorization and Notification Capability (LAANC) is an example of utilizing third parties to facilitate new entrant operations. LAANC automates the required application and authorization approval process for UAS in controlled airspace around airports. This capability provides airspace authorization in controlled airspace near airports through near real-time, automated processing of airspace authorizations facilitated by third-party service suppliers.

Technologies introduced into the NAS by NextGen, especially system-wide information exchange, provide a foundation from which to integrate an increasing number of diverse vehicle types and operations in the NAS. Building on this foundation will enable the integration of new extensible traffic management (xTM) services and service providers to accommodate new types of operations conducted by new types of vehicles such as UAS Traffic Management (UTM) at low altitudes (below 400 feet Above Ground Level [AGL]), Urban Air Mobility (UAM) managing operations through Providers of Services (PSU) for UAM in and around urban areas, and with Upper Class E Traffic Management (ETM) at higher altitudes.

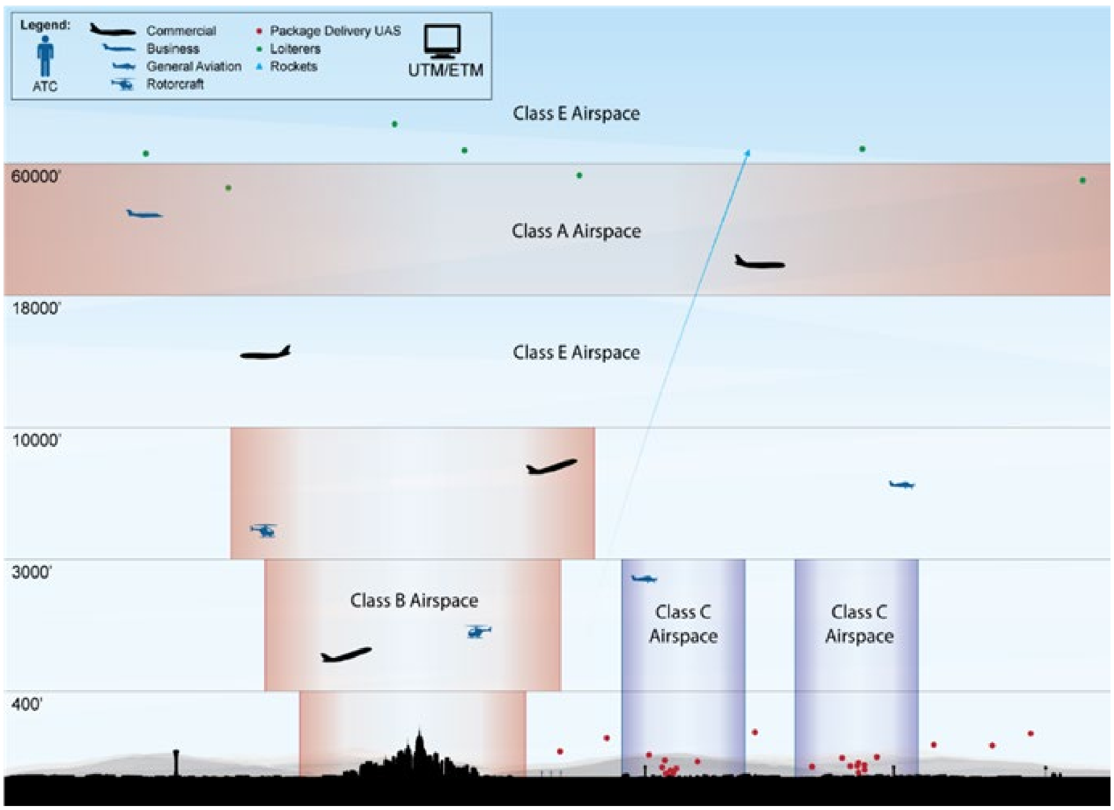


Figure 1-1. NextGen Operational View with Limited Accommodation of New Entrants

1.4 Operational Needs

Although great progress has been made in the FAA's transition towards trajectory based operations, there is still work to be done. With the completion of initial TBO (iTBO) services, all of the key infrastructure needed for TBO will be in place. However, to realize the full benefits of TBO, additional full and dynamic capabilities are needed to deliver the desired operational improvements. Full TBO will further integrate automation capabilities across domains and services in order to greatly improve strategic planning, while dynamic TBO will improve NAS operations through the integration and sharing of information that will enable advanced aircraft and ground automation capabilities to deliver flight specific time-based solutions for re-routes and aircraft sequencing and spacing. These improvements are largely dependent on the exchange and use of information between ground-to-ground and air-to-ground systems as well as more advanced decision support functions that rely on this information.

TBO capabilities beyond iTBO will help to address outstanding operational shortfalls. These operational shortfalls include:

- Limited integration between strategic and tactical traffic management planning
- Lack of access to dynamic real-time data for many data elements by all stakeholders and automation systems
- Limited opportunities for user inputs into airborne reroutes and specific flight preferences and priorities after departure
- Ability to sustain metering during weather reroutes

In addition, there is a lack of automation flexibility in the current system that limits general and business aviation participation in certain elements of the traffic management process such as surface collaborative decision making. Eliminating all of these shortfalls by adding software capabilities based on point-to-point data exchange across FAA systems will be challenging and take time.

Beyond the challenges to complete the transition to full and dynamic TBO, the expected emerging diversity and number of NAS users, operations, and business objectives at all altitudes will challenge the current systems, practices, and processes, and associated information and data needs. Exciting new opportunities in aviation and aerospace are emerging. New vehicles will perform new missions and operate in new ways to execute those missions. Examples of these new operations include space commerce, evolving national security missions, UAS, fully autonomous vehicles, and lighter-than-air vehicles (balloons).

Figure 1-2. Diversity in Future NAS Operations depicts diverse vehicles and the new operations in the NAS that drive the need for new service providers and infrastructure enhancements. Incorporating these new types of NAS users and their anticipated high number of operations requires alternative service methods beyond conventional Air Traffic Management (ATM). New entrants are expected to require services at different altitudes and in different airspace. Airspace will be mixed use where possible, and restricted as needed (e.g., aircraft hazard areas for space launch and reentry).

Low altitude UAS operations (400’ and below) are expected to increase significantly to support emerging business needs, such as package deliveries or infrastructure inspections. At slightly higher altitudes, research into Advanced Air Mobility is helping to safely develop revolutionary new aircraft types that will transform the movement of people and cargo between local, regional, and urban environments. In urban environments, highly automated passenger carrying vehicles are being developed to transport people in new ways. These new Urban Air Mobility vehicles are being developed to move people and cargo between urban and suburban areas previously not served or underserved by aviation.

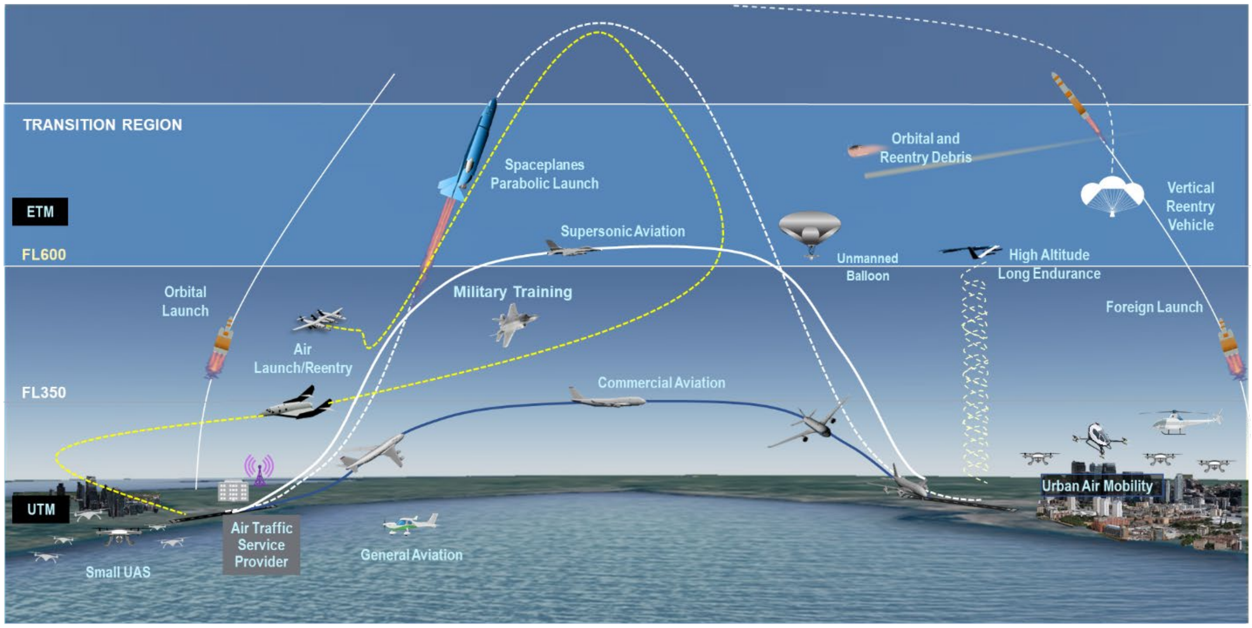


Figure 1-2. Diversity in Future NAS Operations

New vehicles are also being designed to operate at high altitudes above traditional aircraft. These vehicles have a much wider range of performance characteristics and maneuverability profiles compared to traditional aircraft. Vehicles and missions are expected to range from supersonic aircraft carrying passengers to slow moving high altitude long endurance (HALE) vehicles providing telecommunication services. Some of these vehicles are expected to have changing missions or limited maneuverability and will need to provide information different from that provided by traditional flight plans in order to safely de-conflict operations.

The frequency of space launch and reentry operations is expected to continue to increase with new vehicle types and unique characteristics continuing to emerge. Traditionally these operations have been managed by reserving relatively large volumes of airspace with long-time windows, resulting in inefficiencies to other NAS users. However, it is recognized that a more integrated and efficient approach will be needed in the future.

Given the number, type, and expected missions of these new entrants, innovative methods will be needed to safely handle the projected demand for these operations in the future. These new entrants will need to safely interoperate with traditional aviation. To operate effectively and efficiently as these new vehicles and associated industries evolve, the NAS needs to work towards a system that can quickly adopt new, beneficial technologies and business practices. These technologies and opportunities can further today's data rich environment to improve current air traffic management operations while providing services to new types of users.

The FAA and the NAS need to enhance user engagement to a wider set of stakeholders with varying and evolving business needs. The Federal Aviation Regulations (e.g., which include flight rules) drive safety and will need to accommodate the increasing diversity of vehicles expected in the NAS.

1.5 Summary of Info-Centric NAS Vision and Concept

The FAA has developed a vision document that describes the opportunities afforded by technology advances enabling changes to the future environment and the anticipated changes in the areas of operations, safety assurance, and infrastructure. This Concept document describes how this vision will be met from an operational perspective. Below are summary descriptions of both the new vision document and this concept of operations.

1.5.1 Summary of the Vision: *Charting Aviation's Future: Operations in an Info-Centric NAS*

The FAA has developed a new vision document titled *Charting Aviation's Future: Operations in an Info-Centric National Airspace System*. This vision calls for responding to the future needs of NAS users and the expected diversity and volume of operations, by changes in service delivery, infrastructure, and safety management. These changes also incorporate advances in technology and business practices to achieve safety, security, efficiency, and to ensure sustainable evolution and scalability of the NAS.

The future NAS will leverage opportunities in technology to improve the speed and magnitude of TBO benefit delivery while addressing the projected operational diversity and expected growth in new types of operations through the use of new business practices that info-centric information affords. The FAA will provide access and enable new services to be provided for diverse operations as their expected numbers increase.

Technology, such as digital data connectivity, computation power, data storage, and machine learning, will also be rapidly changing and innovating. The FAA will adopt or incorporate proven advanced technology that enables improvement in operational capability and airspace operations. Technology advancements will build on elements of NextGen and will be critical for providing improvements to current operations and the opportunity and foundation for diverse operations.

As the FAA evolves the NAS to the future vision, NextGen capabilities will be leveraged. ATS will rely on automation improvements yielding efficient and predictable operations while maintaining operational flexibility. Time-based management methods based on flight trajectories will increasingly be used. A common operational picture of the NAS will be available by sharing weather, flight, traffic flow, aeronautical, and surveillance information. These improvements within information, precise satellite navigation, ground-based automation, and aircraft systems, among many others, will provide the operational foundation for the future NAS.

The future NAS will evolve to address the expected aviation changes and leverage technology opportunities as summarized in the three areas below:

Operations

Future ATS will continue to provide ATM services in controlled airspace and interoperate with new extensible Traffic Management services**.** By using an integrated information environment, these diverse collaborating traffic management services will evolve to enable increased variety and numbers of new vehicles, missions, and operations to operate routinely and to interoperate across the NAS. A fully integrated information environment will enable processing of vast amounts of information and data sharing to support collaboration, distributed decision making, and interoperability among traffic management services and NAS users. All users will have a more complete picture of operations to use when planning and managing their flights and have increased opportunities for evaluating and selecting a route that best meets their business objectives.

Agile systems and services will be delivered through automation that is adaptable, nimble, interacting, and scalable, with distributed applications. Applying data from the information environment, machine learning, artificial intelligence, and advanced analytics will result in more accurate, predictive models tailored to the operation and situation that will result in improved demand-capacity balancing, which will reduce the need for tactical intervention.

To be scalable, these new operations will require a new model to operate in some locations that does not impose unmanageable additional demands on the current ATS system. To accommodate these new operations, innovative traffic management services, tailored to new entrant characteristics, will be developed and able to coexist with traditional ATS. To exercise these new services, operators will provide services themselves and/or leverage private suppliers for support and infrastructure.

Infrastructure

Future commercial and public assets, services, and infrastructure will deliver ubiquitous services safely and securely among ATS and xTMs. Resilient cybersecurity capabilities and architectures, like zero trust, must be in place to ensure the end-to-end protection of data storage and transfer among the networked entities. Based on authorized access, services will provide common data for operations and analysis. System resiliency, redundancy, and efficiency across communications, navigation, surveillance (CNS), and automation systems and infrastructure will be increased by flexible, reconfigurable, any-to-any connectivity and allow for nearly seamless operations. Automation services will scale to ensure performance, including availability, and will be informed by machine learning to predict failures and demand needs. The evolving system includes infrastructure, systems, and services that change to accommodate the needs of NAS users. The FAA will leverage commercial services and pursue new methods, architecture, processes, and infrastructure to stay on pace with technology changes and their benefits.

Integrated Safety Management

The future NAS will continue a layered approach using tailored safety processes to address diversity of all operations by adapting standards, flight rules and services, and leveraging data and connectivity. Interoperability across services, systems, automated and manual functions, flight rules, and vehicles is needed for safety management. Each operator, service supplier, and manufacturer will address interoperability and safety. Various stakeholders are responsible for in-time safety assurance by continuous monitoring, modeling, and verifying data to detect anomalies and alerts and responses. Models will be continuously receiving real-time data from multiple sources to project safety concerns. Post-operations modeling will focus on causal analysis, inform emerging hazards and corrective actions, and identify shifts in performance to feedback to design assurance and standards.

1.5.2 Summary of the Initial Concept of Operations for an Info-Centric NAS

The Info-Centric NAS provides a flexible framework that leverages new technologies to provide improved services to existing users while allowing the NAS to adapt quickly to evolving operations. By leveraging new technologies, NAS stakeholders are able to cost-effectively integrate the expected growth of new operations and their missions into the NAS. Data sharing and the processes and procedures for the use of data are critical components for interoperability in the NAS, enabling an efficient NAS that provides equitable and fair access to all vehicle types, while maintaining safe operations. An integrated information environment processes information and shares data to support collaboration, distributed decision making, and interoperability among traffic management services and NAS users. Advances in cybersecurity ensure information integrity, while increased network diversity ensures reliability and continuity of service for all operations.

Figure 1-3 depicts an operational view of the Info-Centric NAS with conventional, new, and diverse operations. Supporting the operations are the key services listed across the bottom of the figure: communication, navigation and surveillance, integrated safety management, integrated information management, and ATS and xTM services. The operations and services are enabled by performance-based outcomes, performance-based standards, operating practices, flight rules, airspace design, and an integrated information environment.

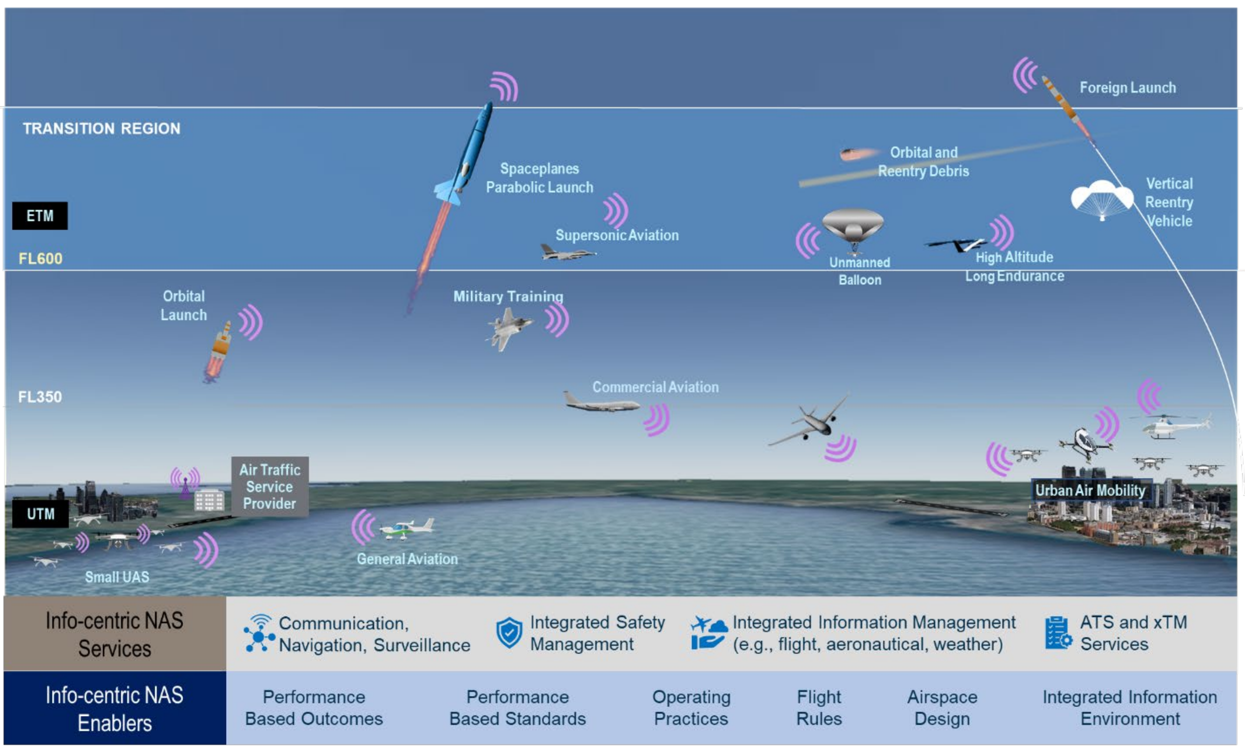


Figure 1-3. Operational View of the Info-Centric NAS

In the Info-Centric NAS, vehicles more precisely predict and share their future locations, improving strategic planning and demand capacity balancing. Operations receive ATM services, provided through ATS by the FAA, or through xTM services that are self-provisioned by operators or provided by third-party service suppliers.

For aircraft flying under ATS control, advances in data sharing and improvements in automated integration and analysis of data improve the speed and magnitude of full and dynamic TBO implementation. Full and dynamic TBO capabilities assist traffic managers in delivering increased flight efficiency, predictability, flexibility, and throughput benefits over that afforded by initial trajectory-based operations. Demand and capacity balancing is improved through the sharing of information, the integration of that information, and the use of a shared integrated picture to make more informed decisions by all parties. These processes are real-time and continuous, reducing instances of lost capacity, and further enhancing the benefits realized by TBO across the NAS. These improvements are delivered in an operational environment where both procedures and flight rules are expected to remain largely unchanged.

Many of the new and diverse operations are expected to gain access to the NAS by making use of xTM services. These services form a cooperative traffic management system within which the operators are responsible for the coordination, execution, and management of their operations. Within this traffic management system, separation is achieved cooperatively across operators via the application of procedures involving data sharing between authorized participants, shared awareness, deconfliction of operational intent, and conformance monitoring using xTM services. These procedures are dictated by the cooperative operating practices (COP) specific to the xTM community being served, and the Tailored Flight Rules (TaFR) being followed, if applicable.

Strategic deconfliction is the primary method of conflict management for operations using xTM services. In strategic deconfliction, conflicts between vehicles' operational intents are identified with longer time horizons than typical for ATS conflict detection, well before the conflict is expected to occur. Typically, strategic deconfliction occurs pre-departure but may also occur in-flight for operations with long flight durations or when operational plans change mid-operation. When conflicts are not mitigated strategically, cooperative separation procedures dictate priorities, responsibility for deconfliction, and how the deconfliction process occurs (e.g., negotiation procedures or right-of-way rules).

Airspace design, management, and use mitigate most interactions between individual xTM and ATS operations, however some interactions are expected. Data sharing, especially operational intent data, together with procedures and rules governing interactions between operations are essential to ensure safety between operations using different traffic management services.

Integrated safety management takes a more expansive, comprehensive, end-to-end approach to safety assurance. Interdependent ATS and xTM elements, such as the airspace, airmen (operator), infrastructure, and aircraft collectively share responsibility and contribute to achieving the overarching safety outcome. Having a shared, data-driven perspective ensures safety is consistently achieved. Integrated safety management leverages operational and performance data to conduct safety assurance activities.

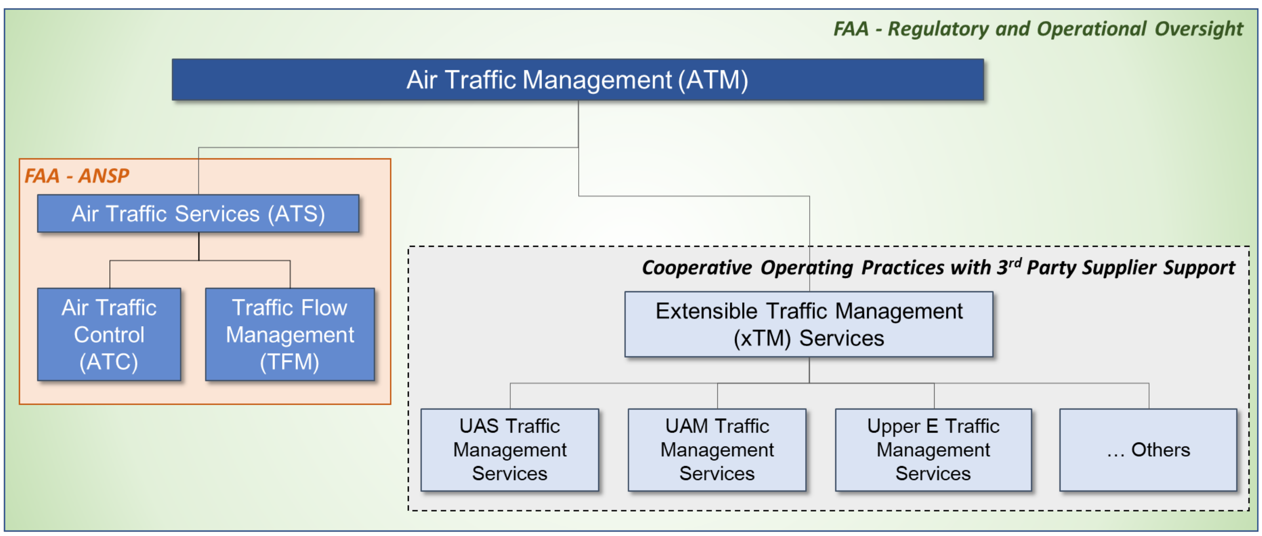
2 Info-Centric NAS Environment

This section and the following sections, describe the NAS environment as it is expected to exist in the targeted 2035 timeframe, thus the present tense is used. Assumptions about the Info-Centric NAS and its operational and technical enablers are included in this section.

2.1 Assumptions

The Info-Centric NAS is evolving amid continuous change and is built to be flexible and adaptable to the changing environment. The following assumptions are expected for the operational environment and enablers of the Info-Centric NAS:

- The FAA continues as the Air Navigation Service Provider (ANSP) of the United States (U.S.) and remains responsible for regulatory and operational oversight of ATM. Figure 2-1. ATM in the NAS shows that the future ATM will consist of 1) ATS that includes both ATC and TFM services provided by the FAA, and 2) xTM Services for diverse operations. Examples of xTM services include UTM, UAM traffic management services, and ETM.



UAS = Unmanned Aircraft Systems
UAM = Urban Air Mobility

Figure 2-1. ATM in the NAS

- The NAS has the same airspace classes as today.
- The regulatory, operational, and technical NAS environment addresses the increasingly diverse types of vehicles and operations.
- Regulatory guidance is in place to enable approval and use of aircraft, air vehicle, equipment, and air/ground systems in the conduct of performance-based flight operations.
- The NAS regulatory framework includes IFR, VFR, and new TaFRs to address requirements for vehicles and operations that cannot meet IFR or VFR regulatory requirements. The flight rules support all NAS users, missions, operations, and their interoperability.

- The FAA has established processes and procedures to review and approve cooperative operating practices and xTM services, and qualify xTM service suppliers and data suppliers, as necessary.
- Regulatory and operational compliance is monitored, facilitated by big data and advanced analytics.
- The NAS infrastructure is scalable (e.g., use of cloud services) and has services that support independently deployed functionality (e.g., microservices) through alternative architectures. These changes enable the FAA to adapt and scale to changing NAS user demands and to keep pace with future technology advancements.
- Operations uncertainty, such as improving flight trajectory predictions and traffic profiles, is reduced (e.g., in areas such as weather and its impact) through the application of applied research in big data and analytics. Methods can further be applied to quantify any residual uncertainty as input to improved decision making.
- The growth of artificial intelligence and machine learning support autonomous vehicle operations and xTM environments enabling more diverse and numerous flight operations more safely than has been humanly possible.
- Human Machine Teaming principles are applied to address human-computer interaction complexities in the Info-Centric NAS (e.g., humans partnering with smart systems to make decisions).
- Comprehensive performance metrics are established to support operations NAS-wide and within ATS and xTM environments. These metrics are used in establishing the day's operational objectives and in demand and capacity balancing. Smart automation systems also apply these performance metrics to guide recommendations.

2.2 Operating Environment

The expected diversity in vehicles and their operations and the pace of change necessitate modifications to enable operations in the NAS environment. To improve service delivery to diverse users and operations, the FAA is expected to leverage commercial infrastructure and assets and external service suppliers for xTM operations. This change also improves the ability of the NAS to adopt new technology more rapidly. Performance-based outcomes describe the measurable performance that is achieved by the system and individual stakeholders seeking to meet specific performance objectives. Three elements work together to achieve the performance-based outcomes: Performance-based standards, flight rules, and operating practices. The diverse operations conducted by new entrants are accommodated by tailored flight rules and cooperative operating practices that work with new airspace constructs to ensure safety.

2.2.1 Public-Private Partnerships

Public-Private Partnerships (PPP) allow the FAA to leverage commercial assets, services, and new technologies. These partnerships can range from ATS leveraging commercial infrastructure and information systems for ATM, to giving regulatory approval for private entities or third-party service suppliers to provide xTM services for new entrants. While there are many definitions of PPP, this concept assumes a broad interpretation to provide flexibility for establishing relationships with commercial entities. Variations of these agreements may account for differences regarding who is responsible for funding and developing every stage of the technical requirements, development, deployment, and operation of a service or capability. Where necessary, the FAA approves private providers (suppliers of commercial infrastructure, services, capabilities, and/or data) that meet the specified operational and performance requirements to operate in the Info-Centric NAS.

Commercial entities often support a broad set of users beyond aviation. New technology is adopted by these entities to accommodate requirements across all their users. By establishing PPPs with these entities, the NAS inherits their more rapid technology adoption. Establishing these partnerships for xTM service delivery is also an efficient and cost-effective way to accommodate emerging aircraft or vehicles and new types of operations in the NAS. In the Info-Centric NAS, ATS have the possibility of using alternative private infrastructure and automation. Examples include platforms (e.g., satellites or HALE aircraft) providing communication services, services for metrological information, cloud services for FAA automation computation and storage, or third-party provided services for flight planning. In addition, PPPs enable the FAA to use commercial services to meet an operational need, such as exchanging pre-departure and departure information with GA pilots via mobile devices.

A flexible and adaptable architecture allows rapid implementation and deployment of services for new applications or operational environments. An integrated information environment, supported by data standards, enables seamless data sharing among public and private entities.

2.2.2 Performance-Based Outcomes

Figure 2-2 shows the inter-relationship of cross-cutting ATM elements: performance-based outcomes, performance-based standards, flight rules, and operating practices. The elements work together to safely accommodate the variety of vehicle operational capabilities and missions.

Performance-based outcomes describe the measurable performance that is achieved by the system and individual stakeholders seeking to meet specific performance objectives. These objectives describe the relative value that stakeholders place upon different operational priorities, such as access, capacity, efficiency, and equity. Stakeholders collaboratively agree to system-level performance objectives. Automation continuously monitors operations, balances situational priorities against the approved cooperative operating practices with FAA oversight to ensure that resources are distributed equitably and safety is maintained. Automation supports decision making by providing actionable recommendations seeking to achieve individual stakeholder performance goals that account for individual operational capabilities while meeting system-level objectives. Stakeholders, for example, may use modeling capabilities to simulate operations and assess alternatives to achieve their desired performance objective without adversely affecting the system-level performance. Such a modeling capability replicates the operational environment to conduct what-if analysis and provide recommendations that align with the agreed upon objectives.

Achieving performance-based outcomes occurs within a well-regulated environment. Performance-based standards, flight rules, and operating practices all influence the achieving of performance-based outcomes. Performance-based standards form the basis for regulatory compliance by defining the required performance needed to perform a given operation. Flight rules define a set of aviation regulations applicable under a specific set of conditions. TaFR describes the regulations of operator and vehicle performance requirements for specific types of new vehicles or operators that cannot meet the requirements for existing flight rules. Operating practices reflect the required interactions (e.g., procedures) among vehicles, operators, and service providers given their operational performance characteristics (e.g., maneuverability, speed). Operators for new vehicles operating within xTM will collaboratively determine these cooperative operating practices.

Performance-based standards, flight rules, and operating practices collectively influence the performance of all operations governed by them. The FAA's regulatory mechanisms will ensure that these are defined and approved to deliver desirable safety outcomes.

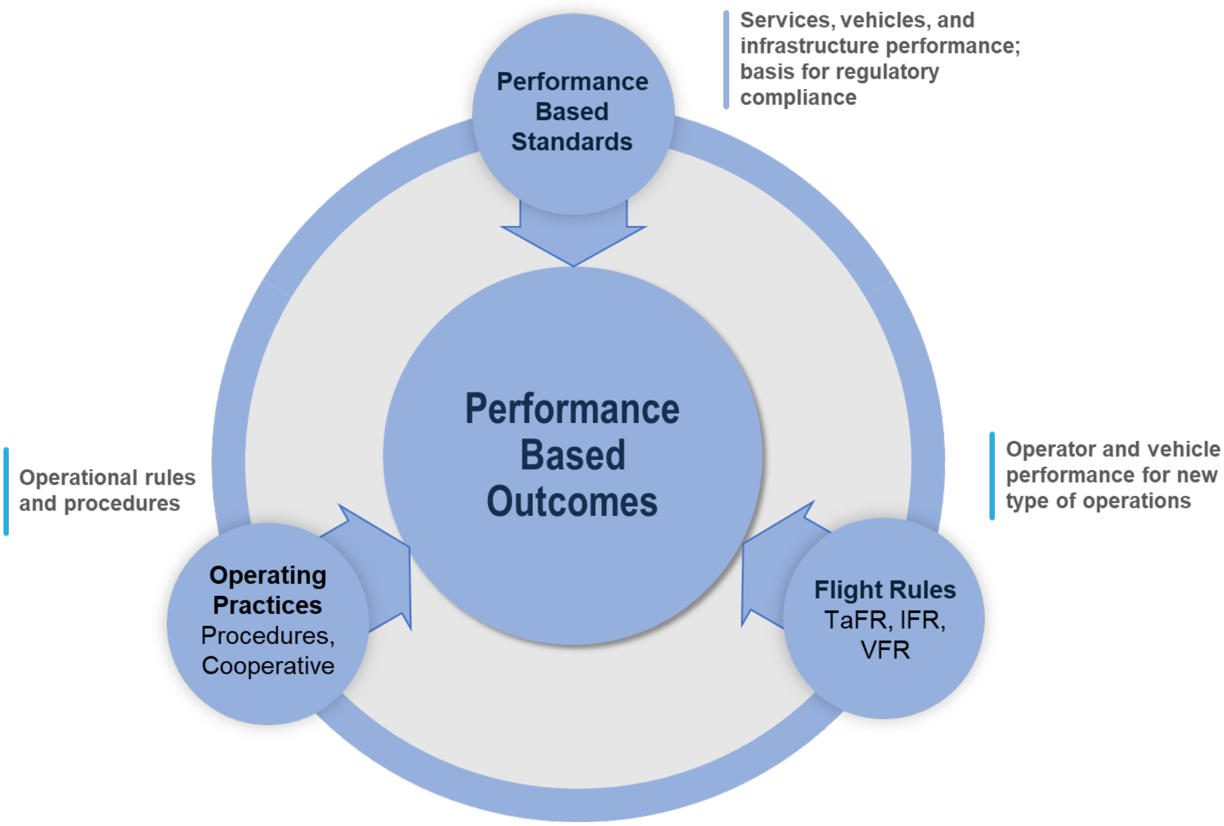


Figure 2-2. Cross-Cutting Elements Interact to Deliver Performance-Based Outcomes

2.2.2.1 Performance-based Standards

Today, joint industry and government technical groups develop performance standards applicable to various systems such as CNS systems. These standards consider various alternative system configurations that may be applied to deliver a capability. For example, combinations of navigation sources with differing performance levels are available to meet overall navigational performance needs. The FAA reviews, recognizes, and codifies these performance-based standards into the regulatory framework, and has the authority to provide additional guidance for NAS operators regarding technology-specific means of compliance with these standards.

In the future NAS, the FAA retains oversight authority to assure compliance. However, the process will evolve to place more emphasis on the performance-based standards with reduced reliance on guidance regarding technology-specific means of compliance. Such a shift is characterized by the following key changes:

- A reduced emphasis on specific means of compliance, with a focus on standards that are more technology agnostic, thereby fostering the adoption of new, innovative technologies.
- Compliance with performance-based standards, and approval processes, may be informed by operational data from automated monitoring coupled with advanced analytics. When leveraging technologies applied outside of aviation, such data may be obtained from other industry applications.
- Data collected from operations may inform the appropriateness of performance-based standards for a given type of operations/operator, providing input for updates to performance-based standards.
- All of the above provide increased flexibility in how NAS stakeholders, including operators and service suppliers, can meet performance-based standards. In addition to new technology, this allows for a wider set of system configurations, allowing for a more resilient NAS.

2.2.2.2 Flight Rules

Current flight operations have regulations defining flight rules (e.g., IFR, VFR) applicable under specific circumstances. New operations may not be able to comply with the requirements for these existing flight rules, though they may desire access to the airspace where these rules apply. TaFRs govern the conduct of new operations both within an xTM or within ATC controlled airspace. These rules are developed as part of regulations to ensure the safety and interoperability with existing flight rules. TaFRs must consider vehicle characteristics (e.g., maneuverability, fully autonomous), capabilities (e.g., equipage), and type of operation(s). For example, an autonomous vehicle may require compliance with a specific set of TaFRs to operate within high-throughput corridors established for UAM flights. Flight rules ensure safety and interoperability by defining the behaviors around integrating, accommodating, and segregating diverse operators.

2.2.2.3 Operating Practices

Operating practices are a set of agreed upon acceptable behaviors, interactions, and procedures for a given operation/airspace. Operating practices to manage conventional ATS might need modifications to manage or limit future interactions with new entrants and to incorporate the associated use of increased automation and smart system support. Services in use by ATS can be monitored and managed from FAA facilities by FAA NAS Operations staff. Monitoring of services includes performance, fault, and security (cybersecurity operations).

New entrants will operate based on cooperative operating practices that are developed and agreed upon by the relevant stakeholders and subject to FAA regulatory authority. These define how individuals operate in the airspace and broadly describe the interactions among the users, specifically including new types of operators and service suppliers. These practices provide boundaries around how an individual operates in relation to others, locally, and more broadly at the system level. For example, UAM operators may define unique operating practices that specify how and when users may access specific airspace, like a UAM corridor, while ensuring that they are still meeting the desired performance outcome for access and equity. These practices may also specify the allowable and required operations within the airspace, like deconfliction procedures. The FAA retains authority to approve cooperative operating practices.

As operations and the environment evolves, practices will also evolve to support these future operations as needed to ensure safety and enable access and efficiency.

2.2.3 Airspace Design

Airspace is designed to meet the diversity and demand of operations and to ensure the safe and efficient organization and use of the national airspace resource. Airspace design in the Info-Centric NAS integrates non-traditional aviation traffic by introducing new airspace design constructs that consider vehicle performance and can be tailored to specific vehicle characteristics. Airspace design and organization mitigates most interactions between ATS and xTM operations and ensures that xTM operations do not impose a burden on ATC.

To integrate non-traditional aviation traffic volume, new airspace design constructs will be needed and will allow for flexibility as traffic demand changes. New vehicles are expected to have a wider range of performance (e.g., climb rates, turn radii, speed ranges) than exists for current air traffic operations. Airspace design therefore needs to consider the diversity of vehicle performance and may need to be tailored to specific vehicle characteristics to incorporate them into the airspace (e.g., corridors for rapidly climbing supersonic aircraft).

The FAA reviews proposed airspace constructs for xTM operations. Collaboratively agreed upon cooperative operating practices are developed that guide the design, organization, and implementation of xTM airspace structures. These practices reflect collaboratively agreed performance-based objectives, such as airspace access, equity, and capacity. The specific airspace constructs may vary across xTM services and locations. Within these new constructs, xTM services are provided and may require specific vehicle performance, operating practices, and authorization (i.e., general or specific to the situation) to use the construct (e.g., to enter, exit, and fly in an airspace construct). Examples of potential airspace constructs include a mesh of available routes and scheduling windows, UAM corridors, and space transition corridors.

The FAA is responsible for determining the airspace allocation for operations using ATS or xTM services in accordance with established access criteria. The FAA is also responsible for the design, organization, and implementation of airspace structures for ATS operations, as well as the development of operating requirements within those airspace structures (e.g., authorization, operating practices, and specifying needed vehicle performance). Airspace structures are allocated based on operations, safety, and established rules.

2.3 Integrated Information Environment

An integrated information environment is a critical infrastructure element and is the key technology enabler of the Info-Centric NAS. As technology advances, the NAS environment is increasingly becoming connected, with a large amount of data collected, exchanged, and interpreted by various systems and services. An Info-Centric NAS leverages ubiquitous data to ensure the interoperability and safety of ATM operations, where participants leverage an integrated information and data sharing environment. An integrated information environment serves as the means of information exchange for all participants and enables the collaboration among diverse traffic management services and the integration of their operations. ATM participants exchange data for increased situational awareness and decision support. At a minimum, it is expected for all vehicles to share some level of position and intent data using this environment. The broader access of information to authorized participants allows decisions to be shifted to the most appropriate participants and enables distributed decisions to be made in real-time with better information.

In addition, the data made available through the integrated information environment presents opportunities to leverage technologies, such as artificial intelligence and machine learning, to enhance capabilities in the NAS. Zero trust cyber security principles ensure that data is protected and only those with the authorization required have access to it. Data rules and standards continuously evolve with changing NAS needs. A flexible and reconfigurable network provides any-to-any connectivity for authorized stakeholders and services. Using more loosely coupled components that can be developed and sustained independently results in infrastructure resources that can be easily scaled up and down, ensuring an appropriate level of service for all users.

2.3.1 Data Use, Rules, and Standards

As the NAS becomes more data rich, NAS stakeholders, including ATM participants, are looking to exchange data about operations and performance for increased situational awareness and decision support. Information is the result of data curation, evaluation, and translation into a contextual output that is meaningful to NAS stakeholders. The integrated information environment must support the ability to discover, exchange, and secure data, and adhere to specific data standards and governance.

The integrated information environment supports the exchange of actual operational data and data created by simulations, where NAS stakeholders serve as authoritative data sources and/or data users. Data discovery and dictionaries allow data users to understand what data is available for their situational awareness and decision support, the relationships among data sets, and who is providing this data/information. Data sharing is based on consensus around the minimum data to be shared, and the timing and frequency of sharing. The authorization for accessing data is dependent on sensitivities in the data, such as proprietary information, and an understanding of how individual stakeholders utilize the data for their own benefits. In addition to access rules, securing data while in storage or being exchanged requires specifics around ensuring data integrity and availability.

Data standards and governance enables this operational data exchange environment. Data standards ensure there is consistency in how data is discovered and shared among diverse NAS stakeholders. This integrated information environment fuses and supplies operational and simulated data from a distributed mix of public and private sources and includes the data characteristics (e.g., estimated uncertainty). Generally, standards provide guidance around data characteristics such as accuracy, completeness, timeliness of data, rate of access, format, and size.

The integrated information environment provides data, along with any data characteristics, with the intent of improving transparency about the data to the decision makers. Data governance specifies how the data will be managed and controlled. In all, data rules and standards for providing and using data in the integrated information environment must be established and continuously align with evolving NAS needs.

2.3.2 Infrastructure

The foundation for this integrated information environment is the NextGen infrastructure. To leverage ubiquitous data and enable a collaborative data sharing environment, this infrastructure must evolve. Improvements that will enhance NAS capabilities and infrastructure include setting up an adaptable and resilient architecture, moving away from monolithic automation systems, and adopting innovative technologies, such as evolution towards scalable computing and storage. For example, the NAS infrastructure can be more scalable by using cloud services. In addition, alternative architectures will support independently deployed functionality (e.g., microservices) that enable the FAA to adapt and scale to changing NAS user demands and keep pace with future technology advancements.

The complexity of sharing operational and simulated data among dispersed stakeholders requires an architecture where services and functions will be deliberately organized to support reuse, maintenance, and efficiency. The integrated information environment, providing data services including data integration from various sources, allows federated actors to reconcile, contextualize, and share relevant information. Depending on the demand for data exchange via the integrated information environment, infrastructure resources may be easily right sized by scaling up and down, ensuring an appropriate level of service for all users, while running at optimal levels. A flexible and reconfigurable network underpins this environment, providing any-to-any connectivity for authorized stakeholders and services, like communication and surveillance services, in real-time for increased situational awareness and decision support. Human Machine Teaming improves the usability of automated systems that perform data analytics, by envisioning automation being adaptive and bi-directional [3], where both humans and automation are learning and collaborating, and automation is becoming a teammate rather than a tool [4].

Cyber security is critical for the Info-Centric NAS. Zero trust cyber security principles ensure that data is protected and only those with the required authorization have access to it. With zero trust, protection capabilities are closer to sensitive resources and enforce an end-to-end system protection, rather than using a single firewall. An overall cybersecurity infrastructure supports comprehensive cyber awareness, incident detection capabilities, and context for effective cyber incident response.

In the Info-Centric NAS, the FAA partners with service suppliers to support ATM operations to enhance their services and allow for improved efficiency. As various xTM services are added to the NAS, the ATM system continues evolving to ensure that the NAS overall is continuously providing comprehensive and equitable service to all operators.

3 Info-Centric NAS Operations

3.1 Operational Principles

The following principles are fundamental for the operation of the Info-Centric NAS:

- Maintain and improve safety, security, and resiliency
- Collaborate with affected stakeholders (e.g., operators and service suppliers) to develop:
    - Operating practices for interactions with and between new entrants, from strategic conflict management through collision avoidance, balancing airspace user and system objectives
    - New methods to provide increased user input into flow management decisions and appropriate access to the NAS enabling new and existing missions
- Ensure operators cannot optimize their own operations at the expense of sub-optimizing an xTM environment or the NAS as a whole
- Incorporate performance-based standards throughout the enterprise
- Leverage PPPs and managed services to achieve economic viability and provide resiliency
- Build in scalability to rapidly expand capabilities to meet operational challenges
- Ensure adaptability and agility to keep pace with unanticipated changes
- Manage airspace that is structured where necessary and flexible when possible, including mixed use airspace
- Provide accessible operational information access among ATS and xTMs to facilitate situational awareness and coordination. The FAA has on-demand access to xTM operational information
- Exchange flight data to facilitate cooperative separation in xTM environments and conflict management provided by ATS in a TBO environment
- Permit a flight or vehicle to operate according to a single set of flight rules (e.g., IFR, VFR, or TaFR) although it may operate under different flight rules over the duration of its operation
- Globally harmonize services and operations of the Info-Centric-NAS

3.2 Participants

Participants in the future Info-Centric NAS include NAS operators and airspace users, the FAA as both a service provider and the regulator/oversight authority for civil operations, suppliers of services and data, and stakeholders with a role in supporting NAS operations.

The FAA continues to provide ATS to traditional NAS users. In an xTM environment, service suppliers assist operators in meeting the xTM operational requirements without needing direct FAA involvement. Operators can self-provision services necessary to meet airspace and xTM requirements and are not required to use external service suppliers. Suppliers may also provide supplemental services such as communications, navigation, and information services (e.g., atmospheric data, weather, surveillance, and airspace advisories/hazards).

3.2.1 NAS Operators/Airspace Users

An operator is the person or entity responsible for the overall management of a vehicle operating in the NAS. The future NAS continues to include traditional commercial aviation, GA, and military operations that make up the vast majority of NAS operations today and expands to include operators of more diverse vehicle types including electric aircraft, very small aircraft flying below conventional aircraft, HALE aircraft flying above conventional aircraft, and various types of space launch and reentry vehicles. Many of these vehicles are uncrewed and autonomous with a more diverse set of operational characteristics.

Vehicles operating in the NAS must be authorized. The operator must meet regulatory responsibilities, plan flights/operations, obtain required vehicle authorization to operate, share intent information as necessary for coordinated flight and deconfliction purposes, and ensure that operations are conducted safely. Operators are responsible for ensuring that any pilot directly in command of an airborne vehicle has access to all information required to maintain safe flight. A pilot may refer to the human pilot who performs flight functions for one or more vehicles or to certified automation that may perform some or all the functions necessary to control a vehicle. In certain airspace areas primarily used by new types of vehicles for different types of operational missions, operators are responsible for managing their own operations based on cooperative separation. These operators may also choose to provide their own xTM services or use third-party service providers.

3.2.2 Federal Aviation Administration

The FAA remains the federal authority over aircraft operations in all airspace, and the regulator and oversight authority for operations in the NAS. The FAA maintains an operating environment that ensures NAS users have access to the airspace resources needed to meet their specific operational objectives and that shared use of airspace can be achieved safely and equitably. The FAA develops flight rules, regulations, policy, and procedures as required to support these objectives.

FAA ATS provides ATC and traffic management services to traditional NAS users as they do today. The FAA may provide separation services to non-traditional NAS users if they are operating in controlled airspace and not participating in separate xTM environments, however this is expected to be the exception and not the normal mode of operation.

3.2.3 Third-Party Suppliers Supporting COP

In an xTM environment, third-party service suppliers may assist the operator in meeting the xTM COP requirements without needing direct FAA involvement. It is expected that each xTM user group will have distinctive operational characteristics and associated requirements fulfilled by unique service suppliers. These services can support operations planning, intent sharing, conflict management, conformance monitoring, and other airspace management functions. Performance-based standards provide the required levels of system and operator performance to which service suppliers must adhere. Operators are not required to use third-party service suppliers to meet airspace and xTM requirements. Suppliers may provide supplemental services, information, or both. Examples of information include atmospheric data, weather, surveillance, and advisory/hazard information related to transit (e.g., terrain and obstacle data). The FAA may need to qualify third-party service or data suppliers depending on the intended use of the information being supplied.

3.2.4 Stakeholders

A stakeholder is any entity with a role in NAS operations, from any angle. Stakeholder is thus a broadly inclusive term that includes, but is not limited to, standards bodies, academia, aircraft/new entrant manufacturers, equipment providers, airport operators, vertiport operators, and space launch and reentry site operators. Public interest stakeholders, as declared by governing processes (e.g., FAA, cooperative operating practices), can access xTM operations data to ensure safety of the airspace and persons and property on the ground, security of airports and critical infrastructure, and privacy of the general public. ATM data can be accessed through dedicated portals or can be routed directly by service providers to public safety entities, local/tribal/state law enforcement agencies, and other relevant federal agencies (e.g., Department of Homeland Security [DHS]) on an as-needed basis. The general public can access data that is determined or required to be publicly available.

3.3 Operations

The Info-Centric NAS is characterized by improved services provided to traditional aircraft as well as the safe introduction of services to address the needs of new diverse vehicles and missions operating within the NAS. Leveraging technological advances, vehicles in the NAS more precisely predict and share their future locations. This information, along with the supporting infrastructure, improves strategic planning, demand capacity balancing, and provides traditional aviation with increased opportunities for user input into flow management decisions affecting their operations. These improvements enable the new diverse vehicles to safely access NAS airspace without undue impacts on the delivery of ATS. Operations receive ATM services provided through ATS by the FAA or through xTM services that are self-provisioned by operators or provided by third-party service suppliers.

Operations in the Info-Centric NAS are organized in this document into operations managed through ATS, operations managed through xTM services, and interoperability.

3.3.1 ATS Managed Operations

For aircraft flying under ATS control, advances in data sharing and improvements in automated integration and analysis of data improve the speed and magnitude of full and dynamic TBO implementation. Full and dynamic TBO capabilities assist traffic managers in delivering the further realization of the increased flight efficiency, predictability, flexibility, and throughput benefits that initial TBO affords. Flight operators have access to the additional and improved information to use when planning and managing their flights providing increased opportunities for making decisions that best meet their business objectives. These improvements further enhance the benefits realized by TBO across the NAS. These improvements are delivered in an operational environment where both procedures and flight rules are expected to remain largely unchanged.

Within ATS, demand capacity balancing is improved through each step of the process: the sharing of information, the integration of that information, and the use of a shared integrated picture to make more informed decisions by all parties (Figure 3-1). The sharing of information across systems and participants provides a more accurate and complete picture of the NAS that enables both the FAA and users to better plan their operations. The data is used to inform decision making including improved estimates of demand and capacity throughout the NAS. The integrated information parameters enables participants to make more informed decisions, such as the need for Traffic Management Initiatives (TMIs), which feeds back into updates of the information participants use to plan and execute their operations. In the Info-Centric NAS, these processes are real-time and continuous, reducing instances of lost capacity and providing efficient demand capacity balancing.

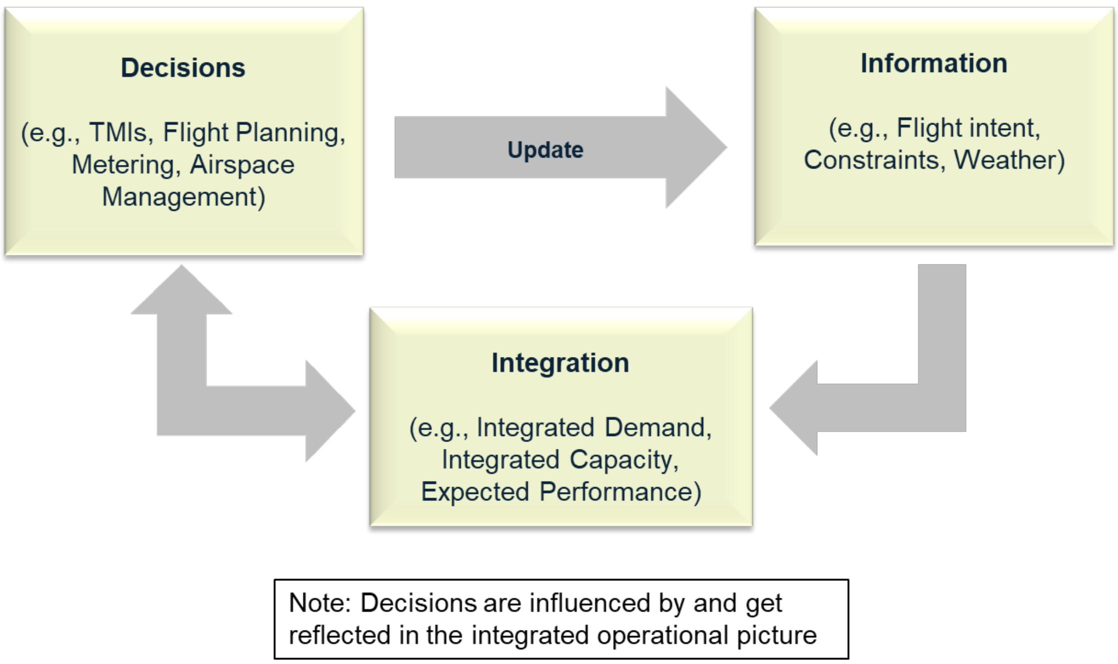


Figure 3-1. Information Becomes Actionable Leading to Decisions

3.3.1.1 Improved Planning through Information Sharing

Building upon the information sharing capabilities established through TBO, flights making use of ATS share their flight intent during planning, and continuously update these intents, even after departure, to reflect decisions as they are made. For example, planned departure and arrival times are updated in real-time for both commercial and GA communities.

Information on constraints, including those due to weather and special activity airspace, is available in real-time. Some of these constraints, such as those due to TMIs, are the result of decisions made. Their impact is reflected in updates to shared flight intent, and updates to the recorded traffic management actions.

All flights provide a more complete picture of NAS demand levels through the sharing of flight intent and preferences via increased connectivity with the aircraft. In addition, flights not previously able to take part in some existing collaborative decision making processes can leverage the connected aircraft to participate. For example, GA and business aviation may use mobile applications to:

- Fully participate in surface collaborative decision making through provision of updated flight information (e.g., departure readiness).
- Participate in improved departure scheduling capabilities into en route departure flows.
- Initiate flights more quickly and safely through receipt of electronic instructions (e.g., mobile clearance delivery).

Information sharing also enables pilots, including those flying under VFR, to receive pertinent information about vehicles in the surrounding airspace, increasing pilots' situational awareness and improving safety.

3.3.1.2 Improved Information for Decision Making through Data Integration

The Info-Centric NAS obtains voluminous amounts of well-structured information. This information can be easily integrated and presented in actionable form for decision making. This is made possible using smart automation systems.

Provided information is synthesized into a shared operational picture of the NAS across planning time frames. For example, a universal demand service integrates 4-dimensional trajectory (latitude, longitude, altitude and time) flight information across strategic and tactical flow time frames. Through such a service, the combined effect of decisions at both strategic and tactical levels can be evaluated to ensure the best combination of actions is selected. For information integration to provide such a picture, smart automation anticipates the effect of tactical flow to better inform strategic flow. For example, automation anticipates the levels that can be safely accommodated by tactical flow, given the expected conditions.

This integrated information is also provided to operators and used by their automation systems to assist with flight planning. Operators incorporate dynamic NAS information into their planning and assess the impact of traffic management decisions on their individual operations.

Even though information is shared continuously in real-time, there are still differences in quality of provided information (e.g., missing or inaccurate data). Data analytics are applied to improve the accuracy of demand and capacity prediction by identifying and adjusting for these effects.

3.3.1.3 Collaborative Performance Based Flow Management

Using the common integrated picture of the NAS available to all parties, established collaborative processes are applied to resolve demand capacity imbalances. These collaborative processes lead to agreed performance goals which serve as a target for decision making across participants. Flight operators collaborate on the establishment of these performance goals and provide input on fleet-specific goals to better enable the prioritization of high-value flights subject to flow management initiatives.

Smart automation systems use the integrated information to evaluate the anticipated operational performance under a variety of decisions across service providers and participants. Automation evaluates traffic management solutions intended to achieve the established performance-based goals. Strategic decisions (e.g., demand and capacity balancing) anticipate future tactical decisions (e.g., traffic synchronization), which improves overall flow management, reduces the instances of lost NAS capacity, and helps ensure that delays needed for demand capacity balancing are taken in the most economical way. Flight operators, aware of decisions and future constraints in real-time, adjust their flight intent, including airborne, in accordance with collaborative processes. As these decisions are made, the real-time plans for individual operations are shared and reflected in the common integrated picture of the NAS.

Decisions recommended by smart automation systems consider uncertainty in the proposed solutions to ensure they provide robust performance. As illustrated in Figure 3-2, based on historical observations, one decision may be better on average and less predictable while another may be only slightly worse on average but very predictable. The Info-Centric NAS allows decisions to consider and quantify these trades. Flow managers or dispatchers can quantify the trade involving re-routes around uncertain constraints, or traffic managers can balance strategic versus tactical flow decisions.

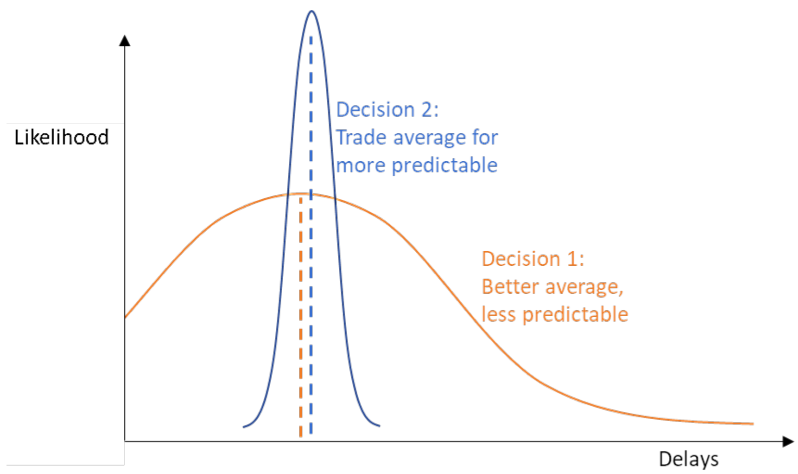


Figure 3-2. Decisions Use Historical Knowledge to Trade Performance Attributes

With more informed decision making, strategic demand and capacity balancing better pre-conditions traffic for future tactical decisions. In turn, this decreases the number and size of tactical trajectory adjustments. Yet the need for tactical traffic management in ATS is not fully eliminated. The remaining uncertainty is reduced and can be estimated enabling more efficient setting of tactical flow management parameters. For example, the settings for delay buffers or the timing of delay absorption execution (e.g., earlier when predictable, later when more uncertain) is improved.

3.3.2 Operations Managed Through xTM Services

Many of the new and diverse operations are expected to make use of xTM services. These services form a cooperative traffic management system within which the operators are responsible for the coordination, execution, and management of their operations. These services are qualified by the FAA and may be self-provisioned or provided by third-party xTM service suppliers. Multiple entities may provide a federated set of xTM services for flights operating within the same airspace. Each xTM has a unique set of cooperative operating practices that are developed to serve any diversity in performance of the vehicles using their services as well as the types of operations using the airspace under their management, including mixed use with ATC or general aviation VFR traffic. All xTM processes are expected to be highly automated throughout the planning and execution of their operations.

3.3.2.1 XTM Operations Planning

Within a given xTM community, FAA approved cooperative operating practices establish the mechanisms for coordination between operators and between xTM service suppliers. xTM services apply cooperative operating practices to manage demand for the airspace they are servicing. Operators may also use additional third-party qualified services to develop and execute their operational plan. These include services providing supplemental third-party information, such as detailed weather or obstacle data at higher resolution within urban environments, at lower altitudes, or at altitudes above approved aviation weather information sources. The FAA qualifies services providing such information for new entrants to use for regulatory dispatch purposes.

xTM operator access to airspace is dependent on:

- The performance level of the vehicle and the associated xTM service requirements
- Airspace structures specifically designed for the vehicles and xTM services being considered
- Applicable TaFRs governing the operation within the airspace structure

New airspace constructs, such as designated airspace, flexible use of cooperative separation below flight level [FL] 600, and UAM corridors, are used to support operations using xTM services. Configurations are selected through an integrated capacity management process, in which established and approved business rules govern the equitable allocation of airspace across all NAS operations. These rules establish mechanisms for obtaining the necessary demand information from operators through xTM service suppliers across all operations. Automation assists in providing recommendations in compliance with business rules which balance the needs of competing interests.

Further refinement of airspace constructs may occur for operations within one xTM community to meet their own capacity needs. For example, at higher demand levels, operations within a UAM corridor may require more stringent performance and participation requirements in order to accommodate additional structures (e.g., “tracks”) within the corridor to increase capacity. As these decisions might involve multiple operators or xTM providers, these decisions are made in accordance with established operating practices.

The high-level of automation for xTM services requires these practices and agreements to be encoded in the systems delivering the services, with information exchanges supporting the interactions.

3.3.2.2 Cooperative Separation

Within a cooperative separation environment, operators are responsible for the planning, coordination, execution, and management of operations without direct ATC involvement. Cooperative separation is achieved via the application of procedures involving data sharing, shared awareness, deconfliction of operational intent, and conformance monitoring using xTM services. These procedures are dictated by the cooperative operating practices specific to the xTM community being served, and the TaFR being followed, if applicable. Data sharing largely involves operators sharing their operational intent. Beyond operational intent data, with increased diversity of vehicles, capabilities, and their systems’ performance, additional operational information is required to determine the applicable separation criteria to apply. Such operational information might include navigation capability, maneuverability, wake or shock-wave sensitivity, and flight status.

Strategic deconfliction is the primary method of conflict management for operations using xTM services. Through these services, operators obtain information on traffic, airspace configurations, obstacles, and meteorology to plan their flights. This planning also includes identifying and resolving traffic and airspace conflicts well before they are expected to occur. Procedures for identifying and resolving these conflicts are defined to enable collaboration across operators using different xTM service suppliers. Strategic deconfliction typically occurs pre-departure but may also occur in-flight for operations with long flight durations or when operational plans change mid-operation.

If a conflict is identified, procedures dictate priorities, responsibility for deconfliction, and how the deconfliction process occurs (e.g., negotiation procedures or right-of-way rules). It is expected that the deconfliction process leading to the adjustment of one or more trajectories is automated.

After operations are strategically deconflicted, the operator is responsible for ensuring that the operation complies with its operational plan and that the operational plan continues to be free of conflict by monitoring shared flight intent and/or tactical vehicle-to-vehicle capabilities. Monitoring of shared flight intent can either be self-provisioned by the operator or done via a third-party service supplier.

When an operator cannot maintain their shared operational intent, within bounds established by the relevant cooperative operating practices, the operator must send notifications of the event, ensure their operational intent is conflict free, and update it. This may require the application of procedures to generate a new conflict free operational intent. If there is a need to leave the xTM designated airspace, the operation must comply with the rules and requirements for the airspace it is entering, including obtaining approval from ATC where necessary.

Operations within UAM corridors are an example of cooperative separation, where strategic deconfliction and tactical separation occur without direct ATC involvement. Requirements for entering a UAM corridor are governed by a set of rules which prescribe access and operational requirements such as the sharing of intent data and ensuring their intent is deconflicted from other operations and known airspace constraints. Once in the UAM corridor, the flight is monitored to ensure it conforms to its operational intent. UAM aircraft capabilities (e.g., detect and avoid [DAA]) may assist in maintaining separation within the UAM corridor. In the case of an off-nominal event, the UAM operator sends a notification of the event and updates their operational intent.

3.3.3 Interoperability

Airspace design (see Section 2.2.3) establishes equitable mechanisms for separating diverse mission types when required to safely manage operations. Cooperative operating practices define these equitable mechanisms which consider operational performance and identify participation requirements. Within xTM designated airspace, these previously defined airspace constructs are managed in accordance with ATM operational needs. Known business rules establish the timing and mechanisms for expressing a need for scheduling airspace structures based on traffic and for returning the airspace for other purposes when no longer needed or directed to do so for other traffic management purposes. In practice, the scheduling of airspace constructs is likely to be predictable for cases with steady demand for some operations (e.g., UTM, UAM operations).

Airspace management plans identify which airspace constructs and configurations are planned for use over time. Using the process described in Figure 3-1, smart automation assesses the integrated demand against performance goals established in the approved business rules and provide TFM recommendations for allocation when there are competing interests. Once airspace management plans are made, they are shared with stakeholders to support the planning and execution of operations. The integrated information environment provides the real-time exchange of operational data. The integration of actual and simulated data supports simulation capabilities

Different airspace constructs have operational and performance requirements for vehicles using them. These requirements might vary based on operational conditions or due to demand and capacity balancing. For example, as the demand for operations increases in number for an area of airspace, the necessary navigational performance to use an airspace construct may become more demanding to accommodate a reduction in required separation to increase airspace capacity.

Airspace design, management, and use mitigates most interactions between individual xTM and ATS operations, however some interactions are expected. In airspace where more than one operating rule is supported, operators can select which service (ATS or xTM) they use, if they meet the service requirements. Sharing data, especially vehicle location and operational intent data, between ATS and xTM automation is essential for safe interactions when ATS supported operations wish to traverse xTM operational airspace. This shared information allows xTM operators to use the information for strategic deconfliction. VFR aircraft may exchange intent data with xTM operations in order to strategically deconflict their flight and assist with separation assurance. ATS may also use this information for providing traffic advisory services in this mixed-use airspace.

For mixed operations, operators must secure any necessary authorizations for access and file flight plans for those portions of the flight operating under ATS. Operators must also ensure operational intent data is shared and, for the portion of the flight operating under xTM services, strategically deconflicted from other operations using xTM services following the applicable procedures.

Upper Class E airspace (above FL600) is an example of airspace where interactions between xTM and ATS operations are expected to occur. Supersonic aircraft operating in this airspace receive services from ATS, however many other operations will be utilizing xTM services. While supersonic aircraft are controlled by ATS, their higher speeds require maneuvers to occur over large airspace areas, and their shock waves might be disruptive or damaging to certain vehicles. These effects must be considered in the establishment of separation criteria. Supersonic flights are expected to be strategically deconflicted from cooperatively separated aircraft within upper class E airspace through the sharing and adjustment of flight intent for all potentially interacting vehicles. Procedures dictate the methods for this deconfliction and associated responses in the event tactical separation is needed.

In support of separation provision and traffic advisory services, ATS has on demand access to the operational plans of vehicle’s utilizing xTM services, as there may be a need to know about individual operations for off-nominal cases or changing circumstances.

For new operations transitioning through controlled airspace, ATS interact with these new vehicles and operations. These operations, together with airspace constructs within which they operate (if applicable), are incorporated into the collaborative processes seeking to achieve performance outcomes. Entry conditions for such operations into controlled airspace require approval from ATS to ensure tactical needs can be handled. Such approvals are informed by improved information from all operations and considered by smart systems providing integrated demand/capacity management leading to desired performance outcomes. As the flights operate, ATC applies applicable procedures to ensure safe separation of all operations under their control (see Section 4.2).

3.4 Integrated Safety Management

The increasing diversity in the vehicles, characteristics (e.g., autonomy, performance), and missions alters the operational environment and associated safety risks. New UTM, UAM, and ETM operations and operators require new practices and controls to be evaluated as part of the Safety Management System (SMS). The FAA uses its regulatory authority to establish and approve new performance and interoperability standards, flight rules, metrics that inform design, operations, and information sharing. Operators are expected to conform to the regulations that address these changes and complete the required SMS analysis to assure that their operation(s) can safely integrate and adapt with the changing environment. An integrated safety management approach requires tailoring within the required SMS and processes to enable an integrated system safety approach for verifying compliance.

Integrated safety management takes a more expansive, comprehensive, end-to-end approach to safety assurance and achieving safety outcomes. FAA's integration focuses on interdependent elements, such as the airspace, airmen (operator), infrastructure, and aircraft. The risks associated with interacting ATS and xTM vehicles and operators become an important aspect of managing the airspace and in determining certification and airworthiness needs. These newly emerging risks are mitigated in an integrated manner throughout the lifecycle, including design, development, and practice. An example safety assurance strategy for autonomous vehicles may address the emerging risks from these complex vehicles and operations performed. Performance-based standards, flight rules, procedures and cooperative operating practices, and data needs must be defined and operationalized to ensure safe nominal and contingent operations. For example, data is shared and used by automation to identify conflicts. Cooperative operating practices inform automation's outputs, such as allowable corrective actions to deconflict.

Integrated safety management formalizes the management of safety outcomes as a shared responsibility among industry and the FAA. NAS participants operate according to their SMS-based processes and procedures, which includes how they work with their suppliers and consumers to assure safety. The FAA oversight of the SMS promotes a shared understanding of the operational environment, potential risks, and associated impacts among NAS stakeholders. Integrated safety management also leverages operational and performance data to conduct safety assurance activities that include more extensive data-driven safety decisions. The safety decisions become more robust because of data transparency (e.g., data is made widely available and shared appropriately among all relevant NAS stakeholders, including operators, service suppliers, airlines, manufactures, and the FAA) and increased collaborative decision making. The ubiquitous information provides each safety decision maker the context to understand the impact of their actions on others and the potential impact of others' actions on their options, including real-time corrective actions. Monitoring of flight data against safety-critical performance indicators also helps in validating compliance with and the adequacy of performance-based standards and enables run-time assurance systems in safety-critical decisions. These tools help detect potential operational issues, and enable in-time alerting, decision making, and corrective action with humans in the loop or not. Having a shared, data-driven perspective ensures safety is consistently achieved.

4 Operational Scenarios

This section presents six operational scenarios that provide operational context around the cross-cutting elements, infrastructure and enablers, and operational principles for the future Info-Centric NAS. These scenarios, summarized in Table 4-1, step through ATM operations, focusing on the integration and interactions of ATS and xTM participants.

Table 4-1. Summary of Scenarios for an Info-Centric NAS

Scenario	Description/Focus Area
Continuous Planning with Smart Systems	An integrated information environment supports simulation capabilities through the exchange of real-time operational data. The simulations produce recommendations to ATS, Operators, and xTM service suppliers for their decision making. Additionally, it enables operations to become performance driven.
Upper Class E Traffic Management Cooperative Separation	ATS, ETM Operators, and ETM service suppliers exchange data via an integrated information environment to support conflict detection and cooperative separation.
Interactions between VFR and xTM Aircraft at Lower-Level Altitudes	Ubiquitous information sharing supports how different ATS and xTM participants interact with one another to ensure safety and efficiency performance outcomes.
Agile and Evolving Services with Self-Healing Systems and Resiliency	An Info-Centric NAS relies on PPP and performance-based standards to operationalize the service-based architecture. Agile and evolving characteristics promote the ability to rapidly adapt to changes in the operational environment.
Scaling Up for Equitable Access with Agile and Evolving Services	Private service suppliers are agile and able to quickly adjust their service provisions based on changes in operational demand.
Safety Risk Management with Connected Aircraft and Smart Systems	In-time safety assurance relies on the real-time monitoring and collecting of performance data, where smart capabilities can alert, provide recommendations, and make corrective actions in-time, leveraging the integrated information environment.

4.1 Continuous Planning with Smart Systems

The continuous planning with smart systems scenario embodies a future operational state where improvements in ATM performance are achieved by leveraging large amounts of data that have been modeled, processed, put into context, and returned as information to the decision maker to select the best path to achieve the performance outcomes for the operation. The scenario shows how an integrated information environment uses actual operational data and simulated data to create a digital representation of the NAS. This digital representation provides an expansive and detailed picture of the current and future state of the NAS and enables decision makers to perform what-if trials to investigate the impact of different decisions. The actors of this scenario could be a wide range of stakeholders (e.g., Flight Operation Centers, Traffic Managers [TMs], Air Route Traffic Control Centers [ARTCCs], and xTM service suppliers) to allow for distributed decision making that enables solutions that better achieve their goals.

This scenario emphasizes collaboration among diverse traffic management systems and stakeholders and using the integrated information environment as the means of exchange for collaboration and coordination. The more extensive use and leveraging of smart systems is a key element of this scenario. Smart systems are intelligent machines that have been taught or learned to perform a range of tasks without explicit instructions. This allows the human operator to become an orchestrator of the operation rather than responsible for executing repeatable tasks that take away time from focusing on the holistic view of the operations.

The Info-Centric NAS is outcome driven, where stakeholders collaboratively define performance goals for a given time or operation. The NAS performance goals are determined through a wide range of measures (e.g., delays, reroutes, throughput, variability from predictions, etc.) and the results are analyzed to see if the desired stakeholder expectations were met. The results also serve as a basis for implementing improvements for future operations.

This scenario depicts how an operator would use a performance goal to get a range of recommendations for traffic planning from the smart system seeking to achieve the goal. This scenario is divided into two sections (1) Simulations Using Data and Applications from All Sources and (2) Decision Making with Human Machine Teaming.

4.1.1 Simulations Using Data and Applications from All Sources

Figure 4-1 shows an integrated information environment provides the means of exchange for simulations to use real operational data. The simulations produce data and use the integrated information environment as a means of exchange for ATS, operators, and xTM service suppliers to extract and utilize information needed to meet their performance goals.

The left side of Figure 4-1 shows actual operational data, such as weather, flight, flow, and aeronautical data that is collected from a wide range of sources. This data has varying levels of quality that are known and taken into consideration when modelling and making decisions based on the information derived from the data. The integrated information environment fuses the data from disparate sources to add context and transforms it into actionable information. The right side of the graphic shows several simulations and machine-learning sources at varying levels of abstraction ranging from TFM, ETM, and UTM operations, to detailed aircraft digital twins. The data obtained from these simulations are fused and put into context when sent to the integrated information environment and turned into actionable information for use by authorized NAS users.

Parties interested in using data from the integrated information environment are able to send data, request trial decision evaluation, and submit performance goals. The integrated information environment, together with the associated simulation elements, can return data, predicted performance outcomes, and a range of recommended actions to achieve performance goals.

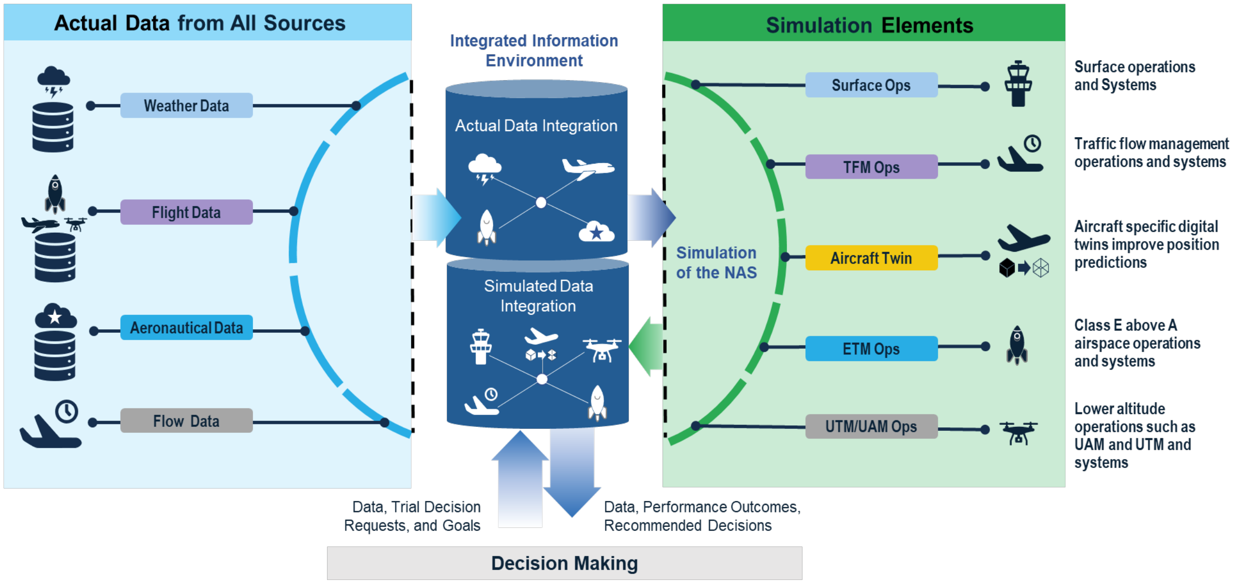


Figure 4-1. Continuous Planning with Smart Systems

4.1.2 Decision Making with Human-Machine Teaming

Figure 4-2 shows a notional process by which NAS stakeholders and operators could team with smart systems to support a performance driven NAS. In the future, all NAS stakeholders collaborate to achieve operational goals for a specific timeframe or operation. These goals could mirror the list of ATM service expectations that were developed in the *Global Air Traffic Management Operational Concept* [5], such as predictability, capacity, efficiency, flexibility, and others. After the NAS stakeholders have decided on the level of goals they want to attain, the goals are shared among ATS, Operators, xTM Suppliers, or any party responsible for the safe and efficient management of traffic in the NAS. Later, these parties submit the performance goals to smart systems that process the information by running models and simulations as previously described. The integrated information environment allows distributed models to interact. Data, trial requests, and goals are used to elicit an array of model and simulation runs. The automation then returns a range of recommendations and predicted performance outcomes, each one with a probability of success. The operators can then study the range of recommendations, make calibrations, and select a path forward that best supports their mission objectives while remaining in line with NAS performance goals. In this scenario, performance goals are the performance objectives the stakeholders aim to achieve, while performance-based outcomes are the measurement of an actual operation.

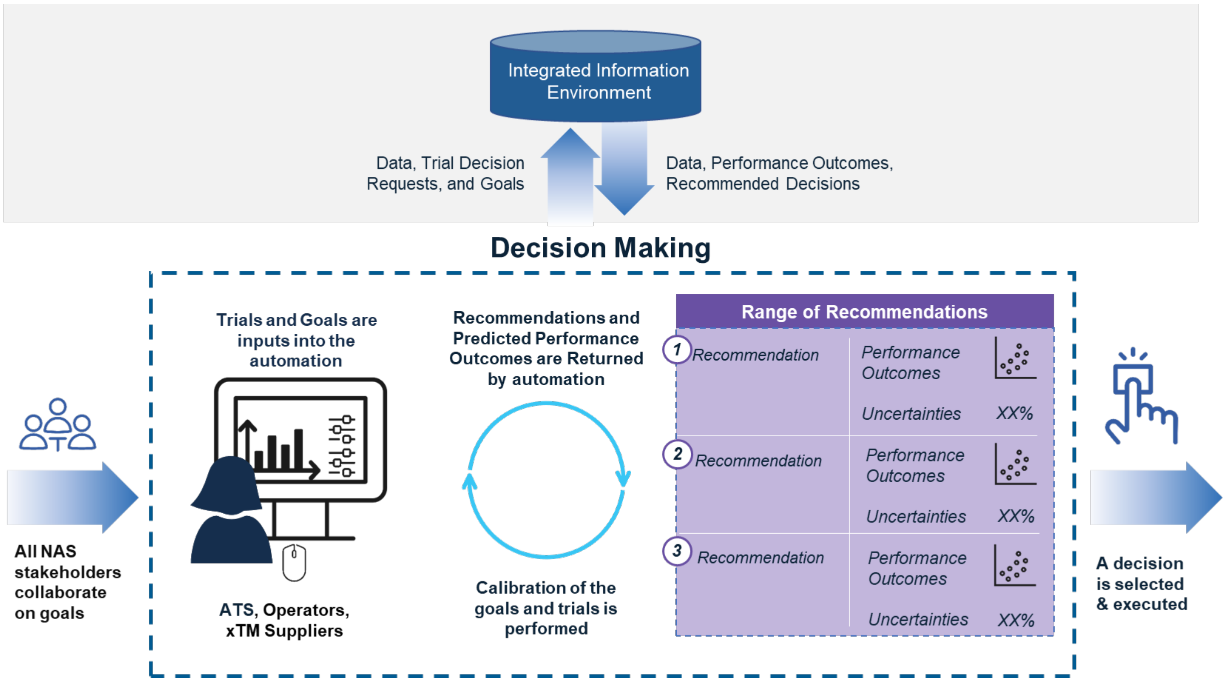


Figure 4-2. Continuous Planning with Smart Systems – Decision Making

As decision makers partner with smart systems to make complex decisions across different levels of the NAS, Human Machine Teaming becomes critical to optimize safe and efficient operations. Furthermore, automation needs to be predictable and transparent in its actions to build trust and buy-in from users.

4.2 Upper Class E Traffic Management Cooperative Separation

In the U.S., Upper Class E airspace is defined as FL600 and above. Operations in this airspace are expected to grow using vehicles of diverse performance characteristics, including supersonic transport vehicles, HALE vehicles, unmanned free balloons, airships, and state/military operations. The performance characteristics, including speeds and maneuverability, can vary significantly between vehicles. Furthermore, some of these vehicles are expected to have uncertainty regarding their planned trajectories with missions that can last for months or up to one year at a time.

Upper Class E airspace is mixed-use airspace, where some vehicles are cooperatively separating from each other in defined areas and others are using ATS. This traffic management approach is referred to as Upper Class E Traffic Management or ETM. Similar to other xTM environments, ETM operators who participate in cooperative separation are responsible for coordination, execution, and management of operations. PPPs have been established to enable operators or private third-party service suppliers to provide and enhance services in a cooperative environment. However, the need to account for disparate vehicle performance characteristics and unique mission types differentiates ETM from other xTM environments.

An operational scenario of a high-altitude unmanned free balloon as it prepares for takeoff, ascends through controlled airspace, and begins its mission in Upper Class E airspace is described below and depicted in Figure 4-3. The scenario highlights a conflict in Upper Class E airspace that is resolved through cooperative separation. Throughout the scenario an integrated information environment is being used as a means of data exchange.

- **Pre-Flight:** A balloon operator is planning a mission to operate in Upper Class E airspace. The vehicle is equipped with equipment for position tracking (e.g., Automatic Dependent Surveillance-Broadcast [ADS-B]) and communication with the operator (e.g., satellite command and control [C2] links). The balloon operator chooses to participate in cooperative separation when in Upper Class E airspace and utilizes an ETM service supplier to ensure their initial operating intent in Upper Class E airspace does not conflict with other planned operations. This is done by leveraging the integrated information environment. When initial flight planning is complete, the balloon operator shares relevant data/information with ATC and negotiates with ATC what is required for their ascent. Intent is coordinated with ATC to ensure tactical needs can be handled in ATC managed airspace.
- **Ascent:** During the ascent phase of flight up to Upper Class E airspace the balloon operator is utilizing ATS and must follow applicable flight rules and regulations. In this example, ATC manages traffic around the ascending balloon. When the balloon enters Upper Class E airspace and participates in cooperative separation, it adheres to the cooperative operating practices established and approved for the airspace. Such operating practices may include right-of-way rules, how often operational intent data needs to be updated/shared for situational awareness and/or deconfliction, and how to express the associated uncertainty with the operational intent data. In Upper Class E airspace, cooperative operators need to continually update their projected position/operation intent data, as many operations are expected to be at altitude for long periods of time (months or up to a year) and cannot deconflict their entire flight path prior to takeoff. This data is constantly being updated and shared within the integrated information environment for operators and service suppliers to monitor current operations and ensure paths remain conflict-free.
- **Cooperative Separation:**
    - **Conflict Detection:** Intent data is routinely analyzed for vehicles participating in Upper Class E airspace cooperative separation areas to determine if there is a future conflict. Intent and other operational data is also exchanged between ETM operators/service suppliers and is available to support air traffic personnel, as required, when they are providing separation services to aircraft that use ATS instead of participating in cooperative separation. What constitutes a conflict must be defined for possible interacting operations, accounting for a variety of safety considerations across involved parties within a performance-based framework. These considerations vary by vehicle type and are based on vehicle characteristics (e.g., maneuverability, ability to withstand wake or pressure wave). Conflict detection provides sufficient look-ahead time for the vehicles to deconflict given system and vehicle performance limitations. In this scenario, data on intent is applied to identify a conflict between the balloon operator and a HALE fixed wing operator.
    - **Conflict Resolution:** TaFR and cooperative operating practices, which are developed collaboratively and approved by the FAA, determine how conflicts are cooperatively managed and resolved in ETM. TaFR could include pre-determined right-of-way rules that work in tandem with cooperative operating practices. Cooperative operating practices could structure how participants exchange information to reach cooperative decisions (e.g., pre-determined bi-lateral agreements, or automated negotiations).

These flight rules and cooperative operating practices consider system and vehicle performance and mission. In this scenario, the fixed wing HALE adjusts its intent to deconflict from the balloon. The fixed wing HALE operator uses automation to:

- Plan a new flight trajectory and intent
- Coordinate that new intent to ensure it is free of conflicts
- Begin to maneuver based on the new flight trajectory
- Share information on the updated intent with other operators as needed/required

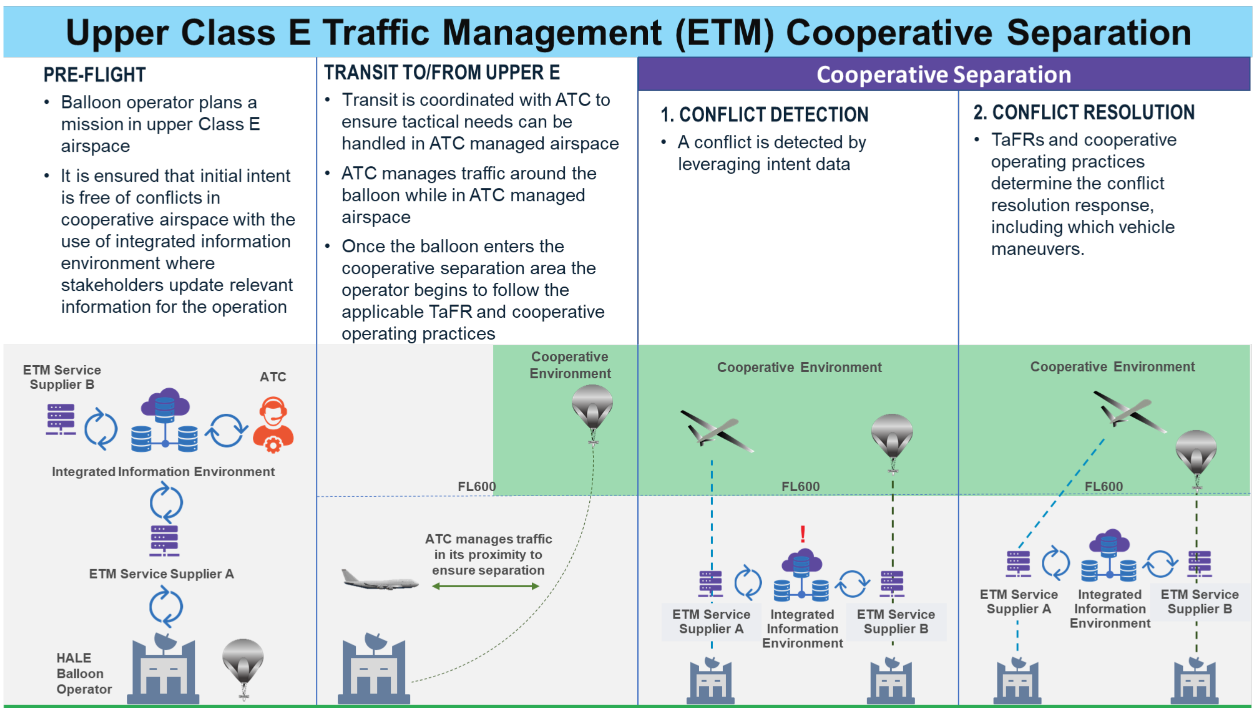


Figure 4-3. ETM Cooperative Separation

4.3 Interactions Between Visual Flight Rules and Extensible Traffic Management Aircraft at Low Altitudes

With an increasing variety of new entrant vehicles and missions operating in the NAS over the coming years, the diversity of operations in any airspace environment grows. This is particularly true in low altitudes, where a wide variety of sUAS missions are envisioned and UAM demand is expected to increase. This scenario addresses the interoperability of these new aircraft with GA operations in Class C, D, and G airspaces in the Info-Centric NAS.

To meet the safety and efficiency needs of the future, all vehicles in low-altitude airspace may be expected to share some level of position and intent data via an integrated information environment. This environment serves as a means of information exchange for all users to have a common situational awareness of the nearby operations.

In this scenario, Figure 4-4 depicts a GA flight flying VFR and descending in the vicinity of UAM and sUAS operations that is planning to land at a small, towered airport. The GA pilot may receive airspace, aircraft position, and intent data (e.g., via a portable device) and shares its intent and position data, when required, with the integrated information environment. Service suppliers along the VFR flight's intended path receive traffic advisory information about the VFR flight's intent and position. Given the information the VFR flight has shared, vehicle operators along the flight's intended path are informed of the flight position and intent. This information is used to ensure there is no conflict between xTM operations and the VFR flight. In addition, the VFR pilot has received information about where other vehicles are operating (UAM corridors and UAS dusting fields), allowing the pilot to have improved situational awareness of the operations in the area and how to avoid the airspace where these vehicles are present.

Simultaneously, a UAM operation is taking place near the airport. The UAM service supplier automation interacts with operators using the integrated information environment to obtain position, intent, and current and planned use of these UAM corridors. In addition, the UAM vehicles have cooperative DAA capabilities enabled by vehicle-to-vehicle communication and separation (e.g., separation within the UAM corridors).

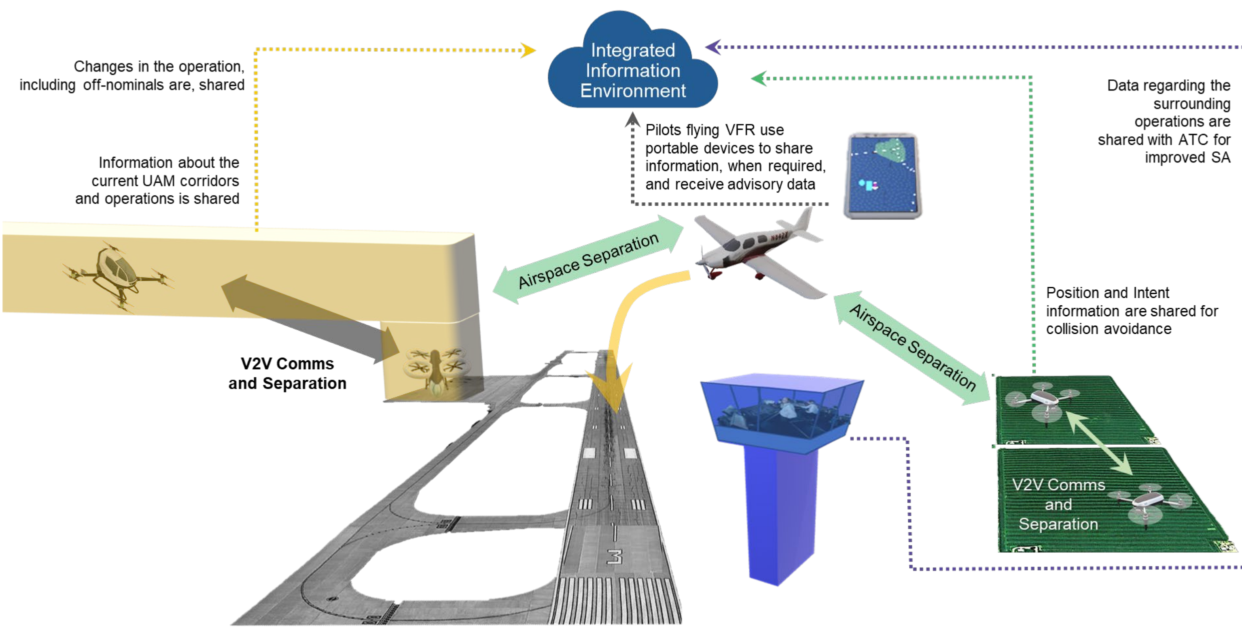


Figure 4-4. Interactions between VFR and xTM Aircraft

Concurrently, a flock of sUAS is dusting crops. The operation volume in which the sUAS are flying is shared with all participants via the integrated information environment. In addition, the sUAS have detect and avoid capabilities that support them in sustaining separation from each other.

Data regarding the surrounding operations, such as the location of UAM corridors and UTM operation volumes, are available on demand to the Tower ATC for improved situational awareness during nominal operations and turn salient during off-nominal operations.

4.4 Agile and Evolving Services with Self-Healing Systems and Resiliency

This scenario highlights a future operational environment with a service-based architecture, where integrated capabilities are modular and organized into distributed services that are managed by various public and private entities. In addition, this scenario shows how these services may quickly adapt and evolve to introduce new self-healing capabilities in response to the need for resilient operations. Self-healing capabilities include monitoring and control (M&C) intelligence to predict, diagnose, and correct issues without human intervention where feasible. Resiliency in the NAS is the ability to provide and maintain an appropriate level of service in a timely manner when facing non-normal conditions, where the architecture and system design do not constrain any required rapid adjustments when returning to normal operations.

To meet the operational needs in the future, the NAS needs a common, reconfigurable, and scalable architecture to accommodate growth and new and updated services. Figure 4-5 shows service-based architecture moves away from the monolithic automation systems, and supports interacting, distributed capabilities that are organized into services. These services may include only the application or include application and the underlying supporting network. ATM services are provided by public and private entities (service suppliers) through partnerships, where the responsibility of developing, deploying, and managing services varies among public and private entities based on the service application and user**.** Performance-based standards inform the design of various architecture layers to which ATS and xTM service suppliers adhere.

These ATM services are provided to the appropriate users to support operations in the NAS. This scenario assumes new types of PPPs will enable operators or private third-party service suppliers to provide and enhance traffic management services in areas where cooperative separation services are permitted for UAM, UTM, and ETM. Figure 4-5 shows how individuals are interconnected and have continuous access to necessary services in the NAS. Ubiquitous services rely on architecture characteristics like agility that allows ATS and xTM service suppliers to quickly evolve and accommodate changes. It also relies on diverse public and private ATM service suppliers that provide redundant services to ensure there are no gaps in service coverage and that these services are delivered securely and safely.

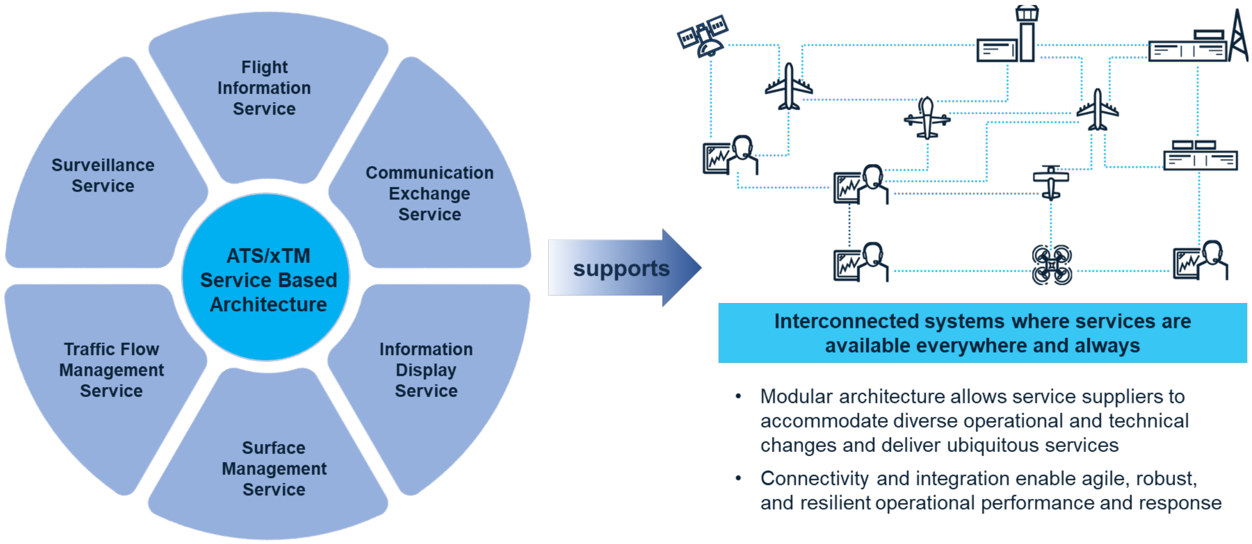


Figure 4-5. Agile and Evolving Services with Self-Healing Systems and Resiliency*: Service Based Architecture for Ubiquitous Services*

Resiliency is achieved by having alternative services and supporting infrastructure. Service suppliers have the ability to reconfigure on an as-needed basis in the design of their services, where performance-based standards inform the required operational performance that service suppliers need to achieve and ensure. Traditional M&C capabilities and services evolve. Self-healing M&C services leverage new technology like machine learning and artificial intelligence to continuously monitor (learn what are good and bad behaviors based on historical operational conditions, data, and events), detect failures (which may be done in real time or pre-emptively assess the performance indicators against actual operational performance), identify appropriate recommendations to resolve, and correct the failure on its own without human intervention or alerting a user it cannot be resolved by automation.

In Figure 4-6, the communication service provides system status data to this self-healing M&C service, informing of its current status and changes in operations, such as a system outage. The self-healing M&C service continuously evaluates the communication service's status, potentially integrating this data with the health status of other communication services to create a broader picture of all NAS communication services. Should a communications pathway go down, as depicted by the red path in Figure 4-6, the self-healing M&C service automatically reconfigures the communication network to bypass the offline node. If the network cannot be successfully automatically reconfigured, the self-healing service may determine the need to scale up current available communication services, which can be provided by different private entities, to ensure adequate communication coverage during this outage. Regardless, if the impetus is an outage or an untrusted person within the network, these self-healing M&C services automatically adjust their resources in a timely manner that is transparent to NAS operators. When automatic reconfiguration occurs, network users may need to assess the adequacy of service if the change results in a reduced level of network performance.

A user, like a technical operations or service maintenance person, may need to step in and provide input in situations when the self-healing M&C service encounters an unknown behavior and cannot determine an appropriate solution. The service alerts the user whenever it has reached this state, allowing the user to determine the appropriate response to resolve the situation. In these situations, it may be necessary to modify operations, taking into account air traffic controller currency and airspace familiarization, instead of reallocating resources or modifying the network configuration. The self-healing service learns from this situation and refines their internal algorithms for making actionable recommendations.

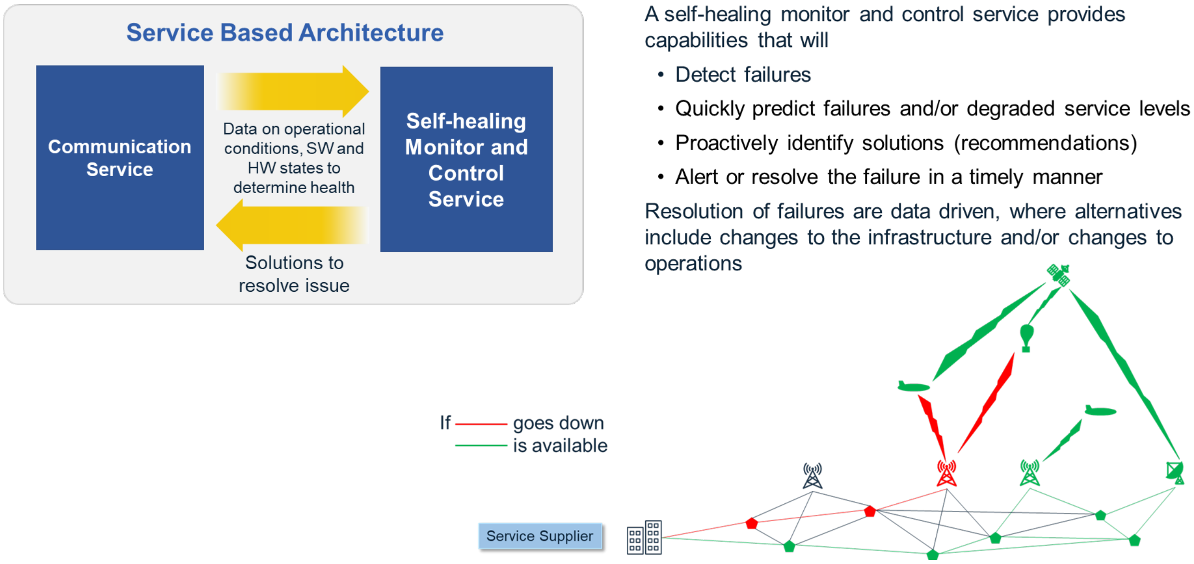


Figure 4-6. Agile and Evolving Services with Self-Healing Systems and Resiliency: *Operational Resiliency through Self-healing Services*

4.5 Scaling Up for Equitable Access with Agile and Evolving Services

Scaling services for equitable access looks at how ATM service suppliers support ATS and xTM operations by rapidly evolving and modifying any provisioned services to respond and keep pace with future operational demands. The operational environment includes a service-based architecture with integrated capabilities that are organized into flexible, configurable, distributed services, managed by various public and private entities. For example, in the Info-Centric NAS, UAS operations may increase and require scaling up of UTM services to accommodate this growth. This scenario describes how UTM service suppliers establish and modify services for UTM operators and assumes that new types of PPPs will be leveraged so operators or private third-party service suppliers may provide and enhance traffic management services for UTM. While the emphasis is on UTM, this scenario may be applied to ATS, UAM, and ETM, where the trigger to scale services (e.g., communication, services) may differ.

In Figure 4-7, this scenario begins with a single service supplier who is supplying a set of services to a subset of UTM operators in the NAS. Through PPPs, a private organization may serve as a service supplier and provide single or multiple services to UTM operators. A UTM environment may have multiple service providers that are providing a range of services to a range of operators. Service suppliers design, develop, and verify that their UTM services adhere to performance-based standards. In addition, UTM service suppliers may follow unique cooperative operating practices that specify how they interact with UTM operators.

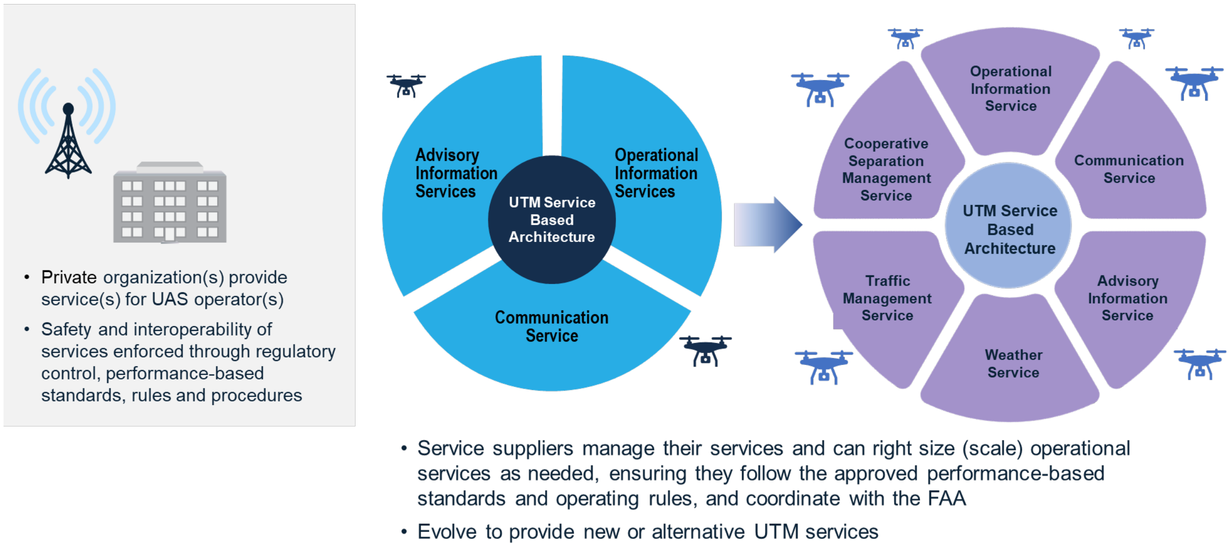


Figure 4-7. Scaling and Evolving Services for UTM Operations

Due to an increase in the number of diverse operations and need to handle additional data exchanges, UTM service suppliers determine the need to scale up current service provisions and offer new additional services. The middle and right-hand side of Figure 4-7 shows the UTM service supplier may initially only provide advisory and information services to operators, such as information regarding potential operational obstacles, and weather forecasts for planning purposes as the airspace operations are less complex. However, as operations increase over time, the operators may need additional traffic management, cooperative separation, and communication capabilities, which UTM service supplier or suppliers scale up and provide. UTM service suppliers add more services to manage complexity and to ensure that their users (operators) have the right access to these services to operate safely and efficiently.

Scaling is about adjusting service provisions to ensure it meets the intended operational demand. These services and service suppliers are agile and evolve to accommodate these evolutions in the environment.

4.6 Safety Risk Management with Connected Aircraft and Smart Systems

This scenario covers safety assurance where a data rich environment is used for data-driven safety decision making. Integrated safety management articulates the value for having a common safety system perspective to evaluate potential problems and issues that are introduced by distributed and diverse systems and operators, and to identify procedures, processes, and operational requirements that mitigate the potential risks. This scenario assumes that vehicles share position, intent, and status data via various networks and the integrated information environment. A connected aircraft uses commercial communications technology to exchange this operational data, like the health status of an individual component that is onboard the aircraft, with appropriate stakeholders and ground systems for further evaluation. A smart system is an intelligent automation system whose data analysis, decision making, and learning algorithms perform a range of tasks without explicit human intervention. This scenario highlights how data shared from the connected aircraft will be used to support in-time safety assurance, with cognitive assistance tools.

In-time safety assurance represents a continuum of safety-related decision making, where data is collected and continuously evaluated in real-time, and alerting and corrective actions are done when necessary. Following performance-based standards, the continuous evaluation of performance and operations use commercially available systems and technology on the connected aircraft, like a mobile device with an enhanced safety monitoring application. During flight, this application could evaluate an aircraft's component's data outputs to evaluate its operational performance against some performance indicator. Figure 4-8 shows that such a tool detects anomalies in the performance data and behaviors. If deemed appropriate, the tool immediately alerts of potential operational or safety issues for a pilot to take immediate corrective action, in real time.

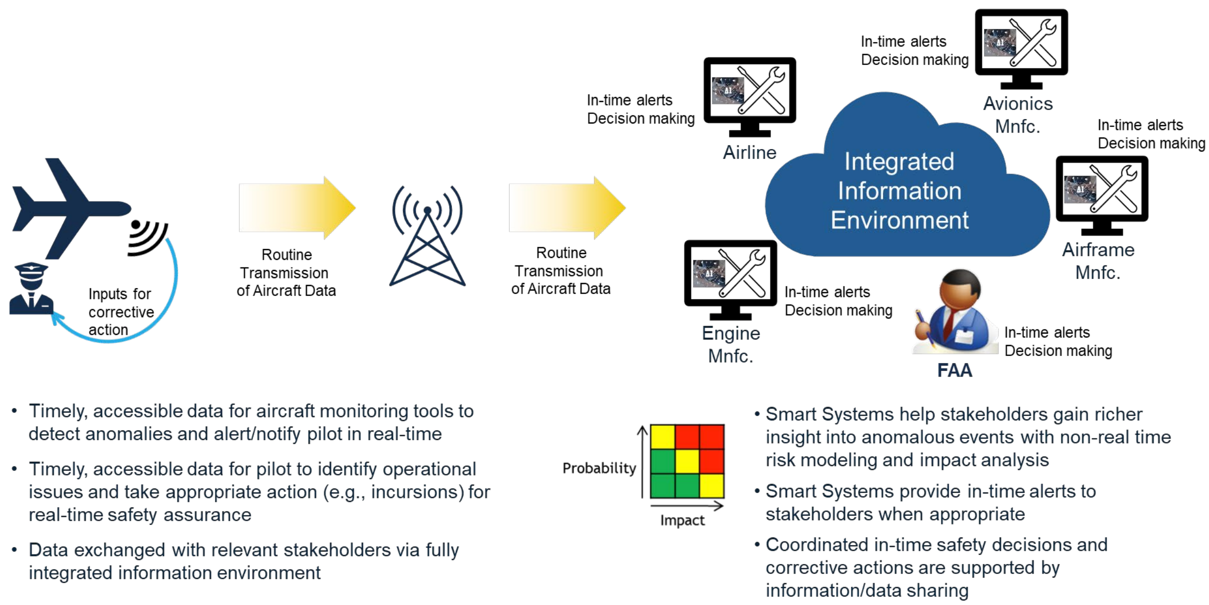


Figure 4-8. In-time Safety Risk Management with Connected Aircraft and Smart Systems

In addition to using the component data to evaluate operational performance in real time, this operational and system data may be used to make other types of safety-related decisions for a specific operator (e.g., airline), such as maintenance and fleet management decisions. In Figure 4-8, data from the connected aircraft are routinely transmitted, in real time, to the relevant stakeholder and their supporting ground systems via individual communication networks. The onboard data includes component health status, state, position, intent, engine health, and more.

Moving away from post-event and operations analysis, the stakeholder leverages smart systems that use provided data from the integrated information environment to identify performance trends and errors in the data, turning the data into valuable information. By assessing anomalies and data trends, these smart systems assist the stakeholder by identifying negative behaviors or tendencies, notifying them of what corrective action is necessary, and providing additional insight, such as the consequence of inaction, needed for in-time decision making. The analysis done here informs future decisions that have a longer horizon, which may be in terms of hours, days, and months. The data from the connected aircraft are evaluated by the smart system that informs maintenance personnel that immediate corrective action is necessary to address a component failure on an inbound flight. It is also feasible that the performance data trends indicate a deeper problem, such as an avionics issue for a specific aircraft type or the need for changes in engine performance levels of a flight operation.

Based on the negative trends, the respective avionics' manufacturer may evaluate the totality of the data across customers to determine if this faulty behavior requires a wider corrective action and for the FAA to issue an advisory or a procedural, functional, or operational improvement, if appropriate. Corrective action may be based on performance data trends, where the recommended action may be local to a specific aircraft or require additional coordination. In the latter, it is imperative that the safety information (like the trends analysis of an avionics' performance) be shared with additional stakeholders, like the manufacturer, in a timely manner so they can use these insights to address safety issues effectively and efficiently.

These smart systems have advanced analytics capabilities that are built upon taking a holistic approach to how individual elements, like the aircraft, operational procedures, operating environment, infrastructure, and the airmen contribute to safety and achieving safety outcomes. These capabilities provide insight into the potential operational and emerging problems and risks, ensuring that NAS stakeholders are meeting the overarching performance-based outcome for safety. Policy, data governance requirements, and procedures are enablers for this scenario and support the secure exchange of data in the NAS via the integrated information environment. At a minimum, this information environment must adhere to guidelines on how data are shared and curated, when data and/or information is reported, and who is authorized to access this information.

5 Summary of Key Impacts of the Info-Centric NAS

The Info-Centric NAS cost-effectively improves the speed and magnitude of operational improvements to existing users while integrating the expected growth of new operators and their missions into the NAS. It provides a flexible framework that allows the NAS to adapt quickly to evolving operations and to leverage new technologies. Data and its sharing are the critical components for interoperability in the NAS, enabling an efficient NAS that provides equitable and fair access to all vehicle types, while maintaining safe operations. An integrated information environment processes information and shares data to support collaboration, distributed decision making, and interoperability among traffic management services and NAS users. Advances in cybersecurity ensure information integrity, while increased network diversity ensures reliability and continuity of service for all operations.

To realize the Info-Centric NAS and the associated benefits, policies, governance, and a performance-based strategy need to be defined. Safety risk management and operations in the Info-Centric NAS drive information and technology. To accommodate diverse operations, service delivery to NAS users is changing and service suppliers are being added. Processes are enhanced for review and approval of standards, rules, regulations, and for oversight of xTM services and service suppliers.

The impacts are organized below in three areas, with associated needs.

1. **Operations:** NAS operations evolve to see conventional aviation and ATS operate alongside diverse users, operations, vehicles, and collaborating traffic management systems. The safe co-existence of these operations will need:
    a. An established process, including any required standards, policy, or guidance, for review, approval, and monitoring of cooperative operating practices
    b. Assessment of any required changes to airspace design and allocation for performance-based operations of diverse operations.
    c. Collaboration among appropriate stakeholders to discuss and reach agreement among and within ATS and xTM service suppliers on measuring, valuing, prioritizing, and balancing operations based on performance-based outcomes (e.g., access, capacity, efficiency, and equity).
    d. Further discussions to explore and understand the relationship of performance-based outcomes to operational objectives and distributed decision making to account for operators optimizing their own operations without adversely affecting the NAS system-level performance.
    e. Established processes to define TaFRs for diverse operations and a data-driven process to oversee and monitor TaFR compliance.
    f. Data-driven processes to measure performance of xTM operations and services.
2. **Infrastructure:** The Info-Centric NAS sees the NAS transition towards a service-based architecture, where integrated capabilities are modular and organized into distributed services that are managed by various public and private entities These changes need:

a. Development of standards for data management and use and governance for data access and exchange to support the increasing dependency on data and an integrated information environment.

b. Architecture, information management, and automation for massive data analytics.

c. Standards, policy and regulations for ATM service delivery and data provision, when appropriate, including a framework to determine which services and data require certification or qualification.

d. Criteria and process to review and approve suppliers that provide technology, services, capabilities, and data to support diverse operations and xTMs, as necessary.

e. Criteria and framework to assess and leverage opportunities in xTMs to improve ATS services and delivery, NAS operations, and NAS management.

3. **Integrated Safety Management:** This more comprehensive, end-to-end approach to safety assurance involves interdependent ATS and xTM elements that all contribute to achieve the safety outcome. For safety to stay abreast of the increasing diversity in vehicles, missions, and operational environments, the Info-Centric NAS needs:

   a. A system-wide safety risk management analysis to understand when total risk in the Info-Centric NAS is unacceptable.

   b. A process to tailor safety requirements for diverse operations and new technologies.

   c. Activities and automation support for a data-driven and integrated safety assurance perspective shared among relevant stakeholders and more extensive, data-driven safety decisions.

   d. Data-driven automated processes to reach more timely decisions in response to changes that support diverse operations and NAS user needs (e.g., new vehicle certification, system enhancements and upgrades, introduction of new technologies and methods).

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Appendix A Glossary

Term	Definition
Cooperative Operating Practices	Operating practices collaboratively developed by affected communities (e.g., operators, service providers, manufacturers) for operating in the airspace. Cooperative operating practices describe interactions between stakeholders (i.e., between operators and service suppliers) within and between ATS and xTMs.
Diverse Users	Operators of any vehicles in the NAS.
Extensible Traffic Management (xTM)	ATM extended to include a variety of new services which include UTM, ETM, UAM Traffic Management and others. These are known as xTMs.
Integrated Safety Management	A layered approach to safety controls that includes managing risks introduced by the integration of distributed and diverse systems and operators.
Performance-Based Outcomes	Reflect the stakeholders' agreed upon measurable strategic objectives that indicate the relative value that stakeholders place between different operational priorities, such as access, capacity, efficiency, and equity.
Performance-Based Standards	Standards that describe the required system and operators' levels of performance, without reference to specific equipage for specific, future operations.
Tailored Flight Rules	New flight rules tailored to ensure safety for new operations when vehicles and operations cannot meet IFR or VFR regulatory requirements.
Ubiquitous Services	ATS or xTM services delivered everywhere, always, and securely

Appendix B Abbreviations and Acronyms

Term	Definition
ADS-B	Automatic Dependent Surveillance-Broadcast
AGL	Above Ground Level
ANSP	Air Navigation Service Provider
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
C2	Command and Control
CNS	Communications, Navigation, Surveillance
ConOps	Concept of Operations
COP	Cooperative Operating Practices
DAA	Detect and Avoid
DHS	Department of Homeland Security
ETM	Upper Class E Traffic Management
FAA	Federal Aviation Administration
FL	Flight Level
GA	General Aviation
HALE	High Altitude Long Endurance
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
iTBO	Initial Trajectory Based Operations
LAANC	Low Altitude Authorization and Notification Capability
M&C	Monitoring and Control
NAS	National Airspace System
NextGen	Next Generation Air Transportation System
PBFM	Performance Based Flow Management
PPP	Public-Private Partnership
PSU	Provider of Services
SMS	Safety Management System
sUAS	Small UAS

Term	Definition
TaFR	Tailored Flight Rules
TBFM	Time-Based Flow Management
TBO	Trajectory Based Operations
TFDM	Terminal Flight Data Manager
TFM	Traffic Flow Management
TM	Traffic Manager
TMI	Traffic Management Initiative
U.S.	United States
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UTM	UAS Traffic Management
VFR	Visual Flight Rules
xTM	Extensible Traffic Management