Joint Planning and Development Office

Concept of Operations for the Next Generation Air Transportation System

DRAFT

Version 0.2

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Preface

The Joint Planning and Development Office (JPDO) is developing a Concept of Operations (CONOPS) for the Next Generation Air Transportation System (NGATS). The final version of the CONOPS will provide an overall and integrated view of NGATS operations in the 2025 timeframe, including key transformations from today's operations.

The development of the CONOPS is an iterative and evolutionary process that will progress using input and feedback from the aviation community. This is Version 0.2 of the document. It provides an initial presentation of air traffic management (ATM) operational concepts focusing on the "block-to-block" operations for a day of flight in the NGATS.

The purpose of this document is to provide the aviation community with a preview of the NGATS CONOPS and receive their comments for improvements. Details of the JPDO comment and review process can be found at the Tech Hanger of www.jpdo.aero. Future versions of this document will include accepted comments as well as expand upon the NGATS concepts to include:

- Aerodrome operations and mission support
- Air traffic management planning and mission support services
- Flight operations planning and mission support services
- Layered adaptive security services
- Network-enabled infrastructure services
- Shared situational awareness services
- Safety management services
- Environmental management services
- Compliance, regulation and harmonization services

This document identifies key research and policy issues that need resolution to achieve national goals for air transportation. In many cases, this document presents "aggressive" concepts that have not been validated but are envisioned to maximize benefits and flexibility for NGATS users. Many potential futures are possible and much will depend on the insights gained by the evolution of the CONOPs. Comments to refine these research issues are requested.

The following page outlines the current and expected development chronology of this CONOPs.

Document Revision Register

Version	Document Content Added	Reviewer	Release Date
0.1	*Initial document that includes the major "day-of-flight" air navigation elements that support operational activities of a flight moving from "block to block"*	*JPDO Staff and Integrated Product Teams*	*May 9, 2006*
0.2	*Major comments from Version 0.1 review*	*Aviation Stakeholder Community*	*July 24, 2006*
1.0	*Major comments from Version 0.2 review*	*Submitted to JPDO Board for Approval*	
1.1	*Initial addition of remaining key NGATS concepts that support operations from "curb to curb" as well as planning and strategic support functions*	*JPDO Staff and Integrated Product Teams*	
1.2	*Major comments from Version 1.1 review*	*Aviation Stakeholder Community*	
2.0	*Major comments from Version 1.2 review*	*Submitted to JPDO Board for Approval*	
2.1	*Operational scenarios, additional definitions, and previous comments not included in prior versions*	*JPDO Staff and Integrated Product Teams*	
2.2	*Major comments from Version 2.1 review*	*Aviation Stakeholder Community*	
3.0	*Major comments from Version 2.2 review*	*Submitted to JPDO Board for Approval*	
3.1 and above	*Additional versions developed as needed*		

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INTRODUCTION

The Concept of Operation (CONOPs) provides a common vision of how the Next Generation Air Transportation System (NGATS) will operate in the 2025 timeframe. This concept provides an operational view of the transformations necessary to achieve the NGATS overall goals. These transformations affect how air traffic and airports are managed, how security is provided to protect our airspace and people, how the environment is protected and enhanced, and how safety and efficiency are achieved.

The CONOPs forms a baseline to initiate a dialogue with the aviation stakeholder community to develop the policy agenda and encourage the research needed to achieve national and global goals for air transportation.

The goals for the NGATS are aimed at significantly increasing the capacity, safety, efficiency, and security of air transportation operations and thereby improving the overall economic well being of the country. These benefits are achieved through a combination of new procedures and advances in the technology deployed to manage passenger, air cargo, general aviation, and air traffic operations. The *NGATS Vision* briefing (2005) identifies eight key capabilities to achieve these goals:

- Network-Enabled Information Access
- Performance-Based Services
- Weather Assimilated into Decision Making
- Layered Adaptive Security
- Broad-Area Precision Navigation
- Aircraft Trajectory-Based Operations
- Equivalent Visual Operations
- Super Density Operations

To meet the NGATS goals, the vision for NGATS is a transformed air transportation system that allows all communities to participate in the global marketplace, provides services tailored to individual customer needs and capabilities, and seamlessly integrates civil and military operations. Some of the significant NGATS characteristics are:

- User Focus
- Distributed Decision-Making
- Integrated Safety Management System
- Internationally Harmonized
- Capitalizing on Human and Automation Capabilities
- Integrated Weather Operations
- Environmental Stewardship
- Robustness and Resiliency
- Scalability

The current draft of the NGATS CONOPs is described in several key areas:

- Air Navigation Service Operations
- Flight Operations
- Net-Centric Infrastructure Services
- Shared Situational Awareness Services
- Security Management Services

Additional topics such as aerodrome operations, safety management, and regulation will be covered in subsequent versions.

AIR NAVIGATION SERVICE OPERATIONS

The overall philosophy driving the delivery of services within the NGATS is to accommodate user preferences to the maximum extent possible. Achievement of many of the NGATS objectives relies on the transforming roles and capabilities of the aircraft and flight crew, along with changes in air traffic management (ATM) capabilities and decision-making authority. Using these new roles and capabilities, ATM services provided by the Air Navigation Service Provider (ANSP) shifts from managing the tactical separation of aircraft to the strategic management of traffic flows.

Performance-based services align ATM assets with user demand. New kinds of flight operations—such as autonomous operations, in which aircraft mange their own tactical separation from each other, and ANSP flow operations, in which precise execution of agreed trajectories allows much higher traffic throughput than is possible today—dramatically improve en-route productivity and capacity. Conflict detection and resolution—both airborne and ground based—are highly automated, allowing for reduced and encounter-specific separation standards.

Significant transformations in the area of air traffic management are summarized in the table below:

Significant Transformation	NGATS Capability
Trajectory-Based Operations	• All operators share flight intent information via four dimensional trajectories (4DTs); the level of specificity varies according to overall system needs to handle demand • Automation manages greater amounts of information on overall demand and forecast conditions and better incorporates probabilistic data to reduce the likelihood of overly conservative decisions • Metering, Controlled Time of Arrival (CTA) exchange, and more flight-specific adjustments increase overall throughput and operator efficiency

Significant Transformation	NGATS Capability
Performance-Based Operations and Services	• Regulatory definition of operational requirements in performance terms rather than specific technology/equipment enables private sector innovation • ANSP service levels aligned with aircraft performance capabilities, allowing aircraft operators to realize the full benefits enabled by their equipment capability
Collaborative Traffic Flow Management (ANSP and Flight Operators)	• Focus is on allocating NAS assets to maximize capacity to meet user demand • Integrated strategic and tactical flow management (TFM) with more agile management of TFM to capitalize on evolving conditions exists • Better decision support increases ability to use capacity in presence of uncertainty
Allocation of Airspace	• Airspace allocation is flexible over different time horizons to meet demand, and flexible over different geographic and vertical boundaries. Airspace restrictions for aircraft capability are applied only when needed • Changes to airspace configuration are provided dynamically to flight crews so that maximum trajectory flexibility to utilize all available airspace
Separation Management	• Separation provision, both airborne or by the ANSP, relies heavily on automation support, allowing reduced and performance-based separation standards for different airspace categories • 4DTs of many aircraft following similar routes may be aligned to nearly eliminate conflicts • Trajectory changes required for separation assurance are communicated via digital communications
Weather/Automation Integration	• Enhanced probabilistic forecasting coupled with network-enabled operations and decision support tools predict best options and facilitate 4DT planning and execution for minimal weather disruption

Future aircraft will have a wider range of performance than today and will support enable varying levels of operations via onboard capabilities and associated crew training. These operations will include performing airborne spacing, airborne separation, and airborne self-separation tasks to safely avoid weather effects and precisely exchange and execute 4DTs. The minimum aircraft capability for operation within managed airspace is a cooperative surveillance system. In trajectory-based airspace, all aircraft also have a capability to receive, transmit, and execute 4DTs and air traffic clearances.

Runway capacity is the primary limiting factor in NAS operations today at the busiest airports; therefore, more efficient runway use is very important. Even with the maximum possible efficiency gains, some aerodromes may need additional runways to accommodate the expected NGATS traffic growth. Implementing super-density terminal procedures, such as new parallel runway procedures, will enable new runways to be built much closer to an existing runway and still achieve the throughput of a single arrival runway, regardless of ceiling and visibility. Surface operations in the NGATS timeframe at medium- and large-demand aerodromes will be highly integrated with other ATM functions, including departures, arrivals, and collaborative traffic management. In addition, non-ATM functions, such as airport landside and airside operations, will benefit from information exchange of aircraft surface position and movement. The following table shows a summary of the major surface operation transformations:

2006	NGATS
Ground surveillance available to ANSP limited. Mostly primary, some secondary surveillance capability installed. Limited effectiveness of runway incursion prevention automation.	Cooperative ground surveillance at most aerodromes, including state vector information (e.g., aircraft speed/direction), with more effective runway incursion prevention automation.
Essentially no cockpit surveillance of other ground traffic/vehicles, other than visual (out of the window).	Integrated surveillance of ground traffic, along with aerodrome layout and taxi routes, with cockpit warning of runway incursions.
Surface movement information (pushbacks, departures, taxi delays, etc.) are mostly not integrated with TFM. Difficult to implement flight-specific traffic management initiatives.	Updated pushback information provides improved surface and departure management. Surveillance of surface movement provides basis for more accurate departure time and taxi delay estimates. Availability of improved departure time estimates significantly improves capability of Flow Contingency Management and Tactical Trajectory Management. Flight-specific traffic management initiatives are handled via automation and data communications.
Many non-towered aerodromes.	Automated Virtual Towers or better where economically feasible.
Inefficient one-in-one-out operations at smaller aerodromes without approach controls or towers.	Elimination of one-in-one-out restrictions at most aerodromes for equipped aircraft.

FLIGHT OPERATIONS

Aircraft operators are individuals or organizations that directly or indirectly operate an aircraft. Aircraft operators include, for example, those who operate aircraft for commercial and business purposes, personal travel, military training or homeland defense. The types of aircraft operated can range from lighter-than-air vehicles and gliders to highly sophisticated aircraft and space vehicles. Aircraft operators include those who operate traditionally piloted aircraft and those who operate aircraft remotely such as Unmanned Aircraft Systems (UAS). In organizations that operate aircraft, multiple individuals may be involved in roles related to flying an aircraft, planning and selecting flight trajectories, and defining strategic objectives.

New levels of technology and additional automation capabilities alter the role of the flight crew and operators in the NGATS. The transition from pilot to aircraft systems manager will continue to evolve. In addition, the functions of UAS will be further refined. The roles of the flight crew in the NGATS include the following primary functions: supervisory override, aircraft system manager, participant in collaborative traffic flow management, and the more traditional "see and avoid" visual flight operator. These roles are more focused on aircraft operators with greater capabilities and on performing trajectory-based operations (TBO).

The capabilities required of an aircraft operating in the NGATS will largely depend on phase of flight, aircraft type, operating environment, and the level of air traffic density supported at the time of the operation. The basic capabilities for TBO will include an area navigation system, aircraft-to-ground (A-G) two-way communications, and cooperative surveillance to track and monitor aircraft.

NET-CENTRIC INFRASTRUCTURE SERVICES

NGATS can achieve the operational improvements envisioned by developing and deploying a comprehensive suite of enterprise services. These enterprise services give operational entities within the NGATS environment a common picture of the operational information necessary to perform their required functions.

Enterprise services can be characterized by the net-centric infrastructure services that provide connectivity and universal access to information and by the services that provide the collection, processing, and distribution of information.

Key transformations of infrastructure services are summarized in the table below:

Enabler	2006	NGATS
Network-Centric Information Sharing	• Limited or no ATM (e.g., traffic) information in cockpit; often, non-common data shared among actors • Not all stakeholders have access to data they need • Stakeholders use custom data sources	• More common ATM information provided to the ANSP service provider, cockpit, and aircraft operators (see Figure 2-1) • Flexible delivery of needed information and services independent of user geographical location • All stakeholders can obtain access to data they need
Aircraft Data Communications	• No data communications for ATM and operational control • Limited access to real-time weather and aeronautical data • Voice communications are routine for ATM	• 4DT, short-term intent, and other data routinely transmitted between aircraft and ANSP • Data communications are routine for ATM; in airspace reserved for TBO, voice communications used only for extraordinary purposes • Capability to permit extensive negotiation between air and ground of 4DT

Enabler	2006	NGATS
Infrastructure Management Services	• Limited ability to maintain operations when a major facility goes out of service • Limited ability to reconfigure resources to maintain operations when a major outage occurs	• Network-centric information sharing and ability to reconfigure resources to maintain operations when a major outage occurs results in ability to maintain normal operations when a major outage occurs

SHARED SITUATIONAL AWARENESS

Key shared situational awareness (SSA) services enable the fundamental operations of the NGATS and transform the national air space operation. The table below highlights these key services and their transformations:

Enabler	2006	NGATS timeframe
Weather Information Services	• Limited common weather information; requires use of skilled interpretation • Limited use in decision support systems; • Limited on-board weather information available during flight	• Single authoritative source of accredited weather information facilitates more consistent decisions among stakeholders • Presents data tailored to user operational needs • Uses integrated weather/decision support systems heavily • Provides automatic updates to users based on operational need
Broad-Area Precision Navigation Services	• Air routes are mostly defined by fixed ground-based navigational aids • Expanding use of RNAV and RNP procedures • Costly ground-based infrastructure in parallel with space-based infrastructure	• Air routes are independent of the location of ground-based navigation aids • RNAV used everywhere; RNP used where required to achieve system objectives • System performance meets operational needs to service the demand
Surveillance Services	• Limited coverage • Limited airborne traffic situational awareness	• Coverage to the surface and in remote areas; capable of meeting NGATS operational needs • Common surveillance data available to all stakeholders (ANSP, defense, security, aircraft operators)
Flight Planning Services	• Limited interactive flight planning capability • Limited ability to receive projections on anticipated conditions that affect aircraft flight plans	• Flight planning information services provide the user with extensive and interactive flight planning capability • Operators receive feedback on anticipated conditions associated with a filed 4DT

Enabler	2006	NGATS timeframe
Flight Object Services	• Multiple similar calculations of flight trajectory, airspace penetrations, time of arrival, etc. leading to inconsistent information about a flight • Information about a flight is specific to an application or location and is inconsistent across applications and locations • Information about a flight is dispersed through many owners	• Flight information is shared in such a way that that leads to consistent trajectory information which can be provided to all authorized flight data users as a service • Flight information is consistent across applications and locations and available to authorized flight data users • Information about a flight is contained in one logical unit
Flow Strategy and Trajectory Impact Analysis Services	• High reliance on oral and textual communication of strategies and concerns • Limited access to both data and tools • Limited decision support capabilities leads to conservative planning	• High reliance on data communications and graphical presentations • Significantly increased access to data, models, and tools • Better decision support to increases ability to use capacity • Common trajectories and analysis capability to improve quality and consistency of decision-making • Automation and information services to increase awareness of constraints and strategies under consideration
Aeronautical Information Services (AIM)	• Much of the AIM is provided by hard copy or voice • Limited ability to receive and process information regarding airspace	• Most of the AIM data is text or graphic presentations; data is consumable by automation for processing • Users are supported by automation capabilities to exchange real-time information regarding airspace

Layered Adaptive Security Services

NGATS will provide effective air transportation system security without limiting mobility or civil liberties by embedding security measures from reservation to destination. Key concepts of the layered, adaptive security (LAS) within NGATS include:

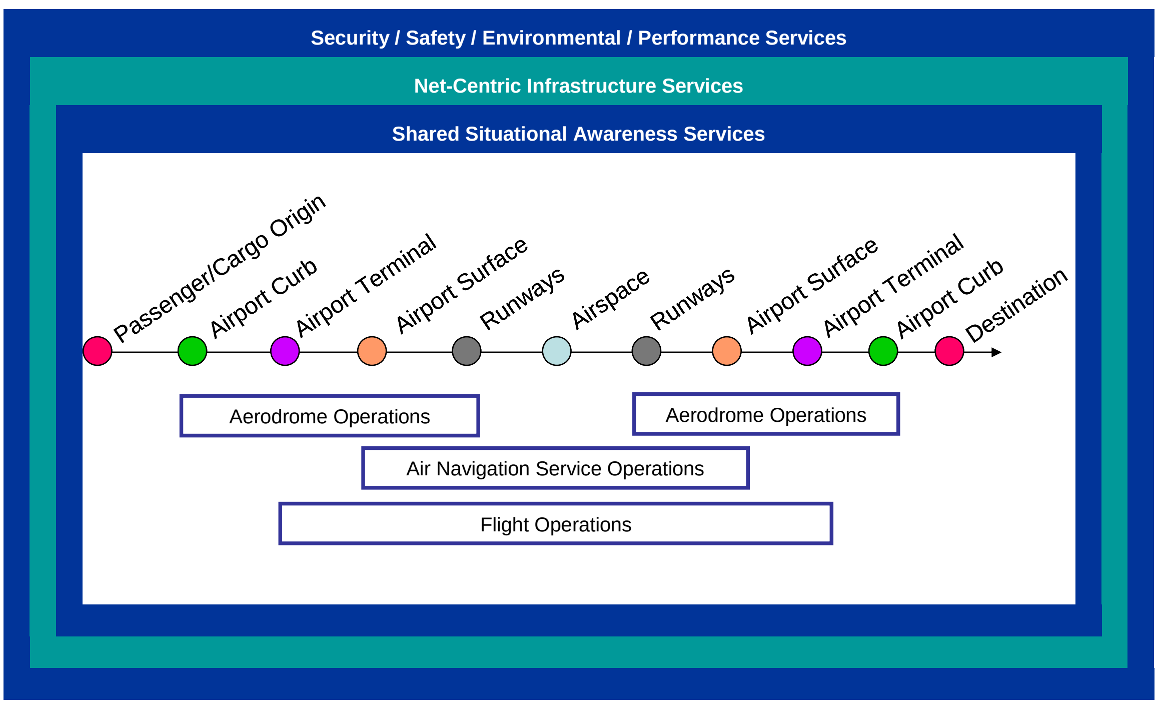
- Integrated Risk Management
- Secure People
- Secure Aerodromes
- Secure Checked Baggage
- Secure Cargo / Mail
- Secure Airspace
- Secure Aircraft

1 Introduction

This document describes the operational concepts supporting the Next Generation Air Transportation System (NGATS) in the 2025 timeframe. These concepts provide an operational view of how air traffic and airports are managed, how security is provided to protect our airspace and people, how goals for protecting and enhancing our environment are achieved, and how processes in government and in civil organizations provide increased safety and efficiency.

The air transportation system is a complex global system with many public and private sector stakeholders. The system includes national defense, homeland security, air traffic management (ATM), commercial and general aviation operators, and airports that support passenger, cargo, recreational, and military flights. The NGATS will integrate national defense and civilian capabilities to provide services to both civil and military users that are harmonized on a global scale. The integrated capabilities of NGATS will provide the capacity needed to meet the nation's need for air travel in the most effective, efficient, safe and secure manner possible. Figure 1-1 provides an overall environment supported by NGATS.

Figure 1-1: The NGATS Scope



This document forms a baseline to initiate a dialogue with the aviation stakeholder community to develop the policy agenda and encourage the research needed to achieve national and global goals for air transportation. As such, this document not only provides an operational view of air transportation in the future and highlights key research and policy issues.

1.1 BACKGROUND

A mandate for the design and deployment of an air transportation system to meet the nation's needs in 2025 was established in the "Vision-100" legislation *(Public Law #108-176*) signed by President Bush in December 2003. The legislation also established the Joint Planning and Development Office (JPDO) to carry out this mission.

This document is a product of the JPDO and describes the operational concept for the NGATS as envisioned in 2025.

> *The United States (U.S.) aviation system must transform itself and be more responsive to the tremendous social, economic, political, and technological changes that are evolving worldwide. We are entering a critical era in air transportation, in which we must either find better, proactive ways to work together or suffer the consequences of … [losing] $30B annually due to people and products not reaching their destinations within the time periods we expect today.*
> *-- NGATS Integrated Plan, 2004*

The JPDO is a joint initiative among the Department of Transportation (DOT), Department of Defense (DOD), Department of Commerce (DOC), Department of Homeland Security (DHS), National Aeronautics and Space Administration (NASA), and Office of Science and Technology Policy in the White House. In addition to these government agencies, the JPDO includes the NGATS Institute, which provides access to the knowledge and skills of many in the private aviation stakeholder communities, enabling a two-way communication process between the Government and the private sector.

The air transportation system transformation is motivated by the need for aviation to grow and continue to serve the nation and international community while responding to tremendous social, economic, political, and technological changes worldwide. Over the next two decades, demand will increase for a system that can provide two to three times the current air vehicle operations; is agile enough to accommodate a changing fleet that includes very light jets, unmanned aircraft systems (UAS), and space vehicles; addresses security and national defense requirements; and can ensure aviation remains an economically viable industry.

The *NGATS Integrated Plan* (2004) recognizes these national needs and identifies 6 national and international goals and 19 objectives for the NGATS (see Table 1-1). Separately, each goal represents an ambitious agenda. Meeting these goals and objectives requires a transformation that embraces new concepts, technologies, networks, policies, and business models.

In 2005, the JPDO developed a high-level vision to communicate the key operating principles and characteristics of the NGATS. This vision emphasizes a shift in how information is accessed, allowing those who use the air transportation system to have more direct access to information affecting their operations. The goal of this Concept of Operations (CONOPS) is to describe a system that meets these national goals.

Table 1-1: NGATS Goals and Objectives

Retain U.S. Leadership in Global Aviation	Expand Capacity
• Retain role as world leader in aviation • Reduce costs of aviation • Enable services tailored to traveler and shipper needs • Encourage performance-based, harmonized global standards for U.S. products and services	• Satisfy future growth in demand and operational diversity • Reduce transit time and increase predictability • Minimize the impact of weather and other disruptions
Ensure Safety	**Protect the Environment**
• Maintain aviation's record as safest mode of transportation • Improve the level of safety of the U.S. air transportation system • Increase safety of worldwide air transportation system	• Reduce noise, emissions, and fuel consumption • Balance aviation's environmental impacts with other societal objectives
Ensure Our National Defense	**Secure the Nation**
• Provide for the common defense while minimizing civilian constraints • Coordinate a national response to threats • Ensure global access to civilian airspace	• Mitigate new and varied threats • Ensure security efficiently serves demand • Tailor strategies to threats, balancing costs and privacy issues • Ensure traveler and shipper confidence in system security

The role of the JPDO is to transform the air transportation system. Part of this transformation involves integrating and reusing capabilities across all aspects of air transportation so that the entire system operates as an interconnected structure. In many cases, this operational concept builds on visionary material that captures the aviation community's goals for different aspects of transportation.

- For ATM, many of the concepts build on the *National Airspace System (NAS) Concept of Operations and Vision for the Future of Aviation* (RTCA 2002) and International Civil Aviation Organization's (ICAO) *Global ATM Operational Concept*, which represents a globally harmonized set of concepts for the future.
- Additional foundational and related conceptual documents will be referenced in future versions of this document.

A point of departure for NGATS is its scope. NGATS encompasses all air transportation, not just ATM. In addition to technological innovation, NGATS emphasizes changes in organizational structure, processes, strategies, policies, and business practice, including shifts in government and private sector roles that are required to fully exploit new technology.

1.2 OVERVIEW OF THE NGATS

The goal of NGATS is to significantly increase the safety, capacity, efficiency, environmental compatibility, and security of air transportation operations and, by doing so, improve the overall economic well-being of the country. These benefits can be achieved through a combination of new procedures and advances in the technology deployed to manage passenger, air cargo, and air traffic operations. The *NGATS Vision* briefing (2005) identifies eight key capabilities that will help achieve these goals:

- **Network-Enabled Information Access:** Through network-enabled information access, information is available, securable, and usable in real time for different communities of interest (COI) and air transportation domains. This greater accessibility enables greater distribution of decision-making and improves the speed, efficiency, and quality of decisions and decision-making. Information can be automatically provided to users with a known need as well as available to users not previously identified as new needs arise. Information access improves operational decisions, enabling system operators and users to make use of risk management practices to enhance safety. Cooperative surveillance for civil aircraft operations, where aircraft constantly transmit their position, will be used with a separate sensor-based non-cooperative surveillance system as part of an integrated federal surveillance approach.
- **Performance-Based Services:** Performance-based operations provide a foundational transformation of the NGATS. Regulations and procedural requirements are described in performance terms rather than specific technology or equipment. The performance-based definition and delivery of services and levels of service will encourage private sector innovation and enable efficiencies throughout the NGATS. In situations involving high demand such as congested airspaces as well as special situations such as natural disasters and law enforcement, minimum performance levels may be required to maximize capacity during specific hours. Service providers can use service tiers to create guarantees for different performance levels so that users can make the appropriate tradeoffs between investments and level of service desired to best suit their needs.
- **Weather Assimilated into Decision-making:** By assimilating weather into decision-making, weather data collection and forecasting improve. In addition, the management and use of information improves as weather information is directly integrated into automation to allow decision-makers to take into account the uncertainties of weather and better understand weather effects. Applying weather probability information and tailoring weather data to individual user needs significantly increases the effective use of weather information and minimizes adverse effects of weather on operations.
- **Layered Adaptive Security:** Though layered adaptive security, the security system is constructed of "layers of defense" (including techniques, tools, sensors, processes, information, etc.) that help reduce the overall risk of a threat reaching its objective while minimally affecting efficient operations. Layered security is additive; failures in any one component will not have a catastrophic effect on other components. For that reason, the system can handle attacks and incidents with less overall disruption. Layered, adaptive security adjusts the deployment of security assets in response to the changing profile of

risks; responses to anomalies and incidents are proportional to the assessed risk of involved individuals or cargo.

- **Broad-Area Precision Navigation:** With broad-area precision navigation, navigation services are provided where and when needed, in accordance with demand and safety considerations, to enable reliable aircraft operations in nearly all conditions. Instead of being driven by geographic constraints, navigation allows operators to define the desired flight path based on their own objectives.

- **Aircraft Trajectory-Based Operations (TBO):** The basis of all operations in the NAS is an aircraft's expected flight profile and its expected departure and arrival times. NGATS uses four-dimensional trajectory (4DT) management as the core for managing the ATM system, ensuring that, to the maximum extent possible, resources are allocated to match known demand and demand is not limited to relatively static resources. The specificity of 4DTs matches the mode of operations and the requirements of the airspace in which an aircraft operates. A major benefit of 4DT is the ability to assess the effects of proposed trajectories and resource allocation plans, allowing both service providers and operators to understand the implications of demand and identify where constraints need further mitigation.

- **Equivalent Visual Operations:** Improved information availability allows aircraft to conduct operations without regard for visibility or direct visual observation. For aircraft, this capability, in combination with broad-area precision navigation, enables increased accessibility, both on the airport surface and during arrival and departure operations. This capability also enables those providing services at airports (such as ATM or other ramp services) to provide services in all visibility conditions, leading to more predictable and efficient operations.

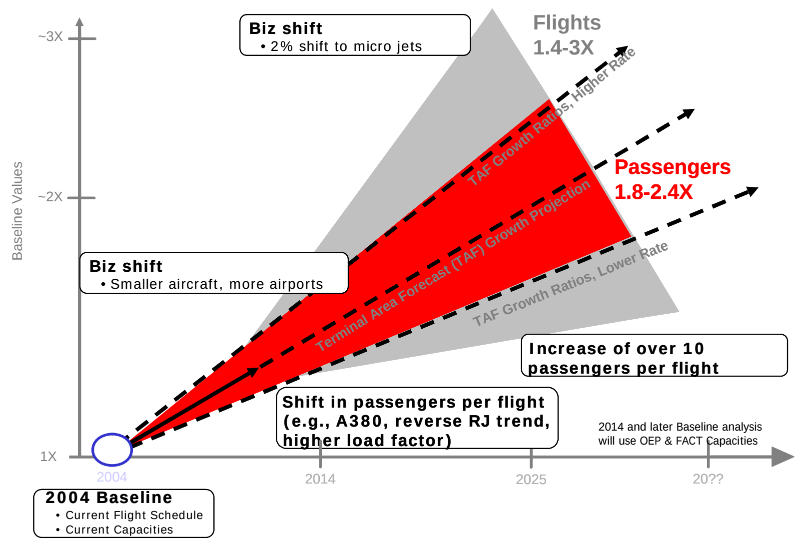
- **Super-Density Operations:** With increasing demand, an even greater need exists to achieve peak throughput performance at the busiest airports while protecting local communities. New procedures to improve airport surface movements, reduce spacing and separation requirements in place today, and better manage overall flows in and out of busy metropolitan airspace provide maximum use of the highest demand airports. Airport terminals also maximize efficiency of egress and ingress, matching passenger and cargo flow to airside throughput while maintaining safety and security levels.

These eight capabilities support the NGATS operational concept. Although not detailed separately, they are incorporated in the concepts described in the following sections. For the remainder of this document, the aerodrome term will be used in place of airport. Aerodrome is a broader term for airport and is defined as an area on land or water including any buildings, installations and equipment used for the arrival, departure, and surface movement of aircraft

1.2.1 NGATS Environment

In the NGATS timeframe, demand for air transportation services is expected to grow significantly from today's levels in terms of passenger volume, amount of cargo shipped, and overall number of flights. With respect to air traffic, changes will occur not only in the number of flights but also in the characteristics of those flights. Figure 1-2 illustrates some of the potential variations in demand characteristics. For example, a range in the potential increase of passengers exists. This range, combined with a potential range in the distribution of passengers to aircraft, may result in a wide range in the number of flights in the NGATS. The NGATS, thus, must be flexible to manage variations in number of passengers, types of aircraft flown, and overall number of flights.

Figure 1-2: Planning for a Range of Futures



In the NGATS, aircraft are expected to have a wider range of capabilities than today and support varying levels of total system performance via onboard capabilities and associated crew training. Many aircraft will have the ability to perform airborne self-separation, spacing, and merging tasks and precisely navigate and execute 4DTs. Along with navigation accuracy, aircraft will have varying levels of cooperative surveillance performance via transmission and receipt of automatic dependent surveillance broadcast (ADS-B) information. In terms of flight operational performance, a wider range of capabilities regarding cruise speed, cruise altitudes, turn rates, climb and descent rates, stall speeds, noise, and emissions will exist. Aircraft without a resident or remote pilot (e.g., some UAS) will operate among regular aircraft; domestic supersonic cruise operations will also be more prevalent.

Aircraft operators are also expected to have a diverse range of capabilities and operating modes. Many operators will have sophisticated flight planning and fleet planning capabilities to manage their operations. Operating modes include all of today's modes, such as traditional hub/spoke operations, point-to-point flights, military/civil training, and recreational flying. Operational demand may vary among highly structured flights (e.g., today's air carrier, cargo, or operators), irregularly scheduled flights with frequent trips to regular destinations with variable dates and times (e.g., air taxi operators or business operators with regular customers), and unscheduled, itinerant flights driven by individual events (e.g., lifeguard flights, personal trips, and law enforcement missions). In addition, new types of operations are expected, including UAS that perform a wide variety of missions (e.g., sensor platforms and cargo delivery) and more frequent commercial space vehicle operations (e.g., suborbital flights to low-earth orbit payload delivery and return missions). Commercial space transport operations are also expected to grow overall, increasing pressures to efficiently balance competing needs for airspace access and efficiency.

Overall, the NGATS is expected to accommodate up to three times today's traffic levels with broader aircraft performance envelopes operating within the same airspace. The NGATS will also have more operators than today, increasing complexity and coordination requirements when traffic management is required. The key NGATS capabilities described in Section 1.2 will be critical in meeting the NGATS goals

Aircraft noise and local air quality emission concerns remain strong (and growing) constraints on system capacity, requiring collaboration among aerodrome operators and the local communities surrounding them. Other environmental concerns that capabilities in the NGATS address include local air quality and water contamination. Other capabilities and procedures are in place to respond to broader climate change concerns.

1.2.2 Key Characteristics of the NGATS

To meet the goals and objectives described above, the NGATS vision involves a transformed air transportation system that allows all communities to participate in the global marketplace and provides services tailored to individual customer needs and capabilities, and seamlessly integrates civil and military operations. The following paragraphs describe some of the significant NGATS characteristics.

User Focus

A major theme of the NGATS is an emphasis on providing more flexibility and information to users of government services and reducing the need for government intervention and control of resources. The NGATS enables operational and market freedom through greater situational awareness and data accessibility, and it aligns government structures, processes, strategies, and business practices with customer needs. The provision of multiple service levels will permit a wider range of tailored services to better meet individual user needs and investment choices.

With a focus on users, the NGATS is also more agile in responding to user needs. Capacity is expanded to meet demand by investing in new infrastructure, shifting NGATS resources (e.g., airspace structures and other assets) to meet demand, implementing more efficient procedures (e.g., reducing separation between aircraft to safely increase aerodrome throughput), and minimizing the effects of constraints, such as weather, on overall system capacity. The system will be nimble enough to adjust cost effectively to varying levels of demand, allowing more creative sharing of airspace capacity for law enforcement, military, commercial, and general aviation users. Restrictions on access to NGATS resources are limited in both extent and time duration to those required to address a safety or security need.

Distributed Decision-making

To the maximum extent, decisions are made at the local level with an awareness of system-wide implications in the NGATS. This includes, to a greater extent than ever before, an increased level of decision-making by the flight crew and flight operations centers (FOC). Stakeholder decisions are supported through access to a rich information exchange environment and a transformed collaborative decision-making (CDM) process that allows wide access to information by all parties (whether airborne or on the ground), while recognizing privacy and security constraints. Information is timely, relevant, accurate, and quality assured. Decision-makers have the ability to request information when they need it, publish information as appropriate, and use subscription services to automatically receive desired information. This information environment will enable more timely access to information and increased situational awareness while providing consistency of information among decision-makers. Because decision-makers will have more information about relevant issues, decisions can be made more quickly, required lead times for implementation can be reduced, responses can be more specific, and solutions can be more flexible to change. To ensure locally developed solutions do not conflict, decision-makers are guided by NAS-wide objectives and test solutions to identify interference and conflicts with other initiatives. Decision-making reverts to higher authority only when the conflict cannot be resolved.

Integrated Safety Management System

The NGATS ensures safety through use of an integrated Safety Management System (SMS) approach for identifying and managing potential problems in a system, organization, or operation. Specifically, NGATS uses a formal, top-down, businesslike approach to manage safety risk, which includes systematic procedures, practices, and policies for safety management, including:

- **Safety Policy:** Defines how the organization will manage safety as an integral part of its operations, and establishes SMS requirements, responsibilities, and accountabilities
- **Safety Risk Management (SRM):** The formal process within the SMS composed of describing the system, identifying the hazards, assessing the risk, analyzing the risk, and controlling the risk; the SRM process is embedded in the processes used to provide the product or service—it is not a separate process
- **Safety Assurance:** SMS process management functions that systematically ensure organizational products or services meet or exceed safety requirements; includes the processes used to ensure safety, including audits, evaluations and inspections, and data tracking and analysis
- **Safety Promotion:** Training, communication, and dissemination of safety information to strengthen the safety culture and support integration of the SMS into operations.

Internationally Harmonized

The ATM system is globally harmonized through collaborative development and implementation of identified best practices in both standards and procedures. International harmonization also requires advocating the highest operational standards for aircraft operators and air navigation service providers (ANSP) to ensure the safest global air transportation system. ICAO Planning and Implementation Regional Groups (PIRG) or multilateral agreements coordinate planning and implementation of NGATS transformations to harmonize the application of technology and procedures. This harmonization allows airspace users to realize the maximum benefits of the NGATS transformations.

Taking Advantage of Human and Automation Capabilities

The NGATS capitalizes on human and automation capabilities to increase airspace capacity, improve aviation safety, and enhance operational efficiency. This capitalization is based on building processes and systems that help humans do what they do best—choose alternatives and make decisions—and helping automation functions accomplish what they do best—acquire, compile, monitor, evaluate, and exchange information. Research and analysis will determine the appropriate functional allocation of tasks among ANSP, flight operators, and automation. It will determine when decision support tools (DST) are necessary to support humans (e.g., identifying conflicts and recommending solutions for pilot approval) and when functions should be completely automated without human intervention.

Weather Operations

In the NGATS environment, weather information is no longer viewed as separate data viewed on a "stand-alone" display. Instead, weather integration is integrated with and supports NGATS decision-oriented automation and human decision-making processes. A common weather picture is used by all stakeholders. This common picture facilitates improved communications and information sharing. NGATS weather information is translated into information directly relevant to NGATS users and service providers, such as the likelihood of flight deviation, airspace permeability, and capacity. Flight trajectory plans are developed with an increased understanding of the potential severity and probability of potential weather hazards, and less airspace is restricted because of weather. Aircraft equipped with capabilities to mitigate the effects of weather will be allowed to tactically fly through certain weather hazards.

Decision support systems directly incorporate weather data and bypass the need for human interpretation, allowing decision-makers to determine the best response to weather's potential operational effects and minimizing the level of traffic restrictions that must be made 2–6 hours ahead. This integration of weather information, combined with the use of probabilistic forecasts to address weather uncertainty and improved forecast accuracy, minimizes the effects of weather on NGATS operations.

Environmental Stewardship

Environmental stewardship is performed in the context of the NGATS objectives. Capacity increases will be consistent with environmental protection goals. New technology, procedures, and policies in the NGATS minimize significant effects from noise, local emissions, and water contamination. NGATS environmental compatibility is achieved through a combination of improvements in aircraft design, aircraft performance and operational procedures, land use around aerodromes, and policies and incentives to accelerate technology introduction into the fleet. In the NGATS, policy and financial incentives are used to accelerate the introduction of environmental technology improvements in aircraft. Intelligent flight planning and improved flight management capabilities enable more fuel-efficient profiles throughout the flight envelope as well as reduced noise approaches and departures in the terminal area. Reinvigorated research and development and refined technology implementation strategies—balancing near-term technology development and maturity needs with long-term cutting edge research—help aircraft keep pace with changing environmental requirements.

Robustness and Resiliency

Overall, the NGATS is more resilient in responding to failures and disruptions and includes contingency measures to provide maximum continuity of service, including business continuity, in the face of major outages, natural disasters, security threats, or other unusual circumstances. Moreover, the increased reliance on automation is coupled with "fail-safe" modes that do not require full reliance on human cognition as a backup for automation failures. Because individual systems and system components can fail, the NGATS maintains a balance of reliability, redundancy, and procedural backups. It provides a system that not only has high availability but also requires minimal time to restore failed functionality.

Scalability

The NGATS is adaptable to meet the tactical changes in traffic load and demand that occur everyday. Its capabilities provide an overall system design that can handle a wide range of operations and modes of operation. Increased use of automation, reduced separation standards, super-density operations, and additional runways allow busy aerodromes to move a large number of aircraft through the terminal airspace during peak traffic periods. Each of these features contributes to an environment that supports growth in operations. New capabilities, such as virtual towers, enable the cost-effective expansion of services to a significantly larger number of aerodromes than is possible with traditional methods of service delivery.

1.3 AUDIENCE AND INTENDED USE

This document forms a baseline to initiate a dialogue with the stakeholder community to jointly develop the policy agenda, identify the research needed to achieve the NGATS operational concept and goals, and ensure global harmonization. Initially, this document will be updated annually as research, implementations, models, policy, budget reality, and other findings are assessed and as further dialogue helps refine common goals and priorities. This document also serves as the official record and repository for operational concept insights that emerge from the in-progress national debate on the scope, characteristics, and capabilities of NGATS.

This operational concept is part of the overall NGATS Enterprise Architecture, and it will help in the formulation of roadmaps and research recommendations to improve overall intergovernmental collaboration in achieving national goals for air transportation. This document, along with other engineering artifacts, also provides the basis for deriving top-level requirements.

The list of key stakeholders includes:

- **Aerodrome Communities:** Cities and towns located in the vicinity of aerodromes that have a vested interest in and are affected by the operation of the aerodrome
- **Aerodrome Operators:** Organizations and people responsible for enabling passenger, flight and cargo operations conducted within an aerodrome with consideration for safety, efficiency, resource limitations, and local environmental issues
- **Aerodrome Tenants:** Organizations and people who offer services at an aerodrome, such as fueling and maintenance services or catering services

- **Air Navigation Service Providers:** Organizations and people engaged in the provision of ATM and air traffic control (ATC)services for flight operators for the purpose of safe and efficient flight operations; ATM responsibilities include communications, navigation and surveillance (CNS) and ATM facility planning, investment and implementation, procedure development, training, and ongoing system operation and maintenance of seamless CNS/ATM services; includes ANSP personnel and ANSP automation
- **Customers:** Organizations and people using the NGATS for personal or business transportation or to transport cargo
- **Flight Operators:** Organizations and people responsible for planning and operating a flight within the NGATS, including flight crews (on the aircraft or controlling it remotely) and flight FOC personnel; flight operators include personal, business, commercial aviation, and commercial organizations, as well as government and military organizations
- **Manufacturers:** Organizations and people who manufacture equipment for flight operators, ANSPs, security and defense providers, etc.; this includes the manufacture of airframes, aircraft engines, avionics, and other aircraft systems and parts, as well as decision support systems and other systems used in the NGATS
- **Owners:** Organizations and people responsible for making investment decisions related to the development and implementation of NGATS and it associated capabilities
- **Regulatory Authorities:** Organizations and people responsible for certain aspects of the overall performance of the aviation industry, including aviation safety, environmental effects, and international trade; regulatory authorities include aviation safety regulators, certification authorities, standardization organizations, environmental regulators, and accident/incident authorities
- **Security and Defense Providers:** Organizations and people responsible for national and homeland defense, homeland security, law enforcement, information security, and physical and operational security of the NGATS
- **Weather Service Providers:** Organizations and people engaged in the provision of aviation weather information products.

1.4 DOCUMENT SCOPE AND ORGANIZATION

This document describes the operational concepts for the NGATS in the 2025 timeframe. This version of the document provides an initial focus on air navigation services and will be expanded in future versions, including a full CONOPS. The document is organized in the following chapters:

- **Chapter 2:** This chapter provides a description of **Air Navigation Operations** within NGATS, including interactions among the ANSP and operators.
- **Chapter 3:** This chapter provides a perspective of **Flight Operations** within NGATS, including activities, capabilities, and practices.

- **Chapter 4:** This chapter provides an initial overview of specific **Shared Situational Awareness Services** that support the ATM-related NGATS concepts. Additional shared situational services and more complete discussions of the initial services will be provided in subsequent versions of this document.
- **Chapter 5:** This chapter provides an initial overview of the **Net-Centric Infrastructure Services** that enable the NGATS enterprise services. Additional net-centric infrastructure services and a more complete discussion of these services will be provided in subsequent versions of this document.
- **Chapter 6:** This chapter provides an outline of **Layered Adaptive Security Services** within NGATS that will be further described in future versions of this document.

The following topics will be addressed in future versions of this document:

- Aerodrome operations and mission support
- Air traffic management planning and mission support services
- Flight operations planning and mission support services
- Additional layered adaptive security services
- Additional net-centric infrastructure services
- Additional shared situational awareness services
- Safety management services
- Environmental management services
- Compliance, regulation and harmonization services

Included in this document are the following appendices that contain supplemental information for the reader:

- **Appendix A:** This appendix provides a summary of roles for the different stakeholders described. Each role may be allocated to a different person or organization, depending on the procedures in place.
- **Appendix B:** This appendix provides a list of definitions and a glossary of terms.
- **Appendix C:** This appendix provides a list of references.

2 Air Navigation Service Operations

2.1 INTRODUCTION

The overall philosophy driving the delivery of services in the NGATS is that user preferences are accommodated to the maximum extent possible and restrictions are imposed only when a real operational need exists. Achievement of many NGATS objectives relies on a transformed role for the aircraft and flight crew, along with changes in aircraft capability and decision-making authority. The provision of ATM services by the ANSP shifts from tactical separation between individual aircraft to strategic management of traffic flows. Two primary transformations help meet overall objectives for increased capacity, safety, predictability, and efficiency: implementation of TBOs and application of performance-based services[1]. Minimum capability requirements are imposed on aircraft operations only as and when needed to achieve sufficient capacity and throughput to meet demand.

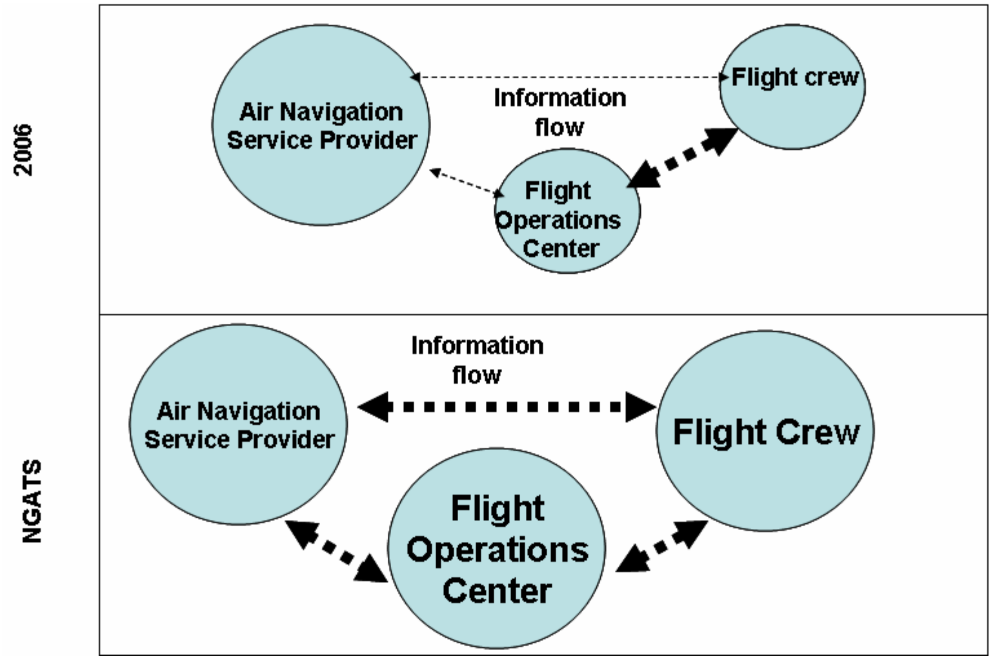
In addition to a shift in decision-making, the overall roles of both the ANSP and flight crew become more strategic in the NGATS. ANSP personnel move from tactical separation tasks to management of flows and trajectories. They will rely on intelligent decision support tools to provide context-sensitive ATM information and automatically perform routine tasks. Increased situational awareness capabilities and supporting automation enables flight crews to assume tactical separation responsibilities in many operations within the NGATS. This shift in roles for the ANSP and flight crew supports the scalability of the NGATS to meet increased demand. Flight operators[2] also more actively participate with the ANSP to facilitate more effective ATM operations while meeting their business objectives (see Figure 2-1).

Performance-based services align ATM assets with user demand. New kinds of flight operations—such as autonomous operations, in which aircraft mange their own tactical separation from each other, and ANSP flow operations, in which precise execution of agreed trajectories allows much higher traffic throughput than is possible today—dramatically improve en-route productivity and capacity. Even with two to three times today's traffic, TBOs enable control of the number and complexity of conflicts. This control ensures the maintenance of safe separation, whether separation assurance is the responsibility of the ANSP or the flight crew. Conflict detection and resolution—both airborne and ground based—are highly automated, allowing for reduced and encounter-specific separation standards.

1 Note that performance-based services include the concept of a performance-based NAS, in which access to services is driven by aircraft capability and end-to-end system compatibility rather than a specific equipage requirement.

2 Operators include airlines, business aircraft operators, on-demand air taxi operators, military, state and federal government, and personal aircraft owners and operators.

Figure 2-1: Relative Influence of ANSP and Aircraft/Pilot in ATM Decisions



In busy terminal airspace, super-density operations significantly increase aerodrome capacity. Because demand on airspace changes over different time horizons, from seasonally to daily, airspace allocation changes over these same time horizons to meet variations in demand. Collaborative trajectory planning and execution by the ANSP and the flight operator is integrated across these time horizons. Automation and information services increase common awareness of the present and predicted state of the ATM system, both locally and system-wide.

The aircraft's 4DT (the flight profile plus the time the profile will be executed) becomes the principal means of communicating both operator preferences and ANSP requirements for a flight, as well as planning and managing a flight. 4DT-capable aircraft have a digital data link to transmit and receive 4DTs and other air traffic clearances. TBOs provide the basis for maximizing access and throughput in high-demand airspace and maximizing user predictability, efficiency, and flexibility in less dense airspace.

Performance requirements will be imposed on airspace only to the extent necessary to achieve the desired throughput, and not solely to limit demand. Operators that equip their fleets to conduct advanced capacity-enhancing operations will receive preferential service from the ANSP. Airspace is still designated for aircraft not equipped for 4DT operations, allowing access to en-route and terminal airspace as well as airspace above FL600 for "near-space" operations. The ANSP may also concentrate some kinds of operations in a particular airspace to achieve capacity benefits or productivity and cost objectives.

Flight operators will collaborate with the ANSP personnel, both to enhance ATM system efficiency and throughput and to allow flight operators to maximize the utility of the ATM system for its specific operation. This collaboration applies both to strategic planning and tactical flight operations. Operators will inform the ANSP of their planned routes and schedules in advance (up to months ahead of time) and negotiate schedules with the ANSP to achieve their business objectives. If demand exceeds capacity even after all possible collaborative efforts, policies transparent and available to all stakeholders will be implemented to manage the excess demand.

Flexible route definitions allow traffic flows to be shifted as necessary to enable more effective weather avoidance, meet defense and security requirements, and manage demand into and out of the terminal environment. Capabilities for managing airspace structure include a common mechanism for implementing and disseminating information on the current airspace configuration to ensure all aircraft meet the performance requirements for any airspace they enter. Similar information on airspace restricted for defense and homeland security ensures these needs are met, maximizes access, and minimizes disruptions to commerce. Using automation to better manage uncertainties associated with weather minimizes airspace capacity limitations and reduces the likelihood of overly conservative actions.

Figure 2-2: Key Transformational Elements for ATM Operations

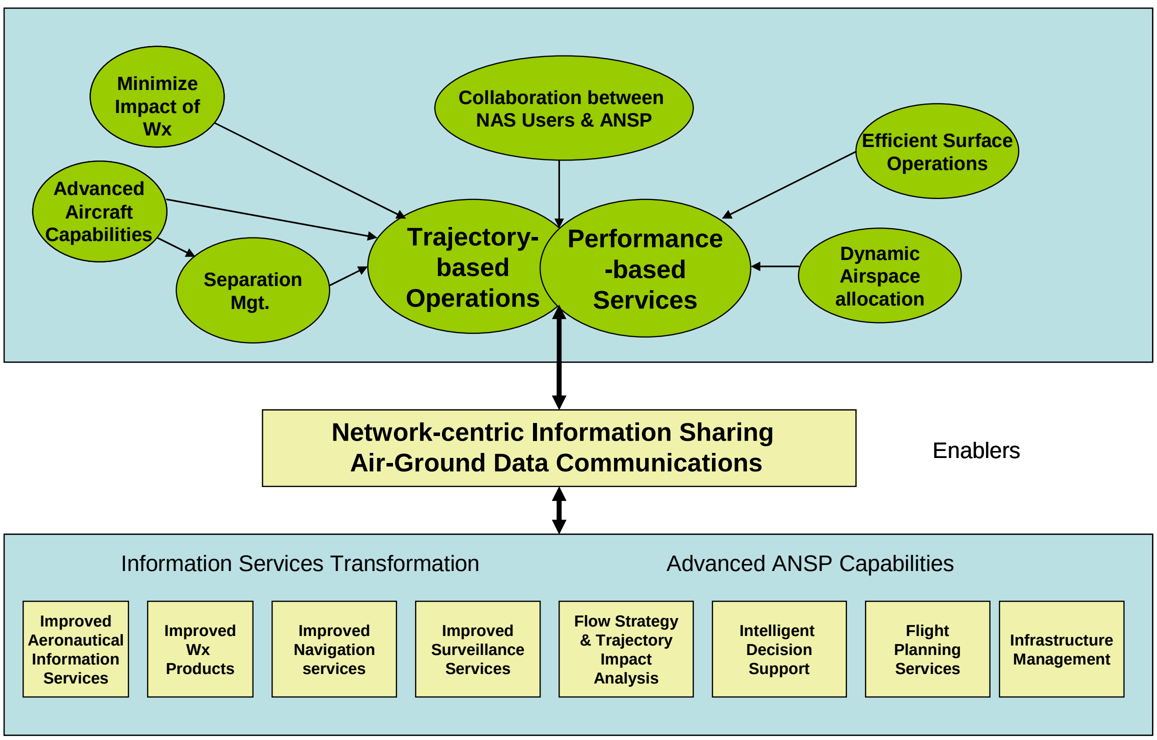


Figure 2-2 illustrates the major transformational elements for ATM operations and the underlying information services. The ATM operational transformational elements depicted by the ovals in Figure 2-2 are described in Table 2-1. Chapters 5 and 6 present the underlying enterprise information and infrastructure services supporting the NGATS transformational elements.

Table 2-1: Significant ATM Transformations

Significant Transformation	2006 Current Capability	2025 NGATS Capability
Trajectory Based Operations	• Uncertainties in demand, weather, and flight trajectories are cognitively handled by ANSP personnel using operational judgment • Significant demand/capacity imbalances are managed through broad flow contingency initiatives and administrative solutions • Time-based metering is used in some localities to improve predictability and throughput	• All operators share flight intent information via 4DTs; the level of specificity varies according to overall system needs to handle demand • Automation manages greater amounts of information on overall demand and forecast conditions and better incorporates probabilistic data to reduce the likelihood of overly conservative decisions • Metering, CTA exchange, and more flight-specific adjustments increase overall throughput and operator efficiency
Performance-Based Operations and Services	• Limited performance requirements are applied to certain airspaces (e.g., oceanic airspace, DRVSM) • Limited application of routes and procedures providing incremental benefits to higher equipped aircraft are available (e.g., required navigation performance [RNP] approaches, Q routes)	• Regulatory definition of operational requirements in performance terms rather than specific technology/equipment enables private sector innovation • ANSP service levels aligned with aircraft performance capabilities, allowing aircraft operators to realize the full benefits enabled by their equipment capability
Collaborative Traffic Flow Management (ANSP and Flight Operators)	• Focus is on managing demand to meet available capacity • Traffic management initiatives are conservative and broad • Strategies and concerns are communicated orally and in writing • Conservative measures are used to manage uncertainty because of weather and other capacity constraints	• Focus is on allocating NAS assets to maximize capacity to meet user demand • Integrated strategic and tactical flow management (TFM) with more agile management of TFM to capitalize on evolving conditions exists • Better decision support increases ability to use capacity in presence of uncertainty

Significant Transformation	2006 Current Capability	2025 NGATS Capability
Allocation of Airspace	• Airspace classification is largely fixed with earth-referenced boundaries; sectors and other controller positions may be combined during low demand; Class B and C airspace volumes are defined to protect all possible runway configurations and accommodate limited charting capabilities	• Airspace allocation is flexible over different time horizons to meet demand, and flexible over different geographic boundaries. Airspace restrictions for aircraft capability are applied only when needed • Changes to airspace configuration are provided dynamically to flight crews so that maximum flexibility is possible in utilizing available airspace
Separation Management	• Tactical separation by individual controller visualizing aircraft trajectories on radar screen and issuing voice instructions limits throughput and flight efficiency • DST provide controllers with strategic awareness of future conflicts and provide a capability to evaluate alternative solutions • Separation standards are relatively fixed	• Separation provision, both airborne or by the ANSP, relies heavily on automation support, allowing reduced and performance-based separation standards for different airspace categories • 4DTs of many aircraft following similar routes may be aligned to nearly eliminate conflicts • Trajectory changes required for separation assurance are communicated via digital communications
Weather/Automation Integration	• Ability to deal with weather is limited to Severe Weather Avoidance Program and similar initiatives; in-flight rerouting causes significant delays and flight inefficiencies	• Enhanced probabilistic forecasting coupled with network-enabled operations and decision support tools predict best options and facilitate 4DT planning and execution for minimal weather disruption

Although TBOs are the core of NAS management for higher performance aircraft, in the NGATS, much low altitude airspace outside of high traffic areas remains similar to today's Class D, E and G airspace. Visual flight rules (VFR) flights have improved access to busy terminal areas. VFR aircraft wishing to transit Trajectory-Based Airspace (defined in Section 2.4) will be capable of receiving and executing a 4DT assigned by the ANSP.

NGATS is fully interoperable with global ATM. Integrated air and ground systems are harmonized through collaborative development of performance-based standards and procedures. ATM activities are also balanced with objectives for environmental performance. New types of aircraft significantly reduce negative effects on communities and the environment, including noise and emissions, further enabling more flexible operations.

System operations are routinely evaluated to determine possible improvements. Intelligent decision support assists decision-makers in managing both strategic and tactical information, while providing guidance regarding the effectiveness of past actions in similar situations. These systems build on the use of operational metrics that measure overall system performance and provide insights into the effectiveness and effects of individual stakeholder decisions. Metrics on overall ATM performance include, for example, the number of operations, delays, cancellations, diversions, filed versus flown miles and altitude, and aerodrome and system efficiency and predictability. Data on overall system performance is quality assured and available widely to stakeholders. Automated assessment of this data, along with the traffic flow and aircraft mix forecasts, will lead to more informed decisions on investments for the future and provide guidance for changes to daily practices.

2.2 TRAJECTORY-BASED OPERATIONS

In TBOs, all basic ATM decisions across all time horizons are fundamentally related to 4DT. 4DTs are the principal language for information exchange, planning, and analysis, enabling greater use of digital communication and ground-based and airborne automation and facilitating coordination and collaboration between aircraft operators and air traffic management. 4DT Management is a shared responsibility between the ANSP, the flight operator and the flight crew. The ultimate responsibility for the management of the flight remains with the flight crew who has final authority for any changes. Because 4DTs play such an important role in the future ATM system, a common understanding of some of the critical concepts associated with 4DTs is important.

2.2.1 Four-Dimensional Trajectories

Aircraft operators, airspace users, ANSP personnel, and other stakeholders (e.g., security providers) will exchange information about individual flights via 4DTs that describe the aircraft path from block to block, including ground path and a time component. As flights are planned, operators provide "best known" information via a 4DT. Section 2.3 describes the collaborative traffic flow management process whereby 4DTs are used to balance operator objectives and constraints with overall NAS performance objectives. Through the collaborative traffic flow management process, the operator and service provider of a flight reach a trajectory agreement. The trajectory agreement includes the 4D path planned for the flight, any CTAs that have been assigned for the flight, and an assigned flexibility volume. Trajectory and other information are stored in the system flight object[3]. The trajectory is defined with only the level of specificity necessary to meet the performance requirements of the proposed operation.

CTAs are assigned to a flight to implement traffic flow initiatives, such as to regulate traffic flows entering congested en-route or terminal areas. CTAs define narrow time windows to cross specific waypoints. CTAs are only used when necessary for traffic flow management. Much larger windows in time are allotted to cross all other waypoints not designated as CTAs, allowing operators more flexibility to optimize their flight operations to meet their needs and unique operational requirements.

3 A flight object is the representation of the relevant information about a particular instance of a flight. The information in a flight object includes (1) aircraft capabilities, including the level of navigation, communications, and surveillance performance, (2) aircraft flight performance parameters, (3) flight crew capabilities, including level of training received to enable special procedures, (4) 4DT profile and intent, containing the "cleared" 4DT profile, plus any desired or proposed 4DTs, and (5) current aircraft position and intent information during the flight. Standards for the definition of a flight object are in development.

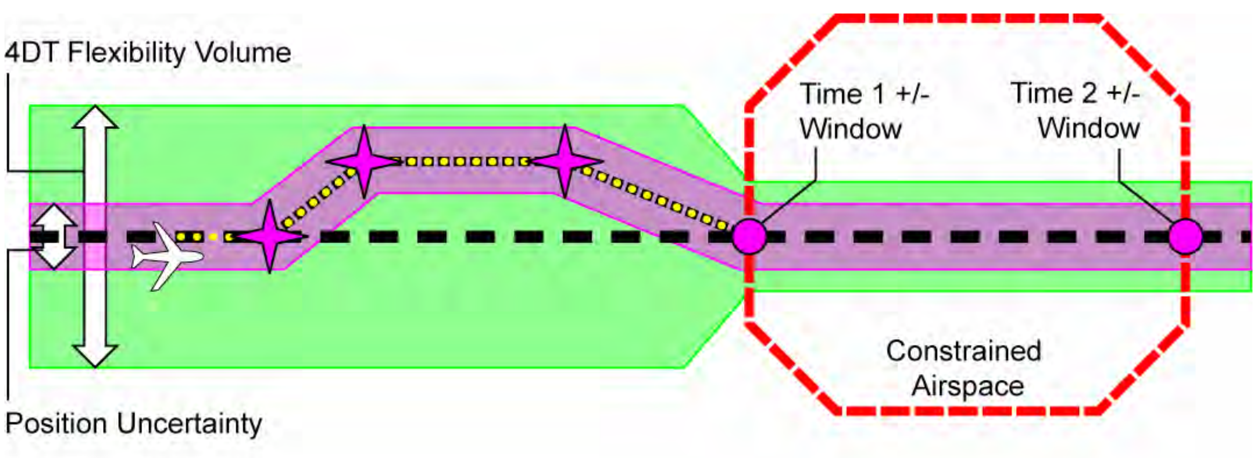
The flexibility volume is assigned by the traffic manager or TSM and represents the extent to which an aircraft is authorized to deviate from the assigned path laterally, vertically, and in time. The flexibility volume defines the operator's flexibility to maneuver without negotiating a new trajectory agreement, and it is assigned based on the density and complexity of traffic in the volume of airspace plus the operations performed by the aircraft. In low-density airspace, the flexibility volume may be quite large. In higher density airspace, the flexibility volume will be smaller. In some cases, the lateral aspect of the flexibility volume is equivalent to the RNP containment for an aircraft. An aircraft picking its way through dynamic inclement weather might have a larger flexibility volume to allow for maneuvering. Maneuvering aircraft are responsible for meeting all assigned CTAs. The objective of the flexibility volume is to balance the following three objectives:

- Allow operators some flexibility to maneuver, when airspace conditions allow, without renegotiating trajectory agreements
- Enable prediction of traffic demand for specific volumes of airspace in the presence of self-separating aircraft
- Allow the ANSP to control the flow of aircraft in dense and or complex airspace and limit maneuvering of self-separating aircraft that would affect high-density flows of ANSP-managed aircraft.

Figure 2-3 depicts a 4DT and flexibility volume. For the first part of the path, the ANSP has designated a large flexibility volume. The operator has freedom to adjust the aircraft trajectory within the flexibility volume without negotiating. Upon entering a volume of constrained airspace, the ANSP constrains the flexibility volume so more flows of traffic can fit through a constrained area.

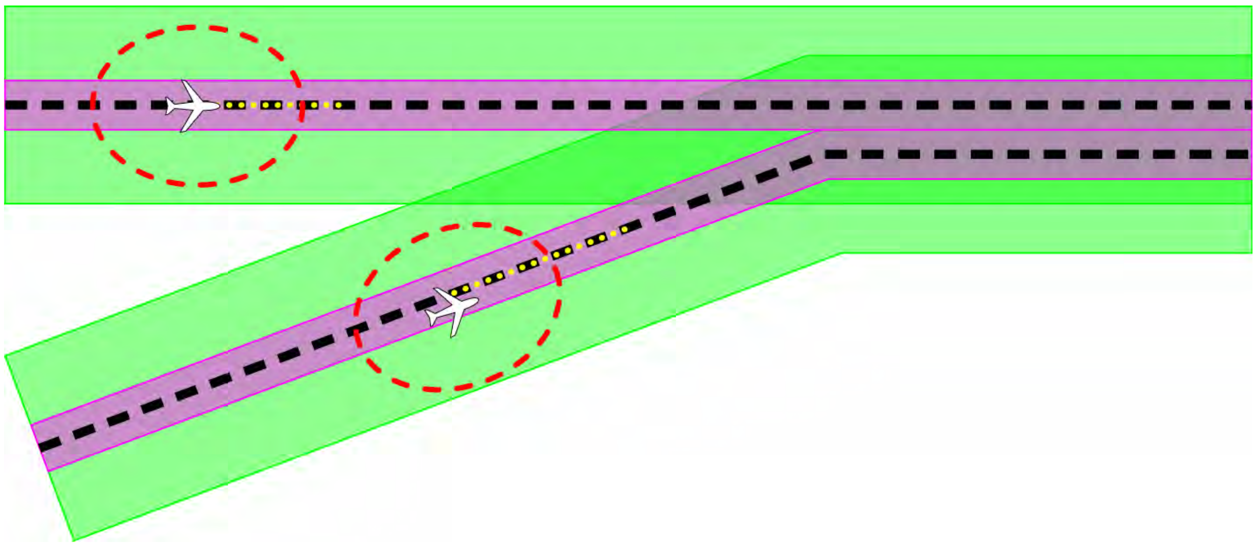
> ***Research issue:*** *What degree of flexibility for self-separating versus managed aircraft is practical when the ANSP is providing TSM?*

Figure 2-3: Four-Dimensional Trajectory with Flexibility Volume



Separation assurance for a given flight may be provided by the ANSP, or the flight may have been delegated responsibility for self-separation. In some areas of airspace, separation assurance for ANSP-managed flights will be provided through assignment of conflict-free flexibility volumes and automated monitoring of position information for conformance. In other areas of airspace, ANSP-managed aircraft will have overlapping flexibility volumes, and the ANSP will actively manage conflicts based on aircraft position information. Figure 2-4 shows an example of two aircraft with intersecting flexibility volumes. Separation assurance is provided by ensuring that a zone around the actual aircraft position (i.e., a separation zone) is protected. The aircraft position information is obtained from each aircraft via cooperative surveillance.

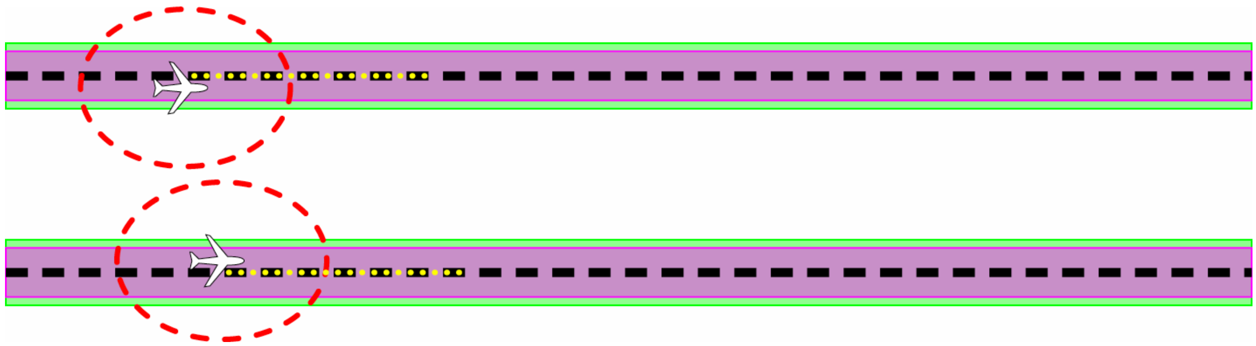
Figure 2-4: Intersecting Flexibility Volumes



Aircraft that have been delegated responsibility for self-separation will typically have large flexibility volumes assigned that are not free of conflict. Self-separating aircraft receive position information from all other aircraft in the area via cooperative surveillance. In addition, all self-separating aircraft transmit near-term intent information via cooperative surveillance, showing the intended near-term path for the aircraft. Airborne conflict detection systems use the position and intent information from other aircraft to detect and develop resolutions to conflicts. As a self-separating aircraft maneuvers within its flexibility volume, it provides updates on its current position and intended path so that ground automation systems and other aircraft can predict its behavior. Maneuvers to resolve conflicts that would result in excursions outside the assigned flexibility volume require negotiation of a new trajectory agreement before implementation. Even though the aircraft stays within its flexibility volume, the separation zone may not be contained within the flexibility volume. For example, for high-precision routes, the separation zone may extend past the flexibility volume, as shown in Figure 2-5.

> ***Research Issue:*** *Is the concept of a flexibility volume an effective means to balance operator flexibility against system predictability and flow management?*
>
> ***Research Issue:*** *What is the minimum level of detail for a 4DT? How does this vary according to the type of operation? What gets transmitted between air and ground?*
>
> ***Research Issues:*** *What capabilities in aircraft flight management and decision support are needed for TBO operations? What are the appropriate contents of the flight object?*

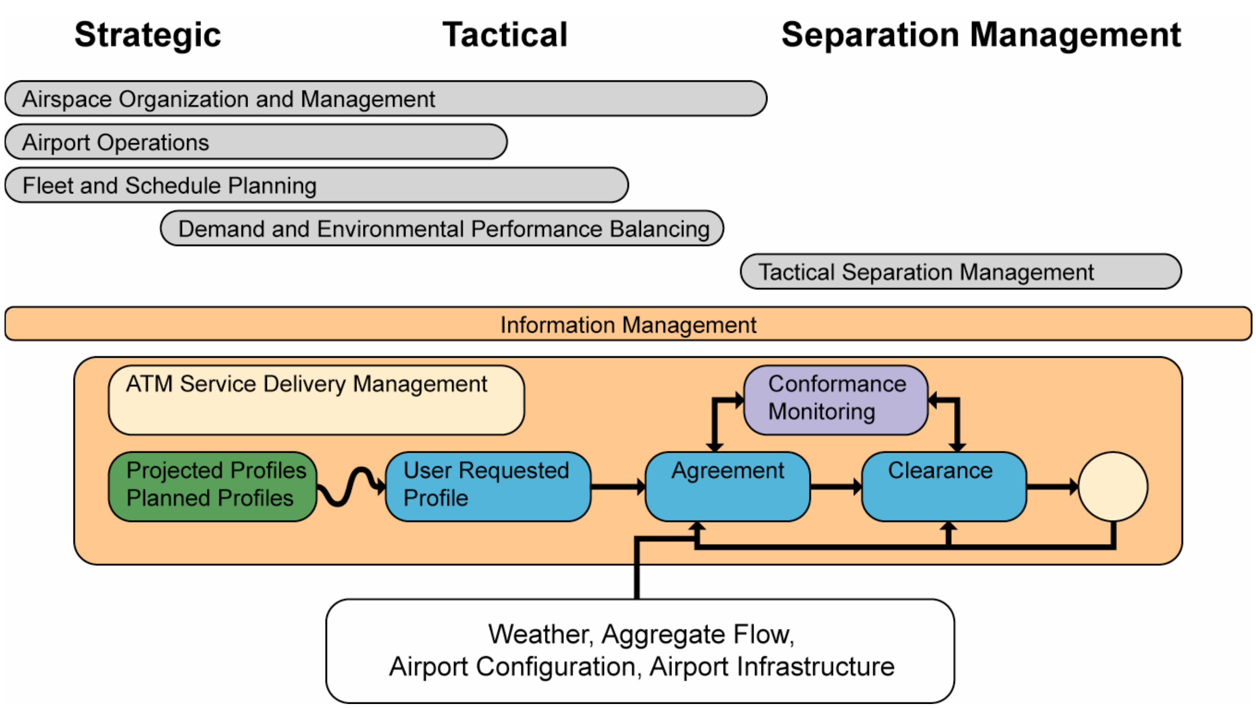
Figure 2-5: Separation Zones for Aircraft



2.2.2 TBO as the Basis for ATM Planning and Execution

One of the key concepts associated with TBO is the integration of trajectory planning and execution across the spectrum of time horizons from strategic planning to tactical decision-making (see Figure 2-6). Strategic aspects of trajectory management include the planning and scheduling of user operations and the corresponding planning and allocation of NGATS resources to meet demand. Overall flows are managed strategically and tactically, as necessary, to ensure safety, security, and efficiency of operations. Tactical components of trajectory management include the evaluation and adjustment of individual trajectories to synchronize access to airspace system assets (or to restrict access, as required) and separation assurance to ensure safe separation among all aircraft.

Figure 2-6: Key Components in Trajectory-Based Operations



Automation takes 4DT proposals from airspace system users (general aviation [GA], commercial, business, military, and government) and assesses them for mutual compatibility with system capacity. Flight operators and ANSP personnel use the results of the analysis to understand where contention for resources is projected to occur. This can be done for multiple planning horizons (months ahead to about 20 minutes ahead) to identify potential problems or capacity imbalances.

In the NGATS environment, weather information is no longer an end product viewed only on a stand-alone display. Rather, weather information is designed to integrate with and support NGATS decision-oriented automation and human decision-making processes, including processes related to TBO. NGATS weather information is translated into information directly relevant to NGATS users and service providers, such as the likelihood of flight deviation, airspace permeability, and capacity.

In NGATS, weather forecast accuracy and reliability improve, thereby making more airspace available and useable. Probabilistic forecasts manage any remaining uncertainty in forecasts. This probabilistic information will enable decision-makers and supporting decision tools to better identify and use available weather-favorable airspace and employ risk-based techniques to airspace management.

Research Issue: *How do we incorporate uncertainty correctly into a control mechanism for the NAS? How do we mathematically formulate the system control problem of a system with embedded uncertainty to minimize the effect of uncertainty, allow enough user flexibility to keep the system stable, and minimize human workload?*

Research Issue: *How would space weather (i.e., solar activity that may affect communications and electronics) affect this concept? What mitigations are in place to reduce the effects of space weather?*

Reliance on TBOs ensures predictability in the system, improves flow management decisions, and increases the use of busy airspace. Moreover, reduced positional uncertainty contributes to reduced minimum separation criteria in most airspace in the NAS, thus optimizing flows between congested areas. In addition, in environments where flight legs may be very long (e.g., oceanic airspace), the increased predictability afforded by conflict-free 4DTs will provide opportunities for increased fuel efficiency and optimal fuel loading. TBOs will minimize excess in-trail separation caused by control imprecision, lack of predictability, and irregularities in arrival flows and maximize use of congested terminal airspace through efficient overall planning (e.g., for the entire aerodrome complex, including surface and air). Operational management of 4DTs will minimize block-to-block transit time by allowing efficient control and spacing of individual flights. As required, 4DTs will also be used on the aerodrome surface to improve surface movement efficiency and safety.

2.2.3 Functional Allocation of TBO Tasks

To accomplish the goals of increased capacity, predictability, and user efficiency in the most cost-effective manner, NGATS will capitalize on human and automation capabilities and employ complementary air and ground technologies in a distributed manner. Humans and automation in the air and on the ground will play important and well-defined roles in NGATS that take advantage of the types of functions each can best perform.

As the NGATS evolves, the increase of available information makes it impossible for humans to be aware of every piece of data within the system and use it in the most effective manner in real time. Instead, intelligent automation is designed to understand constraints, have goals, and operate autonomously within its construct to identify information or opportunities for human action. These computational systems are customized for a task, adaptive, understand user preferences, and can operate on the user's behalf (e.g., by narrowing the choices available for auto-negotiation). Where appropriate, automation takes into account past system performance in formulating recommended solutions to current problems to enable better decision-making.

Automation assumes a far more significant role in the management of real-time operations. In many situations, decision support systems present alternatives to the ANSP personnel or the flight operator. ATM functions, such as compiling and analyzing trajectories against objectives, applying encounter-specific separation standards, and monitoring for off-nominal conditions are increasingly automated.

Human interactions with the system also change. To accommodate shifts in demand from a wide variety of users, ATC will migrate from tactical control of individual flights to strategic management of traffic flows, including strategic separation management. Decision-makers, aided by integrated automation capabilities, will collaboratively develop and update flow plans as operational needs dictate. The NGATS not only changes the way existing functions are performed (e.g., by maintaining safe separation at a minimum specific to aircraft performance capabilities and encounter geometry) but also introduces new functions (e.g., analyzing compatibility of four-dimensional trajectories against user objectives and airspace constraints).

The task of tactical separation assurance—the conventional role of a radar controller—is more often delegated to pilots for various procedures or to ground-based automation. Pilots are delegated responsibility for separation assurance for many procedures—from airborne self-separation, where the pilot is responsible for maintaining separation from all other aircraft, to limited pairwise separation procedures at both high and low altitudes. For such procedures, the flight crew's role in operating the aircraft is both tactical and strategic; ANSP personnel have a greater role in strategic flow management and less of a role in tactical separation assurance (or no role at all because ground automation monitors separation). It must always be

Research Issue: *What is the appropriate functional allocation among ANSP personnel, flight operators, ground-based automation systems, and airborne automation systems?*

Research Issue: *How will increased automation and new technologies affect flight crew and ANSP workload? Items to investigate in this research include the following issues: Do cockpit workload limitations exist that inhibit the proposed technologies? What effect do the changing roles and responsibilities (flight deck versus ANSP, automation versus human, etc.) have on safety? What effect do the changing workload and changing workforce have on safety?*

Research Issue: *What are the cost benefits and safety assessments of ground-based versus airborne conflict detection/resolution automation? What alerts and information displays does a pilot need to safely oversee conflict detection and resolution when no one on the ground is responsible for tactical separation?*

Research Issue: *If the automation fails, what is the backup plan in terms of people/procedures/automation?*

Policy/Liability Issue: *Can automation ever be "responsible" for separation assurance, or is the human (flight operator or ANSP personnel) ultimately responsible?*

clear to both ANSP personnel and the pilot—for each aircraft—who exactly is responsible for separation assurance.

Appendix A shows a high-level comparison of the allocation of existing ATM functions between ANSP personnel and flight operators in 2006 and in NGATS. It does not include a comprehensive list of NGATS functions because a detailed functional task analysis is required as concepts are evaluated and validated. Section 2.4 provides more detailed information about the roles of ANSP personnel and aircraft operators for specific operations in the NGATS.

When assigning tasks to humans, certain considerations—such as situational awareness, workload, and computer-human interface design—will be assessed along with implications for system safety and efficiency. Cost-benefit analysis will then help determine the extent of automation necessary and the allocation of tasks between air and ground systems.

2.2.4 Airspace and Aircraft Trajectory Management

In regard to airspace and aircraft management, TBOs relate to four major functions:

- **Capacity Management (CM):** The design and configuration of airspace and allocation of other NAS resources
- **Flow Contingency Management (FCM):** Strategic flow initiatives addressing large demand capacity imbalances within CM plans
- **Tactical Trajectory Management (TTM):** Adjustment of individual aircraft in flows to make maximum efficient use of a resource
- **Tactical Separation Management (TSM):** The assurance of separation between aircraft

TBOs are used to manage airspace and trajectories. However, certain processes are only invoked when demand exceeds capacity or capacity becomes constrained by weather or special airspace activities. In such cases, airspace management strategies are necessary to balance demand and capacity. Such strategies might include:

- Increasing the capacity of a given area of airspace to accommodate projected traffic growth through reassignment of resources (e.g., personnel, RNP routes)
- Instituting structured routes to reduce traffic complexity
- Assigning high-RNP conflict-free trajectories to reduce traffic complexity
- Establishing traffic flow corridors
- Rerouting traffic to reduce area density
- Assigning CTAs to meter traffic through high-density areas.

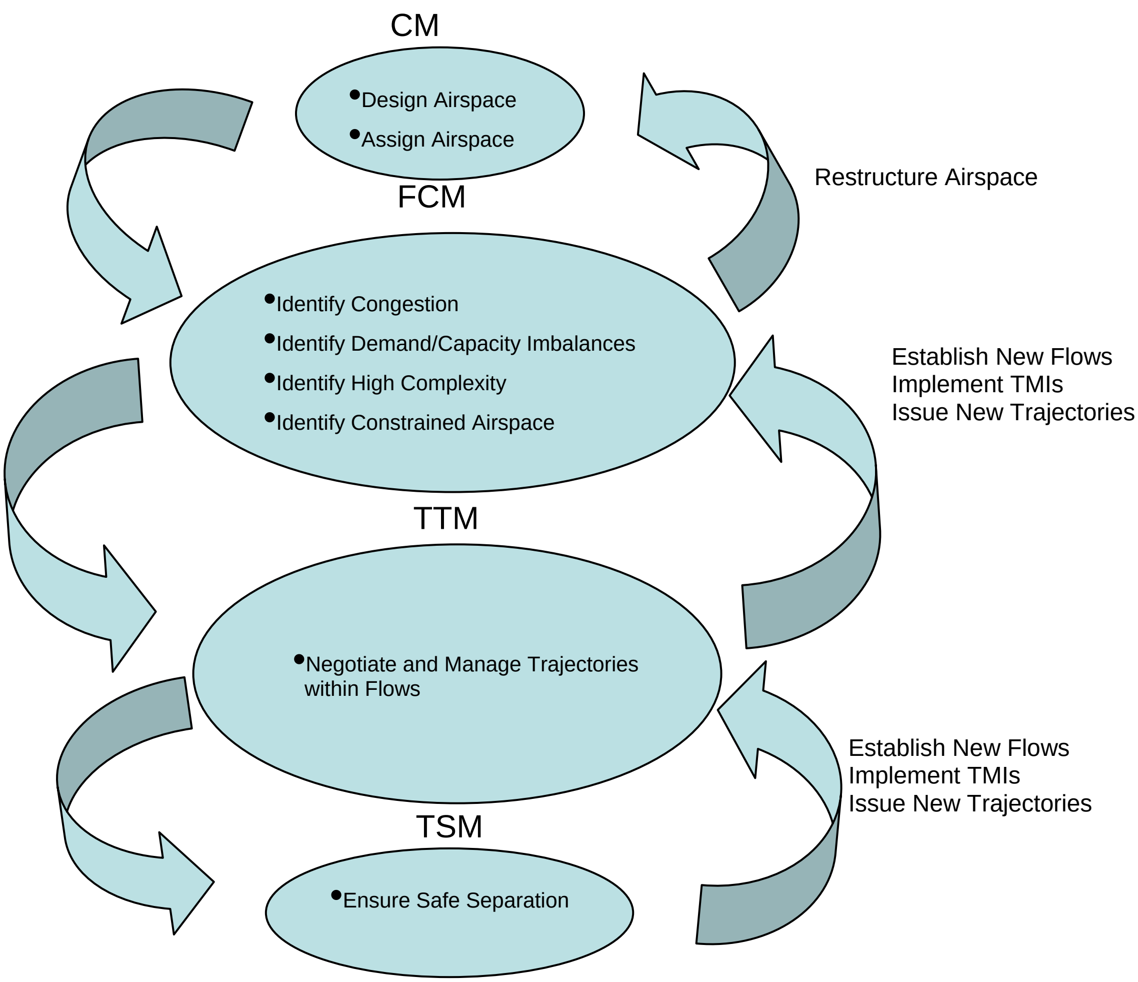
Airspace and trajectory management functions are interactive. The demand/capacity balancing process determines which airspace capacity management strategies to employ across the NAS. Part of the process includes the use of metrics and analyses to determine which strategies were most effective under which conditions. The same strategies may be used to address various objectives.

The objective and number of aircraft affected determine who implements a strategy. For example, the rerouting of traffic to reduce area density might be done by the flow contingency manager or tactical trajectory manager, depending on the aircraft affected (e.g., multiple flows or one flow). Ultimately, the principles of distributed decision-making and basing issue resolution on those most central to an issue determine who implements an initiative.

> ***Research Issue:*** *What are the responsibilities and boundaries among CM, FCM, TTM, and TSM? Can the same individual perform some or all of those responsibilities?*

The CM and FCM processes use proposed trajectories to determine demand. Flow contingency managers work with operators to define the necessary route structures and traffic flow corridors and identify specific numbers of aircraft to reroute to alleviate areas of high congestion. The TTM process identifies specific aircraft for inclusion in traffic flow initiatives and assigns CTAs where traffic metering is required. Airspace management strategies will be applied to ensure that TSM will only confront safe, manageable levels of traffic density and complexity. Figure 2-7 shows how the four airspace and trajectory management functions work together.

Figure 2-7: Interactive Airspace and Trajectory Management Process



Flight operators are involved in all levels of the airspace and trajectory management process. They provide schedule predictability for individual and fleet-level flights for use in demand/capacity balancing, including allocation of airspace and ANSP resources. Flight operators propose their desired trajectories and time of movement (i.e., 4DTs), and the ANSP assesses compatibility of the proposed 4DTs based on the state of the airspace. This collaborative process occurs over a continuum—proposals are assessed 3 months or even 30 minutes in advance.

> ***Research Issue:*** *How will flight operators collaborate with the ANSP? How will they be informed of planned routes? How will the information be processed, presented, etc.?*

Decision-oriented automation, human service providers, and users update weather information as required. NGATS weather capabilities allow rapid notification (machine to machine) of changing weather situations to NGATS decision-makers and users. Decision-oriented automation capabilities are continuously updated with weather to allow decision-makers and users to react to unanticipated, rapidly changing circumstances. Hazardous weather is disseminated in real time. Aircraft may periodically request ("pull") routine weather information affecting their route of flight, but broad-area weather advisories and warnings are issued ("pushed") in real time to all affected aircraft when safety-critical changes occur.

ANSP will not treat weather as "one size fits all." Different aircraft and crews may have varying levels of ability and preferences to operate in specific weather conditions. Individual flight limitations and preferences are key inputs to the flight objects, and users may dynamically update these features. With this knowledge, the ANSP can provide 4DTs tailored to individual flights. Limitations on 4DT options could include pilot or flight crew certification and rating or aircraft type and capabilities, including performance-based weather capabilities, such as airborne weather radar, weather data link, weather sensors, and weather mitigation capabilities (e.g., synthetic vision to overcome low visibility). User preferences might include determinations, such as avoid all heavy-to-severe precipitation areas (i.e., less than 30 DbZ) by at least 20 nautical miles (NM) or avoid all areas with greater than 70 percent chance of light icing by at least 10 NM (lateral) or 1,000 feet (vertical).

International flights no longer pose a special challenge for ATM. Global harmonization between the U.S. Oceanic Flight Information Regions (FIRs) and neighboring FIRs exists. This harmonization includes global information use, management, and interchange; those concepts enable a significant change in the roles of all participants in the ATM system. Where equivalent international environments are the equivalent of NGATS, procedures become harmonized so that the operational benefits gained in U.S. airspace remain in effect in adjacent airspace. ATM considers all trajectories during all phases of flight and manages their interactions. As a result, international flights are considered during capacity planning, 4DTs are coordinated across FIR boundaries so they may be used in the strategic airspace and trajectory management processes, and 4DTs can be globally optimized for long-haul flights.

> ***Research/Policy Issue:*** *To what extent is achieving benefits in U.S. Oceanic FIRs dependent on global harmonization of ATM concepts?*
>
> ***Research/Policy Issue:*** *To what extent is airspace access influenced by the need for internationally harmonized policies and collaboration?*
>
> ***Research/Policy Issue:*** *What level of compatibility in technologies and operational procedures is required?*

Through the ICAO, the plans of all countries must be aligned to ensure, to the greatest extent possible, that solutions are internationally harmonized and integrated and do not unnecessarily impose multiple equipment carriage requirements in the air components of the ATM system, incompatible ATM systems on the ground, or incompatible operational procedures regarding airspace management, demand and capacity balancing, or trajectory management.

2.2.5 Capacity Management

The capacity management process allocates NAS resources based on user plans to meet overall system goals. This process includes the allocation of responsibility for airspace and flight corridors to ANSP personnel as a means to manage workload. It structures routings where required to manage complexity, and it allocates airspace for other purposes, including the operation of state (government) aircraft. Capacity management responds to an aggregation of airspace users' expected or desired trajectories, infrastructure, geographic, and environmental constraints, and it provides airspace assignments and dynamic structured routings to manage that aggregation.

Research/Policy Issue: *To what extent can national policy on access to airspace be transparent and implemented within automation?*

The capacity management process may begin years before a flight is in operation, up to and including the day of operation. It includes both the long- and short-term management and assignment of NAS airspace and trajectories to meet expected demand. This process includes assigning related NAS assets as well as coordinating longer term staffing plans for the airspace assignments. Significant structural changes to airspace (e.g., to accommodate a planned runway or analyze the effect of a proposed runway) are planned years in advance. Airspace is structured at the beginning of each day to meet preplanned demand and forecasted conditions. It is dynamically reconfigured during the day to meet flow requirements, reduce delays, increase resource efficiency, and accommodates disruptions (such as pop-up convection) and outages.

The assignments are worked in collaboration with airspace users to best accommodate both user-requested trajectories and airspace for special use requirements. Static airspace assignments are used for limited applications (e.g., some restricted airspace and unmanaged airspace might remain static); however, static airspace is generally eliminated by employing a dynamic airspace reconfiguration capability so that airspace (including route) assignments are based on operational needs. Airspace structure is set to match the conditions of the day and changes throughout the day. For example, dynamic RNP routes are established to manage high-density operations in both the en-route and the arrival and departure airspace.

Research Issue: *How are airspace flexibility needs balanced with environmental and noise reduction goals?*

Research Issue: *With what frequency would airspace configuration changes be made? What is the effect on flight efficiency, ANSP personnel productivity, etc.? What is the appropriate lead time for changing a configuration? How is the dynamic nature of weather incorporated into temporal decisions on airspace configuration?*

Airspace design must account for the available capacity in the full range of enablers—communications, navigation, personnel, etc. Information sharing creates situational awareness regarding weather (winds, temperature, convection, turbulence, ceiling/visibility with probabilities, and potential effect on resource capability), flight schedules, resource congestion predictions (time and probability), system constraints, security and other temporary flight restrictions, military airspace availability, etc., for more timely and effective decision-making about capacity management. The quality of the information and timeliness of the decisions will ensure that the system is not over constrained and capacity is maximized.

Limitations to the amount of flexibility afforded both airspace boundaries and routes exists, especially at lower altitudes and in terminal airspace where ANSP personnel must be trained on the airspace and associated operating procedures and where environmental restrictions exist.

Defense and homeland security restrictions are dynamically managed to enhance airspace access. The philosophy for airspace restrictions is to provide the maximum available airspace to all users at all times, meet national security needs via priority 4DT reservations, and facilitate immediate user notification of "just-in-time" national needs for restricted airspace. Restricted or special use airspace is managed flexibly and accommodates security and defense needs in a non-disruptive manner. In addition to improved common situational awareness and automated conformance monitoring, management of security and defense needs evolves where practical toward flight-specific access requirements and away from blanket restrictions for access.

DSTs identify the extent to which a given airspace and resource structure solves a congestion problem and provide metrics to measure the extent to which a resource structure meets various system objectives. Where demand is projected to significantly exceed available resources, the flow contingency management process is invoked.

2.2.6 Flow Contingency Management

FCM is the process that identifies potential flow problems, such as large demand capacity imbalances, congestion, high degrees of complexity, blocked or constrained airspace (airspace for special use, weather), or other off-nominal conditions. This collaborative process between flow contingency managers and flight operators facilitates the efficient management of air traffic flow via information on system-wide air traffic flows, weather, aerodrome capacity, and other assets. FCM also involves managing the conflicting objectives of multiple stakeholders regarding the operational use of an airspace volume while taking advantage of available capacity to address demand.

Several guiding principles govern the concept of FCM:

- FCM deals with airspace, aerodrome, and metroplex constraints in an integrated fashion.
- Strategic and tactical decisions are tightly integrated.
- FCM becomes more agile in dealing with uncertainties, developing adaptive traffic management plans that use capacity as it becomes available, and safely dealing with scenarios that become more constrained than expected.
- FCM provides equitable treatment of flight operators and, as much as possible, gives them the flexibility to meet their objectives.
- FCM becomes more focused, affecting only those flights that are necessary to deal with a constraint.

This emphasis on FCM does not imply that rigid, tightly controlled FCM plans are always necessary to deal with constraints. In many cases, the FCM “plan” may identify constraints at a high level and allow flight operators to find solutions in a distributed fashion. In this plan, each operator identifies and executes the solution that best meets his or her priorities and constraints while satisfying the constraints specified in a given FCM plan.

The ATM system is continuously monitored in terms of demand, available capacity, and available resources. When imbalances arise, the Flow Contingency Manager develops strategies in collaboration with airspace users to mitigate problems. These strategies can include establishing trajectories to reduce complexity, restructuring the airspace to provide more system capacity, or allocating time-of-arrival and departure access to runways or airspace. Operators with multiple aircraft involved in an initiative have the flexibility to adjust individual aircraft schedules and trajectories within those allocations to accommodate their own internal concerns (e.g., business, military). The ability for automation to monitor conditions and identify new trends facilitates dynamic refinement of traffic management initiatives (TMI) and reduces the likelihood that TMIs are overly conservative in managing the NAS.

In the NGATS timeframe, ANSP share responsibility with the pilot for strategically directing aircraft to avoid hazardous weather conditions. Any 4DT routing or individual aircraft penetration through hazardous weather areas will be based on coordinated decisions that include at least the individual aircraft and the ANSP. This ANSP assistance is especially important to aircraft with limited or no equipment for weather avoidance.

In addition, new weather mitigation technology (e.g., gust alleviation or wake vortex suppression) may allow higher levels of penetration than previously possible in hazardous weather conditions. The technology provides aircraft capability information to both automation and decision-makers to facilitate weather penetration. Less capable aircraft will mostly avoid hazardous weather areas.

FCM may occur days in advance of a flight (e.g., to address a scheduled special event that significantly increases demand in a particular airspace) or during a flight. As with all TMIs, probabilistic decision-making is used to assess the likely regional and local effects of anticipated flows, weather patterns, and other potential constraints and take incremental actions to reduce the probability of congestion to acceptable levels without overprotecting NAS resources. DSTs help FCM and airspace users analyze alternative strategies and results of any given strategy. As a result of implementing an FCM initiative, new trajectories are assigned aircraft involved in the initiative and the new trajectories are incorporated in the flight object.

Operators are aware of the overall policy for managing demand/capacity imbalances, and they receive feedback on their flights’ expected performance given the imbalance. Based on this feedback, operators can adjust their plans. To the extent that operator actions do not sufficiently address capacity imbalances, the FCM will either implement policy that is transparent to all operators or implement TMIs to ensure that NAS resources are not oversubscribed.

FCM occurs whenever and wherever a structural flow change is necessary. Management of the solution is then completed at the central point of the issue. The flow contingency manager or the tactical trajectory manager manages the solution, depending on the extent of aircraft affected.

Likewise, a flight operations center may be involved in the rerouting of individual aircraft if many of the operator's aircraft are affected. Coordination may also take place with the individual pilot.

2.2.7 Tactical Trajectory Management

TTM provides for the fine tuning required by either the airspace plan or an active FCM initiative to minimize conflicts and ensure efficient individual trajectories within a flow. In contrast to FCM, which deals with overall flows and contention among flows, TTM addresses imbalances within an established flow to ensure that congestion is manageable. Like FCM, TTM is only imposed when resource contention requires.

The airspace plan and FCM are based on trajectories with assumptions regarding the forecasted arrival time by aircraft at resources (e.g., entry/exit to certain airspace, taxiway, or runway). The 4DT may specify CTAs for safety or efficiency. The CTAs are agreements; however, the operator or the ANSP may initiate adjustments to agreements as needed. When agreements are adjusted, the solution includes a likelihood estimate of a future conflict to determine whether the solution should be used. If the likelihood of a conflict is high, the solution trajectory is adjusted to ensure a lower likelihood. TTM provides strategic separation management in that it can be used to reduce the frequency and complexity of aircraft conflicts and the need for tactical separation maneuvers.

TTM considers any active FCM initiatives in establishing the best mitigation to resource contention. It also considers user preferences for the flights as documented in the flight object. TTM can include initiatives such as CTAs at a coordination point or assignment to an RNP route with CTAs. The aircraft operator negotiates a proposed trajectory with the ANSP. TTM is not restricted to aircraft already airborne. Some TTM-initiated trajectory modifications may take place before take-off.

> ***Research Issue:*** *With trajectories manipulated 20 minutes or less ahead, how is trajectory stability affected? What is the effect on aircraft keeping CTAs, and what is the effect on system functions that rely on the CTAs?*

For the terminal area, the TTM assigns each arriving aircraft to an appropriate runway, arrival stream, and place in sequence (aircraft to follow). TTM is also the means by which aircraft are managed in and out of complex, superdensity terminal areas. The TTM is aided by automation that optimizes for a number of factors, including aerodrome throughput, smooth operations, current and forecasted weather changes, airline priorities, etc. TTM also adjusts operations for planned and unplanned aerodrome changes, such as snow plowing, deicing, or changes in runway configuration. TTM also considers needs for runway balancing and arrival terminal and parking location.

Within the constraints established by the FCM, the TTM assigns each departing aircraft to an appropriate runway, departure stream, and place in sequence. The departure assignment is based on runway balancing, parking location, user preference, departure flow toward destination aerodrome, and capability and performance of the aircraft.

TTM does not completely remove the need for tactical separation assurance. In high-density or high-complexity operations, some conflicts will occur; otherwise, aircraft will over-constrain the system and underutilize available capacity. FCM, combined with TTM tuning, will ensure that the conflict management function performed by TSM will only confront safely manageable situations.

2.2.8 Tactical Separation Management

TSM ensures that aircraft maintain safe separation between other hazards and aircraft. The tactical separation provider (TSP) is responsible for TSM. Depending on the operational procedure implemented and on the airspace, the TSP may be the ANSP personnel, the aircraft flight crew, or automation. Automation predicts conflicts and calculates solutions for their resolution while maintaining overall system objectives. Precision navigation, highly accurate position and near-term intent information, and conformance monitoring allow for reduced longitudinal, lateral, and vertical separation standards in much airspace. The use of automation to predict and resolve conflicts, both airborne and with the ANSP, allows for performance-based separation standards tailored to aircraft performance capabilities and the encounter geometry.

> ***Research/Policy Issue:*** *How can performance-based separation criteria based on overall safety risk rather than a human-based, fixed standard applied to all aircraft be implemented?*

Automation, which may be on the ground or in the cockpit, will perform conflict detection and resolution development. If automation is on the ground, a human involved in approving the conflict resolution may also be on the ground. Except in the case of some UASs, pilots must approve the recommended conflict resolutions before they are implemented, whether they are generated on the ground or in the cockpit. Some pilots will have traffic situation displays and conflict alerting to enable them to assume responsibility for tactical separation. Aircraft without this capability will be somewhat restricted in the airspace they can enter and the operations they can perform.

> ***Research Issue:*** *Is it cost-effective or beneficial to have an airborne-based automation conflict detection/prediction system?*
>
> ***Research Issue:*** *To what extent does ANSP automation issue clearances without human approval? For example, is automatic exchange of 4DTs between ANSP automation and the aircraft flight management system (FMS) to resolve a conflict possible?*
>
> ***Research Issue:*** *Can reliable ANSP automation be developed that is capable of providing safe and robust separation assurance without human monitoring or intervention? What level of traffic monitoring is needed on the flight deck when operating in ANSP flow-managed airspace where automation is providing separation assurance? What level of vigilance is needed? What capability beyond the traffic alert and collision avoidance system (TCAS) is needed?*
>
> ***Policy Issue:*** *What are the responsibilities and liabilities of different stakeholders in the event of automation failure?*

Aircraft performing self-separation procedures are required to separate themselves from one another without intervention by the ANSP. Aircraft operators choose their own trajectories overall. Standardized algorithms detect and provide resolutions to conflicts several minutes ahead of the predicted loss of separation. The resolution maneuver is very small—it usually involves a very minor speed or heading change. These algorithms include determination of which aircraft has the “right of way” and which aircraft must maneuver to avoid the other. In the event an aircraft does not perform a required separation maneuver, contingency procedures are invoked so other aircraft can maneuver to maintain safe separation.

For some operations, a single aircraft will have separation authority for a specific maneuver (e.g., for crossing or passing another aircraft). In this case, the ANSP personnel delegate tactical separation authority to the specific aircraft for the duration of the maneuver, after which full separation authority is transferred back to the ANSP personnel.

> ***Policy Issue:*** *How will legal liability issues be dealt with for self-separation?*

Today, most high-performance aircraft are equipped with an aircraft-based collision avoidance system that is independent of the air traffic control system. In the United States, this system is referred to as TCAS; internationally, this system is referred to as ACAS (airborne collision avoidance system). TCAS reduces the risk of collision between aircraft when the separation assurance process fails. Under NGATS, either aircraft or the ANSP will provide tactical separation. In any event, automation will support tactical separation much more than it does today. However, a collision avoidance system independent of the tactical separation system, which acts only in the event the separation assurance process fails, will still likely be required (see ICAO AN-Conf/11, ASAS Circular).

> ***Research/Policy Issue:*** *What are the requirements for a collision avoidance system that is compatible with NGATS tactical separation? Unless mandated otherwise, some aircraft will likely be equipped with legacy TCAS/ACAS systems, which may generate unwanted alerts during normal operations. How should this be accounted for?*

2.3 COLLABORATIVE TRAFFIC FLOW MANAGEMENT

Collaboration between the ANSP and airspace stakeholders accomplishes many of the objectives for capacity management, flow contingency management, and TTM. Collaborative traffic flow management (C-TFM) is the means by which operator objectives and constraints are balanced with overall NAS performance objectives.

The C-TFM process recognizes that the expertise, data, and processing capabilities necessary to balance NAS constraints and multiple operator objectives are distributed across many organizations within the ANSP, flight operators, and other stakeholders. This distribution applies to situation assessment, plan generation, execution, contingency management, and adaptation. C-TFM builds on a number of capabilities in the NGATS:

- Information systems and communication technologies provide shared access to critical information, and they support both real-time and asynchronous collaboration. This access includes communications among ANSP facilities, FOCs, aerodrome and ramp operators, and aircraft.
- Information exchanges are more clearly targeted to the necessary decision-makers.
- Decision support automation and information services provide personnel with the appropriate shared situation awareness, aid in identifying alternative solutions for dealing with a constraint, and help implement the selected solution.

- New roles and responsibilities are allocated to ensure that decision-makers have the necessary knowledge, data, and processing capabilities to accomplish their tasks; safety nets exist to provide resilience in the face of errors and system failures.
- New strategies (such as the use of airspace flow programs; the dynamic use of alternative departure routes; dynamic airspace redesign; and new techniques for handling airspace, aerodrome, and metroplex constraints) increase the traffic management tools available to handle different situations.
- Post-operations analyses are available to operational staff to provide feedback regarding the effects of their decisions; this feedback will help staff learn and improve over time.

Within this environment, flight operators have a range of flight planning capabilities that optimize flights based on individual mission objectives, available aircraft, security and airspace constraints, and forecasted weather (see Chapter 3). Operators also have access to an authoritative source of weather information that provides forecasts and current conditions. Flight planning automation uses both weather data and system constraint data provided from the ANSP in planning individual flights or groups of flights.

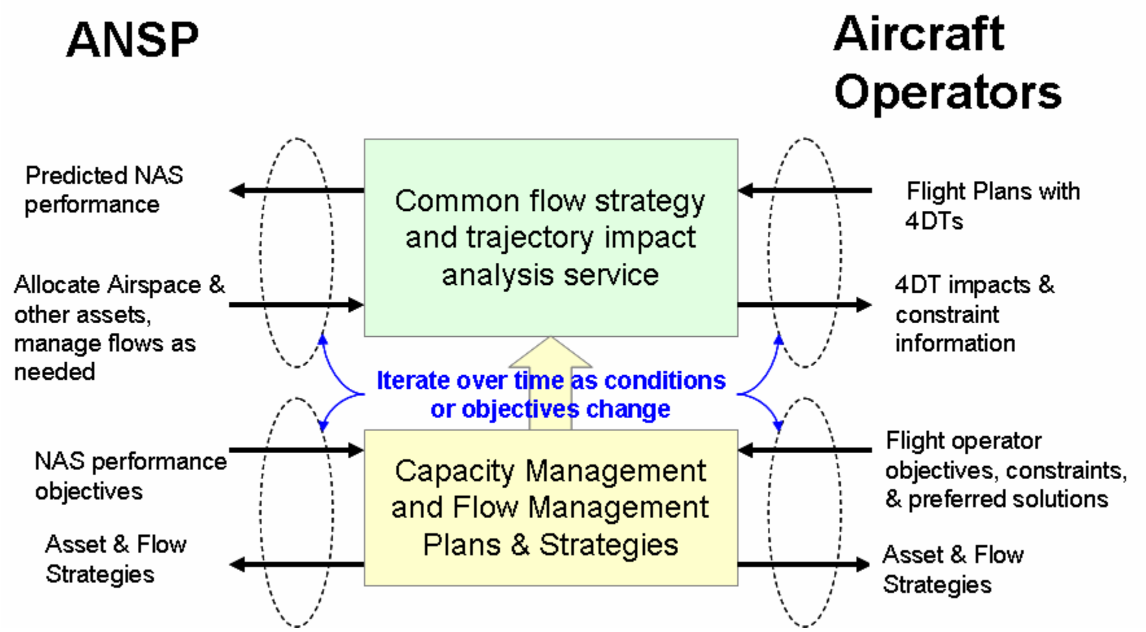
Flight planning is both iterative and interactive. For some operators, flight plans—represented as 4DTs—are planned months in advance. Trajectory and other information associated with the flight are stored in the flight object. As more information becomes available about the conditions affecting a flight, operators are automatically informed and in turn, make adjustments to provide "best known" information via a 4DT. The level of uncertainty will decrease as the time to actual flight departure decreases. Operators also have multiple options for indicating contingency plans associated with a given flight. For example, a filed flight may include alternative 4DTs that represent the operator's preferences. The operator also may provide some contingency criteria to the ANSP to provide guidance for ANSP-generated changes to the 4DT. Operators maintain the ability to negotiate changes to a 4DT and may initiate a 4DT proposal in anticipation of an expected constraint.

Research Issue: *What level of performance (e.g., precision, integrity, latency, accuracy, etc.) is necessary for the different uses of the 4DT? Who performs them (e.g., operator versus ANSP) and where should they be performed? What is the appropriate time horizon?*

Research Issue: *What is the minimum level of detail for a 4DT? How does this vary according to the type of operation? What is transmitted between air and ground?*

Flight planners or an operator's flight planning automation interact with a common flow strategy and trajectory analysis service, available to all NAS stakeholders, that enables common situational awareness of current and projected NAS status and constraints. In addition to having common services to understand the potential effects on a trajectory or the effects of a flow strategy, operators and the ANSP can collaborate on the selection of both capacity management and flow contingency management strategies that balance NAS performance objectives with operator goals and constraints (see Figure 2-8).

Figure 2-8: Information sharing and Collaboration among the ANSP and Operators



Flight operators and the ANSP have a common understanding of overall national goals and desired performance objectives for the NAS. A transparent set of strategies is in place to achieve overall performance objectives, including airspace management to maximize capacity when demand is high and, as required, flow management initiatives to ensure safe levels of traffic are not exceeded when capacity limits are reached. Collaboration and decision-making occur faster when a common awareness of future plans and the effects of alternative strategies to address overall demand exist and all parties have more consistent views of NAS conditions, demand, strategies, and contingency plans.

This common flow strategy and trajectory analysis capability facilitates decision-making and is integrated across all planning horizons. Known flight plans, including 4DT information, are assessed for mutual compatibility with airspace/system capacity as well as other considerations (such as special security requirements). Current and probabilistic forecast weather information is integrated into the analysis to provide a picture of likely conditions and ranges of variability to anticipate. Flight operators and ANSP personnel use the results of the analysis to understand where contention for resources is projected to occur. This analysis can occur for multiple planning horizons (months ahead to about 20 minutes ahead) to identify potential problems or capacity imbalances. As problems are identified, all stakeholders have a common basis for understanding potential capacity management initiatives and any residual flow contingency initiatives required to achieve overall NAS objectives.

Research Issue: *What metrics are required to evaluate system performance at different levels of detail? What processes, tools, and data sources are needed for effective and equitable management of system operations?*

Research/Policy Issue: *To what extent are incentives provided or requirements established for "early filing"? How do these requirements affect scheduled operations versus on-demand operations?*

Research/Policy Issue: *What incentives and consequences exist to encourage desired behaviors by stakeholders?*

As a result of this flow strategy and trajectory analysis capability, operators can better understand the likely effect of overall conditions on a flight or set of flights. In addition, adjustments to flights for flow contingency management needs or other considerations becomes more agile, as both operators and the ANSP can monitor overall system and individual flight status to adjust and refine overall flows and individual trajectories.

2.4 INTEGRATED AIRSPACE OPERATIONS

This section describes the airspace, operations, and associated procedures envisioned for the NGATS timeframe. Particular focus is given to describing operations and their applicability and benefits to the ANSP and NAS users. Overall demand for NAS assets drives the airspace and operations employed in the NGATS. Operations and procedures are selected to achieve the necessary level of capacity, with the underlying philosophy that better equipped aircraft receive a higher level of service and greater access to capacity-limited NAS resources. Restrictions are imposed only as needed to achieve desired capacity.

2.4.1 Overview of Airspace Operations

The two types of managed airspace envisioned for 2025 are trajectory-based airspace and classic airspace. These designations are not necessarily intended to replace the current classes of airspace; rather, they refer to the manner in which operations are conducted. Trajectory-based and classic airspace include en-route, oceanic, and terminal airspace, along with the associated transition airspace.

Future aircraft have a wider range of performance than today and will support varying levels of operations via onboard capabilities and associated crew training. These operations will include performing airborne spacing, airborne separation, and airborne self-separation tasks to safely avoid weather effects and precisely exchange and execute 4DTs. The minimum aircraft capability for operation in managed airspace is cooperative surveillance. In trajectory-based airspace, all aircraft also have a capability to receive, transmit, and execute 4-DTs and air traffic clearances.

Within trajectory-based and classic airspace, differing types of operations are conducted, distinguished by the manner in which procedures are selected and clearances are initiated, transmitted, negotiated, monitored, and revised. Thus, the distinction in operations is directly connected to the minimum set of performance capabilities required to operate in the airspace.

Airspace boundaries and the associated NGATS operations are dynamically defined; airspace boundaries are not tied to ANSP facilities. For aerodromes, the designation of terminal airspace is more flexible and has a relatively smaller “footprint” that is dynamically driven by the necessary operations. The capacity management process (Section 2.2) matches airspace type and operations according to traffic demand, including defense and security requirements, day-to-day operational considerations (e.g., severe weather), and operator objectives. The process also defines boundaries between airspace types in a more flexible manner than exists today.

Capabilities for managing airspace structure include a common mechanism for implementing and disseminating information about the identification and allocation of airspace for other uses (e.g., military SUA, commercial space, special security airspace). This process includes ensuring national needs for defense and homeland security are met, maximizing access to airspace, and minimizing disruptions to commerce.

Operations around aerodromes in the NAS will be managed as terminal airspace but with additional flexibility. Rotorcraft and aircraft capable of vertical flight will be assigned to arrive and depart along routes coordinated with the major fixed-wing flows to and from runways to avoid congestion and improve the overall flow of both types of aircraft. Operational distinctions between oceanic and en-route airspace will fade as performance-based operations become the norm. Some operational considerations remain for oceanic and remote airspace, however. Flexible routes, including the definition of airspace "corridors" for high-density and transitioning flows, allow traffic to shift as necessary to enable more effective weather avoidance, reduce congestion, and meet defense and security requirements.

Table 2.2 presents a summary of operations and required ANSP and aircraft capabilities to conduct those operations.

Research Issue: *What level of flexibility in airspace structure (e.g., routes and boundaries) is needed to achieve operational goals, including efficiency, capacity, and environmental goals? To what extent can the selection of predetermined structures support operational needs? How should flexible routes be defined and displayed to flight crews and ANSP personnel?*

Policy Issue: *How can treaty obligations and international processes for oceanic airspace with NGATS be aligned? Currently, management of airspace beyond 12 miles offshore is delegated to states; international procedures and standards are needed to implement changes in oceanic airspace and procedures.*

Research Needed: *Develop ATM system-wide simulation of all types of NGATS airspace and explore future concept of equipage-based access:*

a. How will aircraft traverse different airspace, including coordination, planning, and data management of aircraft that cross flexible boundaries? Consider any additional cognitive/computational support required by the TTM and TSM.

b. Finalize shape, degree of dynamism, cycle time to change, and control of newly stratified airspace.

Table 2-2: Air Navigation Operations and Capabilities

Operation	Benefit	ANSP Capability	Aircraft Capability	Provision of Tactical Separation
En-Route Trajectory-Based Operations				
• ANSP flow operations	High traffic density	4DT exchange, including updates for TSM, TTM	Exchange and execute 4DT, CTA, RNP Some aircraft have delegated separation capability	ANSP; may be automated and delegated by exception
• Flow corridors	Very high traffic density Preferred routing ANSP productivity	4DT exchange with reduced requirement for updates, TTM	Exchange and execute 4DT, CTA, RNP Delegated separation capability	Procedural separation of corridor from other airspace Aircraft within corridor separate themselves

Operation	Benefit	ANSP Capability	Aircraft Capability	Provision of Tactical Separation
• Basic ANSP-managed operations	Accommodate wider range of aircraft capabilities	4DT exchange, TTM, TSM	Exchange and execute basic 4DT	ANSP supported by automation and may be delegated by exception
• Autonomous operations	Preferred routing ANSP productivity	Reduced 4DT exchange	Exchange and execute 4DT, CTA, RNP Full self-separation	Aircraft
Terminal Operations				
• Merging and spacing	Arrival throughput match to runway capacity ANSP productivity	4DT exchange, TTM, TSM	Exchange and execute 4DT, CTA, RNP Airborne spacing	ANSP supported by automation and may be delegated for some aircraft
• CSPA, paired approaches	Closely spaced runways maintain VMC capacity in all visibility conditions	4DT exchange to establish aircraft on approach, TTM, TSM	Exchange and execute 4DT, CTA, RNP Parallel runway procedures	ANSP, except between aircraft conducting approach
• CDA, other RNP trajectories	Reduced environmental effects High throughput	4DT exchange, TTM, TSM	Exchange and execute 4DT, CTA, RNP	ANSP; may be delegated for some aircraft
• Reduced longitudinal separation on approach	Increased single runway arrival rate	Wake vortex monitoring and automation, TTM, 4DT exchange, runway occupancy monitoring	Exchange and execute 4DT, CTA, delegated separation responsibility for some aircraft	ANSP; may be delegated for some aircraft
Classic Operations				
• Basic procedures	Accommodate all aircraft capabilities Preferred routing sometimes available for more capable aircraft	TTM, TSM	Area navigation (RNAV) (most aircraft), some aircraft more capable	ANSP; may be delegated for some aircraft

2.4.2 Procedures

A basic set of procedures to be used in 2025 exist. The flight object will capture the abilities of aircraft to perform these procedures and, often, the authority of aircraft to perform the procedures. The procedures used most include:

- **Basic ANSP-Managed Procedures:** Aircraft operate within specific clearances given by the ANSP. The ANSP is responsible for ensuring tactical separation among aircraft conducting basic ANSP-managed procedures.
- **RNAV/RNP Procedures:** Aircraft operate within their assigned constrained path (3D trajectory with tight lateral and vertical requirements). Several levels of RNP operations will exist, defined by the tightness of lateral and vertical requirements. The ANSP is responsible for tactical separation among aircraft conducting RNAV/RNP procedures.
- **4DT Procedures:** Aircraft are capable of RNAV/RNP procedures and must meet specified timing constraints on arrival at waypoints. Aircraft operators and ANSP personnel mutually develop 4DT agreements that maximize overall use of constrained NAS resources while providing the most efficient routings. Aircraft are capable of complying with the resulting 4DT procedure in flight. Several levels of 4DT operations will exist, defined by the number of waypoint assignments and the tightness of timing requirements. The provision of separation depends on the airspace and operations conducted.
- **Delegated Separation Procedures:** The ANSP may delegate responsibility to aircraft performing the basic ANSP-managed, RNAV/RNP and 4DT procedures described above to perform specific separation operations using onboard displays and guidance. Examples include passing, crossing, climbing and descending, and turning behind another aircraft. In these operations, the ANSP maintains responsibility for separation from all other traffic while the specified aircraft performs the specific maneuver.
- **Airborne Spacing and Merging Procedures:** In airborne spacing, the aircraft performing the procedure maintains spacing in time or distance from a designated lead aircraft as defined by an ANSP clearance. Cockpit displays and guidance support the aircraft conducting spacing and merging procedures to enable accurate adherence to the spacing criteria. In merging, the aircraft arrives at a merge point in correct sequence with spacing from a lead aircraft as defined by an ANSP clearance. Operations are conducted within assigned 4DT constraints.
- **Parallel Runway Procedures:** Aircraft use delegated separation procedures to safely conduct independent, CSPA to runways (which may be spaced as close as 2,500 feet in low visibility conditions) or dependent, CSPA to runways (which may be spaced less than 2,500 feet).
- **Airborne Self-Separation Procedures:** Aircraft are responsible for maintaining separation from all other aircraft and obstacles or hazards in the airspace. Aircraft follow the “rules of the road” and avoid any maneuvers that generate immediate conflicts with any other aircraft. Aircraft continuously transmit highly accurate, near-term trajectory intent information to other self-separating aircraft so that future conflicts can be predicted

reliably. Airborne self-separation procedures may be conducted in designated autonomous airspace and in other airspace when authorized by the ANSP.

- **Low-Visibility Approach and Departure Procedures:** Aircraft with proper equipage and crew training can conduct landings and takeoffs safely in low-visibility conditions without relying on expensive ground-based infrastructure by using onboard navigation, sensing, and display capabilities.
- **VFR Procedures:** Aircraft use "see and avoid" to separate themselves from other aircraft.

Note that these procedures need not be mutually exclusive; for example, an aircraft performing airborne self-separation procedures may also be performing an agreed-upon 4DT.

2.4.3 Trajectory-Based Airspace

Trajectory-based airspace, as noted above, has a critical aircraft operational capability that differentiates it from classic airspace. In trajectory-based airspace, aircraft have a data communications capability to support the creation, negotiation, and execution of 4DTs and other clearances. TBO form the core of NAS operations in NGATS. Most but not all of today's Class A, B, and C airspace, along with the oceanic track system, is expected to migrate to TBO. Many aircraft operating in 2025 are expected to operate in trajectory-based airspace, although with widely varying capabilities.

En-route trajectory-based airspace will include regions with operations designated as for ANSP flow operations and for autonomous operations. Within ANSP flow airspace, different operations are conducted, depending on demand. The ANSP retains responsibility for tactical separation but may delegate that separation responsibility to equipped aircraft under appropriate conditions. This delegation of responsibility is in contrast with autonomous airspace, in which aircraft are always responsible for maintaining separation from all other aircraft operating in the airspace. When demand in ANSP flow airspace is very high, the ANSP may designate "flow corridors" for equipped aircraft traveling on very similar routes.

En-route trajectory-based airspace, outside of the ANSP flow and autonomous operations regions, will accommodate aircraft equipped for basic 4DT procedures—usually along fairly structured routes as dictated by overall demand (similar to today's Class A airspace). In keeping with the philosophy of providing enhanced services to better equipped aircraft, the ANSP may allow some airborne spacing and separation operations if they benefit the aircraft or reduce the demand on ANSP services.

In flow airspace, 4DT procedures allow the ANSP to precisely schedule traffic in congested airspace, especially as aircraft start to converge approaching a major aerodrome. If given a revised CTA with sufficient lead time, capable aircraft will have options on how to achieve the CTA, including speed adjustments and path lengthening. The ANSP gives clearances to less capable aircraft that are consistent with the previously assigned CTA, which may result in less efficient routing.

To achieve the forecasted increase in aircraft operations, high-demand aerodromes will conduct super-density operations, in which equipped aircraft perform high-level 4DT and delegated separation procedures relative to other aircraft approaching the same aerodrome, as described in the Super-Density Terminal Operations section. Other aerodromes with lower demand will have less restrictive aircraft capability requirements, allowing access to a wider range of traffic, as described in the Flexible Terminal Operations section. For both types of terminal airspace, aircraft conduct parallel runway and low-visibility approach and departure procedures depending on their capabilities. Flexible terminal operations include both trajectory-based and classic operations.

> ***Research Issue:*** *How is the time dimension of airspace classification handled? For example, how far ahead of time will reclassification of a terminal's operation to super-density operations be known? How will aircraft already in flight be handled if the airspace is classified to become more restrictive?*

En-Route ANSP Flow Airspace

All aircraft in en-route ANSP flow airspace conduct 4DT procedures, including precise RNP and data communication to update the 4DT agreements to manage flow, meet changing user objectives, and maintain separation.

TTM ensures overall flows are efficient and controls traffic density and complexity. (For example, TTM and FCM coordination may reduce aircraft density when severe weather in an area is less predictable to prevent potentially difficult resolution situations.). 4DT agreements may include airborne spacing and merging procedures or delegated separation procedures, as appropriate, for the airspace conditions and aircraft capabilities.

TTM significantly reduces the need for tactical separation maneuvers, even though the traffic density will be higher than in today's en-route airspace. ANSP automation manages tactical separation and negotiates short-term, conflict-driven updates to the 4DT agreements with aircraft not conducting delegated separation procedures.

> ***Research Issue:*** *Can automation become the resolver? Do humans have a role in the separation assurance process? The function of separation assurance is thought to be best allocated to automation versus ANSP personnel if traffic is highly deconflicted to avoid human complacency. If research shows this is not the case, ANSP personnel would be required for TSM. What cockpit capability and role for the flight crew is needed if there is no human TSP?*

Flow Corridors

Flow corridors are TBO implemented when the demand along a route of flight is large and the total volume traffic is such that under the normal airspace, operation action would be taken to reduce the demand. The flow corridors are long "tubes" that enclose groups of flights flying along the same path in one direction. They are large enough to accommodate some trajectory flexibility (e.g., horizontal or vertical passing maneuvers, longitudinal spacing). These corridors, which are established in any ANSP flow operation region of the airspace for a specified period of time, provide for high-volume one-way flow; thus, they reduce the normal airspace capacity reserved for each flight. Aircraft within these corridors must be capable of conducting delegated separation, merging and spacing procedures within the corridor, and 4DT procedures.

The use of corridors benefits aircraft both within and external to the corridors. The aggregate flow of aircraft within the corridors requires less total airspace and monitoring than the same number of aircraft flying in standard precision airspace. Without the corridors, the ANSP would have been required to use TMIs to apportion access, assign delays, and, in some cases, force longer alternate trajectories. Further, the corridors allow for higher traffic density with low complexity without the need for ANSP TSP personnel or automation for tactical separation of aircraft in the flow.

> ***Research Issue:*** *What air automation is required for corridors? What automation beyond airborne separation is required?*
>
> ***Research Issue:*** *How is time dimension of corridor definition handled, e.g., during creation and dissolution?*

The corridor is procedurally separated from surrounding traffic and special activity airspace. Traffic within the corridor must maintain a minimum distance from the edge of the corridor (i.e., "the corridor walls have some thickness"). Well-defined procedures for handling entry and exit to the corridor exist as well as activation and deactivation of the corridor itself. Entry into the corridor is negotiated with the TTM, who identifies location and time for entry. Entry based on both the objectives of the entering aircraft and low-density points within the corridor flow. The exit point and time are set with the TTM before entry; however, this can be renegotiated during transit of the corridor. Exit point negotiations allow smooth transition back to more active ANSP personnel involvement. Procedures exist to allow aircraft to safely exit the corridor in the event of a declared emergency.

Autonomous Operations

En-route airspace, including oceanic and remote airspace, may be designated for autonomous operations where operationally feasible and desirable. In this airspace, aircraft conduct both 4DT and self-separation procedures. Rigorous right-of-way rules determine which aircraft should maneuver to maintain separation when a conflict is predicted. These rules specify the conflict resolution maneuver options for resolving the conflict with minimum disruption to the maneuvering aircraft and for preventing a conflict with a third aircraft in the short term. Contingency procedures requiring the other aircraft to execute an avoidance maneuver are invoked in the event the "burdened"

> ***Research Issue:*** *Is developing the capability for aircraft to perform autonomous operations economically justifiable? Is there a sufficient business case for enough users to equip? There needs to be a sufficient total benefit for this capability to offset the cost of developing and equipping with the capability.*
>
> ***Research Issue:*** *What level of onboard functionality is required for flight crews to safely perform autonomous operations within acceptable workload levels in en route airspace? How can human flight crews' operational tasks be designed to conform to good human-centered design? (e.g., How much freedom does the aircraft automation have to exercise without pilot interaction?)*
>
> ***Research Issue:*** *What level of throughput can be safely accommodated in autonomous airspace?*
>
> ***Research Issue:*** *Where are ANSP flow and autonomous airspace operations applied for sufficient capacity to meet NGATS goals?*
> *Policy Issue: Should airspace designation be applied to encourage a particular kind of operation?*
>
> ***Research Issue:*** *Is it cost effective to build the capabilities to perform both ANSP flow and autonomous operations?*
>
> ***Policy Issue:*** *What is the policy for equipage (voluntary, mandatory), and what are the expected result for each? Assume prioritizing three times the capacity over flying everyone everywhere without equipage.*

aircraft does not make the appropriate maneuver within a specified time. Procedures for entry to and exit from autonomous airspace ensure no ambiguity exists as to who is responsible for separation during transitions to and from autonomous airspace.

Aircraft operating in autonomous airspace generally have large flexibility volumes. Flexibility volumes permit the choice of preferred altitudes for flight efficiency and limited route deviations for weather or favorable winds aloft without renegotiation of the 4DT. An FCM function may be needed to impose sufficient structure to ensure that traffic density remains safe, especially around convective weather or other constraints. Aircraft must adhere to the CTA for exiting autonomous airspace and entering denser (and thus restrictive) airspace.

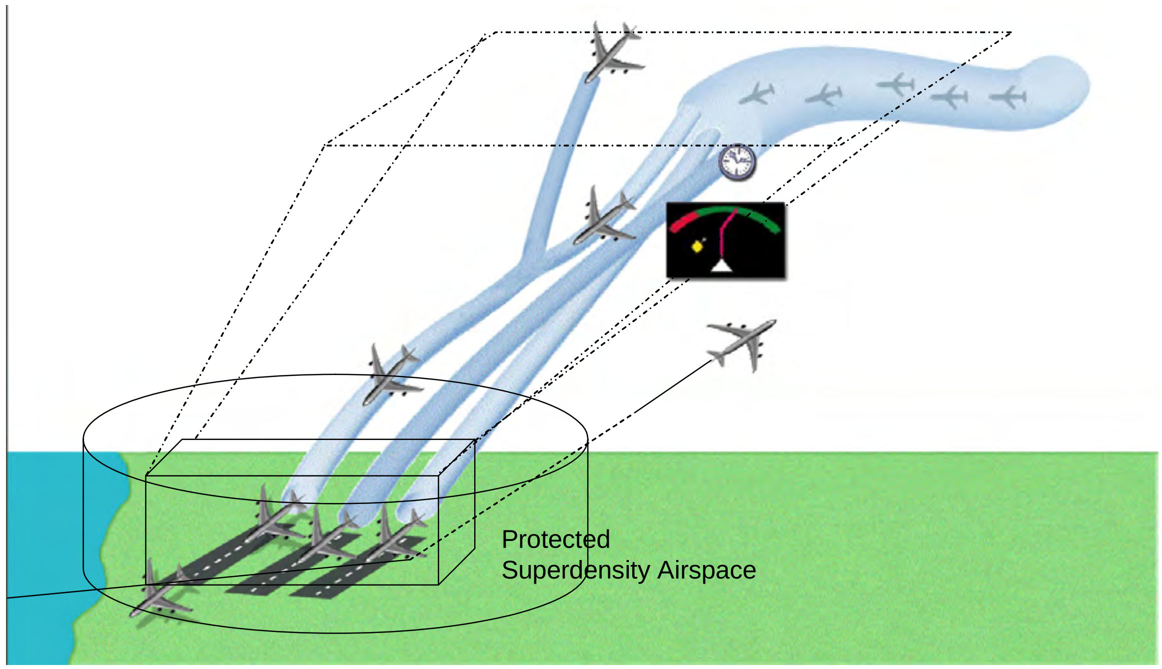
Autonomous operation regions are designated in domestic en-route airspace where demand is moderate and when the ANSP determines this to be operationally feasible.

Super-Density Terminal Operations

At the busiest terminal areas, super-density operations are conducted to achieve maximum throughput while facilitating efficient arrival and departure profiles for equipped aircraft. TFM planning and efficient overall planning for the entire aerodrome complex will help achieve significantly higher aerodrome throughput that ensures arrival flows match the projected aerodrome capacity. In addition to 4DT procedures, aircraft conduct merging and spacing procedures, parallel runway procedures, and low-visibility approach and departure procedures as appropriate. Super-density transitions provide high-density corridors to and from trajectory-based en-route airspace. Super-density operations seamlessly integrate surface operations through transition altitudes to en-route airspace (see Section 2.5 on surface operations).

As illustrated in Figure 2-9, aircraft arriving from all directions receive specific 4DT profiles via data communications as early as possible. As routes converge approaching the aerodrome, arriving traffic conduct airborne spacing and merging procedures that reduce excess spacing between aircraft and maximize throughput. ANSP personnel provide overall tactical separation in this airspace, making full use of aircraft capabilities. Wake vortex detection, tracking, dissipation, and prediction information is also provided to arriving and departing aircraft in the terminal area. The development of quieter aircraft and low-noise approaches eases restrictions currently imposed for noise abatement.

Figure 2-9: Super-Density Terminal Operations



Depending on the runway configuration at the super-density aerodrome, various arrival procedures may be employed. Specific configurations and routes are chosen in near-real time to provide flexibility and maximize arrival and departure throughput, even when severe weather is present. RNP/RNAV routes are prevalent, allowing for closer route spacing than is available today. In-trail aircraft approaching a single runway will achieve and maintain optimum spacing via airborne spacing procedures. Aircraft approaching parallel runways may conduct parallel runway procedures. Other "equivalent visual" approach procedures may also be developed to remove the restrictions imposed today during times of limited visibility and ceilings. At super-density aerodromes, precision approaches are available to every runway, and runway occupancy times are reduced. Low-visibility landing procedures are also conducted. Wake vortex detection, tracking, dissipation, and prediction information is also provided to arriving and departing aircraft in the terminal area.

Research Issue: *Much research work on arrival procedures invoking airborne spacing or airborne separation has already been accomplished, and detailed application descriptions have been developed through RTCA SC-186 and the RTCA/Eurocontrol RFG. More research is needed to determine how these approach procedures are integrated into super-density operations, including ground-based automation support.*

Research Issue: *Super-density operations will result in many aircraft in close proximity. Consequently, an aircraft blundering from its assigned trajectory is much more likely to cause an immediate conflict with another aircraft, and safe avoidance maneuvers may be limited or unavailable. How can super-density operations be conducted safely?*

Charted terminal airspace around super-density aerodromes is defined, including all possible approach and departure configurations similar to today's Class B airspace. Low-capability aircraft that lack access to real-time updates of airspace definition must avoid all charted super-density airspace. Transiting aircraft with access to real-time updates of approach and departure configurations flying in the vicinity of super-density airspace can use the portions of the charted airspace not used for super-density operations, thus gaining increased flexibility and access to a greater amount of airspace.

Super-density operations may be required at more aerodromes than today's Class B aerodromes to handle the projected traffic increase; however, as super-density operations restrict access to high-capability aircraft, they are only designated when warranted by demand (e.g., some aerodromes may be super density during peak traffic hours but not super density otherwise). Satellite aerodrome operations are incorporated into super-density operations if demand or operational conditions warrant; otherwise, access is provided via negotiation of an appropriate 4DT.

Research Issue: *How can this concept be made compatible with the environmental process for airspace design?*

Research Issue: *At a minimum, how "high tech" is the real-time update of airspace configuration? Would an ATIS-like voice identification of a configuration suffice, so as to provide information to the widest variety of operators and thus allow maximum airspace access?*

Research Issue: *Safety analysis, including longitudinal spacing and path containment for non-blundering aircraft, must specify the blunder monitoring performance required.*

Research Issue: *How much control authority is required on the aircraft for onboard CTA to effectively manage arrival flow? That is, how far ahead of time does an aircraft need to receive the CTA to perform to a desired level of control authority that is operationally feasible?*

Research Issue: *How far in advance must these airspace definitions be solidified to meet charting and automation requirements?*

Research issue: *To what extent are super-density and flexible terminal operations affected in the presence of current or forecasted weather (convective weather, winter conditions, etc.)? Does the airspace remain classified as super-density or flexible airspace in the presence of these conditions?*

2.4.4 Classic Airspace

Aircraft not equipped to exchange and execute a 4DT will fly in classic airspace, including en-route, oceanic, terminal, and surface operations. The basic ANSP-managed procedure is the predominant clearance. Both IFR and VFR operations are conducted in classic airspace. As more aircraft are equipped for TBO, the demand for classic airspace will decline but will still exist. Wherever practical, "classic" aircraft operations will be accommodated, including when transiting though airspace normally designated for TBO. 4DT aircraft may, of course, fly in classic airspace and may often receive enhanced service when enabled by the aircraft capability.

Building on their cooperative surveillance capability, many aircraft will have enhanced traffic situational awareness, resulting in safer and more efficient operations—especially in congested areas around aerodromes.

Classic En-Route Operations

Classic en-route operations will be conducted similar to today, with some improvements made possible through cooperative surveillance and the RNAV capabilities of most classic aircraft. In classic airspace, the ANSP provides separation services only to IFR aircraft. VFR aircraft will operate as they do today.

Where classic en-route operations are conducted in today's Class A airspace, ANSP personnel are responsible for tactical separation. However, aircraft equipped for ANSP flow and autonomous airspace operating in classic airspace will have advantages over unequipped aircraft. Equipped aircraft may not be constrained to fixed routes when traffic density permits user-preferred routing, and they may engage in self-separation procedures when the ANSP TSP personnel grants authority. Note that automation must be aware of the aircraft's capability to perform these operations, and the aircraft must display the capability appropriately to the ANSP personnel. Routes are relatively inflexible for less equipped aircraft. The sample aircraft capability range includes highly equipped short-haul aircraft or "classic" turbojet aircraft[4].

> ***Research Issue:*** *Is it practical to allow self-separating aircraft to operate among managed aircraft?*

Near-Space Airspace Operations

Current operations above the Class A boundary of FL600 are of mixed performance; these "near-space" operations continue and expand in diversity in the NGATS timeframe. This is classic on-top in that these aircraft are not required to have real-time data communications. Thus, a wide variance in vehicle performance exists (e.g., aerostats, long-endurance "orbiting" UASs, medium and high speed research/reconnaissance aircraft, suborbital spacecraft, launching and reentering orbital spacecraft). Any aircraft that can safely operate at these altitudes is permitted. Traffic density is low. Where necessary, separation is provided based on geographic area and/or altitude assignments, with non-maneuvering vehicles charted as obstacles. Charted transitions provide access to and from this airspace.

The benefit of this airspace is that it preserves access at all times to the widest range of vehicles, as is done today. Many of the users of this airspace, today and in the future, are expected to have unique needs that require use of this airspace. Because this airspace is envisioned to be a much higher elevation than practical for most NAS operations, demand will likely continue to be low.

Non-managed Operations

Blocks of "uncontrolled" low altitude airspace continue to exist in the future in some remote areas. Operations are unchanged from today's Class G airspace. No ANSP services are provided, except as required to coordinate entry to a different class of airspace. VFR procedures are used by most aircraft, as is done today, while some aircraft equipped for "sense and avoid" procedures may operate in low-visibility conditions. Note that cooperative surveillance may not be a requirement for non-managed operations.

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4 "Classic" aircraft will have expanded to include many of today's modern aircraft that do not meet high RNP requirements.

There may continue to be "uncontrolled" aerodromes in the future. Operations will be unchanged from today's procedures around uncontrolled aerodromes. No ANSP services will be provided (such as automated virtual towers [AVT] services), except as required to coordinate entry into a different class of airspace.

> ***Research Issue**: For "electronic VFR," what is the minimum airborne separation assurance required for flight in IMC conditions? Is traffic situational awareness good enough? Will appropriate avionics be inexpensive enough that imposing a minimum capability is not an undue burden?*

Flexible Terminal Operations

Super-density terminal operations are only conducted when demand warrants. At aerodromes where traffic demand is lower, and at super-density aerodromes during times of low demand, operations requiring lower aircraft capability are conducted, allowing access to a wider range of users while retaining some of the throughput and efficiency advantages of super-density operations. Both trajectory-based and classic operations may be conducted within flexible terminal operations. 4DT procedures will be employed to provide equipped aircraft with efficient low-noise trajectories. Aircraft equipped for airborne spacing and merging procedures and for parallel runway procedures may get priority over lesser equipped aircraft when high demand exists. The ANSP can much more easily accommodate aircraft transiting flexible terminal airspace or landing at a satellite aerodrome with fewer aircraft capability requirements than required for super density operations. ANSP personnel provide tactical separation in this airspace, making full use of spacing and separation capabilities of equipped aircraft.

> ***Research Issue:** How can this concept be made compatible with the environmental process for airspace design?*
>
> ***Research Issue:** At a minimum, how "high tech" is the real-time update of airspace configuration? Would an ATIS-like voice identification of a configuration suffice, so as to provide information to the widest variety of operators, and thus allow maximum airspace access?*
>
> ***Research Issue:** Collision risk analysis, including longitudinal spacing and path containment for non-blundering aircraft, needs to specify the blunder monitoring performance required, if any.*
>
> ***Research Issue:** How practical is it to mix high-precision operations with less capable operations in the same airspace?*

Classic Terminal Operations

Aerodromes that do not experience high demand levels will operate similarly to today. Airspace will be statically defined and charted. Aircraft with various equipage levels will have access to this classic terminal airspace. RNAV routes (without RNP requirements) will be common, allowing for more organized flows into the terminal airspace.

> ***Research Issue:** Can the airspace associated with airports be reduced from current Class D/airport traffic area volumes?*

2.4.5 Tower Operations

Aircraft control towers will provide much the same service as today, but operations will be significantly enhanced. Particularly in low-visibility conditions, the ANSP can safely make more efficient use of runways through real-time depiction in the tower of the location and intent of arriving and departing aircraft, as well as any aircraft intending to cross an active runway. At super-density aerodromes, the surface management automation will generate and transmit taxi instructions via datalink, including hold short instructions, virtually eliminating runway incursions and other taxi errors. This ability also leads to higher taxi speeds and eliminates requests for progressive taxi instructions. Tower operations will be integrated with arrival and departure management for maximum overall efficiency. Achieving maximum runway throughput implies a departure queue to ensure efficient use of departure runways.

Staffed Virtual Towers

Tower services may be provided remotely from a location away from at the aerodrome. These Staffed Virtual Towers, (SVTs) provide services similar to existing towered aerodromes. Reliable surface surveillance of all aircraft and vehicles, monitoring of environmental conditions, and robust procedures will help this occur safely. The benefits of SVT operations include the provision of tower services to a larger number of aerodromes than is provided today, significantly reduced physical infrastructure costs, and the potential for ANSP personnel to service multiple airfields from a single physical location. Because more aerodromes will have sequencing and separation services, the system is capable of additional throughput compared to one-in-one-out operations at non-towered aerodromes today. In addition, SVTs provide productivity gains when compared with the number of personnel required if services are provided from physical towers at all locations. Consolidating staffed tower operations from multiple aerodromes and within aerodromes that would otherwise require two towers into a single staffed virtual tower during periods of lower demand—most likely at night—will also result in productivity gains.

> ***Research Issue:*** *How small an airport is economically practical for SVT operations?*

Automated Virtual Towers

Improved services to some currently uncontrolled and lower density aerodromes will be provided by Automated Virtual Towers (AVTs). AVTs provide sequencing services and basic aerodrome information without the use of ANSP personnel at an enhanced level compared to the typical non-towered aerodrome today. The NGATS envisions AVTs can be deployed for non-towered aerodromes and provide services at smaller towered or SVT facilities during off-peak hours . Because more aerodromes will have sequencing services, the system will receive additional throughput compared to one-in-one-out operations at non-towered aerodromes today. Aircraft will conduct self-separation procedures to enable simultaneous operations in instrument meteorological conditions (IMC) at non-towered aerodromes supported by AVTs. AVTs provide increased system capacity through more effective use of smaller aerodromes. Users will benefit from more reliable access to smaller aerodromes, more efficient air-taxi operations, avoidance of major aerodromes, and increased transportation services to rural communities.

> ***Research Issue:*** *How can automated weather decision-making capabilities mitigate the effects of winter weather on surface operations?*
>
> ***Research Issue:*** *How large or busy an airport is operationally feasible for AVT operations? How small an airport is economically feasible for AVT operations?*
>
> ***Research Issue**: For "electronic VFR," what is the minimum airborne separation assurance required for flight in IMC conditions? Is traffic situational awareness good enough? Will appropriate avionics be affordable enough so that imposing a minimum capability is not an undue burden?*

Aircraft must establish digital communications with the AVT system to use an AVT-controlled aerodrome. Arriving traffic will be given a sequence for the runway via AVT services and will have predefined taxi routes to the ramp. Aircraft will be responsible for separating from other surface traffic, including runway crossings. Departing aircraft will follow standard taxi routes to the runway end. The AVT will provide sequencing of aircraft to the runway.

2.5 SURFACE OPERATIONS

Runway capacity is the primary limiting factor in NAS operations today at the busiest aerodromes; therefore, more efficient runway use is very important. Even with the maximum possible efficiency gains, some aerodromes may need additional runways to accommodate the expected NGATS traffic growth. Implementing super-density terminal procedures, such as the parallel runway procedures described in Section 2.4.2, will enable new runways to be built much closer to an existing runway and still achieve the throughput of a single arrival runway, regardless of ceiling and visibility. Surface operations in the NGATS timeframe at medium- and large-demand aerodromes will be highly integrated with other ATM functions, including departures, arrivals, and collaborative traffic management. In addition, non-ATM functions, such as aerodrome landside and airside operations, will benefit from information exchange of aircraft surface position and movement. Table 2-3 shows a summary of the major transformations.

Table 2-3: Surface Operation Transformations

2006	NGATS
Ground surveillance available to ANSP limited. Mostly primary, some secondary surveillance capability installed. Limited effectiveness of runway incursion prevention automation.	Cooperative ground surveillance at most aerodromes, including state vector information (e.g., aircraft speed/direction), with more effective runway incursion prevention automation.
Essentially no cockpit surveillance of other ground traffic/vehicles, other than visual (out of the window).	Integrated surveillance of ground traffic, along with aerodrome layout and taxi routes, with cockpit warning of runway incursions.
Surface movement information (pushbacks, departures, taxi delays, etc.) are mostly not integrated with TFM. Difficult to implement flight-specific traffic management initiatives.	Updated pushback information provides improved surface and departure management. Surveillance of surface movement provides basis for more accurate departure time and taxi delay estimates. Availability of improved departure time estimates significantly improves capability of FCM and TTM. Flight-specific traffic management initiatives are handled via automation and data communications.
Many non-towered aerodromes.	AVTs or better where economically feasible.
Inefficient one-in-one-out operations at smaller aerodromes without approach controls or towers.	Elimination of one-in-one-out restrictions at most aerodromes for equipped aircraft.

In today's system, a general lack of planning capability exists for deicing; in fact, the decision to deice is often made at pushback. This lack results in long delays. In NGATS, improved prediction of icing conditions and the need for deicing are integrated into ramp and surface management functions, allowing for inclusion of the additional time for deicing in departure management planning.

Operations at the busiest aerodromes—most likely those implementing super-density terminal operations—are designated super-density surface operations. Where this level of operation and consequent aircraft capability is not required, flexible surface operations are conducted, allowing access to a wider range of aircraft. Both kinds of surface operations are described in the following section.

Super-Density Surface Operations

The goals of super-density surface operations are to move aircraft safely with robust runway incursion prevention, maximize runway throughput, and minimize taxi times. Taxi operations are integrated into the aircraft's 4DT, allowing the ANSP to complete capacity management and flow contingency management activities and provide streamlined departure management. Onboard displays of assigned taxi route, coupled with display of surface traffic and other hazards, enable aircraft to safely taxi at or near normal taxi speeds in low visibility and at night and virtually eliminate runway incursions and other taxi errors. Cockpit and ground automation allow aircraft to plan for crossing active runways and taxi across when the runway is clear without tower intervention.

The same level of shared situational awareness and collaborative planning between the ANSP and users applied to super-density surface operations is applied to the aircraft in flight. This enables much more efficient use of aerodrome facilities, such as gates, taxiways, ramps, fuel trucks, and deicing facilities for both the ANSP and user than currently possible. To accommodate super-density procedures, advanced technology and procedures may modify same-runway separation standards and runway occupancy rules. These modifications may include use of active wake vortex detection systems and automated aircraft braking systems that can optimize brake application to safely reach a pre-coordinated runway exit. (Safety analysis will determine whether any of the preceding concepts can be safely implemented, both generally and at specific aerodromes and runway ends.) The benefits to the system include increased capacity and efficiency at super-density terminal areas, improved ANSP productivity for managing taxi operations, and environmental advantages, such as reduced emissions per flight and reduced aerodrome noise. The benefit to the user is better taxi efficiency and access to aerodrome facilities.

Flexible Surface Operations

As with flexible terminal airspace, flexible surface operations allow access to a wider range of aircraft than super-density surface operations. Taxi operations are integrated into the aircraft's 4DT, allowing the ANSP to complete Capacity management and flow contingency management activities and provide streamlined departure management. Many of the other enhancements described for super-density surface operations are applied to flexible surface operations as dictated by demand and the surface layout of a particular aerodrome. However, access is still granted to the widest possible range of users.

2.6 AIR NAVIGATION SERVICES MISSION SUPPORT

The new operational concepts, technologies, and services within NGATS offer opportunities for resource management and allocation that do not exist today. Resource allocation and management is a strategic function that addresses where and how physical assets and humans are allocated within NGATS and used to efficiently provide necessary services. It also addresses how to allocate limited resources when demand exceeds capacity. As an interactive, collaborative, and performance-based system, NGATS will provide the ability to:

- Forecast long-term and short-term changes in demand
- Plan needed changes in air navigation, aerodrome and flight capacity, and resources
- Implement and manage resources
- Evaluate how well the system supports demand.

Resource allocation and management involves many capabilities, such as forecasting to project how traffic is likely to evolve in the future, adaptive investment and management services, and post-operational analysis that can compare how the system performs over time. These capabilities will enable ANSP mission support and aerodrome operation and flight operator mission support.

In future versions of this document, this section will address the operations and services that provide mission support to air navigation service provider operations and their transformations within NGATS, including:

- Mission support planning
- Certification management
- Regulation management
- Financial and investment management
- Logistics management
- Facilities and equipment management
- Performance management
- Safety, security, and continuity of operation services.

3 Flight Operations

3.1 INTRODUCTION

Aircraft operators are individuals or organizations that directly or indirectly operate an aircraft. Aircraft operators include, for example, those who operate aircraft for commercial purposes, business support, personal travel, or homeland defense. The types of aircraft operated can range from lighter-than-air vehicles and gliders to highly sophisticated aircraft and space vehicles. Aircraft operators include those who operate traditionally piloted aircraft and those who operate aircraft remotely. In organizations that operate aircraft, multiple individuals may be involved in roles related to flying an aircraft, planning and selecting flight trajectories, and defining strategic objectives.

This section provides an overview of how operators interact with and use NGATS capabilities to achieve their objectives. In the NGATS timeframe, interactions between operators and the NGATS are less driven by the regulatory framework under which they operate; instead, operators' capabilities and investments drive these interactions. Section 3.2 outlines some of the planning activities and interactions that occur before a flight departs. Section 3.3 highlights some of the transformations that occur during flight execution. The NGATS accommodates a wider range of flight operations than is possible today. Section 3.4 provides perspectives related to transatmospheric operations, vertical flight operations, and UAS operations. Section 3.5 provides a summary of operator capabilities envisioned for the NGATS, including airframe capabilities and other capabilities related to planning and monitoring flights.

Operator Goals and Business Models

Operators have a range of objectives for operating flights, depending on their business models. Some of the ranges of operator business models include the following:

- **Scheduled Operators:** Scheduled operators carry people and freight. Their schedules are typically determined at least 1 month in advance of the intended operation. The primary objectives associated with scheduled operations are maintaining schedule integrity and operating efficiency. For many operators, the ability of the NGATS to accommodate growth in schedules is also important.
- **On-Demand Operators:** On-demand operators provide service that may be scheduled less than several hours to 1 day in advance. These on-demand operations may include multiple segments, some of which may change during the operation. On-demand operators include air taxi, charter, company business aircraft, medical transportation, and other operations that provide services to the public. The objectives for on-demand operations include access to NGATS resources and operating efficiency. In the NGATS, on-demand operations are integrated with scheduled traffic for minimum system disruption.

- **Personal Aircraft Operators:** Personal aircraft operators use aircraft for both personal travel and recreation. Under NGATS, the objective for personal aircraft operators is equitable access to NAS resources—both aerodromes and airspace. For many operators, another goal is the conducting VFR operations with minimal restrictions.
- **State/Military Aircraft Operators:** State and military aircraft operators use the NGATS for a range of objectives, including transporting people and goods, defending the homeland, and maintaining operational readiness. This broad category includes aircraft operated by agencies, including DOD, NASA, DHS (U.S. Coast Guard [USCG] aircraft, Customs and Border Patrol, etc.) and DOT (flight inspection aircraft), as well as aircraft operated by the governments of other sovereign states. Aircraft operated for state and military needs include aircraft with highly unique performance and operational requirements as well as aircraft identical in performance and operational requirements to their civil counterparts. State and military operators require access to all areas of the NGATS and may, at certain times, require the NGATS to accommodate aircraft that do not meet all expected capability and performance requirements. These operators may also require priority access to complete a specific mission or objective. Military aircraft operators require the ability to operate in areas designated for their special use to conduct training and proficiency operations.

Principles in Operator Interactions with the NGATS

From an operator perspective, there are a number of key principles related to the operation of flights in the NGATS:

- The NGATS accommodates a range of operator goals and business models and does not inherently favor one business model over another.
- Operators have broad access to NGATS with minimal restrictions; NGATS resources are managed to maximize utility to operators. Restrictions are imposed only for reasons of projected congestion, security, or safety.
- NGATS stakeholders maximize their ability to achieve their goals and business objectives by actively participating in the C-TFM process. This involves not only information exchange and negotiation with respect to flight trajectories but also involvement in the process of allocating resources to the NAS. Operators that do not participate in the C-TFM process or that operate flights not known in advance of the implementation of traffic management programs by the NGATS may experience access restrictions under some conditions.
- Access to airspace and aerodromes is capability driven; minimum requirements are defined when increased capacity is needed to meet demand. For example, operating in some airspace may require the ability to conduct specific operations (e.g., RNP routes).
- When excess demand exists that cannot be addressed by using performance-based operations and applying C-TFM, a transparent policy, known by all operators and stakeholders, provides the resolution to prioritize access to NGATS resources. This policy includes accommodating some level of on-demand operations.

- Other national objectives for the NGATS are considered in addressing access to NAS resources. For example, military, state, and civil aircraft that are involved in national security, homeland defense, responses to national disasters, policing actions, life guarding actions, fire-fighting actions, and movement of high-ranking government officials receive priority; in some cases, these operations may require airspace segregation.

3.2 FLIGHT MANAGEMENT

Flight management involves functions completed before the execution of a flight, including:

- Strategically deciding where to operate flights or provide services
- Acquiring aircraft and investing in aircraft and other capabilities that are compatible with the operator's overall objectives
- Planning individual flights to match an operator's objectives and constraints (for many operators, this is done by an FOC or equivalent function)
- Participating in the C-TFM process to adjust individual flights or multiple flights in response to operator or ANSP constraints and to collaborate on overall strategies to manage flows in the NGATS.

Note that this version of the NGATS CONOPS focuses on the latter two functions. Subsequent version of this document will include more details on flight management.

3.2.1 Flight Planning and Dispatch

Operators may have their own FOC or may receive flight planning services from a third party. Flight planning and dispatch is enhanced by improved access to information, such as anticipated weather and environmental conditions, and by the identification of other constraints that may affect a flight.

For IFR operations, aircraft from each of the operational communities (especially aircraft associated with military/state and personal operators) may at times traverse airspace where difference operations are being conducted including unmanaged airspace. As part of the flight planning function, operators file a flight plan with a 4DT with a level of specificity that supports the operations performed in airspace traversed by the flight plan.

With the dynamic allocation of airspace and resources, the minimum requirements for operating in a region of airspace may change (either temporally or geographically) based on environment, overall demand, or other factors. Through NGATS services, flight planners can modify and change their 4DTs based on current and projected requirements as well as preferences.

3.2.2 Collaborative Traffic Flow Management

The overall C-TFM process, described in Section 2.3, is related to creating shared situational awareness and balancing operator and ANSP needs. NGATS enterprise services provide this shared situational awareness and a set of collaboration capabilities. In NGATS, all ranges of operators have—if they choose—access to C-TFM data exchange. Although it is anticipated that most interactions with C-TFM will involve data communications through the network sharing information services, operators without an FOC will have access to C-TFM processes via a personal computer located at home, in an FBO, or through a flight service station function. The degree of negotiation is likely to change with the size of fleet, giving operators some flexibility in scheduling multiple flights. In NGATS, all operators can see the constraints and request alternatives.

The NGATS environment revolutionizes the C-TFM process. In NGATS, machine-to-machine "negotiation" replaces labor-intensive, telephone-based processes. For example, the net-enabled operations (NEO) environment and the availability of data link better inform operators and pilots about weather-related constraints and their effect on the air transportation system (e.g., reduced capacity). Decision support automation on the operator side is fully integrated with automation on the ANSP side to enable streamlined development of effective weather-related strategic and tactical decisions. For example, FOC automation can provide operators with alternative solutions from which to choose in addressing weather constraints. In addition, automation not only focuses on actual and forecasted weather but also tracks and considers an individual flight's weather-related preferences (e.g., airline business objectives), limitations (e.g., pilot training), and capabilities (e.g., weather mitigation).

In NGATS, these operator considerations are incorporated into decision-making, along with set of pre-collaborated preferences for efficient flight. These preferences may be changed via collaboration as conditions dictate, such as when the intended outcome is not realized. For example, weather conditions may affect a single operator unduly (e.g., pop-up convective weather at or near a hub aerodrome), and it may be necessary for the ANSP to intervene to restore equity. In the case of fully automated decision-oriented systems (machine to machine), pre-coordinating these rules is particularly important in ensuring user involvement in decision-making. In summary, NGATS decision-making automation and improved shared situational awareness bring C-TFM to a new level and help ANSPs and operators to be more effective partners in NGATS decision-making.

Provision of Flight Information

Most operators in the NGATS have, at minimum, an efficient and affordable means of providing flight information and plans to gain a greater awareness of system status and constraints. However, operators' ability to receive, process, analyze, and distribute critical information could improve under the new C-TFM process. Common information and data services with appropriate data protection and privacy mechanisms could enhance shared situational awareness and improve decision-making among NGATS stakeholders (including both operators and ANSPs). Operators could also collaborate with the ANSP to determine strategies to manage capacity and overall flows of traffic.

When operators have increased access to the C-TFM process, more traffic is "known" to the NGATS, providing better predictability. As a result, nearly all available system capacity can be used efficiently, and less conservative measures are required to account for the effect of "unknown" flights.

Aircraft flights included in this data exchange process are considered "known" traffic once their flight plan information is entered into the system, which may be months or hours ahead of time.

Once a flight is "known," the ANSP can account for it in any traffic management initiative (TMI) it considers or initiates. For traffic management purposes, "unknown" flights are flights the C-TFM process is unaware of in advance or flight plans filed after the initiation of a traffic management program. This advance time varies depending on a number of factors, such as weather, congestion, routing, and fidelity of the flight intent information provided by the operator. Flights considered "known" before a TMI is generated are generally afforded fewer delays and more direct routings than flights that are "unknown."

Collaborative Airspace Management

Improved information flow and better information, along with higher capability aircraft, reduce the amount of airspace that must be segregated for different operations. For example, it is anticipated that in airspace associated with super-density aerodromes/airspace, aircraft arriving and departing from these aerodromes will fly in airspace with a very limited flexibility volume and an extremely high degree of conformance within this boundary. Thus, the amount of airspace reserved for these flights will be smaller than what is reserved traditionally. With adequate and reliable transfer of information to aircraft not flying within these constrained routes, operators have access to more airspace than today. Operators without an ability to receive dynamic updates of airspace, however, may have less flexibility in flight operation. Thus, the amount of airspace available to the operator depends on the operator's ability to receive specific information on the airspace boundaries.

Through the C-TFM process, operators can work with the ANSP on capacity management strategies, including strategies for managing dynamic airspace. A key aspect of capacity management is establishing airspace boundaries to increase capacity while providing efficiency of operations to the ANSP and operators. As indicated earlier, operators play a larger role in allocating NGATS assets in the C-TFM process. For example, if the ANSP anticipates that a significant block of airspace may be constrained (e.g., because of a forecasted weather condition), the C-TFM process would be employed to determine the point at which 4DTs need to be adjusted to the forecasted constraint. Depending on the probability of the constraint, operators and the ANSP may agree on a strategy to launch their flights as planned and then modify their flights later, if necessary. Shared situation awareness of both the likelihood of the constraint and the likely effects of the constraint enable operators and the ANSP to better match and adjust strategies with overall objectives.

Collaboration among the ANSP and aircraft operators helps manage needs for segregated airspace. For example, if a military operator plans to reserve airspace for a set of operations, the military operator and the ANSP will negotiate to balance the need to reserve the airspace with other civil needs for the airspace. Potentially, the ANSP and the military operator may agree to adjust the airspace boundaries or the time of operation to accommodate civil needs. However, a military need may also outweigh a civil need and, for a given mission, preempt other planned uses.

3.3 FLIGHT EXECUTION

New levels of technology and additional automation capabilities alter the role of the flight crew and operators in the NGATS. The transition from pilot to aircraft systems manager will continue to evolve. In addition, the UAS function will be further refined. The roles of the flight crew in the NGATS include the following primary functions: supervisory override, aircraft system manager, participant in the C-TFM function, and the more traditional "see and avoid" visual flight operator. These roles are more focused on aircraft operators with greater capabilities and on performing TBO.

In the supervisory override role, the flight crew is responsible for operating the aircraft and taking any actions deemed necessary to correct system malfunctions that occur during flight. During surface operations, the flight crew has full control of the aircraft and is responsible for maneuvering it and determining if it is fully functional before takeoff. For some aircraft, flight management automation may be used for surface operations as well.

As aircraft system manager, the flight crew monitors the automatic functions of the aircraft to ensure correct operation and prepare to resolve any system malfunctions that occur during flight. The flight crew also continues to have final authority regarding the operation of the aircraft, and it has final decision authority on all matters pertaining to the direct operation of the aircraft.

The flight crew's role in the C-TFM function is to provide information regarding the state of the aircraft both in terms of aircraft operation and operating environment. The flight crew also adds the element of operating experience to the decision-making process used for C-TFM. The flight crew must agree on and support any decisions made regarding aircraft routing. Operators, through their flight crews, can make short-term adjustments to their planned routes to avoid hazardous weather or other conditions.

3.3.1 IFR Operations

During a flight, it may become necessary or desirable to modify a 4DT. Reasons for the change include changes in wind, turbulence, convective weather, potential conflict with another aircraft, in-flight emergencies, equipment failure, or diversion. Typically, the initiating action comes from either the flight crew or the operator; however, the ANSP may initiate a request. In all instances, a change is coordinated among all parties and agreed on before execution. Operational considerations when modifying a 4DT include fuel remaining to complete the mission, weather along the revised route, aircraft performance parameters, and the ability to successfully complete the 4DT contract.

With autonomous operations, the flight crew may immediately execute a deviation unless it creates a traffic conflict. If a proposed deviation creates a traffic conflict, the standard rules in effect for that airspace determine whether or not the flight crew can initiate the deviation and how to resolve any subsequent traffic conflicts. In other classes of airspace, the flight crew must coordinate with the ANSP before initiating a deviation.

Many state aircraft—primarily those operated by the military—require transition between seamless operations among civil aircraft and exceptional flight requirements (i.e., needing special services from the ANSP or departing airspace managed by the ANSP) during a single flight. Examples include a fighter aircraft that departs from an installation (normal NAS operations), transitions to specially protected airspace (segregated operations), and then returns to home station (normal NAS operations). Aerial refueling (AR) missions are another example. The individual components of the mission will likely operate in similar fashion to civil users until AR operations are initiated; at that point, the operation becomes unique and remains so until the AR mission is accomplished and aircraft once again operate seamlessly in the NAS.

Other state aircraft may require access to segments of the national airspace for which they do not have NGATS-determined required performance capabilities. This situation occurs where a particular airframe may not be able to accommodate a specified equipage parameter because of physical limitations of the airframe or adverse effects on the aircraft's ability to perform its designated function—i.e., as a weapon system. Other examples include airframes projected for retirement that the operating agency will not be able to modify but that must still operate in certain NGATS-envisioned performance-based strata.

3.3.2 VFR and EVFR Operations

VFR flight operations are conducted under NGATS with the underlying principle that VFR operations are restricted only when ANSP personnel workload or safety prohibit VFR aircraft from accessing certain airspace. There is no expectation that the weather and operating requirements for VFR flight will change significantly in NGATS. Access to managed airspace and most aerodromes requires cooperative surveillance.

When operating in classic airspace, operators planning VFR flights may file a flight plan with the ANSP. They may also submit a request for "flight following" services from the ANSP, which is normally granted on a workload permitting basis. In this airspace, the ANSP provides separation services only for IFR flights, so VFR flights continue to have responsibility to see and avoid other traffic, terrain, and obstacles. On a workload-permitting basis, VFR flights may be granted access to airspace where TBO are the norm, just as such access is granted in Class B airspace today. Access may be enhanced for VFR flights that can receive and execute a 4DT and that have the ability to receive and display real-time airspace updates. Early filing is also likely to increase the probability the ANSP can accommodate the request if it includes entry into highly congested airspace.

Trajectory-based terminal airspace is dynamically assigned, unlike today's airspace in which Class B and C airspace encloses all possible approach and departure configurations of major aerodromes. Thus, under appropriate conditions, the ANSP may grant greater access to VFR flights than is possible today. VFR flights capable of complying with ANSP restrictions, such as flying a specified trajectory, may be granted even greater flexibility to fly their desired routes.

In addition to VFR operations, some operators conduct electronic visual flight rules (EVFR) operations. EVFR operations are conducted similarly to VFR flights, but they have relaxed cloud clearance and visibility requirements, based on the aircraft's onboard capabilities. Because EVFR aircraft may lose external visual reference for some period of time, flight crews have appropriate training for EVFR operations in IMC. The flight crew performs separation using cooperative surveillance and traffic displays. EVFR operations do not require the aircraft to sense non-cooperative targets. Note that EVFR flights are a type of flight operation and are distinct from IFR flights. IFR flights that receive airborne separation assurance clearances from the ANSP remain under IFR.

> ***Research Issue:*** *What regulatory requirements and operating approvals will be required to conduct EVFR?*

3.4 SPECIAL VEHICLE OPERATIONS

3.4.1 Unmanned Aircraft Systems

UAS operations are some of the most demanding operations in the NGATS. UAS operations include scheduled and on-demand flights for a variety of civil, military, and state missions. In all cases, UAS perform their vital missions while maintaining the safety and efficiency of the NAS.

Because of the range of operational uses, UAS operators require access to all NGATS airspace. The types of operations envisaged also require the ability to loiter, transit, and operate in high-density airspace. For these operations, UAS operate in airspace similar to piloted aircraft operating in performance-based airspace. To interoperate with traditional piloted aircraft, UAS have similar operational characteristics. Because UAS may also operate in airspace in which cooperative surveillance may not be required, UAS have the responsibility to sense and avoid other aircraft. This may include responsibility for separating from aircraft that do not have cooperative surveillance in some airspace.

Research Issue: *Are these UAS requirements achievable at a reasonable cost; if not, what requirements should be levied on other aircraft to enable UASs to operate safely in the system?*

3.4.2 Vertical Flight

Rotorcraft, tiltrotor, V/STOL, ESTOL, and similar aircraft have different flight capabilities and limitations from fixed-wing aircraft, and they often perform unique and demanding missions.

Transport category IFR-capable rotorcraft are being acquired in larger numbers. With growing ground congestion, these aircraft have increased utilization. In addition to civil uses, rotorcraft continue to have an increasing role in homeland security and other missions. Rotorcraft provide emergency medical services all areas and cities of the United States, and they increasingly perform IMC operations. Rotorcraft are also used for UAS applications for commercial, police, and security applications. These operations add to the density and complexity of operations, particularly in and around urban areas. With this increased traffic, decisions regarding the dynamic allocation of low-altitude airspace often include anticipated rotorcraft operations.

Although some vertical flight operations are stand-alone, others require operation within terminal airspace. These operations may be allowed within controlled terminal airspace based on the aircraft performance capabilities with the requirement to avoid controlled fixed-wing flight paths within the terminal airspace.

3.4.3 Trans-Atmospheric Operations

Trans-atmospheric operations can be characterized as scheduled operations with very limited duration that require a large envelope of airspace—especially during recovery operations. The actual performance requirements of these vehicles are still in development. (Please note that space operations are outside of the NGATS.) The primary effect of trans-atmospheric operations on NGATS operations occurs when the space vehicles transition into and out of the airspace.

In the NGATS, commercial and military space transportation systems are routine. It is expected that space travel will evolve and orbital flight will be initiated from airborne platforms and ground launch sites. As these airborne launch vehicles transit the national airspace structure, issues of flight track and separation assurance take on greater significance. Careful coordination occurs between the operators of airborne transport vehicles that provide air launch insertions and the ANSP. These operations require advanced planning to allow air navigation service providers to establish proper horizontal and vertical separation assurance to avoid conflict with other traffic operating in the NGATS.

One method the ANSP uses to provide service to trans-atmospheric operators is the creation of temporary special use airspace transition corridors based on trajectory information provided by the launch operator. These airspace corridors establish both lateral and vertical airspace volumes for a given time window. These transition corridors may also be used to segregate NGATS traffic from space vehicles as they return from space to the point of intended landing.

3.5 OPERATOR CAPABILITIES

Most interactions between the operator and the ANSP (e.g., for C-TFM) involve data communications. NGATS information and enterprise services enable this interaction to occur. The amount of useable information and the performance service levels received depend on the sophistication of an operator's systems. Interacting with the C-TFM system to perform modeling and analysis requires more sophisticated capabilities than simply submitting and receiving flight plan information.

The major difference in service levels will be associated with an operator's ability to receive and request 4DT changes and receive changes in airspace information. Key factors determining service level include:

- The possibility that an operator will receive information,
- The specificity of the information received, and
- The proven reliability or integrity of the information.

Access to airspace may be restricted from those that cannot receive updates on boundary changes. The ANSP may grant requested trajectory changes only on a workload-permitting basis if the pilot can only interact with the system via voice. The degree of negotiation is likely to change with the size of the fleet—the larger the fleet, the greater the flexibility operators have in scheduling multiple flights. Also, large operators (or a large group of many operators) may be able to invest more in participating in the C-TFM process.

3.5.1 Aircraft and Airframe Capabilities

The capabilities required of an aircraft operating in the NGATS will largely depend on phase of flight, aircraft type, operating environment, and the level of air traffic density supported at the time of the operation. The basic capabilities for TBO will include an area navigation system, aircraft-to-ground (A-G) two-way communications, and cooperative surveillance to track and monitor aircraft.

Area Navigation. RNP is the standard means of achieving the accuracy and integrity required to meet the navigation requirements of a performance-based system. Navigation information will most likely be space-based with ground-based augmentation in high-density terminal airspace. This system may be supplemented by inertial-based referenced systems of significantly greater accuracy and lower cost than exist today. Required navigation performance values will vary depending on the intended operation (en route, terminal, approach), traffic density, environment, security, and available navigation infrastructure.

> ***Research Issue:*** *What systems and capabilities are used to supplement or back up the space-based satellite infrastructure? How are navigation and surveillance backup strategies related?*

Aircraft-to-Ground Communication. Because of the large amount of information that will be available and the need to communicate it quickly and efficiently, a digital communications capability will provide the bulk of communication activities, but voice radio will remain available for VFR operations, certain critical and tactical communications, and as a backup system to digital datalink.

Aircraft in NGATS will be capable of exchanging information with the FOC, the ANSP, and other aircraft to exchange flight trajectory information, provide surveillance information, make flight plan (4DT) amendments, send and receive weather information, and receive surface movement instructions. Commercial and state/military operations will exchange information with their respective operational control systems. This information exchange will include but is not limited to flight planning and trajectory negotiation, aircraft performance and maintenance data, flight following information, and passenger-related information.

> ***Research Issue:*** *What A-G capabilities and technologies are required to enable a communications service that is affordable, available globally, and fully interoperable?*

The A-G communications service will provide the needed bandwidth and ensure, to an appropriate level, message integrity and security. Certain types of information will be exchanged directly between the aircraft systems and the ANSP. Other data exchanges, such as those that support the C-TFM function, may require flight crew acknowledgement or interaction.

Surveillance. All aircraft, with the exception of those operating in unmanaged airspace, will have a cooperative surveillance capability. Because of the increased security requirements in the NGATS, it is likely that surveillance equipment on aircraft will be automatic and will not involve any interaction with the flight crew.

> ***Research issue:*** *Is an autonomous operations capability economically and operationally justifiable?*

Note that future versions of this document will include updates to this section that will incorporate the aircraft capabilities identified in Chapter 2 as well as other non-ATM capabilities postulated within this operational concept.

3.5.2 Flight Management Capabilities

Many operators use automation for highly sophisticated logistics optimization to handle all aspects of reservation and flight planning. These technologies usually interact with the ANSP strategically by communicating predicted demand to and from cities as aircraft deployments change (in some manner of C-TFM) and tactically within a few hours of flight by communicating an optimized plan. In NGATS, operator ground capability will include widespread data link capability between the FOC (either company dedicated or contract) and the aircraft.

Note that this section will be completed in a later version of this document.

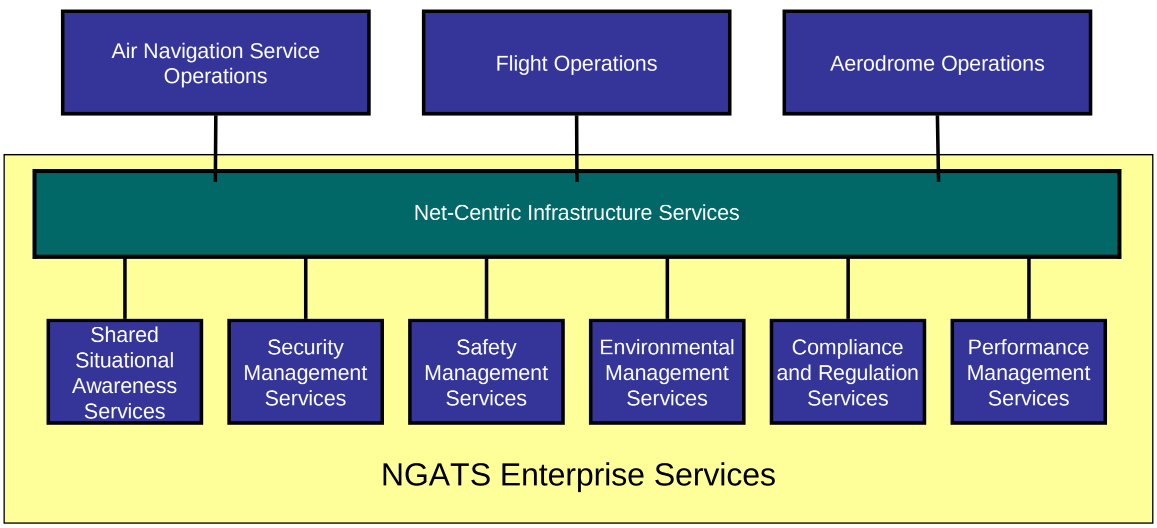
4 Net-Centric Infrastructure Services

This chapter introduces key concepts of net-centric infrastructure services. These and additional net-centric infrastructure concepts will be fully addressed in future versions of this document.

4.1 INTRODUCTION TO ENTERPRISE SERVICES

NGATS can achieve the operational improvements envisioned in this CONOPS by developing and deploying a comprehensive suite of enterprise services. These enterprise services give operational entities within the NGATS environment a common picture of the operational information necessary to perform their required functions. The enterprise services and their relationship to the operational entities are shown in Figure 5-1.

Figure 4-1: NGATS Enterprise Services



Enterprise services can be characterized by the net-centric infrastructure services that provide connectivity and universal access to information and by the services that provide the collection, processing, and distribution of information. This chapter provides an initial discussion of the net-centric infrastructure services that support NGATS with a focus on air navigation service support requirements. Subsequent chapters describe the enterprise services that use this net-centric infrastructure to support the operational requirements of NGATS.

> ***Please note: This chapter provides an initial introduction of net-centric infrastructure services of security concepts that will be enhanced in future versions of this document. Comments are requested on the content of this chapter and the direction for future versions.***

4.2 KEY TRANSFORMATIONS OF INFRASTRUCTURE SERVICES

Table 4-1: Infrastructure Transformations

Enablers	2006	NGATS
Network-Centric Information Sharing	• Limited ATM (e.g., traffic) information in cockpit; often, non-common data shared among actors • Not all stakeholders have access to data they need • Stakeholders use custom data sources	• More common ATM information provided to the ANSP service provider, cockpit, and aircraft operators (see Figure 2-1) • Flexible delivery of needed information and services independent of user geographical location • All stakeholders can obtain access to data they need
Aircraft Data Communications	• No data communications for ATM and operational control • Limited access to real-time weather and aeronautical data • Voice communications are routine for ATM	• 4DT, short-term intent, and other data routinely transmitted between aircraft and ANSP • Data communications are routine for ATM; in airspace reserved for TBO, voice communications used only for extraordinary purposes • Capability to permit extensive negotiation between air and ground of 4DT
Infrastructure Management Services	• Limited ability to maintain operations when a major facility goes out of service • Limited ability to reconfigure resources to maintain operations when a major outage occurs	• Network-centric information sharing and ability to reconfigure resources to maintain operations when a major outage occurs results in ability to maintain normal operations when a major outage occurs

4.3 CORE ENTERPRISE SERVICES

Network-centric information sharing provides greater access to improved common data, which facilitates shared situational awareness and distributed decision-making. As a result, different actors make more consistent decisions because they work from a common source of information. Decision-making improves because different decision-makers have timely access to relevant data. This service also enables changes in roles among decision-makers. For example, pilots have access to real-time traffic and weather information, which provides better situational awareness and enables more decisions to be made in the flight deck. Similarly, the ANSP has access to highly accurate flight and intent data derived from the aircraft's avionics systems, enabling better management of overall traffic flows.

Network-centric information sharing also enables more flexible allocation of assets for the ANSP. Airspace allocation is both dynamic and flexible. Supporting information services ensure that ANSP personnel receive all necessary information regardless of their physical location or the selected airspace configuration, which enables airspace to be independent of facility boundaries. Necessary information includes the needed communications, navigation, and surveillance services associated with providing air navigation services to operators. For example, voice communications are flexibly relayed to the appropriate ANSP personnel.

Stakeholder costs also decrease as the NGATS moves from using customized interfaces to network capabilities that interconnect assets through an addressable NGATS-wide network infrastructure. International and enterprise-wide communication protocols that are independent of the underlying communications infrastructure facilitate logical data exchange between COI.

NGATS information sharing services also provide enhanced security, safety, and privacy protection with broader access options to a greater number of stakeholders.

Research Issue: *How much flexibility is practical from an economic perspective (e.g., connectivity) and an operational perspective (e.g., local knowledge training requirements)?*

Net-centric information sharing services in the NGATS enable improved coordination among government agencies to allow each to meet its mission. For example, consistent surveillance information services provide a common picture among the ANSP and security agencies. However, net-centric information sharing services improve exchanges of routine information as well, such as identifying when passengers will crowd aerodrome customs and immigration halls or information about significant delays in security that may affect flight departures and ATM plans.

4.4 GROUND NETWORK SERVICES

This section will be addressed in future versions of this document

4.5 AIR-GROUND NETWORK SERVICES

With the transformed role of the flight crew and flight deck in the NGATS, data communications are critical for ensuring data is available for flight deck automation and ensuring avionics can support flight crew decision-making and provide real-time data to the ANSP about operational aspects of flights. Data communications are the primary means of communication between the flight deck and the ANSP for airspaces that require data communications capability for clearances and 4DT amendments; for these aircraft, voice communications between the flight deck and ANSP personnel is used only for extraordinary purposes.

Data communications are central to TBO, including:

- Use of 4DTs (including pushback and taxi) for planning and execution on the surface
- Machine-based trajectory analysis and separation assurance
- Aircraft separation assurance applications that require flight deck situational awareness of surrounding aircraft 4DTs and short-term intent.

In addition, as indicated above, the NGATS involves increased sharing of improved common data among the flight deck, operator, and ANSP. This data includes ATC clearances, current and forecasted weather, notices to airmen, hazardous weather warnings, updated charts, current and special aircraft data, and other required data (RTCA, 2002). Information exchange also includes weather observations made by the aircraft that are automatically provided to the ground (for inclusion in weather analysis and forecasts) and other aircraft. The NGATS will have a level of required communications performance (RCP) for each of these data communications functions.

4.6 INFRASTRUCTURE SERVICES MISSION SUPPORT

In the NGATS timeframe, information systems facilitate the monitoring of infrastructure health and remote maintenance to maintain service availability and automatically alert the community about the status of NGATS assets. One of the key transformations resulting from NGATS is the ability to operate NGATS with the loss of a limited number of key facilities. Network-enabled operations and infrastructure management services provide continuity of operations in the event of a major outage (such as a major hurricane or a terrorist event).

5 Shared Situational Awareness Services

5.1 INTRODUCTION

This chapter introduces the concept of shared situational awareness (SSA) services. NGTAS is dependent upon and is enabled by SSA services in concert with the net-centric infrastructure described in Chapter 5. The very transformation of the air transportation system is dependent upon the deployment of SSA. The following elements of SSA are introduced in this chapter:

- Weather Information Services
- Broad-Area Precision Navigation Services
- Surveillance Services
- Flight Planning Services
- Flight Object Services
- Flow Strategy and Trajectory Impact Analysis Services
- Aeronautical Information Services (AIM)

Please note: This chapter introduces initial element of SSA that will be enhanced and expanded in future versions of this document. Comments are requested on the content of this chapter and direction for future versions.

5.2 KEY TRANSFORMATIONS OF SHARED SITUATIONAL AWARENESS

Key shared situational awareness (SSA) services enable the fundamental operations of the NGATS and transform the national air space operation. Table 6-1 highlights these key services and their transformations.

Table 5-1: Shared Situational Awareness Transformations

Enabler	2006	NGATS timeframe
Weather Information Services	• Limited common weather information; requires use of skilled interpretation • Limited use in decision support systems; • Limited on-board weather information available during flight	• Single authoritative source of accredited weather information facilitates more consistent decisions among stakeholders • Presents data tailored to user operational needs • Uses integrated weather/decision support systems heavily • Provides automatic updates to users based on operational need

Enabler	2006	NGATS timeframe
Broad-Area Precision Navigation Services	• Air routes are mostly defined by fixed ground-based navigational aids • Expanding use of RNAV and RNP procedures • Costly ground-based infrastructure in parallel with space-based infrastructure	• Air routes are independent of the location of ground-based navigation aids • RNAV used everywhere; RNP used where required to achieve system objectives • System performance meets operational needs to service the demand
Surveillance Services	• Limited coverage • Limited airborne traffic situational awareness	• Coverage to the surface and in remote areas; capable of meeting NGATS operational needs • Common surveillance data available to all stakeholders (ANSP, defense, security, aircraft operators)
Flight Planning Services	• Limited interactive flight planning capability • Limited ability to receive projections on anticipated conditions that affect aircraft flight plans	• Flight planning information services provide the user with extensive and interactive flight planning capability • Operators receive feedback on anticipated conditions associated with a filed 4DT
Flight Object Services	• Multiple similar calculations of flight trajectory, airspace penetrations, time of arrival, etc. leading to inconsistent information about a flight • Information about a flight is specific to an application or location and is inconsistent across applications and locations • Information about a flight is dispersed through many owners	• Flight information is shared in such a way that that leads to consistent trajectory information which can be provided to all authorized flight data users as a service • Flight information is consistent across applications and locations and available to authorized flight data users • Information about a flight is contained in one logical unit
Flow Strategy and Trajectory Impact Analysis Services	• High reliance on oral and textual communication of strategies and concerns • Limited access to both data and tools • Limited decision support capabilities leads to conservative planning	• High reliance on data communications and graphical presentations • Significantly increased access to data, models, and tools • Better decision support to increases ability to use capacity • Common trajectories and analysis capability to improve quality and consistency of decision-making • Automation and information services to increase awareness of constraints and strategies under consideration
Aeronautical Information Services (AIM)	• Much of the AIM is provided by hard copy or voice • Limited ability to receive and process information regarding airspace	• Most of the AIM data is text or graphic presentations; data is consumable by automation for processing • Users are supported by automation capabilities to exchange real-time information regarding airspace

5.3 WEATHER INFORMATION SERVICES

An integrated, common picture of the weather situation facilitates decision-making among the diverse set of NGATS stakeholders. Common weather services reduce or eliminate the need for stakeholders to manually gather, interpret, and integrate diverse weather data to realize a coherent picture of the weather situation; instead, automation assistance helps achieve a coherent picture for dissemination to interested parties.

A central enabler for this weather capability is access to a single authoritative source for current and forecasted weather information that includes horizontal, vertical, time, and probability components (x, y, z, t, plus probability). This source is not a single database—it is a network of information sources. As a result, operation costs for stakeholders decrease through the elimination of customized point-to-point interfaces from user systems to multiple sensors and sources.

In NGATS, weather information is tailored to the operational needs of interested parties to facilitate a consistent view of weather information. For example, if multiple stakeholders look at levels of convection for a geographic area, the locations and intensity of the convection are the same. Maintenance of weather information at different resolutions, time scales, and geographic areas enables this tailoring of common data. For example, weather information for an aerodrome will be at a higher resolution and more rapidly updated than for international locations.

Digital communications deliver alerts regarding significant weather changes to stakeholders. For example, the flight deck receives key weather updates along the route of flight, thereby enhancing dynamic decision-making and flight safety. Stakeholders and the automation that supports stakeholder decision-making use NGATS weather services. Both ANSP and user automation systems use this authoritative source of weather information, including probabilities, to facilitate collaboration on NGATS decisions. The use of a single authoritative weather data source is a basis for collaborative NGATS decision-making (e.g., flow planning); however, stakeholders may use other sources at their own risk (e.g., to make flight routing decisions).

> ***Policy Issue:*** *What is the role of the information available from private weather providers in realizing the single authoritative weather source and in NGATS decision-making?*

5.4 BROAD-AREA PRECISION NAVIGATION SERVICES

NGATS enables aircraft and surface vehicles to operate independently of ground-based navigation aids. Broad-area precision navigation services provide the level of accuracy and availability necessary to support the demand for use of aerodrome and airspace resources. RNAV is the standard method of navigation in the NAS; in some airspace, the higher performance of RNP navigation

> ***Research Issue:*** *What is the cost-effective mix of non-terrestrial, terrestrial, and aircraft-based systems to meet NGATS navigation information service needs?*

is required to achieve operational objectives[5]. Aircraft performance requirements vary by airspace, and navigation reliability and availability are provided in accordance with the requirements of different airspace classes.

5.5 SURVEILLANCE SERVICES

NGATS relies on cooperative surveillance information from aircraft in managed airspace. Surveillance information services from cooperative surveillance provide one of the key elements for TBO in the NGATS, and they support the needs of defense and security providers. Surveillance coverage includes a broad range of operational domains ranging from remote areas (e.g., Alaska, oceanic regions, and northern and southern borders regions) to aerodrome surface areas at the busiest air hubs. Surveillance information services will thus improve the speed, efficiency, and quality of decisions.

NGATS surveillance information services, coupled with improved surveillance accuracy, latency, integrity, and availability, will enable:

- Reduced separation standards
- Comprehensive tracking of aircraft and vehicles operating on the aerodrome surface to improve safety, security, and operational effectiveness
- Increased service to under-used airspace, aerodromes, and runways
- Improved 4DT information by providing intent and conformance monitoring
- Dynamic allocation of airspace
- Autonomous and delegated separation operations
- Merging and spacing operations.

Improved surveillance is providing many new functions that range from situational awareness to full self-separation. Different levels of required surveillance performance (RSP) will be associated with each new surveillance-derived capability. To achieve the high level of requirements for surveillance, it is envisioned that some airspaces will require both a primary and a backup surveillance system. Note that later versions of this document will incorporate additional non-cooperative surveillance services and their security uses.

5.6 FLIGHT PLANNING SERVICES

Flight planning information services provide users with the interactive flight planning capability, with or without the aid of an FOC, to file a user-preferred flight plan. This filing can be done preflight or in real-time during flight in response to changing conditions. Operators receive automated feedback on the flight plan filed, including any system constraints that would affect

5 This transformation is occurring today with the evolution to performance-based navigation as documented in the FAA's "Roadmap for Performance-Based Navigation."

the flight as filed such as the presence of congestion or reserved airspace, significant weather, and performance-based airspace capability requirements for the planned route.

5.7 FLIGHT OBJECT SERVICES

The flight object is the representation of the relevant information about a particular flight. The flight object contains information about aircraft capabilities, aircraft flight performance parameters, flight crew capabilities, 4D profiles (intent plus desired or proposed 4DTs), and aircraft position and near-term intent.

A flight object is created for each proposed flight and is updated as the flight progresses from its pre-departure phase through arrival at the gate. It provides consistent, up-to-date flight information and is the common reference for a single flight. At any point in time, the flight object has a single owner who is able to accept requests to modify the flight object and then to make the new version available. The owner can be a person or automation, on the ground or on the aircraft. Global standards ensure interoperability of the flight object across flight information regions.

Services are provided to instantiate, modify, and distribute the flight object. Services such as flight planning services are provided to manipulate a single flight object or groups of flight objects, so that consistent results are available to all stakeholders. Therefore, trajectories in the flight object reflect the current application of constraints and preferences, and updates to the flight object trigger changes in constraints as demand for resources varies. The availability of user preferences and recorded flight history information facilitate the collaboration process. Aircraft and flight crew capabilities are known to the ANSP when there are requests that the flight crew execute particular maneuvers or operations, or penetrate airspace or weather.

> ***Research Issue:*** *What level of Flight Object information needs to be shared to build consistent trajectories across systems and achieve sufficient interoperability?*

5.8 FLOW STRATEGY AND TRAJECTORY IMPACT ANALYSIS SERVICES

Most of the information exchange that occurs between the Federal Aviation Administration (FAA) and air carriers relates to responses to TFM flow problems, mainly because of severe weather. In the NGATS timeframe, users will have more flexibility to choose alternatives to avoid congestion in the air, severe weather, or congested aerodromes. Instead of playbook routes, users will be able to replan their flights in a completely flexible manner. The ANSP will provide continuous forecasts of traffic flow problems, and users will have a greater ability to plan their own contingencies. The ANSP will only intervene with ground delays or reroutes when the actions taken by the users do not solve the problem. Information exchanges will likely become more of a "publish and subscribe" central database and less a point-to-point exchange. The C-TFM network will become a part of the net-centric information sharing infrastructure. The C-TFM network will use more standards, and it will be easier for users to access and easier for new applications to be added.

5.9 AERONAUTICAL INFORMATION SERVICES

Stakeholders will receive aeronautical information, including flight operators and ANSP personnel, with more accuracy and in a timely manner. This includes near-real-time transmission of airspace and route information to the aircraft. Aeronautical information services include updates on:

- Airspace restrictions
- Current performance requirements for airspace access and operations
- System outages
- Aerodrome status information
- Static information, such as approach plates and certain fixed airspace definitional data, such as fixed special activity airspace and aerodrome information.

Updates to aeronautical information are performed in real time and provided in a manner that allows users to readily understand the changes. The information is user friendly and available in digital form (graphically or via digital text). The data is also machine readable and supports automated processing of information for TBO.

6 Layered Adaptive Security Services

6.1 INTRODUCTION

NGATS will provide effective air transportation system security without limiting mobility or civil liberties by embedding security measures from reservation to destination. This chapter introduces initial key concepts of the layered, adaptive security (LAS) within NGATS in the following categories:

- Integrated Risk Management
- Secure People
- Secure Aerodromes
- Secure Checked Baggage
- Secure Cargo / Mail
- Secure Airspace
- Secure Aircraft.

Cyber security is addressed in the Chapter 5, Net-Centric Infrastructure Services. Non-cooperative surveillance is addressed in Chapter 6, Shared Situational Awareness Services.

> ***Please note: This chapter provides an outline of security concepts that will be enhanced in future versions of this document. Comments are requested on the intent of this chapter and direction for future versions.***

6.2 INTEGRATED RISK MANAGEMENT

Risk management is the ongoing process of understanding the threats, consequences, and vulnerabilities that can be exploited by an adversary in order to determine which actions can provide the greatest total risk reduction for the least impact on limited resources. The NGATS layered, adaptive security's Integrated Risk Management (IRM) capability is an overall federated risk assessment and risk mitigation process to guide multiple security service enterprises in making decisions, allocating resources, and taking actions under conditions of uncertainty. Risk management will be continuous, from the strategic to the tactical level.

6.2.1 Risk Management Process

The primary objectives of the Risk Management Process are evaluating the effects of defined threats, assessing the vulnerability, and evaluating and prioritizing assets and functions for the air transportation system.

6.2.2 Security Risk Management

Strategic and tactical risk management will be approached in security layers.

IRM - Secure People

The NGATS IRM Secure People Capability will develop validated and cross-referenced watch lists to ensure that passengers and aviation workers are not identified risks.

IRM – Secure Aerodromes

The NGATS IRM Secure Aerodromes Capability will determine high risk aerodrome terminal and remote facilities that will require increased specific resources for infrastructure and security technology investments and more robust security operations.

IRM - Secure Checked Baggage

The NGATS IRM Secure Checked Baggage capability will perform assessments and develop mitigation priorities based on probabilities of attack with the set of threat objects for this vector.

IRM - Secure Cargo/Mail

The NGATS IRM Secure Cargo/Mail capability will assess risks for Cargo/Mail throughout the shipping chain from source to exit from the NGATS. The shipping chain includes cargo source, containerization, freight consolidation/forwarding, cargo/mail screening locations, air transport to destination as well as all intermediate storage and transport.

IRM - Secure Airspace

The NGATS IRM Secure Airspace capability will identify locations of national critical infrastructure, assets, population centers, and activities which might warrant airspace protection to determine airspace risk profiles. These risk profiles will guide flight planning, security restrictions and response to anomalies/incidents.

IRM - Secure Aircraft

The NGATS IRM Secure Aircraft capability will assess risks and vulnerabilities for different aircraft types. This would include risks to the aircraft itself as well as the risk of the aircraft used as a terrorist instrument.

6.2.3 Net-Centric Integrated Risk Management Collaboration Environment

IRM utilizes the NGATS net-centric infrastructure capability to receive all accessible, authorized information within the NGATS as inputs to IRM's risk assessment analysis and to distribute the outputs from the IRM process to all the authorized stakeholders as needed.

6.2.4 Risk Management Strategy Monitoring and Follow Up

The Risk Management Process will use operational data to constantly update and refine its methods and outputs.

6.3 SECURE PEOPLE

The NGATS LAS capability will prevent those people who pose a threat from gaining access to the air transport system through pre-screening, identification, screening, and intervention.

6.3.1 Passenger Screening

Pre-Screening

Passenger pre-screening will be based on the NGATS credentialing process.

Check Point Screening

Operational check-point screening will include those technologies, policies, and procedures to detect the presence of Chemical, Biological, Radiological, Nuclear and Explosive (CBRNE) threats and weapons.

6.3.2 Aviation Workers Screening and Credentialing

Aviation workers will be screened based on the NGATS credentialing process.

6.4 SECURE AERODROMES

Aerodromes will be secured with integrated and unobtrusive security technologies providing facility security enabled by advanced network-centric capabilities within the net-centric infrastructure. Spaceports will be provided with the same or modified security system and processes depending on the IRM process outputs.

6.4.1 Terminal Facilities - Landside

Aerodrome infrastructure security will use the Recommended Security Guidelines for Airport Planning, Design and Construction defined by TSA as a baseline. NGATS terminal security operations including check-in, security screening and bag-check/screening will be extended to remote, portable or off-site terminal sites to better distribute initial security screening load and increase throughput. Access control and facility surveillance with net-centric infrastructure integration will provide physical security against CBRNE threats. The Aerodrome Security Command Center (SCC) enables real-time update of threat information, monitors aerodrome operations and adjusts the security layers based upon risk assessments and intelligence.

6.4.2 Terminal Facilities – Airside

Airside surveillance including vehicle access will be accomplished through a variety of net-centric infrastructure based advanced sensor and access control systems. Where cost-effective, advanced systems will reduce the opportunity for threat insertion onto aircraft.

6.4.3 Other Aerodrome Facilities

Non-terminal facilities including hangars, fuel storage areas, warehouses, control towers office buildings and related structures will be secured using appropriate levels of technologies and procedures as determined by threat and risk assessments.

6.4.4 Aerodrome Perimeter

Sensor arrays tied to existing ground surveillance radar and unmanned ground vehicles and/or unmanned aerial systems detect movement through the perimeter and alert Aerodrome SCC for appropriate response. . General aviation facilities will utilize appropriate perimeter security systems and procedures based on threat and risk assessments.

6.5 SECURE CHECKED BAGGAGE

Operational checked baggage screening will include those technologies, policies, and procedures to detect the presence of Chemical, Biological, Radiological, Nuclear and Explosive (CBRNE) threats and weapons.

6.5.1 Checked Baggage Screening

NGATS baggage screening systems for CBRNE prevent checked baggage containing threats from entry onto aircraft. These NGATS systems will have reduced footprint, be capable of rapid deployment, and have reduced false alarms while sensor fusion increases the range and accuracy of threat detection

6.6 SECURE CARGO/MAIL

Checked cargo/mail will be prevented from endangering aircraft, aviation facilities or people. The air cargo system will be prevented from being used as a threat vector. Policy, procedures, information and technology will be utilized to accurately detect threat-bearing cargo from while maintaining the flow of commerce. The air cargo shipping information is shared within the net-centric infrastructure system, enabling authorized stakeholders to have constant status of risk assessment, threat information and security related anomalies while in the air shipping chain.

6.6.1 Known/Certified Shipper

The NGATS LAS for air cargo will use a tiered certification process offering certifications for Known Shipper and Certified Shipper status based upon various levels of screening capability, cargo integrity technologies and other NGATS credentialing processes.

6.6.2 Screening and Inspection

All air cargo will be screened for CBRNE and weapons threats prior to loading on an aircraft. The NGATS cargo screening process will permit aerodrome and off-site cargo screening facilities by registered screening agents to ensure the free flow of commerce.

6.6.3 Surface Transportation Security of Screened Cargo

Cargo screened prior to arrival to the air cargo facility on aerodrome will be surrounded by a "chain of custody" umbrella providing net-centric infrastructure linked tracking and protection, from origination to the aerodrome in a secure environment which is be sealed and tamper-proof. Cleared Unit Load Devices (ULD) are covered with blast containment and locked with tamper-proof netting and locking pallet ring mounts.

6.7 SECURE AIRSPACE

The risk of external attacks on aircraft and other airborne vehicles anywhere in the National Airspace System (NAS) will be reduced with the NGATS LAS. Flight plan threat levels will be assessed and counter measures developed based on each situation. Aircraft that pose a threat will be detected and prevented from gaining access to the NAS. Airspace access and flight procedures will be implemented.

In NGATS, Secure Airspace is a joint responsibility among many institutional entities. These entities include: ANSP, Defense Service Provider, Security Service Provider, FOCs, flight operators, local and international communities. Restricted airspace information and their violation alerts will be shared among all stakeholders based on specific information exchange rules to be established. Such information sharing will be facilitated through the NGATS net-centric infrastructure.

6.7.1 Airspace Violation Detection, Alerting, and Monitoring

Potential violations of restricted airspace are detected and transmitted through net-centric infrastructure to operational personnel who have positive control responsibilities for the aircraft including the flight operator and the ANSP. Through net-centric infrastructure and SSA applications, monitor and provide cooperative and non-cooperative surveillance of air vehicles to detect and respond appropriately to anomalies in air vehicle flight.

6.7.2 Counter MANPADS

Based on a risk and threat assessment, appropriate Counter MANPADS systems and procedures will be implemented to protect terminal airspace

6.8 SECURE AIRCRAFT

Many aircraft within NGATS will have on-board systems and modifications to detect and prevent external attacks and internal assaults. These capabilities will preclude the aircraft or its contents from becoming a target, or from being used as a weapon. Capabilities will be supported by aircraft modification such as hardening specific components, human based countermeasures such as airspace violations displays, secure air/air and air/ground communications, adaptive flight procedures and shared situational awareness for aircrew, air traffic management and on board security.

6.8.1 Cockpit, Cabin and Cargo Hold Surveillance (CCCHS).

A cockpit, cabin and cargohold surveillance capability will be established. In-flight cabin and cargohold monitoring for CBRNE threats will enhance the welfare of passengers and security of the aircraft.

6.8.2 Secure Flight Deck and Cabin

On-board Federal law enforcement officers will detect, deter, and defeat hostile acts targeting air carriers, aerodromes, passengers, and crews. With advanced air-to-ground and air-to-air information communication and net-centric infrastructure systems, on-board security personnel can identify other on-board resources and convey real-time information to the NGATS security system and ANSP.

6.8.3 Aircraft Hardening

Aircraft components such as cockpit bulkheads, cargo containers, cargo hold, on-board sensors and defense systems, can prevent, deter or reduce the effects of attacks. NGATS aircraft design standards identify, prioritize and shield critical flight systems from direct energy weapons and electromagnetic pulse (EMP) technologies and events.

Appendix A: ATM Functions in 2006 and NGATS

Air Navigation Service Provider Functions	
2006 Functions	**Corresponding NGATS Functions**
Area Supervisors, Airspace Designers, (Special Use Airspace/Space Launch Coordinator are Partially Comparable) Design and strategically allocate airspace. Adjust the assignment of airspace to tactical separation providers (primarily by combining and decombining sectors). Structure routings (air and ground) where required.	**Capacity Managers in Collaboration with Airspace Users and Flight Operators** Design and strategically allocate airspace. Dynamically adjust the assignment of airspace to tactical separation providers. Structure routings (air and ground) where required, and flexibly allocate airspace for other purposes, including the operation of state (government) aircraft.
Traffic Management Specialist/Coordinator Identifies potential flow problems, such as large-demand capacity imbalances, congestion, high degrees of complexity, and blocked or constrained airspace (e.g., for special use, weather), and collaborates on traffic management initiatives.	**Flow Contingency Provider in Collaboration with Flight Operators** Identifies potential flow problems, such as large-demand capacity imbalances, congestion, high degrees of complexity, and blocked or constrained airspace (e.g., for special use, weather), and collaborates to develop flow strategies (i.e., aggregate trajectory solutions).
Traffic Management Specialist/Coordinators, Air Traffic Controllers (e.g., En-Route D-Side) Ensure traffic management initiatives are carried out. Perform planning for flights entering sector, identify future conflicts (i.e., strategic separation management), and coordinate resolutions with adjacent sectors.	**Tactical Trajectory Manager in Collaboration with Flight Operators** Predict individual flight contention within a flow for resources, identify complex future conflicts (i.e., strategic separation management), and coordinate individual trajectory resolutions. This is focused on near-tactical management of individual trajectories within a flow.
Air Traffic Controllers (e.g., En-Route R-Side) Provide tactical separation (e.g., within a 5-minute window) to separate aircraft from other aircraft and special use airspace, and organize and expedite the flow of traffic.	**TSP or Flight Operator Depending on the Airspace and the Operation** Eliminate residual conflicts left by the three strategic functions of TBO. Automation detects the conflicts and provides the resolution.

Air Navigation Service Provider Functions	
2006 Functions	**Corresponding NGATS Functions**
Flight Service, Flight Operations Center Personnel, or Third-Party Service Providers Provide flight planning and weather services. General aviation operators also may interact with third-party (fee for service) vendors who provide weather and other (e.g., flight planning) services through dedicated computer terminals, direct phone contact or through the web.	**Automated Dissemination to Operators and Flight Crews, FOCs, Third-Party Service Providers** Provide flight planning and weather services. ANSP role is limited to safety-critical in-flight assistance. Operators may also interact with third-party weather providers or their own FOC.

Flight Operator Functions	
2006 Functions	**Corresponding NGATS Functions**
Flight Crew Responsible for the control of an individual aircraft while it is moving on the surface or while airborne.	**Flight Crew, Individual Pilot, or Automata** Responsible for the control of an individual aircraft while it is moving on the surface or while airborne. Under autonomous operations, responsible for separation.
Dispatcher Person responsible for originating and disseminating flight information, including flight plans. Responsible for operational control of day to day flight operations.	**Flight Planner** Person or organization responsible for making tactical decisions about what flights to operate and when and where they will operate. May be the same as flight crew. Flight planner is the interface with the ANSP in trajectory negotiation. Operators with multiple aircraft involved in the initiative have the flexibility to adjust individual aircraft schedules and trajectories within those allocations to accommodate their own internal business concerns, both preflight and in flight.
Flight Scheduler Person or organization responsible for making strategic decisions about what flights to operate and when they will operate.	**Flight Scheduler** Person or organization responsible for making strategic decisions about what flights to operate and when they will operate.

Appendix B: Definitions and Glossary

Term	Definition
3D	Three-Dimension
4DT	Four-Dimensional Trajectory
ADS-B	Automatic Dependent Surveillance-Broadcast
A-G	Air-Ground
Aerodrome	A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure, and surface movement of aircraft
Airborne Self-Separation	Refers to all aircraft within the airspace or aerodrome movement area maintaining separation from all other aircraft within the airspace or aerodrome movement area according to defined rules and separation criteria. The ANSP is not responsible for tactical separation between aircraft. This CONOPS uses the term “autonomous airspace” for self-separation airspace. This CONOPS also includes self-separation in mixed equipage airspace. When authorized by the ANSP, equipped aircraft in this airspace maintain separation from all other aircraft, including those managed by the ANSP.
Airborne Separation	Refers to separation delegated to an individual aircraft to maintain separation from a designated aircraft either in flight or on the aerodrome movement area, such as for a crossing or passing maneuver. Separation of these aircraft from all other aircraft and from all other aircraft to which separation has not been delegated remains the responsibility of the ANSP. Pairwise separation and closely spaced parallel approaches are in this category.
Airborne Separation Assurance	Refers to a capability of the aircraft to maintain awareness of and separation from other aircraft, airspace, terrain, or obstacles. There are four different levels of airborne separation assurance (based on the RTCA definition)—airborne traffic situational awareness, airborne spacing, airborne separation, and airborne self-separation.
Airborne Spacing	Refers to the capability of one aircraft to achieve and maintain a defined distance in space or time from another aircraft. Separation responsibility remains with the ANSP.

Term	Definition
Airborne Traffic Situational Awareness	Refers to flight crew knowledge of nearby traffic depicted on a cockpit traffic display without any change of separation tasks or responsibility.
Aircraft	From the Aeronautical Information Manual (AIM): *Device(s) that are used or intended to be used for flight in the air, and when used in air traffic control terminology, may include the flight crew*. ICAO definition: *Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface*. An aircraft can include a fixed-wing structure, rotorcraft, lighter-than-air vehicle, or a vehicle capable of leaving the atmosphere for space flight.
Air Navigation Service Provider (ANSP)	Used generically to refer to the organization, personnel, and automation that provide separation assurance, traffic management, infrastructure management, aviation information, navigation, landing, airspace management, or aviation assistance services for airspace users.
Airspace Classification	Airspace with a common air traffic management interest and use, based on similar characteristics of traffic density, complexity, air navigation system infrastructure requirements, aircraft capabilities, or other specified considerations wherein a common detailed plan will foster the implementation of interoperable CNS/ATM systems.
Air Traffic Management (ATM)	The dynamic, integrated management of air traffic and airspace—safely, economically, and efficiently—through the provision of facilities and seamless services in collaboration with all parties.
ANSP Flow Airspace	High-density, moderate complexity airspace where the flight operator executes a 4DT agreement. Tactical trajectory management ensures the overall flows are well behaved so that potential conflicts are kept to a minimum. Tactical separation management is performed automatically by ground automation. If conflicts are detected, the ground automation issues revised 4DTs to the flight deck.
Area navigation (RNAV)	A method of navigation that permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids, the limits of the capability of self-contained aids, or a combination of these.
Area navigation (RNAV) operations	Aircraft operations using an RNAV system. RNAV operations include RNAV and RNP applications.

Term	Definition
Area navigation (RNAV) route	An ATS route established for the use of aircraft capable of employing area navigation.
ATC	Air Traffic Control
Automated Virtual Tower (AVT)	The provision of sequencing services and basic aerodrome information, without the use of ANSP personnel, at a level that is enhanced compared with typical non-towered aerodromes in 2006.
Auto-Negotiation	The interaction among two or more systems to identify a specific operational response acceptable to the parties (e.g., flight operator and ANSP) served by the automated system. The automated systems would use the known operating constraints or user preferences to identify the preferred response.
Autonomous Airspace	Low-to-moderate density airspace where self-separation enables maximum user flexibility in exchange for high capability equipage of aircraft.
Broad-Area Precision Navigation	Performance-based area navigation that provides the ability to operate on flight paths that are independent of the location of ground-based navigation aids. The navigation is capable of determining a three-dimensional position with precision sufficient to support the operation.
Capacity	The maximum number of aircraft that can be accommodated in a given time period by the system or one of its components (throughput).
Capacity Management	The long-term and short-term management and assignment of NAS airspace and routes to meet expected demand. This includes assigning related NAS assets as well as coordinating longer term staffing plans for airspace assignments. It includes the allocation of airspace to airspace classifications based on demand, as well as the allocation of airspace and routes to ANSP personnel to manage workload.
Classic En-Route Airspace	Low altitude en-route airspace away from busy terminal areas that accommodates mixed capability aircraft, including those under visual flight rules.
COI	Communities of Interest

Term	Definition
Complexity	A description of how non-homogeneous the traffic demand is. Factors that cause complexity to be higher are large numbers of vertically transitioning aircraft, large numbers of crossing paths, large variation in speeds, etc.
Conflict	Any situation involving an aircraft and a hazard in which the applicable separation minima may be compromised.
CONOPS	Concept of Operations
Constraint	Any limitation on the implementation of an operational improvement, or a limitation on reaching the desired level of service.
Controlled Time of Arrival (CTA)	The assignment and acceptance of an entry/use time for a specific NAS resource. Examples include point in space metering, time to be at a runway, or taxi waypoints.
Cooperative Surveillance	The aircraft relays its three-dimensional position. Non-cooperative surveillance would be the determination of an aircraft's three-dimensional position without the aircraft participating.
Corridor	A corridor is a long "tube" of airspace that encloses groups of flights flying along the same path in one direction. It is airspace procedurally separated from surrounding traffic and special use airspace, and is reserved for aircraft in that group. There is a minimum distance that traffic within the corridor must maintain from the edge of the corridor (i.e., "the corridor walls have some thickness").
COU	Concept of Use
CSPA	Closely Spaced Parallel Approach
Demand	The number of aircraft requesting to use the ATM system in a given time period.
DoD	Department of Defense
DST	Decision Support Tool
Enablers	Initiatives, such as (new) technologies, systems, operational procedures, and operational or socioeconomic developments that facilitate the implementation of operational improvements or of other enablers.

Term	Definition
Equivalent Visual Operations	The capability to provide aircraft with the critical information needed to maintain safe distances from other aircraft during non-visual conditions, including a capability to operate at levels associated with VFR operations on the aerodrome surface during low-visibility conditions. The ANSP personnel delegate separation responsibility to the flight operators. This capability builds on net-enabled information access, certain aspects of performance-based services, and some elements of broad-area precision navigation and adaptive, layered security.
EVO	Equivalent Visual Operations
FAA	Federal Aviation Administration
FCM	Flow Contingency Management
Flexible Airspace	Airspace boundaries and routes are not static. They may be shifted as necessary to enable effective weather avoidance, meet defense and security requirements, and manage demand. Airspace allocation to different airspace classifications is also flexible. It changes dynamically (in terms of time or geographic boundaries) to meet demand. Airspace restricted for higher performance operations only exists when necessary to manage demand.
Flight Object	A flight object is the representation of the relevant information about a particular instance of a flight. The information in a flight object includes (1) aircraft capabilities, including the level of navigation, communications, and surveillance performance (e.g., FMS capabilities), (2) aircraft flight performance parameters, (3) flight crew capabilities, including level of training received to enable special procedures, (4) 4DT profile and intent, containing the “cleared” 4DT profile plus any desired or proposed 4DTs, and (5) aircraft position information and near-term intent. Standards for the definition of a flight object are in development.
Flight Operators	The flight crew, individual pilot, or automata responsible for the control of an individual aircraft while it is moving on the surface or is airborne.
Flow Contingency Management	The process that identifies potential flow problems, such as large demand capacity imbalances, congestion, high degrees of complexity, blocked or constrained airspace, or other off-nominal conditions. It is a collaborative process between ANSP personnel and airspace users to develop flow strategies to resolve the flow problems. Examples of flow strategies include establishing routing to reduce complexity, restructuring airspace, and allocating access to airspace or runways.

Term	Definition
FMS	Flight Management System
FOC	Flight Operations Center
Four-Dimensional Trajectory (4DT)	A 4DT represents the "centerline" of a path, including waypoints, plus lateral, longitudinal, and vertical positioning uncertainty. The "trajectory" is defined with only the level of specificity necessary to meet the performance requirements of the proposed operation. There are four notions imbedded in the 4DT—flexibility volumes, CTA, separation zones, and intent information. The level of specificity of the 4DT will depend on the operating environment in which the flight will be flown.
GA	General Aviation
Hazards	The objects or elements from which an aircraft can be separated. These include other aircraft, terrain, weather, wake turbulence, incompatible airspace activity, and, when the aircraft is on the ground, surface vehicles and other obstructions on the apron and maneuvering area.
Human-Centric	The ATM system is designed around the capabilities and limitations of humans. It assigns functions to humans that are best performed by them, and it provides automation assistance when it can improve decision-making or make the human's tasks easier. It does not imply that humans are always in direct control.
Human Factors	The discipline concerned with the understanding of interactions among humans and other elements of a system. It is application of theory, principles, data, and other scientific methods to system design to optimize human well-being and overall system performance.
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions

Term	Definition
Intelligent Agents	Within the context of this operational concept, refers to a computational system that includes the following characteristics: is aware of constraints, has goals, and operates autonomously within its construct to identify information or opportunities for human action. It is customized for an area or task, is adaptive, knows the user's preferences/interests, and can operate on their behalf (e.g., by narrowing the choices available through auto-negotiation). As such, this concept's definition is consistent with commonly accepted industry standards.
Intent	Information on planned future aircraft behavior, which can be obtained from the aircraft systems (avionics). It is associated with the commanded trajectory and takes into account aircraft performance, weather, terrain and ATM service constraints. The aircraft intent data correspond either to aircraft trajectory data that directly relate to the future aircraft trajectory as programmed inside the avionics or the aircraft control parameters as managed by the automatic flight control system. These aircraft control parameters could either be entered by the flight operator or automatically derived by the flight management system.
JPDO	Joint Planning and Development Office
Layered Adaptive Security	The security system will be constructed in "layers of defense" to detect threats early and prevent them from meeting their objective while minimally affecting efficient operations. Aerodromes and aircraft will be designed to be more resilient to attacks or incidents. Building on the "net-enabled information access" and "performance-based services" capabilities, risk assessments will begin well before each flight so that people and goods will be appropriately screened as they move from the "aerodrome" curb to the aircraft, or as they support aerodrome/aircraft operations. As technology matures, screening will be unobtrusive and more transparent to the individual. All people and cargo that "touch" or are carried by an aircraft will be positively identified. Responses to anomalies and incidents will be proportional to the assessed risk of the involved individuals or cargo.
Metroplex	A group of two or more adjacent aerodromes whose arrival and departure operations are highly interdependent.
Mixed Equipage Airspace	Low to moderate density, low-complexity airspace where demand is not high enough to drive the requirement for higher aircraft capability. A minimum set of aircraft capability is required to operate in this airspace. The function of tactical separation will be performed by ANSP personnel for some aircraft within this airspace, while other aircraft within this airspace may be engaging in (delegated) self-separation.

Term	Definition
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
Near-Space Airspace	Low-density, low-complexity airspace at very high altitudes that accommodates a wide range of special operations (e.g., high-speed reconnaissance aircraft, aerostats, long-endurance orbiting unmanned aircraft systems).
Net-Enabled Information	An information network that makes information available, securable, and usable in real time to distribute decision-making. Information may be pushed to known users and is available to be pulled by other users, including users perhaps not previously identified as having a need for the information.
NGATS	Next Generation Air Transportation System
Non-managed Airspace	Uncontrolled, low-altitude airspace where no ANSP services are provided, except as required to coordinate entry to a different class of airspace.
ORD	Chicago O'Hare International Airport
OSTP	Office of Science and Technology Policy
Performance-Based Navigation	Performance-based navigation specifies RNAV system performance requirements for aircraft operating along an ATS route, on an instrument approach procedure, or in airspace. Performance requirements are defined in terms of accuracy, integrity, continuity, availability, and functionality needed for the proposed operation in the context of a particular airspace concept. Performance requirements are identified in navigation specifications that also identify the navigation sensors and equipment that may be used to meet the performance requirement.
Performance-Based Operations	Use of performance capability definition versus an "equipment" basis to define the regulatory/procedural requirements to perform a given operation in a given airspace.

Term	Definition
Performance-Based Services	There are multiple service levels aligned with specified user performance thresholds to provide choices to users depending on needs, required communication, navigation and surveillance performance, environmental performance criteria, security parameters, etc. Services will be flexible according to the situation and consolidated needs of the users. Services vary from area to area in terms of airspace and "aerodrome" surfaces, and they vary with time as needs dictate. Preferences are established based on user capability, equipage, training, security, etc. The performance-based approach is used to analyze risks (safety, security, environment, etc.) instead of "equipment-based" approaches. The performance-based services capability will enable a definition of service tiers and allow the government to move from equipment-based regulations to performance-based regulations.
PFD	Primary Flight Display
PRM	Precision Runway Monitor
RCP	Required Communications Performance
Required Navigation Performance (RNP)	RNAV operations with on-board navigation containment and monitoring.
RNAV	Area Navigation
RNP X Specification	A navigation specification that includes requirements for onboard performance monitoring and alerting.
Route	A 3D path through space with no time component. Unlike corridors, aircraft can cross routes as operational need requires, with proper tactical separation provided to all aircraft.
RSP	Required Surveillance Performance
Separation Minima	The minimum displacements between an aircraft and a hazard that maintain the risk of collision at an acceptable level of safety.
Situational Awareness	Refers to a service provider's or operator's ability to identify, process, and comprehend important information about what is happening with regard to the operation. Airborne traffic situational awareness is an aspect of overall situational awareness for the flight crew of an aircraft operating in proximity to other aircraft.

Term	Definition
SOIA	Simultaneous Offset Instrument Approach
SUA	Special Use Airspace
Super-Density Flexible Airspace	The specific airspace configurations or routes chosen in near-real time to provide flexibility and maximize arrival and departure throughput. Is smaller than or lies within super-density protected airspace.
Super-Density Protected Airspace	The charted airspace protecting super-density terminals that is somewhat larger than the actual airspace used operationally. Statically defined for low-capability aircraft that do not have access to real-time updates of airspace definition.
Tactical Separation Management	The function of ensuring aircraft or vehicles maintain safe separation minima from other aircraft or vehicles, protected airspace, terrain, weather, or other hazards. The function may be performed by ANSP personnel, the flight operator, and/or automation.
Tactical Trajectory Management	The function of fine-tuning trajectories as required by the airspace plan or an active flow contingency management initiative to minimize pairwise contention and ensure efficient individual trajectories within a flow.
TFM	Traffic Flow Management
TMI	Traffic Management Initiative
Trajectory-Based Operations	The use of four-dimensional trajectories as the basis for planning and executing all flight operations supported by the air navigation service provider.
Transition Corridors	Tubes of airspace that allow aircraft to transition through autonomous airspace and ANSP flow-managed airspace to near-space airspace. The tactical trajectory manager provides the transition, coordinates, and reserves times for aircraft traveling to near-space airspace.
TSM	Tactical Separation Management
TSP	Tactical Separation Provider
TTM	Tactical Trajectory Management
UAS	Unmanned Aircraft System

Term	Definition
Unmanned Aircraft System (UAS)	A pilotless aircraft is flown without a pilot-in-command onboard and is either remotely or fully controlled from another place (ground, another aircraft, space), or programmed and fully autonomous. The UAS includes the pilotless vehicle, control system, and operator.
U.S.	United States
VFR	Visual Flight Rules
Virtual Tower	The ability to operate the surface and aerodrome without direct visual observation.
VLJ	Very Light Jet
VMC	Visual Meteorological Conditions
WAAS	Wide Area Augmentation System

Appendix C: References

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