

Emerging Definition of Next-Generation of Aeronautical Communications

Robert J. Kerczewski
NASA Glenn Research Center
Cleveland, Ohio, USA
+1 216 433 3434, rkerczewski@nasa.gov

Abstract—Aviation continues to experience rapid growth. In regions such as the United States and Europe air traffic congestion is constraining operations, leading to major new efforts to develop methodologies and infrastructures to enable continued aviation growth through transformational air traffic management systems. Such a transformation requires better communications linking airborne and ground-based elements. Technologies for next-generation communications, the required capacities, frequency spectrum of operation, network interconnectivity, and global interoperability are now receiving increased attention. A number of major planning and development efforts have taken place or are in process now to define the transformed airspace of the future. These activities include government and industry led efforts in the United States and Europe, and by international organizations. This paper will review the features, approaches, and activities of several representative planning and development efforts, and identify the emerging global consensus on requirements of next generation aeronautical communications systems for air traffic control.

TABLE OF CONTENTS

1. INTRODUCTION
2. AIR TRANSPORTATION SYSTEM PLANS AND ROADMAPS
3. RTCA NATIONAL AIRSPACE SYSTEM CONCEPT OF OPERATIONS AND VISION FOR THE FUTURE OF AVIATION
4. MOBILE COMMUNICATIONS NETWORK ARCHITECTURE (MCNA)
5. JOINT PLANNING AND DEVELOPMENT OFFICE (JPDO)
6. INTERNATIONAL AIR TRANSPORT ASSOCIATION (IATA)
7. EUROCONTROL/FEDERAL AVIATION ADMINISTRATION FUTURE COMMUNICATIONS STUDY
8. SPECTRUM ISSUES
9. SUMMARY
10. REFERENCES

1. INTRODUCTION

The relative reduction in the cost of air transportation coupled with the increased buying power of large segments of the world's population and the migration of peoples between continents on an unprecedented scale is fueling major increases in regional and international air travel. The globalization of economic activities is requiring increased international business travel. The world's major airlines all operate international routes, and complex scheduling requires a major portion of their fleet to be able to operate in various regions of the world.

The current method of air traffic management (ATM), based on radar surveillance and tactical intervention of human air traffic controllers to keep aircraft separated, evolved in the 1950s and 60s and has provided a safe and efficient air transportation system. However, the physical limitations of direct control of air traffic by humans are now limiting air traffic growth. The question is now being posed as to whether another major shift in ATM methods, such as the one which occurred five decades ago with the introduction of radar surveillance, is needed again

Air traffic service providers, users of the airspace, and other segments of the global aviation community are now participating in a debate about the structure and form of the future air transportation system. Within this debate consensus is emerging on several key points. First, a major transformation of the system is required within the next 20 years in order to accommodate expected levels of air traffic growth. Second, different regional technical solutions for providing ATM are expensive and counterproductive, and global harmonization of systems is necessary. Third, future ATM will consist of management of 4-dimensional (4-D) aircraft trajectories, where flight plans chart aircraft location in time and space and airspace management consists of strategic coordination of these plans, as opposed to today's tactical separation of aircraft within small sectors of airspace. Fourth, a major increase in the amount of information developed and shared between airspace system users and service providers is needed to enable this future vision.

For communications, navigation and surveillance (CNS) systems and the avionics required on aircraft to make use of CNS systems for aeronautical navigation, a trend has

emerged in which, for a number of reasons, increasing numbers of distinct regional solutions are required. Users, however, are resisting this trend due to the high cost to equip, operate and maintain many separate systems needed to operate a single aircraft in several regions of the world. The pressure for global harmonization of systems which has emerged in the current debate about the future of air transportation is in large part a result of this resistance. It would not be possible to implement a major new ATM system if the users find it economically infeasible to change CNS equipment.

A number of recent major planning efforts, some of which are on-going, have proposed a future air transportation system from different viewpoints. These planning efforts envision major changes in ATM and place significant requirements on the supporting communications infrastructure. These planning efforts are revealing in more and more detail the nature and quantity of information movement required to enable future ATM concepts, and it is clear that current aeronautical communications systems, even new systems that are just beginning to be deployed, are inadequate to support these future concepts. Therefore, various ATM planning efforts are beginning to come to grips with both the need for advanced new aeronautical data communications systems as well as the need to achieve a globally interoperable solution so that users of the air traffic system can afford to install and operate new communications equipment when needed. This paper will examine several of these ATM planning efforts and examine results pertaining to the possible future of globally harmonized aeronautical communications, and draw some conclusions about what new types of systems may need to be developed.

2. AIR TRANSPORTATION SYSTEM PLANS AND ROADMAPS

As consensus emerges on the need for a major overhaul of the air transportation system, different segments of the aviation community are weighing in with planning efforts, architectural studies, roadmaps, and other high-level goals and objectives. Five of these are selected for review in this paper: RTCA Concept of Operations - December 2002, the Joint Planning and Development Office's Next Generation Air Transportation System Concept, the International Air Transport Association Roadmap, the Mobile Communications Network Architecture, and the Eurocontrol/FAA Future Communications Study. In the following sections, each is reviewed for its general content and results and conclusions on the possible impact on globally harmonized communications requirements are presented.

3. RTCA NATIONAL AIRSPACE SYSTEM CONCEPT OF OPERATIONS AND VISION FOR THE FUTURE OF AVIATION

RTCA is a US Federal Advisory Committee that develops consensus-based recommendations on contemporary aviation issues. Among RTCA's objectives are: coalescing aviation system user and provider technical requirements; analyzing and recommending solutions to system technical issues; developing consensus on application of pertinent technology to fulfill user and provider requirements; and assisting in the development of appropriate technical materials. The RTCA presents an industry consensus in that all members of the aviation industry – users, suppliers and service providers – participate in its activities.

RTCA developed and published the National Airspace System (NAS) Concept of Operations (ConOps) and Vision for the Future of Aviation in 2002. This concept describes the evolution of the NAS toward a consensus vision in which a globally harmonized ATM system allows users to make operational decisions maximizing their operational performance while maintaining safe and efficient flow of traffic. The concept relies upon state of the art CNS to allow aircraft to operate more efficient 4-D flight profiles. Advanced information technology, automation, and collaboration enable decision support capabilities and system-wide coordination resulting in increased system capacity, improved safety, and enhanced operational efficiency. Aircraft centric performance, as opposed to equipment standards, allows a user-focused system providing a constraint-free environment for users.

The RTCA ConOps supports the notion of shifting from air traffic control to airspace system management with controller intervention only by exception. It describes the needed information and technology advances migrating from primarily ground infrastructure and voice communications to ground and airborne systems exchanging digital CNS data. The concept describes the future operational procedures and required supporting information for the airport surface, arrival/departure, enroute, and international oceanic flight domains. The concept does not reference specific communications, navigation or surveillance technologies and is therefore open to new approaches which meet the evolving required performance criteria, with the requirement of global harmonization, particularly for the oceanic domain. The information backbone is the System Wide Information Management (SWIM) concept.

The RTCA ConOps provides a foundation for understanding future communications requirements in the form of the information needed from and for different system entities, and requires a major increase in digital data communications needs. It relies on underlying information management (SWIM) interacting with the system through a network-oriented communications infrastructure. It does

not recommend specific technical solutions, but leaves those solutions to be developed on a globally harmonized basis.

In summary, the RTCA ConOps has a focus on providing maximum user flexibility to operate within the airspace to its maximum benefit, while the ATM system itself provides a management function for maximizing both operational efficiency and safety. To achieve this, the underlying concept involves 4-D flight trajectories negotiated and implemented with high precision. State of the art CNS systems allow users to maintain the agreed upon trajectories, however users are able to select levels of equipage that correspond to the requirements for airspace sectors in which they wish to operate. A major increase in digital information flow between airborne and ground entities, based on a network-oriented approach in conjunction with a SWIM infrastructure is required.

4. MOBILE COMMUNICATIONS NETWORK ARCHITECTURE (MCNA)

The MCNA development effort under the FAA's Global CNS System Phase II contract was co-funded and co-managed by NASA Glenn Research Center and the FAA [5]. MCNA encompasses the aggregate of all voice and data communication capabilities in support of CNS services for ATM operations. Like SWIM, MCNA is a key enabling technology for transformation of the NAS towards network centric operations (NCO). The MCNA task was established from the perspective of assuring that the air-ground and air-air communications capabilities will be compatible with, and supportive of, the needs of SWIM as necessary to enable NCO. The SWIM system will enable the ubiquitous sharing of information between applications, a result of integrating ATM applications via common network mechanisms. The SWIM environment will enable both anticipated and non-anticipated users of information.

As a mobile extension of SWIM, the MCNA provides structured mechanisms to extend the applications and benefits of SWIM to mobile elements of the NAS, providing air-ground and air-air data communications for safety critical services, regularity of flight communications and tailored delivery of advisory information and user-specific situational information. The MCNA significantly expands SWIM's ability to perform NCO that provide for reduced aircraft spacing in all domains under normal conditions, and rapid, efficient responses to disruptions in the NAS. A broadly deployed MCNA enables mobile users anywhere in the NAS to have timely, reliable, secure access to the information needed for efficient collaborative decision making, optimized routes for reduced fuel consumption and emissions, and 4-D trajectory negotiation, continuous descent approaches and tailored arrivals in congested traffic of mixed aircraft, for increased airspace capacity in all flight domains.

MCNA fulfills the network-centric operational requirements which are either expressly or implicitly defined in other future operational concept definitions and roadmaps. MCNA requires a considerable increase in communications capacity and capability, but does not provide specific technical solutions, which are intended instead to be developed by appropriate organizations in a globally harmonized approach.

In summary, the MCNA has assumed advanced ATM operational concepts (e.g. 4-D trajectory management) that will require significant data flows between air and ground-based elements of the airspace needed to support transformational ATM concepts. The MCNA has not focused on technical solutions, but has derived specific communications network infrastructure requirements and identified key elements for creating a mobile communications network that is compatible with, and complementary to the ground-based SWIM environment. Although the detailed technical results of the study are beyond the scope of this paper, the overriding result is that a significant effort is required to develop and implement the airborne portion of the future network-based information access infrastructure that the JPDO's NGATS and other advanced concepts requires.

5. JOINT PLANNING AND DEVELOPMENT OFFICE (JPDO)

The JPDO is a joint planning activity among US government agencies with the goal of defining the Next Generation Air Transportation System (NGATS) and coordinating research and development efforts of the constituent organizations required to develop and implement the NGATS [2]. The organizations involved in the planning include: Department of Defense; Department of Transportation; Federal Aviation Administration; National Aeronautics and Space Administration; Department of Commerce; and Department of Homeland Security. The JPDO is currently in the process of fully defining NGATS operational processes and requirements. Key capabilities of NGATS as envisioned in the year 2025 are:

- **Global Secure Access to Net Centric Information**
Real time free flow of information, with appropriate levels of security and priority, enables system wide shared situational awareness based on the concept of network-centric operations to collect, process and disseminate information to and from all users.
- **Airborne Information Web**
The airborne information web is a broadband communications network providing secure broad area information dissemination, digital and voice communication, and surveillance.
- **Broad-Area Precision Navigation**
This capability will enable precision approaches and global availability of navigational services while greatly

reducing ground-based landing systems and navigational aids.

- Required Total System Performance (RTSP) – Equip for Service
Required total system performance, which emphasizes CNS performance, but may include other performance attributes, is defined at different levels based on ATM requirements. Users can choose where and when to operate and equip appropriately.
- 4D Trajectory Management
Users and providers enter into contracts for 4-D trajectories defined from gate to gate, exchanged via the airborne information web, with required changes negotiated collaboratively in real time, providing system wide strategic traffic management.
- National Dynamic Airspace
Airspace is dynamically reconfigured as needed to deal with temporary high demand areas, airspace use restrictions, and overall system efficiency, safety and security needs.
- Seamless Weather Assimilation Into Decision Loops
Seamless weather involves the collection of weather sensor data to create a national database, making rapidly updated weather data available for strategic decision making.
- Equivalent Visual Operations
Operations equivalent to visual under low-visibility conditions enable airport surface, arrival/departure operations and separation assurance to maintain system capacity.
- Super Density Operations
Capacity at high density airports is maximized through increased runway capacity, reduced runway occupancy time, and multiple simultaneous operations per runway.

The NGATS key capabilities rely on network-enabled digital communications requiring a significant increase in communications capacity. Global interoperability of systems and ATM concepts is an essential element. Details of the NGATS, including technical requirements for communications systems, remain to be determined through research and development by the JPDO members.

In summary, the JPDO is, through the NGATS plan, developing detailed approaches to a number of key air traffic problems. Although it too envisions a 4-D trajectory management approach, which maximizes system-level air traffic flow for en-route and oceanic environments, it also considers ways to increase traffic throughput in dense environments, approaches to dealing with weather to minimize weather induced delays and congestion, and to enable dynamic reconfiguration of airspace to accommodate traffic density shifts and off-nominal conditions. The JPDO has placed significant emphasis on underlying infrastructure capabilities required to implement this concept, focusing on network centric information access, broadband information dissemination through an airborne information web, precision navigation and required total system performance. Although communications system performance is not called

out separately, a major increase in communications system performance and bandwidth is required for network-centric information access, broadband information dissemination, and high RTSP levels.

6. INTERNATIONAL AIR TRANSPORT ASSOCIATION (IATA)

IATA represents a majority of the world's international airlines, and in this capacity has developed the One Sky...Global ATM document as a roadmap for transitioning to a future global ATM system [3]. The vision defined in this document focuses on taking advantage of existing and future ATM improvements, reducing costs to users, and in particular on reducing the proliferation of standards and regional technical solutions and equipage requirements.

Key elements of the IATA roadmap include development of new concepts to maximize capacity at airports under all conditions, system-wide balancing to resolve local demand and capacity constraints, and improving the interface between ATM, airports and aircraft operators. Collaborative planning and decision making are optimized with enhanced real time information sharing. System performance is maximized through such methods as dynamic spacing and sequencing of arriving/departing aircraft and enhanced and synthetic vision systems. The IATA roadmap stresses an evolutionary communications infrastructure that converges to a single globally harmonized, compatible and interoperable system.

The IATA roadmap focuses on near and mid-term system improvements to transition to a long term ATM concept, maximizing the use of existing and planned assets to increase capacity and reduce costs. Increased information sharing, and in particular a global approach to ATM and the underlying communications infrastructure are key features of IATA's vision.

In summary, the airlines through IATA want to gain maximum benefits from existing equipment through an evolving ATM system. This ATM system will incorporate many attributes considered important for long term ATM transformation. The most important attribute required of evolving communications systems is to converge to a globally harmonized solution, minimizing variation of technical standards and technical solutions between regions.

7. EUROCONTROL/FEDERAL AVIATION ADMINISTRATION FUTURE COMMUNICATIONS STUDY

A significant effort in harmonizing future aeronautical air-ground communications is underway in the

TABLE I – Summary of ATM Concepts and Attributes

ATM Concept	Aviation Community Segment	Primary AMT Attributes	CNS Information Attributes	Comments
RTCA ConOps	Aviation industry-based federal advisory committee	Management of 4-D flight trajectories. User flexibility. Advanced information technology allowing automation, airspace management instead of aircraft control.	State-of-the-art CNS for high precision operations. Increased information flow. Are-ground data network integrated with SWIM.	Mid/long term system improvements. Evolving transformation of airspace and ATM.
MCNA	US government sponsored/managed industry study	Based on need for network-centric ATM operations. Extends SWIM from ground to mobile environment.	Development of infrastructure enabling network centric operations. Greatly increased communications flow among mobile elements of the airspace.	Mid/long term concepts. Focus on information and communications network infrastructure to support transformed airspace operations.
JPDO NGATS	US Government Agencies	Management of 4-D flight trajectories. Increasing operations in dense environment. Mitigating weather impacts. Dynamic airspace reconfiguration.	Network-centric information access. Broadband information dissemination. Precision navigation. Required total system performance.	Long-term major transformation of air traffic system.
IATA One- Sky – Global ATM roadmap	Airlines	Maximize airport capacity. System wide balancing. Improving information interface for collaboration between ATM, airports and operators to maximize system performance.	Global harmonization of systems, through evolving communications infrastructure.	Near/mid-term system improvements; minimize new equipage while maximizing use of existing/emerging systems.
Eurocontrol/FAA Future Communications Study	US and European government study	Develop communications operating concept and technology options to provide communications capacity for global ATM through 2030. Support air traffic and airline services.	Globally harmonized communications system solution, based on NGATS-type requirements. Determine and advocate for required spectrum to support new systems.	Mid-long term communications concepts. Focus on eventual convergence to globally harmonized communications solution. International participation.

Eurocontrol/FAA Future Communication Study (FCS). This study responds to recommendations from the International Civil Aviation Organization (ICAO) Aeronautical Communication Panel resulting from deliberations of the Air Navigation Conference – 11 (ANC-11, August 2003). The intent of the ICAO ANC-11 recommendations was to provide a path towards global interoperability of air-ground communications while investigating technology alternatives. The FCS emerged from Eurocontrol and FAA discussions as a way to progress the recommendations of ANC-11.

NASA is providing technical support to the FAA to perform the FCS, which has several objectives: provide communications capacity to support ATM through 2030; provide for a realistic transition to a global solution for service providers and airspace users; support air traffic services and airline operational communications; address spectrum depletion issues; and investigate multi-mode avionics. The study includes business themes (multi-national framework, industry involvement, and business models) and technical themes (improvements to current systems, identify operating concept, investigate new technologies, identify roadmap, investigate flexible airborne architecture, and study spectrum requirements). The Communications Operating Concept and Requirements (COCR) will identify and document consensus future operational requirements and derive the communications requirements to enable those concepts. The current version is available through ICAO [5]. The COCR describes two phases of the operational concepts. Phase 1 beginning in 2015, is characterized by the evolution of communications services from voice to data and the ATM operational paradigm shift from “management by intervention” to “management by planning and intervention by exception.” Phase 2 occurs through 2030, and involves the evolution of communications services to support 4-D trajectory-based ATM, where ATM evolves to a monitoring function instead of active control, heavily dependent on NCO and SWIM.

NASA has participated in the investigation of new technologies for application to air-ground communications. The first phase of this technology assessment, a pre-screening exercise, has been completed [6]. This study included an aeronautical spectrum assessment; the development of consensus evaluation criteria with Eurocontrol; the evaluation of more than 50 possible technology candidates (from commercial cellular, wireless, public safety services, satellite communications, custom narrowband and broadband aviation, and military solutions); evaluation and ranking of the candidates; and development of a sensitivity analysis tool. Eurocontrol sponsored a parallel technology prescreening effort.

Using the consensus evaluation criteria and methodology, which were approved by the ICAO ACP Working Group of the Whole, the NASA and Eurocontrol assessments produced agreement on some potentially feasible technologies: a broadband VHF solution; an L-band

datalink solution similar to VHF Digital Link Mode 3 (VDL-3); a public safety service protocol called P-34; wideband CDMA; and Inmarsat’s Aero-BGAN service. Eurocontrol’s set of solutions also include Airport Data Link, while NASA’s included VDL-3, the IEEE 802.16 standard, and the Iridium satellite system. The second phase of the FCS technology assessment is now performing a detailed study of a subset of possible technologies.

The FCS is a continuing study and is the most significant attempt to define a globally harmonized solution for aeronautical communications. It is based upon the COCR, which is aligned with the developing consensus on the future air transportation system, in particular the JPDO’s NGATS, relying on broadband digital communications to provide a network-centric aviation information system to enable a 4-D trajectory-based future ATM concept.

In summary, the FCS, instigated to develop an internationally coordinated approach to achieving a globally harmonized future communications infrastructure, is based on requirements for advanced future ATM concepts such as are described by the JPDO’s NGATS, RTCA, and other concepts. The FCS is refining a Communications Operating Concept and Requirements document intended to provide detailed technical requirements for future ATM communications infrastructure. In addition, various potential technical solutions are being assessed for their potential to meet these requirements. An emphasis on existing commercial standards, rather than proprietary or custom solutions, is intended to help minimize the cost of future systems. An important outcome is also expected to be an understanding of electromagnetic spectrum requirements, discussed further below.

8. SPECTRUM ISSUES

A key issue in the discussion of next generation aeronautical communications links is the availability of adequate electromagnetic spectrum. Since the use of the spectrum is regulated by the International Telecommunications Union, the development of a consistent international approach to allocating spectrum for aviation use is essential. A key venue for this coordination is the ICAO Aeronautical Communications Panel Working Group F, which develops for ICAO approval a position for aviation to be advocated at meetings where such allocations are decided, such as the World Radiocommunications Conference, next held in the fall of 2007. Many parties contribute to this discussion through working papers and meetings, such as the FAA, Eurocontrol, and various research organizations, industry representatives and aviation authorities from around the world [7]. As noted above, the Eurocontrol/FAA Future Communications Study has also addressed potential spectrum requirements.

Here is a brief overview of the aviation spectrum situation. Currently air-ground aviation safety communications are

overwhelmingly analog voice in the VHF band, 118-137 MHz. This spectrum is becoming severely congested with very little room available to accommodate growth. The shift of some communications from analog voice to digital data will enable some extension of the use of this band for about 10 years, by most estimates. However, the types of transformational concepts described above will quickly overwhelm the capacity of this band. In addition, there is an expectation that unmanned aerial vehicles (UAV) will proliferate in the future, placing an additional burden on aviation spectrum as they require not only communications in safety-protected spectrum, but also telemetry links to control and monitor the flight of the aircraft.

Two spectrum bands under consideration for reallocation to future aviation safety communications links include the Microwave Landing System (MLS) extension band, 5091-5150 MHz, and some portion of the Distance Measuring Equipment (DME) band, 965-1215 MHz (L-Band). As the DME band also includes military applications, the reallocation of portions of this band additionally requires coordination with military users. The MLS extension band is being studied for a number of uses, including airport surface wireless communications, telemetry for aircraft testing, and security applications. The DME band is being studied for air ground communications links for both regular civilian aircraft as well as UAVs.

9. SUMMARY

The need to address capacity and efficiency limitations in the global air transportation system is acknowledged by all segments of the aviation community. Operational concepts, architectural studies, and roadmaps intended to define a major transformational shift in the global air transportation system are under development by a number of organizations representing the requirements of disparate aviation system users and service providers.

Table I summarizes the major attributes of the five concepts examined in this paper. These concepts have been proposed by key segments of the aviation community. There is a difference in the timeframes of interest to the different segments. However, consensus concepts are emerging, including: the need for a major transformation of the system within the next 20 years; the need for global harmonization of ATM systems and supporting network-oriented digital communications infrastructure; convergence toward 4-D trajectories as the basis for ATM; and the need for a major increase in the amount of information developed and shared between users and providers to enable network-centric operations. In addition, the need for additional protected spectrum for aviation safety communications is a major issue that needs to be addressed by the international aviation community.

Globally harmonized communications infrastructure for aviation is a vision shared by most members of the aviation community, but the attainment of this goal will require

continued efforts. From the current state of studies and concepts, it can be concluded that a new digital air-ground communication link must be developed, with initial implementation before 2020. An air-air communication link component is very likely to also be required, although perhaps later than the air-ground system. A key requirement of these links is to be able to support network-based information access capability. High levels of availability, integrity and security are, of course, essential to aviation safety communications. Emphasis will be on use of commercially developed technologies in order to reduce costs and enable reasonable update and infusion of improved technical standards. Use of frequency spectrum outside the traditional VHF aviation band will be necessary.

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BIOGRAPHY



Robert J. Kerczewski has been involved with research and development of satellite communications systems and applications since for the Analex Corporation (1982-1986) and NASA (1986-present). He holds a BEE degree from Cleveland State University (1982) and an MSEE degree from Case Western Reserve University (1987). He is currently the Project Manager for the NASA's Advanced CNS Architectures and System Technologies (ACAST) Project.