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NATIONAL AIRSPACE SYSTEM
Concept of Operations

and

Vision for the Future of Aviation

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Foreword

This report was approved by the RTCA Free Flight Steering Committee on November 15, 2002.

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- Analyzing and recommending solutions to system technical issues that face aviation as it continues to pursue increased safety, system capacity, and efficiency;
- Developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and
- Assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization (ICAO) and the International Telecommunication Union and other appropriate international organizations can be based.

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Preface – The Bridge to the Future

The community has a vision for the future, which provides the basis for this revised concept of operations.

That vision establishes a globally harmonized, uniform Air Traffic Management System that allows users to make operational decisions based on their own economic business case while enabling the safe, orderly, and expeditious flow of air traffic. The system will maximize benefits and achieve seamless operations.

Our vision of the National Airspace System takes full advantage of globally harmonized, advanced aircraft, space, and ground capabilities. The future system maintains the importance of people, supported by automation, to manage operations. Through state-of-the-art communications, navigation, and surveillance and air traffic management enhancements, aircraft operate along more efficient auto-negotiated four-dimensional flight profiles that make the most efficient use of airport and airspace resources available. Operations are increasingly aircraft-centric, focusing on performance rather than equipment standards; with use of required navigation performance as a key step in enabling greater efficiency, flexibility, and capability enhancements. Access to real-time information for decision making supports efficient national airspace system operations when capacity limitations such as weather adversely impact the system. Enhanced system supported coordination and decision support capabilities allow the system to migrate beyond human centric operations. This concept of operations describes the continued evolution of the National Airspace System as the bridge to the future.

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A Vision for the Future of Aviation

Aviation and aerospace transportation are critically important to commerce, travel, and security within the United States and around the world. The economic value of domestic aviation alone is difficult to overstate. Today the industry struggles; system operators (airlines and general aviation) can barely afford to remain in business; the air traffic system is nearing capacity and too often, customers do not receive the service they need and expect. However, with the right steps aviation will recover and thrive, remaining a cornerstone of the nation's economic growth. Working together, government and industry evolve a system that not only meets growing demand, but also enhances service. Future aviation system improvements will facilitate new and innovative multi-modal alternatives for moving passengers and goods door to door. This fosters local economic benefits commensurate with the nation's overall gains. Future developments make possible revolutionary new services that may enable the public to: 1) routinely traverse short distances in air cars, 2) fly from New York to Tokyo in two hours on hypersonic vehicles, and 3) take a trip to a resort in orbit.

As technological innovations enhance every aspect of aviation, human interactions with the system change. Strategic planning becomes the humans' primary focus, and automation assumes a far more significant role in the management of real time operations. As humans and their technology evolve, society responds with economic and cultural growth.

Our vision is simple: all users operate without constraint in a system that enhances today's high level of safety and security, while providing equitable access. This is the vision of Free Flight for the 21st century.

This vision reflects the philosophy that user requirements drive the global aviation system and the services it provides. A user focus is imperative because system users, including the airlines, passengers, general aviation, and the military, are major contributors to the nations economic wellbeing by supporting the business, personal, and national defense needs of the country. Without a vibrant aviation system, the aforementioned needs cannot be satisfactorily met and the national economy will suffer.

1. AVIATION IS CRITICALLY IMPORTANT TO THE ECONOMY

As a cornerstone of the US economy, aviation is a key catalyst for economic growth and has a profound influence on our quality of life. It integrates the world economy and promotes the international exchange of people, products, investments, and ideas. Indeed, to a very large extent, civil aviation has enabled small community and rural populations to enter the mainstream of global commerce by linking such communities with worldwide population, manufacturing, and cultural centers.

Civil aviation products and services generate a significant surplus for the US trade accounts and are in the forefront in the development and use of advanced technologies. Fundamentally, civil aviation touches much more than the flying public. Recent analysis of the US aviation industry indicates the total impact of civil aviation exceeded $900 billion per year and 11 million jobs, representing nine percent of the US gross domestic product. To ensure the continued viability of this segment of the US economy, a sustained long-term effort is required to modernize the US aviation system and increase its capacity, to reduce congestion and delays through innovative solutions. The resulting benefit of personal and economic cost savings would stimulate US economic growth and employment; businesses would realize greater efficiencies and thus compete more effectively in the global arena. The US trade surplus from aviation manufacturing activity and air transport services would once again begin to increase; the quality of life for US citizens would improve; and environmental benefits would accrue from reduced aircraft emissions.

Data through July 2002 shows the US air transportation system annually accommodating 320,000 active civilian and 15,000 US military aircraft. The system provides safe, rapid, comfortable, and efficient transportation for 826 million commercial and general aviation passengers and 24 billion ton-miles of cargo. The ability of aviation to foster economic growth and engender social mobility is not, however, guaranteed. The cumulative effect of the economic downturn through 2002 and the tragic events of September 11, 2001, resulted in significant economic and personal costs. Restrictions on general aviation

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operations and others reached unacceptable levels. Without swift, long term, and thorough intervention, there will be further harm to the US economy, the competitiveness of its industries, and all who rely on aviation in the conduct of their business and personal affairs. Conversely, additional investment in the nation's aviation infrastructure facilitates economic growth and employment and restores US aviation leadership.[1]

2. ACCOMMODATING GROWTH TO 2020

The FAA and industry forecast that air traffic operations are expected to increase 150 to 250 percent in the next two decades. Therefore, the nation must use its existing and new resources much more efficiently.

New runways with appropriate airspace modifications and operational procedures offer the greatest potential for improving airport throughput and increasing system capacity. Effectively addressing community environmental concerns significantly reduces the current ten-year timeline normally taken to add a new runway to meet the predicted growth in demand. However, new runways alone will not generate the requisite system capacity increases without more efficient runway use. National aviation and aerospace system users will utilize all suitable runways at America's 5,400 public use airports. New procedures, technology, and infrastructure improvements significantly enhance individual airport and system capacity during low visibility conditions and reduce the congestion and delays associated with weather induced capacity reductions. New aircraft technologies provide aircrews with a full situational awareness of nearby aircraft and the airport itself through displays and virtual vision capabilities. This enables good weather operations during bad weather.

New technologies and procedures increase airspace system capacity by mitigating wake vortices and their effects. Improvements in the prediction and avoidance of wake vortices allow reductions in the "buffers" used in the separation of aircraft to increase airport throughput. In addition, new airframes use performance-enhancing materials and adaptive wing designs to further reduce overall aircraft weight and vortex magnitude. Those two reductions in combination shorten runway occupancy times and allow larger aircraft to operate at airports with shorter runways.

In addition to weather near the airport, actual or forecast events, such as thunderstorms reduce available airspace, restrict traffic flows, and generate increased delays. Inaccurate forecasts, such as bad weather that does not materialize, can also lead to disruptions and delays. There are significant improvements in the accuracy of weather forecasts, as well as improvements in the procedures and technologies used to manage the uncertainty of these forecasts. This results in more effective management of flight operations generating increased user and system efficiencies.

A more dynamic and flexible use of airspace better accommodates the varying traffic demands at any given time making better use of the airspace and allowing users to operate more efficiently. The use of dynamic lateral and vertical traffic control boundaries reduces traffic flow restrictions associated with fixed boundaries. Flexibility in airspace use is the key; permitting dynamic airspace modifications to accommodate traffic flows. Maintaining equitable access to the airspace and associated resources optimizes their economic value.

Human cognitive limitations restrict the number of aircraft that can use an airspace resource even when additional physical capacity of the resource exists. Therefore, the fielding of improved automation is essential to overcome human imposed constraints that limit operational flexibility and predictability. Achieving the highest performance levels requires more sophisticated automation support capabilities.

Aviation, including the air traffic control system and aircraft, must be human centric but technology intensive. Humans perform best at higher-order decision-making, but can only monitor and interact with

[1] DRI•WEFA, Inc., A Global Insight Company, *The National Economic Impact of Civil Aviation* (Washington D.C.: DRI•WEFA, Inc., A Global Insight Company, 2002)

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a limited number of aircraft at one time. Automation, which can process large amounts of data augments human abilities to compensate for human limitations of attention and memory capacity. Enhanced airborne and ground automation enables the system to accommodate significant increases in traffic demand and operate more efficiently. As a result, future air traffic controllers assure the separation of aircraft by intervening only by exception. Nevertheless, humans must continue to be responsible for higher-order decision making tasks.

Moreover, increases in demand for aviation services necessitate new human tasking not only for controllers, but also for pilots and dispatchers. Automation must augment the execution of their tasks to improve performance and achieve a higher capacity air traffic control system. For example, cognitive-based visualizations including graphical/heads up representations enhance controller, dispatcher, and pilot situational awareness and management. Automation, including "what-if" tools are the key to enhancing human capabilities.

The system accommodates new aircraft, aerospace vehicles, and aviation technologies. They are designed to make the most efficient use of airport and airspace resources. To increase system efficiency and predictability, aircraft arrive at various points at specified times on an identified path. In addition, controllers, aircrews, and dispatchers share up-to-date information about all aspects of all flights. This enables the execution of the most efficient plan from a system wide perspective. Appropriate flight deck tools provide the pilot with easily understandable and context relevant information. This information provided by graphical displays, aural alerts, tactile and heads-up displays, allows the pilot to be a full partner in the air traffic management decision making process.

Nonetheless, capacity increases will not completely eliminate the congestion resulting from unpredictable events such as severe weather, system outages or even unanticipated changes in demand. The imbalance between capacity and demand causes the significant growth of delays and severely disrupts the movement of passengers and goods. Improved collaboration with users, enhanced accuracy of demand and capacity predictions, and improvements in system modeling and measurement lead to a better understanding of alternative strategies, enabling more informed decisions.

When airport and airspace resources cannot temporarily accommodate demand, applying models of fairness ensures equitable resource allocation. Users receive allocations of capacity resources in a manner that gives them flexibility to manage those resources efficiently. This mitigates the impact of congestion on the movement of passengers and goods and improves system and passenger predictability.

3. THE FUTURE BEYOND 2020

In the far future, greatly enhanced aerospace mobility exists as the result of numerous improving and enabling technological innovations. Aerospace transportation, extending from the home to space, facilitates trade, travel, communication, and recreation and results in vast improvements in human productivity and quality of life. Such technological enhancements to aerospace mobility affect the types of vehicles as well as the complexity and the operating envelopes of an aerospace traffic management system. As humans and their interaction with technology evolves society responds with economic and cultural growth.

Technological innovation leads to vehicles with increased efficiency and optimal performance based on the dynamic needs of the public. Air cars address short-haul ground vehicular congestion. Vertical takeoff and landing vehicles with high cruise speeds and no runway requirements permit long-haul travel to more remote locations while lessening the traffic burden on major airports. Hypersonic vehicles enable time-efficient travel for customers with time-sensitive needs for worldwide travel. Space vehicles and conceptual vehicles such as the space elevator provide access to earth's orbit, where new human ventures such as micro-gravity manufacturing and space tourism flourishes. Such a wide range of aerospace vehicles significantly increases the level of complexity of the aerospace traffic management system. As the system complexity increases, a new operating envelope evolves.

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Technological enhancement of human capability and how that enhancement changes human interaction pushes the system to its new operating envelope. Cognitive decision making and higher-order thought serve the system best through the human, where monitoring and processing of predetermined operations works best through artificial intelligence and automation. Future aircraft and aerospace systems optimally utilize human capabilities, automating, where appropriate, the functions performed by pilots and controllers. The human role within the system moves towards strategic planning, and the tactical separation role moves towards full automation.

The aviation system of today, a fundamental part of the nation's economy, is reaching its operational limits. These limitations will be overcome through a continuing government and industry partnership to develop innovative concepts, vehicles, procedures, and technologies needed to accommodate the ever-increasing demand for aviation services.

The future of aviation is bright and the path to that future is clear. The sky is no longer the limit.

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EXECUTIVE SUMMARY

This National Airspace System (NAS) Concept of Operations identifies an evolution of capabilities to continue and improve NAS safety and efficiency well into the 21st century. This consensus agreement reflects the results of deliberations by government and industry representatives under the auspices of the Free Flight Steering Committee.

The concepts are presented from an environmental, airspace user, and service provider perspective. The environmental perspective provides a general description of expected technological and procedural changes. The user perspective describes these changes as well as adjustments in roles for the user. Similarly, the service provider perspective describes how the role of the service provider evolves. The document also describes NAS evolution in terms of three periods; near term (up to 2005), mid term (2005-2010), and far term (beyond 2010).

The expanded use of advanced information technology, automation, and collaboration in NAS modernization provides increased airspace capacity, improved aviation safety, and enhanced operational efficiency for aircraft operators and service providers. The concept describes how the aviation community achieves this by utilizing these advances in technology to support the human in doing what they do best – choosing alternatives and making decisions, while the technology accomplishes what it can do best - the acquisition, compilation, evaluation and exchange of information. This concept provides an operational description of these needed information and technology advances supported by the continued migration from a NAS based on a ground infrastructure and voice communications to one that encompasses both ground and airborne systems using the exchange of digital data as the primary type of communications.

NAS Management (Strategic Flow and Resource Management): As we move into the 21st century, a *System Wide Information Management (SWIM)* capability ensures that all stakeholders have access to all relevant information. A comprehensive information exchange process allows users to improve their planning of flight operations in anticipation of changes to NAS capacity and traffic conditions and to minimize congestion or possible delays. Users are key participants in the planning of traffic flow management initiatives and arrange their resources to help resolve flow problems. Such initiatives are planned and executed to provide the highest level of service given the resources available. The planning and execution of strategic flow initiatives is carried out using decision support tools with the automatic exchange of results. In contrast to the past, both demand and capacity are managed by allocating access to resources, collaborative rerouting, and by maximizing the remaining capacity through realignment of sectors and associated resources.

Flight Planning and Emergency Alerting Services: The flight deck, flight operations center, and service provider have interactive flight planning capabilities with immediate access to real-time data. User-preferred routing is available to properly equipped aircraft for both domestic and international flights. Controlled times of arrival are the primary method for regulating flows. The flight profile includes the planning and filing for fuel-efficient parabolic profiles. Requests and counter proposals are auto-negotiated and updated in both the planning and airborne phases of flight. In response to air traffic management system changes and user preferences, *intelligent agents*, which are computational systems that operate autonomously, compare the changes to the known user and service provider objectives and provide the best alternatives to decision-makers. Aircraft have enhanced emergency locator transmitters that utilize discrete codes and satellite navigation positioning to aid in search and rescue, thus improving the timeliness and availability of emergency and alerting services.

Surface: Data link provides route of flight clearances, airport information, positions of other aircraft, taxi routes, and weather conditions (current, forecast, hazardous) to more users at more airports. Voice communications are available for the unequipped and as backup in the event of an individual unit failure. Departure and arrival runway assignments are based not only on the location of the assigned gate but also

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on the surface automation's prediction of congestion and the related taxi plan. Decision support systems provide sequences and controlled time of movements to/from gates/ramps. They also determine queuing based on the most efficient use of airport capacity based on current constraints (e.g., weather). For departures, taxi time updates and the associated estimates included in the taxi plan are coordinated automatically with airspace automation to efficiently sequence ground traffic to match projected traffic flows aloft. This continuous update of the flight profile improves real-time planning for both the user and the service provider, which also improves the effectiveness of ongoing traffic management agreements. Total airport surface surveillance provides all stakeholders with aircraft and vehicle location information. This surveillance capability coupled with enhanced navigation provides for zero-visibility operations.

Arrival/Departure: Aircraft operate along optimum profiles in the transition to and from the airport. Integrated decision support systems enable these efficient flows from high altitude anchor points to multiple paths serving the airport. The flight deck receives these negotiated routes via *System Supported Coordination (SYSCO),* a capability that places information in the correct context for the decision-maker. Satellite navigation with vertical guidance makes it possible to provide precision instrument approaches and departures at practically any landing facility. Pilots monitor these paths on a moving map display. Modifications to service provider procedures and improvements in turbulence and wake vortex avoidance facilitate a reduction in separation standards. Controlled times of arrival are routinely used for managing arrivals through specific portions of the airspace. Dynamic airspace management matches traffic volume to multiple enhanced navigation arrival and departure routes. Enhanced all weather landing systems allow for multiple paths to final approach to facilitate full use of runway capacity. Virtual vision devices on flight decks enable more "visual like" operations regardless of weather conditions.

Enroute: Decision support systems such as the conflict probe, resolution advisor, and automatic trial planning assist the service provider in developing safe and effective traffic solutions and also enable free maneuvering in low-density airspace. Time-based metering is used by an increasing number of en route facilities. Technology enhancements provide expanded use of procedures with lower separation minima that are based on improved system performance. Operations on structured routes only exist in high-density areas, to avoid terrain and active special use airspace, and to facilitate the transition between areas with differing separation standards. Data link services include air traffic control clearances, current and forecast weather, notices to airmen and hazardous weather warnings, updated charts, current weather, special use airspace status, and other required data. Sector boundaries are modified to accommodate dynamic traffic flows (Note: Definitions provides additional information). The high-altitude airspace structure has laterally defined sectors that encompass much larger areas than exist today. Multiple navigation paths are available to all suitably equipped users. These auto-negotiated and automatically loaded routes allow aircraft to perform at or near their most efficient profile even when the user preferred trajectory is not available. Such capabilities are available in flight and apply to all aircraft to include spacecraft and remotely operated aircraft.

International Oceanic: Most aircraft meet the required navigation and communication performance to allow for further reductions in lateral and longitudinal separations. Service providers have a common set of rules and operational procedures for a harmonized enroute/international oceanic system. *SYSCO* enables improved coordination among all service providers, domestic and international. The positions of all controlled aircraft are determined through automated means and are displayed to the service provider. Separation assurance is accomplished with the aid of decision support systems and a visual display system similar to that used in en route. Data link enables seamless communications. *Intelligent agents,* operating on behalf of the user and service provider, monitor the flight environment, analyze conditions and auto-negotiate proposed adjustments to the flight profile in response to changes in system constraints. The proposed changes permit the as-flown profile to more closely align with either the user's original preferred profile or an updated profile. Since user objectives are varied, the system can accommodate the different operational preferences and responses to the same changes in system conditions.

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Summary: The concepts described are subject to modification. Therefore, this document will receive regular reviews and updates as necessary to reflect changes in FAA and user strategy. Both the FAA and the user community will use this document to coordinate activities related to the development and implementation of air traffic services and operational capabilities within the NAS.

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1 INTRODUCTION

This document provides an evolutionary concept of operations for the National Airspace System (NAS) in the United States. It is intended to identify the needs and requirements of NAS users and service providers and to serve as the basis for an incremental and a benefits-driven approach toward a modern Air Traffic Management (ATM) system.

A modern ATM system uses advanced information technology available today (e.g., satellite navigation, digital communication, and computer decision support systems (DSS)) to increase airspace capacity, improve aviation safety, and increase the operational efficiency for aircraft operators and service providers alike. It is also intended to form the basis upon which the Federal Aviation Administration (FAA) and the user community plan procedural, investment, and architectural decisions. These decisions result in the operational capabilities needed to achieve an ATM system that meets the needs of 21st century aviation. This concept represents the results of government and industry collaboration and consensus under the auspices of the Free Flight Steering Committee. Representatives of the aviation community, including the FAA, commercial airlines, general aviation, business aviation, Department of Defense (DoD), pilots, and service providers, among others, participated in the development of this concept of operations. Within the FAA, it represents the work of Air Traffic Services, with support from the organizations of the Associate Administrators for Certification & Regulation, Commercial Space Transportation, Research & Acquisition, and labor organizations. It supercedes the *NATIONAL AIRSPACE SYSTEM Concept of Operations*, dated December 13, 2000 [1].

This concept of operations reflects the continued migration of the NAS from a system that uses a ground-based infrastructure to one that encompasses both ground-based and airborne systems. The development of a coherent strategy for the entire NAS requires participation by the entire aviation community including the FAA, the DoD, airlines, general aviation, pilots, and service providers, among others. The participation of numerous FAA organizations and airspace users in the development of this concept demonstrates recognition of the need to ensure that government and industry technology development and implementation programs are clearly defined and coordinated early in the concept formulation process.

1.1 Background

Free Flight[2] is an innovative approach to a modern ATM system born out of the need for increased user flexibility, operating efficiencies, and safety to meet the growing demands of air transportation. The RTCA Task Force on Free Flight developed the Free Flight approach in 1995. The Task Force produced a report entitled *The Final Report of RTCA Task Force 3: Free Flight Implementation* [2] that further defined Free Flight, evaluated the Free Flight architecture and technology needs, and identified an incremental transition to Free Flight. The RTCA Task Force 3 report also outlined specific operational

[2] Free Flight is "…a safe and efficient operating capability under instrument flight rules (IFR) in which the operators have the freedom to select their path and speed in real-time. Air traffic restrictions are only imposed to ensure separation, to preclude exceeding airport capacity, to prevent unauthorized flight through Special Use Airspace (SUA), and to ensure safety of flight. Restrictions are limited in extent and duration to correct the identified problem. Any activity which removes restrictions represents a move toward Free Flight."

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