



U.S. Department of Transportation
Federal Aviation Administration

The Future of the NAS

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“As we continue to check off NextGen milestones, it is important to periodically re-examine our path ahead and ensure we remain on the right track. NextGen was built on the premise that we must remain nimble and adaptable to changing needs.”

— James T. Eck, Assistant Administrator for NextGen

Letter from the Assistant Administrator for NextGen

I am pleased to present the FAA's Future of the NAS report that updates our plans for the continued modernization of our national airspace system. This is a cross-agency effort and reflects the FAA's plan forward with continued partner collaboration. In it you will see that the overarching objectives for the future remain the same — maximizing airspace capacity with more sophisticated and seamlessly integrated information about the future position of aircraft at a given time — while maintaining the safest air travel possible.

We have made great progress since the Next Generation Air Transportation System (NextGen) was just a concept. We have consistently leveraged our investments to deliver benefits to the National Airspace System (NAS) every day. Air traffic controllers already have better information to track and separate aircraft safely and efficiently. Pilots have more aeronautical, traffic, and weather information inside the cockpit. Airlines fly faster, more direct routes to get passengers to their destinations more quickly while burning less fuel and producing fewer emissions. We are on target to meet our original high-level objectives for NextGen by 2025. By that time, major NextGen transformational systems will be in place, and we expect to achieve additional individual benefits by leveraging NextGen capabilities all along the way. Beyond that date, we will continue to accrue benefits through enterprise-level advanced applications, additional aircraft equipment, and full workforce adoption of a time-based management system.

As we continue to check off NextGen milestones, it is important to periodically re-examine our path ahead and ensure we remain on the right track. NextGen was built on the premise that we must remain nimble and adaptable to changing needs. We know more now than we did in 2011 when we published the NextGen Mid-Term Concept of Operations. Working closely with stakeholders, we invested in research and pre-implementation work to determine the feasibility of advanced concepts and their associated benefits. The target is the same but the pathway is being refined. Concepts not deemed feasible or beneficial are no longer reflected in the Future of the NAS. What continues to be reflected is the dynamic nature of the NAS. We must accommodate new entrants such as unmanned aircraft and commercial space vehicles, as well as address evolving challenges such as cybersecurity and NAS sustainment and resiliency.

This document will be used to guide future research, planning, and investment decisions. It will provide the guide rails as we discuss near-term deployment activities and far-term investments with the aviation industry. We are focusing on three key themes: delivering improved services, ensuring seamless integration, and meeting new challenges.

The FAA appreciates the continued support for efforts to ensure our air transportation system remains the safest and most efficient possible. I trust that this document will provide a good basis from which we will work with the aviation community, the operational workforce- and other stakeholders to plan and prioritize future investments and to achieve seamlessly integrated enterprise benefits. Together, we can continue to ensure aviation excellence and leadership for generations to come.



James T. Eck

Assistant Administrator for NextGen

Purpose

The purpose of this document is to describe the concepts and activities that are planned to be delivered for the Future of the NAS by 2025. The implementation of these concepts will complete the transformation of the NAS to a Next Generation air transportation system. The overarching objectives for the future National Airspace System (NAS) remain constant — meet the need for increased capacity and efficiency while maintaining safety and mitigating environmental impacts.

The Federal Aviation Administration (FAA) continually strives to make aviation safer and smarter, deliver benefits through technology and infrastructure, and enhance our global leadership. At the forefront of the transformation to the future NAS is our commitment to improve NAS operations and ensure the vitality of the U.S. economy through the continued evolution of the Next Generation Air Transportation System (NextGen). In addition to providing improved services to users, plans must accommodate shifts in user demand profiles, adjust to changes in technology, and control costs in a tight budget environment. This document describes the capabilities being pursued to fulfill the NextGen Mid-Term Concept of Operations, as well as those activities needed to sustain legacy services and improve our processes for developing, deploying, and providing NAS operational services safely and smartly.

The technical solutions for many NextGen capabilities have been defined, and much of the foundational infrastructure has been deployed. Research results, exchange standards, completed airspace redesign projects, and new operational and aircraft procedures have all laid the groundwork for modernizing future NAS services. This document will tie the work already accomplished through NextGen with the work yet to do to deliver improved services to airspace users and seamlessly integrate new operations and technologies across the NAS. These modernization initiatives must be achieved while addressing

challenges such as Unmanned Aircraft Systems (UAS), cybersecurity, resiliency, and cost containment. *Figure 1: NextGen Enterprise Transformation* provides an overview of the modernized NAS.

FAA Accomplishments and Path Forward

The FAA has made tremendous progress in modernizing the NAS. Much of our foundational infrastructure has been upgraded with state-of-the-art technology and equipment. The majority of the surveillance and navigation infrastructure is in place and enabling the transition to satellite-based navigation and surveillance as the primary means of service delivery. The Automatic Dependent Surveillance–Broadcast (ADS-B) system which provides improved surveillance accuracy for precise, satellite-based aircraft position tracking has been deployed.

Airspace redesign and revised procedures are improving flight efficiency and capacity. The transition to Performance Based Navigation (PBN) through the establishment of a network of thousands of precisely defined PBN routes is making the flow of air traffic more efficient. The FAA is working closely with operators in local areas to design routes that provide the greatest possible benefit. For example, the capability called Established on Required Navigation Performance (RNP) allows operators to fly shorter, more direct approach paths that save fuel, cut aircraft exhaust emissions, and minimize delays.

Wake Recategorization Phase 1 is allowing tighter arrival and departure sequences, resulting in smoother surface flows and flight efficiency improvements, especially during peak periods. The FAA has approved the use of Enhanced Flight Vision Systems (EFVS) to help pilots meet visibility requirements for specified operations, and provided solutions for lowering the Runway Visual Range minima at certain airports. Both capabilities increase access to airports in low visibility conditions.

Installation of the new automation platform in our en route facilities has been completed, and steady progress is being made in upgrading the terminal automation systems. Initial NextGen software applications have also been implemented.

Tools that assist controllers with managing new wake separation standards and PBN procedures have been added to terminal and en route automation systems to increase the benefits associated with these new procedures. New Collaborative Air Traffic Management (CATM) tools are available to assist traffic planners with formulating solutions for flight-specific Traffic Management Initiatives (TMI). The tools account for airspace user preferences and options, and provide the ability to assess the impact of a set of reroutes on system parameters such as demand.

Users have increased access to information through the implementation of Digital Notices to Airmen and the provision of Traffic Flow Management System-generated reroutes

through System Wide Information Management (SWIM). The FAA's aviation weather research has resulted in more accurate and higher resolution weather forecasts, as well as improved icing and turbulence forecasts that are now operationally available through the National Weather Service. Initial trajectory based operations (TBO) improvements have been implemented. They expand and extend time-based metering capabilities, and provide new tools to assist controllers with speed adjustments needed to achieve metering times. The FAA has also developed and publicly released the Aviation Environmental Design Tool (AEDT) for environmental analysis from local to global scales and is using AEDT to assess the environmental performance of the NAS.

In addition to providing new capabilities, the FAA technical operations workforce continues to maintain over 40,000 pieces of NAS equipment installed at over 6,000 locations to provide highly reliable service. As equipment reaches the end of its life and can no longer be maintained at an acceptable

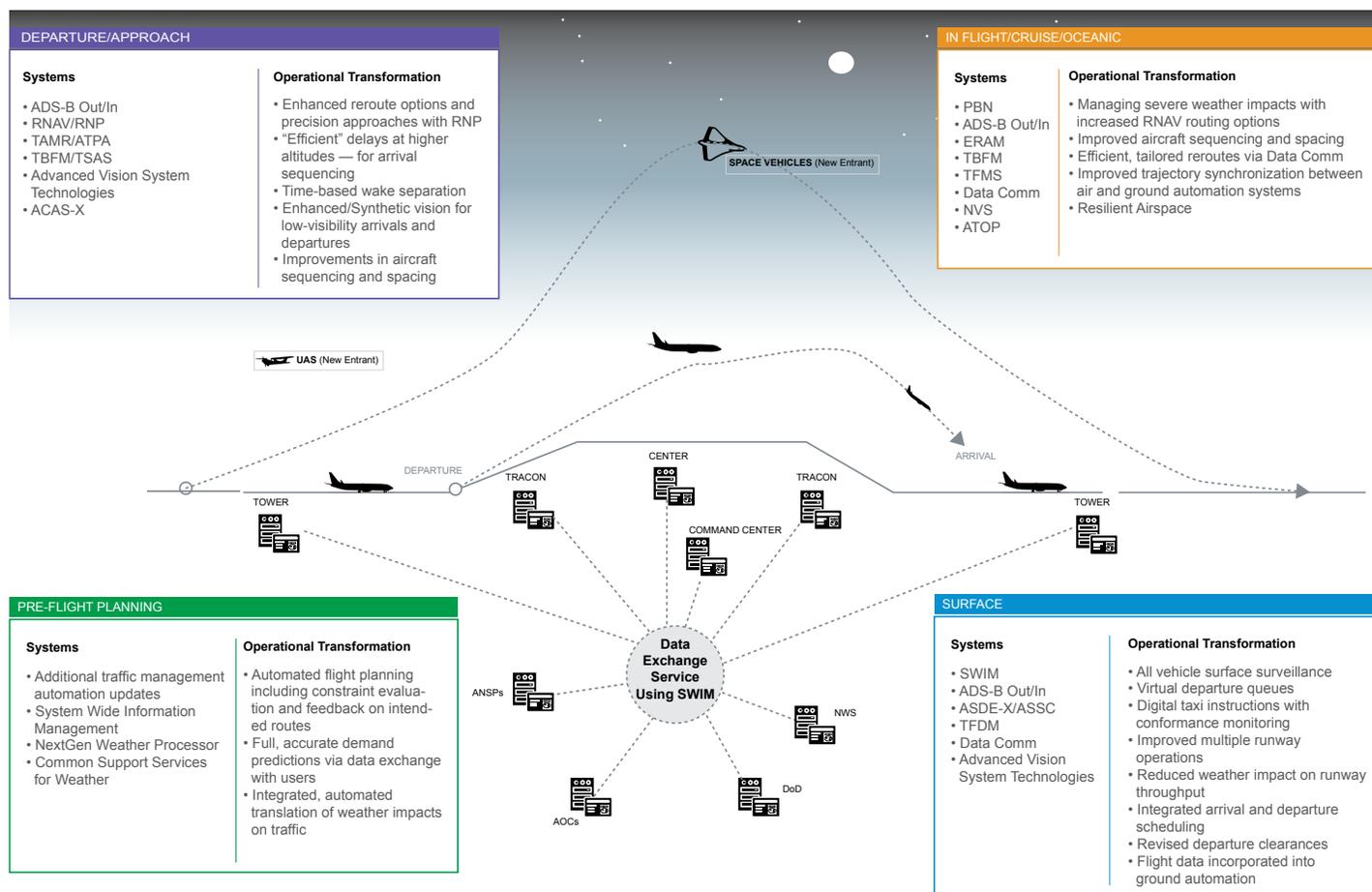


Figure 1: NextGen Enterprise Transformation | Source: FAA/NextGen

availability level, it must be replaced. Recent investment decisions have been made to improve NAS sustainment, operations and maintenance, and resource management.

The FAA is replacing remote monitoring and logging systems, and national test equipment necessary to monitor and test the health of the NAS. Fuel storage tanks and power cable systems are being replaced. Unstaffed infrastructure, that includes the FAA’s roughly 30,000 unstaffed navigation and landing, surveillance, and weather facilities and related assets, is being replaced, and an energy management and compliance program to orchestrate NAS-wide energy and water use reduction is being implemented. The replacement of these assets increases reliability of NAS services and availability of NAS capacity. Eliminating instances of reduced capacity due to system failures decreases air traffic delays. In addition, the FAA has invested in mobile asset management technologies and a new NAS Recovery Communications System to increase system resiliency in the event of a catastrophic incident.

Improvements to both air-to-ground data communications and ground-to-ground voice communications are under way. The first phase of Data Communications (Data Comm) has achieved success through the implementation of revised departure clearances at initial sites. This capability will significantly reduce weather-related departure delays through the faster execution of revised, full route departure clearances which will reduce the risk of airport gridlock and result in improved strategic management of NAS resources.

Great progress has been made in deploying the foundational infrastructure of the future NAS. There is still work to do to achieve the full realization of the operational benefits enabled by NextGen as can be seen in *Figure 2: Building the Future*. For example, the remaining automation infrastructure, such as new tower automation, must still be developed and deployed. Software applications needed by controllers to provide more predictable and efficient services across tower, terminal, and en route domains

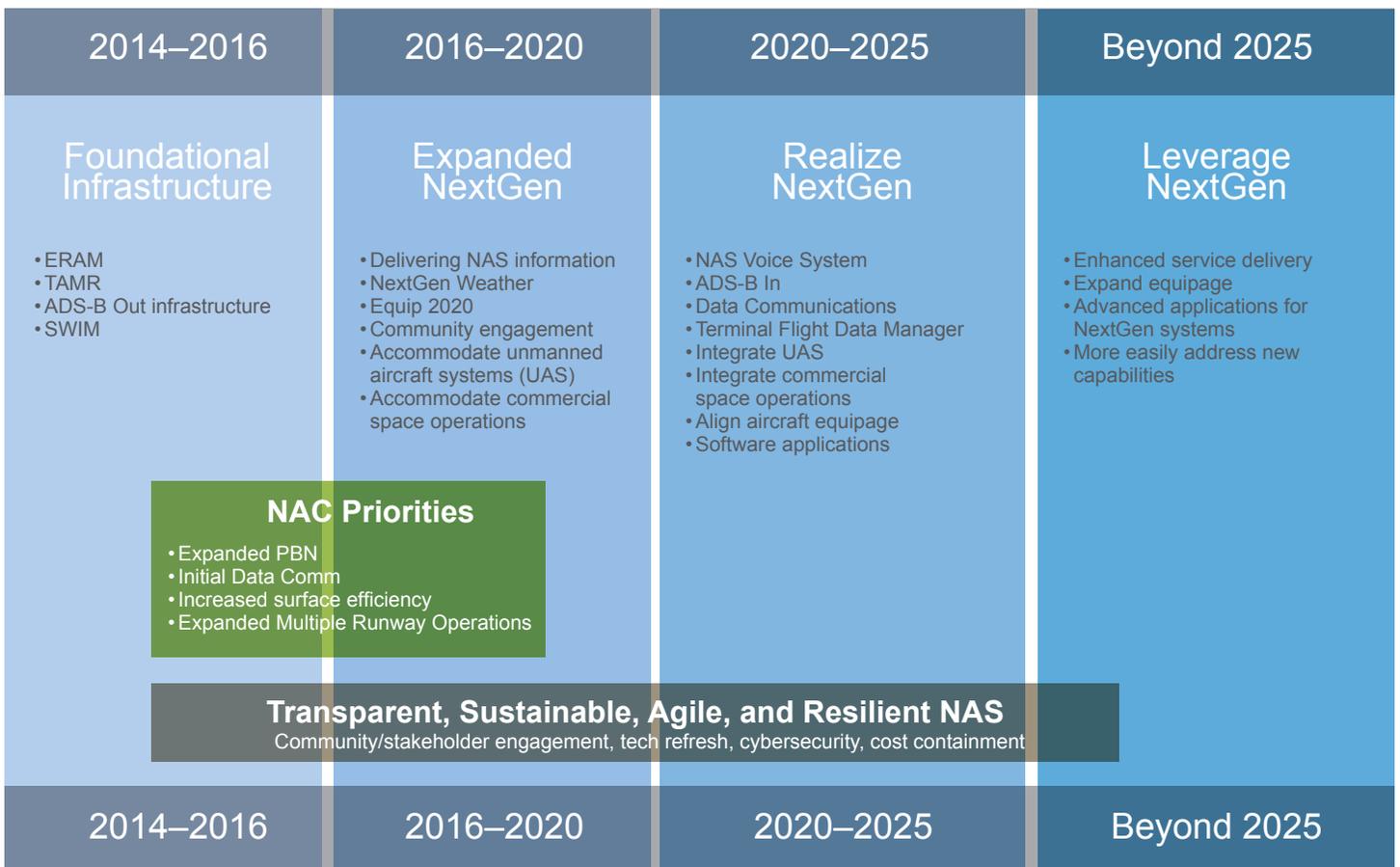


Figure 2: Building the Future | Source: FAA/NextGen

must still be developed and deployed. The communications programs need to be deployed nationally, and users will need to equip with the required systems — both on the ground and aboard the aircraft — to complete this transformation.

NextGen is a collaborative effort between the FAA and the aviation community. Benefits depend on all stakeholders investing in the airspace modernization effort. Improvements in aircraft engines, airframes, fuel technologies, and avionics form a vital contribution to NextGen.

FAA plans must also meet new challenges such as accommodating new service demands of UAS and commercial space entrants, mitigating cybersecurity risks, minimizing aviation's impact on the environment, and ensuring the NAS is resilient in a manner that contains cost in a challenging budget environment.

The FAA will continue to work with the user community through the RTCA's NextGen Advisory Committee (NAC) to prioritize the implementation timing for NextGen service improvements contained in this document, while the FAA continues to prioritize other NAS improvements necessary to sustain operations and provide efficient, streamlined services.

How this Document Relates to Other NextGen Concept Documents

The original NextGen vision was documented in the Concept of Operations for the Next Generation Air Transportation Systemⁱ by an interagency Joint Planning and Development Office. This document, released in 2007, identified key research and policy issues that needed to be resolved in order to achieve national goals for air transportation. The FAA's NextGen Mid-Term Concept of Operations for the National Airspace Systemⁱⁱ, released in 2011, reflected those concepts that should be pursued for the Mid-Term. The documents provided high-level descriptions of the visionary concepts that should be researched as potential solutions for NextGen.

In many cases, the Mid-Term Concept presented ambitious but not yet validated operational descriptions envisioned to maximize benefits and flexibility for NAS users. It noted many possible futures which would depend

on the insights gained by evolving concepts. The Future of the NAS reflects those insights from concept evolution and technology assessments. It provides lower level details about how technology is being used to meet the original Mid-Term Concept. It is a narrative aid for industry and the agency to plan for the future and prioritize future investments. This prioritization will influence future iterations of our planning materials, such as the NAS Enterprise Architecture and NAS Segment Implementation Plan, as research and planning mature.

Document Structure

The Future of the NAS is structured to highlight three key themes: Delivering Improved Services, Seamless Integration, and Meeting New Challenges. These themes describe the important capabilities that need to be developed and implemented over the next decade to truly transform NAS operations and provide the desired benefits to the user community.

The first section of this document describes how the NextGen concept has matured and evolved over time. The next section describes the operational benefits that the FAA will provide the user community through implementation of future NAS capabilities. The remaining sections describe the improvements that are planned for the future of the NAS to yield these operational benefits.

Delivering Improved Services describes how current operational services will be improved to increase capacity and efficiency. Seamless Integration discusses how the seamless integration of data enables the FAA and stakeholders to have a common understanding of both current and future NAS status to improve strategic planning and increase flexibility. Meeting New Challenges describes the capabilities and processes that will be employed to address new challenges such as incorporating new entrants into the NAS, cybersecurity, and cost containment. Certain concepts, most notably TBO, will enable both improved services and benefits from integrated data. However, to avoid duplication specific concept elements are only discussed in one section. For example, although CATM is an important element of the TBO concept, it is discussed under integrated data. ➔



The NextGen Mid-Term Concept of Operations for the National Airspace System (NextGen Mid-Term Concept) provided an operational view of the NAS as defined by a set of operational concepts. The operational capabilities described in this document are consistent with the NextGen Mid-Term Concept. Over time the detailed implementation plans have matured through concept validation and altered the way in which certain NextGen capabilities will be delivered. Additionally, many other factors continue to evolve the NextGen implementation plan, including the implementation approach and timing for new operational capabilities. Such factors include stakeholder input, results of aviation rulemaking committees, and RTCA special committees, research results, technology selections, lessons learned, independent assessments, and affordability.

NextGen investments have been and will continue to be prioritized based on technology and concept maturity, as well as stakeholder interest. High priority concepts for the user community and those with high benefits are being pursued to achieve early operational capabilities. RTCA's NextGen Mid-Term Implementation Task Force, Task Force 5, prioritized the first set of capabilities users wanted NextGen to deploy by 2015. A joint effort with the RTCA's NAC resulted in a second set of prioritized capabilities to be deployed by 2018. Both sets of recommendations called for delivering near-term benefits to our stakeholders and greatly influenced the NextGen Implementation Plan.

RTCA special committees continue to provide recommendations on technical and operational standards. Input from these committees has deepened our understanding of technical maturity and resulted in changes to the definitions and timing for lower level operational concepts. Some of these changes included finding alternative technical solutions that took advantage of existing aircraft equipment. Moving forward, some of the significant future NextGen operational improvements will be based on new avionics, such as Data Comm and ADS-B, and users will need to equip with the associated avionics to realize the benefits afforded by these capabilities.

Research results have influenced the chosen operational solution to solve a given mission shortfall. Concepts that posed too high a technical risk (e.g., no technical solution is yet available) have been deferred. Some concepts that required more research to garner evidence of the perceived operational benefits have also been deferred for implementation into the later segments of NextGen.

Operational implementation plans have also evolved to meet changing user demands. Although the need to incorporate commercial space and unmanned aircraft into the NAS was a common theme in the original NextGen Mid-Term Concept, these new entrants have requested access to the NAS earlier and in different ways than originally envisioned.

External and internal assessments continue to influence FAA acquisition priorities and implementation plans. A 2014 report from the Department of Transportation's (DOT) Office of the Inspector Generalⁱⁱⁱ, a recent National Research Council^{iv} review of NextGen, and a MITRE^v independent assessment provided recommendations on improvements to our processes to ensure implementation planning appropriately accounts for agency and user needs, while ensuring that benefits associated with operational improvements are achieved.

Internal FAA reviews similarly influence priorities and plans. Many of the recommendations and lessons learned from internal assessments have become the standard way of doing business. The FAA is finding smarter ways to conduct outreach to the user community, field facilities, and the controller workforce to ensure the operational benefits associated with new implemented capabilities are achieved.

Lastly, the NextGen Facilities and Equipment (F&E) budget has influenced the evolution of the future NAS. At a time when enacted funding levels were less than projected, the F&E budget also had added requirements to sustain legacy services that have not yet been replaced, to fund new NextGen leased services, and to technically refresh NAS

systems as they reach the end of their life. Whereas the old NAS systems were largely custom products for which the government owned the design and the software code, the current NAS is increasingly comprised of commercial hardware and software products that have a much shorter economic life. The need to technically refresh commercial products that are no longer supported in the commercial marketplace is the new reality that will continue to place pressure on the F&E budget.

Concepts have been delayed or discarded due to a combination of technical immaturity, funding, stakeholder interest, user equipage, and changing needs and benefits cases as traffic demand projections have changed. The concepts that

are no longer considered part of the NextGen Mid-Term Concept are listed in Appendix B. Given the 2016 budget and predicted out-year funding levels, the FAA will work towards achieving an initial operating capability for the concepts described in this document by 2025.

Based on our stakeholder feedback, new technical opportunities, and lessons learned, this document highlights the evolving areas of emphasis for the NAS through 2025. The FAA will continue to collaborate with stakeholders, examine implementation progress, assess achieved benefits and remaining shortfalls, and adapt as needed to mature and deploy capabilities that deliver operational improvements to the aviation community. →

NextGen investments have been and will continue to be prioritized based on technology and concept maturity, as well as stakeholder interest. High priority concepts for the user community and those with high benefits are being pursued to achieve early operational capabilities.

Benefits of the Future NAS

One of the initial objectives of NextGen was to improve the flexibility of the NAS to accommodate increased traffic, while improving operational efficiencies. Remaining focused on fulfilling this vision continues to be a national imperative. While FAA will continue to work with airports to add new runways where needed, NextGen has a vital role in optimizing the safe and efficient movement of aircraft so that users can make the most use of available runway capacity at congested airports.

A DOT 30-year outlook report, *Beyond Traffic: Trends and Choices 2045*, estimated flight delays and congestion cost the U.S. economy more than \$20 billion each year. In addition, the report predicts the total number of people flying on U.S. airlines will increase by 50 percent over the next two decades. If capacity is to keep pace with increased demand for services, changes are needed in the way services are provided.

Capacity and Efficiency

NextGen improves service delivery by providing users with more efficient routings, reduced delays, increased flexibility, increased accommodation of user preferences, and a more resilient NAS. Improved service delivery must accommodate the needs of new commercial space entrants and UAS in a manner that is safe. The FAA will provide users with flexibility where possible and improved structured routings where needed.

NextGen improvements will provide opportunities for users to fly more fuel efficient PBN routes. The expanded use of time-based metering will increase the precision with which an aircraft meets its scheduled time of arrival at a metering point. These capabilities will contribute to more optimal aircraft descent profiles and move the delay needed for safe runway sequencing to higher altitudes, which increases fuel efficiency. These tools, along with the transition to new satellite-based surveillance, will provide more accurate position information. This will increase capacity by enabling controllers to separate aircraft closer to mini-

imum separation standards. In some locations, separation standards may actually be reduced to increase capacity.

The improved capture, management, and dissemination of aeronautical information will increase overall operational efficiency (e.g., efficient use of airspace due to better and more timely information sharing) and safety (e.g., enhanced situational awareness) in the NAS.

Improved weather forecasts integrated into decision support tools will provide more routing options around weather and may decrease the volume of airspace that needs to be avoided. Automation tools will assist air traffic managers with modifying aircraft routing in response to changing weather conditions or congestion, and users will have increased flexibility in choosing the reroute options that best meet their business objectives.

Users will have increased opportunities to provide preferences for both strategic and tactical route planning through expanded data exchange mechanisms. The introduction of a safety-critical data communications link between the ground and aircraft automation systems will enable the system to adjust more rapidly to changing conditions.

Airspace users exchanging improved demand predictions with the FAA will provide better information regarding the need for traffic management initiatives. This improved information sharing will decrease overall delays and allow users to play a role in choosing which flights absorb the necessary delay needed to safely operate the NAS.

Improvements to controller tools will enable increased access to planning information and assist controllers with improved aircraft sequencing. These automation tools can reduce traffic complexity and cognitive workload, and provide opportunities for en route sector controllers to increasingly manage more aircraft simultaneously and accommodate optimized profile ascents and descents with less required intervention for sequencing and spacing.

Resiliency

The outage following the 2014 Chicago Center fire demonstrated the need for improved system resiliency. Beyond the near term solutions of a new contingency strategy and airspace coverage plans, the FAA will look for opportunities to use new NextGen technologies to make it possible for an FAA facility to access another facility's surveillance, communications and flight plans, enabling the swift resumption of operations at an alternative location.

Reduced Environmental and Energy Impacts

Reduced flight time, surface delays, fuel efficient PBN routes, and optimal descent profiles reduce fuel use and provide environmental benefits to society. Fuel savings translates to unreleased carbon dioxide and net reductions in the climate impact from aviation emissions. Airframe and engine improvements, as well as alternative jet fuels currently in the research phase, can lead to additional emission and energy benefits in the future. Noise reductions will also come from airframe and engine improvements, as well as changes in aircraft operations. The FAA will also continue to improve our understanding of the impacts of noise to better inform the development of noise mitigation solutions. The environmental vision for the FAA is to develop and operate a system that achieves environmental protection while allowing for sustained aviation growth.

Safety

As air and ground systems, and the data that supports them are improved and aligned, they will form a comprehensive air-ground safety network that improves the overall safety of surface and airborne operations. Better and seamless information access provides users and operators in the NAS with common situational awareness and a more accurate view of the system, resulting in improved decision-making and an increase in system safety.

Improved surveillance and controller decision support tools also enhance safety. Better traffic collision avoidance systems, new traffic information displays, improved navigation accuracy, and increased performance monitoring and alerting are enhancing safety and situational aware-

ness on the flight deck. As NAS initiatives are researched and implemented, safety will continue to be the FAA's number one priority. The effect of NAS changes on safety will be determined through improved data sharing, analysis and modeling capabilities.

Global Leadership

To realize NextGen's full benefits steps must be taken to ensure NextGen is capable of extending beyond our nation's borders. NextGen aims to harmonize systems and procedures to ensure civil and military interoperability across international boundaries. The FAA, in partnership with industry, is working to ensure the NAS is globally interconnected through data exchange standards, as well as other globally harmonized operational and technical standards, procedures, avionics capabilities, and equipage milestones. This will allow airspace users to realize the maximum benefits of NextGen transformations, while ensuring the air transportation system is responsive to concerns such as aviation's impact on global climate change, and the cost of aviation.

As NextGen modernizes the U.S. air transportation system, the FAA will continue to inform the global aviation community of program performance and outcomes to promote modernization and global harmonization. Providing leadership in the area of modernization and air navigation harmonization also helps ensure the FAA retains its role as the world leader in aviation. ➔

Trajectory Based Operations

The NextGen concept calls for Air Traffic Control (ATC) services to transition to trajectory based operations. The transition to TBO has remained a constant cornerstone of NextGen. It will leverage improvements in navigation accuracy, communications, surveillance, and automation to decrease the uncertainty of an aircraft's path in four dimensions — lateral (latitude and longitude), vertical (altitude) and time — which will result in significant improvements in strategic planning. Better strategic planning will decrease the need for tactical intervention.

These improvements are leveraged through the system-wide sharing of information with all authorized users, resulting in consistent information across all systems and actors. Better information and seamless information access based on standard information exchange models provide users and operators in the NAS with common awareness, a more accurate view of the system, and improved decision making tools to increase system capacity and safety, improve flight efficiency, and provide users with increased flexibility and predictability.

Strategic planning will improve through the use of high confidence estimates of the aircraft's location and altitude at given points of time. In the current system, future demand is estimated based on limited knowledge of the route the pilot plans on taking, the chosen cruising altitude for the flight, and the estimated departure time. Strategic planning tools are forced to make assumptions about the altitude and arrival times along the route to assess whether there is a demand/capacity imbalance. When controllers have to maneuver aircraft away from conflicting traffic or weather, resulting changes to the route are often unknown to the rest of the system and make it difficult for air traffic management to conduct precise strategic planning.

TBO will provide improved knowledge of the estimated time of departure and the arrival time at each waypoint along the entire route of flight. These times will be shared

between air and ground automation systems and used to improve assessments of demand/capacity balancing. Air-to-ground data communications will be leveraged to execute required traffic flow changes more quickly and efficiently. This will ensure the ground automation systems are aware of clearances provided to the flight deck, resulting in a consistent view of the four-dimensional trajectory (4DT) across the NAS. TBO will lead to better flow planning and increasingly improve the ability to handle demand-capacity imbalances or off-nominal events in a more strategic and efficient manner.

The improved knowledge of the 4DT may lead to a reduction in the separation buffers controllers add to account for uncertainty and a significant decrease in the use of less efficient tactical maneuvers issued to maintain safe separation. TBO provides the ability for aircraft to fly the most optimal route (using PBN), and the ground automation to manage NAS resources based on ground-generated estimates of aircraft arrival times along the route.

In a mixed-equipage TBO environment, controller tools will assist with identifying and managing aircraft equipage differences. Flight deck capabilities to fly full PBN trajectories will be used in place of voice instructions for speed and vectoring. The result will be maximum utilization of available airspace capacity with near optimal flight efficiency. To achieve the full benefits of TBO, users must equip with the required avionics including PBN, air-to-ground Data Comm, and ADS-B In.

Performance Based Navigation

NAS services will be improved by providing a flexible route structure, with defined routes where needed, to enable aircraft to fly the most direct and fuel efficient flight path. Moving away from point-to-point navigation and procedures based on published jet routes, to a more dynamic PBN environment, results in improvements in the areas of airspace capacity, flight efficiency,

and safety, along with lower fuel consumption and aircraft exhaust emissions.

Great strides have been made in adding PBN routes for all domains — oceanic, arrival/departure, and en route. The NAS is increasingly optimizing the use of published PBN procedures to maximize capacity while maintaining common patterns needed by controllers to maintain safety. Navigation services will continue to evolve to increasingly deliver improved services according to the guiding principle of providing the appropriate PBN tool to meet a specific operational need. As emerging advancements in surveillance and communication become widely available in the NAS, the FAA and aviation stakeholders will continue to innovate and integrate navigation technologies.

In the en route environment, a smart route structure will continue to evolve where needed, and flexible point-to-point routing will be used where feasible. In high-density arrival/departure airspace, the use of PBN routes will

continue to improve to ensure that airport capacity is maximized through the use of repeatable and predictable route options that decrease the need for controllers to vector an aircraft off of a route for sequencing, spacing, and separation. Area navigation (RNAV) departure and arrival routes will be provided unless there is an operational need for RNP to avoid terrain or obstacles, or if airspace/procedure considerations necessitate RNP. *Figure 3: Evolution of Navigation* shows the operational differences using ground-based navigation aids versus RNAV and RNP.

Decision support tools will aid controllers in maximizing throughput on PBN routes and provide alerts when an aircraft is laterally deviating from its assigned route. This new environment is dynamic strategically, rather than tactically, because PBN provides opportunities to change operations multiple times throughout a day. Performance Based Navigation and procedures are selected and adjusted dynamically based on conditions within the NAS and predicted demand.

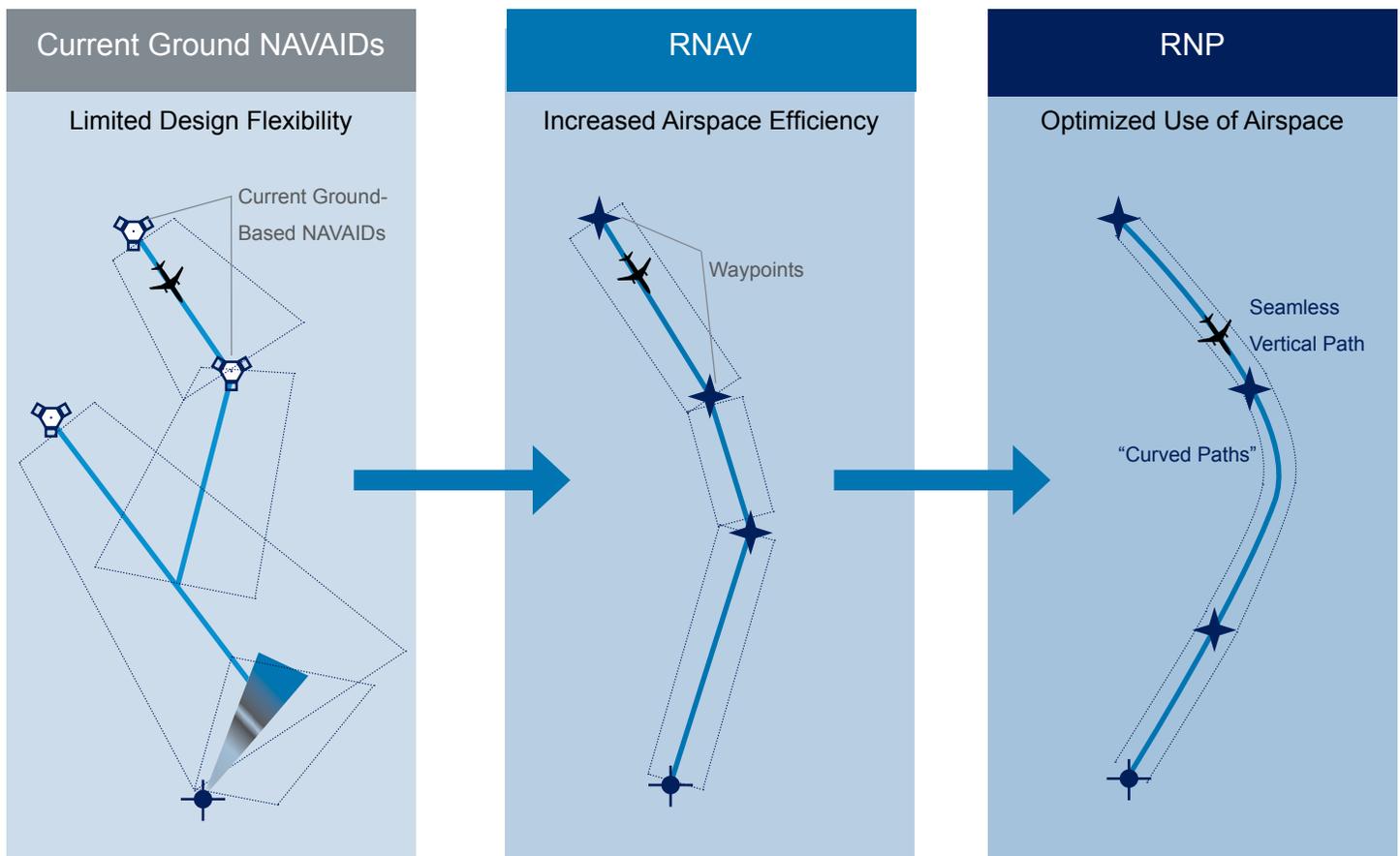


Figure 3: Evolution of Navigation - Operational differences using ground-based navigation aids versus RNAV and RNP | Source: FAA/NextGen

Moving forward, the FAA will continue to collaborate with stakeholders to ensure a successful transition to a PBN-centric NAS. Further, the FAA will continue to work with airports and communities to balance PBN efficiency with reductions in noise exposure to underlying neighborhoods. As PBN capabilities evolve, the FAA will continue to innovate and improve the integration of new navigation technologies. Clear guidance will be given for performance levels and alternatives across a range of operational scenarios. The type of procedure deployed will meet the operational need.

Air-to-Ground Data Communications

Currently, PBN route selections are made pre-departure. Once aircraft are airborne, needed route changes must be simple because each aircraft receives a unique clearance over the radio from a controller. The pilot writes down the new clearance on a piece of paper, reads it back to the controller — who confirms the pilot read it back correctly — and then the pilot types it into the flight management system (FMS). In domestic airspace, there

is no integration of information between the aircraft and ground automation beyond secondary surveillance position, FAA assigned beacon code, and altitude information. With Data Comm, all pilot actions will be conducted through the digital exchange of information for appropriately equipped aircraft. The message or clearance will be received, reviewed, confirmed, accepted, and loaded into the FMS electronically. Pilots will receive these messages anywhere, whether on the ground or mid-flight. Controllers will be able to send revised clearances to multiple aircraft rapidly. (See Figure 4: Operational Changes with Data Communications.)

Data Comm will be integrated into the ground and airborne automation systems and become the primary means for conducting routine coordination and revising route clearances. Initially, pilots will receive Data Comm messages using Future Air Navigation System (FANS) Version 1/A avionics with services transitioning to also provide messages to Aeronautical Telecommunications Network (ATN) avionics for the advanced TBO capabilities. Initial airport applications will enable revised departure clear-

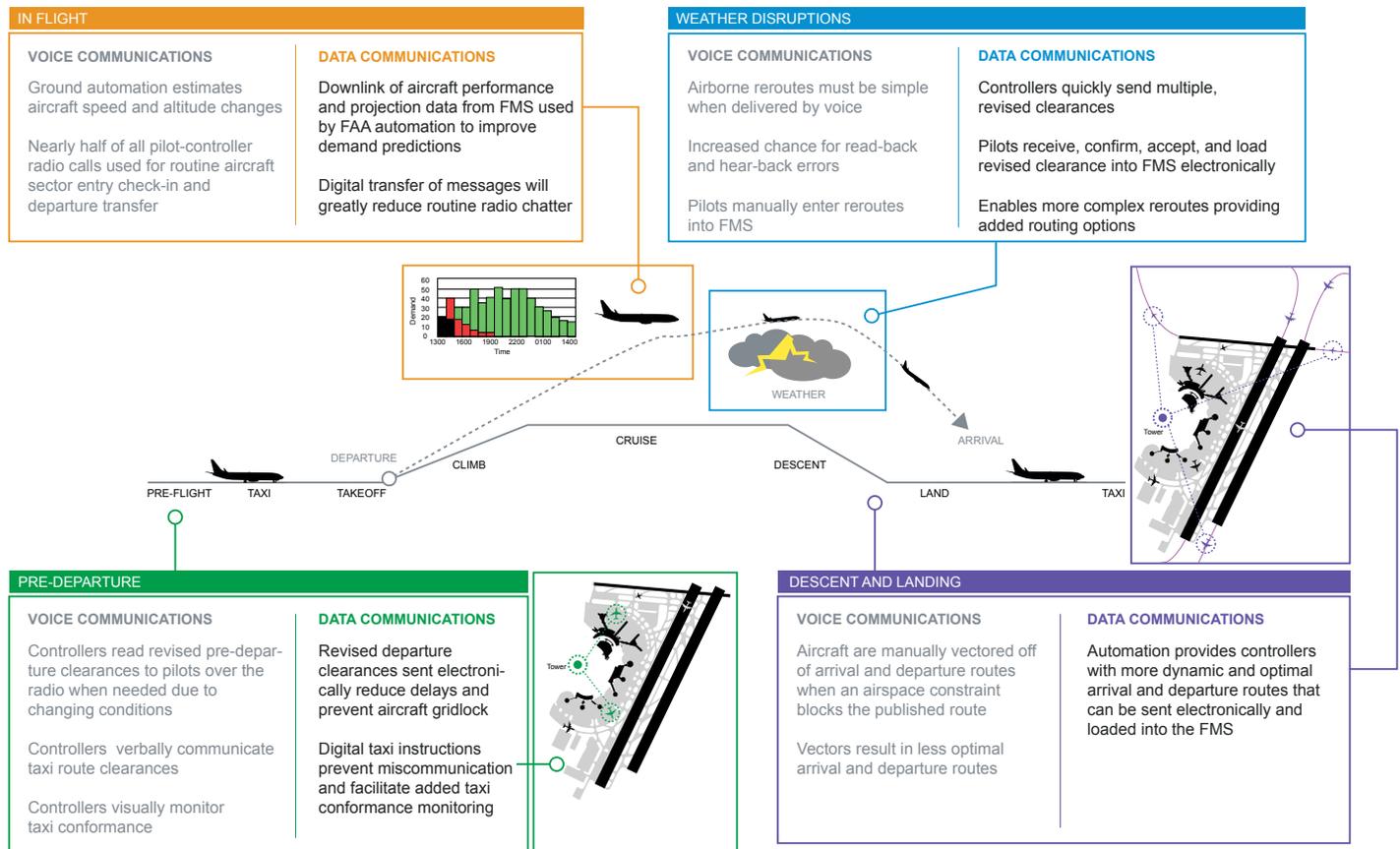


Figure 4: Operational Changes with Data Communications | Source: FAA/NextGen

ances via Data Comm. Initial en route services will provide airborne reroutes, limited controller initiated routes and control instructions, as well as routine controller-pilot communications. Full en route services will enable Data Comm to be used for additional controller initiated routes and control instructions, as well as holding instructions, tailored arrivals, and other messages including beacon codes and stuck microphone checks.

The initial implementation will enable the controller to send new clearances to the cockpit based on routes that have been preloaded into the FMS or latitude/longitude coordinates which expands the solution set for strategic flow management. This phased implementation approach will advance the NAS towards TBO, and achieve near-term benefits, while providing more time for the international community to reach agreement on the ATN Baseline 2 message set and avionics to enable advanced TBO capabilities in line with global standards.

The implementation of Data Comm to domestic airport and en route operations will lead to a fundamental shift in controller-pilot communications. Air-to-ground frequencies will be less congested, making it easier for both pilots and controllers to hear critical instructions and information. The reduction in voice communication will reduce pilot and controller workload and enhance sector team, flight deck, and flight operations center (FOC) operational efficiencies. To achieve these operational benefits, users must equip with the necessary avionics.

Development work for more advanced data communications capabilities will continue. These later applications will include additional messages enabling more complex and optimal reroutes such as Dynamic RNP (D-RNP) and 4D trajectories, as well as digital taxi instructions and advanced interval management. To achieve the benefits of these capabilities, the user community must equip with the Baseline 2 Data Comm system.

With the 4D trajectory capability, the aircraft's intent in the form of an expected extended profile from the FMS allows air traffic management automation systems and the flight deck to have a synchronized view of the intended trajectory. This will improve the accuracy of the 4DT and lead to better strategic planning based on new information. D-RNP is being evaluated as a po-

tential solution for efficient departure, en route routing and metering, descent arrivals, and Metroplex activities. This capability enables precise adjustments of aircraft arrival and departure streams, and enables aircraft to continue to fly Optimized Profile Descent (OPD) procedures with minimal disruption in areas of high volume or airspace constraints.

When an airspace constraint is introduced due to adverse weather, high traffic density, special activity airspace activation, or a combination of these, aircraft routes are adjusted to minimally alter traffic streams to circumvent the constraint. This action maintains flow or throughput in lieu of reverting to vectors, point-to-point transitions, or conventional Standard Terminal Arrivals which all may require additional traffic management initiatives to restrict traffic flow.

Optimized Profile Descent

The future NAS aims to provide procedures that allow for the most optimized profile descents that can be approved without compromising arrival capacity (*See Figure 5: Operational Change with OPD on page 18*). In low and medium sized terminal areas, this will be accomplished through the design and implementation of PBN procedures. In airport and airspace operations where demand does not approach runway capacity and airspace interactions with other arrival and departure traffic are minimal, the aircraft's Required Time of Arrival capability may be used to reduce communications and improve aircraft staging by assigning times with large buffers that enable the aircraft to fly more unique OPDs. Early time assignment will enable flights to be cost-effectively adjusted at altitude. This may be the only mode of operation at many airports and may be used for off-peak operations at major airports.

In high-density environments where airspace limitations preclude unique OPDs for each aircraft, a more integrated approach is required through the combined use of PBN procedures and automation tools. The airspace becomes more highly structured with multiple OPD procedures designed and available to provide efficient descent and arrival routes for multiple wind and weather conditions. The Metroplex airspace initiative is working towards developing this structure where needed. These routes are de-

signed to maintain airspace throughput while providing fuel efficient descents for most of the fleet.

This common structure provides a basis for controller and pilot tools to assist with sequencing, spacing, and separating aircraft while maintaining those maneuvers that keep the aircraft as close as possible to the fully optimized descent profile. New aircraft and ground-based capabilities will help controllers and pilots meet arrival sequencing and spacing requirements while preserving the fuel efficiencies gained through OPDs. These tools will enable flight path planning prior to the aircraft's top-of-descent point to minimize deviations from the optimal descent. These timing and spacing automation tools will increase the likelihood for the success of a full PBN operation.

Improvements to Aircraft Sequencing and Spacing

Aircraft sequencing and spacing tools will assist with optimizing airspace capacity and flight efficiency throughout the route of flight. Both aircraft and ground-based automation tools are being researched to achieve this transition to time based sequencing and spacing, an important component of the TBO concept. The FAA is working with the user community, through the NAC, to determine the best combination of these capabilities to use in a given operational environment. The following paragraphs describe how each of these capabilities could contribute to achieving this operational improvement.

The expanded use of time-based spacing will allow aircraft to stay on fuel-efficient paths at higher levels of demand and optimize throughput along these trajectories. Ground

automation system changes will support TBO and provide tools to assist controllers with maximizing throughput, managing aircraft separation in a mixed navigational and wake-performance environment, and keeping aircraft on the optimized route. As aircraft fly precisely and efficiently on common expected paths, controllers can monitor aircraft path progression and separation with the assistance of automation tools, and act if needed to maintain adequate spacing and separation.

Expanded use of time-based sequencing and scheduling to the terminal domain will increase throughput and enable more fuel efficient descents. As seen on page 19, *Figure 6: Operational Change with Terminal Sequencing and Spacing (TSAS)*, the increased precision of time-based spacing reduces the likelihood of low altitude delay vectors needed to achieve runway separation. En route controllers will use time-based metering tools to merge aircraft into arrival streams, adjust aircraft speed and path assignments to meet metering times, and assist terminal controllers with the sequencing and spacing of aircraft throughout the arrival phase of flight. These tools rely on the ability of aircraft to fly PBN arrival procedures to maximize system and individual flight efficiencies. The proper PBN procedures for time-based metering will evolve based on the available ground and airborne-based capabilities.

Pilots may assume a broader role in aircraft spacing with the use of ADS-B In applications which will improve inter-aircraft spacing. For users who equip with this capability, tighter aircraft spacing may be achieved. Researchers are also evaluating whether this application could even-

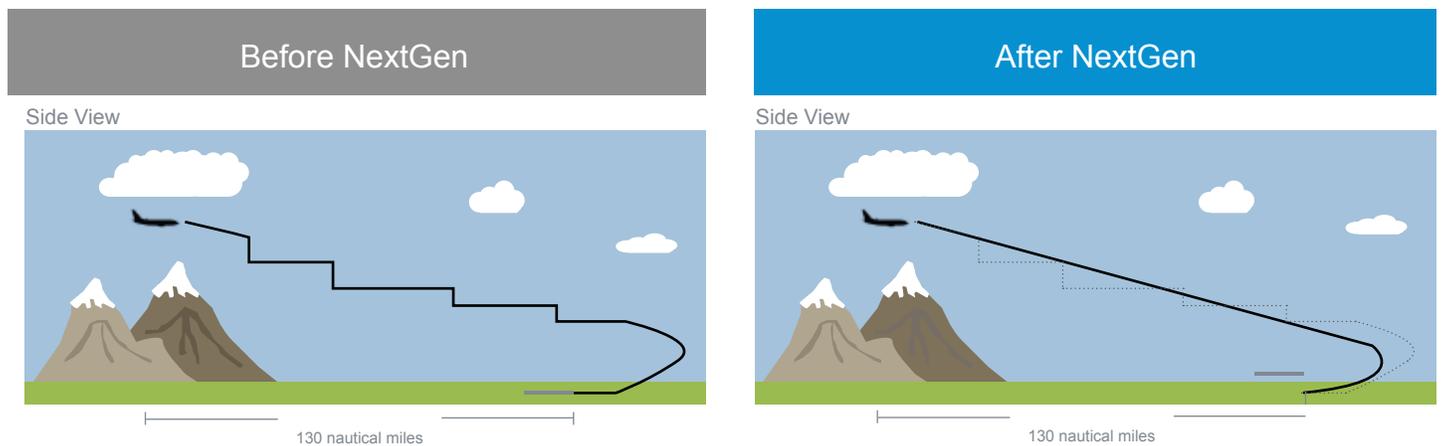


Figure 5: Operational Change with OPD | Source: FAA/NextGen

tually reduce required aircraft separation for equipped aircraft in certain operational conditions, increasing airspace capacity by delegating spacing and sequencing to the flight deck.

Improved position and velocity measurement accuracies offered by ADS-B, new aircraft functionality, new procedures, and ground automation enhancements to support this operational improvement will all work together to enable flight crews to establish and maintain a given time or distance from a designated aircraft, in order to more precisely meet ATC-assigned spacing intervals. These capabilities will increase efficiency and throughput in capacity-constrained airspace without negatively impacting pilot and controller workload, and task complexity in maintaining optimal spacing and separation between aircraft. In addition, voice communications congestion and the

number of necessary controller traffic interventions will be reduced. Ground automation will assist air traffic controllers in identifying opportunities for using aircraft sequencing and spacing applications, and in assigning the time and distance interval between the aircraft. Aircraft avionics will calculate speed adjustments needed to meet the assigned spacing, and provide the speed change instructions to the crew to enable them to appropriately space their aircraft from the target aircraft. Pilots will adjust aircraft speed accordingly and notify the controller if the interval cannot be maintained.

Improvements to Separation Assurance

ADS-B will be the principal means of aircraft surveillance. Increased surveillance accuracy and update rates from ADS-B will improve safety and efficiency in the NAS.

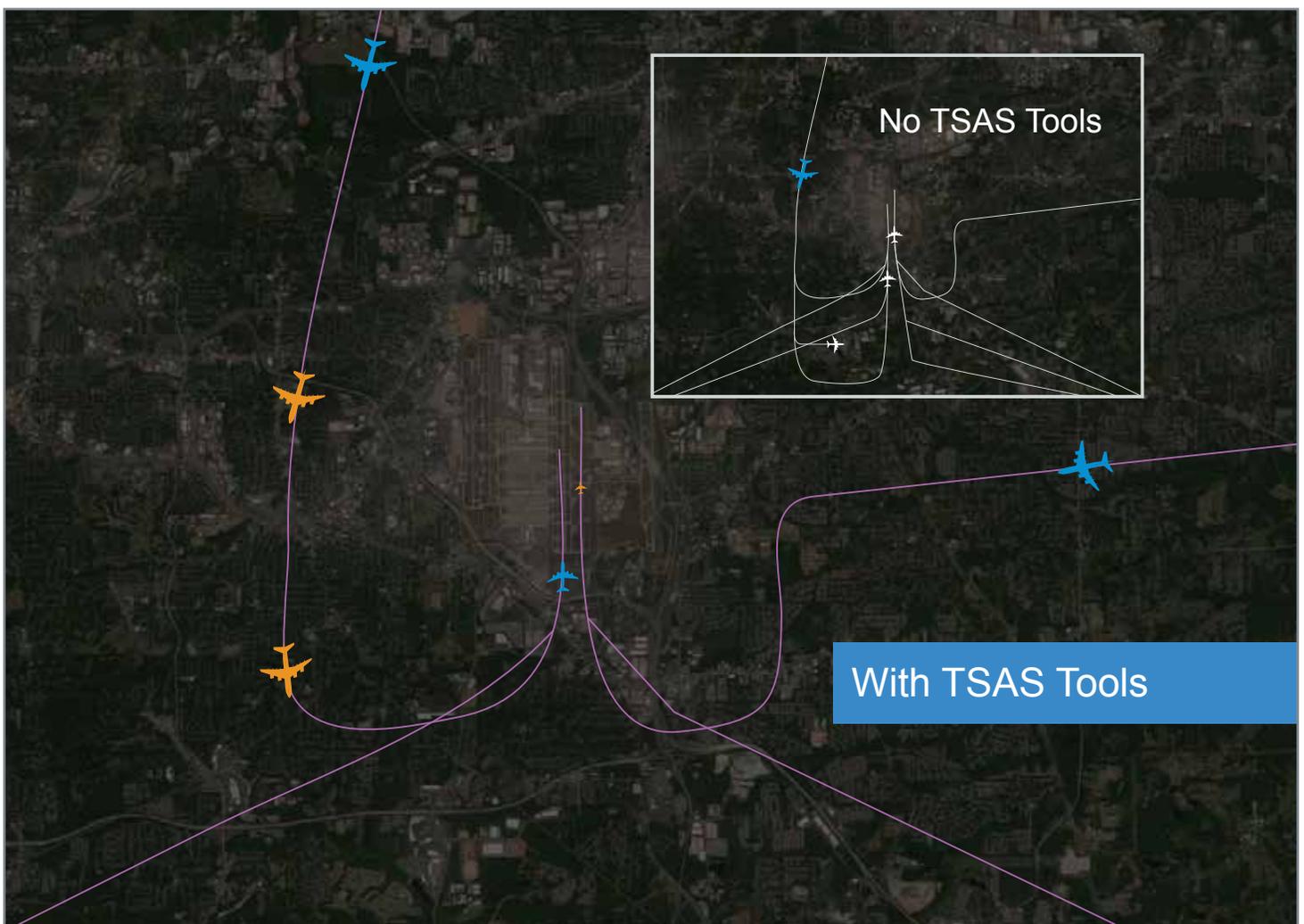


Figure 6: Operational Change with Terminal Sequencing and Spacing | Source: NASA

ADS-B combines precise aircraft location, direction, and ground speed derived from the Global Positioning System (GPS) with other data, and broadcasts this information from an aircraft to ATC and other nearby appropriately equipped aircraft. ADS-B avionics provide ATC with updated aircraft state information approximately every second compared to the 5 to 12 second update rate of radars used today. As aircraft equip with ADS-B by the January 2020 mandate, reduced separation standards will be possible in selected areas of en route airspace and controllers may be able to space aircraft closer to minimum separation standards.

ATC will use secondary surveillance radars to supplement ADS-B with radar providing backup and integrity monitoring (validation). Primary radars will continue to be used in terminal airspace to maintain safe ATC operations, as well as enabling radar services for operators in airspace where ADS-B is either not required or unavailable. Radar surveillance in en route airspace will continue to serve national defense objectives, and support advisory ATC radar services where available, through coordinated investments and operations of long-range radar systems by Department of Defense, Department of Homeland Security and the FAA.

Beyond 2025, the NAS may begin to implement alternatives to secondary radar as the backup to ADS-B. The FAA is investigating emerging sensor and signal processing techniques, and alternative procurement approaches to selecting future surveillance technologies.

On the airport surface, ADS-B is integrated with Airport Surface Detection Equipment—Model X and Airport Surface Surveillance Capability systems available at the busiest airports. As ADS-B equipage increases, surface surveillance systems will become even more robust. After 2020, ADS-B will also provide cooperative surface surveillance at many other airports that do not currently have this capability. Enhanced ATC capabilities for closely spaced parallel runway approach operations will be achieved through the use of ADS-B and expanded surface multilateration (MLAT) coverage integrated with terminal automation systems. The automated broadcast of aircraft and vehicle positions to ground and aircraft sensors/receivers will provide a digital display of the airport environment, which complements visual observation of the air-

port surface to improve situational awareness. Aircraft and ground vehicles will be identified and tracked to provide a comprehensive picture of the surface environment to the controller, equipped aircraft, and flight operations centers.

Decision support system algorithms will use enhanced target data to support identification and alerting of those aircraft at risk of runway incursion. These expanded capabilities are dependent on successfully demonstrating the ability to safely use MLAT alone for surface surveillance.

As all of the new PBN capabilities make greater use of airspace and changes to separation, new aircraft collision avoidance systems aboard the aircraft will use the more precise ADS-B surveillance data with new optimized surveillance and tracking algorithms to decrease the false alert rate for these procedures.

In the oceanic environment, international air traffic growth through 2025 and beyond will necessitate additional reductions in aircraft separation. The increasing number of FANS/Controller Pilot Data Link Communications/Automatic Dependent Surveillance—Contract aircraft operating over the Pacific, North Atlantic and Western Atlantic will enable the FAA to reduce longitudinal separation to 20–30 nautical miles (nm).

The FAA plans to evaluate alternatives to reduced oceanic separation including space-based ADS-B, which may provide oceanic controllers additional traffic situational awareness and aid in search and rescue. Reduced separation standards will be leveraged to expand user preferred routes over the oceans. Over the Gulf of Mexico, ADS-B surveillance using terrestrial receivers has allowed separation reductions to 5nm for equipped aircraft operating at altitudes over 28,000 feet, allowing quicker access and more efficient flight paths.

Increased Access to Airports

The FAA has made great strides in increasing access to airports through the expanded use of satellite-based navigation for precision approaches, and new rules that are bringing IMC capacity closer to VMC capacity. Moving forward, additional improvements will be made by expanding services for smaller airports and making surface operations more efficient for high density airports through

new automation, communications, navigation, and surveillance capabilities.

The FAA is expanding access to airports under low-visibility conditions by leveraging new and existing aircraft technologies combined with necessary ground infrastructure improvements. Visibility minimums for approach, landing, takeoff, and departure are dependent on aircraft equipment, ground infrastructure, and runway marking and lighting.

Some Enhanced Flight Vision System (EFVS)-equipped operators currently can use the equipment to meet approach and takeoff visibility requirements under certain conditions, as well as depart from some runways with reduced infrastructure (e.g., without centerline lighting). *Figure 7: Operational Change with EFVS* shows the operational change for pilots with this technology.

Ongoing rulemaking actions are working towards expanding EFVS approach operations to enable equipped operators to proceed with the approach when the weather is reported below published visibility or ceiling requirements, and to continue EFVS use all the way to landing. The higher performance of new and improved aircraft equipment has mitigated the necessity for some ground-based infrastructure, providing access to runways that do not have all of the traditionally required ground based infrastructure for a given procedure.

Research is under way to see if new technologies, such as EFVS and a highly accurate aircraft location display system in the cockpit, can improve low-visibility airport taxi operations. Further study will also determine how new, advanced vision system technologies, such as Combined Vision System and Synthetic Vision Guidance System, can provide access to airfields that would otherwise be closed during periods of poor visibility. The research



Figure 7: Operational Change with EFVS | Courtesy of Kollsman, Inc.

can also assess whether more reductions to visibility minimums can be safely approved using this technology.

These improvements are increasingly enabling pilots to safely achieve the lowest possible weather minimums for approach, landing, taxi, takeoff, and departure. Lowering the visibility minimum under which airport operations can be conducted increases airport capacity and reduces the number of costly diversions. The use of satellite-based technologies to conduct precision approaches will be expanded to accommodate lower visibility minimums for landing.

The Wide Area Augmentation System will continue to provide access for many pilots to the vast majority of the country's runways, by providing vertically-guided landing approaches in IMC conditions at all qualified locations throughout the NAS, as well as providing the navigation and positioning basis for the tightest separation critical procedures. The FAA will continue to work with industry to determine the appropriate role for Ground Based Augmentation Systems Cat III landing systems.

For non-towered and locally controlled airports, high-definition cameras able to pan, tilt and zoom; surveillance and meteorological sensors; microphones; radio communications; and decision support tools are being investigated as solutions for providing improved advisory and sequencing operations remotely. Research is under way, in collaboration with state and local governments, to determine whether these technologies can provide improved services in IMC beyond the current one-in/one-out limitations. Remote tower operations using other than direct visual means may provide for increased access, capacity, and safety.

At high density airports, controllers can quickly data link revised departure clearances to the cockpit when needed due to weather or other airspace changes. This decreases departure delays and avoids aircraft gridlock that can ensue when arrivals continue to land while delayed departures wait for revised clearances. Additional improvements to surface operations at high density airports will be discussed later in the next section of this document. ➔

Research is under way to see if new technologies, such as EFVS and a highly accurate aircraft location display system in the cockpit, can improve low-visibility airport taxi operations.

Seamless integration encompasses end-to-end operations and the data, systems, and people that have an operational role in the NAS. From flight planning to execution on the surface and through departure, en route and arrival airspace, operations will be seamlessly integrated because the necessary information will flow seamlessly across the various systems and people involved in the ATM process. The data that pilots, flight operations personnel, controllers, and air traffic managers use to perform their roles will be integrated and shared across ground automation systems and between the air and the ground. To achieve the desired operational benefits from seamless integration, the systems and tools will be designed and implemented in a manner that promotes usability.

Current FAA systems, including en route, terminal, and oceanic ATC and traffic flow management systems, are largely independent entities which share limited data. Although information exchange capabilities exist between the traffic management system and user's Flight Operations Centers (FOC), user input to traffic management initiative decisions are largely limited to voice planning teleconferences. Decisions are not based on a shared visual picture of status. They are based on forecasts using current NAS status tables and a textual description of the current operations plan.

The lack of information integration leaves the human operator to synthesize the data and make coordination decisions with partial situational awareness. There can be multiple unsynchronized views of the aircraft's 4DT such as the controller's, pilot's, and dispatcher's individual mental models, multiple unique trajectories within the ATC separation assurance, traffic flow management, and FOC automation tools, and the trajectory contained within the aircraft's flight management system. The lack of shared information hinders the ability to create accurate demand and capacity predictions and forces traffic managers to make broad-based decisions that account for the large amount of uncertainty. As a result, decisions that could be made early in the flight to resolve separation or flow is-

ues with minimally invasive trajectory changes are made very late when there is less uncertainty, at the cost of major flight path disruptions.

Users base their operational decisions on their chosen source of weather forecasts and limited understanding of the true capacity/demand imbalance in the system. Similarly, the FAA assumes that all flights will be ready to depart based on the filed flight plan departure time, and receives no additional data from users on the likelihood of that flight being ready to depart on time.

NextGen will improve operational decision making and execution through improved data sources, the integration of data within and between systems, and the sharing of information between the FAA and user community. Ensuring that FAA, aircraft, and FOC personnel and automation systems are basing air traffic management decisions on the same information is an important component of the future NAS. *Figure 8: Operational change with SWIM* presents a graphical depiction of this operational change using System Wide Information Management (SWIM).

The digital exchange of all NAS information is a vital component to ensuring a common understanding of demand and capacity. The sharing of digital data is required to ensure a common situational awareness between the FAA and the user community, and a necessary precursor for effective negotiation required to make trajectory operations work. By using automation, central to the interchange of information, the NAS shifts from supporting flight paths with individual trajectories to a full 4-D trajectory environment.

The collection, integration, and dissemination of data into information must be treated as an integral part of the modernization. To do this, the information has to be intentionally managed in a manner that promotes discovery, access, and consumption by all authorized consumers. Subsequently, sharing the managed information on a system-wide basis will allow the air traffic management

(ATM) community to conduct its business and operations in an even safer and more efficient manner.

The display of information must be integrated in a manner that facilitates access and use by the human operator on the ground and in the air. This will be especially important for air traffic management in a mixed equipage environment where all users will not have the navigation performance to fly all routes nor the equipage to participate in advanced operations such as the ability to receive a complex reroute clearance from Data Comm. ATM tools and information displays will be designed and implemented in an integrated way that assists controllers and traffic managers in the identification and use of the appropriate operational options for each user based on their equipage. If these capabilities are not integrated seamlessly, the full potential benefit from these operational improvements will not be realized.

The future ATM system will be founded on unambiguous information exchanges, high integrity information management, and collaborative decision making. The key to efficient operation of the ATM system is interoperability within the ATM environment. This will be enabled by advanced communications systems, standard interfaces,

authoritative source data, and information management based on standard information exchange models.

Information Management

Information management and the mechanisms which facilitate accurate information distribution through common standards and global interoperability are an important element of the future NAS. The focus on information management will result in improved operations that avoid inefficient processes such as manual data input and duplicate data entries. Information management improvements will include improved data quality (e.g., accuracy, resolution and, integrity) that is monitored and controlled, the timely distribution of information, and digital exchange and processing mechanisms. Enterprise Information Management will be the strategic discipline for management, governance, and use of information.

Improved information-sharing mechanisms will enable the development of a common operating picture that includes the best possible integrated depiction of the historical, real-time, and planned or foreseen future state of the ATM situation. An improved and common operating picture will result in significant improvements in strategic planning for

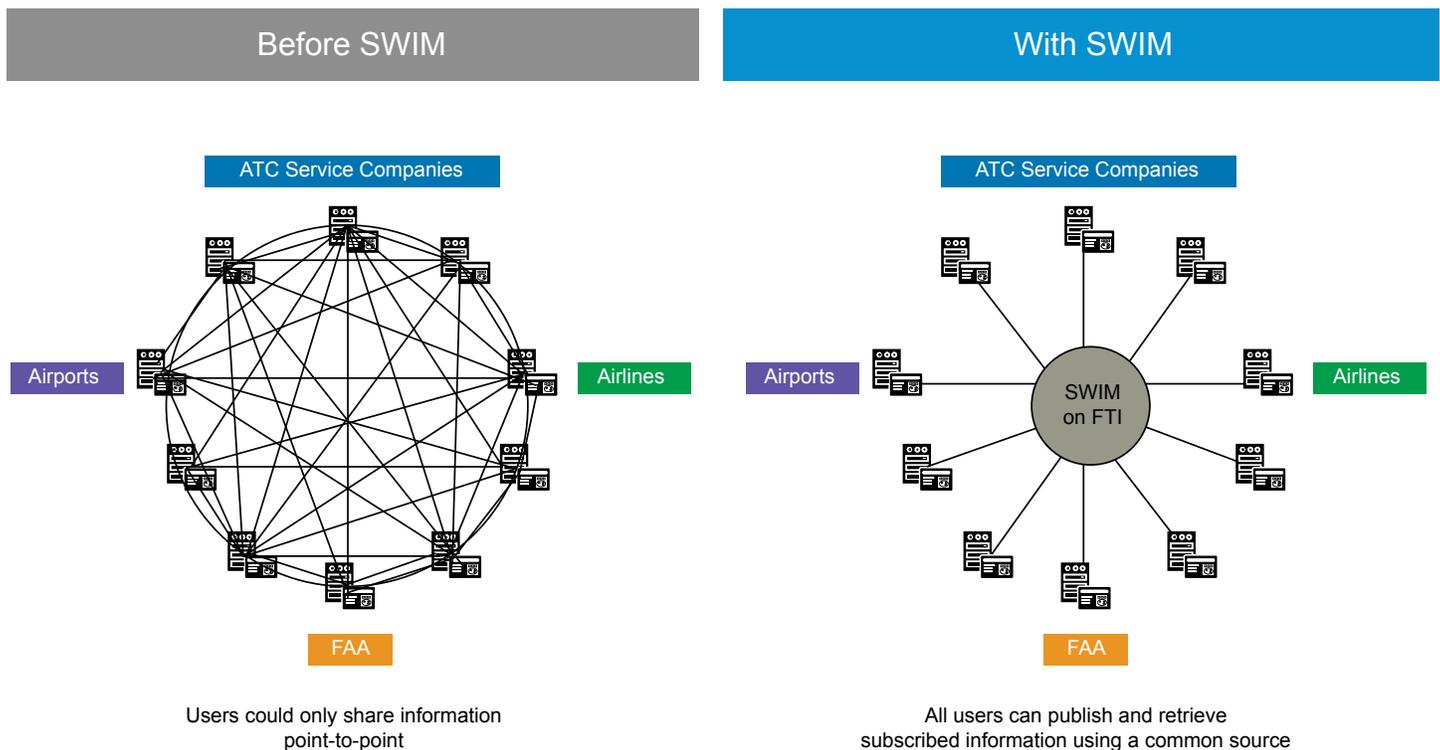


Figure 8: Operational change with SWIM | Source: FAA

the FAA and operators. It must account for differences in the frequency and magnitude within which different data elements change over time from nearly static to extremely dynamic. Users must be able to easily access and filter the information they need.

To realize this improvement, information-sharing mechanisms must ensure global interoperability beyond a single information domain perspective to account for the integration of data across other relevant domains. This requires that common geospatial and temporal components be represented consistently across the data sources. ATM systems will fuse information from multiple data domains, such as aeronautical, flight, and weather data, to support knowledge-based decision making. The way forward involves managing data elements as information, considering all these aspects.

NextGen will change the current method of raw data exchange to a model that uses data as a service, using standard exchange models accessible across common data distribution platforms using SWIM. Common exchange models based on international standards provide opportunities for rapid development at lower cost for all nations and regions. To meet the requirements of the global ATM community, several aspects of information management have been improved, including operational needs identification, setting efficiency objectives and making use of emerging information technologies.

Standards for the Flight Information Exchange Model, the Weather Information Exchange Model, and the Aeronautical Information Exchange Model will provide the means to better manage our future internal enhancements, and facilitate coordination and cooperation in near real-time with our neighboring air navigation service providers. Implementing standardized exchange models enables the ATM community to take advantage of a range of commercial applications and tools. Information exchange standards use more robust parsing software to support common data formats. Additional data fields can be added to the model without causing all software interfacing with the information to be updated to accommodate the change, unless the new information is desired. The ability to share standard data with our global partners will provide improved surface and flight efficiencies, and environmental benefits for international flights.

Improved Information Incorporated Into Decision Making

Static and Dynamic Information Access

All information required for safe flight navigation is available on demand. This includes both static (e.g., terrain, obstacles, information contained in Letters of Agreement), and dynamic (e.g., Notices to Airmen and weather) information. Users can access this information from anywhere through information portals using SWIM, and receive tailored information based on the planned route of flight. The information will also be made available in the cockpit via third party service providers.

The capture and distribution of special activity airspace (SAA) definition, schedules, and status information will be automated and such information will be integrated into ATC and flow planning automation. This capability will provide increased access to SAA airspace and facilitate flight planning. In order to accommodate new entrants, as discussed later in this document, SAA boundaries may become increasingly dynamic making this capability extremely important for meeting new challenges.

Improved Weather Information Integrated into Decision Making

The majority of air traffic control delays in the current system are due to weather. Hazardous weather conditions reduce airspace capacity, resulting in unavoidable delays. Today's reliance on uncertain forecasts and cognitively-generated solutions contribute to the volume of airspace around which aircraft are rerouted for a given weather event.

NextGen improvements will provide decision makers with access to advanced automation capabilities that directly and advantageously integrate weather information into decision support processes and tools. The amount of subjectivity in today's weather interpretations will be reduced significantly. Improvements in weather data and forecasts provide opportunities to automate the translation of weather data into aviation constraints and NAS impact assessments, and to assimilate this data into air traffic management decision making. Decisions associated with the management of air traffic in the face of weather

constraints will be more consistent and predictable. Overall decision making will improve during adverse weather events, in all domains and times of interest, by leveraging state-of-the-art, translated weather information that is integrated into automated decision processes.

The increased connectivity of the aircraft expands the amount of information available on the state of the atmosphere, both geographically and temporally. With this change, detailed advisory mappings of turbulence, icing, and winds are available to the FOC and the flight deck. These frequently updated mappings enable the aircrew to better manage the flight without relying on verbal exchange of ride conditions. In addition, air-to-ground data exchanges will provide a means for the aircraft to provide additional observed and sensed weather information which can be used to improve the understanding of weather conditions and forecasts.

Improved Integrated Surface Information

Currently, tower operations are conducted by air traffic controllers with limited automation support. Tower controllers use paper flight data strips based on information from the en route automation system. At high density airports, they also have a surface radar display, a traffic management display, and a view of terminal radar data. Tower controllers cognitively synthesize data from these disparate systems to conduct strategic and tactical planning for the airport. As airport operations are not automated per se, information on traffic status in the airport environment is not shared with other automation systems.

NextGen will provide an automation platform to support tower operations at high density airports that will allow for the electronic processing and distribution of flight data, the integration of flight and surveillance data, and the sharing of airport data with flight, fixed based, and airport operators. These capabilities will improve airport traffic management through the integration of arrival, departure, and surface scheduling tools. The process of pushback, taxi, clearance, and departure becomes more consistent and predictable.

Surface automation tools will integrate estimated arrival times from en route and terminal time-based metering tools with surface departure flow management tools

to generate predicted airport and runway schedules for arrivals and departures, providing better demand/capacity balancing and increased overall airport capacity and efficiency.

The integration of airport surface surveillance information at larger airports provides vital movement information. Integrating surface surveillance information into enhanced decision support systems provides earlier flight status information that improves flow planning. Departure scheduling and sequencing will be based on arrival traffic, flight operator schedules, and the available capacity of departure merge points. Controllers will better assess departure routes relative to weather and traffic flow constraints and suggest pre-coordinated departure routes. The use of automated virtual departure queues will minimize the physical queue in the movement area, saving fuel and reducing emissions. Automation will assist controllers with integrating surface movement with departure sequencing to ensure departing aircraft meet departure schedule times.

Beyond 2025, controllers will be able to send generated taxi instructions to the aircraft via data link, and automation will assist with monitoring the aircraft's progress against the taxi instructions. Surface automation tools to assist with taxi route planning and conformance monitoring will be developed to enhance efficiency and safety.

Collaborative Air Traffic Management

Expanded information exchange mechanisms and improved information sources create opportunities for a more Collaborative Air Traffic Management (CATM) environment based on increased sharing of data between the FAA and airspace users. This collaboration will extend to FOCs and the aircraft to enable execution of flight trajectories that more closely align to business objectives. Collaboration will range from managing strategic flow constraints to individual separation resolutions.

A shared view, constructed from a digital exchange of information among systems, improves the ability of each party to participate in timely decision making when trajectory changes are warranted. *See Figure 9: Operational Changes with CATM on page 28.* User's objectives are evaluated and prioritized to find a trajectory that most

closely meets the user’s needs, while adhering to the prioritized constraints. Users can receive feedback on constraints based on either entire routes or route segments. Once airborne, FOCs may have input into their preferences for reroutes depending on the complexity of the constraint and the amount of time available before the decision needs to be made.

In the terminal environment, airport and flight operators share surface flight status data with ATC automation platforms to improve estimated flight times and demand forecasts, thereby improving coordination and efficiency among stakeholders. Automation will give the FAA and operators a common picture of individual flight status as well as a better picture of overall NAS demand.

The sharing of surface surveillance information that precisely tracks aircraft, vehicles, and objects on the surface

improves coordination, efficiency, and situational awareness. The data will assist users with planning and staging their aircraft around the airport surface more efficiently. Surface processes that are more efficient will enable flight operators to reduce fuel consumption and emissions.

CATM and information sharing improve the demand estimates against which constraints are assessed. With the integration of time based automation across the NAS, the addition of surface automation, increased user inputs on flight readiness, and the downlink of aircraft trajectory data, the FAA will achieve more accurate demand predictions. With an improved demand picture, traffic managers can better assess whether there is a demand/capacity imbalance and make better decisions about the need for scheduling, sequencing and other traffic management initiatives. ➔

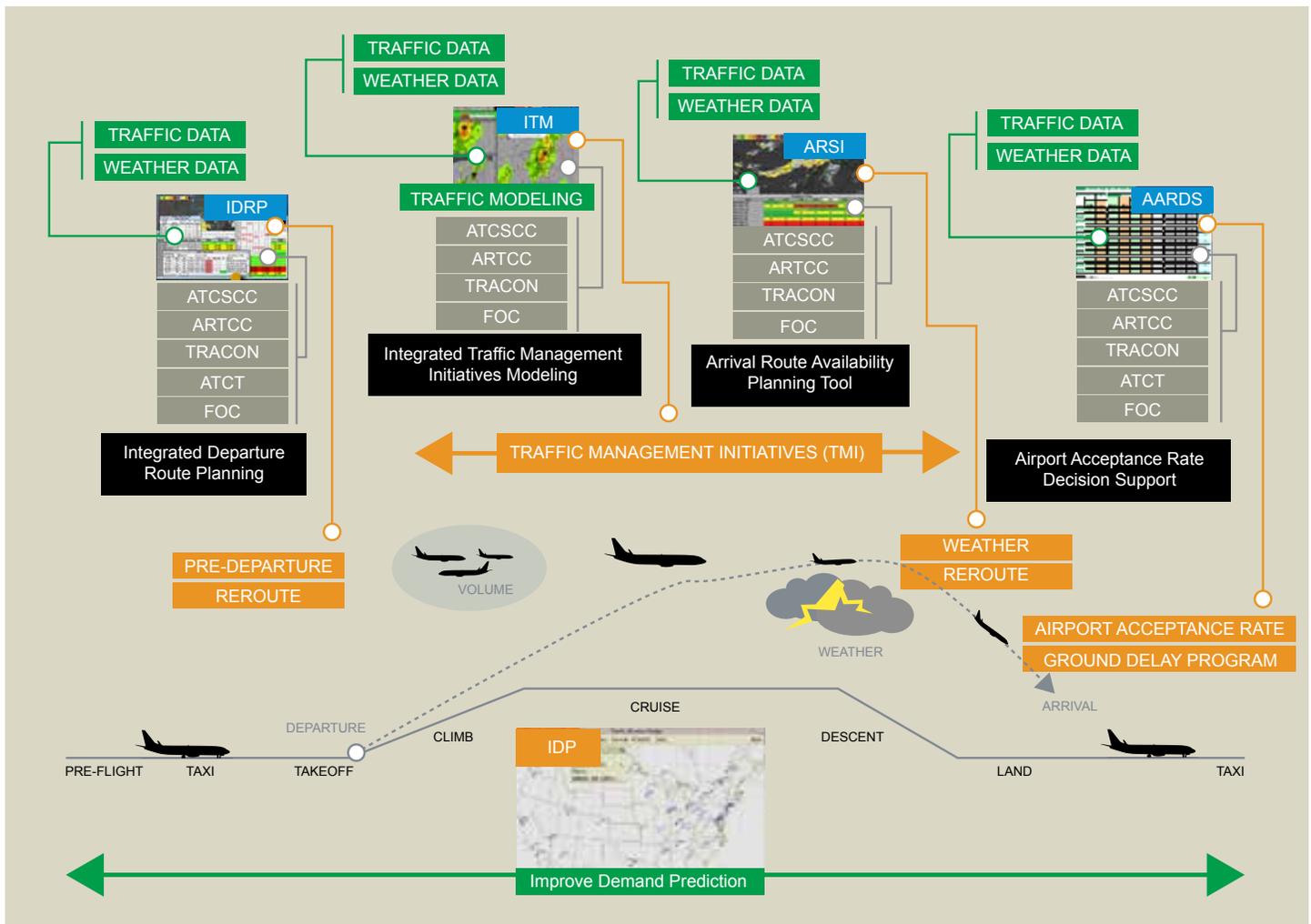


Figure 9: Operational Changes with CATM | Source: FAA/NextGen/MITRE

Surface automation tools will integrate estimated arrival times from en route and terminal time-based metering tools with surface departure flow management tools to generate predicted airport and runway schedules for arrivals and departures, providing better demand/capacity balancing and increased overall airport capacity and efficiency.

Meeting New Challenges

The FAA must work towards mitigating new challenges and find affordable ways to safely integrate new entrants. New emerging cybersecurity threats must be mitigated to ensure shared data access does not introduce risks to operations and system integrity. The FAA will look for opportunities to use new technologies to make the NAS more resilient in the case of a prolonged loss of service and in the face of new service interruptions introduced by an increased reliance on satellite-based services. As NAS services and technologies expand, the FAA must look for better ways to do business to contain development, implementation, and operating costs. Lastly, the workforce must be given the skills needed to successfully operate and maintain these modern technologies.

New Entrants

The demand for access to airspace by Unmanned Aircraft Systems (UAS) and commercial spacecraft is evolving. The FAA is actively pursuing ways to integrate these new entrants into the NAS in a safe and efficient manner with minimal impact on other NAS users. This involves determining the required automation support, as well as the surveillance, communication, and navigation capabilities that account for the unique performance characteristics of UAS, launch, and reentry vehicles. Many NextGen technologies are expected to facilitate this integration. NextGen improvements in Collaborative Air Traffic Management and the management of special activity airspace will be leveraged to accommodate these new entrant operations in the NAS.

Commercial Space

The move to an information-based model in the NAS allows launch and reentry vehicle operators to be more fully integrated in strategic and tactical planning. Operators will provide their unique mission characteristics and operational constraints, such as necessary launch windows, and receive access to current and forecast states of the NAS. Many of the collaborative air traffic management

improvements, discussed previously, are leveraged to assist with commercial space flight planning. Operators will have the ability to trial-plan missions and submit them for analysis and feedback. Automation will evaluate proposed mission parameters and assess NAS impacts. Feedback will be provided to operators to assist in developing mission parameters (launch/reentry/landing schedule, window duration, location, and trajectory) where possible that minimize NAS impacts while enabling mission goals to be realized. The mission planning process will be streamlined, reducing the amount of lead time needed to coordinate NAS resources. Analysis of past performance data will be used to improve pre-mission planning feedback to operators.

The FAA is seeking to transition from an approach that protects from failure using preemptive airspace restrictions to an approach that operates for success through limited airspace restrictions, increased mission monitoring capabilities, and the ability to effectively respond to contingencies. (See *Figure 10: Future Commercial Space Operations*). Operations will benefit from improved ground, and in some cases, vehicle-based communication with operators. Real-time launch and reentry vehicle tracking will be integrated into FAA air traffic management systems. Launch and reentry vehicle health will be monitored by the operator and status provided to traffic managers in real-time to support quick implementation of contingency plans in the event of a mission failure.

New automation capabilities will improve the ability of traffic managers, controllers, and air-operators to respond to actual off-nominal events in near real-time. Special Activity Airspace (SAA) protects aircraft from entering airspace in which space operations pose a potential hazard. NextGen improvements will facilitate access to SAA for launch and reentry vehicle operations. Automation will replace the current manual processes for displaying active SAA volumes that protect aircraft from the trajectory of the launch vehicle, and the associated aircraft hazard area SAA that is created to protect aircraft from debris in the

event of a catastrophic launch or reentry event. This real-time off-nominal response capability will allow nominal hazard areas to be smaller and active for shorter time durations, reducing NAS impacts.

The FAA is currently researching the development of separation standards between aircraft and space vehicles, focusing initially on the benign, non-explosive phase of flight for the space vehicles, such as captive-carry operations and unpowered glide flights. This research is aimed at developing more advanced concepts that separate launch and reentry vehicles from other aircraft based on separation standards as opposed to airspace restrictions. The FAA is also researching concepts to explore the implications of potential international point-to-point suborbital space vehicle operations.

Unmanned Aircraft Systems

Significant efforts are ongoing to determine how UAS can be safely integrated into the NAS, with a focus on provid-

ing a clear delineation of separation responsibility; automation support where needed for the FAA to fulfill that responsibility; and the appropriate surveillance, communications, and navigation capabilities that account for the unique attributes of UAS.

UAS operations in the NAS in controlled and uncontrolled airspace will be increasingly common. New rules will be published, and policies and procedures created to support a range of UAS operations, reducing the need for waivers and exemptions. ATC and UAS operators will take advantage of NextGen technologies and capabilities, as they become available, to support increasing UAS activity in the NAS.

For those UAS operations that are integrated, safety will depend on compliance with conventional aircraft operating principles augmented by unique requirements for UAS. For example, the use of a detect and avoid (DAA) capability for maintaining separation from other aircraft and obstacles could be required for certain operations.

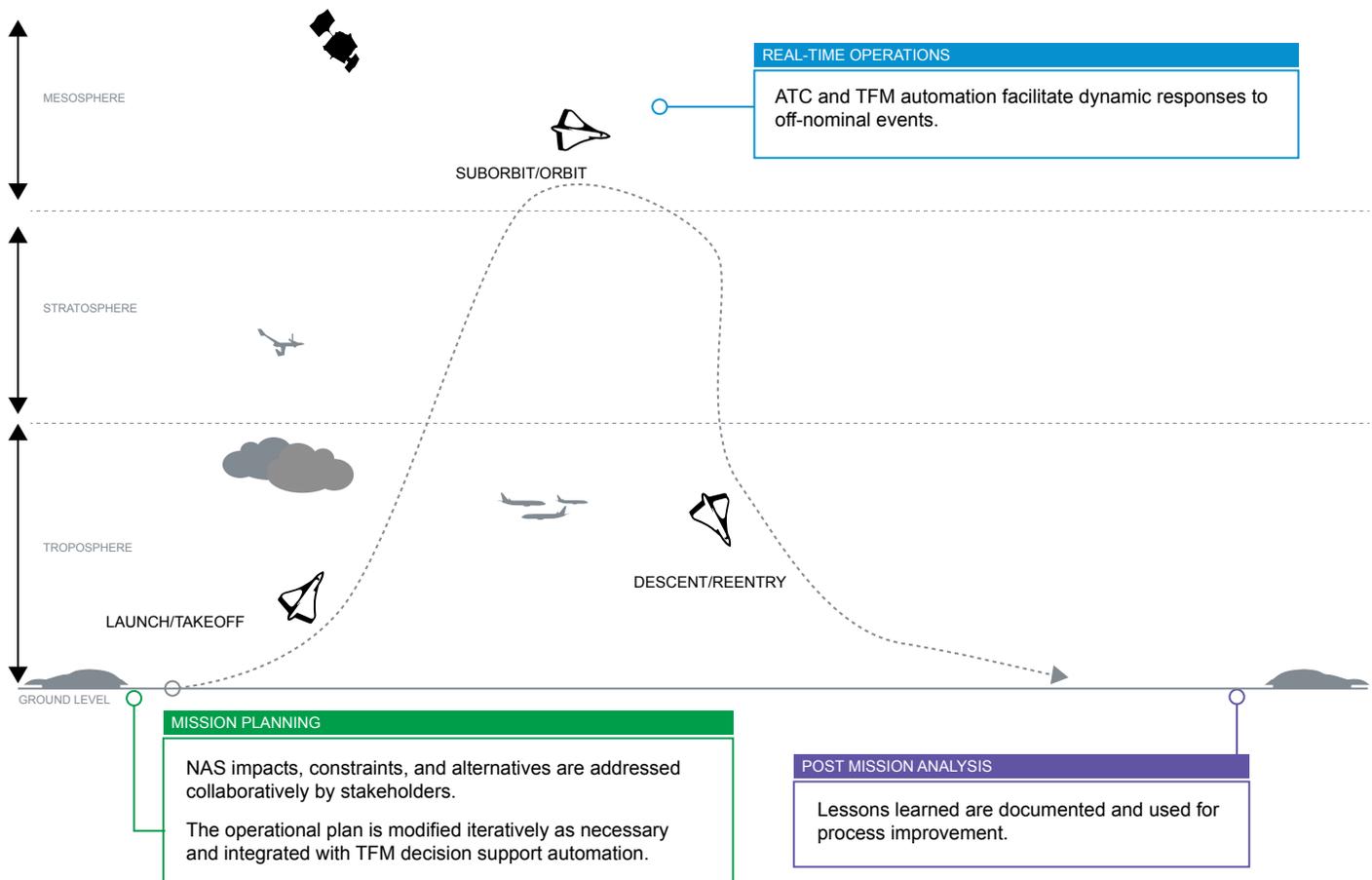


Figure 10: Future Commercial Space Operations | Source: FAA/NextGen/Commercial Space

Those UAS that cannot comply with the principles for integrated operations will be managed by rules, procedures, and/or airspace constructs (route or allocated airspace). In some cases, safety will be ensured by limiting operations to low altitude designated areas or by applying other risk mitigations as appropriate to safely enable the operation. In collaboration with our partner agencies and industry stakeholders, the FAA will continue to research potential concepts for managing UAS operations safely within uncontrolled low altitude airspace.

With all operations, separation responsibility will be clearly established and the appropriate ATC procedures will be in place to support UAS operations. See *Figure 11: Future UAS Operations*, which shows the range of UAS operations envisioned in the future NAS. Enhancements to air traffic automation will assist with assessing the impact of UAS activities on other operations in the NAS. Proce-

dures and policies will resolve competition for NAS resources in a predictable, efficient, and equitable manner. UAS operators who file flight plans will receive feedback on airspace constraints. Automated assessments during flight plan negotiation will consider unmanned aircraft performance limitations and their impact on overall NAS operations. Air traffic controller tools will be improved to handle the unique flight characteristics of UAS operations.

NextGen capabilities, such as the NAS Voice System (NVS), will enable the seamless integration of communications between pilots-in-command (PIC) of UAS and air traffic controllers. Controllers will communicate to all pilots, whether via ground-to-ground or air-to-ground communications, using the same systems. This will improve the efficiency and reliability of exchanges between the UAS pilot and ATC, while maximizing situational awareness and minimizing latency concerns.

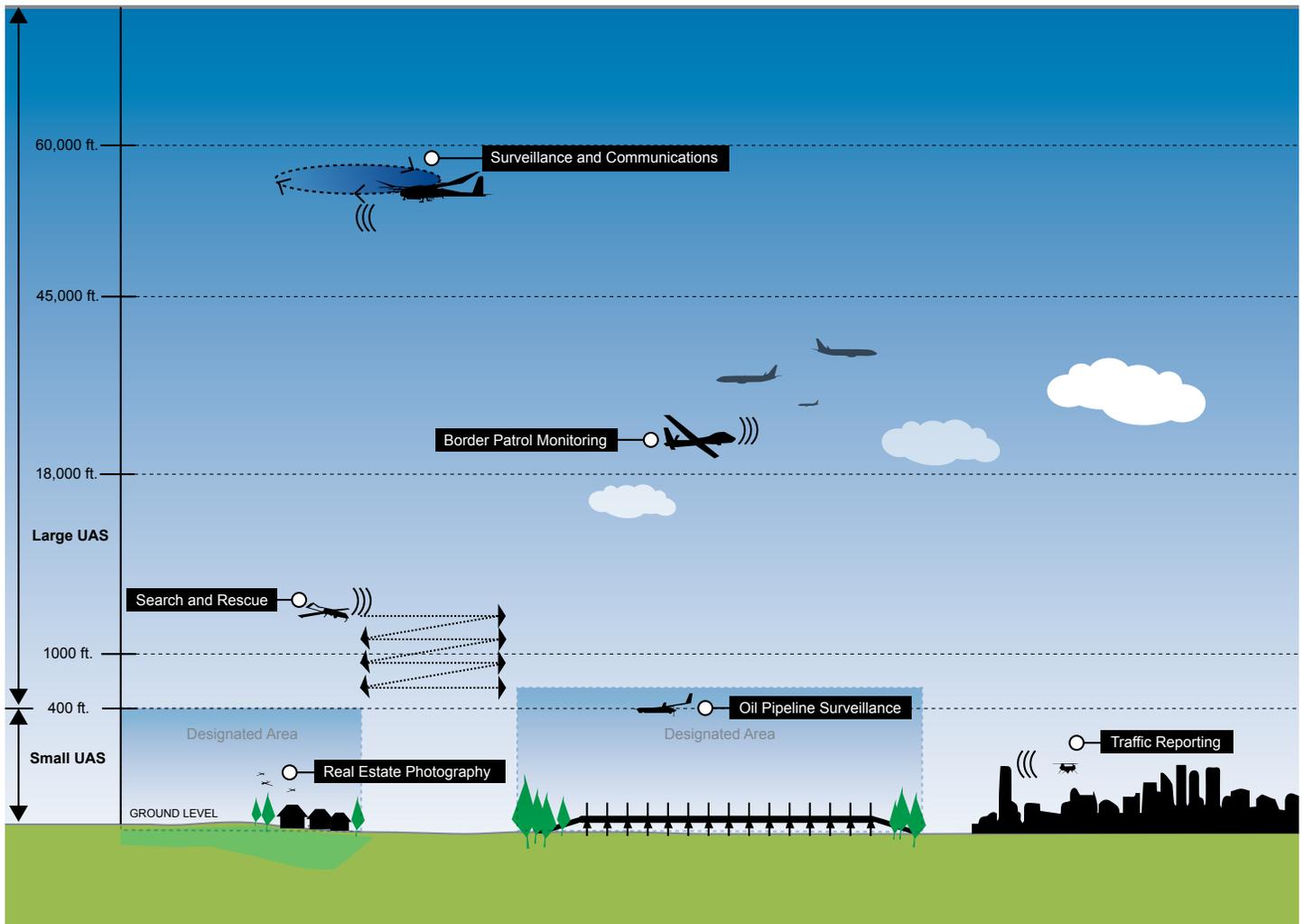


Figure 11: Future UAS Operations | Source: FAA/NextGen

Environmental Protection

The FAA is working to find solutions to protect the environment in ways that allow for sustained aviation growth. Through its environment and energy strategy, the FAA is advancing analytical capabilities, developing new operational procedures, maturing new aircraft technologies, removing the barriers to sustainable alternative jet fuels, and implementing policies, standards, and measures to reduce noise and emissions, and improve energy efficiency. These efforts are providing societal benefits by limiting and reducing future aviation environmental impacts to levels that protect public health and welfare, and ensure energy availability and sustainability.

Environmental analytical capabilities, such as those provided by the FAA's Aviation Environmental Design Tool, enable thorough analysis of aviation's environmental effects and interdependencies. Environmentally efficient operational procedures, such as OPDs, are being designed in ways that reduce the environmental impacts of aircraft operations. PBN solutions that result in more direct routing reduce fuel consumption and emissions during ascent and descent. Improvements in traffic management strategic planning will reduce delays on the ground and in the air, resulting in improved environmental performance.

Historically, new technologies have offered the greatest success in reducing aviation's environmental impacts. New engine and airframe technologies will continue to play key roles in achieving aviation environment and energy goals. The FAA is looking for ways to accelerate the development and commercial deployment of environmentally promising aircraft technologies and sustainable alternative fuels. Aircraft technologies focus on reduction in aircraft noise, emissions, and fuel burn.

Sustainable alternative jet fuels are a key element of the FAA environment and energy strategy. These fuels can help the environment by reducing emissions that contribute to climate change and degrade air quality. In addition to helping the environment, these fuels could also help to expand jet fuel supplies beyond petroleum, improving jet fuel price stability, enhancing supply security, and contributing to economic development. The FAA has taken a comprehensive approach to overcome barriers to the development and deployment of sustainable alternative jet fuels. The agency has established strong partner-

ships with the private sector, international partners, and other federal agencies, and facilitates exchanges among the alternative jet fuel stakeholder community.

Cybersecurity

The increasingly interconnected NAS system presents new cybersecurity challenges. The FAA will take an active role in characterizing system deficiencies, and prioritizing investments to remedy the gaps; evaluate new technologies that provide cyber resilience; and provide testing and prototyping support for modifications. Guaranteeing cyber resiliency will mean taking a fresh look at how the overall NAS behaves under sustained malicious actions by well-equipped adversaries.

While the threats are many, there are technologies and new research areas that promise solutions to some of the cyber challenges. The FAA will explore ways to take advantage of these new advances through examination of foundational competencies and emerging capabilities such as resilient self-adaptation and big data analytics. Methods to secure the NAS in an environment where the trustworthiness of some systems is unknown will be researched.

The development of a robust cyber testing capability will help to identify and quantify known risks. The development of cyber resilience measures will assist with prioritizing investments. These techniques will be used to identify ways to protect the NAS in novel, more timely and resilient ways.

NAS Sustainment

The FAA must meet the challenge of balancing funding requirements for providing new services against those needed to maintain existing FAA facilities and equipment. ATC facilities provide the backbone for the current and future NAS. Many FAA facilities are old and there is a maintenance backlog to sustain or replace buildings, power, and environmental systems.

There is also a continuing need to technically refresh commercial products that are no longer supported in the commercial market place. The FAA will need to continue to balance the need for sustaining the NAS infrastructure against the need to improve services in a tight budget environment.

NAS Resiliency

New NextGen technologies will make it possible for an FAA facility to access another facility's flight plans, surveillance, and communications enabling the swift resumption of operations at a different location. NVS will provide a more flexible voice communications architecture using Voice over Internet Protocol (IP). This more agile and flexible communications architecture will contribute to a more resilient NAS by enabling the rapid transfer of existing ground-to-ground and air-to-ground voice communications to other facilities during off-nominal events. Improvements in information exchange methods will facilitate the transfer of flight and surveillance data. These capabilities will enable the restoration of critical services to achieve 90 percent of normal operations within 24 hours of a major outage, and 100 percent of critical services in as little as one week.

Some commercial technologies are becoming obsolete and will no longer be available for use within the NAS. The FAA will continue to monitor these technological changes so that services that rely on commercial infrastructures can still be provided as antiquated technology is no longer supported. One of the key areas where this transition is already taking place is the telecommunication industry's shift from time division multiplexing to IP services. This shift provides a challenge that will affect tens of thousands of circuits across the NAS. New technology must ready the NAS for this shift through system modernization and technology refresh for native IP compatibility. The benefits of this technology change will result in a more resilient NAS due to the rapid configurability of IP communication services.

The shift to satellite-based navigation and surveillance results in the need to find a cost-effective solution to ensure resiliency in the event of a loss or interruption of these satellite-based services.

Cost Containment

As new services are accommodated, the FAA must rationalize and rebalance existing services while modernizing our existing infrastructure in order to reduce costs. Building the more efficient NAS of the future requires difficult decisions regarding redefining service offerings and rebalancing resources to align with future air traffic demands.

The balance between improving NAS services through NextGen and sustaining existing services is what makes the NAS Efficient Streamlined Services (NESS) initiative so important. NESS matches air traffic services, resources, and facilities to air traffic demand, including reducing and eliminating redundant or outmoded services, facilities, and equipment, as well as reducing maintenance costs. NESS also explores innovative business methods, technologies, and techniques for offering similar services in a more efficient and cost effective manner. The future of the NAS is dependent on achieving NextGen benefits, while streamlining and adapting services to integrate new operations. The FAA must identify smarter, safer, and more efficient ways to provide NAS services and meet new user priorities.

In order to streamline the timely development and delivery of PBN procedures, automation tools will be developed to support the review and maintenance of procedures which will reduce recurring costs and provide additional resources for new development.

Reducing the number of unique systems that provide the same capability will also be examined as a way to reduce cost. For example, NVS will replace numerous current voice switching systems with a common platform that will support controller-pilot and controller-controller voice communications.

Many of the key software, computer processing, and information management capabilities required for the NAS are now commercially available commodities. The commercial marketplace has adopted standard interfaces, languages, and protocols to gain cost and operational efficiencies. Information-intensive industries like banking and internet commerce have driven the commercial marketplace to develop fast, highly reliable, and secure network-oriented information systems that may be capable of meeting NAS requirements. The rapid changes in technology, software, and systems also drive the need to modernize the approach, standards, and methods of securing the FAA's network, along with improvements to the technology and processes used to support NAS operations.

The global marketplace has driven commercial logistics and supply-chain management to a new level. While the FAA and, in particular, air traffic management (ATM), require unique capabilities, these can be built on current

commercial technologies and business processes. NextGen will continue to implement new capabilities and operational improvements through strategic enterprise enhancements utilizing new technology and commercial services. This will create opportunities for standardization resulting in efficiencies and cost savings by reducing unique system implementations.

In conjunction with other government agencies, the FAA monitors weather and traffic in the NAS using an array of radar technologies. Research will continue to look for new technologies that can integrate weather and traffic surveillance technologies to replace separate legacy radar systems. These systems could be distributed and interconnected to improve coverage, performance, and overall system robustness. Opportunities to replace all secondary surveillance beacons with multilateration will also be explored.

PBN services will match the capacity and efficiency demands of airports and routes. As a result, the FAA will reduce NAS operating costs by eliminating surplus capabilities — such as procedures and ground infrastructure — in locations where they are not needed for backup, in the event of a GPS service disruption.

Instrument Landing System (ILS) rationalization will assess the need to retain CAT I equipment at sites where it is not needed for back-up or does not benefit a particular procedure. The FAA has added Distance Measuring Equipment (DME) capability to provide GPS backup for lateral navigation in en route and high-density Metroplex airspace. This addition will assure the continuous availability of high-efficiency PBN procedures. For those users not equipped with DME, finding an alternative backup to GPS, other than VORs, is a challenge that must be met. In the interim, a minimum operational network of VORs will be maintained while new technology to eliminate the need for VORs is explored.

The FAA will investigate the creation of a “service-oriented navigation” architecture that will research technologies that use any signal emitters for which a location and time can be discerned. This would allow for a more robust and less vulnerable positioning capability than those afforded by relying only on U.S. government assets.

NAS operational maintenance will be improved through increased efficiencies in maintenance practices and fast-

er restoration of services through improved asset tracking, streamlined parts ordering, more centralized remote maintenance and monitoring, and the implementation of Reliability Centered Maintenance (RCM). RCM will determine the appropriate failure management strategies to ensure safe and cost-effective operations of a physical asset in a specific operating environment. These improvements will be brought about by an information-rich, automated, integrated, and pro-active based operations and maintenance environment.

As NextGen operational capabilities are delivered, the FAA will examine the NAS-wide impacts and identify the extent to which deployed system capabilities address the original objective. New system engineering practices, such as model based systems engineering, will ensure that the appropriate rigor is applied to the planning, acquisition, development, and implementation of capabilities. New best practices will ensure stakeholder benefits are delivered at the least cost. Opportunities for improved and more efficient processes will be explored such as agile acquisition, improved engineering techniques, and architecture models, and overall service improvements through the use of new technology, such as cloud computing.

To support the rapid integration of new capabilities, new engineering and acquisition processes will be used, where appropriate, to iteratively and frequently deliver smaller increments of new functional capabilities in a disciplined fashion. The FAA will look for more opportunities to collaborate with users and other stakeholders to identify, prioritize, and deliver capabilities in a manner that is more responsive to changes in operations, technology, and budgets.

Workforce

The future workforce is growing up in a digital age, with information instantly accessible and decision-support technology readily available through software applications. It embraces the technology and information that NextGen brings to air traffic and NAS operations management. The future NAS remains a human-centered NAS. All improvements require full investigations of how they may change the techniques and manner with which ATM service provider and operator personnel conduct their roles and tasks. Operational transition strategies will be used to guide selection and training to meet the evolving knowl-

edge, skills, and abilities of the workforce.

NAS evolution requires innovation throughout all life-cycle phases, from the research laboratory to operations in the field. The use of information technology will make internal processes and workflow easier across all lines of business. ATM will use this technology to collaborate with the user community, while technical operations personnel will use the technology to improve logistics and maintenance practices.

New capabilities, most notably controller decision support automation applications and the introduction of air-to-ground data communications will enable air traffic controllers to handle more traffic by reducing workload associated with tasks such as sequencing and spacing, and route clearances. The workload savings associated with these tools will enable controllers to provide increased service to NAS users.

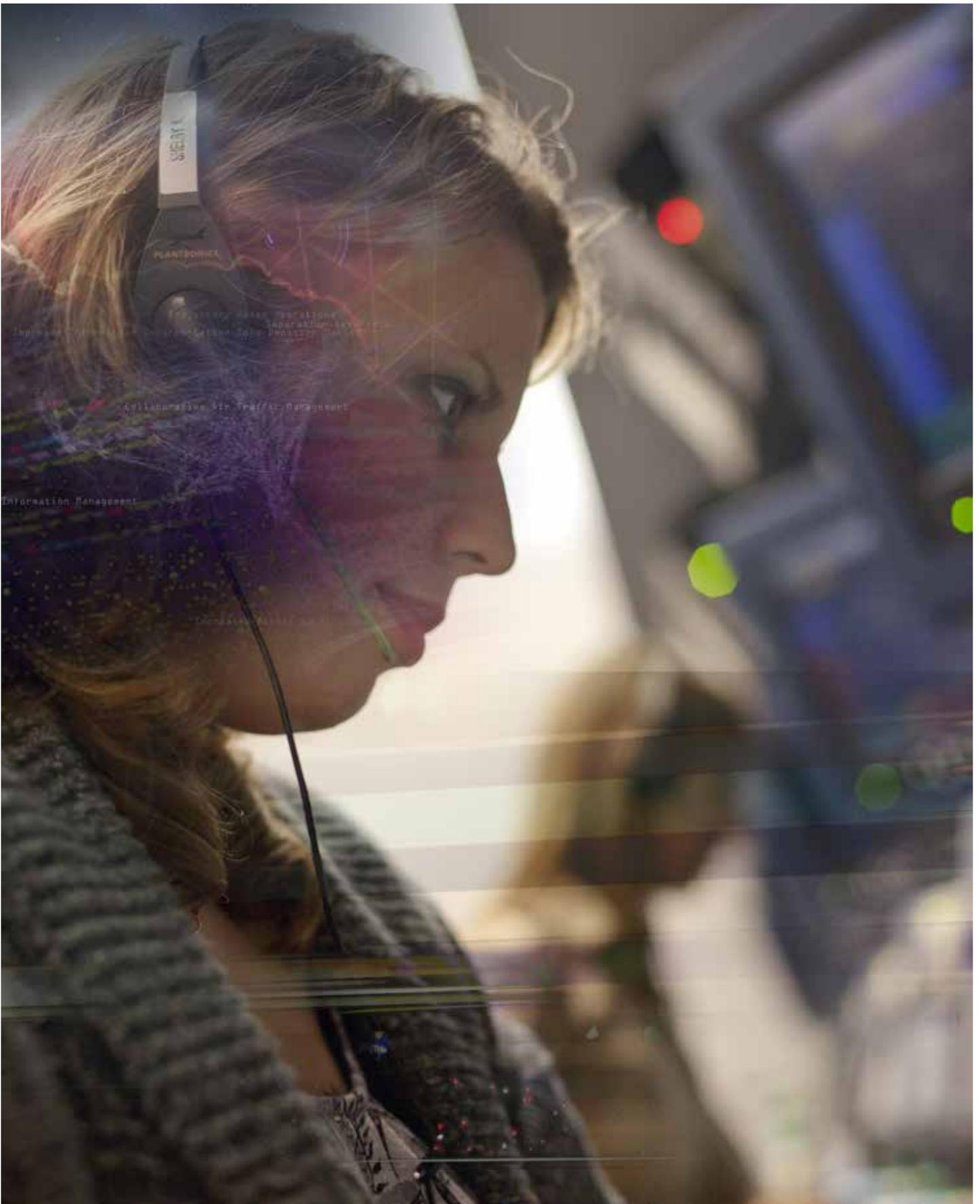
The FAA is strengthening the relationship with its workforce and labor partners to understand and facilitate any

new skills necessary to manage the future NAS. Recurrent ATC training will need to evolve from a focus on automation manipulation to one that ensures all actors in the NAS understand the changing operational concepts and their implications for how services are provided. The process requires the engagement and ownership of the entire aviation workforce including pilots, controllers, inspectors, regulators, flight safety professionals, engineers, program managers, and technicians.

The agency's Workforce of the Future Strategic Initiative^{vi} is focused on ensuring that the FAA's workforce will have the leadership, technical, and functional skills necessary to safely and productively transition to and manage the needs of the future NAS. This transformation includes leadership development, skills identification, skills development, and attracting talent. This will ensure that the FAA has the right employees, with the right skills, in the right place, at the right time to conceive, develop, implement, operate, and maintain the future NAS. →



America's National Airspace System is a network of people, procedures, and equipment. Pilots, controllers, technicians, engineers, inspectors, and supervisors work together to make sure millions of passengers move through the airspace safely every day.



By taking advantage of improved technologies, insights from industry, and training, the future workforce will be more productive | Source: FAA/NextGen

Appendix A: Acronyms, Initialisms and Abbreviations

4DT	Four Dimensional Trajectory	IMC	Instrument Meteorological Conditions
ACAS-X	Airborne Collision Avoidance System X	IP	Internet Protocol
ADS-B	Automatic Dependent Surveillance–Broadcast	MLAT	Multilateration
AEDT	Aviation Environmental Design Tool	NAC	NextGen Advisory Committee
ANSP	Air Navigation Service Provider	NAS	National Airspace System
ASDE-X	Airport Surface Detection Equipment–Model X	NESS	NAS Efficient Streamlined Services
ASSC	Airport Surface Surveillance Capability	NextGen	Next Generation Air Transportation System
ATC	Air Traffic Control	NVS	NAS Voice Switch
ATCSCC	Air Traffic Control System Command Center	OPD	Optimized Profile Descent
ATM	Air Traffic Management	PBN	Performance Based Navigation
ATN	Aeronautical Telecommunications Network	PIC	Pilot-in-Command
ATOP	Advanced Technologies & Oceanic Procedures	PTM	Pair-Wise Trajectory Management
ATPA	Automated Terminal Proximity Alert	RCM	Reliability Centered Maintenance
CATM	Collaborative Air Traffic Management	RNAV	Area Navigation
DAA	Detect and Avoid	RNP	Required Navigation Performance
Data Comm	Data Communications	RTCA	Radio Technical Commission for Aeronautics
DME	Distance Measuring Equipment	SAA	Special Activity Airspace
DOT	Department of Transportation	SWIM	System Wide Information Management
D-RNP	Dynamic RNP	TAMR	Terminal Automation Modernization and Replacement
EFVS	Enhanced Flight Vision Systems	TBFM	Time Based Flow Management
ERAM	En Route Automation Modernization	TFDM	Terminal Flight Data Manager
F&E	Facilities and Equipment	TFMS	Traffic Flow Management System
FAA	Federal Aviation Administration	TSAS	Terminal Sequencing and Spacing
FANS	Future Air Navigation System	TBO	Trajectory Based Operations
FMS	Flight Management System	TMI	Traffic Management Initiatives
FOC	Flight Operations Center	UAS	Unmanned Aircraft System
GPS	Global Positioning System	VMC	Visual Meteorological Conditions
		VOR	Very high frequency (VHF) Omnidirectional Range

Appendix B: List of Deferred Mid-Term Concepts

The NextGen Mid-Term Concept of Operations for the National Airspace System (FAA, Version 2.2, March 31, 2011) provides descriptions of the concepts originally envisioned for the Mid-Term. The following concept elements contained in the document have been deferred beyond 2030.

- » High Altitude Exclusionary Airspace
- » Future NextGen Facilities
- » Dynamic Airspace
- » Big Airspace
- » Staffed NextGen Tower for Large ATCT towers (still being researched for non-towered and non-federal towers)
- » Automated Conflict Resolution

End Notes

ⁱJoint Development and Planning Office. (June 14, 2007). Concept of Operations for the Next Generation Air Transportation System, Version 2.0.

ⁱⁱFederal Aviation Administration. (March 31, 2011). NextGen Mid-Term Concept of Operations for the National Airspace System, Version 2.2.

ⁱⁱⁱDepartment of Transportation, Office of the Inspector General. (November 20, 2014). Planning for High-Priority NextGen Capabilities Underway, But Much Work Remains for Full Realization of Benefits - Federal Aviation Administration, (Report Number: AV-2015-012).

^{iv}National Research Council, Computer Science and Telecommunications Board. (2015). A Review of the Next Generation Air Transportation System: Implications and Importance of System Architecture.

^vThe MITRE Corporation. (October 2014), NextGen Independent Assessment and Recommendations, (Report Number: MP140440).

^{vi}Federal Aviation Administration. Workforce of the Future Strategic Plan FY 2015-FY2018
https://my.faa.gov/content/dam/myfaa/org/staffoffices/ahr/workforce_of_the_future/wi-strategic-plan-final.pdf



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