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Communications System Architecture Development for Air Traffic Management and Aviation Weather Information Dissemination

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December 2000

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Space Administration

Glenn Research Center

December 2000

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Preface

This document is the NASA AATT Task Order 24 Final Report. NASA Research Task Order 24 calls for the development of eleven distinct task reports. Each task was a necessary exercise in the development of comprehensive communications systems architecture (CSA) for air traffic management and aviation weather information dissemination for 2015, the definition of the interim architecture for 2007, and the transition plan to achieve the desired End State. The eleven tasks are summarized below along with the associated Task Order reference. The output of each task was an individual task report. The task reports that make up the main body of this document include Task 5, Task 6, Task 7, Task 8, Task 10 and Task 11, as defined below. The other tasks provide the supporting detail used in the development of the architecture. These reports are included in the appendices. The detailed user needs, functional communications requirements and engineering requirements associated with Tasks 1, 2 and 3 have been put into a relational database and provided as an electronic attachment to this Final Report.

Task Overview

Task 1: Identification of User Needs. – Our Team identified user needs and the communications system functional requirements for ATM and weather dissemination applications (AWIN) by: 1) performing a comprehensive literature/document review; 2) compiling a comprehensive list of applicable user needs; and 3) prioritizing this list into ATM and weather user needs. This data formed the basis for assessing the functional requirements. In addition to the ATM and AWIN requirements, a third category Onboard Operator/Passenger, was developed to collect additional cabin communications requirements that must be considered in the overall architecture approach.

We used the literature/document review to assimilate a comprehensive knowledge base of the existing and proposed NAS architectures, and to develop an initial description of user needs. The review included all references contained in the Research Task Order and other relevant information obtained from technical libraries and the Internet. The requirements included those for the service provider (ATM automation), the airspace user (flight deck), and the user flight planning facilities such as Airline Operations Centers (AOCs), Onboard Operator and Airline Passenger (APAX).

Task 2: Develop Communications System Functional Requirements. – Task 2 refines the set of user needs developed in Task 1 into specific communications requirements. It identified the types of message traffic, with projected message volumes. RTCA DO 237 served as the foundation for the ATM and AOC message categories defined in Task 2. The NASA report entitled Data Communications Requirements, Technology and Solutions for Aviation Weather Systems – Phase I Report, Lockheed Martin, 1999, served as the basis for sizing weather-related products. The requirements were considered in terms of domain and phase of flight.

Task 2 focused on the types of products needed to satisfy requirements, to trace more easily from user requirements to architectures. It consists of a list of communication system function requirements associated with the lists of user needs identified in Task 1.

We made this association by relating all user needs, functional requirements, and engineering requirements (Task 3) to a list of functional capabilities and NAS Services.

Task 3: Develop Communications System Engineering Requirements. - Task 3 drove the remainder of the effort, since it developed the specific engineering values from the functional requirements that were needed to assess various technological solutions. The *Operational Requirements for the ADLS* served as a foundation for this effort and was supplemented by the FARs and more recent efforts such as those conducted by Eurocontrol. This approach provided the constraints necessary to help test architectural choices posed by later tasks.

Task 4: Develop Preliminary/Candidate Communications System Architectural Concepts. – Task 4 developed a common base for architectural alternatives. The architecture is "end-to-end" and considers ground systems and avionics as well as classes of users with different types of avionics and different capabilities. Task 4 developed a common base for architectural alternatives.

In addition to requiring access to government-operated ATM and weather systems, aircraft may require access to AOC and to commercial services for information or for passenger communications. For any given mode of communication, there are likely to be multiple candidate links. By comparing the capabilities of the candidate links we identified and assessed other constraints.

Task 5: Develop 2015 AATT Architecture. – The 2015 AATT Architecture Development task use architectural concepts developed in Task 4 that were based on the communication system requirements of Task 3. For this task, we developed a comprehensive 2015 Communications System Architecture (CSA) that encompasses AATT and AWIN requirements. We identified technologies for Air-Ground and Air-Air communications, along with the standards and protocols.

The 2015 CSA represents the evolutionary establishment of the foundation for aeronautical information exchange. This foundation provides the users of the NAS with common data for all user types that provides enhanced safety through common situational awareness and provides optimum efficiency through collaborative decision making. The CSA will support general information broadcast as well as direct exchange and query of information through point-point links.

> **Task 5.1: Air-Ground and Air-Air Communications/Datalinks Technical Description**. - Based on the requirements developed in Task 3 and our investigation of known potential communications/datalink technologies, we provided a detailed end-to-end description of each of the communication/datalinks that are a part of our 2015 architecture. Architecture link types (both voice and data) that support aircraft-aircraft, aircraft-air traffic control (including control and traffic management), aircraft-flight information service, and aircraft-aircraft operations were addressed. The architecture employs the most suitable links based on the overall system performance requirements.
>
> **Task 5.2: Communications Architecture Network, Standards and Protocol Description.** – Based on our 2015 CSA, we provided a definition of the network standards and protocol requirements necessary to support each datalink for our

architecture to achievement of a harmonized 2015 CSA. This definition includes the identification of any interoperability requirements and standards, such as those for aeronautical flight, traffic, and commercial information. We build on existing standard work in the areas of flight and traffic information and identify the changes necessary to support our 2015 architecture.

Task 5.3: Ground-Ground Communications. - Based on the definition of our 2015 architecture, we identified unique implications for the Ground-Ground communications network infrastructure including any obstacles with respect to gaining access and transmitting data as necessary to optimize the 2015 CSA.

In many of the Concept of Operations reports published to date, there is a clear need for the implementation of a NAS-wide information sharing capability. We anticipate that this capability will be implemented in the 2012 time frame and thus should be considered as the interface for the 2015 CSA. The current concept for NAS-wide information sharing calls for a collection of local and national information services that provide for the dissemination of airport, airspace, weather, infrastructure, and active flight data (including surveillance data and flight object data) through multiple virtual private networks. This concept assumes an interface with a robust Air-Ground and Air-Air communications architecture in order to provide the desired Air Traffic Services.

Task 6: Develop AATT 2007 Architecture. - This task used the definition of the 2015 CSA from Task 5 and requirements from Task 3 to define candidate transition CSAs that lead to the 2015 CSA.

The proposed CSA for the 2007 time frame must fit with the expected evolutionary state of the NAS. In the 2007 time frame, the NAS will not yet have integrated data communications or standards. Likewise, the NAS will be in the process of making its most significant change, that of moving from the current Host-centric flight data processing to one of distributed flight objects across all ATC facilities. This change will enable the use of four dimensional flight trajectory information and will completely change the use of flight plan information as we know it today.

Task 7: Develop AWIN 2007 Architectures. – This task used the selected concept from Task 5 and requirements from Task 3 to define candidate CSAs that lead to the 2015 CSA. We identified the most promising CSAs for AWIN and further developed them to the level of detail necessary to allow the identification of technology gaps that may impede implementation. We ensured that the proposed CSAs would fit within the transition plan identified in Task 8.

We developed three 2007-state architectures that encompassed the AWIN requirements. We identified technologies for Air-Ground and Air-Air communications along with the standards and protocols that they will use. The architectures address key issues such as: (1) Data Dissemination, (2) Crew Monitoring, Presentation and Decision Aids, and (3) Weather Product Generation.

The proposed architectures must deliver accurate, timely, and precise weather data.

Task 8 (para 4.9) Develop Transition Plan. - This task developed a technical plan that detailed the transition from the current CSA to the 2015 CSA developed in Task 5. The plan demonstrated that the state architecture is credible. Our approach was to develop the transition plan based on the definition of a set of key milestones that begins with the 2015 CSA and proceeds backward in time through additional milestones. We identified elements and activities along the critical transition path, described their significance and contribution to the transition, and highlighted their contributions to the identification of key milestones. The set of required key milestones includes not only the mid-term (2007) architectures for air traffic management and aviation weather dissemination, but also those key milestones necessary to achieve and retain consistency with the evolving overall NAS Architecture (as currently defined in NAS Architecture Version 4.0). Furthermore, the transition plan for the CSA development from the current state through the 2015 state is fully consistent with the planned evolution of the NAS in terms of all its technical, programmatic, and fiscal (inter) dependencies identified in the NAS Architecture baseline.

Task 9: Characterize Current and Near term Communications System Architecture. – For this task, we documented the current CNS in sufficient detail to form a baseline for the 2007/2015 CSA development.

Tasks 9.1 and 9.2: Communications/Data Link Applications and Relevant Data Link Programs. –

This report provides a comprehensive list that contains the system objectives, the primary benefits being derived or expected by users, the status of each program (i.e., operational system, prototype, proof-of-concept) and projected deployment, and the communication medium employed.

Task 9.3: Communications/Datalink Technical Characterization. - Using the format specified in Task 5.1 (para 4.6.1), we characterized the current and near-term data link technologies listed in SOW Paragraph 4.10.3. We gave specific consideration to identifying those characteristics that could present potential safety issues such as overall system availability and message delivery rates.

Task 9.4: Networks, Standards and Protocols. - This report maps the data link technologies identified in Task 9.3 (para 4.10.3) to the appropriate network standards and protocols and described their ability to support current and near term data links.

Task 10: Identify Communications System/Technology Gaps. – This report identifies the communication system or technology gaps for the 2007 and 2015 time frames that are not being addressed by existing or planned development or research programs. We ensured that the technology gaps are integrated into a system perspective.

Task 11: Identify Components for R&D. – The results of the previous task form the basis for recommendations for R&D. We examined each of the gaps identified in Task 10 in detail by the definition of targeted R&D efforts. Although in many cases the technology to fill the gaps exists today, certain components have not been tailored to the aeronautical communications environment. This report describes the basic technologies and solution candidates needed to implement all of the characteristics in the aeronautical environment for the planned ATM and AWIN applications and the projected Onboard Operator and passenger services.

Communications System Architecture Development For Air Traffic Management & Aviation Weather Information Dissemination

Research Task Order 24

Subtask 4.6, Develop AATT 2015 Architecture

(Task 5.0)

Prepared By

ARINC
Science Applications International Corporation (SAIC)
TRW

Submitted to
NASA Glenn Research Center
under
Contract NAS2-98002

May 2000

Table of Contents

Table of Figures

Table of Tables

1 Executive Summary

1.1 Background

The Advanced Air Transportation Technologies (AATT) initiative has a number of project sub-elements ranging from advanced ATM concept development to aircraft systems and operations. It also has an Advanced Communications for Air Traffic Management (AC/ATM) task with a goal of enabling an aeronautical communications infrastructure through satellite communications that provides the capacity, efficiency, and flexibility necessary to realize the benefits of the future ATM system and the mature Free-Flight environment. Specifically, the AC/ATM task is leveraging and developing advanced satellite communications technology to enable Free Flight and provide global connectivity to all aircraft in a global aviation information network. The task directly addresses the Office of Aerospace Technology (OAT) Enterprise Pillar One Enabling Technology Goal of increasing aviation throughput as part of the AATT Project. The objectives of the AC/ATM task are to:

1. Identify the current communication shortfalls of the present ATM system
2. Define communications systems requirements for the emerging AATT concept(s)
3. Demonstrate AATT concepts and hardware
4. Develop select high-risk, high payoff advanced communications technologies.

The technical focus of the AC/ATM task has centered on the development of advanced satellite communications technology as a select high-risk, high payoff technology area in support of ATM communications (objective 4 above). Although the thrust of the task has been satellite communications (SATCOM), aeronautical air-ground communications will be provided for the foreseeable future by a number of different communications systems/data links, including HF, VHF, L-band, and SATCOM. Relevant advanced technology development for any of these systems requires that a comprehensive technical communications architecture exist. In satisfaction of objectives 1 and 2, a comprehensive technical communications system architecture must be defined and developed. That architecture must address the user communications requirements of the future mature ATM system that the various data links mentioned can support.

1.2 Objectives

The objective of Task 5 is to develop a 2015 AATT Communication System Architecture; i.e., to develop a Communication System Architecture (CSA) with the potential for implementation by 2015. This CSA is to be comprehensive and driven by derived communications system engineering requirements. It must include a detailed technical description of all communications/data links required by the 2015 architecture, including all air-ground and air-air links, with each required communications/data link defined with respect to its end-to-end link characteristics. The CSA must provide a definition of the network, standards, and protocol requirements for the overall architecture and for each data link. It must identify and provide mitigating solutions for any unique implications to the ground-ground communication network infrastructure in realizing or implementing the identified air-air and air-ground data links.

1.3 Technical Approach

The specific Task 5 objective of developing a 2015 AATT Communication System Architecture must be viewed within the context of the overall National Airspace System (NAS) and the services it provides. For example, NASA's Office of Aerospace Technology has identified a technology objective stating:

While maintaining safety, triple the aviation system throughput, in all weather conditions, within 10 years.

This objective clearly indicates the need to view the CSA in the full context of the NAS and, in particular, the Air Traffic Management (ATM) component of the NAS. To provide that context, we extracted user needs and high-level goals (Task 1) from multiple sources, including other NASA and FAA programs, RTCA activities, and industry. From these needs and goals, we developed a consensus vision and concept of operations for the 2015 architecture to provide a "top down" perspective. We further refined the operational concept into nine communication technical concepts that formed our functional communication architecture.

The functional communication architecture was used to formulate alternative technology solutions for the physical architecture based on the results of our communication loading analysis (Section 4) and our determination of communication link capabilities (Section 5). This process is illustrated in Panel A of Figure 1.3-1.

Concurrent with the process of defining technology alternatives for the 2015 AATT communication system architecture, we reviewed the current NAS Architecture plans to develop a "bottom up" perspective of what systems and capabilities are expected to be in place in 2015. With this "projected" definition, we were able to compare the 2015 AATT CSA technology alternatives to the bottom-up view 2015 NAS Architecture to identify the differences (or "gaps") between the two and to develop a 2015 AATT Architecture. This process is illustrated in Panel B of Figure 1.3-1. Task 10 and Task 11 will identify the gaps more comprehensively and make recommendations on areas of research or development to close them. These tasks, along with the Transition Plan task (Task 8), also will define an effective transition path from today's NAS Architecture, through a 2007 Architecture (Task 6) and the 2007 AWIN Architecture (Task 7), to the 2015 AATT CSA.

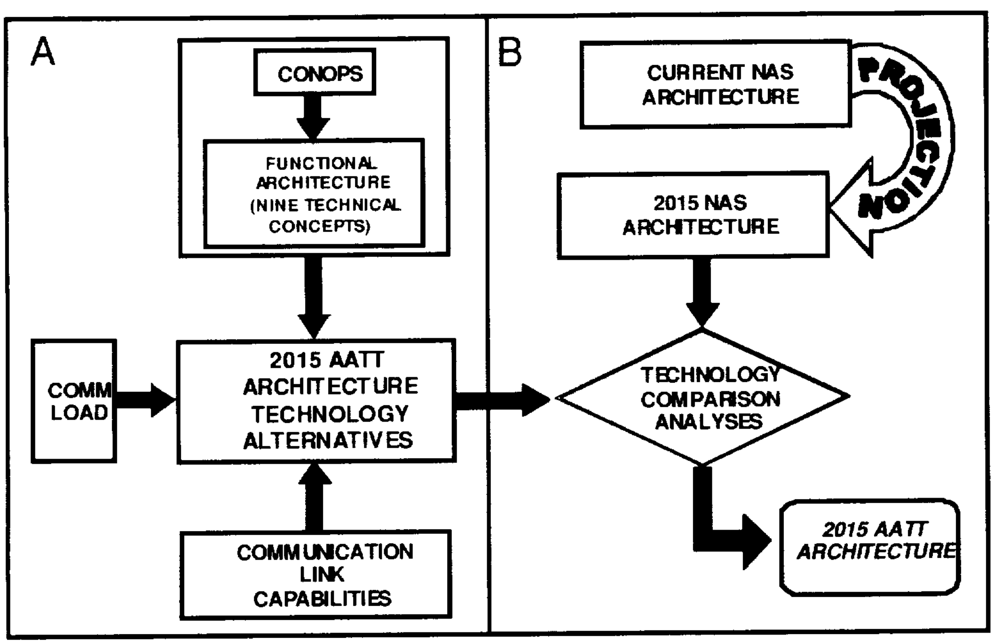

Figure 1.3-1. 2015 AATT Architecture Development Method

1.4 Results of This Task

The 2015 time frame represents the final phases of transition from the era of analog voice communication and islands of diverse information to the new era of digital data exchange through integrated networks using common data. The results of this transition are an integrated collection of systems and procedures that efficiently use the capacity of the NAS while balancing access to all user classes and maintaining the highest levels of safety. As depicted in Figure 1.4-1, efficient collaboration among users is built on a foundation of common data that composes the information base. This data can be logically divided into a static component, representing data that changes infrequently such as maps, charts, etc., and a dynamic component, representing data that changes frequently such as the weather, traffic flow status, and aircraft position. This information base provides common situational awareness to all users who choose to participate. In this time frame, there a variety of users who will choose to participate at various levels of equipage ranging from voice only through multi-mode radios and fully modular avionics. All users are accommodated, however, and will receive benefits commensurate with their levels of equipage.

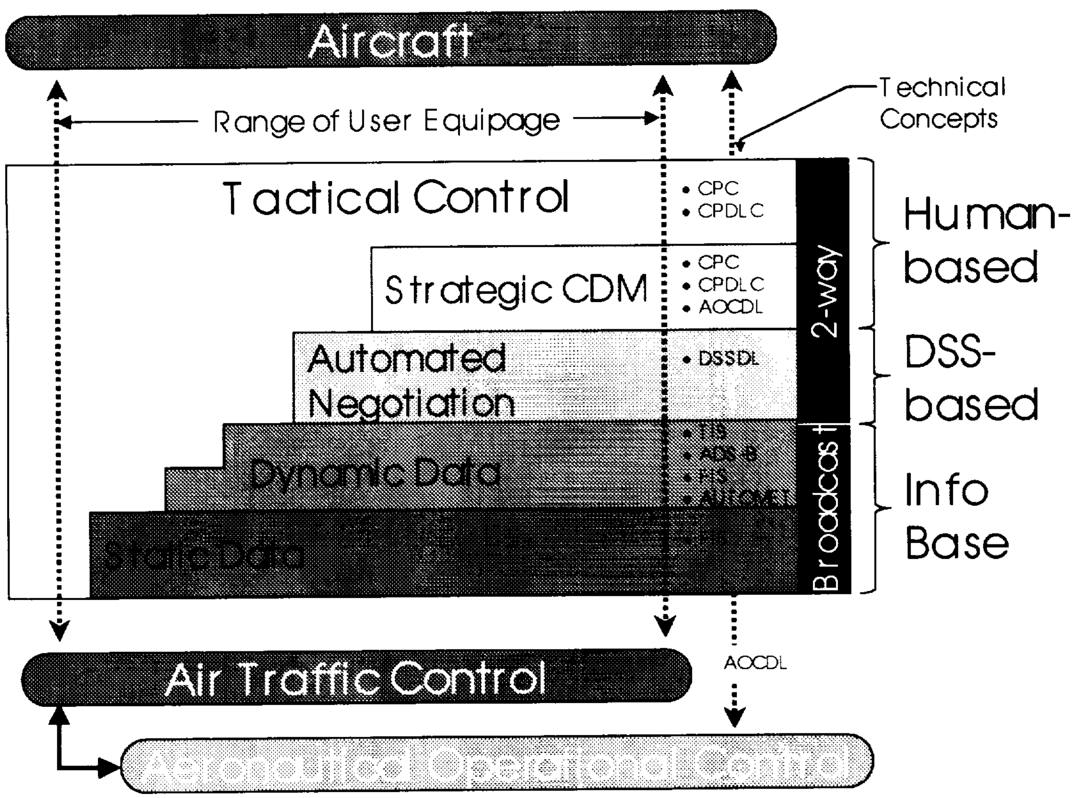

Figure 1.4-1. Air-Ground Communication Levels

The challenge in maintaining the information base is to keep the dynamic data current for all participating users so that optimum decisions can be made. Given a common information base, decision support systems can analyze this data continuously to develop optimum solutions for individual aircraft trajectories as well as trajectories for groups of aircraft. This negotiation takes place between aircraft Decision Support System (DSS) tools and between aircraft and ATC DSS tools. When optimum solutions (or inability to find a solution) are determined, pilots and controllers are notified for confirmation (or other appropriate action). This action takes the form of strategic collaborative decision making or tactical control. In either event, data exchange continues using specified data link messages with voice communication used when it is the only practical means.

Our analysis of user needs and the latest concepts of operation led us to define these levels of air-ground communication and to also define a collection of technical communication concepts for categorizing the various levels of data exchange that we discovered. These technical concepts are defined in Table 1.4-1 and also are highlighted within their applicable levels in Figure 1.4-1. A more detailed explanation of each technical concept can be found in Section 3 of this report.

The combinations of these technical concepts form the functional communications architecture shown in Figure 1.4-2. Our use of the NAS-Wide Information System (NWIS) at the center of the functional architecture represents a key assumption in performing this analysis. In the 2015 time frame, the ground-side NAS has evolved to the point that it contains a collection of data that is commonly defined and virtually available among all participating nodes using the most efficient communications paths available. Additionally, each participating node – either airborne or ground – has sufficient processing and storage capability that these capabilities will not be limiting factors in the timely exchange of information between nodes.

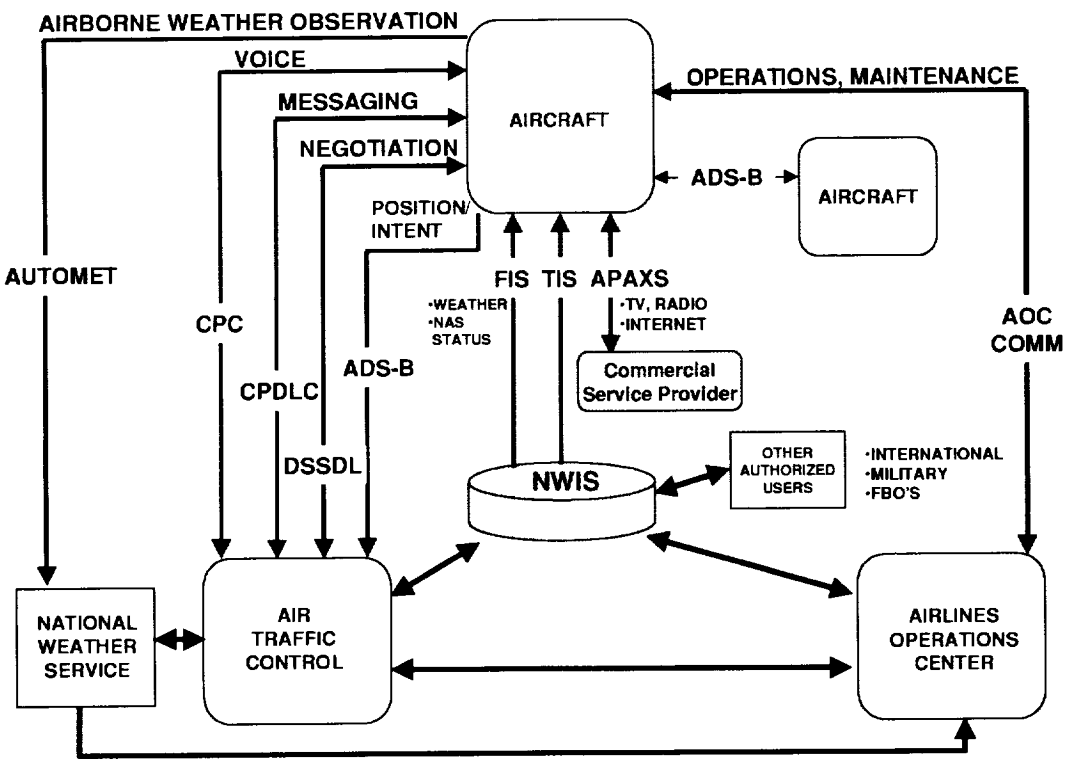

Figure 1.4-2. 2015 AATT Functional Communication System Architecture

The transformation of the functional architecture into a physical architecture was accomplished by comparing the message load requirements for each functional interface (Section 4) with the capabilities of the enabling communications links (Section 5).

Table 1.4-1. 2015 Technical Concepts

Technical Concept Definition	Technical Concept Name
Aircraft continually receive Flight Information to enable common situational awareness	Flight Information Services (FIS)
Aircraft continually receive Traffic Information to enable common situational awareness	Traffic Information Services (TIS)
Controller - Pilot voice communication	Controller - Pilot Communication (CPC)
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	Controller-Pilot Data Link Communications (CPDLC)
Aircraft exchange performance / preference data with ATC to optimize decision support	Decision Support System Data Link (DSSDL)
Aircraft continuously broadcast data on their position and intent to enable optimum maneuvering	Automated Dependent Surveillance-Broadcast (ADS-B)
Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance	Airline Operational Control Data Link (AOCDL)
Aircraft report airborne weather data to improve weather nowcasting/forecasting	Automated Meteorological Transmission (AUTOMET)
Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service	Aeronautical Passenger Services (APAXS)

We determined the functional interface loading by logically grouping the message requirements that were identified in Tasks 1, 2, and 3 of this Task Order. We recognized, however, that the air-ground exchange of data would not be the same for all aircraft. We therefore chose to use three classes of aircraft: low-end general aviation (Class 1), high-end general aviation and commuter aircraft (Class 2), and commercial carriers (Class 3). These classifications lead to a better traffic load estimate since the number, frequency, and type of message in many cases depends on where the aircraft is and what type of equipage it has. Additionally, we chose to partition the analysis by domain so that the air-ground communication architecture could be optimized to meet any special regional requirements. A summary of the peak communication loads for 2015 is provided in Table 1.4-2.

Table 1.4-2. Summary of Peak Communication Loads for 2015 (kbps)

Data Message Traffic for All Classes of Aircraft (K-bits per second)						
2015	**Airport Uplink**	**Airport Downlink**	**Terminal Uplink**	**Terminal Downlink**	**En Route Uplink**	**En Route Downlink**
FIS	0.2	0.0	0.9	0.0	6.9	0.0
TIS	23.7	0.0	7.0	0.0	20.5	0.0
CPDLC	3.4	2.9	1.3	0.9	1.1	1.3
DSSDL	0.2	0.3	0.1	0.2	0.1	0.1
AOC	0.4	8.4	0.6	8.5	0.2	3.5
ADS Reporting	0.0	16.1	0.0	3.3	0.0	1.5
AUTOMET	0.0	0.0	0.0	4.4	0.0	6.2
APAXS	0.0	0.0	0.0	0.0	131.7	115.5

As mentioned previously, the NAS in 2015 requires a data exchange capability that supports the establishment of an air-ground information base. The technical concepts that support this information base are FIS, TIS, ADS-B, and AUTOMET. Taken individually, a solution for each of these concepts could be developed from one of the individual links identified in Table 1.4-3. When viewed from a systems perspective, however, the notion of an integrated data exchange capability begins to emerge. Candidate links that could meet this integrated data exchange need should be capable of supporting data rates on the order of hundreds of kilobits per second.

Table 1.4-3. Capacity Provided by Various Communication Links

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
	kbps	Channels	Channels	Aircraft	
HFDL	1.8	2	1	50	Intended for Oceanic
ACARS	2.4	10	1	25	ACARS should be in decline as users transition to VDL Mode 2
VDL Mode 2	31.5	4+	1	150	System can expand indefinitely as user demand grows
VDL Mode 3	31.5*	~300	1	60	Assumes NEXCOM will deploy to all phases of flight
VDL Mode 4	19.2	1-2	1	500	Intended for surveillance
VDL – B	31.5	2	1	Broadcast	Intended for FIS
Mode-S	1000**	1	1	500	Intended for surveillance
UAT	1000	1	1	500	Intended for surveillance/FIS
SATCOM	-	-	-	-	Assumes satellites past service life
Future SATCOM	384	15	1	~200	Planned future satellite
Future Ka Satellite	2,000	~50	~50	~200	Estimated capability - assumes capacity split for satellite beams
Fourth Generation Satellite	>100,000	>100	>100	Unknown	Based on frequency license filings

* Channel split between voice and data.

** The Mode-S data link is limited to a secondary, non-interference basis with the surveillance function and has a capacity of 300 bps per aircraft in track per sensor (RTCA/DO-237).

In addition to data exchange, the NAS also requires a two-way data messaging capability to support the efficient coordination of information, decision making, and the delivery of clearances and advisories. The technical concepts that support this are AOCDL, DSSDL, and CPDLC. Candidate links that could meet these needs should be ATN compliant and capable of supporting data rates on the order of tens of kilobits per second.

A summary of the applicable communication links that we project will be capable of supporting the communication loads for each technical concept is provided in Table 1.4-4.

Table 1.4-4 2015 AATT Technical Concepts to Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Flight Information to enable common situational awareness	FIS					✓ (boxed)		✓	✓	
Aircraft continuously receive Traffic Information to enable common situational awareness	TIS					✓	(empty box)	✓	✓	
Controller - Pilot Communication	CPC	✓ (boxed, circled)		✓ (boxed, circled)						
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	CPDLC			✓ (boxed, circled)						
Aircraft exchange performance / preference data with ATC to optimize decision support	DSSDL			✓ (boxed, circled)						
Aircraft continously broadcast their position and intent to enable optimum maneuvering	ADS-B				✓		✓ (boxed)	✓		
Pilot - AOC data exchange supports efficient air carrier/air transport operations and maintenance	AOCDL		✓					✓		✓
Aircraft report airborne weather to improve weather nowcasting/forecasting	AUTOMET		✓					✓		✓
Passengers enjoy in-flight television, radio, telephone, and internet service	APAXS								✓	✓

✓ Acceptable Alternative; □ NAS Architecture; ○ AATT CSA Recommendation

From an integrated NAS Architecture perspective, we feel that an attempt should be made to minimize the number of aircraft radios required to operate efficiently while recognizing the desirability of maintaining a level of robustness across CNS avionics. With this in mind, our optimum aircraft would have a multimode VHF radio to support two-way messaging, a broadband UAT or SATCOM radio to support data exchange, a Mode-S radio to support surveillance and collision avoidance, and finally a radio to support navigation. (Note: surveillance and navigation analysis were not considered within the scope of this analysis).

For CPC, CPDLC, and DSSDL, our recommendation follows that of the NAS Architecture. The implementation of VDL-3 will more than adequately accommodate the ATC needs of 2015 and beyond. The transition to VDL-3 could be problematic, however, given the load projections for the VDL-2 network. There will continue to be a need to maximize the communication capacity of VHF data links operating in the protected aviation spectrum. Accordingly, we recommend further research in the areas of link modulation and data compression to increase the overall bit transfer rate, network prioritization schemes that combine voice and data, and the development of designs for virtual air ground links that will maximize the use of available frequencies.

We have not made a recommendation for FIS, TIS, or ADS-B, because we feel that there is additional research required to provide sufficient data to support a recommendation. An integrated data exchange capability as we discuss in this analysis is not currently envisioned in the NAS Architecture. Additionally, the link decision currently underway on ADS-B can have a significant influence on the overall communication system architecture. With regard to the implementation of UAT or SATCOM, one potential advantage of using UAT would be that the majority of aircraft would already have a UAT radio [if it is (one of) the technology (ies) chosen for ADS-B] and a UAT terrestrial network would have been established. Additionally, UAT avionics have been designed to support all classes of aircraft. Implementation of UAT should consider the use of dedicated channels and protocols for ADS-B and TIS to optimize their performance, while FIS and AUTOMET could employ a more standard broadcast scheme. An advantage of SATCOM would be the wide area access provided without the need for a terrestrial network and the use of a commercial service provider. A current disadvantage for next genration SATCOM, however, is that antennas and receivers must be adapted for the aviation market (size, weight, cost) and must overcome the condition of rain attenuation for broadcast.

We have not made a recommendation for AOCDL because it is a commercial link. The current plans for implementation of AOCDL is via VDL-2 using four allocated AOC frequencies. Costs for two-way SATCOM service may be attractive for the AOCs if it is coupled with some form of APAXS that make it cost competitive with VDL-2.

AUTOMET is problematic in that our load projections exceed any VDL solutions. However, in all likelihood, AUTOMET will begin on the AOCDL VDL-2 network in the 2007 time frame. If an integrated data exchange capability is developed as described above, we would recommend it for AUTOMET. Absent that, we recommend that AUTOMET continue to use the same link as AOCDL (VDL-2 or SATCOM).

Finally, for APAXS, the use of SATCOM will be driven by the commercial industry desire to provide high-data-rate services to passengers such as real time television and Internet access. These services are already available to private executive and business aircraft. Air Traffic Service providers should stay aware of these efforts and look for opportunities to exploit this method of data transmission. Accordingly, we recommend that further study be conducted to determine the possibility for innovative partnerships or incentives that may leverage the involvement of commercial service providers in the delivery of selected air traffic services via SATCOM. For example, providers of broadcast entertainment channels to aircraft could be required to provide an air traffic services channel that is freely accessible by all aircraft. This example is similar to the requirement that cable television providers have with regard to providing public access channels.

In summary, for the 2015 time frame, a majority of Class 1 aircraft are equipped with a VHF multimode radio for voice and data communications and ADS-B avionics that transmit their derived position via the selected link (Mode-S, VDL-4, or UAT), which allows pilots to receive extended flight following and separation services due to the extended coverage of the ADS-B receiver network. Flight and traffic information is provided through UAT or SATCOM. Many corporate jets and other high-end users will have provision for passenger services such as Internet or television via satellite.

Class 2 users differ from Class 1 users in that some Class 2 users have access to AOCDL that provides operations and maintenance data via VDL-2. Additionally, in this time frame, the majority of Class 2 users will be equipped with a multimode radio that supports VDL-3 voice communications. Flight and traffic information is provided through UAT or SATCOM. Some Class 2 users may also equip for APAXS via satellite.

The Class 3 users see the greatest change in communications from the 2007 time frame. Virtually all Class 3 aircraft will be equipped with multimode radios that support controller-pilot voice and data communications via VDL-3. In addition, these aircraft will exchange performance and preference data with ATC via VDL-3 DSSDL. Flight and traffic information are provided through UAT or SATCOM. Two-way SATCOM will be available to support passenger Television and Internet services and may begin to support aircraft-AOC and aircraft-ATC data exchange.

Class 3 aircraft will be the majority users of ADS-B via the selected link (Mode-S, VDL-4, or UAT) due to the maneuvering benefits derived from equipage. HFDL will continue to be used by some aircraft to support oceanic operations.

An overview diagram of the 2015 AATT Architecture alternative using broadband satellite is shown in Figure 1.4-3 and a terrestrial broadband alternative is depicted in Figure 1.4-4.

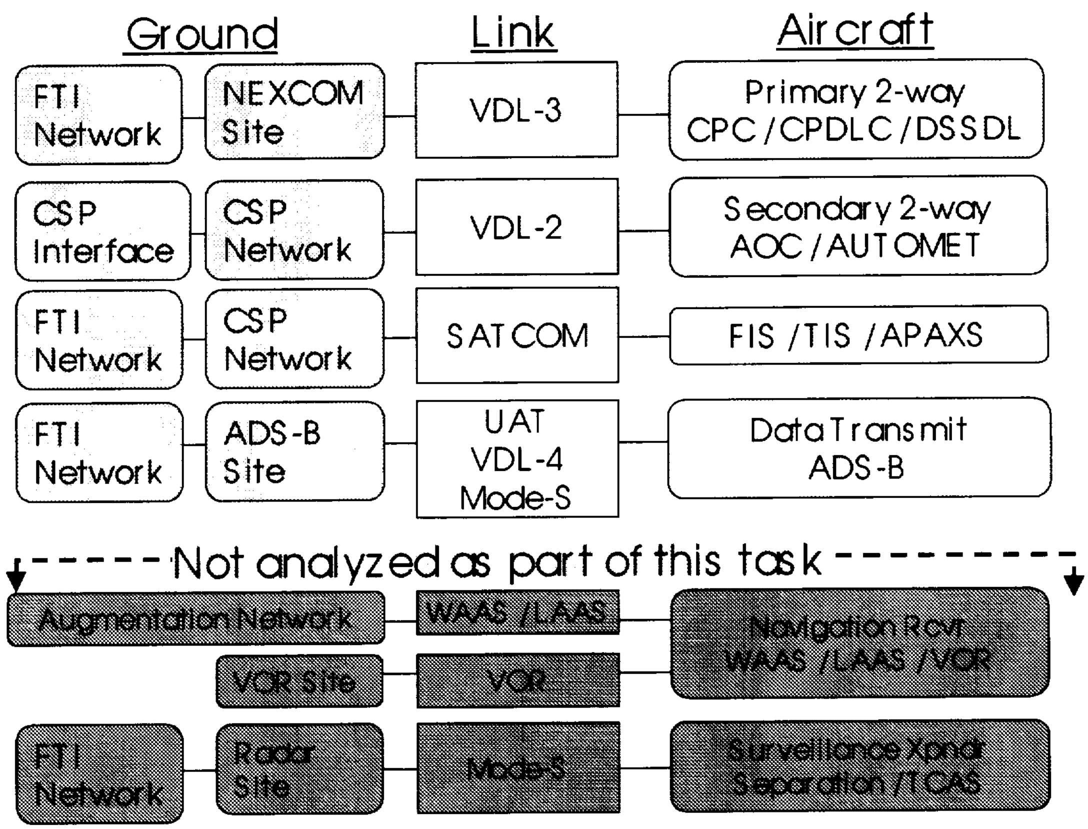

Figure 1.4-3. 2015 AATT Architecture Alternative - SATCOM Based Broadband

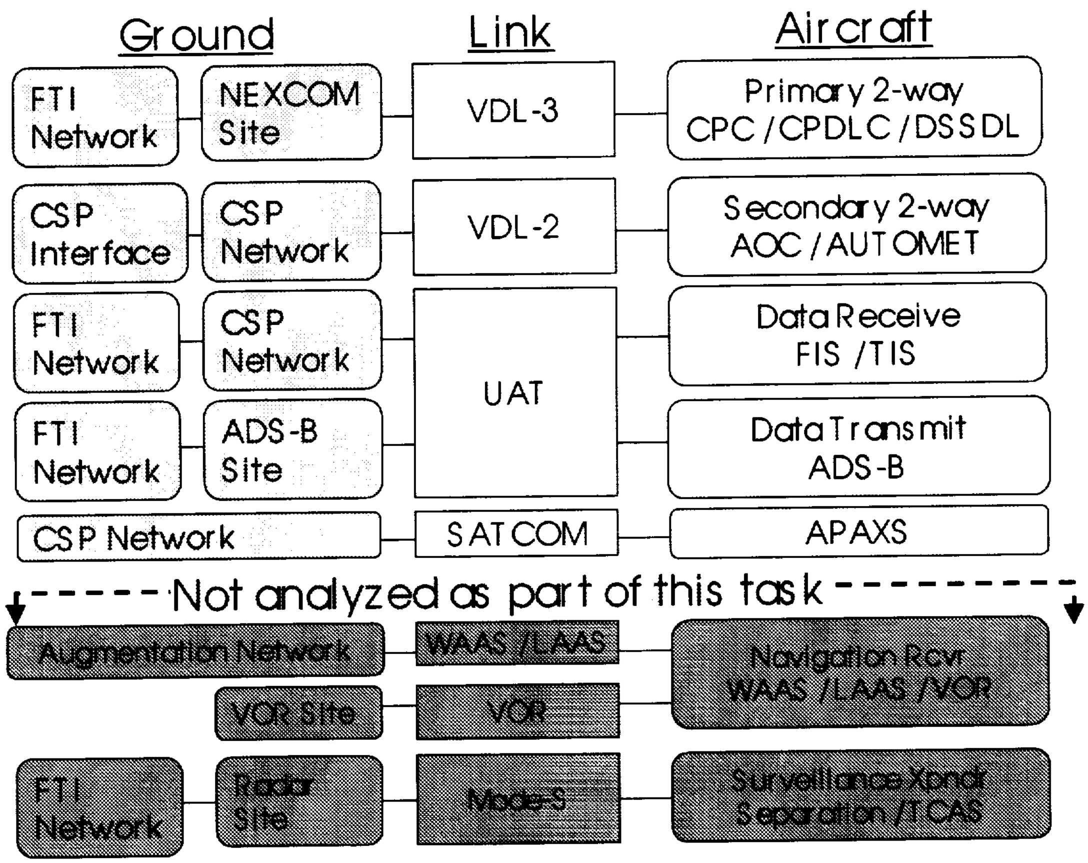

Figure 1.4-4. 2015 AATT Architecture Alternative - Terrestrial Based

2 Introduction

This report responds to a specific task under AATT Research Task Order (RTO) 24, develop AATT 2015 Communication System Architecture (CSA).

2.1 Overview of Task 5

The objective of Task 5 is to develop a 2015 AATT Communication System Architecture; i.e., to develop a communication system architecture (CSA) with the potential for implementation by 2015 that can fulfill the goal of providing the collection and dissemination of aviation related information to and from various classes of aircraft.

Task 5 is one of eleven related tasks in the AATT RTO 24, Communications System Architecture Development for Air Traffic Management and Aviation Weather Information Dissemination. The relationships among these tasks are depicted in Figure 2.1-1. Task 5 builds upon the communications system concepts developed in Task 4 and uses requirements from Task 3 to define the recommended 2015 AATT architecture. Task 6 develops the 2007 AATT Architecture, and Task 7 develops the 2007 Aviation Weather Information (AWIN) Architecture. Elements of Task 9 define and determine what is achievable in 2015. The results of these tasks all feed tasks 8, 10, and 11.

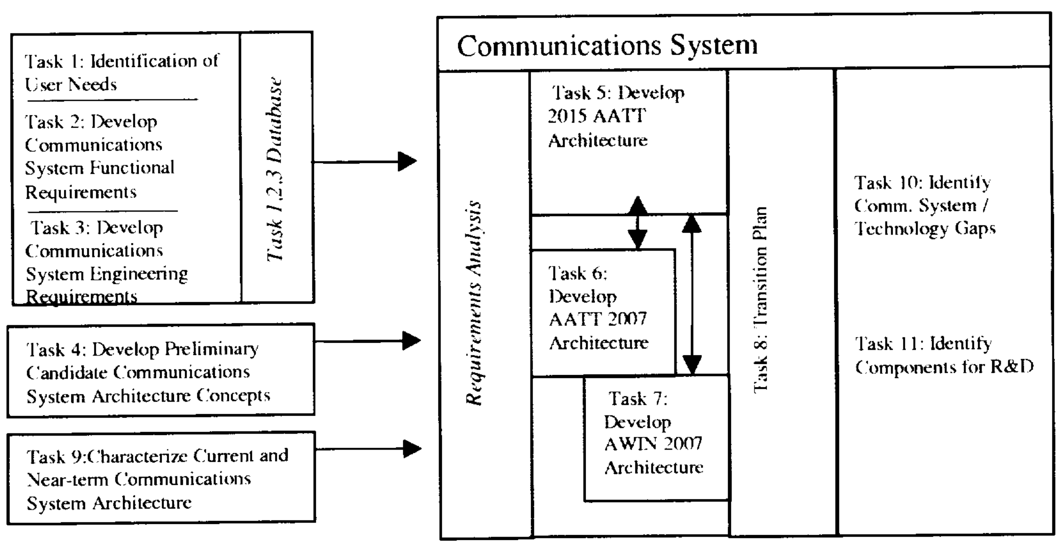

Figure 2.1-1. Relationship to Other Tasks

Task 5 began with a review of the relevant user needs and functional communications requirements collected in Tasks 1, 2, and 3 of this Research Task Order to develop a communications functional architecture for 2015 based on the nine communication technical concepts presented in Section 3 and discussed in detail in Section 3.1. The functional communication architecture was used to formulate alternative technology solutions for the physical architecture based on the results of our communication loading analysis and our determination of communication link capabilities. Concurrent with the process of defining technology alternatives for the 2015 AATT communication system architecture, we reviewed the current NAS Architecture plans to develop a "bottom up" perspective of what systems and capabilities are expected to be in place in 2015. With this "projected" definition, we were able to compare the 2015 AATT CSA technology alternatives to the bottom-up view 2015 NAS Architecture to identify the differences (or "gaps") between the two and to develop a recommended 2015 AATT Architecture. Tasks 10 and 11 will identify the gaps more comprehensively and make recommendations on areas of research or development to close them. These tasks, along with the Transition Plan task (Task 8), also will define an effective transition path from today's NAS Architecture, through a 2007 Architecture (Task 6) and the 2007 AWIN Architecture (Task 7), to the 2015 AATT CSA.

To ensure data availability to meet the needs of all users of the Air Traffic Services, three classes of users were defined as follows:

Class 1: Operators who are required to conform to FAR Part 91 only, such as low-end General Aviation (GA) operating normally up to 10,000 ft. This class includes operators of rotorcraft, gliders, and experimental craft and any other user desiring to operate in controlled airspace below 10,000 ft. The primary distinguishing factor of this class is that the aircraft are smaller and that the operators tend to make minimal avionics investments. A small number of aircraft are not equipped with radios, but these aircraft are outside the realm of a communications architecture.

Class 2: Operators who are required to conform to FAR Parts 91 and 135, such as air taxis and commuter aircraft. It is likely that high-end GA and business jets and any other users desiring to operate in controlled airspace will invest in the necessary avionics to be able to achieve the additional benefits.

Class 3: Operators who are required to conform to FAR Parts 91 and 121, such as Commercial Transports. This class includes passenger and cargo aircraft and any other user desiring to operate in controlled airspace. These users will invest in the avionics necessary to achieve the additional benefits.

Based on the user needs and functional communications requirements presented in Tasks 1 and 2, the table below presents the high level objectives to be met by the resulting communications architecture. These user goals and operational requirements have been grouped according to user class.

Table 2.1-1. User Goals and Operational Requirements

Class 1 User Goals	**Class 2 User Goals**	**Class 3 User Goals**
• Minimize/streamline interaction with ATM system • Make communications transparent and seamless for the pilot • Expand access to more airports in IMC conditions (High-end GA)	• Reduce limitations and delays caused by weather • Provide instrument approaches to more airports	• Expand the use of user preferred routes and trajectories • Increase airport capacity in IMC • Increase system predictability • Reduce weather related delays • Minimize time and path length for routing around hazardous weather
Class 1 Operational Requirements	**Class 2 Operational Requirements**	**Class 3 Operational Requirements**
Class 1 users require: • On demand weather • Weather at more sites • User friendly formats ("user friendly" includes graphical, oriented to flight path, uncluttered, easy to interpret by solo pilot, etc.) • More real-time updates	Class 2 users require: • Weather at a greater number of sites • More real-time weather at remote sites	The Class 3 users, desiring a combination of preferred routes and increased capacity, require: • More precise weather information for routing • Weather information consistent with that seen by controllers and operations centers • Higher density grids at higher update rates to support decision support systems like CTAS and wake vortex prediction systems

The information above emphasizes a flow of information that generally is ground-to-air. Aircraft will be required, however, to downlink a greater number of aircraft parameters and intent information to feed automation and decision support systems (CTAS, wake vortex prediction, etc.).

This Task 5 effort identifies the criteria and provides an assessment of the suitability of each mode of communications and communications links for each potential aviation application. These assessments concentrated on engineering requirements and addressed the benefits to specific types of users, thereby driving user equipage decisions. From a CSA perspective, the implications of airspace users that have varying levels of capability are considered, so airspace mix also is considered. Based on the supporting technical detail found throughout Section 3, the resulting recommended 2015 AATT Communications Architecture is presented in Section 3.4.

2.2 Overview of the Document

Section 1 is an executive summary that provides a high-level synopsis of this document.

Section 2 introduces the task and provides the necessary background and context, including the relationship of Task 5 to other RTO 24 tasks.

Section 3 provides a recommended 2015 Architecture in the context of the supporting technical detail used to develop the recommendation. It provides architecture concepts, characteristics, and considerations. It discusses the following topics in order:

- Our approach to developing architecture alternatives
- A summary of the 2015 AATT communication system architecture technology alternatives, including advantages and disadvantages of each in comparison to the projected 2015 NAS Architecture
- The recommended 2015 AATT communication system architecture with rationale for selection.

Section 4 presents the technical detail of the communication load analysis. It discusses the following topics in order:

- Calculation methodology
- Numerical results of the message load calculations
- Implications and conclusions drawn from the numbers.

Section 5 provides the technical details of the communications links.

- Link characteristics (SOW 4.6.1)
- Significant points and tradeoffs considered in link selection
- Network, standards, and protocol requirements for the overall architecture and for each data link, including any interoperability requirements between different networks, standards, and/or protocols
- Implications for the ground-ground communication network infrastructure in realizing/implementing the air-air and air-ground data links identified in SOW 4.6.1, along with potential mitigating solutions
- Technical obstacles with respect to gaining access and transmitting the data via the ground infrastructure.

Section 6 describes some of the characteristics of the ground-ground communications relevant to the AATT communication systems architecture.

3 Defining the 2015 Communication System Architecture

3.1 Introduction

The architecture development concepts presented in this section are not unique to Task 5 (2015 AATT Architecture); rather, they apply equally well to Task 7 (2007 AWIN Architecture) and Task 6 (2007 AATT Architecture).

The 2015 AATT Architecture provides a top-down perspective of the enabling systems that best satisfy the user requirements and operational concepts. In contrast, the 2015 NAS Architecture represents a projection of the FAA modernization path from today's NAS Architecture into the 2015 time frame. A critical and embedded aspect of the process of defining the 2015 AATT Architecture is to compare it to the 2015 NAS Architecture for the purpose of identifying gaps that can be further addressed to potentially bring the two architectures into alignment.

The analysis leading to the definition of the 2015 AATT Architecture involved the three primary tasks shown in Panel A of Figure 3.1-1: (1) defining an overall functional architecture to satisfy the desired services, (2) defining the information to be exchanged while providing the services (i.e. communication loading), and (3) identifying the enabling mechanisms (i.e. communication links) that are suitable for exchanging the information. Based on these tasks, we identified communications technology alternatives that were candidates for the 2015 AATT Architecture.

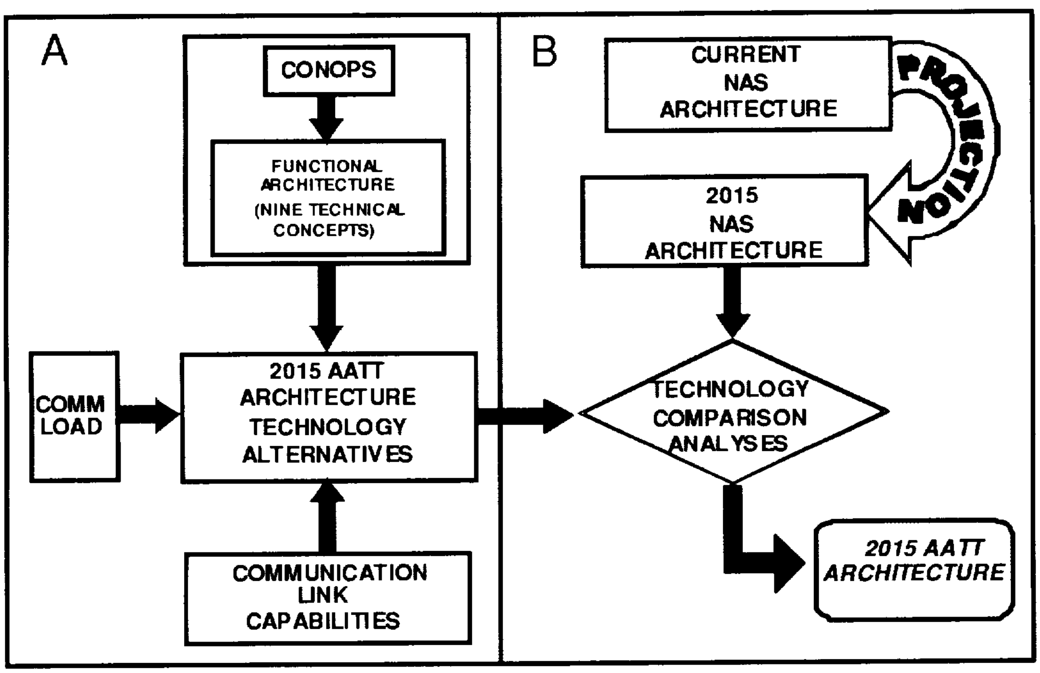

Figure 3.1-1. 2015 AATT Architecture Development Method

Definition of the functional architecture first requires an understanding of the desires of the aviation community. To gain this understanding, we reviewed a wide range of user requirements as documented in Tasks 1, 2, and 3 and drew upon knowledge gained through our team's in-depth involvement in the development of the NAS Architecture. We organized our results by air traffic services and the functional capabilities into which the services logically divide, and then matched the message type requirements that were identified in Task 2 with this service/functional capability structure. The result was a *service-driven view of the message types* that had been identified. [Note that, for our purposes, a message type is a logical grouping of information that represents all data forms within that type, including raw data, commands, images, etc.]. We then focused these message types further with crosscutting technical concepts derived from the CONOPS for the purpose of defining the functional architecture. Finally, by applying the appropriate enabling communication links to the functional architecture, we transformed it into the physical communications architecture. These relationships are illustrated in Figure 3.1-2.

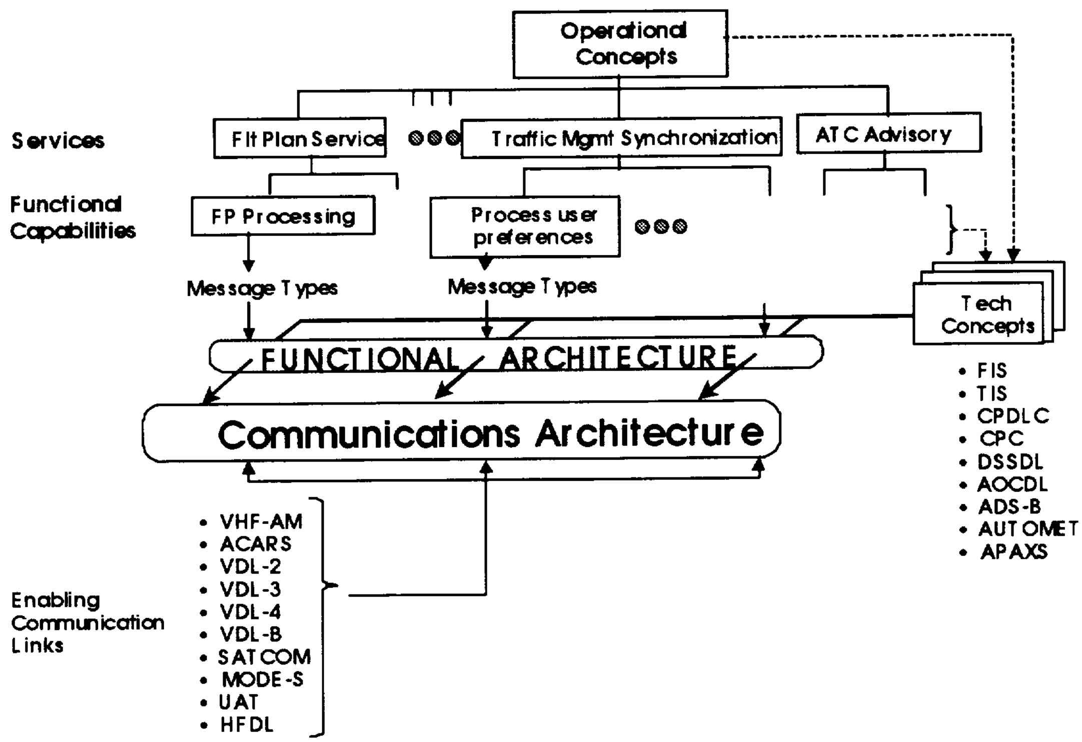

Figure 3.1-2. Operational Concepts to Communications Architecture

At the highest level are the operational concepts that provide the top down vision for what is desired. In the 2015 time frame, the drivers for the operational concepts are born out of the need for increased user flexibility with operating efficiencies and increased levels of capacity and safety to meet the growing demand for air transportation. These concepts are characterized by: (1) removal of constraints and restrictions to flight operations, (2) better exchange of information and collaborative decision making among users and service providers, (3) more efficient management of airspace and airport resources, and (4) tools and models to aid air traffic service providers.

The operational concepts provide a context for measuring progress and for assessing whether or not the infrastructure is being provided to support the vision. The vision provided by the operational concepts draws upon the results of efforts such as the ATS Concept of Operations for the National Airspace System in 2005, the Concept Definition for Distributed Air/Ground Traffic Management (DAG-TM), and current and emerging industry trends.

From a communication architecture perspective, it is important to understand the services that will enable the operational concepts, along with their supporting functions and the various message types that are the products of those functions. The services identified for this task and their related functional capabilities were identified in Tasks 1,2, and 3 and are summarized in Table 3.1-1, which also includes the Message Type Identifiers for the information exchange to support these functional capabilities.

Table 3.1-1. Services and Associated Functional Capabilities

Service	Function Name (Functional Capability)	Msg ID (M#)
Aeronautical Operational Control (AOC)	Collaborate with ATM on NAS Projections and User Preferences	M25
	Monitor Flight Progress - AOC	M23
		M33
		M6
	Airline Maintenance Support	M8-M12
	Schedule; Dispatch; and Manage Aircraft Flights	M30
ATC Advisory Service	Provide In-flight NAS Status Advisories	M17
	Provide In-flight or Pre-flight Traffic Advisories	M32
	Provide In-flight or Pre-flight Weather Advisories	M13
		M14
		M15
		M18
		M20
		M21
		M22
		M26
		M27
		M28
		M29
		M35
		M37
		M39
		M4
Flight Plan Services	File Flight Plans and Amendments	M22
		M24
		M32
	Process Flight Plans and Amendments	M16
		M32
		M34
		M40
On-Board Service	Provide Administrative Flight Information	M5
		M7
	Provide Public Communications	M31, 41, 42
Traffic Management Strategic Flow Service	Provide Future NAS Traffic Projections	M38
Traffic Management Synchronization Service	Process User Preferences	M2
	Project Aircraft In-flight Position and Identify Potential Conflicts	M1
		M3
	Provide In-flight Sequencing; Spacing; and Routing Restrictions	M36
	Provide Pre-flight Runway; Taxi Sequence; and Movement Restrictions	M32
		M36

Table 3.1-2 below provides a textual description of the Message Type corresponding to each Message Type Identifier. These messages may be voice, text, or graphical images.

Table 3.1-2. Message Types and Message Type Identifiers

Message Type Identifier	Message Type
M1	ADS
M2	Advanced ATM
M3	Air Traffic Information
M4	Not used - see M43, M44
M5	Airline Business Support: Electronic Database Updating
M6	Airline Business Support: Passenger Profiling
M7	Airline Business Support: Passenger Re-Accommodation
M8	Airline Maintenance Support: Electronic Database Updating
M9	Airline Maintenance Support: In-Flight Emergency Support
M10	Airline Maintenance Support: Non-Routine Maintenance/ Information Reporting
M11	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)
M12	Airline Maintenance Support: Routing Maintenance/ Information Reporting
M13	Arrival ATIS
M14	Not used - see M43, M44
M15	Convection
M16	Delivery of Route Deviation Warnings
M17	Departure ATIS
M18	Destination Field Conditions
M19	Diagnostic Data
M20	En Route Backup Strategic General Imagery
M21	FIS Planning – ATIS
M22	FIS Planning Services
M23	Flight Data Recorder Downlinks
M24	Flight Plans
M25	Gate Assignment
M26	General Hazard
M27	Icing
M28	Icing/ Flight Conditions
M29	Low Level Wind Shear
M30	Out/ Off/ On/ In
M31	Passenger Services: On Board Phone
M32	Pilot/ Controller Communications
M33	Position Reports
M34	Pre-Departure Clearance
M35	Radar Mosaic
M36	Support Precision Landing
M37	Surface Conditions
M38	TFM Information
M39	Turbulence
M40	Winds/ Temperature
M41	System Management and Control
M42	Miscellaneous Cabin Services

Message Type Identifier	Message Type
M43	Aircraft Originated Ascent Series Meteorological Observations
M44	Aircraft Originated Descent Series Meteorological Observations

Given a definition of the message types that require air-ground communication, the next step was to organize them further in a logical fashion that supports the development of a functional communication architecture. To accomplish this organizational construct, we examined the operational concepts and the service functional capabilities to identify ways to focus the functional architecture. Based on that examination, we defined nine unique technical concepts related to air ground communications that span the functional capabilities and that can be used to drive the definition of the functional architecture. These technical concepts are defined in Table 3.1-3 below:

Table 3.1-3. Air-Ground Communications Technical Concepts

Technical Concept Definition	Technical Concept Name
Aircraft continually receive Flight Information to enable common situational awareness of weather and NAS status	Flight Information Services (FIS)
Aircraft continually receive Traffic Information to enable common situational awareness of the traffic in the area	Traffic Information Services (TIS)
Controller-Pilot data messaging supports efficient Clearances, Flight Plan Modifications, and Advisories	Controller-Pilot Data Link Communications (CPDLC)
Controller-Pilot voice communication to support ATC operations	Controller-Pilot Communications (CPC)
Aircraft exchange performance / preference data with ATC to optimize decision support	Decision Support System Data Link (DSSDL)
Pilot-AOC data messaging supports efficient air carrier/air transport operations and maintenance	Airline Operational Control Data Link (AOCDL)
Aircraft broadcast data on their position and intent continuously to enable optimum maneuvering	Automated Dependent Surveillance-Broadcast (ADS-B)
Aircraft report airborne weather data to improve weather nowcasting/forecasting	Automated Meteorological Reporting (AUTOMET)
Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service	Aeronautical Passenger Services (APAXS)

Using these technical concepts as drivers, we next defined the functional architecture for air ground communications as shown in Figure 3.1-3.

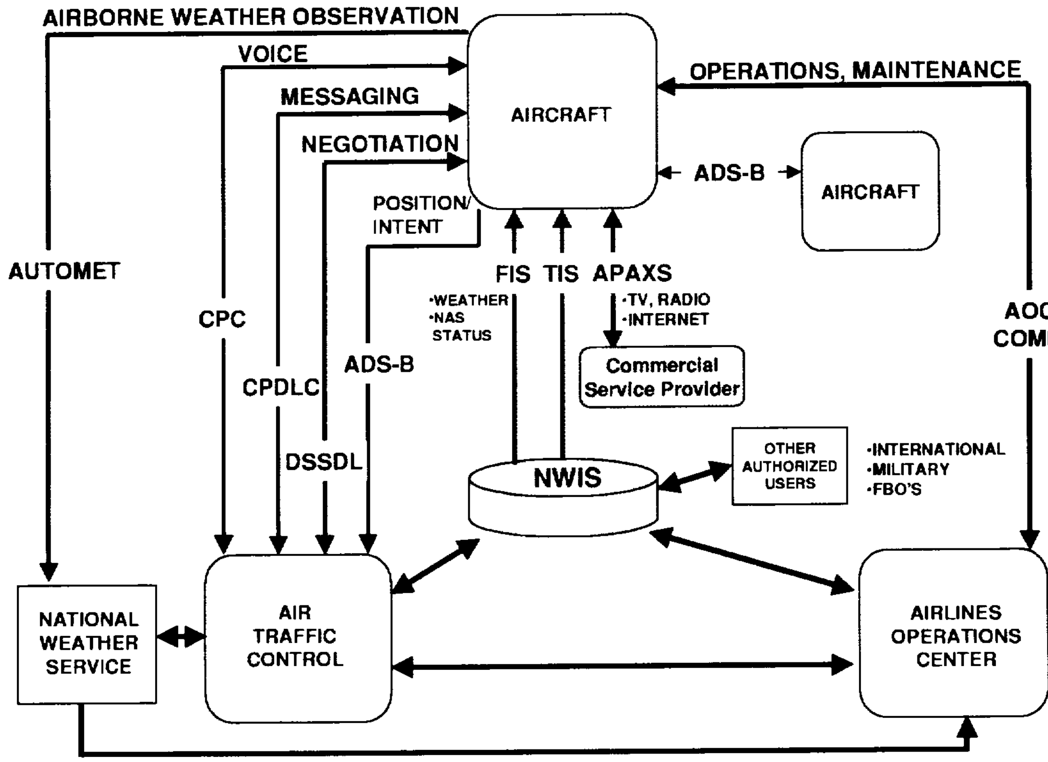

Figure 3.1-3. Functional Architecture for Air-Ground Communications

Our next step was to organize the functional capability message types into categories that are associated with each technical concept. The following table shows the resulting message categories, including message content for each category, mapped to the individual technical concepts listed in Table 3.1-4.

Table 3.1-4. Message Categories Mapped to Technical Concepts

Category.	Technical Concept	Description of Concept
1	Flight Information Services (FIS)	Aircraft continually receive Flight Information to enable common situational awareness
2	Traffic Information Services (TIS)	Aircraft continuously receive Traffic Information to enable common situational awareness
3	Controller-Pilot Data Link Communications (CPDLC)	Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)
4	Controller Pilot Communications (CPC) Voice	Controller - Pilot voice communication
5	Decision Support System Data Link (DSSDL)	Aircraft exchange performance / preference data with ATC to optimize decision support
6	Airline Operational Control Data Link (AOCDL)	Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance
7	Automated Dependent Surveillance (ADS) Reporting	Aircraft continuously transmit data on their position and intent to enable optimum maneuvering

Category.	Technical Concept	Description of Concept
8	Automated Meteorological Reporting (AUTOMET)	Aircraft report airborne weather data to improve weather nowcasting and forecasting
9	Aeronautical Passenger Services (APAXS)	Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service

The organization of message types into the categories listed above is listed in Table 3.1-5.

Table 3.1-5. Organization of Message Types into Message Categories

Message Category	Message Category Identifier	Message Type Identifier	Message Type
FIS	1	M13	Arrival ATIS
	1	M15	Convection
	1	M17	Departure ATIS
	1	M18	Destination Field Conditions
	1	M20	En Route Backup Strategic General Imagery
	1	M21	FIS Planning – ATIS
	1	M22	FIS Planning Services
	1	M26	General Hazard
	1	M27	Icing
	1	M28	Icing/ Flight Conditions
	1	M29	Low Level Wind Shear
	1	M35	Radar Mosaic
	1	M37	Surface Conditions
	1	M38	TFM Information
	1	M39	Turbulence
	1	M40	Winds/ Temperature
TIS	2	M3	Air Traffic Information
CPDLC	3	M24	Flight Plans
	3	M29	Low Level Wind Shear
	3	M32	Pilot/ Controller Communications
	3	M33	Position Reports
	3	M34	Pre-Departure Clearance
	3	M41	System Management and Control
DSSDL	5	M2	Advanced ATM
	5	M16	Delivery of Route Deviation Warnings
	5	M24	Flight Plans
AOCDL	6	M9	Airline Maintenance Support: In-Flight Emergency Support
	6	M10	Airline Maintenance Support: Non-Routine Maintenance/ Information Reporting
	6	M11	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)
	6	M12	Airline Maintenance Support: Routing Maintenance/ Information Reporting
	6	M19	Diagnostic Data
	6	M23	Flight Data Recorder Downlinks
	6	M25	Gate Assignment
	6	M30	Out/ Off/ On/ In
	6	M8	Airline Maintenance Support: Electronic Database Updating

Message Category	Message Category Identifier	Message Type Identifier	Message Type
ADS-B	7	M1	ADS
AUTOMET	8	M43	Aircraft Originated Ascent Series Meteorological Observations
	8	M44	Aircraft Originated Descent Series Meteorological Observations
APAX	9	M5	Airline Business Support: Electronic Database Updating
	9	M6	Airline Business Support: Passenger Profiling
	9	M7	Airline Business Support: Passenger Re-Accommodation
	9	M31	Passenger Services: On Board Phone
	9	M42	Miscellaneous Cabin Services

At this point, having established a functional architecture and a corresponding relationship to the message types, we can combine it with the results of the communication load analysis (Section 4.0) and the communication link analysis (Section 5.0) to develop suitable technology alternatives for the 2015 AATT physical communication system architecture. This development of technology alternatives begins with Section 3.2 where the applicable communication links are identified for each technology concept, and a comparison is made with the NAS Architecture, projected to 2015, for purposes of gap comparison and as part of developing a recommended 2015 AATT CSA.

3.2 2015 AATT Communication System Architecture Development

The 2015 time frame represents the final phases of transition from the era of analog voice communication and islands of diverse information to an era of digital data exchange through integrated networks using shared data. The results of this transition are a collection of systems and procedures that efficiently use the capacity of the NAS while balancing access to all user classes and maintaining the highest levels of safety. As depicted in Figure 3.2-1, efficient collaboration among users is built on a foundation of shared data. This data can be divided logically into a static component representing data that changes infrequently (such as maps, charts, etc.) and a dynamic component representing data that changes frequently (such as the weather, traffic flow status, and aircraft position). This information base provides common situational awareness to all users who choose to participate. The challenge in maintaining the information base is to keep the dynamic data current for all participating users so that optimum decisions can be made. Given a common information base, decision support systems can analyze this data continuously to develop optimum solutions for individual aircraft trajectories as well as trajectories for groups of aircraft. This negotiation takes place between aircraft DSS tools and between aircraft and ATC DSS tools. When optimum solutions (or inability to find a solution) are determined, pilots and controllers are notified for confirmation (or other appropriate action). This action takes the form of strategic collaborative decision making or tactical control. In either event, data exchange continues using specified data link messages with voice communication used when it is the only practical means.

In 2015, there still will be a range of users who will choose to participate at various levels of equipage from voice only through multi-mode radios and fully modular avionics. All users are accommodated, however, and will receive benefits commensurate with their levels of equipage.

The remainder of this section develops the 2015 AATT communications system architecture based on the set of technical concepts presented in Figure 3.1-3 and briefly outlined above. Each subsection begins with a description of the technical concept and the introduction of a concept single line drawing. The purpose of the single line drawing is to highlight the end-to-end connectivity required at the concept level necessary to execute the technical concept. This provides a structure that allows us to determine technical as well as concept gaps. Next, the communication load requirements for the concept are discussed followed by an identification of the communication link alternatives that could satisfy the load requirements. Finally, the NAS Architecture approach for the concept is identified. The NAS Architecture is the FAA's fifteen-year strategic plan for modernization of the NAS. The objective of NAS modernization is to add new capabilities that will improve efficiency, safety and security while sustaining existing services.

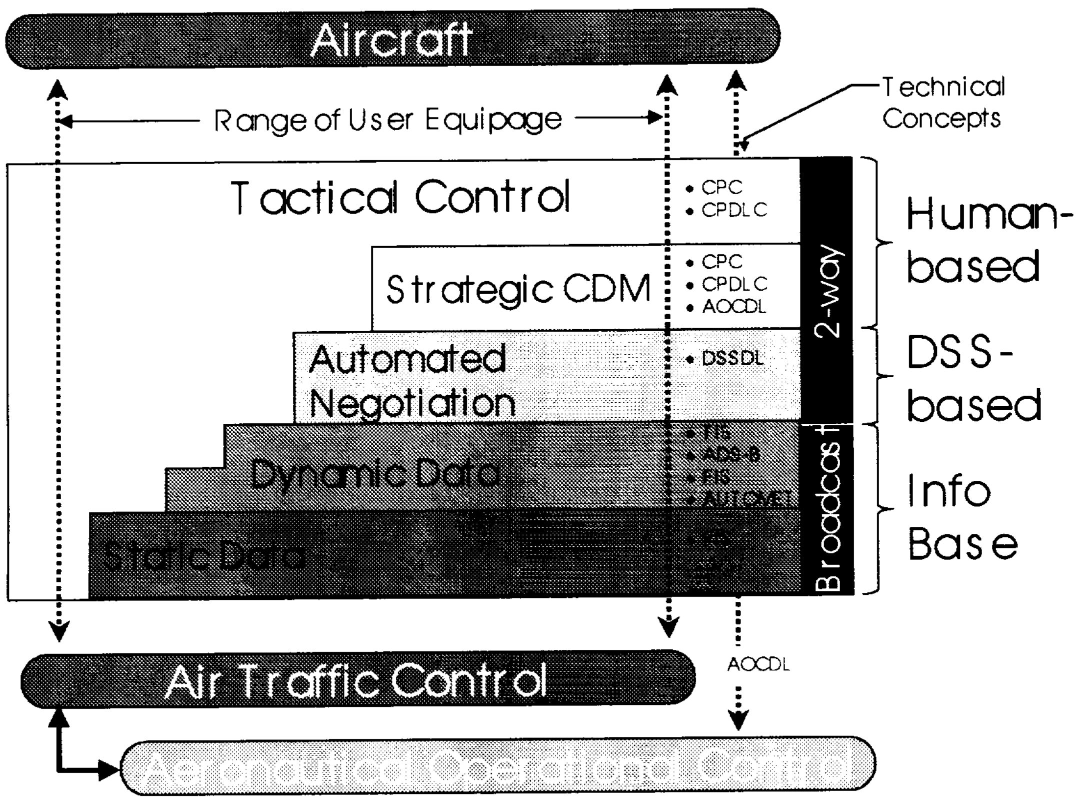

Figure 3.2-1. Air-Ground Communications Levels

3.2.1 Flight Information Services (FIS)

The FIS technical concept provides one of the foundation functions for maintaining the static and dynamic data requirements for the information base of the NAS. In this concept, aircraft receive flight information continuously in order to enable common situational awareness for pilots that supports their ability to operate safely and efficiently within the NAS. Flight information consists of NAS weather information, NAS status information and NAS traffic flow information. Flight information is considered advisory and for the purposes of air-ground communications is classified as routine (see section 4.2 for further details). FIS information is intended for transmission to all classes of users. Thus, any selected link alternative must be capable of installation and use in any aircraft regardless of class. The single line diagram for FIS is shown in Figure 3.2-2.

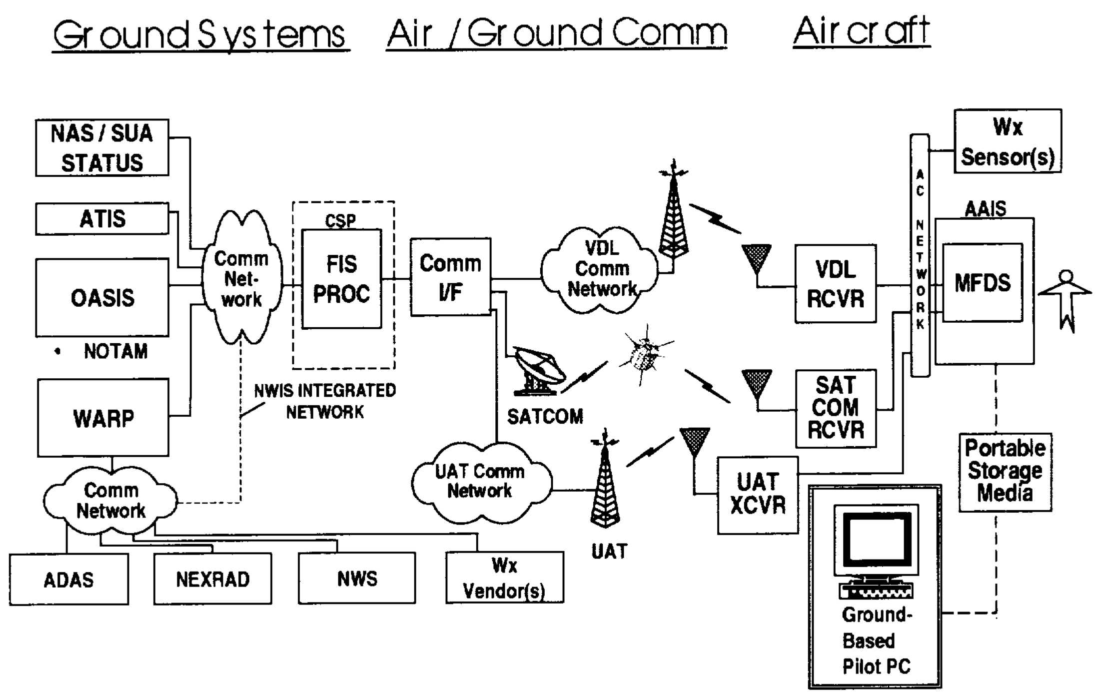

Figure 3.2-2. Flight Information Service in 2015

The Weather products transmitted via FIS may include observations and forecasts, weather radar data, winds and temperature aloft, and gridded forecast data. The NAS status information may include NOTAMs, airport conditions and configurations, and active/inactive status of special use airspace. NAS traffic flow information may include active and pending restriction data, and other traffic flow initiative information.

During the requirements analysis conducted in Tasks 1 through 3, it was thought that some types of FIS products might be tailored for a specific flight and delivered only to an aircraft that requested it, while other FIS products were not flight specific and would be suitable for broadcasts. In this form the messages require conversion from 2-way to broadcast or vice versa for our analysis. These message types are shown in Table 4.3-5 and Table 4.3-6.

For FIS, the NAS Architecture plans to rely on commercial service providers to supply products regionally to the aircraft via four allocated 25kHz VHF frequencies using VDL-B.

Our communication load estimate for broadcast FIS is the same for 2007 as for 2015 as we were unable to identify any additional products. If there were no growth in load, the architecture could be sustained with technology refresh as systems become obsolete. The FIS load data is derived from Table 4.5-6 and Table 4.5-7.

For the initial analysis, the architecture was evaluated with FIS data transmitted to the aircraft using a two-way (request/reply) data link or a transmit-only broadcast data link, depending on the message type, as identified in Tasks 2 and 3.

In order to get a domain broadcast estimate we combine the FIS flight specific and non-flight specific data (Table 4.3-10) and make the appropriate unit conversions to produce Table 3.2-1. For purposes of estimation, if we assume a region consisting of one en route center, a consolidated terminal area and four airports, then the total communication requirement for the region would be 7.2 kbps on the broadcast link and 66 kbps on the two-way link. This greatly exceeds the capacity of a VDL channel, precluding the use of this approach on the channels currently allocated for FIS. In addition, this approach would require the use of separate radios for broadcast and two-way FIS and complicated avionics to combine the results on a display.

Table 3.2-1 FIS 2-way + broadcast Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
FIS – Domain	9.9	9.4	17.2	
Region (x) [1]	39.6 (4)	9.4 (1)	17.2 (1)	66
FIS - Regional Broadcast		0.6	6.6	7.2

Note: (x) is domain multiplier

Even for information of a general nature, it could be delivered to every flight over two-way links. Given the dynamic nature of FIS data, however, a two-way data link would require a constant request/reply method that is inefficient in terms of channel overhead and suffers in performance directly proportional to the number of aircraft (see Section 4.3.2). Our estimate of the two-way communication loading for FIS (if all messages were two-way) identifies the need for uplinks ranging 1373 kbps for 2015 in a geographic area covering airspace for four airports, a consolidated TRACON, and en route. This far exceeds any VDL link capacities and would require a move to Broadband links. Detailed analysis included applying overhead factors for two-way communications to all non-flight specific messages; since this is not considered a viable solution, the details analysis is not included here.

From a communication standpoint, broadcast communication is considered desirable for FIS because it is the most efficient in terms of overhead and component design. There are two methods that we considered for aggregating broadcast data: single channel and multi-channel.

Aggregate – Single Channel:

In this method, all data for transmission is collected and transmitted on a single channel. This requires that all data must be received and processed onboard the aircraft in order to select the specific FIS data of interest.

The advantage for this method is that there is a single channel that can be monitored to receive all data. This is the least complex implementation method. The disadvantage can come when the total data set becomes so large that is takes an unacceptable amount of time to transmit it to the aircraft. For FIS we feel that 5 minutes is a good upper bound for total data transmission. This would mean that whatever FIS data the aircraft operator used would have a transmission latency of no more than 5 minutes.

Aggregate – Multi-Channel:

In this method, all data for transmission is collected and divided into logical data sets that are each transmitted on their own channel. This method is similar to "Cable TV" where each channel carries a unique set of data. In this method a processor onboard the aircraft would only listen to the channels that contained data of interest. The advantage for this method is faster data updates. The disadvantage is the added complexity of the processing algorithms and the need for additional channels. Once again, we feel the goal should be the receipt of any desired data within 5 minutes.

Either of these methods can be applied to a local, regional, or national level. The most desirable for FIS would be a national aggregate single channel broadcast because of its simplicity of implementation.

If the messages identified in Table 4.4-3 as two-way messages for FIS were instead broadcast, at the same frequencies as shown in the table, the total communication load would be reduced to the loads shown in Table 3.2-2. Note that the communication load is reduced not only because products are transmitted only once for all aircraft to receive, but also because the protocol overhead for broadcast is less than the overhead for two-way communication.

Table 3.2-2 FIS Communication Load Requirements (kilobits per second) to Broadcast all FIS Message Types

	Airport	Terminal	En Route	Total
FIS - Domain	0.2	0.9	6.9	
FIS - Region	1.0 (5)	4.5 (5)	6.9 (1)	12.4
FIS - National				248 (20)

Note: (x) is domain multiplier

Using the same example of a region including en route airspace and five airports and terminals, the total load requirement is 12.4 kbps. This is within the capacity of a VDL-B channel. One disadvantage of regional coverage is that the pilot can only receive FIS data for the region that they are flying in. In some situations this can limit the pilots ability to perform strategic planning.

Aggregation of this data to a national level can conservatively be estimated by multiplying the regional estimate by 20 (the number of CONUS centers). This yields a national broadcast load of 248 kbps. This would exceed the capacity of any VDL link but could be supported by UAT or SATCOM links.

Technology Gap

One of the greatest challenges to national implementation of FIS (including region by region) is establishment of the A/G ground network. From this aspect, the establishment of a multi-use broadband data exchange network becomes more appealing. Our analysis indicates that VDL-B can accommodate the delivery of FIS data to the aircraft if performed on a regional basis and given the assumptions for data size and compression ratios identified in Section 4.3. National broadcast or two-way FIS implementations will require the higher capacity solutions that are currently in the early stages of implementation. A summary of the possible FIS communication links is shown in Table 3.2-3.

The government should explore innovative methods for establishing a national air-ground broadband data exchange network. This effort should cover all aspects of the air-ground network from location to physical access to operation and maintenance. For example, the government could make their terrestrial air-ground communication sites accessible to commercial service providers, even potentially turning them over to third parties for operation and maintenance, as many wireless telecommunication providers are doing today.

Table 3.2-3 FIS Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Flight Information to enable common situational awareness	FIS					[✓]		✓	✓	

✓ Acceptable Alternative; [ ] NAS Architecture; ( ) AATT CSA Recommendation

3.2.2 Traffic Information Services (TIS)

The TIS technical concept is another of the foundation functions necessary for maintaining the dynamic data requirements for the information base of the NAS. In this concept, aircraft receive trajectory information of all aircraft continuously in order to enable common situational awareness for pilots that enhances their ability to operate safely and efficiently within the NAS. TIS information consists of real time aircraft position data that is received by ATC from their ground-based surveillance sensor network consisting of primary and secondary radars and dependent surveillance receivers. The received aircraft position data is combined with trajectory and intent data and then broadcast to participating aircraft. TIS information is provided without any ground controller involvement. TIS information is used onboard the aircraft to support tactical maneuvering and trajectory planning decisions by the pilot. The performance requirements for transmission of TIS data to support tactical maneuvering are much more stringent (0.5 seconds) than for support of trajectory planning (120 seconds). To be useful for trajectory planning for ten or twenty minutes ahead, the TIS information needs to cover a large volume of airspace. The recommended architecture supports tactical maneuvering and trajectory planning, so the communication loading is much higher than if only tactical maneuvering were supported. The end-to-end connectivity diagram for TIS is shown in Figure 3.2-3.

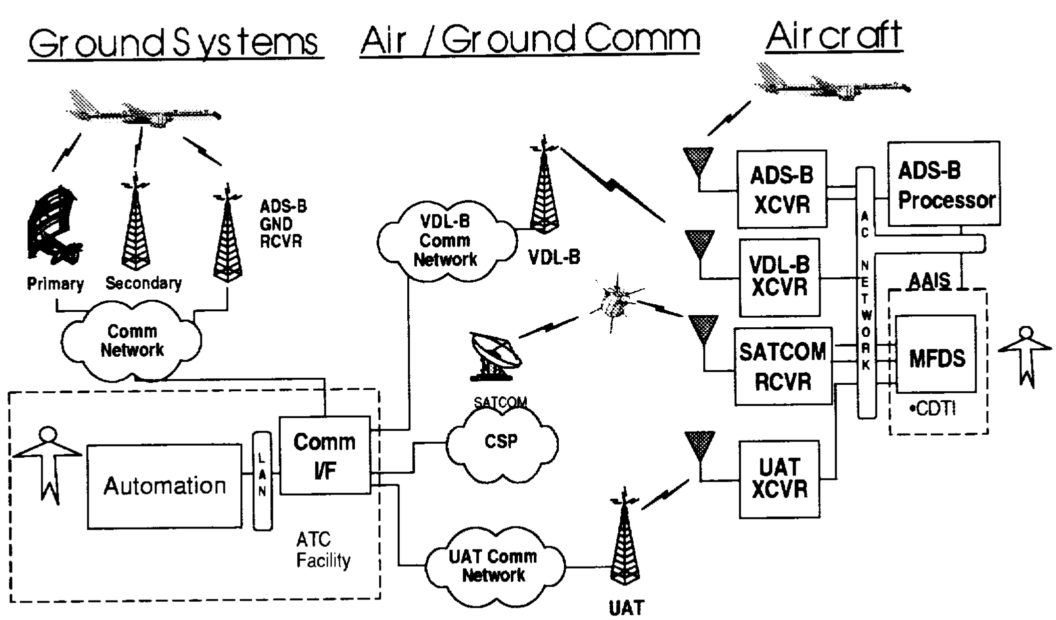

Figure 3.2-3 TIS Connectivity Diagram in 2015

TIS has been identified for broadcast communication. Broadcast communication is considered desirable because it is the most efficient in terms of overhead and design. There are two methods that we considered for implementation of broadcast data.

Aggregate – Single Channel:

All data for transmission is collected and transmitted on a single channel. In this method all data must be processed onboard the aircraft in order to select the data of interest.

The advantage for this method is that there is a single channel that can be monitored by all aircraft to receive all data. This is the least complex implementation method. The disadvantage can come when the total data set becomes so large that it takes an unacceptable amount of time to transmit. In the case of TIS there are two different data sets as described above. For the "maneuvering" data set we feel that data transmission every 0.5 seconds is required in order to meet the performance requirements for decision support in maneuvering the aircraft. This would mean that whatever data you used would have a transmission latency of no more than 0.5 seconds[1]. For the "trajectory planning" data set we feel that data transmission every 2 minutes is adequate to support long range trajectory planning.

Aggregate – Multi-Channel:

All data for transmission is collected and divided into logical data sets that are each transmitted on their own channel. This is similar to "Cable TV" where each channel carries a unique set of data. In this method a processor onboard the aircraft would only listen to the channels that contained data of interest. The advantage for this method is faster updates. The disadvantage is more complex processing algorithms and the need for additional channels. Once again, for TIS, we feel the goal should be the receipt of maneuvering data within 0.5 seconds and trajectory planning data within 2 minutes.

These methods can be applied to local, regional, or national levels. The most desirable communication method for TIS would be a national aggregate single channel broadcast because of its simplicity of implementation. Our communication load analysis for national TIS (see Table 4.5-8) indicates that 425 kbps is required. This exceeds the capacity of any VDL link and would require the implementation of a UAT or SATCOM solution. Breaking the load into regional or local implementations (see Table 4.5-7) brings the requirement within the capacity of VDL-B.

Implementing a VDL-B solution, however, is problematical in that each VDL channel would require an additional 25kHz VHF frequency in each sector or region of implementation to avoid inerference. This could not be supported under the current frequency allocation scheme meaning that implementation of a multi-channel VDL-B solution would need to wait until frequencies have been reallocated as a part of the NEXCOM implementation. This will begin in 2010 and will be complete by 2015. One implication of waiting until the 2010-2015 time frame, however, would be the restriction of early maneuvering benefits for ADS-B since without TIS (or 100% ADS-B equipage) the pilot has no assurance of complete traffic situational awareness while conducting a maneuver. An additional, and potentially even more problematic implication, is that these frequencies are the same ones that would be required for the DSSDL concept, which would be using VDL-3. Given these considerations it is not recommended that TIS be implemented within the 118MHz – 137MHz aviation spectrum.

The volume of traffic information depends on the number of aircraft, since data must be included in the TIS broadcast for each aircraft in the airspace. Table 3.2-4 shows the peak data rate volumes. For a volume of airspace including five airports, five terminal and en route, the peak volume would be 50.5 kbps.

Table 3.2-4 TIS Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
TIS - Domain	21.3	6.4	18.5	
TIS - Region	N/A	32.0 (5) [1]	18.5	50.5
TIS - National	N/A	52.7 [1139] [2]	153.2 [4140]	205.9

Note 1: Region defined as 1 En Route, 5 Terminal
Note 2: National Peak Total number of aircraft per domain

[1] We specify transmission latency versus data latency to differentiate between how often the data is transmitted versus how often the data is refreshed.

In our analysis there are only 2 other links to consider that offer enough performance to support TIS: UAT and SATCOM. UAT offers link performance in the range of 1 Mbps that would easily support the TIS requirement. SATCOM offers link performance in the range of 2 Mbps that would also easily support the TIS requirement. Table 3.2-5 provides an overview of UAT and SATCOM. One potential advantage of using UAT would be that the majority of aircraft would already have a UAT radio (if it is the technology chosen for ADS-B) and a UAT terrestrial network would have been established. An advantage of SATCOM would be the wide area access provided without the need for a terrestrial network and the ability to use a commercial service provider. Each of these links is currently in the developmental stages and requires further research to establish their viability.

Table 3.2-6 provides a summary of the TIS communication links. The NAS Architecture currently identifies Mode-S as the recommended communications link for TIS. Based on our load analysis, however, we do not feel that Mode-S will be capable of supporting TIS in 2015.

Table 3.2-5 UAT and SATCOM overview

	UAT	Ka SATCOM
Base	• Terrestrial • FAA Radar, Navigation and/or Air-Ground Communication sites	• Space • Assume desirable CONUS coverage • Commercial service providers
Capacity	1 Mbps	> 2Mbps
PRO's	• If selected as ADS-B link, all aircraft would eventually have UAT radio • Use of FAA sites • Avionics design complete – standards in development	• CONUS coverage without maintenance of terrestrial network • Higher data rates • Most likely will be available from commercial service providers
CON's	• Maintenance of terrestrial network • Additional radio required if not selected as part of ADS-B • Most likely will require FAA ownership and operation – currently no funding identified	• Immature avionics design - no standards – unproven for small GA aircraft • Additional radio required

Table 3.2-6 TIS Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Traffic Information to enable common situational awareness	TIS						□	✓	✓	
✓ Acceptable Alternative		□ NAS Architecture				★ Restricted Operation				

Technology GAPS

The gaps associated with the implementation of TIS via UAT or SATCOM are the identification of suitable spectrum (independent of that used for ADS-B, in the case of UAT) and the development of antennas and avionics that are suitable for use on all aircraft.

Initial UAT avionics design is complete with field testing due to begin in the fall of 2000 as part of the Safe Flight 21 CAPSTONE program. Use of satellite communication links requires the demonstration of aeronautical mobile technologies for antenna, receivers, link algorithms, protocols, and standards. A major technology focus for broadband communications services is the need to provide more bandwidth (with a focus on Ka-band). Given the migration to these frequencies, the need exists for higher efficiency transmitters (both space and terrestrial), more adaptive bandwidth versus power efficient modulation, forward error correction coding (including turbo codes and bit/modulation symbol interleaving), and much expanded use of variable bit rate formats and dynamic multiplexing techniques such as asynchronous transfer mode (ATM) based technologies. Antennas and receivers must be adapted for the aviation market (size, weight, cost) and must overcome the problems of rain attenuation for broadcast TIS over satellite.

3.2.3 Controller-Pilot Communications (CPC)

Voice communication is the foundation of air traffic control. Thus, even as we move toward a higher utilization of data exchange for routine communications, it is critical to maintain a high quality, robust voice communication service. The implementation of NEXCOM will provide both digital voice and data capabilities. New multi-mode radios will be able to emulate the existing VHF-AM analog modulation and other selected modulation techniques using software programming.

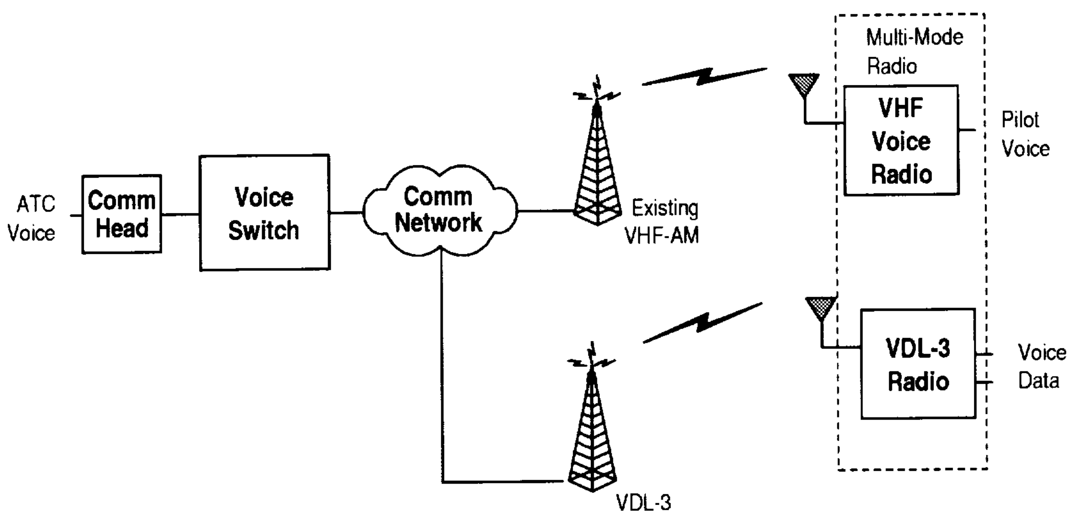

Figure 3.2-4. CPC Air/Ground Voice Communication in 2015

The CPC communication links are shown in Table 3.2-8. The NAS Architecture plans to transition controller pilot voice communication to an FAA supported VDL-3 network in the 2010-2015 time frame. Our VDL-3 link analysis indicates that a single VDL-3 sub-channel supports 4.8 kbps. Our communication load analysis indicates that a single VDL-3 sub-channel is sufficient to support controller pilot communication under worst case loading conditions. We therefor recommend that the AATT CSA maintain the NAS Architecture recommendation.

Table 3.2-7 CPC Load Analysis Results

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	2.7	1.3	0.7	0.7	2.0	0.5
2	0.9	0.4	0.3	0.3	0.2	0.1
3	1.2	0.5	0.0	0.0	0.0	0.0
Total	7.0		1.9		2.7	
Voice Channels Required (P=0.2)	8		3		4	

Table 3.2-8 CPC Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Controller - Pilot voice communication	CPC	[✓]		[✓]						

✓ Acceptable Alternative   [ ] NAS Architecture   ★ Restricted Operation

Technology Gap

CPC provides the voice communications capability for the NAS. Provisions of CPC via packetized data communication will transition in 2010-2015. From a technology gap standpoint, there are concerns in the area of voice digitization. Further research can be performed to improve the digital voice compression techniques at rates of 4800 bps. Additionally, our estimate for peak traffic loading (described in Section 4.5.4) indicates that the maximum number of voice channels required to support the En Route domain is 6. Under the current scheme for implementation of voice channels, however, there is one channel dedicated to each sector. A typical en route center can have approximately 40 sectors – or 40 channels. Thus, the development of a virtual network that could eliminate the need for dedicated channels (while maintaining adequate margins of safety) offers the potential for substantial recovery of channels that could be used to support demand for service within the VHF aviation spectrum.

3.2.4 Controller-Pilot Data Link Communications (CPDLC)

The objective of CPDLC is to provide a data messaging capability between controllers and pilots that will reduce voice frequency congestion and provide a more precise and efficient means of communicating instructions and requests. CPDLC begins with the creation and initiation of a message by a controller or pilot. CPDLC messages are ATN compliant, which accommodates message prioritization. Fixed or free-text messages are supported. In the 2015 time frame CPDLC will transition from a limited message set capability via a VDL-2 commercial network to a full message set capability that supports prioritization via the FAA VDL-3 network.

In the 2015 time frame the NAS Architecture projects the use of VDL-3 for CPDLC. Our link analysis has determined that a single VDL-3 sub-channel can conservatively support 4.8 kbps of data. Our communication load analysis identifies load requirements by domain as indicated in Table 3.2-9. The data in Table 3.2-9 is developed by adding the uplink and downlink for each domain in Table 4.5-6

Table 3.2-9 CPDLC Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route
CPDLC- Domain	6.3	2.2	2.4
CPDLC – (Estimate per Sector)	1.6 (4)	0.3 (7)	0.1 (20)

The above table indicates that a single VDL-3 sub-channel will easily support the single-sector loading projections for 2015. We recommend that the AATT CSA maintain the NAS Architecture approach for CPDLC.

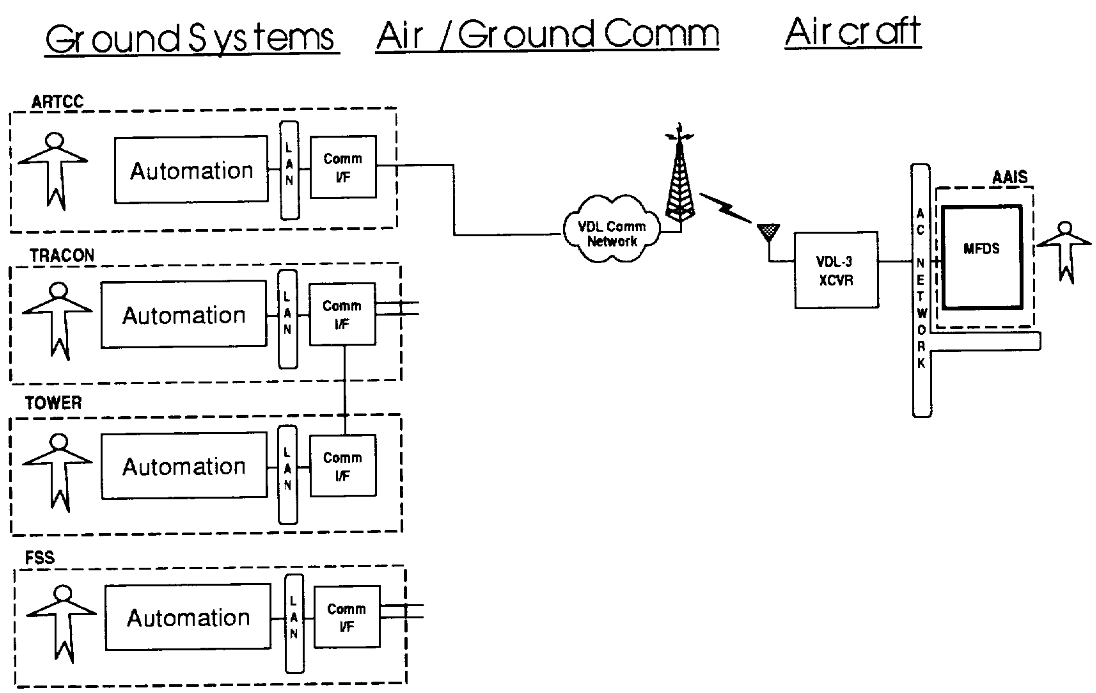

Figure 3.2-5 CPDLC Controller/Pilot Data Link Communications in 2015

The CPDLC communication links are shown in Table 3.2-10.

Table 3.2-10 CPDLC Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Controller - Pilot messaging supports efficient Clearances Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	CPDLC			✓						
✓ Acceptable Alternative		☐ NAS Architecture				★ Restricted Operation				

Technology Gap

There are no technology gaps identified for CPDLC via VDL-3.

3.2.5 Decision Support System Data Link (DSSDL)

As we establish the NAS-Wide Information System and promote the exchange of common data among participating nodes of the NAS, a data exchange method must be created that allows aircraft to participate as if they were "ground-based" nodes (i.e., they would have the same access and integrity of information as ground nodes). This is the objective of DSSDL. DSSDL provides a capability for the transfer of data between aircraft avionics and ATC automation (or other aircraft). Its purpose is to accommodate real time exchange of data that does not require human intervention or acknowledgement. The data transferred by DSSDL supports calculations by DSS algorithms that will be used by controllers and pilots to make decisions. Initially, this data exchange is not fully automated in that the controller or pilot must authorize its use by the aircraft DSS/ATC DSS, which is similar to the exchange and use of pre-departure clearance data today. In time, however, with system experience and the acceptance of controllers and pilots, DSSDL will become a fully automated method of negotiating/notifying change among participating nodes of the NAS. Figure 3.2-6 depicts the major elements of DSSDL.

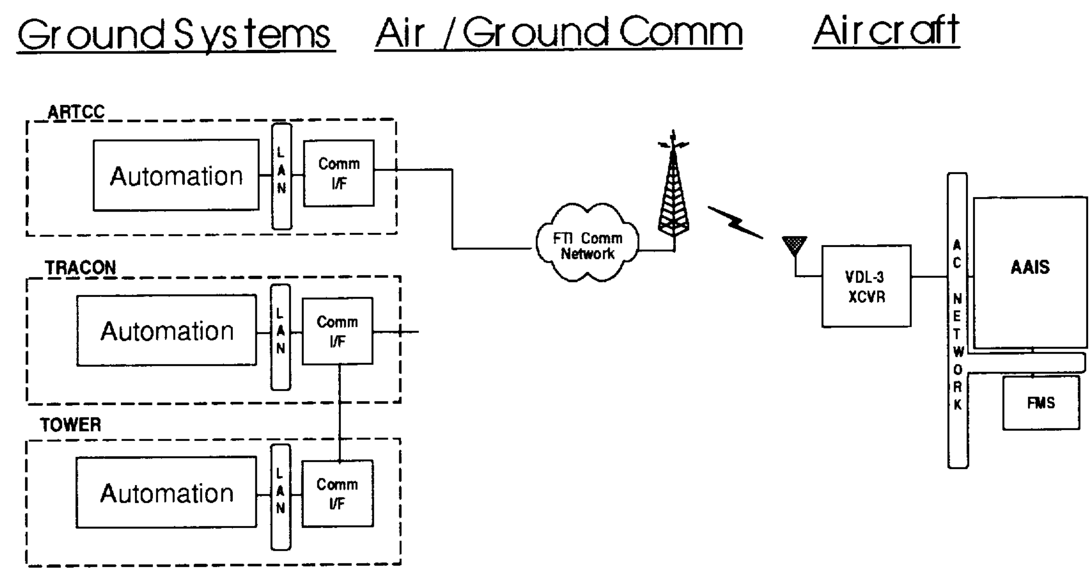

Figure 3.2-6 Decision Support System Data Link in 2015

Examples of DSSDL aircraft data include preference data for arrival time, meter fix, turbulence avoidance, approach/runway, performance data such as weight or trajectory change (route deviation warnings), and flight plan change requests. Examples of DSSDL ATC data are local TFM constraints and expected near term constraint changes.

DSSDL provides the data to DSS tools that are used to support the negotiation of preferred trajectories between pilots and controllers. As such, aircraft avionics and controller workstations must be designed to maintain workloads at a comfortable level, while ensuring that the decision-making process is timely and intuitive.

DSSDL preferences that result in clearance changes (i.e. flight plan or trajectory updates) will be provided to the aircraft via CPDLC message. For example, an aircraft preference for turbulence avoidance eventually may result in an ATC originated CPDLC message to CLIMB TO (*level*).

DSSDL is applicable only to aircraft that have an advanced FMS that supports integration with an onboard data link. Initial DSSDL messages most likely will be aircraft-to-ATC only, indicating preferences for routes or arrival times.

ASSUMPTIONS

- Only aircraft with avionics that allow integration of data link information into the flight management system can use DSSDL
- Data can be processed directly by ATC automation or aircraft avionics, but the results must be accepted by controller/pilot prior to use by automation in air traffic control or flight operations.
- DSSDL is an essential service.

The DSSDL communication links in 2015 are shown in Table 3.2-11.

Table 3.2-11 DSSDL Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft exchange performance / preference data with ATC to optimize decision support	DSSDL			[✓]	✓		✓	✓		✓
✓ Acceptable Alternative		[ ] NAS Architecture				★ Restricted Operation				

It should be noted that while Mode-S and UAT also have data link capability that theoretically could be used to support DSSDL, they are not ATN compliant and are not recommended.

Our link analysis has determined that a single VDL-3 sub-channel can conservatively support 4.8 kbps of data. Our communication load analysis identifies load requirements for DSSDL in the 2015 time frame by domain as indicated in Table 3.2-12.

Table 3.2-12 DSSDL Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route
DSSDL – Domain	0.45	0.24	0.12
DSSDL – (Estimated by Sector)	0.12 (4)	0.03 (7)	0.01 (20)

The table above indicates that a single VDL-3 sub-channel will easily support the DSSDL loading projections for 2015. We recommend that the AATT CSA maintain the NAS Architecture approach for DSSDL.

Technology Gap

The following items require further definition in order to implement a DSSDL capability. These areas are currently under study by the FAA so they are not included in the gaps addressed in Task 10/11.

- Ground automation that can accept data input via direct data link and allow controller authorization
- Protocols that support routing and prioritization
- Data integrity / error correction algorithms
- Avionics that can accept data input via direct data link and allow pilot authorization

3.2.6 Automated Dependent Surveillance-Broadcast (ADS-B)

ADS-B aircraft continuously broadcast their position, velocity, and intent information using GPS as the primary source of navigation data to enable optimum maneuvering. ADS-B will support both air-ground and air-air surveillance. The major operational environments improved by ADS-B include "gap-filler" surveillance for non-radar areas, surface operations, pair-wise maneuvers, and approach/departure maneuvers. ADS-B equipped aircraft with CDTI equipment will provide enhanced visual acquisition of other ADS-B equipped aircraft to pilots for situational awareness and collision avoidance. Pilots and controllers will have common situational awareness for shared separation responsibility to improve safety and efficiency. When operationally advantageous, pilots in ADS-B equipped aircraft may obtain approval from controllers for pair-wise or approach/departure maneuvers. In the future, en route controllers in centers with significant radar coverage gaps will provide more efficient tactical separation to ADS-B equipped aircraft in non-radar areas. The received ADS-B surveillance data will enable controllers to "see" ADS-B equipped aircraft and reduce separation standards in areas where they previously used procedural control. The end-to-end connectivity diagram for ADS-B is shown in Figure 3.2-7.

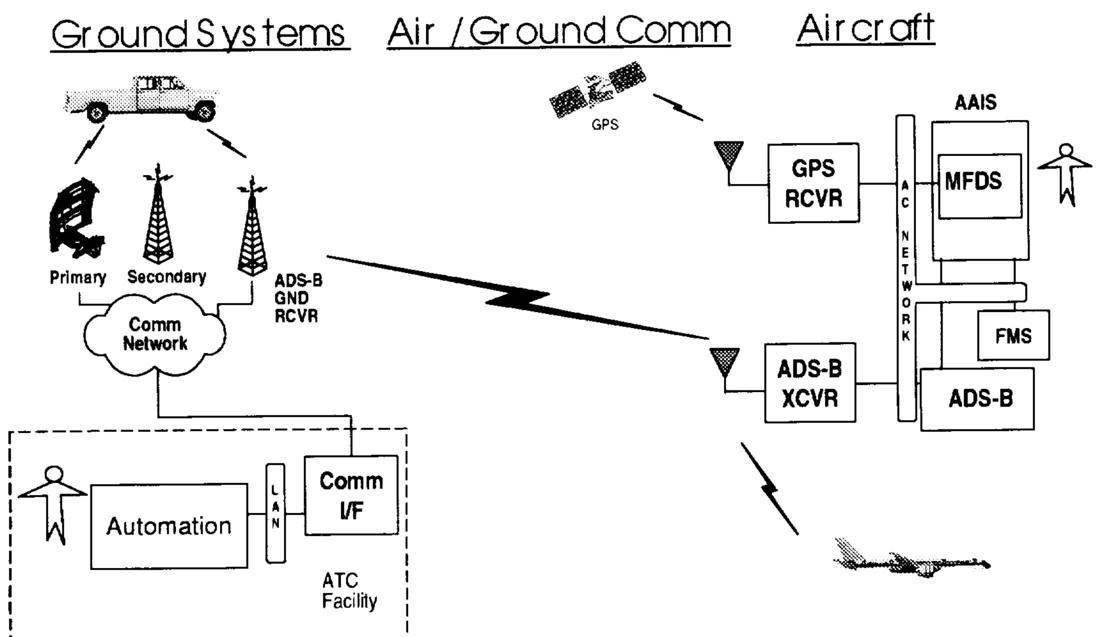

Figure 3.2-7 ADS-B Connectivity Diagram in 2015

ADS-B messages containing identification, state vector, intent, status and other information are assembled by aircraft avionics. ADS-B equipped aircraft broadcast the assembled messages over the ADS-B link twice per second (worst case) for reception by other ADS-B equipped aircraft or ATC ground stations. ADS-B equipped aircraft receive the messages over an air-air communication link, process the data, and display it on the cockpit display for improving situational awareness of the pilot. The aircraft automation function processes the intent and track data for other aircraft, performs collision management, and displays traffic and DSS information to the pilot to support air-air operations such as pair-wise maneuvers and collision avoidance.

ATC ground stations receive messages from ADS-B equipped aircraft over the air-ground communication link, process the messages, and send them to the responsible ATC facility. ADS-B and other primary and secondary surveillance data are processed by ATC automation along with ADS-B intent data to provide controllers with the necessary displays and controls to perform separation assurance and other ATC services. The ADS-B message content is consistent with the MASPS for ADS-B (RTCA/DO-242). ADS-B messages are designed to be flexible and expandable to accommodate potential ADS-B applications that are not yet designed. The surveillance data portion of an ADS-B message is used to support tactical and advisory ATC services, while the intent and other portions of an message supports more strategic services such as traffic synchronization.

While the emphasis in this architecture is on ADS-B, Automatic Dependent Surveillance - Addressable (ADS-A) is used in the oceanic domain and other remote areas such as Alaska. ADS-A will provide surveillance of intercontinental flights in oceanic airspace using a HF data link or satellite communications. Aircraft equipped with future navigation systems such as FANS-1A or ATN avionics will exchange information such as identification, flight level, position, velocity, and short-term intent with ADS-A ground equipment in oceanic Air Route Traffic Control Centers. Ground equipment and automation will display the aircraft position and track to oceanic controllers that will allow current oceanic lateral and longitudinal separation standards to be reduced for properly equipped aircraft. Additionally, controller will permit aircraft pairs equipped with ADS-B avionics to perform pair-wise maneuvers such as in-trail climbs or descents in selected oceanic airspace.

As part of the NAS Architecture, ADS-B will be deployed in a phased approach consistent with aviation community needs, FAA priorities, and projected budgets. In general, for each ADS-B operational environment, experiments and prototype demonstrations conducted as part of Safe Flight 21 lead to operational key site deployments. Key site deployments represent the increment where operational procedures and certified systems are used to deliver daily service. Following key site deployment, additional "pockets" of ADS-B will be deployed on a benefits-driven basis. These deployments eventually could result in national deployment. In the 2007 time frame initial deployment will be started for the "pocket" areas. Much of the initial ADS-B deployment will enable air-to-air use of ADS-B in selected airspace to demonstrate operational feasibility and achievement of estimated benefits. The extent of aircraft equipage and demand from the aviation community will be a factor in determining the strategy for deployment of ADS-B ground stations.

Our communication load analysis for ADS-B is shown in Table 3.2-13 and Section 4.6. Note that ADS-B is broadcast to all aircraft and ground stations within the range of the transmitter, so the communication requirement is not domain specific.

Table 3.2-13 ADS-B Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
ADS-B	16.1	3.3	1.5	20.9

In the airport domain, it is also necessary to consider surface vehicles such as baggage trucks, fuel trucks, snow plows, etc. If there are 75 moving vehicles broadcasting once per 1.1 seconds and 150 stationary vehicles broadcasting every ten seconds, the communication load increases to 28 kbps. Besides exceeding the capacity of some links, this load could produce clutter on the displays. Development of an approach for handling ADS-B at the airport should undergo research.

The ADS-B communication link options are shown in Table 3.2-14. The FAA is engaged in a program to evaluate three candidate ADS-B technologies (Mode-S Squitter, UAT, VDL-4) with a link decision expected in 2001. 1090 MHz Extended Squitter is derived from existing Secondary Surveillance Radar (SSR) Mode-S technology. This technology operates on a single frequency (i.e., 1090 MHz) operating at a data rate of 1 Mbps shared with other secondary surveillance radar users. Baseline ICAO standards for

1090 MHz extended squitter exist and RTCA/EUROCAE standards are under development, as well as updates to the existing ICAO standards.

Table 3.2-14 ADS-B Communication Link Options

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continously broadcast their position and intent to enable optimum maneuvering	ADS-B				✓		[✓]	✓		
✓ Acceptable Alternative		☐ NAS Architecture				★ Restricted Operation				

Universal Access Transceiver (UAT) is a technology developed by the Mitre Corporation supporting both uplink and downlink broadcast services. UAT would operate on an as-yet-undetermined single dedicated frequency near 1000 MHz (966 MHz is being used for test purposes) at a data rate of 1 Mbps. UAT has been selected as the ADS-B technology in the Alaskan CAPSTONE initiative. Initiation of UAT standards development by RTCA is currently under consideration.

VDL Mode 4 is a technology operating on multiple dedicated VHF channels with a nominal data rate of 19.2 kbps per channel. VDL Mode 4 employs time division multiple access with both a self-organizing mode and a ground managed mode. VDL Mode 4 standards currently are under development by ICAO and EUROCAE.

The FAA, in close cooperation with the aviation community and international organizations, is working to define the operational concepts for ADS-B, evaluate the three candidate ADS-B link technologies, and plan for the transition to ADS-B in the NAS. The most important factor in the successful implementation of ADS-B is the Link Technology Decision scheduled for 2001. The goal is to have a single global ADS-B technology. This goal may not be achieved, but global standards for ADS-B technologies must be developed so ADS-B aircraft can operate both in CONUS and internationally. The Link Technology Decision could result in a combination of the ADS-B technologies. The ADS-B communication links used in the 2007 to 2015 time frame will depend on the link decision.

Technology Gap

A potential ADS-B technology gap is the human factors for display of ADS-B aircraft. A human factors study should be performed to define the symbology and content of controller and pilot displays. The symbology should indicate the source and quality of the positional data to support different operations and separation standards for normal or degraded operations.

Another potential gap is the availability of ADS-B communication avionics compatible with the technology or combination of technologies that result from the Link Technology Decision. Standards are already in work for the three potential ADS-B technologies. There could be additional work to define integrated standards if a combination of ADS-B technologies is selected.

As described above, an environment in which many vehicles are reporting, such as an airport, is likely to stress the system. Any solution must make it possible for any aircraft in the airport environment to see any ground or airborne vehicle, without presenting "noise" to aircraft at higher altitudes. Using separate frequencies for airborne and surface vehicles is a potential solution, but fails to help the pilot on a low visibility final approach where a surface vehicle (including a landed aircraft) is approaching a runway. The CDTI might be able to filter out non-threatening vehicles, this would help with visual clutter, but not help RF congestion. Use of lower power emitters or signal polarization might serve to limit the broadcasting range of surface vehicles. Research would help in being able to engineer a solution.

3.2.7 Airline Operational Control Data Link (AOCDL)

Aircraft Operational Control (AOC) – Pilot/Aircraft – AOC data exchange supports efficient air carrier/air transport operations and maintenance. The AOC's prime responsibility is to ensure the safety of flight and to operate the aircraft fleet in a legal and efficient manner. The AOC's business responsibility requires that the dispatcher conduct individual flights (and the entire schedule) efficiently to enhance the business success and profitability of the airline. Most major airlines operate a centralized AOC function at an operations center that is responsible for worldwide operations. Typical AOC data exchange supports airline operations (OOOI, flight data, position reporting, etc.) and maintenance (performance, diagnostic, etc.) Figure 3.2-8 depicts the major elements of AOCDL. The AOCDL communication links are shown in Table 3.2-15.

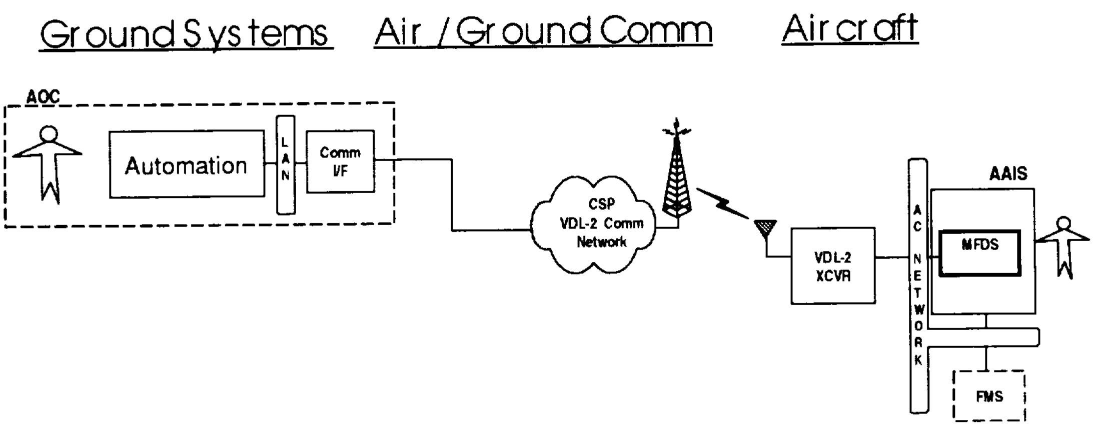

Figure 3.2-8 AOC Data Link in 2015

ASSUMPTION

A majority of current ACARS users will have migrated to VDL-2 use by 2007.

Table 3.2-15 AOCDL Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Pilot - AOC data exchange supports efficient air carrier/air transport operations and maintenance	AOCDL		✓					✓		✓
✓ Acceptable Alternative		☐ NAS Architecture ◯ AATT CSA Recommendation								

In the 2015 time frame, the AOC data link has become a significant part of the collaborative decision making process between ATC, AOC, and the aircraft. Our communication loading analysis for AOCDL by domain is shown in Table 3.2-16.

Table 3.2-16 AOCDL Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
AOCDL	8.8	9.1	3.7	
Worst Case	35.2 (4)	9.1 (1)	3.7 (1)	48

Note: (X) is domain multiplier

Our communication load analysis, summarized in Table 3.2-16, projects peak loading for AOCDL from 3.7 – 9.1 kbps. Because frequency assignments for AOCDL are not based on domain (although volume of messages is), it is necessary to consider the communication load generated in a worst case area, such as one including en route airspace, a consolidated TRACON, and four airports. This environment requires 48 kbps. The current plan for AOCDL is to use four 25kHz frequencies to support AOCDL. Each frequency when used in a VDL-2 mode provides an effective data rate of 19.2 kbps. Thus we can expect 76.8 kbps from four channels. This is sufficient to support the projected demand in any environment in 2007. This merits more detailed analysis, since only four VDL-2 channels are expected to support the AOCDL communications load and the CPDLC/DSSDL loads as mentioned earlier; this combined load would require a capacity of 51.2 kbps. Once the transition to VDL-3 for data communications begins the CPDLC/DSSDL load on VDL-2 will decrease, providing capacity for continued AOCDL growth. Additionally, more AOC frequencies can be allocated to VDL Mode 2 to further increase capacity. Our projected demand justifies serious consideration of other high performance communication links, most especially SATCOM. Costs for two-way SATCOM service may be attractive for the AOCs if it is coupled with some form of APAXS that make it cost competitive with VDL-2.

Technology Gap

Given our projections for communications loading it is likely that some of the channels may operate near saturation. Research should be conducted to establish a means to sense channel overload and provide for a controlled degradation of service. There are no technology gaps for implementation of AOC data link via VDL-2. Technology gaps would exist however, should implementation over another communication link be chosen. Use of satellite communication links requires the demonstration of aeronautical mobile technologies for antenna, receivers, link algorithms, protocols, and standards. A major technology focus for broadband communications services is the need to provide more bandwidth (with a focus on Ka-band). Given the migration to these frequencies, the need exists for higher efficiency transmitters (both space and terrestrial), more adaptive bandwidth versus power efficient modulation, forward error correction coding (including turbo codes and bit/modulation symbol interleaving), and much expanded use of variable bit rate formats and dynamic multiplexing techniques such as asynchronous transfer mode (ATM) based technologies. Antennas and receivers must be adapted for the aviation market (size, weight, cost) and must overcome the problems of rain attenuation.

3.2.8 Automated Meteorological Transmission (AUTOMET)

AUTOMET definition is currently under the auspices of the RTCA SC 195 which has developed Minimum Interoperability Standards (MIS) for Automated Meteorological Transmission (RTCA DO-252) for wind, temperature, water vapor and turbulence. Conceptually, aircraft participating in an AUTOMET service program must be able to respond to AUTOMET commands issued by a ground-based command and control system. Downlink message parameters (e.g., frequency, type, etc) are changed by uplink commands from the ground-based systems and are triggered by various conditions (agreed to in advance by the airline, service provider and NWS), or by a request from an end user. Goals of the AUTOMET system are: 1) Increase the amount of usable weather data that is provided to the weather user community; 2) Increase the resolution of reports, forecast products and hazardous weather warnings to make providers of weather information more operationally efficient; 3) Increase the knowledge of the state of the atmosphere and decrease controller workload by automatically transmitting hazardous weather conditions to the ground and other aircraft to improve the ATC system.

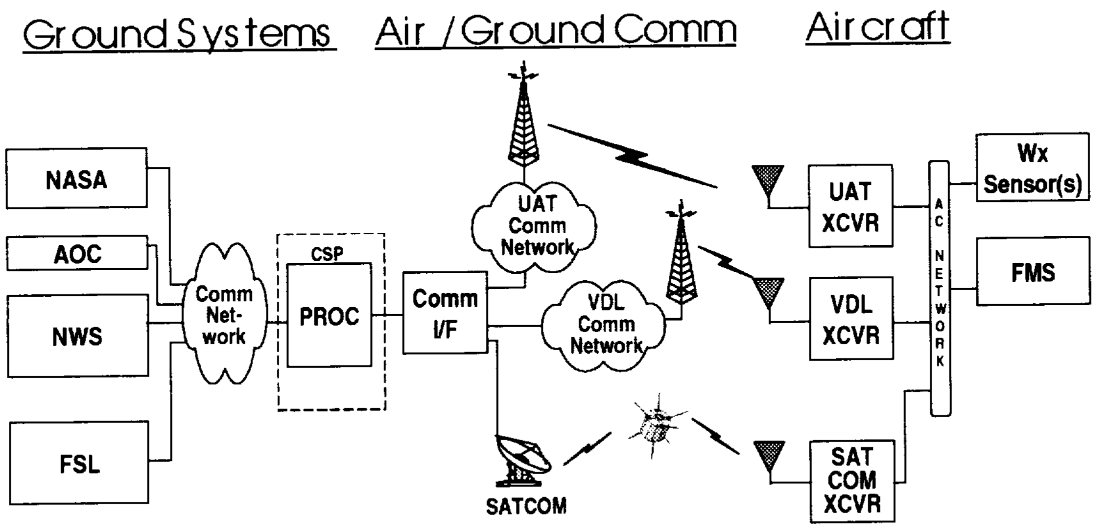

Figure 3.2-9. Automated Meteorological Transmission (AUTOMET) in 2015

The AUTOMET communication links are shown in Table 3.2-17. For aircraft weather reporting using AUTOMET, a number of aircraft collect wind, temperature, humidity, and turbulence information in flight and automatically relay the information to a commercial service provider using VDL Mode 2. The service provider collects and reformats the information and then forwards the information to the National Weather Service (NWS). The NWS uses this AUTOMET information and weather data from other sources to generate gridded weather forecasts. The improved forecasts are distributed to airlines and the FAA to assist in planning flight operations. The gridded weather data, based on AUTOMET data, is also provided to WARP for use by FAA meteorologists and used by several ATC decision support system tools to improve their predictive performance.

Table 3.2-17 AUTOMET Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft report airborne weather to improve weather nowcasting/forecasting	AUTOMET		✓					✓		✓
✓ Acceptable Alternative		☐ NAS Architecture								

Our communication loading analysis for AUTOMET is shown in Table 3.2-18 for each domain. The data in this table indicates that the downlink of all potential AUTOMET products in all domains could potentially saturate the capacity of a VDL-2 channel (19.2 kbps) in conjunction with other messages on the link. In all likelihood AUTOMET data will be downlinked on whatever data link is used to support AOCDL. Thus, if both AOCDL and AUTOMET are combined, the capacity of VDL-2 may be exceeded, methods to filter or compress the amount of data sent to the ground to limit the probability of saturating the VDL-2 channel may be needed. If AOCDL moves to SATCOM, however, there will be sufficient capacity to handle all projected AUTOMET data. As AUTOMET is mainly focused on GA aircraft though a move to SATCOM would bring with it the technology gaps associated with SATCOM.

Table 3.2-18 AUTOMET Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
AUTOMET	N/A	4.4	6.2	
Worst Case	N/A	4.4 (1)	6.2 (1)	10.6

Note: (X) is domain multiplier

Technology Gap

With the potential gaps notes above, from an air/ground communications standpoint, work is currently underway to develop standards for the implementation of AUTOMET. From an avionics perspective, further research could be performed to develop a sensor package that requires no calibration by the pilot or aircraft owner. It is essential to ensure that the data delivered from an AUTOMET sensor be accurate at all times in order to maintain the integrity of the forecast model.

3.2.9 Aeronautical Passenger Services (APAXS)

Passengers enjoy in-flight television, radio, entertainment, telephone, and Internet services. Our analysis of communication trends indicates that there will be a commercial demand for real-time television, radio, and Internet service to airline passengers and corporate travelers on business jets. Industry surveys have shown that while prerecorded programs and movies are a lower priority for passengers than reading, sleeping, and working, there always has been a high interest in live television. One service provider had surveys conducted that indicated 50% of respondents were interested, and 35% would be willing to pay $3-5 per flight for live television—the principal interest being in Cable News Network (CNN). This demand for service most likely will be satisfied through digital, high-data-rate satellite channels—most likely in the Ka-band. Figure 3.2-10 depicts the major elements of APAXS.

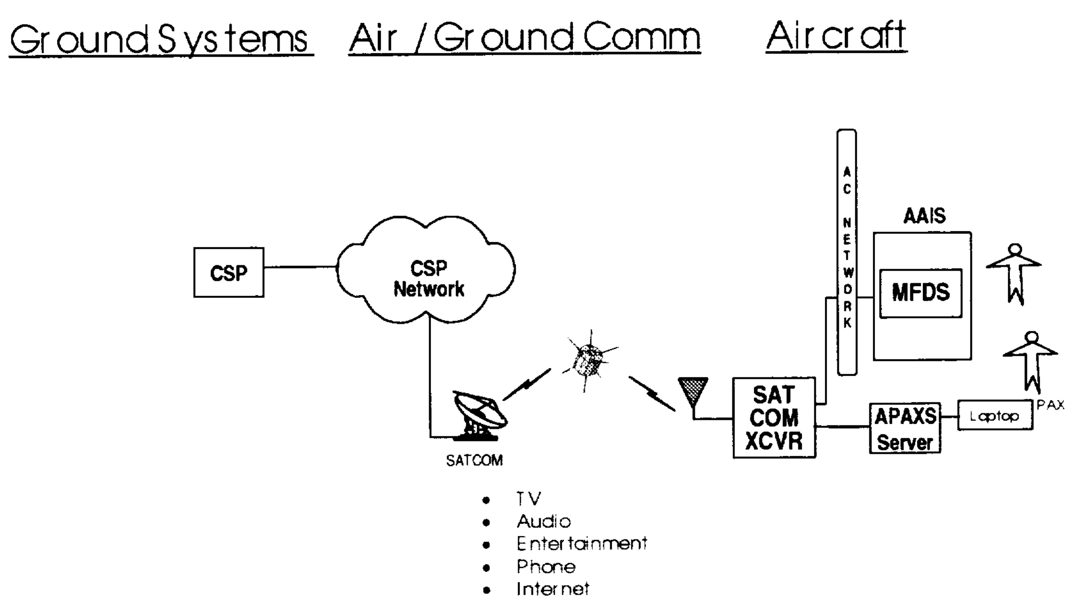

Figure 3.2-10. Aeronautical Passenger Services in 2015

ASSUMPTION

Commercial demand will drive satellite service for the aircraft.

While APAXS is not a service associated with any air traffic management function, it is likely that commercial demand will have driven direct broadcast satellite service to be available in the cabin. This availability is particularly important to note since it may provide an opportunity to support air traffic services that would not be possible otherwise. The APAXS communication links are shown in Table 3.2-20. Note, there are no plans for this in the current NAS architecture.

Table 3.2-19 APAXS Load Analysis Results (kilobits per second)

	En Route Uplink	En Route Downlink
APAXS – Domain	132	116
APAXS – CONUS	2635	2311

Table 3.2-20 APAXS Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Passengers enjoy in-flight television, radio, telephone, and internet service	APAXS								✓	✓

✓ Acceptable Alternative   ☐ NAS Architecture   ★ Restricted Operation

Accordingly, we recommend that further study be conducted to determine the possibility for innovative partnerships or incentives that may leverage the involvement of commercial service providers in the delivery of selected air traffic services. For example, providers of broadcast entertainment channels to aircraft could be required to provide an air traffic services channel that is freely accessible by all aircraft. This example is similar to the requirement that cable television providers have with respect to public access channels.

A freely accessible high-data-rate channel could be used to provide FIS and TIS (strategic only) for all aircraft operating in the CONUS region.

Technology Gap

Suitable antenna/receiver design to resolve rain attenuation and provide a suitable (cost, size, weight) solution for all aircraft types.

3.3 2015 Communication System Architecture Link Alternatives Summary

This section provides a summary of the communication links that can be available to support the 2015 CSA. Each link is described in detail in Section 5 of this document and is summarized below in Table 3.3-1.

Table 3.3-1. Capacity Provided by Various Communication Links

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
	kbps	Channels	Channels	Aircraft	
HFDL	1.8	2	1	50	Intended for Oceanic
ACARS	2.4	10	1	25	ACARS should be in decline as users transition to VDL Mode 2
VDL Mode 2	31.5	4+	1	150	System can expand indefinitely as user demand grows
VDL Mode 3	31.5*	~300	1	60	Assumes NEXCOM will deploy to all phases of flight
VDL Mode 4	19.2	1-2	1	500	Intended for surveillance
VDL – B	31.5	2	1	Broadcast	Intended for FIS
Mode-S	1000**	1	1	500	Intended for surveillance
UAT	1000	1	1	500	Intended for surveillance/FIS
SATCOM	-	-	-	-	Assumes satellites past service life
Future SATCOM	384	15	1	~200	Planned future satellite
Future Ka Satellite	2,000	~50	~50	~200	Estimated capability - assumes capacity split for satellite beams
Fourth Generation Satellite	>100,000	>100	>100	Unknown	Based on frequency license filings

* Channel split between voice and data.
** The Mode-S data link is limited to a secondary, non-interference basis with the surveillance function and has a capacity of 300 bps per aircraft in track per sensor (RTCA/DO-237).

A summary of the peak communication loads for 2015 is provided in Table 3.3-2.

Table 3.3-2. Summary of Peak Communication Loads for 2015 (kbps)

2015	Airport Uplink	Airport Downlink	Terminal Uplink	Terminal Downlink	En Route Uplink	En Route Downlink
FIS	0.2	0.0	0.9	0.0	6.9	0.0
TIS	23.7	0.0	7.0	0.0	20.5	0.0
CPDLC	3.4	2.9	1.3	0.9	1.1	1.3
DSSDL	0.2	0.3	0.1	0.2	0.1	0.1
AOC	0.4	8.4	0.6	8.5	0.2	3.5
ADS Reporting	0.0	16.1	0.0	3.3	0.0	1.5
AUTOMET	0.0	0.0	0.0	4.4	0.0	6.2
APAXS	0.0	0.0	0.0	0.0	131.7	115.5

The NAS requires a data exchange capability that supports the establishment of an air-ground information base. The purpose of establishing and maintaining this information base is to provide the foundation for common situational awareness that in turn will provide the environment for efficient, collaborative, decision making. The technical concepts that support this information base are FIS, TIS, ADS-B and AUTOMET. Taken individually, a solution for each of these concepts could be developed from one of the individual links identified in Table 3.3-1. When viewed from a systems perspective, however, the notion of an integrated data exchange capability begins to emerge. This data exchange capability does not currently exist and the integrated need is not currently recognized in the NAS Architecture. The candidate links that could meet this need are in the initial stages of deployment or design. These are UAT and SATCOM respectively (although SATCOM would not support ADS-B).

Table 3.2-5 provides an overview of UAT and SATCOM. One potential advantage of using UAT would be that the majority of aircraft would already have a UAT radio (if it is the technology chosen for ADS-B) and a UAT terrestrial network would have been established. Additionally, UAT avionics have been designed to support all classes of aircraft. An advantage of SATCOM would be the wide area access provided without the need for a terrestrial network. Implementation of UAT should consider the use of dedicated channels and protocols for ADS-B and TIS in order to optimize their performance while FIS and AUTOMET could employ a more standard broadcast scheme.

The NAS also requires a data message exchange capability to support the efficient coordination of information, decision making, and the delivery of instructions. The technical concepts that support this are AOCDL, DSSDL, and CPDLC. The implementation of VDL-3 will more than adequately accommodate the ATC needs of 2015 and beyond.

3.4 Recommended 2015 AATT Communication System Architecture

In 2015 the physical AATT Communication System Architecture will consist of a communications link that supports continuous data exchange between the aircraft and ground. Additionally, a virtual air-ground communications network that routes message data over the most efficient path will also be available. In this time frame, all aircraft will be equipped with multimode radios that are capable of supporting data and voice communication via VDL-3. Aircraft will continue to downlink airborne weather information to NWS using the most economical communications path. Finally, some commercial aircraft will be equipped with SATCOM-based passenger service links that provide broadcast television, audio, and 2-way telephone and Internet capabilities for a service charge. A summary of the links is provided in Table 3.4-1.

Table 3.4-1 2015 AATT Technical Concepts to Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Flight Information to enable common situational awareness	FIS					[✓]		✓	✓	
Aircraft continuously receive Traffic Information to enable common situational awareness	TIS					✓	[ ]	✓	✓	
Controller - Pilot Communication	CPC	[(✓)]		[(✓)]						
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	CPDLC			[(✓)]						
Aircraft exchange performance / preference data with ATC to optimize decision support	DSSDL			[(✓)]						
Aircraft continously broadcast their position and intent to enable optimum maneuvering	ADS-B				✓		[✓]	✓		
Pilot - AOC data exchange supports efficient air carrier/air transport operations and maintenance	AOCDL		✓					✓		✓
Aircraft report airborne weather to improve weather nowcasting/forecasting	AUTOMET		✓					✓		✓
Passengers enjoy in-flight television, radio, telephone and internet service	APAXS								✓	✓
✓ Acceptable Alternative		[ ] NAS Architecture	( ) AATT CSA Recommendation							

In this time frame, the primary method of voice communication in the NAS is via VDL-3 with VHF-AM being used only in limited low-density airspace. The Class 1 user continues to receive flight information via VDL-B or SATCOM, with voice reporting as a backup over the VDL-3 link from a flight service specialist or an air traffic controller.

A majority of Class 1 aircraft are equipped with ADS-B avionics that transmit their derived position via the selected link (Mode-S, VDL-4, or UAT), which allows pilots to receive extended flight following and separation services due to the extended coverage of the ADS-B receiver network. Flight and traffic information is provided through UAT or SATCOM.

Class 2 users and Class 1 users differ in that some Class 2 users have access to AOCDL that provides operations and maintenance data via VDL-2. Additionally, in this time frame, the majority of Class 2 users will be equipped with a multimode radio that supports VDL-3 voice communications. Flight and traffic information is provided through UAT or SATCOM. Some Class 2 users may provide passenger services via SATCOM as well.

The Class 3 users see the greatest change in communications from the 2007 time frame. Virtually all Class 3 aircraft will be equipped with multimode radios that support controller-pilot voice and data communications via VDL-3. In addition, these aircraft will exchange performance and preference data with ATC via VDL-3 DSSDL. Flight and traffic information is provided through UAT or SATCOM. Two-way SATCOM will be available to support passenger Internet services and may begin to support aircraft-AOC and aircraft-ATC data exchange.

Class 3 aircraft will be the majority users of ADS-B via the selected link (Mode-S, VDL-4, or UAT) due to the maneuvering benefits derived from equipage. HFDL will continue to be used by some aircraft to support oceanic operations.

An overview diagram of the 2015 AATT Architecture alternative using broadband satellite is shown in Figure 3.4-1 and a terrestrial broadband alternative is depicted in Figure 3.4-2.

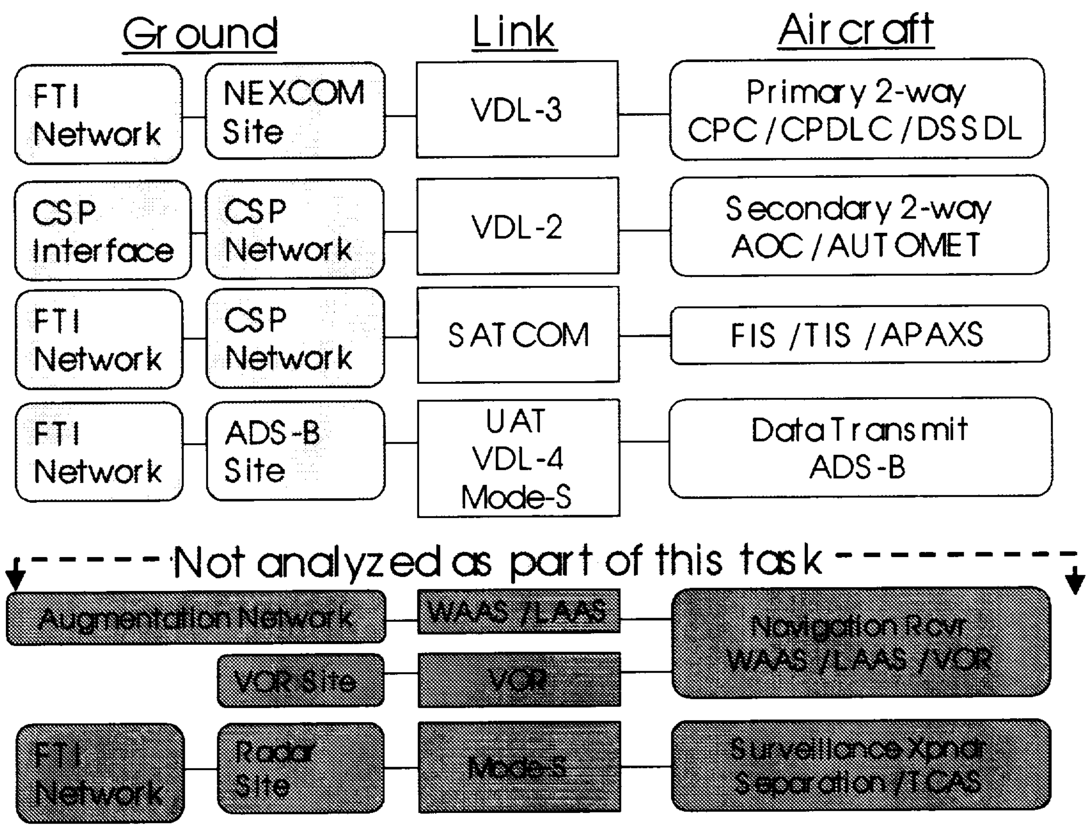

Figure 3.4-1. 2015 AATT Architecture Alternative - SATCOM Based

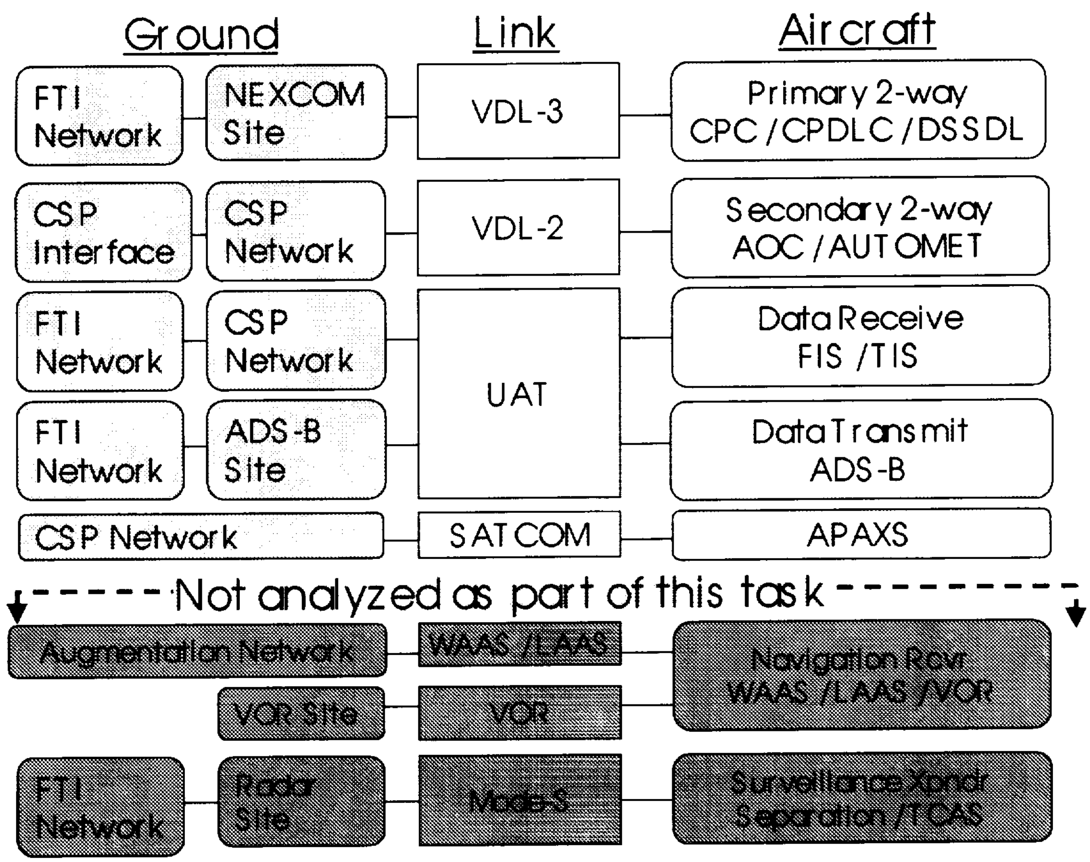

Figure 3.4-2. 2015 AATT Architecture Alternative - Terrestrial Based

There will continue to be a need to maximize the communication capacity of VHF data links operating in the protected aviation spectrum. Accordingly, we recommend further research in the areas of link modulation and data compression to increase the overall bit transfer rate, network prioritization schemes that combine voice and data, and the development of designs for virtual air ground links that will maximize the use of available frequencies.

Finally, the use of SATCOM will be driven by the commercial industry desire to provide high-data-rate services to passengers such as real time television and Internet. Air Traffic Service providers should stay aware of these efforts and look for opportunities to exploit this method of data transmission.

Accordingly, we recommend that further study be conducted to determine the possibility for innovative partnerships or incentives that may leverage the involvement of commercial service providers in the delivery of selected air traffic services via SATCOM. For example, providers of broadcast entertainment channels to aircraft could be required to provide an air traffic services channel that is freely accessible by all aircraft. This example is similar to the requirement that cable television providers have with regard to providing public access channels.

4 Communication Loading Analysis

4.1 Air-Ground Communications

The overall approach to the air-ground communications load analysis is illustrated in Figure 4.1-1 and presented in detail in the following sections. Air-ground communications service requirements are addressed in Section 4.2. Air-ground messages and messages per flight are calculated in Section 4.3. Voice message traffic per flight is calculated in section 4.4. Projections for the peak number of flights in 2015 and the total traffic load are calculated in Section 4.5. Section 4.6 addresses air-to-air message traffic.

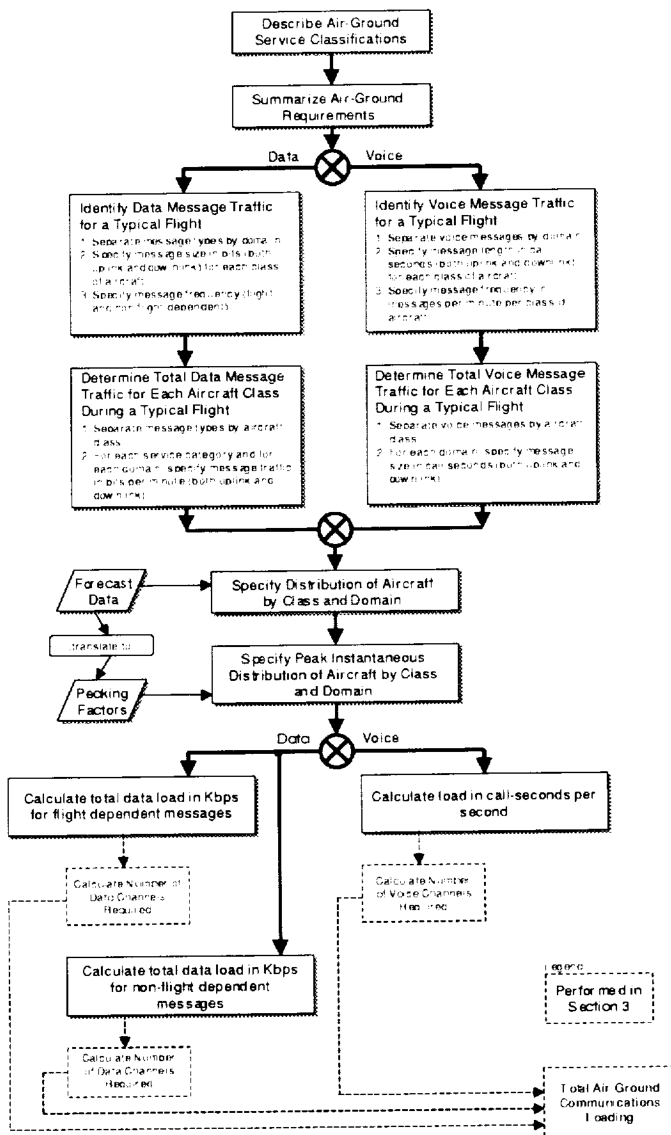

Figure 4.1-1. Communications Load Analysis Method

In this analysis, the term air-ground is used when the direction of the transmission is not relevant. Whenever direction is important, the terms uplink (ground-to-air) and downlink (air-to-ground) are used. The terms message and message traffic are used when the distinction between voice and data messages is not important. Otherwise, the term voice message or data message is used.

All message traffic is assigned to one of nine technical concept categories to simplify calculations and to provide insights that guide the architectural solutions presented in Chapter 3. The technical concept categories are shown in Table 4.1-1 and represent logical groupings of message types based on application and similar communications service requirements.

Table 4.1-1 Air-Ground Technical Concept Classifications

Category.	Technical Concept	Description of Concept
1	Flight Information Services (FIS)	Aircraft continually receive Flight Information to enable common situational awareness
2	Traffic Information Services (TIS)	Aircraft continuously receive Traffic Information to enable common situational awareness
3	Controller-Pilot Data Link Communications (CPDLC)	Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)
4	Controller Pilot Communications (CPC) Voice	Controller - Pilot voice communication
5	Decision Support System Data Link (DSSDL)	Aircraft exchange performance / preference data with ATC to optimize decision support
6	Airline Operational Control Data Link (AOCDL)	Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance
7	Automated Dependent Surveillance (ADS) Reporting	Aircraft continuously transmit data on their position and intent to enable optimum maneuvering
8	Automated Meteorological Reporting (AUTOMET)	Aircraft report airborne weather data to improve weather nowcasting and forecasting
9	Aeronautical Passenger Services (APAXS)	Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service

Throughout the analysis, traffic is segregated by airspace domain and class of aircraft. The domains consist of airport, terminal, en route, and oceanic as defined in Table 4.1-2. By separating traffic loads according to domain, the air-ground communication architecture can be optimized to meet unique regional requirements. The three classes of aircraft are low-end general aviation (Class 1), high-end general aviation and commuter aircraft (Class 2), and commercial carriers (Class 3), as described in Table 4.1-3. The classification by domain and aircraft class gives a more precise traffic load estimate since the number, frequency, and type of message in many cases depends on where the aircraft is and what type of equipage it has. Table 4.1-4 shows the estimated aircraft population in each class that is equipped for a particular technical concept. The percentages in Table 4.1-4 were developed using FAA forecasts and engineering judgement. The values are only approximate but have been specified to the nearest percent to maintain internal consistency.

Table 4.1-2 Airspace Domains

Domain	Definition and Comment*
En route	Airspace in which en route air traffic control services are normally available. The average duration in this domain is 25 minutes per en route center.
Terminal	Airspace in which approach control services are normally available. The average duration in this domain is 10 minutes.
Airport	Airspace, including, runways and other areas used for taxiing, takeoff, and landing, in which tower control services are normally available. The average duration in this domain is 10 minutes.
Oceanic	Airspace over the oceans of the world, considered international airspace, where oceanic separation and procedures per the International Civil Aviation Organization are applied. The average duration in this domain is 180 minutes.

*Average duration of flights are taken from *Aeronautical Spectrum Planning for 1997-2010*, RTCA/DO-237, January 1997, p. F-4.

Table 4.1-3 Aircraft Classes

Class of Aircraft	Definition and Comment
Class 1	Operators who are required to conform to FAR Part 91 only, such as low-end General Aviation (GA) operating normally up to 10,000 ft. This class includes operators of rotorcraft, gliders, and experimental craft and any other user desiring to operate in controlled airspace below 10,000 ft. The primary distinguishing factor of this class is that the aircraft are smaller and that the operators tend to make minimal avionics investments.
Class 2	Operators who are required to conform to FAR Parts 91 and 135, such as air taxis and commuter aircraft. It is likely that high-end GA and business jets and any other users desiring to operate in controlled airspace will invest in the necessary avionics to be able to achieve the additional benefits.
Class 3	Operators who are required to conform to FAR Parts 91 and 121, such as Commercial Transports. This class includes passenger and cargo aircraft and any other user desiring to operate in controlled airspace. These users will invest in the avionics necessary to achieve the additional benefits.

Table 4.1-4 Percent of Aircraft Equipped for Each Technical Concept in 2015

Technical Concept	Class 1	Class 2	Class 3
FIS	52%	74%	79%
TIS	53%	65%	90%
CPDLC	48%	76%	98%
CPC (voice)	100%*	100%	100%
DSSDL	10%	34%	70%
AOCDL	N/A	5%	51%
ADS Reporting	53%	65%	90%
AUTOMET	52%	74%	79%
APAXS	2%	3%	46%

* Aircraft that are not equipped with a radio are excluded from the CSA.

4.2 Air-Ground Communications Service Requirements

General communications service requirements include priority, call setup time, latency, availability, restoration times, and NAS interfaces. Availability and restoration times depend on NAS priority level, which in turn drive the level of link redundancy needed. Table 4.2-1 shows requirements for each technical concept.

Table 4.2-1. Air-Ground Service Requirements

Technical Concept.	Priority	Availability Restoration Time	Call Setup Time	Latency End to End	Aircraft Interface
FIS	Routine	0.99 1.7 hour	≤10 sec	~10 sec	FAA NWIS Network
TIS	Critical, Essential	0.99999 6 seconds	≤ 5 sec	~1 sec	FAA Surveillance Network
CPDLC	Critical	0.99999 6 seconds	≤ 5 sec	~1 sec	FAA Air-Ground Com Network
CPC	Critical	0.99999 6 seconds	≤ 5 sec	~400 msec	FAA Air-Ground Com Network
DSSDL	Essential	0.999 10 minutes	≤ 5 sec	~1 sec	ATC Automation
AOCDL	Routine	0.99 1.7 hour	≤ 10 sec	~10 sec	Commercial Service Provider
ADS	Critical	0.99999 6 seconds	≤ 5 sec	~1 sec	Surveillance Network
AUTOMET	Routine	0.99 1.7 hour	≤ 30 sec	~10 sec	Commercial Service Provider
APAXS	Routine	0.99 1.7 hour	≤ 30 sec	~10 sec	Commercial Service Provider

The NAS System Requirements Specification defines priority levels as follows:

- Critical services are those which, if lost, would prevent the NAS from exercising safe separation and control of aircraft. For critical services the availability goal is 0.99999 and the goal for service restoral time is 6 seconds.
- Essential services are those which, if lost, would reduce the capability of the NAS to exercise safe separation and control of aircraft. For essential services the availability goal is 0.999 and the goal for service restoral time is 10 minutes.
- Routine services are those which, if lost, would not significantly degrade the capability of the NAS to exercise safe separation and control of aircraft. For routine services the availability goal is 0.99 and the goal for service restoral time is 1.68 hours.

Coverage requirements for air-ground services are assumed to be:

- Fully redundant coverage for continental United States (CONUS), Hawaii, Alaska, Caribbean islands, Canada, Mexico, and Central and South America.
- Single coverage over the Pacific and Atlantic Ocean regions (redundant coverage is assumed to be provided by other CAAs and by commercial service providers
- Single coverage over the polar regions

Voice traffic in 2015 is assumed to use digital links with a data rate of 4800 bits per second. This rate, in conjunction with a channel bit error rate (BER) of 10^{-5} after error correction, should be adequate to satisfy voice quality requirements. This BER is equivalent to a worst-case block error probability of 10^{-2} for each kilobit block and is assumed to be satisfactory for planned data services as well as digital voice service.

Oceanic communications requirements are somewhat relaxed from en route requirements. Availability for critical communications is assumed to be 0.9999 with a restoral time of 6 seconds and a message latency of 10 seconds.

These service requirements are used in the load analysis for purposes of grouping messages with similar service and delivery requirements. They are also used to select communications link technologies and develop of the overall architecture presented in Chapter 3. The latency requirement in Table 4.2-1, for example, would appear to preclude the use of geosynchronous satellites for critical voice services (CPC voice) due to satellite propagation delays, which exceed 200 milliseconds. Although latency is considered a "soft" requirement in this analysis, the architecture solution in Chapter 3 does not use geosynchronous satellites for CPC voice service because of the excessive propagation delay.

4.3 Air-Ground Data Message Traffic Requirements

Information on message sizes and frequencies came from a number of sources. A unique message identifier (Msg ID), shown in Table 4.3-1, is assigned to the various message types to simplify the analysis. In some cases, these message types represent specific messages with a fixed length and repetition rate. In general, however, message types are merely representative of the type and the characteristics are simply an average.

Table 4.3-1. Message Types and Message Type Identifiers

Message Type Identifier	Message Type
M1	ADS
M2	Advanced ATM
M3	Air Traffic Information
M4	Not used - See M43, M44
M5	Airline Business Support: Electronic Database Updating
M6	Airline Business Support: Passenger Profiling
M7	Airline Business Support: Passenger Re-Accommodation
M8	Airline Maintenance Support: Electronic Database Updating
M9	Airline Maintenance Support: In-Flight Emergency Support
M10	Airline Maintenance Support: Non-Routine Maintenance/ Information Reporting
M11	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)
M12	Airline Maintenance Support: Routing Maintenance/ Information Reporting
M13	Arrival ATIS
M14	Not used - See M43, M44
M15	Convection
M16	Delivery of Route Deviation Warnings
M17	Departure ATIS
M18	Destination Field Conditions
M19	Diagnostic Data
M20	En Route Backup Strategic General Imagery
M21	FIS Planning – ATIS
M22	FIS Planning Services
M23	Flight Data Recorder Downlinks
M24	Flight Plans
M25	Gate Assignment

Message Type Identifier	Message Type
M26	General Hazard
M27	Icing
M28	Icing/ Flight Conditions
M29	Low Level Wind Shear
M30	Out/ Off/ On/ In
M31	Passenger Services: On Board Phone
M32	Pilot/ Controller Communications
M33	Position Reports
M34	Pre-Departure Clearance
M35	Radar Mosaic
M36	Support Precision Landing
M37	Surface Conditions
M38	TFM Information
M39	Turbulence
M40	Winds/ Temperature
M41	System Management and Control
M42	Miscellaneous Cabin Services
M43	Aircraft Originated Ascent Series Meteorological Observations
M44	Aircraft Originated Descent Series Meteorological Observations

Each message type is mapped to an aircraft class and airspace domain based on information in the reference source and expert knowledge. The messages are further assigned to technical concept categories to aid in the presentation of data and to simplify the communications architecture design process.

Some message types are extremely large and compression is required in order to reduce communications loads. The compression ratios assumed in this analysis are shown in Table 4.3-2. In some cases, the same message is sent with different compression ratios because the required resolution is not the same in all domains (e.g., M15 and M28). Note that all traffic loading data presented in this chapter has been compressed according to Table 4.3-2 and no further compression should be applied.

Throughout the analysis voice and data traffic are treated separately to deal with the unique requirements each imposes on the communications architecture.

Table 4.3-2. Data Compression Factors Used (1:1 assumed for all other messages)

Domain	Msg ID	Compression*
Terminal Tactical	M18 M20 M27 M29 M37	10:1 10:1 10:1 10:1 20:1
Terminal Strategic	M15 M28 M35	50:1 50:1 10:1
En Route Tactical	M39	50:1
En Route Near Term Strategic	M15 M26 M28 M37 M39	20:1 20:1 20:1 20:1 20:1

Domain	Msg ID	Compression*
En Route Far Term Strategic	M15 M26 M28	50:1 50:1 50:1

**Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase I Report, Aviation Weather Communications Requirements*, Lockheed Martin Aeronautical Systems

4.3.1 Data Message Traffic per Flight

Data message traffic tables are developed for each class of aircraft based on the particular set of messages required by that class in a given domain. Note that frequency units are expressed in terms of messages per flight or messages per minute per flight, depending on the nature of the communications. For messages that occur on a periodic basis and are independent of the number of aircraft, frequencies are expressed in terms of messages per minute. These non-flight dependent messages are listed in a separate table (see Table 4.3-6) and only added the total communications load after other calculations are completed. The largest common unit used to express message frequencies and flight times was a minute; this time unit was chosen as the basic unit for all calculations because it helps to distinguish between traffic loads channel data rates.

Data message traffic by flight for each class of aircraft is summarized in Table 4.3-3, Table 4.3-4, and Table 4.3-5. These tables do not represent peak traffic, but rather the expected traffic with departures and arrivals evenly distributed within each domain. All message sizes are expressed in bits.

Table 4.3-3. Data Message Traffic for Class 1 Aircraft (flight dependent)*

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
FIS	M17	En Route	1 msg/flt	3200	1 msg/flt	64
	M21	Terminal	1 msg/flt	400	1 req/flt	56
	M22	Airport	1 msg/10 sec	2100	1 req/flt	64
	M22	Terminal	1 msg/10 sec	2000	6 req/flt	64
	M22	En Route	1 msg/10 sec	2000	4 req/flt	64
	M28	En Route	1 msg/flt	45000	N/A	N/A
CPDLC	M32	Airport	10 msg/flt	123	10 msg/flt	32
	M32	Terminal	9.6 msg/flt	123	13.1 msg/flt	32
	M32	En Route	10.2 msg/flt	118	17.4 msg/flt	34
	M34	Airport	1.25 msg/flt	1800	2.25 msg/flt	304
	M41	Airport	5 msg/flt	720	4 msg/flt	720
	M41	Terminal	2 msg/flt	720	1 msg/flt	720
	M41	En Route	6 msg/flt	720	5 msg/flt	720
DSSDL	M16	Airport	1 msg/5 flts	800	1 msg/5 flts	800
	M16	Terminal	1 msg/5 flts	800	1 msg/5 flts	800
	M16	En Route	1 msg/5 flts	800	1 msg/5 flts	800
	M2	Airport	1 msg/flt	40	1 msg/flt	960
	M2	Terminal	1 msg/flt	40	1 msg/flt	960
	M2	En Route	1 msg/flt	40	1 msg/flt	960
	M38	Airport	2 msg/flt	800	2 msg/flt	800
	M38	Terminal	1 msg/2 flt	800	1 msg/2 flt	100

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
DSSDL	M38	En Route	1 msg/flt	800	1 msg/flt	100
ADS Reporting	M1	Airport	1 msg/flt	128	1 msg/1.1 sec	144
	M1	Terminal	1 msg/flt	128	1 msg/5.33 sec	144
	M1	En Route	1 msg/flt	128	1 msg/12.1 sec	144
AUTOMET	M14	Airport	N/A	N/A	10 msg/flt	430
	M14	Terminal	N/A	N/A	3 msg/minute	430
	M14	En Route	N/A	N/A	1 msg/15 minutes	430
	M4	Terminal	1 msg/flt	56	1 msg/5 minutes	1760
	M4	En Route	1 msg/flt	56	1 msg/5 minutes	1760
	M43	Terminal	1 msg/flt	56	3 msg/min	512
	M43	En route	1 msg/flt	56	1 msg/6 min	2152
	M44	En Route	1 msg/flt	56	1 msg/2min	3544

*Compressed per Table 4.3-2

Table 4.3-4. Data Message Traffic for Class 2 Aircraft (flight dependent)*

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
FIS	M17	En Route	1 msg/flt	3200	1 msg/flt	64
	M21	Terminal	1 msg/flt	400	1 req/flt	56
	M22	Airport	1 msg/10 sec	2100	1 req/flt	64
	M22	Terminal	1 msg/10 sec	2000	6 req/flt	64
	M22	En Route	1 msg/10 sec	2000	4 req/flt	64
CPDLC	M32	Airport	10 msg/flt	123	10 msg/flt	32
	M32	Terminal	9.6 msg/flt	123	13.1 msg/flt	32
	M32	En Route	10.2 msg/flt	118	17.4 msg/flt	34
	M34	Airport	1.25 msg/flt	1800	2.25 msg/flt	304
	M41	Airport	5 msg/flt	720	4 msg/flt	720
	M41	Terminal	2 msg/flt	720	1 msg/flt	720
	M41	En Route	6 msg/flt	720	5 msg/flt	720
DSSDL	M16	Airport	1 msg/5 flts	800	1 msg/5 flts	800
	M16	Terminal	1 msg/5 flts	800	1 msg/5 flts	800
	M16	En Route	1 msg/5 flts	800	1 msg/5 flts	800
	M2	Airport	1 msg/flt	40	1 msg/flt	960
	M2	Terminal	1 msg/flt	40	1 msg/flt	960
	M2	En Route	1 msg/flt	40	1 msg/flt	960
	M38	Airport	2 msg/flt	800	2 msg/flt	800
	M38	Terminal	1 msg/2 flt	800	1 msg/2 flt	100
	M38	En Route	1 msg/flt	800	1 msg/flt	100
AOCDL	M10	Terminal	3 msg/flt	480	3 msg/flt	10400
	M11	Airport	6 msg/flt	480	6 msg/flt	10080
	M11	Terminal	6 msg/flt	480	6 msg/flt	10080
	M11	En Route	6 msg/flt	480	6 msg/flt	10080
	M12	Airport	3 msg/flt	480	3 msg/flt	10400
	M12	Airport	3 msg/flt	480	3 msg/flt	5200
	M12	Terminal	3 msg/flt	480	3 msg/flt	5200
	M12	En Route	3 msg/flt	480	3 msg/flt	10400
	M12	En Route	3 msg/flt	480	3 msg/flt	5200

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
AOCDL	M19	Terminal	N/A	N/A	1 msg/min	50
	M19	En Route	N/A	N/A	1 msg/min	50
	M23	En Route	N/A	N/A	1 msg/flt	3000
	M25	Airport	1 msg/flt	10	1 msg/flt	10
	M30	Airport	1 msg/flt	10	1 msg/flt	10
	M30	Terminal	1 msg/flt	10	1 msg/flt	10
	M33	En Route	2 msg/flt	10	2 msg/flt	80
	M8	Airport	3 msg/flt	480	3 msg/flt	10400
	M8	Terminal	3 msg/flt	480	3 msg/flt	10400
	M8	En Route	3 msg/flt	480	3 msg/flt	10400
	M9	Terminal	1 msg/flt	2600	4 msg/flt	240
	M9	En Route	1 msg/flt	2600	4 msg/flt	240
ADS Reporting	M1	Airport	1 msg/flt	128	1 msg/1.1 sec	144
	M1	Terminal	1 msg/flt	128	1 msg/5.33 sec	144
	M1	En Route	1 msg/flt	128	1 msg/12.1 sec	144
AUTOMET	M14	Airport	N/A	N/A	10 msg/flt	430
	M14	Terminal	N/A	N/A	3 msg/minute	430
	M14	En Route	N/A	N/A	1 msg/15 minutes	430
	M4	Terminal	1 msg/flt	56	1 msg/5 minutes	1760
	M4	En Route	1 msg/flt	56	1 msg/5 minutes	1760
	M43	Terminal	1 msg/flt	56	3 msg/min	512
	M43	En route	1 msg/flt	56	1 msg/6 min	2152
	M44	En Route	1msg/flt	56	1 msg/2min	3544

*Compressed per Table 4.3-2

Table 4.3-5. Data Message Traffic for Class 3 Aircraft (flight dependent)*

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
FIS	M17	En Route	1 msg/flt	3200	1 msg/flt	64
	M21	Terminal	1 msg/flt	400	1 req/flt	56
	M22	Airport	1 msg/10 sec	2100	1 req/flt	64
	M22	Terminal	1 msg/10 sec	2000	6 req/flt	64
	M22	En Route	1 msg/10 sec	2000	4 req/flt	64
	M28	En Route	1 msg/flt	45000	N/A	N/A
CPDLC	M32	Airport	10 msg/flt	123	10 msg/flt	32
	M32	Terminal	9.6 msg/flt	123	13.1 msg/flt	32
	M32	En Route	10.2 msg/flt	118	17.4 msg/flt	34
	M34	Airport	1.25 msg/flt	1800	2.25 msg/flt	304
	M41	Airport	5 msg/flt	720	4 msg/flt	720
	M41	Terminal	2 msg/flt	720	1 msg/flt	720
	M41	En Route	6 msg/flt	720	5 msg/flt	720
DSSDL	M16	Airport	1 msg/5 flts	800	1 msg/5 flts	800
	M16	Terminal	1 msg/5 flts	800	1 msg/5 flts	800
	M16	En Route	1 msg/5 flts	800	1 msg/5 flts	800
	M2	Airport	1 msg/flt	40	1 msg/flt	960
	M2	Terminal	1 msg/flt	40	1 msg/flt	960
	M2	En Route	1 msg/flt	40	1 msg/flt	960
	M38	Airport	2 msg/flt	800	2 msg/flt	800
	M38	Terminal	1 msg/2 flt	800	1 msg/2 flt	100
	M38	En Route	1 msg/flt	800	1 msg/flt	100

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
AOCDL	M10	Terminal	3 msg/flt	480	3 msg/flt	10400
	M11	Airport	6 msg/flt	480	6 msg/flt	10080
	M11	Terminal	6 msg/flt	480	6 msg/flt	10080
	M11	En Route	6 msg/flt	480	6 msg/flt	10080
	M12	Airport	3 msg/flt	480	3 msg/flt	10400
	M12	Airport	3 msg/flt	480	3 msg/flt	5200
	M12	Terminal	3 msg/flt	480	3 msg/flt	5200
	M12	En Route	3 msg/flt	480	3 msg/flt	10400
	M12	En Route	3 msg/flt	480	3 msg/flt	5200
	M19	Terminal	N/A	N/A	1 msg/min	50
	M19	En Route	N/A	N/A	1 msg/min	50
	M23	En Route	N/A	N/A	1 msg/flt	3000
	M25	Airport	1 msg/flt	10	1 msg/flt	10
	M30	Airport	1 msg/flt	10	1 msg/flt	10
	M30	Terminal	1 msg/flt	10	1 msg/flt	10
	M33	En Route	2 msg/flt	10	2 msg/flt	80
	M8	Airport	3 msg/flt	480	3 msg/flt	10400
	M8	Terminal	3 msg/flt	480	3 msg/flt	10400
	M8	En Route	3 msg/flt	480	3 msg/flt	10400
	M9	Terminal	1 msg/flt	2600	4 msg/flt	240
	M9	En Route	1 msg/flt	2600	4 msg/flt	240
ADS Reporting	M1	Airport	1 msg/flt	128	1 msg/1.1 sec	144
	M1	Terminal	1 msg/flt	128	1 msg/5.33 sec	144
	M1	En Route	1 msg/flt	128	1 msg/12.1 sec	144
AUTOMET	M14	Airport	N/A	N/A	10 msg/flt	430
	M14	Terminal	N/A	N/A	3 msg/minute	430
	M14	En Route	N/A	N/A	1 msg/15 minutes	430
	M4	Terminal	1 msg/flt	56	1 msg/5 minutes	1760
	M4	En Route	1 msg/flt	56	1 msg/5 minutes	1760
	M43	Terminal	1 msg/flt	56	3 msg/min	512
	M43	En route	1 msg/flt	56	1 msg/6 min	2152
	M44	En Route	1msg/flt	56	1 msg/2min	3544
APAXS	M31	En Route	5 10-min/flt	1440000	5 10-min/flt	1440000
	M42	En Route	1 msg/flt	1000000	20 msg/flt	1000
	M5	En Route	3 msg/flt	5200	6 msg/flt	480
	M6	En Route	2 msg/flt	5200	2 msg/flt	480
	M7	En Route	2 msg/flt	5200	2 msg/flt	480

*Compressed per Table 4.3-2

Table 4.3-6. Non Flight Dependent Data Message Traffic (all aircraft classes)*

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)
FIS	M15	En Route	4 products/60 minutes	252000
	M15	En Route	6 products/60 minutes	306000
	M15	Terminal	6 products/60 minutes	252000
	M18	Terminal	60 products/60 minutes	1300
	M20	En Route	4 products/60 minutes	2800000
	M26	En Route	2 product/60 min	144000
	M26	En Route	6 products /60 min	350000

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)
FIS	M27	Terminal	60 products /60 min	5510
	M28	En Route	6 products /60 min	219000
	M28	En Route	2 products/60 min	27000
	M40	En Route	1 product/60 minutes	54000
	M40	En Route	6 product/60 minutes	262500
	M29	Terminal	6 products/60 min	480
	M35	Terminal	31 products/60 minutes	7350
	M37	En Route	4 products/60 minutes	28800
	M39	En Route	1 product/60 minutes	27000
	M39	En Route	6 product/60 minutes	131000
	M39	En Route	4 product/60 minutes	252000
TIS	M3	Airport	1 msg/2 sec	224
	M3	En Route	1 msg/6 sec	224
	M3	Terminal	1 msg/4.8 sec	224

*Compressed per Table 4.3-2; all downlink traffic is flight dependent and therefore excluded from this table

Non-flight dependent products usually are large messages that are identical for all recipients. They can be sent on a periodic basis and the number of times they are sent is not dependent on the number of flights. The message characteristics are assumed to be the same for all classes and domains, with the exception of TIS messages. The size of TIS messages varies depending on the number of aircraft being reported. The total communications load will therefore depend on whether the message is being transmitted nationwide or just to the aircraft in a small region.

4.3.2 Data Message Load Per Flight

In order to convert messages per flight to communications channel loading, several assumptions are required regarding the duration of flights, communications protocol overheads, and message characteristics:

- ATN protocol overheads are applied to all connection-oriented messages, i.e., CPDLC, DSSDL, AOCDL, and AUTOMET messages, plus flight dependent FIS messages.
- The ATN protocol network layer overhead varies according to message context and message size; the actual overhead spans a wide range of documented values. RTCA/DO-237, for example, uses a protocol overhead of 136% for uplink messages and 1376% for downlink messages. (These values are biased toward the maxima that can be expected; the average overhead on downlink traffic is likely to be far less in practice.) For very short messages (i.e., CPDLC), this analysis assumes an average uplink overhead of 100% and an average downlink overhead of 200%. For longer messages (i.e., all other ATN traffic), the average overhead is assumed to 20% in both directions. These assumptions are in general agreement with the results of ARINC overhead predictions for various AOC messages.
- Non-flight dependent FIS messages and all TIS messages include a network layer overhead of 10% for error detection and synchronization.
- A physical layer overhead of 50% is assumed on all connection-oriented data messages (RTCA/DO-237).
- Modulation efficiency for D8PSK is assumed to be 1.25 bps per Hertz (RTCA/DO-237).
- The average time a flight spends in each airport domain is 10 minutes (RTCA/DO-237).
- The average time a flight spends in each terminal domain is 10 minutes (RTCA/DO-237).
- The average time a flight spends in each en route domain is 25 minutes per center; an average flight spans two centers.

- The average time a flight spends in the oceanic domain is 180 minutes.
- Only AUTOMET message types M43 and M44 are included in the data communications loading calculations; these messages are assumed to contain all the information found in other AUTOMET messages and are larger in size. Message sizes and frequencies are based on the 1999 draft RTCA Minimum Interoperability Standard for AUTOMET.
- 8 bits per character is used to convert messages size in characters to message size in bits for AUTOMET messages M43 and M44; all other messages were expressed as bits in the source documents used.
- All AUTOMET traffic is suppressed in the airport domain to reduce channel requirements; the data is highly redundant and duplicates what is available from fixed airport weather sensors.

These assumptions are used to convert data message traffic in Tables 4.3-3, 4.3-4 and 4.3-5 into bits per flight per minute for each Technical Concept and class of aircraft. To get bits per minute per flight, the message size in bits is multiplied by the frequency in messages per minute times the proportion of aircraft equipped (Table 4.1-4). If the messages are on a per flight basis, the conversion requires multiplying the message size in bits times the number of messages per flight in a particular domain divided by the time a flight spends in that domain to obtain bits per minute per flight. This number is then multiplied by the proportion of aircraft equipped (Table 4.1-4) to arrive at the estimates shown in Table 4.3-7, Table 4.3-8, and Table 4.3-9.

Table 4.3-7. Data Message Traffic for Aircraft Class 1 (bits per min per flight)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	9434.9	4.8	9015.6	32.9	16419.7	9.6
CPDLC	815.6	671.2	301.9	196.9	254.5	289.7
DSSDL	25.9	39.2	8.6	16.8	5.8	7.0
AOCDL	N/A	N/A	N/A	N/A	N/A	N/A
ADS Reporting	6.8	4162.9	6.8	859.1	2.7	378.4
AUTOMET	N/A	N/A	4.2	1150.2	3.4	1595.4
APAXS	N/A	N/A	N/A	N/A	N/A	N/A

*Compressed per Table 4.3-2

Table 4.3-8. Data Message Traffic for Aircraft Class 2 (bits per min per flight)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	13426.6	6.8	12829.8	46.9	23366.5	13.6
CPDLC	1291.4	1062.7	478.0	311.7	403.0	458.7
DSSDL	88.1	133.2	29.4	57.3	19.6	23.9
AOCDL	52.0	997.2	70.6	1007.6	28.3	414.3
ADS Reporting	8.3	5105.5	8.3	1053.7	3.3	464.1
AUTOMET	N/A	N/A	6.0	1636.8	4.8	2270.4
APAXS	N/A	N/A	N/A	N/A	N/A	N/A

*Compressed per Table 4.3-2

Table 4.3-9. Data Message Traffic for Aircraft Class 3 (bits per min per flight)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	14333.8	7.3	13696.7	50.1	24945.3	14.6
CPDLC	1520.6	1313.8	616.4	401.9	519.7	591.5
DSSDL	100.8	193.5	60.5	117.9	40.3	49.2
AOCDL	530.2	10171.4	720.4	10277.9	288.5	4225.7
ADS Reporting	11.5	7069.1	11.5	1458.9	4.6	642.6
AUTOMET	N/A	N/A	6.4	1747.4	5.1	2423.8
APAXS	N/A	N/A	N/A	N/A	148255.2	130046.4

*Compressed per Table 4.3-2

4.3.3 Non Flight Dependent Data Message Traffic

The total number of FIS and TIS messages transmitted does not vary with the number of flights or the instantaneous airborne count. For these non-flight dependent messages, the message size in bits is multiplied by the frequency in messages per minute and listed separately in Table 4.3-10. Note that the length of a TIS message is directly proportional to the number of aircraft reporting in a local, regional, or national area, depending on the communications architecture assumed. The values in Table 4.1-4 (Percent of Aircraft Equipped for Each Technical Concept) are not used in this calculation since number of aircraft equipped to receive TIS messages does not affect the channel loading.

Table 4.3-10. Non-Flight Dependent Data Message Traffic (bits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	N/A	N/A	38,154.1	N/A	391,695.3	N/A
TIS	7392.0/acft	6.2	3080.0/acft	6.2	2464.0/acft	2.5

*Compressed per Table 4.3-2

4.3.4 Oceanic Data Message Load Per Flight

In the oceanic domain, data message traffic includes en route messages plus certain messages unique to oceanic flights. It is assumed that users in 2015 will want to receive the full complement of en route messages in the oceanic domain, if the communications links can support it. Using the same messages and message frequencies in the oceanic domain would provide seamless communications when transiting the NAS. Table 4.3-11 is only presented for Class 3 aircraft since the other classes are used primarily for domestic flights.

Table 4.3-11. Oceanic Data Message Traffic for Aircraft Class 3 (bits per min per flight)*

Technical Concept	Airport		Terminal		Oceanic	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	N/A	N/A	N/A	N/A	6,912.0	0.0
CPDLC	N/A	N/A	N/A	N/A	361.6	515.8
DSSDL	N/A	N/A	N/A	N/A	6.7	8.5
AOCDL	N/A	N/A	N/A	N/A	47.0	865.9
ADS Reporting	N/A	N/A	N/A	N/A	1.0	41.5

Technical Concept	Airport		Terminal		Oceanic	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
AUTOMET	N/A	N/A	N/A	N/A	0.9	3,068.2
APAXS	N/A	N/A	N/A	N/A	40,260.0	40,032.0

*Compressed per Table 4.3-2

4.4 Voice Traffic

ATC voice traffic is not included with data message traffic even though it can be digitized and sent as a data message. This is because CPC voice communications are highly interactive and require immediate acknowledgement. For reasons of safety, ATC voice services must also meet stringent availability, reliability, and diversity requirements that exceed what is required for most data messages. The premium paid for this type of service dictates that its use be limited to critical communications. By 2015, it is assumed that terminal and en route voice communications to high-end aircraft will have transferred completely to CPDLC.

APAXS voice messages are routine and are not included in airport and terminal domains where it is assumed that on-board telephones must remain stowed for reasons of safety. Predicted passenger telephone calls are based on the assumption that 5% of the passengers place a 5 minute call in a one-hour period. The time is equally divided between uplink (listening) and downlink (talking) channels. For purposes of this analysis, only Class 3 aircraft are assumed to have passenger telephony. Note that voice traffic is expressed in call-seconds, i.e., the amount of time an uplink or downlink channel is in use.

Table 4.4-1. Voice Message Traffic in 2015 (call-seconds)

Message	Domain	Class	Uplink	Downlink	Msgs. per Flight
CPC Clearances	Airport	1	5 sec	5 sec	1/flt
CPC Clearances		1	5 sec	1 sec	2/flt
CPC Clearances		2	5 sec	5 sec	1/flt
CPC Clearances		2	5 sec	1 sec	2/flt
CPC Clearances		3	5 sec	5 sec	1/flt
CPC Clearances		3	5 sec	1 sec	2/flt
CPC Clearances	Terminal	1	5 sec	10 sec	1/flt
CPC TOC*		1	5 sec	5 sec	1/flt
CPC Advisories	En Route	1	20 sec	5 sec	1/flt
APAXS	En Route	1	150 sec	150 sec	0.05 passngr/hr

* Transfer of Communications

The total voice traffic per flight is calculated by multiplying the duration of the voice message by the number of times the message occurs and dividing by the time spent in the domain. The results are summed for each domain and class of aircraft to get the total per flight requirements.

Table 4.4-2. CPC Voice Message (call-seconds per min per flight)

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	1.5 sec	0.7 sec	1.0 sec	1.5 sec	0.8 sec	0.2 sec
2	1.5 sec	0.7 sec	N/A	N/A	N/A	N/A
3	1.5 sec	0.7 sec	N/A	N/A	N/A	N/A

The APAXS passenger telephony calculations assume an average flight has 90 passengers and that 5% of the passengers in a given hour will talk for 150 seconds and listen for 150 seconds. Since the time spent in en route per flight is 50 minutes, the uplink and downlink load is 0.05 calls per passengers per hour x 90 passengers per flight x 5/6 hour per flight x 150 seconds per call / 50 minutes per flight = 11.3 call-seconds per minute per flight while en route.

Table 4.4-3. APAXS Voice Message (call-seconds per min per flight)

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
3	N/A	N/A	N/A	N/A	11.3	11.3

4.5 Traffic Load Analysis

4.5.1 Flight Forecasts

The average traffic load is developed from the per flight message traffic multiplied by the expected number of flights in 2015. Communications links, however, are generally designed for peak loads to avoid increased delays or blocking when traffic is heaviest. Peak flights by domain for 1998 are therefore projected out to 2015 to estimate the peak load. The projections shown in Table 4.5-1 represent a 25% increase in operations between 1998 and 2015 for the aircraft classes of interest. FAA forecasts for terminal area itinerant aircraft operations are used because they correspond closely to the number of flights and are readily available from FAA forecast data by class of aircraft. For simplicity, it is assumed that the percent growth within each aircraft class and domain is the same as the percent growth in total aircraft operations.

Table 4.5-1. Peak Number of Flights (Aircraft) by Domain in 2015

Year	Operations*	Airport	Terminal	En Route
1998	73,169,228	154	110	400
2015	91,433,515	192	137	500

*APO Terminal Area Forecast Summary Report, TAF System Model

Applying the forecast distribution of operations for each class of aircraft to the number of flights in each domain provides the approximate distribution of flights by class and domain for 2015 as shown in Table 4.5-2.

Table 4.5-2. Estimated Peak Distribution of Flights by Class and Domain in 2015

Class	Operations*	Airport	Terminal	En Route
1	51,883,989	109	78	284
2	17,545,459	37	26	96
3	22,004,067	46	33	120
Total	91,433,515	192	137	500

*APO Terminal Area Forecast Summary Report, TAF System Model

4.5.2 Data Traffic Load

Multiplying the peak number of flights in Table 4.5-2 by the messages per flight in Table 4.3-7, Table 4.3-8, and Table 4.3-9 results in the estimated peak loads shown in Table 4.5-3, Table 4.5-4, and Table 4.5-5.

Table 4.5-3. Peak Data Message Traffic for Aircraft Class 1 in 2015 (kilobits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	1,028.4	0.5	982.7	3.6	1,789.7	1.0
CPDLC	88.9	73.2	32.9	21.5	27.7	31.6
DSSDL	2.8	4.3	0.9	1.8	0.6	0.8
ADS Reporting	0.7	453.8	0.7	93.6	0.3	41.3
AUTOMET	N/A	N/A	0.5	125.4	0.4	173.9

*Compressed per Table 4.3-2

Table 4.5-4. Peak Data Message Traffic for Aircraft Class 2 in 2015 (kilobits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	496.8	0.3	474.7	1.7	864.6	0.5
CPDLC	47.8	39.3	17.7	11.5	14.9	17.0
DSSDL	3.3	4.9	1.1	2.1	0.7	0.9
AOCDL	1.9	36.9	2.6	37.3	1.0	15.3
ADS Reporting	0.3	188.9	0.3	39.0	0.1	17.2
AUTOMET	N/A	N/A	0.2	60.6	0.2	84.0

*Compressed per Table 4.3-2

Table 4.5-5. Peak Data Message Traffic for Aircraft Class 3 in 2015 (kilobits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	659.4	0.3	630.0	2.3	1,147.5	0.7
CPDLC	69.9	60.4	28.4	18.5	23.9	27.2
DSSDL	4.6	8.9	2.8	5.4	1.9	2.3
AOCDL	24.4	467.9	33.1	472.8	13.3	194.4
ADS Reporting	0.5	325.2	0.5	67.1	0.2	29.6
AUTOMET	N/A	N/A	0.3	80.4	0.2	111.5
APAXS	N/A	N/A	N/A	N/A	6,819.7	5,982.1

*Compressed per Table 4.3-2

Combining the peak data message load for each aircraft class and converting to kilobits per second gives the aggregate loads shown in Table 4.5-6. Here it is seen that APAXS and FIS account for most of the traffic load in 2015.

Table 4.5-6. Combined Peak Data Message Traffic for All Aircraft Classes in 2015 (kilobits per second)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	36.4	0.0	34.8	0.1	63.4	0.0
CPDLC	3.4	2.9	1.3	0.9	1.1	1.3
DSSDL	0.2	0.3	0.1	0.2	0.1	0.1
AOCDL	0.4	8.4	0.6	8.5	0.2	3.5
ADS Reporting	0.0	16.1	0.0	3.3	0.0	1.5
AUTOMET	N/A	N/A	0.0	4.4	0.0	6.2
APAXS	N/A	N/A	N/A	N/A	113.7	99.7

*Compressed per Table 4.3-2

Aggregate non-flight dependent traffic loads are shown in Table 4.5-7 for regional coverage and in Table 4.5-8 for national coverage. The two tables are different because uplink TIS message size increases according to the number of aircraft in the area of interest. Regional TIS message sizes are based on the peak number of aircraft that would be found in a given domain (the smallest region of interest). The TIS traffic in Table 4.5-7 is calculated by multiplying traffic in Table 4.3-10 by the peak domain traffic in Table 4.5-2. The results are divided by 60 x 1000 to express the load in kilobits per second. From this table it can be seen that the combined FIS and TIS en route peak load would require a 27.1 kbps uplink channel and the peak airport load would require a 23.7 kbps uplink channel.

Table 4.5-7. Regional Non-Flight Dependent peak Data Message Traffic for All Aircraft Classes in 2015 (kilobits per sec)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	N/A	N/A	0.6	N/A	6.5	N/A
TIS	23.7	0.0	7.0	0.0	20.5	0.0

*Compressed per Table 4.3-2

TIS message sizes in Table 4.5-8 for national coverage are based on estimates of the peak instantaneous airborne count for all domains. The peak instantaneous nationwide count in 2000 is roughly 5,500 aircraft. By 2015 it is assumed this will grow 25% to a total of 6,875 peak airborne aircraft. These aircraft are assumed to be distributed within the three domains in the same proportions found in Table 4.5-1, i.e., 1,595 in airport domains, 1,139 in terminal domains, and 4,142 in en route domains. Table 4.3-10 is multiplied by these flights to get the peak loads shown in Table 4.5-8. The table shows that nationwide (the largest area of interest), a TIS uplink channel has to carry 425 kilobits per second to meet peak loads. Approximately half of this load results from the combined operations of all airport domains.

Table 4.5-8. National Non-Flight Dependent Peak Data Message Traffic for All Aircraft Classes in 2015 (kilobits per sec)*

Technical Concept	Airport		Terminal		En Route		National
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink	Uplink
FIS	N/A	N/A	0.6	N/A	6.5	N/A	7.1
TIS	196.4	0.0	58.5	0.0	170.1	0.0	425.0

*Compressed per Table 4.3-2

4.5.3 Oceanic Traffic Load

Peak oceanic flights are estimated based on peak hour contacts by Oakland and New York centers. Of the two, New York is slightly higher with 84 flights en route in the peak hour in 2000. Assuming 25% growth by 2015, the messages rates per flight in Table 4.3-11 are multiplied by 105 peak flights in 2015 and divided by 60 x 1000 to get kilobits per second. The table shows that a 12.8 kbps uplink and 7.9 kbps down link is sufficient for peak air traffic services, and a 70.5 kbps channel is sufficient in each direction for passenger services.

Table 4.5-9. Total Oceanic Data Message Traffic in 2015 (kilobits per second)*

Technical Concept	Airport		Terminal		Oceanic	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	N/A	N/A	N/A	N/A	12.1	0.0
CPDLC	N/A	N/A	N/A	N/A	0.6	0.9
DSSDL	N/A	N/A	N/A	N/A	0.0	0.0
AOCDL	N/A	N/A	N/A	N/A	0.1	1.5
ADS Reporting	N/A	N/A	N/A	N/A	0.0	0.1
AUTOMET	N/A	N/A	N/A	N/A	0.0	5.4
APAXS	N/A	N/A	N/A	N/A	70.5	70.1

*Compressed per Table 4.3-2

4.5.4 Voice Traffic Load

Peak CPC voice traffic is shown in Table 4.5-10. The number of call-seconds per minute per flight from Table 4.4-2 is multiplied by the peak number of flights in Table 4.5-2 and then divided by 60 seconds per minute to get channel occupancy in call-seconds per second. The total for each domain represents the number of full-period uplink or downlink analog voice channels required. To minimize the chance of all channels being in use at the same time, extra capacity can be added to the system. Assuming a multi-server queue with exponentially distributed call duration as a worst-case model for air-ground communications, the number of channels needed for a given probability of blocking can be calculated. In this analysis, it is assumed that there should be no more than one chance in five of finding all channels busy. Under peak traffic conditions with a 0.2 probability of all channels being busy, it is seen that the busiest airport domain in 2015 requires 8 voice channels. The busiest terminal domain requires 3 voice channels and the busiest en route domain requires 4 channels.

Table 4.5-10. Peak CPC Voice Messages in 2015 (call-seconds/second)

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	2.7	1.3	0.7	0.7	2.0	0.5
2	0.9	0.4	0.3	0.3	0.2	0.1
3	1.2	0.5	0.0	0.0	0.0	0.0
Total	7.0		1.9		2.7	
Voice Channels Required (P=0.2)	8		3		4	

Peak passenger APAXS calls are estimated by multiplying the call-seconds per minute per flight in Table 4.4-3 times the peak number of flights in Table 4.5-2 (11.3 call-seconds per minute per flight x 120 en route flights = 1356 call-seconds per minute). This quantity is then divided by 60 seconds per minute to get channel occupancy in call-seconds per second as shown in Table 4.5-11. A multi-server queuing model is again used to calculate the number of voice channels needed for there to be no more than one chance in five that all channels are in use. The table shows that the peak passenger load in the busiest en route domain would require 39 voice channels. The total number of voice channels required nationwide might have approximately 10 times the traffic or 370 voice channels since other en route domains are below the peak en route domain and do not all peak simultaneously.

Table 4.5-11. Peak APAXS Voice Messages in 2015 (call-seconds/sec)

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
3	N/A	N/A	N/A	N/A	22.6	22.6
Total	N/A		N/A		45.2	
Voice Channels Required (P=0.2)	N/A		N/A		39	

4.6 Air-Air Traffic

Air-to-air broadcasts originate from individual aircraft so the message load is directly proportional to the number of aircraft. It is assumed that aircraft originated data messages are for ADS-B surveillance applications, with minimal use of other applications proposed for ADS-B. From Table 4.5-6, it can be seen that the peak ADS-B traffic in the airport, terminal, and en route domains is 16.1 kbps, 3.3 kbps, and 1.5 kbps respectively. Postulating a "worst case" scenario where one aircraft is receiving ADS-B data from four airport domains, one terminal domain, and one en route domain (e.g., New York center), the total traffic would be 4 x 16.1 kbps plus 1 x 3.3 kbps plus 1 x 1.5, or 69.2 kilobits per second as the maximum required air-to-air link capacity in 2015. This represents approximately 532 ADS-B equipped aircraft on the ground or in the air that might be using an air-to-air link.

5 Networks, Standards, and Protocol Requirements

The recommended architecture includes the continuation of voice communication (with migration from analog to digital), data communication using ATN protocols, and broadcast communication using industry standard or proprietary protocols.

This section provides the technical detail of the data links available for the 2015 architecture. Much of this information also is presented in the Task 9 Report, *Characterize the Current and Near-Term Communications System Architectures,* which provides additional information on applications, standards, protocols, and networks. The links discussed in this section are:

- Analog Voice - DSB-AM
- Digital Voice
  - VDL Mode 3
  - Inmarsat-3
- Data Communication using the ATN
  - VHF Digital Link Mode 2 (VDLM2)
  - VHF Digital Link Mode3 (VDLM3)
  - Inmarsat-3
  - Inmarsat-4 (Horizons)
  - Other GEO Satellite Systems (e.g., Astrolink)
  - ICO Global (MEO system)
  - Iridium (LEO system)
  - ORBCOMM (LEO system)
  - High Frequency Data Link (HFDL)
- Ground-to-Air Broadcast Systems
  - VHF Digital Link Broadcast (VDL-B)
- Air-Air and Air-Ground Broadcast Systems
  - Mode-S
  - Universal Access Transceiver (UAT)
  - VHF Digital Link Mode 4 (VDLM4)

5.1 Standard Description Template

Each link is characterized according to section 4.6.1 of the Task Order and organized using the following template.

CHARACTERISTIC	Segment	DESCRIPTION
System Name		Name
Communication type	R/F Ground	HF, VHF, L-Band, SATCOM ...
Frequency/Spectrum of Operations	R/F Ground	Frequency
System Bandwidth Requirement	R/F Ground	Bandwidth for channel and system
System and Channel Capacity	R/F	Number of channels and channel size
Direction of communications	R/F	Simplex, broadcast, duplex....
Method of information delivery	R/F Ground	Voice, data, compressed voice

CHARACTERISTIC	Segment	DESCRIPTION
Data/message priority capability	R/F Ground	High, medium, low
System and component redundancy	R/F Ground	
Physical channel characteristics	R/F	Line of sight (LOS), other
Electromagnetic interference	R/F	Text description
Phase of Flight Operations	Ground	Pre-flight, departure, terminal ....
Channel Data Rate	R/F Ground	Signaling rate
Robustness of channel and system	R/F	Resistance to interference, fading...
System Integrity	R/F Ground	Probability
Quality of service	R/F Ground	Bit error rate, voice quality
Range/coverage	R/F Ground	Oceanic, global, regional...
Link and channel availability	R/F Ground	Probability
Security/encryption capability	R/F Ground	Text description
Degree/level of host penetration	R/F	Percentage or class of users
Modulation scheme	R/F	AM, FM, D8PSK,....
Access scheme	R/F	CSMA, TDMA, ...
Timeliness/latency, delay requirements	R/F Ground	Delay
Avionics versatility	R/F	Application to other aircraft
Equipage requirements	R/F	Mandatory, optional
Architecture requirements	R/F Ground	Open System or proprietary
Source documents		References

Integrity is the ability of a system to deliver uncorrupted information and may include timely warnings that the information or system should not be used. Integrity is provided by the application, transport and network layers (rather than the link and physical layers) and is usually specified in terms of the probability of an undetected error. The integrity values in the following link descriptions thereby reflect service integrity requirements rather than "link integrity" requirements. The only meaningful measure of "link integrity" is a bit error rate, which is shown under quality of service.

Comm Link	System integrity (probability)
Voice DSB-AM	No integrity requirement for 2015 voice services
VDLM2	CPDLC and DSSDL will be ATN compliant services and require the end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message to be less than or equal to $10E^{-8}$ per message
VDLM3	No integrity requirement for 2015 voice services; ATN compliant services must meet an end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message to be less than or equal to $10E^{-8}$ per message
VDL-B	ATN compliant services must meet an end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message to be less than or equal to $10E^{-8}$ per message
Mode-S	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has been supplied to the ADS-B system. ADS-B system integrity is $10E^{-6}$ or better on a per report basis. [Note: Due to constraints imposed by the Mode S squitter message length, multiple messages must typically be received before all required data elements needed to generate a particular ADS-B report are available.]
UAT	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has been supplied to the ADS-B system. ADS-B system integrity is $10E^{-6}$ or better on a per report basis. Currently, the UAT worst-case overall undetected error probability for an ADS-B message is $3.7x10E^{-11}$, which exceeds the minimum requirement. [Note: For UAT, ADS-B messages map directly (one-to-one correspondence) to ADS-B reports; they are not segmented as they are in Mode S ADS-B).
Inmarsat-3	ATN compliant services must meet an end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message to be less than or equal to $10E^{-8}$ per message

Comm Link	System integrity (probability)
GEO Satellite	ATN compliant services must meet an end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message to be less than or equal to $10E^{-8}$ per message
MEO Satellite	ATN compliant services must meet an end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message to be less than or equal to $10E^{-8}$ per message
ICO Global Satellite	ATN compliant services must meet an end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message to be less than or equal to $10E^{-8}$ per message
Iridium Satellite	ATN compliant services must meet an end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message to be less than or equal to $10E^{-8}$ per message
HFDL	ATN compliant services must meet an end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message to be less than or equal to $10E^{-8}$ per message

5.2 Analog Voice

5.2.1 VHF DSB-AM

Most current ATC communication in the NAS is carried out using analog voice. Most of this communication uses double side-band amplitude modulation (DSB-AM) in the VHF Aeronautical Mobile (Route) Service band, using 25 kHz channels. Some military aircraft use UHF; controllers in oceanic sectors use a service provider for relaying HF messages to and from aircraft.

DSB-AM has been used since the 1940s, first in 100 kHz channels, then in 50 kHz channels. Recently, Europe has further reduced channel spacing to 8.33 kHz channels in some air space sectors due to their critical need for more channels. In the United States, the FAA provides simultaneous transmission over UHF channels for military aircraft. In the Oceanic domain beyond the range of VHF, aircraft use HF channels. Voice limits communications efficiency since the controller must provide all information verbally. Studies have shown that controller workload is directly correlated to the amount of voice communications required. Voice is subject to misinterpretation and human error and has been cited as having an error rate of 3% and higher. With the introduction of ACARS, AOC voice traffic dropped significantly although it is still used.

By 2015, most domestic sectors will have transitioned to digital voice using VDL-3, which will be mandatory in many classes of airspace. Although spectrum congestion is currently a problem, channel loading will cease to be a limiting factor as the busiest sectors are converted to VDL-3, which is more efficient than DSB-AM, and more pilot-controller communications will be conducted using data links instead of voice links.

Federal Air Regulations Part 91/JAR OPS 1.865 require two-way radio communications capability to operate an aircraft in class A, B, C or D airspace. Additionally, two-way radio communication is required to operate an aircraft on an Instrument Flight Plan in class E airspace. Two-way radio communication with ATC must be maintained continuously. ICAO has similar requirements.

Since many national authorities do not have current plans to implement VDL-3 for voice, aircraft that fly in international airspace probably will continue to need to use radios that support the current DSB-AM modulation, as well as 8.33 kHz channelization for parts of Europe.

Voice is necessary for the foreseeable future and is likely to continue as primary means of communication. Any changes in voice technology are likely to occur only with digital voice; and the legacy analog voice probably will continue unchanged.

Table 5.2-1. Analog Voice/VHF DSB-AM Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Analog voice/VHF double sideband (DSB)—amplitude modulated (AM)**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	Leased telephone channels
Frequency/ Spectrum of Operations	RF	117.975 MHz—137 MHz
System Bandwidth Requirement	RF	Nominal 3 kHz per channel with audio input 350 - 2,500 Hz 760 channels total in VHF band @ 25 kHz spacing/channel
	Ground	N/A
System and Channel Capacity (number of channels and channel size)	RF	Nominal 3 kHz per channel with audio input 350 - 2,500 Hz 760 channels total in VHF band @ 25 kHz spacing/channel System is constrained by frequency allocation, not technical limits. Expansion to 112 MHz has been discussed if radionavigation systems are decommissioned.
	Ground	Telephone line per assigned radio frequency
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Simplex - Transmission or reception on a single frequency but not simultaneously.
	Ground	Voice telephone lines are duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Voice
	Ground	Voice
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	N/A
	Ground	N/A
System and component redundancy requirement (1/2, 1/3, etc):	RF	Airborne - One unit required for GA, two units for air carrier. Redundancy: GA typically equips with two units (1:1); air carrier equips with three units (1:2).
	Ground	1:1 plus some overlap of ground stations
Physical channel characteristics (LOS, OTH, etc.):	RF	Line of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics:	RF	RTCA DO-160C, Sections 15, 18, 19, 20, and 21.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	3 kHz
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Voice communications are error prone and highly variable. An error rate of 3% has been measured in high activity sectors.
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	VHF voice communications are generally considered poor due to system and background noise. (The human ear is VERY good at puling voice out of a noisy AM signal.) A standard voice quality metric has not been applied.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 250 nm at 30,000 feet 100 nm at 5,000 feet Coverage: United States including the Gulf of Mexico.
Link and channel availability	RF	Exceeds 99.7%

CHARACTERISTIC	SEGMENT	DESCRIPTION
Security/ encryption capability	RF	N/A
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	All commercial, all military and most GA aircraft equipped. All aircraft participating in IFR airspace are required to equip. Approximately 20,000 GA aircraft use only unrestricted airspace and do not equip with a radio.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Double sideband—Amplitude Modulation (DS-AM)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Normal signal propagation delay
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	System	Respond to 75% of calls within 10 seconds and 94% of calls within 60 seconds
	System	No measured data. Air Traffic Controllers determine access and priority based on traffic and situation.
Avionics versatility (applicability to other aircraft platforms)	Avionics	Any aircraft equipped with VHF transmitter and receiver.
Equipage requirements (mandatory for IFR, optional, primary, backup,	Avionics	Mandatory for IFR flight operations; not required in uncontrolled airspace.
	Ground	Ground stations required for coverage.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications, etc.)	RF/Avionics	Signal in space characteristics are set by National and International standards. Avionics are developed by vendors with proprietary designs. Some integration with navigation.
	Ground	Vendors provide ground communications using proprietary hardware/software designs and commercial telecommunications standards.
Source documents		Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; ARINC Quality Management Reports, Air/Ground Voice Performance

5.3 Digital Voice

The only available terrestrial network for digital voice is VDL Mode 3. As specified in ICAO Annex 10, Chapter 6, "VHF Air-Ground Digital Link," VDL-3 uses the same modulation techniques as VDL Mode 2 and uses the same physical layer protocols with a few exceptions.

The VDL Mode 3 system is required to support a transparent, simplex voice operation based on a "Listen Before Push to Talk" channel access.

The ICAO "Manual on VHF Digital Link (VDL) Mode 3 Technical Specifications" requires that the vocoder "incorporate and default to the Augmented Multiband Excitation (AMBE) vocoder algorithm, version AMBE-ATC-10, from Digital Voice Systems, Incorporated (DVSI) for speech compression unless commanded otherwise." A single specific algorithm is specified to achieve interoperability.

Technical characteristics for VDL Mode 3, which includes digital voice, are listed in the table below.

Table 5.3-1. VDL Mode 3 Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Very High Frequency Digital Link Mode 3 (VDL Mode 3)**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	Very High Frequency (VHF)
	Ground	Undetermined

CHARACTERISTIC	SEGMENT	DESCRIPTION
Frequency/ Spectrum of Operations:	RF	118-137MHz
System Bandwidth Requirement:	RF	25KHz/channel; Radios are specified for 112-137 MHz tuning range.
	Ground	Undetermined
System and Channel Capacity (number of channels and channel size):	RF	As a system, VDL Mode 3 can be used for all frequencies in the VHF aeronautical band, pending frequency sharing criteria. VDL Mode 3 is planned as the replacement for all current ATC analog voice frequencies, approximately 500 channels. Each VDL Mode 3 frequency provides four subchannels per 25KHz channel.
	Ground	Fractional T-1 interfaces indicated in draft specification.
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Simplex - Transmission or reception on a single frequency but not simultaneously, within a subchannel. Subchannels can communicate independently with TDMA scheme.
	Ground	Undetermined
Method of information delivery (voice, voice recording, data, combination, etc.):	RF	Pulse code modulated voice or data in any given subchannel
	Ground	Data, ATN-compliant network protocols
System and component redundancy requirement (1/2, 1/3, etc):	Ground	Undetermined, 1:1 is current practice.
	RF	Ground components: 1:1 is current practice Airborne: 1:2
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	VDL Mode 3 will begin deployment for voice function in approximately 2005 for En Route phase of flight. Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight will be added as the system expands.
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	10,500 symbols/sec (3 bits per symbol) 31.5 Kbps/channel 4.8 Kbps/subchannel, 4 subchannels/channel
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Digital = BER of 10^{-3} for minimum, uncorrected signal BER of 10^{-6} daily average
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Voice: The PCM voice will be encoded using an 8 kHz sampling rate at a resolution of 16 bits per sample.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 200 nm at 30,000 feet 80 nm at 5,000 feet Coverage: Implementation will begin in 2005 with U.S. En Route. Coverage will expand to all U.S. phases of flight.
Link and channel availability	RF	Radio availability =.99999
Security/ encryption capability	RF	No encryption at RF level. Should support ATN defined encryption and authentication at application level.
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	System is in implementation. Will be available to commercial, G/A, and military aircraft

CHARACTERISTIC	SEGMENT	DESCRIPTION
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Time Division Multiple Access (TDMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	< 250 msec
	System	< 250 msec
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Ground	Ground stations required for service/coverage.
	Avionics	NEXCOM will initially be deployed in analog voice Mode to allow fielding and aircraft equipage. When switched to digital voice Mode, approximately 2006, equipage will be mandatory for high En Route.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)		Signal in space and protocols are defined by National and International standards. Ground equipment will be provided by vendors using proprietary designs. VDL data can support numerous applications.
Source documents		Implementation aspects for VDL Mode 3 system (version 2.0), VDL Circuit Mode MASPS and MOPS, Aeronautical Mobile Communications Panel (AMCP); Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; RTCA /DO-224.

For satellite networks, which are operated by service providers rather than by national authorities, the SARPs specify vocoders selected by the service providers, subject to the AMCP validation process. Inmarsat uses several vocoders, depending on the specific service; the specifications are contained in Annex 10, Chapter 4. Specifications for vocoders for AMS(R)S using Next Generation Satellite Systems will be contained in technical manuals referenced by Annex 10, Chapter 12. No NGSS technical manuals have been approved yet.

At present, only Inmarsat provides satellite voice service satisfying the requirements of AMS(R)S. Iridium planned to provide AMS(R)S service for voice and data, but Iridium is no longer viable. Technical characteristics of the Inmarsat voice service are presented in the table below, along with data aspects of the Inmarsat-3 service.

Table 5.3-2. Inmarsat-3 Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Inmarsat-3**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	SATCOM – GEO satellite. Five satellites.
	Ground	Ground Earth Stations (GES)
Frequency/ Spectrum of Operations:		C Band ~ 4,000 to 8,000 MHz, and L Band ~1,000 to 2,000 MHz
System Bandwidth Requirement	RF	10 Mhz satellite 17.5 kHz for 21Kbps channel with A-QPSK modulation 10 kHz for 10.5 Kbps channel with A-QPSK 8.4 kHz for 8.4 Kbps channel with A-QPSK 5.0 kHz for 4.8 Kbps channel with A-QPSK 5.0 kHz for 2.4 Kbps channel with A-BPSK 5.0 kHz for 1.2 Kbps channel with A-BPSK 5.0 kHz for 0.6 Kbps channel with A-BPSK
	Ground	N/A
System and Channel Capacity (number of channels and channel size)	RF	Six channels per aircraft for Aero H (High) for current equipage Voice at either 9.6 kbps or 4.8 kbps Data at 10.5 - to 0.6 kbps Maximum voice capacity with additional aircraft equipment is 24 voice channels.
	Ground	N/A
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Complex - see Access scheme block
	Ground	Half Duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Digitally encoded voice & data services
	Ground	Digitally encoded voice & data services
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None - Pilot can seize voice channel if needed
	Ground	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	2 ground stations per region; one satellite per region; Some aircraft may have redundant avionics
	Ground	2 ground stations per region
Physical channel characteristics (LOS, OTH, etc.):	RF	Geosynchronous Satellite LOS, with ~ 1/3 earth footprint
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Primarily Oceanic. Currently InMarSat is not allowed to operate in domestic airspace.
Channel data rate (digital) and/or occupied band width (analog) requirement:		Voice: 10.5 Kbps/with 0.5 Forward Error Correction; Data: Aero-H: 9.6 Kbps; Aero-I: 4.8 Kbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Highly robust
System integrity (probability)	System	BER of 10^{-3} for voice, 10^{-5} for data

CHARACTERISTIC	SEGMENT	DESCRIPTION
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Voice is toll quality. Call blocking probability less than 1 per 50 attempts in busy hour
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	1/3 Earth Regional: Indian Ocean, Pacific Ocean, East Atlantic and West Atlantic regions overlap and cover the entire earth within +/- 85 degrees latitude.
Link and channel availability	RF	98.8% (spot beam) Satellite operates within the 10 MHz band assigned to AMS (R) S for satellite service by ICAO.
Security/ encryption capability	RF	N/A
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Commercial aircraft approximately 1,000 equipped out of estimated 2,000 oceanic fleet.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Aeronautical-Quadrature Phase Shift Key (A-QPSK), Aeronautical variation of QPSK
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	P-Channel (Packet): Time Division Multiplexing (TDM) for signaling and user data (ground-to-air) R-Channel(Random): Slotted Aloha, aircraft-to-ground signaling T-Channel (Reservation): TDMA - used for reserving time slots C-Channel (Circuit-mode): Used for voice
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	8 seconds/95% for 380 octet user packet at 10.5 kbps 45 seconds/95% for 380 octet user packet at 600 bps
	System	End to end delay within acceptable limits for voice transmission
Avionics versatility (applicability to other aircraft platforms)		Size and weight of Avionics and antenna are prohibitive for small aircraft.
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Optional
	Ground	Ground Earth Stations (GES) required for receipt of satellite signals
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary hardware and software
	Avionics	Independent data link
Source documents		Inmarsat SDM; Nera System Summary; Inmarsat fact sheets; Annex 10, Aeronautical Telecommunications, International Civil Aviation Association (ICAO); ARINC Market Survey for Aeronautical Data Link Services; INMARSAT Aeronautical System Definition Manual

Although it is technically feasible to use "Voice over IP" (or voice over CLNP in the case of the ATN), we know of no such standards to have been considered for aeronautical use. The protocols are specified by ITU Recommendation H.323, "Packet Based Multimedia Communication Systems." If packet mode voice were used instead of circuit mode, it would be necessary to amend the FAR and corresponding ICAO requirements that two-way communication be maintained continuously.

5.4 Data Communication Using the ATN

The recommended architecture assumes that all two-way data communication is conducted using ATN compliant subnetworks. It is important to note that the Aeronautical Telecommunication Network is not a single network managed by one organization, but is similar to the Internet in that it uses a set of requirements to enable end-to-end communications over a collection of separate but interconnected networks.

All ATN implementations must comply with Chapter 3 of Annex 10, Volume III, Part1 and the related "Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN)," ICAO DOC 9705/AN956, or subsequent revisions.

The ATN architecture makes it possible to use a broad variety of subnetworks, with interfaces already specified for VDL Modes 2 and 3. In addition, the Technical Manual specifies mappings of the ATN priority levels to the priority levels defined for, inter alia, VDL and Mode-S. Satellite service providers can support the ATN through the use of a subnetwork dependent convergence facility (SNDCF) using ISO/IEC 8208:1995: "Information Technology—Data Communications—X.25 Packet Layer Protocol for Data Terminal Equipment." Because other protocols may be more suitable for use with satellites, the ATN Panel has begun work on SNDCF for other protocols.

Arguably, it would be beneficial for the AATT 2015 architecture to have an SNDCF for the internet protocol (IP). Besides producing benefits of greater availability of implementations and likelihood of commercial investment in improving the protocols, research has begun on improvements for TCP/IP when using satellite communications. Existing protocols, including the OSI protocols on which ATN is based, do not fully address the satellite environment, which includes greater propagation delays, more noise, asymmetric channels for some implementations, and other characteristics.

Because of the limited demand for OSI, there is minimal likelihood of major technological advances in OSI protocols. ISO/IEC Joint Technical Committee 1 disbanded the committees working on OSI, with some projects cancelled and other project transferred to different subcommittees. The ITU continued to support the projects that had been collaborative with JTC1. We expect that there will be convergence between ATN and TCP/IP protocols, with future versions of ATN migrating to TCP/IP and enhancements to TCP/IP to support mobile routing, quality of service and other capabilities at the levels of performance and integrity needed for aeronautical route service communications.

The use of ATN routers makes it possible to use satellite or terrestrial links without the application being concerned about the link, as long as the link satisfies the requirements for Quality of Service (QoS) and policy based routing. This openness gives users the flexibility to decide on which communication equipment and services to use.

5.4.1 VDL Mode 2

VDL Mode 2 is a 1990s concept for aeronautical data link. It has been designed by the international aviation community as a replacement for ACARS. Many of the limitations of ACARS have been overcome in the VDL Mode 2 system. The best known improvement is the increase in channel data rate from the ACARS 2.4 kbps rate to a 31.5 kbps rate. The improved rate is expected to increase user data rates 10 to 15 times over the current ACARS. The variation is dependent upon user message sizes, channel loading assumptions, and service provider options. VDL Mode 2 can carry all message types carried by ACARS plus Air Traffic Service messages such as CPDLC which require performance levels of latency and message assurance not possible with ACARS.

VDL Mode 2 is a subnetwork in the Aeronautical Telecommunication Network, ATN, concept. ATN has been developed by ICAO to provide a global air/ground and ground/ground network for all aviation related traffic. ATN addresses both the communications aspects and the applications.

Table 5.4-1. VDL Mode 2 Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**VHF Digital Link Mode 2** (VDL Mode 2)
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	ARINC Data Network System (ADNS) & ARINC Packet Network (APN)
Frequency/ Spectrum of Operations		136.975MHz, 136.950MHz, 136.925MHz, 136.900MHz currently approved for VDL in international frequency plans. The 136.500 - 137.0 MHz band (20 channels) is potentially assignable to VDL Mode 2 in the U.S. Additional frequencies are based on availability and sharing critieria.
System Bandwidth Requirement	RF	25KHz
	Ground	Primary 56 Kbps , dial backup 64 Kbps ISDN
System and Channel Capacity (number of channels and channel size)	RF	Unlimited system growth - primarily dependent on regulatory frequency allocation. Ground stations are capable of four independent frequencies. Initial deployment will be based on aircraft equipage and will only require 1-2 frequencies.
	Ground	APN X.25 packet switched services and IP and ATN protocols
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Simplex - Transmission or reception on a single frequency but not simultaneously.
	Ground	Simplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	data
	Ground	data
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
	Ground	The VDL Mode 2 ground network can prioritize messages over the wide area network and within the ground station in accordance with ATN priority schemes. Once presented to the radio for transmission, messages are not preempted.
Physical channel characteristics (LOS, OTH, etc.)		
	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	RTCA DO-160C, Sections 15, 18, 19, 20, and 21.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	First VDL Mode 2 usage expected in 2000 in En Route. Potentially applicable to all domestic phases of flight: Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	31.5 kbps/25KHz channel
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Design availability for Initial Operating Capability (IOC) is .9999. Higher availability will be achieved with additional ground stations and supporting network components for critical airports and applications.
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Within the VDL Mode 2 subnetwork, the probability of a lost packet is less than 10^{-7}. The subnetwork uses logical acknowledgements for packet delivery assurance. An additional end-to-end message assurance is applied to assure message delivery (all packets for a message).

CHARACTERISTIC	SEGMENT	DESCRIPTION
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 200 nm at 30,000 feet 80 nm at 5,000 feet Coverage: Implementation will begin in 2000 with U.S. En Route and high density airports (Airspace A and B). Coverage will expand as users equip.
Link and channel availability	RF	The availability of each ground station is 0.997. Ground station availability based on providing RF signal so radio and all components included. For typical applications, two ground stations will be available to achieve 0.9999 system availability.
Security/ encryption capability	RF	None at the RF level - VDL Mode 2 will support authentication and encryption of applications as planned by ATN.
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	None - system to be deployed in 2000. VDL Mode 2 is applicable to all user classes but is expected to be first implemented by air carriers and regional airlines operating in Class A airspace (above 18,000 feet) and associated Class B airspace airports.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Carrier Sense Multiple Access (CSMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	95% of messages delivered within 3.5 seconds within the VDL Mode 2 subnetwork. End-to-end delivery is estimated at 95% within 5 seconds.
Avionics versatility (applicability to other aircraft platforms)	System	VDL Mode 2 can be used for all applications.
	Avionics	VDL Mode 2 can be used on any class aircraft.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.)	Ground	Ground stations must be installed for coverage
	System	Signal in space characteristics are set by National and International standards. Avionics are developed by vendors with proprietary designs. Can share VHF equipment with other applications (VHF voice).
Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)		The digital radios used by VDL Mode 2 are capable of providing analog voice service and/or VDL Mode 3 service with appropriate software and hardware additions. Radio is dedicated to one Mode when installed.
Source documents		ARINC VDL Mode 2/ATN Briefing for FAA

5.4.2 VDL Mode 3

VDL Mode 3 also is an ATN subnetwork. VDL Mode 3 has been designed for Air Traffic controller-pilot communications for both voice and data. VDL Mode 3 uses time division to split each 25 kHz channel into four subchannels, which can be any combination of voice or data. This approach allows VDL Mode 3 to provide a traditional voice service and a data link service over a single system. Each subchannel operates at 4.8 kbps. For voice service, VDL Mode 3 includes a voice encoder/decoder (vocoder) that allows digital signals to be converted to voice. As a data channel, VDL Mode 3 can provide data service at 4.8 kbps in each data subchannel.

VDL Mode 3 is under development by the FAA as part of the NEXCOM program. Initially, NEXCOM will provide digital radios to replace the current 25 kHz analog radios and will continue to operate in the double side-band amplitude modulated (DSB-AM) voice service mode.

Beginning in 2010, the digital radios will be reprogrammed to support the implementation of VDL-3. The technical characteristics of VDL Mode 3 are described in Table 5.3-1 above.

5.4.3 Inmarsat-3

Currently limited aviation communications is available via satellite. The Inmarsat GEO satellite provides voice and low-speed data service to aircraft in the Oceanic domain. The data service has been used to supplement HF voice air traffic control. Satellite voice for air traffic has been limited to emergency voice. The satellite services are installed on aircraft for commercial passenger voice service and the air traffic control services are provided as a secondary consideration. In an emergency, the pilot has priority access to the communication channel. The large dish size used for GEO satellites is expensive and difficult to install on smaller aircraft such as GA. Cargo aircraft do not have the passenger voice communications support, and therefore, traditionally have not been equipped with satellite communications equipment.

The technical characteristics of Inmarsat-3 are described in Table 5.3-2 above.

5.4.4 Inmarsat-4

The Inmarsat-4 (Horizons) satellites are proposed for 2001. Due to the crowded spectrum in L-band, Horizons may be deployed at S-band. Data rates of 144 kbps with an Aero-I aircraft terminal and 384 kbps with an Aero-H terminal are forecast. The Horizons satellites may have 150-200 spot beams and 15-20 wide area beams.

Table 5.4-2. Technical Characterization of Inmarsat 4—Horizons

Characteristic	Segment	Description
System Name:		**Inmarsat 4 - Horizons**
Communications/link type (HF, VHF, L-Band, SATCOM, other):Ground	RF	SATCOM - GEO. Four satellites
	Ground	Ground Earth Stations
Frequency/ Spectrum of Operations:	RF	S Band under consideration, L-Band dependent on world allocation
System Bandwidth Requirement:	RF	18 Mhz estimated
	Ground	Unknown
System and Channel Capacity (number of channels and channel size):	RF	Estimated 1,000 circuits/satellite using 15-20 beams
	Ground	
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Duplex
	Ground	
Method of information delivery (voice, voice recording, data, combination, etc.):	RF	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	Unknown
	Ground	Unknown
System and component redundancy requirement (1/2, 1/3, etc):	RF	Unknown
	Ground	Unknown
Physical channel characteristics (LOS, OTH, etc.):	RF	Geosynchronous satellite, LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	Some S Band interference possible from existing ground station sources

Characteristic	Segment	Description
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	Primarily Oceanic. Currently InMarSat is not allowed to operate in domestic airspace.
Channel data rate (digital) and/or occupied bandwidth (analog) requirement:	RF	144 kbps and 384 kbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Relatively robust. Terrain multipath
System integrity (probability)	System	Unknown, should be equal or greater than INMARSAT 3
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Unknown, should be equal or greater than INMARSAT 3
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	System	Geo-stationary worldwide
Link and channel availability	System	Unknown
Security/ encryption capability	System	Unknown
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Future system
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	System	Unknown
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	System	Unknown
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	System	Unknown
Avionics versatility (applicability to other aircraft platforms)	System	Probable size and weight of avionics indicate that it will be difficult to equip small aircraft
Equipage requirements (mandatory for IFR, optional, primary, backup)	System	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Will require ICAO SARPs
Source documents		ARINC Market Survey for Aeronautical Data Link Services

5.4.5 Other GEO Satellite Systems

Other GEO satellites have been proposed that potentially are applicable to the aviation market. They are described further in the Task 9 report. They include the AMSC/TMI satellites, Loral Skynet, CyberStar and Orion satellites, the ASC and AceS systems, and the proposed Celestri combination GEO/LEO satellite system. They are not discussed further in this report due to their limited service offering or due to their limited remaining satellite life expectency. Many details of proposed satellites are unavailable either because they are proprietary developments or the designs still are in development. A representative 2007 GEO system based on the LM/TRW Astrolink and Hughes Spaceway systems is presented below.

Table 5.4-3. GEO Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		LM/TRW Astrolink GEO, Hughes Spaceway GEO. (At least one of these or a similar system should be operational in 2007)
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	Ka-band
	Ground	Unknown
Frequency/ Spectrum of Operations:	RF	Ka-band, 20 GHz downlink from satellite, 30 GHz uplink to satellite
System Bandwidth Requirement:	RF	500 MHz or more, each direction, maybe split 4 or 7 ways for frequency reuse in each cell (spot beam)
	Ground	
System and Channel Capacity (number of channels and channel size):	RF	16kbps to 2Mbps standard channels, hundreds of channels available. Over 100Mbps gateway or hub channels.
	Ground	Unknown
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	duplex, may be asymmetric
	Ground	Duplex
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	Multiple priorities available
	Ground	Unknown
System and component redundancy requirement (1/2, 1/3, etc):	RF	Design life of 10 to 15 years, high system availability (0.9999 goal)
	Ground	Unknown, typically multiple ground stations in view
Physical channel characteristics (LOS, OTH, etc.):	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	possible interference from terrestrial Ka-band systems (LMDS, fiber alternatives systems), regulated through spectrum licensing
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	All
Channel data rate (digital) and/or occupied band width (analog) requirement:		FDM/TDMA burst (packet) channels, variable bit rates, 1 to 100+ Mbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	variable rate coding and variable data rates to mitigate deep rain fades, many frequencies available to avoid fixed interference
System integrity (probability)	System	0.9999 availability typical goal

CHARACTERISTIC	SEGMENT	DESCRIPTION
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	10^{-9} or better typical
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	global possible, but most systems do not intend to cover oceans and polar regions, GEO systems point spot beams to land masses and high population areas in particular
Link and channel availability	RF	0.9999 availability typical goal
Security/ encryption capability	RF	terminal authentication during access encryption can be overlaid, but not a basic feature
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Fixed ground terminal service beginning in 2003
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	digital, QPSK, burst (packets), FEC variable rates 1/2 or higher
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	FDM/TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	latency: approx. 0.3 second for GEO
	System	
Avionics versatility (applicability to other aircraft platforms)		Not designed for fast moving terminals, can be achieved if business is identified and the developer designs capability.
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	optional
	Ground	
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
	Avionics	Independent
Source documents		FCC and ITU spectrum license applications, conference publications

5.4.5.1 ICO Global

MEO satellite systems have been proposed for the Aeronautical Mobile Service. MEO systems have several advantages over the GEO and LEO approaches. The reduced transmission distance of MEO systems provides a higher link margin. Compared to LEO systems, the MEO satellites are in view to an individual aircraft longer and experience less frequent handoffs. Boeing, ICO-Global, Celestri, and Teledesic are possible MEO satellites for the 2007 time frame. The following table is based on the ICO-Global system.

Table 5.4-4. ICO Global Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**ICO Global**
Communications/link type (HF, VHF, L-Band, SATCOM, other):		SATCOM MEO satellites; 10 satellites in two planes of 5 each (plus 2 spares)
Frequency/ Spectrum of Operations:	Service Band, Uplink	2.170 – 2.200 GHz
	Service Band, Downlink	1.98 – 2.010 GHz
	Feeder Band, Uplink	6.725 – 7.025 GHz
	Feeder Band, Downlink	5 GHz (AMS(R)S)
	Crosslink Band	N/A
System Bandwidth Requirement:	System	Unknown
System and Channel Capacity (number of channels and channel size):	RF	24,000 circuits total/4.8 Kbps voice
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Duplex
Method of information delivery (voice, voice recording, data, combination, etc.):	RF	GSM Voice
Data/message priority capability / designation (high, intermediate, low, etc.):	System	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	10 satellites in two planes of 5 each (plus 2 spares)
Physical channel characteristics (LOS, OTH, etc.):	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	Service Link Margin 8.5 dB, DO-160D for avionics
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	All
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	4.8 Kbps voice
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Moderate. Max one-satellite duration: 120 minutes Connectivity characteristics: Simultaneous fixed view required
System integrity (probability)	System	Not stated
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Unknown
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	System	Full earth coverage
Link and channel availability	RF	Not stated

CHARACTERISTIC	SEGMENT	DESCRIPTION
Security/ encryption capability	System	Not stated
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	RF	None
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	QPSK
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	TDMA (implied that path diversity and combining will be used
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Latency: ~140ms path + sat switching + 100ms in 2 codecs
Avionics versatility (applicability to other aircraft platforms)	RF	No avionics available.
Equipage requirements (mandatory for IFR, optional, primary, backup)	RF	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
Source documents		ARINC Satellite Study

5.4.5.2 Iridium

The Iridium service is the only service other than Inmarsat that became operational and announced plans for an AMS(R)S service; the Iridium service now has been terminated. The Iridium system is shown in the following template to represent potential LEO systems, although Iridium has gone bankrupt and will not be available. The 66 satellite Iridium LEO system was designed for mobile voice and low-speed data and has been proposed for aeronautical mobile users. FCC filings had indicated future Iridium versions would provide higher speed data services. In addition to the low data rate, LEO systems must overcome the frequent handoff problem that occurs as a satellite transits the user location.

Table 5.4-5. Iridium Satellite Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**Iridium**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	SATCOM; LEO satellites; 66 satellites in 6 planes of 11 each (plus 12 spares)

CHARACTERISTIC	SEGMENT	DESCRIPTION
Frequency/ Spectrum of Operations	Service Band, Uplink	1.62135 – 1.62650 GHz (AMS(R)S)
	Service Band, Downlink	1.62135 – 1.62650 GHz (AMS(R)S)
	Feeder Band, Uplink	29 GHz
	Feeder Band, Downlink	19 GHz
	Crosslink Band	23 GHz
System Bandwidth Requirement	System	10.5 MHz
	Channel	31.5 kHz/50 kbps/12 users
System and Channel Capacity (number of channels and channel size)	RF	3840 circuits/sat; 56,000 circuits total
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	System	duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	System	Voice and data
Data/message priority capability / designation (high, intermediate, low, etc.)	System	None
System and component redundancy requirement (1/2, 1/3, etc)	RF	66 satellites in 6 planes of 11 each (plus 12 spares)
	Ground	Satellite-satellite switching for high ground system availability
Physical channel characteristics (LOS, OTH, etc.)	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics	RF	Service link margin: 16.5 dB no combining min BER 10^{-2} DO 1600 for avionics
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	All
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	2.4 Kbps and 4.8 Kbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	High. Max one-satellite duration: 9 minutes Connectivity characteristics: Flex to any station at any location
System integrity (probability)	RF	$1x10^{-6}$
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Compressed voice, toll quality
Range/ Coverage/ footprint (oceanic, global, regional / line-of-sight	System	Full earth coverage
Link and channel availability	RF	99.5%
Security/ encryption capability	System	Proprietary protocol

CHARACTERISTIC	SEGMENT	DESCRIPTION
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	RF	No aviation usage
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	QPSK, FEC rate ¾,
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	FDMA/TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	12 ms path; 175 ms total
Avionics versatility (applicability to other aircraft platforms)	RF	No avionics available
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
Source documents		ARINC Satellite Study

5.4.6 ORBCOMM

Although the Orbcomm service does not operate in an AMS(R) band, it is used for provision of routine weather products to aircraft; the system is described below.

Table 5.4-6. Technical Characterization of Orbcomm

Characteristic	Segment	Description
System Name:		**ORBCOMM**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	SATCOM – LEO satellites. 35 satellites currently, an additional launch is planned for 2000 (enhancing coverage in the equatorial regions of the world).
	Ground	Ground Earth Station
Frequency/ Spectrum of Operations:	Downlinks	137 –138 MHz and 400 MHz
	Uplinks	148 – 150 MHz
System Bandwidth Requirement:	RF	50 kHz
	Ground	N/A

Characteristic	Segment	Description
System and Channel Capacity (number of channels and channel size):	RF	Unknown
	Ground	N/A
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Simplex
	Ground	Unknown
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	None
	Ground	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	GES redundancy. Satellites are overlapping in coverage.
	Ground	GES is redundant and has two steerable high-gain VHF antennas that track satellites.
Physical channel characteristics (LOS, OTH, etc.):	RF	Low Earth Orbit (LEO) satellites. LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	N/A
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	All
Channel data rate (digital) and/or occupied bandwidth (analog) requirement:	RF	2400 bps uplink; 4800 bps downlink; 9600 bps downlink (future)
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Not stated
System integrity (probability)	System	Not stated
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Store and forward message assurance
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	Worldwide coverage
Link and channel availability	RF	Not stated
Security/ encryption capability	RF	Not stated
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	No avionics available.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Not stated
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Not stated
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Unknown
	System	Unknown
Avionics versatility (applicability to other aircraft platforms)	Avionics	Avidyne markets the Echo Flight system, which uses Orbcomm for delivery of weather products on a request-reply basis.

Characteristic	Segment	Description
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Not approved
	Ground	GES required for receipt of satellite signals
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
	Avionics	N/A
Source documents		www.orbcomm.com

5.4.7 HFDL (GLOBALink/HF)

HF data link provides an alternative to oceanic satellite data and HF voice communications. The aircraft changes are small, consisting primarily of a radio upgrade and a new message display capability. HF antenna and aircraft wiring can remain the same. HFDL is cheaper to install and operate than satellite. For cargo aircraft that do not need the passenger voice service of satellite, HFDL provides a cost effective data link. HFDL is adaptive to radio propagation and interference. It seeks the ground station with the best signal and adjusts the data signaling rate to reduce errors caused by interference. HFDL service is faster, less error prone, and more available than traditional HF voice communications. HFDL has not yet been approved for carrying air traffic messages and aircraft equipage is just beginning.

Table 5.4-7. HFDL Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		HIGH FREQUENCY DATA LINK (HFDL) (GLOBAlink/HF)
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	High Frequency (HF)
	Ground	ARINC Data Network System (ADNS) & ARINC Packet Network (APN)
Frequency/ Spectrum of Operations:		2.8 MHz to 22 MHz
System Bandwidth Requirement:	RF	3 kHz Single Side band, carrier frequency plus 1440 Hz. Each Station provides 2 channels
	Ground	N/A
System and Channel Capacity (number of channels and channel size):	RF	Two channels per ground station
	Ground	ADNS & APN X.25 packet switched services
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Half-duplex
	Ground	Full duplex with a separate channel for each transmit and receive path, however the communications equipment often blocks receive voice when the operator is transmitting resulting in a half-duplex operation.
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data

CHARACTERISTIC	SEGMENT	DESCRIPTION
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	N/A
	Ground	A ground based priority and preemption capability that enables Air Traffic Services (ATS) messages to be delivered ahead of Aeronautical Operational Control (AOC) messages. A higher priority single or multiblock ATS message will be serviced before lower priority multiblock messages. The transmission of lower priority multiblock messages will resume when the higher priority message is completed. Lower priority messages will be delivered in their entirety to the aircraft. Lower priority single-block messages are not preempted due to protocol and avionics implementation requirements. The immediate preemption by higher priority messages of lower priority multiblock messages is also supported.
System and Component Redundancy	RF	HFDL Ground Stations (HGS) are geographically located to provide a 1 / 2 equipment diversification with each site transmitting two frequencies to provide a 1 / 4 relationship for radio frequencies.
	Ground	ETE availability for HFDL through ADNS and APN provides redundancy with an availability of 1.00000. In the North Atlantic Region redundancy is also provided with an equipment availability of.99451 for the passport backbone Access Module. In the Pacific Region total redundancy is provided ETE.
Physical channel characteristics (LOS, OTH, etc.):	RF	Via ionosphere
Electromagnetic interference (EMI) / compatibility characteristics:	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	Adaptable to propagation conditions: 1800, 1200, 600, 300 bps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Signals in the HF band are influenced by the characteristics inherent in transmitting through the ionosphere, which include various emissions from the sun interacting with the earth's magnetic field, ionosphere changes, and the 11-year sunspot cycle which affects frequency propagation. HF is also affected by other unpredictable solar events. Frequency management techniques are used to mitigate these effects
System integrity (probability)	System	No integrity requirement for 2007 data services, Forward error detection
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	95% of uplink message blocks in 60 seconds (one-way); 95% of uplink message blocks in 75 seconds (round-trip); 99% of uplink message blocks in 180 seconds (round-trip
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	3,000 nm from each ground station. Ten stations deployed as of December 1999 with 3-4 more sites under consideration to complete Global coverage.
Link and channel availability	RF	≥99.8% End to End Operational Availability
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Commercial aircraft, 50-100 equipped. New service with potential 8,000 users

CHARACTERISTIC	SEGMENT	DESCRIPTION
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	M-Phase Shift Keying (M-PSK) 1800 (8-PSK); 1200(4-PSK); 600 (2-PSK); 300 (2-PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.) Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Slotted TDMA
Timeliness/latency delay requirements	RF	Uplink end-to-end: 2 minutes/95%, 6 minutes/99% of messages Downlinks end-to-end: 1 minute/95%, 3 minutes/99%
Avionics versatility (applicability to other aircraft platforms)	Avionics	Any aircraft equipped with HF transmit and receive equipment and the appropriate HFDL interface unit
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Avionics	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications, etc.)	System	Signal in space defined by national and international standards. HF Voice equipment may be shared with other HF applications (i.e., HF voice).
Source documents		Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; ARINC Quality Management Reports, Air/Ground Voice Performance; ARINC specification 635-2 ARINC Aeronautical Data Link Proposal, 1997; HFDL Ground Station System Segment Specification

5.4.8 Effects of Modulation Schemes on Performance

The ICAO AMCP and RTCA Special Committee 172 for data link considered a number of modulation schemes. The ones considered in detail were Differential Eight-Phase Shift Keying (D8PSK), Eight-Level Frequency Modulation (8LFM), 4-ary Quadrature Amplitude Modulation (4QAM), and 16-ary QAM (16QAM). Key considerations were a desire to achieve the maximum bit rate within the existing 25 kHz channel spacing.

The resulting report showed that Working Group C examined four detailed proposals for the VDL Mode 2 modulation scheme (namely 4QAM, 16QAM, 8LFM, and D8PSK) after having been provided background information on these and many other digital modulations. Based on analysis, simulation and direct measurement, the following conclusions are presented:

4QAM has insufficient throughput and is eliminated from consideration as a primary modulation. It initially was to be the backup mode for 16QAM where a link could not be established because of range or fading.

16QAM is the most complex scheme and is significantly more costly than the others. It has a less certain performance at longer ranges and under fading conditions.

8LFM with a nonlinear transmitter that can provide more RF power on the channel provides more margin than D8PSK. D8PSK has greatly superior ACI performance for digital modulation against digital modulation however.

D8PSK has been found to be the most efficient digital modulation scheme that can be implemented with currently available technology while meeting the spectral limitations of a 25 kHz channel.

D8PSK provides a channel data rate of 31.5 kilo bits per second with a baud rate of 10.5 k baud and three bits per symbol.

The analysis indicated that 16QAM could yield a throughput of 37.8 kb/s for longer (1024 octet) messages. Potentially, weather services would use longer message sizes and could benefit from the greater throughput. The Adjacent Channel Interference (ACI) would be a significant factor however, if a weather service is proposed in the aeronautical VHF band. An additional consideration will be the expected availability of radios and experience with D8PSK due to their use for VDL Mode 2 and Mode 3.

5.4.9 ACARS Transition

Although ACARS currently is used for data communication, the existing ACARS networks are being transitioned to VDL-2. ARINC's GLOBALink™ service is designed to be used as an ATN compliant subnetwork, but it includes provisions for supporting legacy ACARS applications. Nevertheless, because of the superior performance of VDL-2 with respect to the Mode A network, and the more stringent performance requirements of ATM communications vis-à-vis AOC, the legacy ACARS network is not considered part of the recommended AATT architecture for 2015.

5.5 Ground-to-Air Broadcast Communication Using Non-ATN Protocols

Ground-to-air broadcast services will not be used for safety, distress, or urgency communication, so they are not subject to the same stringent requirements as ATM communications. Since the intention of the architecture is to leverage available capacity on commercial satellites, the service provider is likely to determine the specifications for the protocols, although these often will be based on ITU recommendations or TCP/IP standards in preference to proprietary protocols.

Suitability of the service providers' protocols may need to be determined on a case-by-case basis. The ICAO AMCP has formalized a set of acceptability criteria for evaluating potential providers of Next Generation Satellite Services (NGSS). We recommend that acceptability criteria be developed for broadcast systems. In addition, it would be useful to develop upper layer protocols for interfacing to broadcast service providers so that a broadcast application would need to support only one interface regardless of the service provider.

5.5.1 VHF Digital Link—Broadcast (VDL-B)

VDL-B is a broadcast variation of VDL Mode 2. Currently intended for Flight Information Services, VDL-B provides weather information to suitably equipped aircraft. The broadcast approach can increase the throughput of data to the user since the protocol overhead of request/reply and confirmation are not required. Under the FIS Policy, two VHF band frequencies were provided to each of two vendors for implementation. As a condition of the frequency, each vendor is required to transmit a minimum set of weather products. The vendor is allowed to charge fees for additional optional products such as weather graphics. The protocols for the FIS-B systems are partially proprietary and may be specified by the vendor. The vendors are expected to use the D8PSK physical layer, but the upper layers are not standardized.

VDL-B is not an ICAO SARPs-recognized version of VDL. The VDL-B term has been used to describe a data link intended primarily or solely for broadcast of data one-way to aircraft. Weather and traffic information frequently are recommended applications for broadcast functions. The description in this report is based on VDL Mode 2 and FIS, which is the most common usage of the term VDL-B. Other variations of VDL-B are possible since it is not an official term or definition.

Table 5.5-1. VDL Broadcast Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**VHF Data Link—Broadcast (VDL-B)**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	Leased telco for current implementation. VDL Mode 2 network possible in the future. Other proprietary solutions possible.
Frequency/ Spectrum of Operations		118-137MHz
System Bandwidth Requirement	RF	25KHz
	Ground	N/A
System and Channel Capacity (number of channels and channel size)	RF	Two frequencies per vendor, Total of four frequencies.
	Ground	Leased telco.
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Broadcast
	Ground	Duplex (return needed for ground station monitor and control)
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
	Ground	VDL-B is a proposed broadcast service that provides advisory and weather information to all aircraft monitoring the channel. The information provided contributes to the safety of flight. This service is similar to Flight information services (FIS)
System and component redundancy requirement (1/2, 1/3, etc)	RF	Since FIS is an advisory service, high availability is not required and redundancy will probably not be used.
	Ground	None expected.
Physical channel characteristics (LOS, OTH, etc.)	RF	Line of sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-1600
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	The FIS-B information will be available in all phases of flight if the aircraft is within range of the ground station. En Route will have the most coverage while coverage on the ground will be limited. Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	31.5 KBPS if D8PSK used 19.2 for GMSK Other data rates possible
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	RF is robust and resistant to interference, fading, multi-path, atmospheric attenuation, weather
System integrity (probability)	System	Based on non-critical service category, availability is estimated as 0.99

CHARACTERISTIC	SEGMENT	DESCRIPTION
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Unknown
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	LOS (180 nautical miles for aircraft at 25,000 feet) 80 nm at 5,000 feet
Link and channel availability	RF	0.99
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Intended for G/A market but available to all users.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK) or Gaussian Mean Shift Keying (GMSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Broadcast mode has not been defined
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Unkown
	System	> 5 seconds
	Avionics	Optional
	Ground	Required for message transmission
Avionics Versatility	Avionics	If D8PSK approach used, then the radio could be used for multiple applications.
Equipage Requirements	RF	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	Ground	Required for message transmission
	System	Proprietary hardware/software mix.
	Avionics	Can share VHF equipment with other applications
Source documents		None

5.5.2 Satellite Digital Audio Radio Service (SDARS)

The Satellite Digital Audio Radio Service (SDARS) was established to provide continuous nationwide radio programming with compact disc quality sound. It is intended to be able to offer niche programming that will serve listeners with special interests. In addition, SDARS has the technological potential to provide a wide range of audio programming options to rural and mountainous sections of the country that historically have been under-served by terrestrial radio.

Two companies, American Mobile Radio Corporation and CD Radio (now Sirius Satellite Radio), were awarded frequency authorizations by the FCC.

Although the intended purpose of the system is to provide audio entertainment for automobiles and remote areas, the 64 kHz channels could serve as media for data broadcasts (including graphics) as well. Both companies have established agreements with automobile manufacturers to install radios, which indicates that there are manufacturers for the receivers and antennas. If this technology were used for transmission of weather maps, the market for these products could extend beyond aviation, as many operators of truck fleets might be interested in acquiring broadcast weather services or other broadcast capabilities.

Table 5.5-2. SDARS Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**Satellite Digital Audio Radio System (SDARS)**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Satellite Broadcast, S-band
Frequency/ Spectrum of Operations		Sirius Satellite Radio has the license for 2320-2332.5 MHz; AMRC has the license for 2332.5-2345 MHz
System Bandwidth Requirement	RF	12.5 MHz
System and Channel Capacity (number of channels and channel size)	RF	Sirius offers fifty 64 KHz channels
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Broadcast
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Digital Audio
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	Dedicated channels
System and component redundancy requirement (1/2, 1/3, etc)	RF	Two satellites
	Ground	Unknown
Physical channel characteristics (LOS, OTH, etc.)	RF	Line of sight
Electromagnetic interference (EMI) / compatibility characteristics	RF	Unknown
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Not intended for aeronautical applications
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	No published information
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Unknown
System integrity (probability)	System	Unknown
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	High
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Regional - intended for U.S.

CHARACTERISTIC	SEGMENT	DESCRIPTION
Link and channel availability	RF	Unknown
Security/ encryption capability	RF	Unknown - probable proprietary signal to deter theft
Avionics	RF	N/A
Equipage Requirements	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	N/A
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	XM
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Unknown
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Unknown
	System	Unknown
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	System	Proprietary
Source documents		FCC and Sirius web sites

5.6 Air-Air and Air-Ground Broadcast Communications

5.6.1 Mode-S

Mode-S is an evolution of the traditional Secondary Surveillance Radar (SSR). For Mode-S, each aircraft has a unique 24-bit address, which allows transmission selectively addressed to a single aircraft instead of broadcast to all aircraft in an antenna beam. The Mode-S transponder has 56 bit registers that can be filled with airborne information such as aircraft speed, waypoint, meteorological information, and call sign. The information in the register can be sent either by an interrogation from the ground system or based on an event such as a turn. For ADS-B, equipped aircraft can exchange information without a master ground station. Although capable of sending weather and other information, the Mode-S communications capability is allocated to support its surveillance role and will consist of aircraft position and intent. ADS-B uses the Mode-S downlink frequency (i.e., 1090 MHz) and link protocols to squitter (i.e., spontaneously broadcast) onboard derived data characterizing the status (current and future) of own aircraft or surface vehicle via various ADS-B extended squitter message types (e.g., State Vector [position/velocity], Mode Status [identification/type category/current intent], and On-Condition [future intent/coordination data]).

Table 5.6-1. Mode-S Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**Mode S**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	
	Ground	L-Band (also known as D-Band)
Frequency/ Spectrum of Operations:		1090 MHz, +/- 1MHz
System Bandwidth Requirement:	RF	2 MHz (based on the existing Mode-S downlink)
	Ground	Leased telecommunications
System and Channel Capacity (number of channels and channel size):	RF	Single 2 MHz channel
	Ground	Leased telecommunications
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Broadcast from aircraft
	Ground	Ground stations transmit at 1030 MHz and receive at 1090 MHz. For ADS-B service, receive only stations have been proposed.
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	Surveillance function has priority over communications function
	Ground	None. The probability of successful message reception and report update are specified (see Table 3-4 of RTCA DO-242 ADS-B MASPS) depending upon the specific operational applications being supported by the ADS-B system. In this broadcast system more critical data (as determine by the operation being supported) are broadcast more frequently to improve the probability of message reception and report update.
System and component redundancy requirement (1/2, 1/3, etc):	RF	This depends on the ADS-B equipage class, its hardware implementation, and the specific operational applications being supported. The system level minimum availability requirements for equipage classes A1 through A3, for example, is 0.999. This, coupled with the minimum system level continuity of service requirement for the probability of being unavailable during an operation of no more than 2 x 10 –4 per hour of flight along with the specific availability requirements for the operation being performed (e.g., parallel approach), will determine whether equipment redundancy is needed to satisfy the operational requirement. This is expected to be part of the certification process and will be based on the intended use of the ADS-B equipment and the operational approval(s) being sought.
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics:	RF	ADS-B equipment has broad EMI requirements: transmitting and/or receiving equipment shall not compromise the operation of any co-located communication or navigation equipment (i.e., GPS, VOR, DME, ADF, LORAN) or ATCRBS and/or Mode-S transponders. Likewise, the ADS-B antenna shall be mounted such that it does not compromise the operation of any other proximate antenna.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Operational applications supported by ADS-B have been identified across all phases of flight, except possibly pre- and post-flight.
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	1 Mbps Mode-S provides data link capability as a secondary service to surveillance. Extended length message, ELM, format provides 80 user bits per 112 bit message. A typical rate is one ELM per four seconds (RTCA DO-181)

CHARACTERISTIC	SEGMENT	DESCRIPTION
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	The L-Band frequency is subject to fading and multi-path; Mode-S uses a 24-bit parity field and forward error detection and correction (FEDC) to help address this.
System integrity (probability)	System	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has been supplied to the ADS-B system. ADS-B system integrity is 10^{-6} or better on a per report basis. [Note: Due to constraints imposed by the Mode-S extended squitter message length, multiple messages must typically be received before all required data elements needed to generate a particular ADS-B report are available.]
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Mode-S system performance for undetected error rate is specified to be less than one error in 10^{7} based on 112-bit transmissions.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Assuming LOS exists, range performance depends on traffic density and the 1090 MHz interference environment (i.e., ADS-B uses the same frequency as ATC transponder-based surveillance). In low-density environments (e.g., oceanic) range performance is typically 100+ nm, while in a high-traffic density and 1090 interference environments (e.g., LAX terminal area) the range performance is on the order of 50 to 60 nm with current receiver techniques (improved processing techniques have been identified that are expected to provide range performance to 90 nm in dense environments).
Link and channel availability	RF	100%, as ADS-B is a true broadcast system
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	TBD, since still being developed. However, a significant number of initial implementations are expected to occur in aircraft already equipped with TCASII/Mode-S transponders (commercial air transport and high-end business aircraft). This area of equipage (i.e., TCASII/Mode-S) is expected to increase as the ICAO mandate for TCASII Change 7 (called ACAS in the international community) starts to occur in 2003.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Pulse Position Modulation (PPM) Each ADS-B message consists of a four pulse preamble (0.5 microsecond pulses, with the 2nd, 3rd, and 4th pulses spaced 1.0, 3.5, and 4.5 microseconds after the 1st) followed by a data block beginning 8 microseconds after 1st preamble pulse. The data block consists of 112 one-microsecond intervals with each interval corresponding to a bit (a binary "1" if a 0.5 pulse is in the first half of the interval or a "0" if the pulse is in the second half of the interval.
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Random access; squitter transmissions are randomly distributed about their mean value between some fixed high and low limits (e.g., "one-second" squitters have a one second mean value and are randomly transmitted every 0.8 to 1.2 seconds). This done to minimize collisions on the link. When collisions do occur, the receiver uses the next available message (which in a broadcast system like ADS-B will arrive shortly) to obtain the data.
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	
	ADS-B System	ADS-B uncompensated latency must be less than 1.2 ms or 0.4 ms depending upon the uncertainty of the position data (error [95% probable]) being used to support a particular operational application. The error is categorized according to navigation uncertainty categories (NUCs) from 1 to 9, with the higher NUCs indicating more accurate position data. The 1.2 ms requirement applies to NUCs less than 8 (0.05 to 10 nm position error), while the 0.4 ms must be met for NUCs 8 or 9 (3 to 10 m error).

CHARACTERISTIC	SEGMENT	DESCRIPTION
Avionics versatility (applicability to other aircraft platforms)	Avionics	ADS-B as defined is intended to be applicable to all aircraft category types as well as surface vehicles operating in the aircraft movement area of an airport. A range of equipage classes have been defined to accommodate the various levels of user requirements from GA to air transport.
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Avionics	No mandate of the ADS-B system is planned. However, if ADS-B equipment is used to perform a particular operation (e.g., IFR), a specific ADS-B equipage class, with certain minimum performance characteristics (e.g., transmitter power), will be required.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.)	Ground	No mandate of the ADS-B system is planned. However, if FAA were to use ADS-B to monitor ground vehicles on the airport movement areas, all such vehicles would have to be equipped with at least a minimum (i.e., broadcast-only) ADS-B system.
Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	System	ADS-B uses the Mode-S architecture which is a sub-network of the ATN and is based on an open system architecture.
	Avionics	The signal in space characteristics are defined by national and international forums.
Source documents		RTCA DO-242 ADS-B MASPS, RTCA DO-181 Mode-S MOPS, draft material for 1090 MHz ADS-B MOPS

5.6.2 Universal Access Transceiver (UAT)

The Universal Access Transceiver concept is intended for distribution of surveillance and weather data. It uses a unique hybrid access method of TDMA and random access. The TDMA portion is used to transmit the traffic and weather information while the random access portion is used by aircraft to transmit their own location in conformance with the RTCA DO-242 broadcast approach. The system is experimental and currently operates on a UHF frequency of 966 MHz. The bandwidth of the system is 3 MHz and a suitable frequency assignment would be difficult. UAT has not been standardized and is not currently recognized by ICAO/ATN. The system is being evaluated in the Safe Flight 21 initiative and would become an open system architecture if developed. The UAT implementation of ADS-B functionality had as its genesis a Mitre IR&D effort to evaluate a multi-purpose broadcast data link architecture in a flight environment. Its use for ADS-B was seen as a capacity and performance driver of the link. The current evaluation system (no standard exists or is in process at this time) uses a single frequency (experimental frequency assigned), a binary FM waveform, and broadcasts with 50 W of power. The system provides for broadcast burst transmissions from ground stations and aircraft using a hybrid TDMA/random access scheme. The UAT message structure, net access scheme, and signal structure have been designed to support the RTCA DO-242 ADS-B MASPS (i.e., to transmit State Vector, Mode Status, and On-Condition messages and provide the corresponding ADS-B reports for use by operational applications). The UAT is also investigating support for other situational awareness services (e.g., TIS-B & FIS-B) through sharing of the channel resources with ADS-B.

Table 5.6-2. UAT Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**UAT**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	UHF
Frequency/ Spectrum of Operations	System	The UAT evaluation system operates on an experimental frequency assignment of 966 MHz. [Note: This band was selected due to the availability of spectrum. However, the system is not frequency specific and could operate in any suitable spectrum.]
System Bandwidth Requirement	RF	3 MHz
	Ground	≥ 1 MHz

CHARACTERISTIC	SEGMENT	DESCRIPTION
System and Channel Capacity (number of channels and channel size)	RF	One channel, 2 MHz
	Ground	Single 1 MB/s channel
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Two part: Ground broadcasts information to aircraft, aircraft transmit position information.
	Ground System	Telco
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
System and component redundancy requirement (1/2, 1/3, etc)	Ground	None, broadcast system. The probability of successful message reception/report update are specified (see Table 3-4 of RTCA DO-242 ADS-B MASPS) depending upon the specific operational applications being supported by the ADS-B system. The more critical data (as determine by the operation being supported) have minimum requirements that broadcast more frequently to improve the probability of message reception and report update. [Note: The ground station TDMA access protocol (see access scheme description below) may have some capability for message prioritization. However, this could not be determined from the documentation available.]
	RF	This is still to be determined. It depends on the ADS-B equipage class, its hardware implementation, and the specific operational applications being supported. The system level minimum availability requirements for equipage classes A1 through A3, for example, is 0.999. This, coupled with the minimum system level continuity of service requirement for the probability of being unavailable during an operation of no more than 2×10^{-4} per hour of flight, along with the specific availability requirements for the operation being performed (e.g., parallel approach), will determine whether equipment redundancy is needed to satisfy the operational requirement. This is expected to be part of the certification process and will be based on the intended use of the ADS-B equipment and the operational approval(s) being sought.
Physical channel characteristics (LOS, OTH, etc.)	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics	RF	UAT is being designed for operation on a clear channel. Interference to or from off-channel systems can only be assessed once an operational frequency is identified. DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Primarily En Route but operational applications supported by ADS-B have been identified across all phases of flight, except possibly pre- and post-flight. UAT is being designed to support all ADS-B applications (as defined by DO-242)
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	1 Mbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	In general, the UHF frequency is subject to fading and multipath; UAT uses a 48-bit Reed-Solomon forward error correction (FEC) code and a 24-bit cyclic redundancy code (CRC) (acts as a 24-bit parity code) to help address this.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System integrity (probability)	System	UAT will be judged according to ADS-B standards. ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has been supplied to the ADS-B system. ADS-B system integrity is 10^{-6} or better on a per report basis. Currently, the UAT worst-case overall undetected error probability for an ADS-B message is $3.7x10^{-11}$, which exceeds the minimum requirement. [Note: For UAT ADS-B messages map directly (i.e., one-to-one correspondence) to ADS-B reports (i.e., they are not segmented as they are in Mode-S ADS-B).]
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Worst-case overall undetected error probability for an UAT ADS-B message is $3.7x10^{-11}$
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	LOS. Similar to VHF: 200 nm at 30,000 feet, 80 nm at 5,000 feet. The UAT proposal is to establish a series of ground stations to provide coverage over the U.S. at low (5,000 feet) altitude.
Link and channel availability	RF	Estimated at 0.99 since it will be an advisory service.
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	None. This is a new system design that is not implemented. It currently has appeal and support from the GA community who perceive it to be a lower cost and possibly improved performance alternative to other ADS-B candidate systems (i.e., Mode-S and VDL Mode 4). However, frequency allocation, product development, and standardization/certification of a final design will have to occur before the validity of this perception can be determined.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	UAT uses both TDMA and Binary Continuous Phase Frequency Shift Keying in its signal cycle. The TDMA signal is used by the ground station for broadcast uplink. The Binary portion is used by aircraft to report position.
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	UAT uses multiple access techniques: time division multiple access (TDMA) in the first portion (e.g., 188 ms) of a one second "frame" (i.e., slots to separate ground station messages from the aircraft and surface vehicle messages) and random access in the second portion (e.g., 812 ms) of the frame for ADS-B messages from aircraft and surface vehicles.
Avionics versatility (applicability to other aircraft platforms)	RF	UAT is being designed to meet ADS-B requirements. ADS-B uncompensated latency must be less than 1.2 ms or 0.4 ms depending upon the uncertainty of the position data (error [95% probable]) being used to support a particular operational application. The error is categorized according to navigation uncertainty categories (NUCs) from 1 to 9, with the higher NUCs indicating more accurate position data. The 1.2 ms requirement applies to NUCs less than 8 (i.e., 0.05 to 10 nm position error), while the 0.4 ms must be met for NUCs 8 or 9 (i.e., 3 to 10 nm error).
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	RF	Optional

CHARACTERISTIC	SEGMENT	DESCRIPTION
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	Avionics	UAT is a new system design being developed from scratch to meet ADS-B requirements. Therefore, since ADS-B as defined is intended to be applicable to all aircraft category types as well as surface vehicles operating in the aircraft movement area of an airport, UAT should be expected to have the avionics versatility needed to address the set of ADS-B requirements. A range of ADS-B equipage classes have been defined to accommodate the various levels of user requirements from GA to air transport
	Ground	Design information available to all vendors
	System	UAT is a new system and currently does have any standards (e.g., RTCA MOPS or ICAO SARPS).
Source documents	UAT	UAT system information was obtained from various briefings to RTCA SC-186 Plenary meetings and private Mitre correspondence. The system description is largely for an evaluation system involved in the current Safe Flight 21 tests and can be expected to change.

5.6.3 VDL Mode 4

VDL Mode 4 is a combined communication and surveillance concept. VDL Mode 4 also is termed Self-Organizing TDMA in reference to the ability of the system to mediate access to the time slots without reliance on a master ground station. With STDMA, the users can vary their channel access (number of time slots used) based on their need and the current loading of the channel. This technique makes VDL Mode 4 highly flexible and adaptable but less consistent in performance for critical functions. ICAO currently is validating the surveillance application for VDL Mode 4. Both Gaussian Filtered Frequency Shift Keying (GFSK) at 19.2 kbps and D8PSK at 31.5KBPS have been proposed for VDL Mode 4. Recently the D8PSK mode was removed from consideration based on superior performance by the GFSK method.

Table 5.6-3. VDL Mode 4 Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Very High Frequency Digital Link Mode 4 (VDL Mode 4)**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	VHF
	Ground	Undetermined
Frequency/ Spectrum of Operations:		118-137MHz
System Bandwidth Requirement:	RF	25KHz, Since all users need to exchange information on a common channel, VDL Mode 4 will use only one frequency/channel in an area.
	Ground	Undefined
System and Channel Capacity (number of channels and channel size):	RF	VDL Mode 4 is a developmental system. This information has not been defined.
	Ground	Undefined
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Simplex - Transmission or reception on a single frequency but not simultaneously. Channel is shared using TDMA.
	Ground	Half Duplex
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	data
	Ground	data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	ATN subnetwork expected
	Ground	Undefined - none expected

CHARACTERISTIC	SEGMENT	DESCRIPTION
System and component redundancy requirement (1/2, 1/3, etc):	RF	none required, optional redundancy defined
	Ground	Unknown
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics:	RF	N/A
Channel data rate (digital) and/or occupied bandwidth (analog) requirement:	RF	19.2KBPS using Gaussian Filtered Frequency Shift Keying (GFSK); 31.5KBPS using D8PSK
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	Will meet or exceed the requirements for VDL Mode 2 where RF is robust and resistant to interference, fading, multi-path, atmospheric attenuation, weather
System integrity (probability)	System	Undetermined (should be in range of 10^{-6})
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Undetermined
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Line Of Sight (180 nautical miles for aircraft at 25,000 feet) 80 nautical miles at 5,000 feet
Link and channel availability	RF	Undefined , due to surveillance requirement should meet 0.99999
Security/ encryption capability	RF	none
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Available to commercial, G/A, and military aircraft (will also be available aircraft to aircraft) Current users estimated as 100 GA.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	GFSK = 19.2 KBPS D8PSK = 31.5 KBPS
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Self-Organizing Time Division Multiple Access (S-TDMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Will meet or exceed VDL Mode 2 (< 250 msec)
Avionics versatility (applicability to other aircraft platforms)	System	Will meet or exceed VDL Mode 2 (< 5 seconds)
	Avionics	N/A
Equipage Requirements	Avionics	Optional

CHARACTERISTIC	SEGMENT	DESCRIPTION
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	Ground	Mandatory for receipt and transmission of messages
	System	proprietary, patented
	Avionics	VHF equipment could be shared with other applications
Source documents		VDL Mode 4 Standards and Recommended Practices (SARPS) Draft, Version 5.4, 21 March 1997; VDL Mode 4 Acceptance Presentation, Helios Technology VDL Mode 4 CNS/ATM applications; Delivering CNS/ATM applications with VDL Mode 4

5.7 Protocols for Passenger Communications

Protocols for providing communication services to passengers are not pertinent to the NAS architecture except to the extent that the protocols facilitate or preclude using the link for ATM or AWIN. Certification requirements already include specifications regarding harmful interference.

Digital television compression techniques (Digital Video Broadcasting [DVB] group standards), broadband Internet, corporate communications, and interactivity are pushing new developments in the space segment entirely dedicated to digital data transfer. Such services are Astrolink (Lockheed Martin), Skybridge (Alcatel), and Galenos (Eutelsat). Multicasting Internet data over satellite (addressing a number of selected end users) becomes a common service. MPEG 4 and Null Packet Optimization (NPO) increase the efficiencies of data transfer.

On the other hand, the satellite industry is affected by heavy competition from the optical fiber network and is pushed out from highly populated areas. Broadcasting and global access will remain the uncontested satellite business area.

5.8 Summary

The communications links are summarized in Table 5.8-1, which presents the key performance characteristics. The most significant consideration in our review has been the need to provide high bandwidth and capacity. As shown, existing and near term links are limited in bandwidth and capacity and will be unable to meet the future traffic load from FIS and TIS. Message latency is also a significant consideration, especially for the ATC critical message types. Considerations such as modulation scheme, frequency, integrity, range and protocol are important design considerations buy are not the major factors for selecting a future data link.

Table 5.8-1. Capacity Provided by Various Communication Links

Comm Link	Bandwidth	System/ Channel Capacity	Channel Data Rate	Message Latency
DSB-AM Voice	25 kHz	Shared bi-directional channels, 118-137 MHz	No data	250 msec.
HF Voice	25 kHz	Shared bi-directional channels, 118-137 MHz	No data	3 minutes
ACARS	25 kHz	Shared bi-directional channels, 118-137 MHz	2.4 kbps	5 seconds, mean plus one sigma
VDL Mode 2	25 kHz	Shared bi-directional channels, 118-137 MHz	31.5 kbps	3.5 seconds, 95%
VDL Mode 3	25 kHz	Four subchannels per 25 kHz	31.5 kbps	250 msec.

Comm Link	Bandwidth	System/ Channel Capacity	Channel Data Rate	Message Latency
		channel, 118-137 MHz		
VDL Mode 4	25 kHz	Shared bi-directional channels, 118-137 MHz	19.2 kbps – 31.5 kbps	250 msec.
VDL – B	25 kHz	Shared bi-directional channels, 118-137 MHz	31.5 kbps	< 3.5 seconds, 95%
Mode-S	2 MHz	Single channel, 1090 MHz	1000 kbps Total, effective rate 300 bps/aircraft[2]	1.2 msec.
UAT	3 MHz	Single channel	1000 kbps	1.2 msec.
GEO Satellite	500 MHz	Hundreds of channels	16 – 2,000 kbps	300 msec propogation
MEO Satellite	30 MHz	24,000 voice circuits	5-6 kbps	100 msec propogation
LEO Satellite		3,840 voice circuits	2.4 – 9.6 kbps	100 msec propogation
HFDL	3 kHz	Two channels per ground station	2.4 kbps	> 5 seconds, mean plus one sigma

5.9 Link Considerations

5.9.1 Ground based systems

All aviation communications systems based on ground stations have limitations of coverage and range. The majority of aviation communications systems are line of sight limited. The radio frequency power available permits operation at distances up to 200 nautical miles (nm).. The curvature of the earth however, blocks the signal to aircraft unless the aircraft is at high altitude. At low altitudes such as 5,000 feet, the line of sight range is reduced to 30 nm. Mountains also block signals and reduce potential coverage. Satellites are much less limited in coverage but do become constrained by available power. A geosynchronous satellite can cover one-third of the earth but the radio frequency power will be far less than for terrestrial systems. Traditionally satellite systems have used dish antennas to increase received power. Newer satellite concepts include low earth orbit (LEO) and medium earth orbit (MEO) systems that are closer to the earth, which improves the available power while reducing the coverage for each satellite.

5.9.2 Frequency band

The aviation industry traditionally has used frequency spectrum allocated specifically to aviation applications and protected by national and international law from interference. Under international agreement, the aviation communications frequencies are limited to ATC and AOC use. Services such as entertainment and passenger communications have been prohibited. All of the VHF systems, voice DSB-AM, ACARS, VDL Mode 2, Mode 3, and Mode 4 are designed to operate within the current 25 kHz channel spacing of the 118 - 137 MHz protected VHF band.

Three major configurations of satellite systems were considered. GEO systems depend on satellites in geosynchronous orbit. Usually a single satellite provides wide area coverage that is essentially constant. Coverage is not possible at the poles. MEO satellites move relative to the earth and their coverage shifts. A number of satellites are needed and earth coverage is virtually complete. A failure of a single satellite causes a short-term outage. LEO satellites move quickly relative to the earth and require numerous satellites for full earth coverage; therefore, an outage of a single satellite is short-term.

[2] RTCA DO-237, Jan 1997

5.9.3 General Satellite Comments

Alternatives to these systems likely will be provided by established service provides, such as Inmarsat, and Boeing, which is aggressively pursuing multimedia to the passenger with asymmetrical return link. There will be a premium charge for this type of system relative to fixed ground terminals, particularly when outside of populated areas.

Boeing already has demonstrated direct video broadcast (DVB) standard communication to the aircraft. The emerging DVB-RCS (return channel satellite) standard probably will be capable of asymmetric communication with aircraft and be available in 2007.

By 2015, EHF (Q/V) band systems operating in the 37.5-40.5 GHz and 47.2-50.2GHz range should be available in addition to Ka-band systems. The EHF systems will have similar capabilities to Ka systems, with greater bandwidth and higher data rates, but more severe rain fade. The following table lists system characteristics based on FCC filings. Most of these EHF systems never will be fielded. None of them are likely until the Ka-band systems are saturated. It is expected at least one EHF System will be available in 2015.

Table 5.9-1. EHF Satellite FCC Filings

Company	System Name	Service Type	Architecture NGSO (No. of planes) GSO (No. of slots)	Communications System Phased Array Antenna	 On-Board Processing	Cost ($B)	Data Rates (Mbps)
CAI Satcom	N/A	FSS	1 GSO (1)	No	No	0.3	38
Denali	Pentriad	FSS & BSS	9 HEO (3 at 63.4°)	Yes	No	1.9	10 - 3875
GE Americom	GE*StarPlus	FSS	11 GSO (9)	No	Yes	3.4	1.5-155
Globalstar	GS-40	FSS	80 LEO (10 at 52°)	Yes	No	N/A	2 - 52
Hughes	Expressway	FSS	14 GSO (10)	No	No	3.9	1.5 - 155
Hughes	SpaceCast	BSS	6 GSO (4)	No	No	1.7	0.4 - 155
Hughes	StarLynx	MSS	20 MEO (4 at 55°) 4 GSO (2)	Yes	Yes	2.9	<2 portable <8 vehicle
LEO One USA	Little LEO	MSS	48 LEO (8 at 50°)	No	Yes	0.3	0.032 - 0.256
Lockheed Martin	Q/V-Band System	FSS & BSS	9 GSO (9)	Yes	Yes	4.7	0.384 - 2488
Lockheed Martin	LM-MEO	FSS	32 MEO (4 at 50°)	Yes	Yes	6.82	10.4 - 113.8
Loral	CyberPath	FSS	4 GSO (4)	Yes	Yes	1.2	0.4 - 90
Motorola	M-Star	FSS	72 LEO (12 at 47°)	Yes	No	6.2	2 - 52
OSC	OrbLink	FSS	7 MEO (1 at 0°)	No	No	0.9	10 - 1250
PanAmSat	V-Stream	FSS	12 GSO (11)	No	No	3.5	1.5 - 155

Company	System Name	Service Type	Architecture NGSO (No. of planes) GSO (No. of slots)	Communications System		Cost ($B)	Data Rates (Mbps)
				Phased Array Antenna	On-Board Processing		
Spectrum Astro	Aster	FSS	25 GSO (5)	No	No	2.4	2 - 622
Teledesic	V-Band Supplement	FSS & BSS	72 LEO (6 at 84.7°)	Yes	Yes	1.95	10 -100 up 1000 down
TRW	Global EHF Satellite Network	FSS	15 MEO (3 at 50°) 4 GSO (4)	Yes	Yes	3.4	1.5 - 1555

GSO = Geostationary Orbit, NGSO = Non- Geostationary Orbit, MEO = Medium Earth Orbit, LEO = Low Earth Orbit
BSS = Broadcast Service Satellite, FSS = Fixed Service Satellite, MSS = Mobile Service Satellite
Note that the Cost column numbers are generally artifacts of FCC financial rules, not actual system costs.

Ka and extremely high frequency (EHF) systems are intended for fixed or slowly moving terminals, not for aviation speed terminals (path delay variation, Doppler, frequent hand-off between spot beams). Coding and other link margin features may be used to compensate for fast motion when above atmospheric degradation (rain). The GEO and MEO systems avoid oceans by not pointing spot beams there (systems with phased array antennas will be capable of pointing at oceans) and LEO systems plan to power down the satellites while over the oceans or low population areas. These issues are not technological problems; they are design choices based on business cases. To insure capability for aeronautic use, economic opportunity needs to be communicated to the system developers (business cases supporting premium charges, particularly over unpopulated areas).

6 Ground–Ground Communications

The NAS Ground-Ground Communication Systems Architecture will evolve greatly between 2000 and 2015. Much of the infrastructure needed to support this evolution already is planned within the NAS Architecture, so the 2015 CSA is not likely to raise any new issues for the NAS.

6.1 Distributed Processing

The most significant impact on the NAS architecture is likely to be the transition from local databases to the NAS-wide information system (NWIS), which implements the concepts of flight objects. As envisioned in NAS Architecture V4.0, the flight object is a logical entity in a fully distributed database architecture. The flight object is characterized as a logical entity rather than as a physical entity because it is not necessary for all the data that the flight object comprises to exist in a single physical location.

For example, the flight object might comprise data from the flight plan, additional data assembled within the NAS as the flight progresses, and data that resides at an AOC, such as characteristics of the aircraft, gate assignments, and other information maintained by the aircraft operator. The physical representation of the flight object might contain some data, but also would contain links to other data. Thus, the data values are stored non-redundantly, minimizing the need to synchronize updates.

Use of the flight object to support DAG-TM imposes the requirement on ground systems to be able to assemble a regional or NAS-wide picture of air traffic, including projected movement through the airspace. The controlling facility for an aircraft always will have current location and trajectory information, so it will be able to transmit updates to all other NWIS servers so that every facility has access to current information. NWIS represents a significant increase in the amount of NAS-wide information, but this already is considered in the NAS 4.0 architecture, so it is not an issue.

This database architecture implies a communications architecture in which the FAA is connected to all participating airlines and other participating operators. This type of connectivity will be provided by the FAA Telecommunications Infrastructure (FTI) program and by subsequent upgrades for interfacility communications. Communication between the FAA and AOCs is likely to use ATN-compliant systems, including features for network management and security, that were not included in the first edition of the ICAO Manual for ATN Communications. There will be a need for the ATN to support Subnetwork Dependent Convergence Facilities for other protocols besides ISO/IEC 8208 in order to work with the modern communication network protocols used by FAA and airlines ground systems.

As work on decision support systems progresses, standard formats for data elements must be agreed upon or other techniques must be used to ensure interoperability between the FAA's systems and the various airlines. If source data for the flight object fields are not standardized, the FAA should investigate techniques being developed for electronic commerce, such as the use of the XML protocol, which would allow each AOC to continue to use its own formats.

Weather services will continue to require access of weather databases residing at various locations. To some extent, the ground-ground communication is outside the scope of the NAS since weather service providers may use non-government weather sources and will use commercial communication service providers. Nevertheless, there will continue to be a need for the Air Traffic Control System Command Center and other FAA facilities to have access to weather data. These requirements already are considered for FTI.

6.2 Information Security

The increased connectivity of the NAS communications systems will make it even more important to implement information security measures. Coordination between the FAA and AOCs requires communication. The "Manual of Technical Provisions for the Aeronautical Telecommunication Network," ICAO Document 9705, is being revised to address information security, but this covers only those areas that affect interoperability; i.e., the protocols. Protection of the ground systems is outside the scope of a communications SARPs.

ICAO guidelines (cf. ADPS Manual Part I Chapter 3 Appendix B) recognize the need to "take account of the need to protect the system against unauthorised access and unauthorised transmission" when implementing a data link based system. Whether recognition of this need will translate into programs of work is unknown, but it is quite possible that this topic will be considered as "local matter." The FAA and most AOCs are likely to have strong policies on information security.

Programs to improve public access to FAA weather data, traffic information, congestion data, and other data intended to improve pilots' and travelers' information also will increase the vulnerability of the NAS communication systems to attacks. These are areas for continued research and development.

6.3 Effects of Commercialization

One very significant trend in recent years is the commercialization of service providers, including the handing over of operation of airport and other air navigation facilities and services by governments to autonomous authorities or even to the private sector. Within the NAS, the government has operated most aeronautical communication systems, with oceanic communications (HF and satellite) being a notable exception.

The provision of ATM facilities and services is, under the Chicago Convention, the responsibility of national authorities. The commercialization of such provision therefore necessitates both prescribed delegation of operational functions of governments and changed regulatory functions of governments. The recommended architecture uses broadcast satellites only for non-safety-critical services. Communication services provided by commercial service providers for safety-related communications presumably will require certification, which is an inherently governmental function that is not subject to delegation. With the FTI program, the FAA is increasing its reliance on commercial communication service providers for operation of networks, so it will gain greater understanding of the issues related to the use of commercial service providers.

For both ground-ground and air-ground communication services, the ability to adopt commercial networks for aeronautical use can provide the ability to gain improved performance through the use of new technology. As discussed above, security is becoming increasingly important for aeronautical applications, but progress on ICAO security standards is slow. On the other hand, commercial communication providers serve a market that demands increased security very soon; this increase is needed to implement e-commerce and other applications involving financial transactions or personal privacy, so there is a significant investment in security techniques.

6.4 Infrastructure

Because the current NAS uses only two communication service providers for air-ground communications (ARINC and SITA), and those service providers focus on aeronautical communication, connectivity between the FAA and service providers is well-established and stable.

ATN routing protocols make it possible for ground end systems to communicate to an aircraft without regard to the subnetworks being used as long as all subnetworks are ATN-compliant and have a defined Subnetwork Dependent Convergence Facility (SNDCF). It no longer will be necessary for an automation system to have different communication interfaces depending on whether the data is being transferred via satellite, HFDL, etc.

Satellite broadcasts will not use ATN protocols, since ATN does not yet have provisions for a broadcast capability. Consequently, it will not be possible to use the ATN routers in the NAS networks for access to the broadcast communication providers unless those service providers establish an ATN gateway. It is more likely that the NAS will need to include a TCP/IP (or possibly a proprietary) interface to the communication service provider. Because the ATN routers will not be useable for this interface, it probably will be necessary to implement a gateway between the NAS and the broadcast providers; this would be similar conceptually to the gateways used for access to ACARS networks.

VDL-3 and any other networks with voice capability will be digital and thus require vocoders. If the FAA implements digital voice for interfacility and intrafacility communications, this could lead to potential voice quality problems when air-ground vocoders might be operated in tandem with vocoders existing in other links of an end-to-end communications chain. As each vocoder introduces a deterioration of signal quality, this situation could result in an unacceptable deterioration of the voice signal quality as perceived by end users. This issue has been discussed by ICAO's ATS Voice Switching and Signaling Study Group (AVSSSG) and within the Aeronautical Mobile Communications Panel, but has not been resolved. This issue is discussed in Task 10.

Although the recommended architecture uses satellites only for air-ground communications, there are situations in which satellite communication would be beneficial for ground-ground communications, especially where it is expensive or difficult to provide infrastructure.

In addition, some sparsely populated areas such as Alaska have remote air-ground sites that do not have backup ground-ground connectivity for those events when the primary link fails. In other cases, backup links are available, but these require diverse, hence expensive, leased lines that have very low usage. Satellite services could replace low duty-cycle applications currently served by leased lines, saving landline costs and the hardships of maintenance in remote areas.

The use of satellites (and commercial service providers) helps avoid problems of co-site interference. If VHF broadcast required additional transmission facilities, co-site interference issues might occur if the new transmitters were geographically near other facilities. Use of commercial service providers also is beneficial because it relies on the service providers to build and maintain the ground facilities.

Most communication networks for aeronautical communications have a redundancy requirement to achieve the required availability. For satellite ground-earth stations (GES), there should be ground-ground links to two geographically distant GESs so they would not be affected by the same local atmospheric conditions. This is especially important for satellite systems that are affected by rain attenuation; in this case, one of the GES should be located in an area with below average precipitation.

6.5 Mobile Communication Issues

Mobile communications imposes a requirement to be able to address a specific aircraft using the ICAO 24-bit aircraft identification from anywhere within the NAS. Any ATN-compliant system provides this capability, so it is not an issue.

Until—and unless—there is a convergence of ATN and TCP/IP protocols, there will be a continued need for gateways, protocol converters, or other devices to accommodate multiple protocols. Communications to aircraft, airlines, and other CAAs is likely to use ATN protocols, and intrafacility communication is likely to use TCP/IP. Convergence of the ATN protocols to take advantage of future commercial development in TCP/IP would make it possible to exploit the commercially available systems instead of being required to implement special systems for use only in aviation. Standards work is necessary to define the convergence of the protocols. This work needs to include consideration of the transition issues.

Because the OSI protocols used for the ATN have very few users outside of aviation, most of the research and development is targeted towards TCP/IP. Until there is convergence of ATN to use the commercially popular protocols, additional research is likely to be needed to improve the performance of the ATN. Although ATN routers are designed to be able to support use of satellite links, most of the laboratory work on the ATN has been conducted using terrestrial links. Experience with TCP/IP for satellite communications has uncovered performance issues, some of which already are being researched by NASA. Similar research is needed to identify the performance issues related to the use of the ATN in satellite based networks, to determine the system tuning parameters or other changes to maximize the utility of satellite subnetworks in the ATN.

Communications System Architecture Development For Air Traffic Management & Aviation Weather Information Dissemination

Research Task Order 24

Subtask 4.7, Develop AATT 2007 Architecture

(Task 6.0)

Prepared By

ARINC
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Table of Contents

Table of Figures

Table of Tables

1 Executive Summary

1.1 Background

In 1995, NASA began the Advanced Air Transportation Technologies (AATT) initiative to support definition, research and selected high-risk technology development to enable the implementation of a new global Air Traffic Management (ATM) system. The AATT Project has a number of project sub-elements, ranging from advanced ATM concept development to aircraft systems and operations. The AATT Project also has an Advanced Communications for Air Traffic Management (AC/ATM) task. The AC/ATN task goal is oriented toward enabling an aeronautical communications infrastructure through satellite communications that provides the capacity, efficiency, and flexibility necessary to realize the benefits of the future ATM system and, specifically, the mature Free-Flight (F/F) environment. The AC/ATM task is leveraging and developing advanced satellite communications technology to enable F/F and provide global connectivity to all aircraft in a global aviation information network. The task directly addresses the Office of Aerospace Technology (OAT) Enterprise Pillar One (Enabling Technology) Goal of increasing aviation throughput as part of the AATT Project. The objectives of the AC/ATM task are to:

1. Identify the current communication shortfalls of the present ATM system.
2. Define communications systems requirements for the emerging AATT concept(s).
3. Demonstrate AATT concepts and hardware.
4. Develop select high-risk, high payoff advanced communications technologies.

The technical focus of the AC/ATM task has centered on the development of advanced satellite communications technology as a select high-risk, high payoff technology area in support of ATM communications (objective 4 above). Although the thrust of the task has been satellite communications (SATCOM), it is understood that currently and for the foreseeable future aeronautical air-ground communications will be provided by a number of different communications systems/data links including HF, VHF, and L-band, as well as SATCOM. Furthermore, it is further recognized that relevant advanced technology development for any of these systems requires first that a comprehensive technical communications architecture exist. In satisfaction of objectives 1 and 2, there is a need to define and develop a comprehensive technical communications system architecture that addresses the user communications needs and resulting communications requirements of the future mature ATM system that the various data links mentioned can support. The purpose of this research task order (RTO) is the development of this communications system architecture.

1.2 Objectives

The specific objective of Task 6 is to develop a 2007 AATT Communications System Architecture — i.e., to develop a communication system architecture (CSA) with the potential for implementation by 2007 that can fulfill the goal of providing the collection and dissemination of air traffic control (ATC) information to and from the various aviation platform classes.

1.3 Technical Approach

While the Task 6 objective addresses collection and dissemination of traffic information, it must be viewed within the context of the overall National Airspace System (NAS). Although the Task 6 statement of work (SOW) required only that ATM communications be addressed, since the same overall infrastructure will support all aeronautical communications, the weather portion has been retained to maintain the full context.

To provide that context, we extracted user needs and high-level goals (Task 1) from a wide variety of sources, including other NASA and FAA programs, RTCA activities, and industry. From these needs and goals, we developed a consensus vision and concept of operations for the 2015 architecture (Task 5) to provide a "top down" perspective. Based on the message requirements defined in Task 2, we further refined the operational concepts into nine communication technology concepts. These formed our functional communications architecture.

Concurrent with the process of defining technology alternatives for the 2015 communications system architecture (Task 5), the current NAS Architecture was reviewed to develop a "bottom up" perspective.

Using this projected definition, we compared technology alternatives available in 2007 (section 5), and conducted a communication loading analysis (section 4) to derive a recommended 2007 AATT Architecture (section 3) that could be "on the path" from the current (2000) NAS Architecture to the 2015 AATT Architecture.

The Transition Plan task (Task 8) defines an effective transition path from today's NAS Architecture, through 2007, to the 2015 AATT Architecture. Tasks 10 and 11 will discuss technology gaps and make recommendations on areas of research or development to close them.

1.4 Results of This Task

The 2007 time frame represents a collection of waypoints in the transition from the era of analog voice communication and islands of diverse information to a new era of digital data exchange through integrated networks using common data. This is a challenging time since many of the technical concepts are in their early stages. The challenge in this time frame is to maintain a longer term focus toward the integrated national system strategies of 2015 lest an "easy" near term local solution be implemented that cannot scale to the national level. Maintaining this big-picture view can be difficult given the demand for fast user benefits. The penalties for these fast benefits, however, will be paid in slower transitions, since aircraft owners tend to retain their avionics for extended periods to amortize their investment.

As we formulated the 2007 communication systems architecture, we maintained our focus on the plans for 2015 that are detailed in Task 5. With the 2015 CSA as our focus, we first analyzed our air-ground levels of communication (shown in Figure 1.4-1) and determined that each level was still valid for the 2007 time frame. However, since a number of the levels are in their initial stages, they would not be fully integrated. As waypoints, the technical concepts can be viewed in three groups

- Controller Pilot Voice (CPC)
- Two-way data exchange (CPDLC, DSSDL, AOCDL)
- Broadcast data exchange (FIS, TIS, ADS-B, AUTOMET)

These technical concepts are defined in Table 4.1-1 and also are highlighted within their applicable levels in Figure 1.4-1. A more detailed explanation of each technical concept can be found in Section 3 of this report.

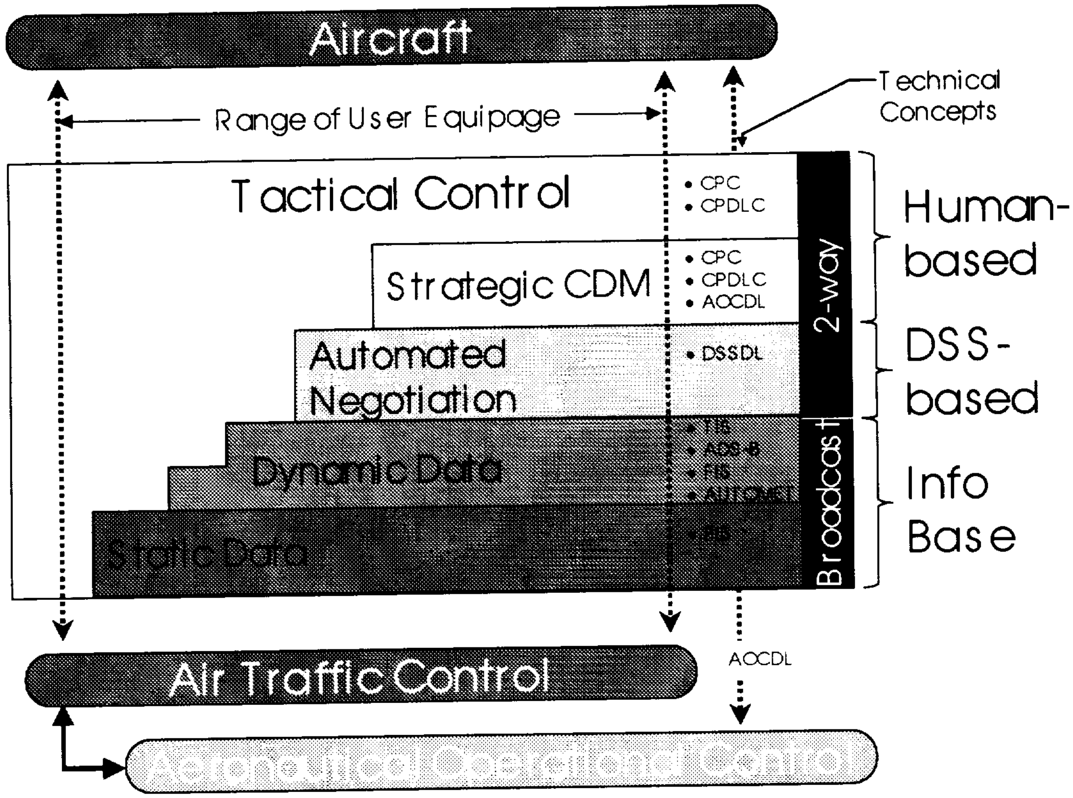

Figure 1.4-1. Air-Ground Communication Levels

The combinations of these technical concepts form the functional communications architecture shown in Figure 1.4-2. Our use of the NAS-Wide Information System (NWIS) at the center of the functional architecture represents a key assumption in performing this analysis. In the 2015 time frame, the ground-side NAS has evolved to the point that it contains a collection of data that is commonly defined and available among participating nodes using the most efficient communications paths available. Additionally, each participating node – either airborne or ground – has sufficient processing and storage capability that these capabilities will not be limiting factors in the timely exchange of information between nodes. For these assumptions to hold in 2015, it is essential that the engineering analysis and design for the NWIS be completed in the 2004 time frame so that it is in the initial phases of implementation in 2007. If this does not hold, the requirement for making data appear "common" will fall on the individual applications and processors. Either way, the integration task will be challenging.

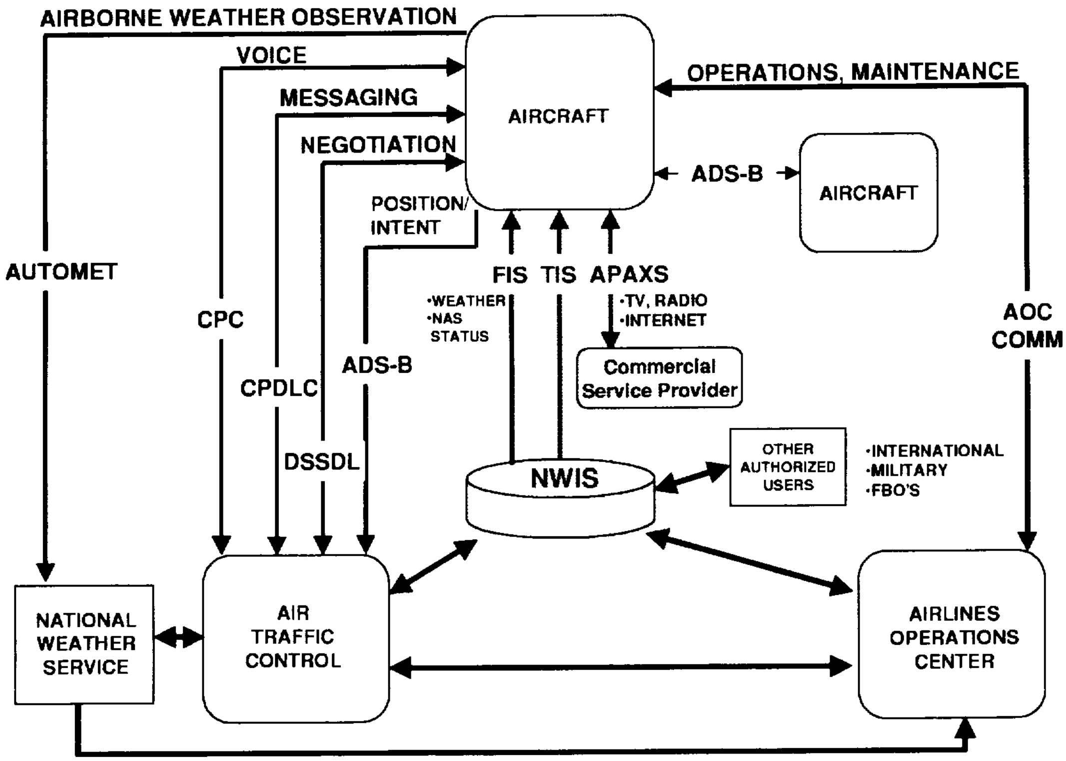

Figure 1.4-2. 2007 Functional Communication System Architecture

The transformation of the functional architecture into a physical architecture was accomplished by comparing the message load requirements for each functional interface (Section 4) with the capabilities of the enabling communications links (Section 5). We determined the functional interface loading by logically grouping the message requirements that were identified in Tasks 1, 2, and 3 of this Task Order. We recognized, however, that the air-ground exchange of data would not be the same for all aircraft. We chose, therefore, to use three classes of aircraft: low-end general aviation (Class 1), high-end general aviation and commuter aircraft (Class 2), and commercial carriers (Class 3). These classifications lead to a better traffic load estimate since the number, frequency, and type of message in many cases depends on where the aircraft is and what type of equipage it has. Additionally, we chose to partition the analysis by domain so that the air-ground communication architecture could be optimized to meet any special regional requirements. A summary of the peak communication loads for 2007 is provided in Table 3.3-2.

As mentioned previously, the NAS requires a voice capability, a two-way data messaging capability, and a broadcast data exchange capability. The broadcast data exchange capability supports the establishment of an air-ground information base. The technical concepts that support this information base are FIS, TIS, ADS-B, and AUTOMET. For FIS, a commercial service provider will supply FIS products via VDL-2 to the aircraft. TIS is a principal enabler of ADS-B maneuvering and trajectory planning. Hence, the deployment of TIS will parallel that of ADS-B. The current ADS-B deployment strategy calls for implementation in "local pockets" in the 2007 time frame. This strategy would allow the use of VDL-B to support TIS in the interim, although VDL-B is not a viable solution for the long term given the number of VHF frequencies required.

AUTOMET load projections exceed any VDL solutions. In all likelihood, however, AUTOMET will begin on the AOCDL VDL-2 network in the 2007 time frame. If an integrated data exchange capability is developed, we would recommend it for AUTOMET. Absent that, we recommend that AUTOMET continue to use the same link as AOCDL (VDL-2 or SATCOM).

In the current planning described above, a solution for each of these concepts is developed from one of the VHF data links identified in Table 3.3-1. These must be interim solutions, however, as VDL cannot support these concepts at the national level. Clearly, VDL is not the link needed to support an integrated data exchange capability. Candidate links that could meet this integrated data exchange need should be capable of supporting data rates on the order of hundreds of kilobits per second. The absence of a recognized requirement for an integrated broadcast data exchange capability represents the greatest deficiency in today's NAS modernization planning. This capability potentially could be supported by terrestrial- or space-based solutions, each of which would emerge from one of the following paths. A terrestrial-based solution most likely will emerge if UAT is chosen for ADS-B; this solution would drive the establishment of a terrestrial network of UAT transceivers that, given proper planning, could support FIS, TIS, and AUTOMET. A space-based solution most likely will emerge from the demand to place real time television and Internet service in commercial airline cabins. Once again, given proper planning, this could support FIS, TIS, and AUTOMET.

We cannot make a recommendation for FIS, TIS, or ADS-B, because we feel that there is additional research required to provide data sufficient to support a recommendation. An integrated data exchange capability as we discuss in this analysis is not currently envisioned in the NAS Architecture. Additionally, the link decision currently underway on ADS-B can have a significant influence on the overall communication system architecture. Consequently, we have identified two alternative architectures for further study.

In 2007 there still is a primary reliance on VHF-AM for controller pilot voice communication in the terminal and airport domains. However, we anticipate that as a result of successful Preliminary Eurocontrol Tests of Air/Ground Data Link (PETAL-II) trials in Europe and CPDLC trials in the US, a majority of class 2/3 aircraft operators will modify their multi-mode radios to take advantage of CPDLC in the En Route domain.

Unfortunately, in the 2007 time frame there is only one viable two-way data link to support the CPDLC, DSSDL, AOCDL (and potentially AUTOMET) needs: The VDL-2 service provided on the AOC allocated frequencies. Our communication load analysis, summarized in Table 3.3-2, projects peak loading for AOCDL of 40.3 kbps. This loading by itself would require three VDL-2 channels to serve a single worst-case geographic area, which raises the question of how the demand for this limited resource will be managed. We know from our analysis in Task 5 that after the FAA converts its air-ground voice network to VDL-3, it will be capable of satisfying the CPDLC and DSSDL demands. Thus, the challenge in the near term is to develop an effective transition strategy that is focused on the desired 2015 goal. From a CPDLC and DSSDL standpoint, our recommendation would be to develop a plan for allocation of additional frequencies (on a temporary basis) to support the interim demand. From an AOCDL standpoint, given the projected demand, serious consideration of other high performance communication links, most especially SATCOM, should be made. Costs for two-way SATCOM service may be attractive for the AOCs if it is coupled with some form of APAXS that make it cost competitive with VDL-2.

For APAXS, the use of SATCOM will be driven by the commercial industry desire to provide high-data-rate services to passengers. Such services include real time television and Internet access. Air Traffic Service providers should stay aware of these efforts and look for opportunities to exploit this method of data transmission. Accordingly, we recommend that further study be conducted to determine the opportunities for innovative partnerships or incentives that may leverage the involvement of commercial service providers in the delivery of selected air traffic services via SATCOM. For example, providers of broadcast entertainment channels to aircraft could be required to provide an air traffic services channel that is freely accessible by all aircraft. This example is similar to the requirement that cable television providers have with regard to providing public access channels.

In summary, for the 2007 time frame, a majority of Class 1 aircraft is still equipped with a VHF-AM radio for voice communications. Flight information is provided via a commercial service provider using VDL-B for those aircraft that are equipped.

Class 2 users differ from Class 1 users in that some Class 2 users have access to AOCDL that provides operations and maintenance data via VDL-2. Some Class 2 users will choose to equip for ADS-B based on benefits that they can receive in the areas that they fly. Flight information is provided via a commercial service provider using VDL-B for those aircraft that are equipped.

The Class 3 users will be equipping with multimode radios that support two-way data link communications via VDL-2. Some Class 3 users will choose to equip for ADS-B based on benefits that they can receive in the areas that they fly. Flight information is received via AOCDL using VDL-2 or SATCOM. Two-way SATCOM will be available to support passenger Television and Internet services and may begin to support aircraft-AOC data exchange.

Finally the selection of a communications architecture for 2007 must be performed in the context of the 2015 AATT communications architecture in order to ensure that the alternatives selected are on a path to the 2015 architecture. A summary of the viable communication links for 2007 and 2015 is shown in Table 1.4-1.

Table 1.4-1. Summary of Technical Concept to Communication Link by Time Frame

Technical Concept	VHF-AM	VDL-2 / ATN	VDL-3 / ATN	VDL-4 / ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
FIS					2007 2015		2007* 2015*	2007* 2015*	
TIS					2007 2015	2007*	2007* 2015*	2007* 2015*	
CPDLC		2007	2015						
CPC	2007 2015		2015						
DSSDL		2007	2015						
AOCDL		2007 2015					2007* 2015*		2007* 2015*
ADS-B				2007* 2015*		2007* 2015*	2007* 2015*		
AUTOMET		2007 2015					2007* 2015*		2007* 2015*
APAXS								2007* 2015	2007* 2015
	* Possible Implementation								

The 2007 AATT Architecture alternatives are shown in Figure 1.4-3 and Figure 1.4-4.

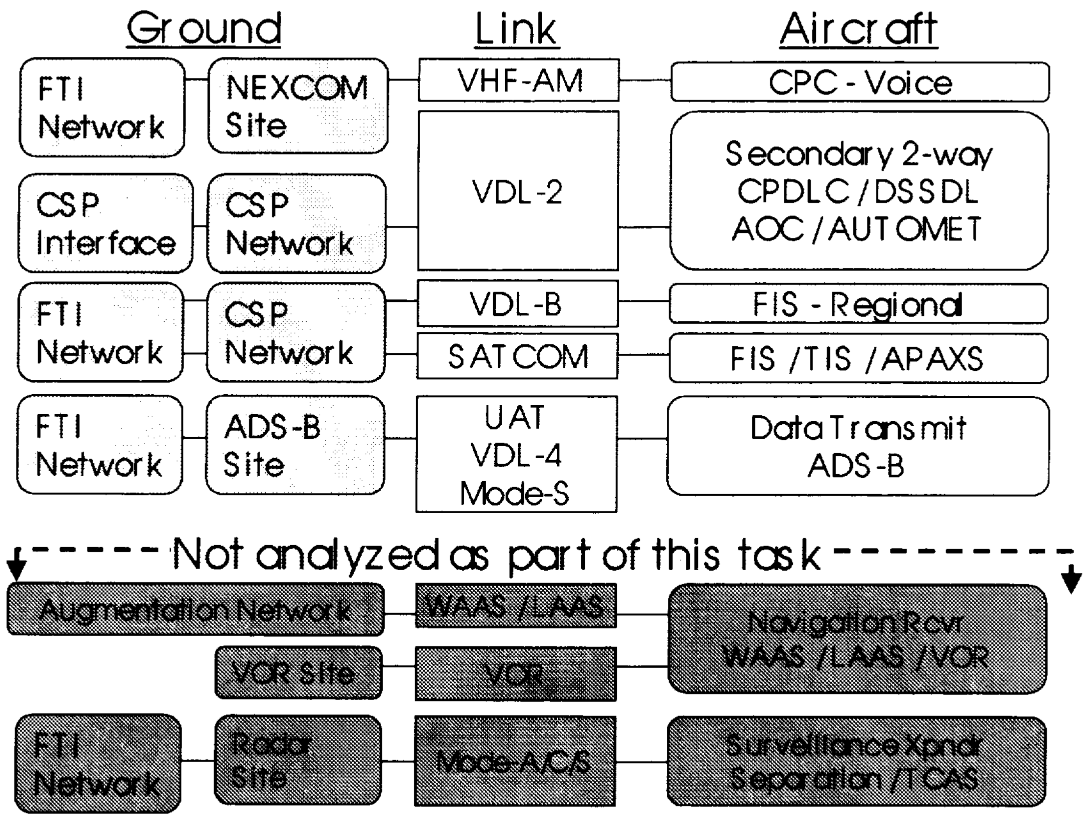

Figure 1.4-3. 2007 AATT Architecture - SATCOM Alternative

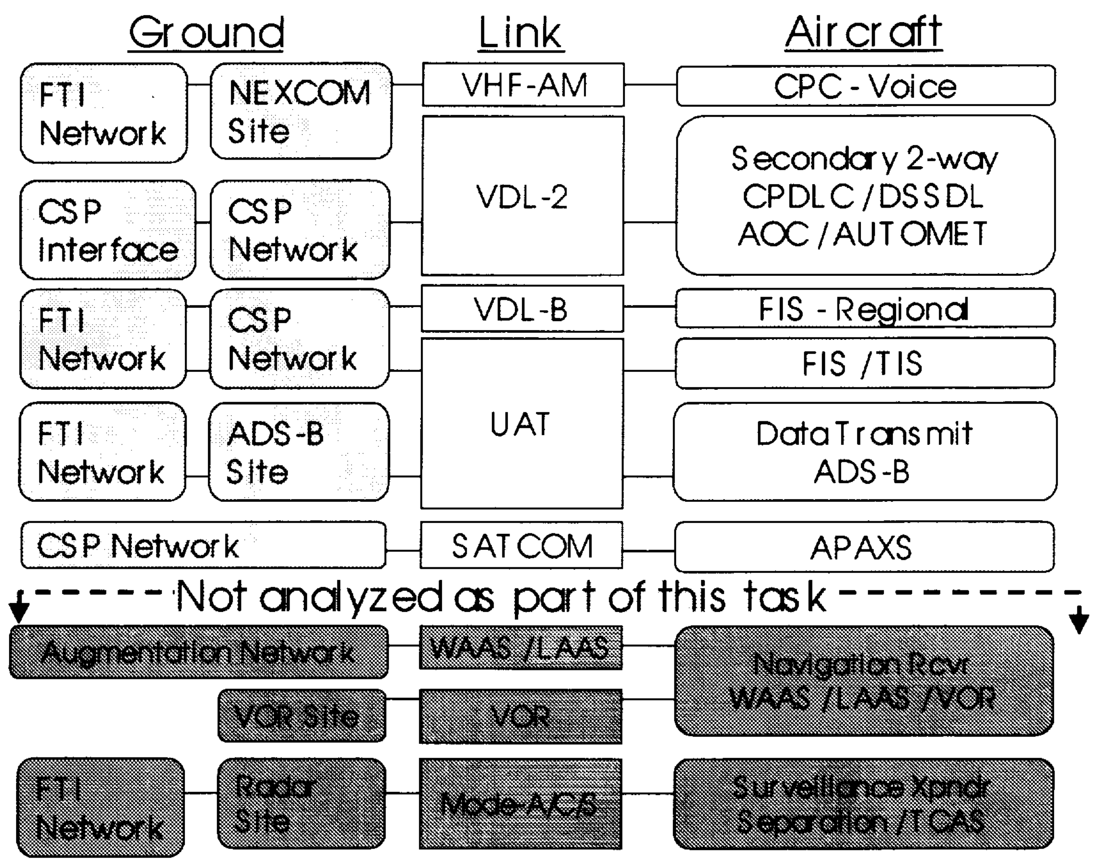

Figure 1.4-4. 2007 AATT Architecture - UAT Alternative

2 Introduction

In 1995, NASA began the AATT initiative to support definition, research, and selected high-risk technology development. This report responds to a specific task under AATT Research Task Order (RTO) 24: Develop AATT 2007 Communications System Architecture.

2.1 Overview of Task 6

The specific objective of Task 6 is to develop a 2007 AATT Communications System Architecture, i.e., to develop a communication system architecture (CSA) with the potential for implementation by 2007 that can fulfill the goal of providing the collection and dissemination of air traffic control (ATC) information to and from the various aviation platform classes.

Task 6 is one of eleven related tasks in the AATT RTO 24, Communications System Architecture Development for Air Traffic Management and Aviation Weather Information Dissemination. The relationships among these tasks are depicted in Figure 2.1-1. Task 5 develops the 2015 AATT Architecture, and Task 7 develops the 2007 Aviation Weather Information (AWIN) Architecture. Task 6 builds upon the communications system concepts developed in Task 4 and uses the definition of the 2015 AATT Architecture from Task 5 and requirements from Tasks 1-3 to define the recommended 2007 AATT Architecture. Elements of Task 9 define and determine what is achievable by 2007. The results of these tasks all lead into Tasks 8, 10, and 11.

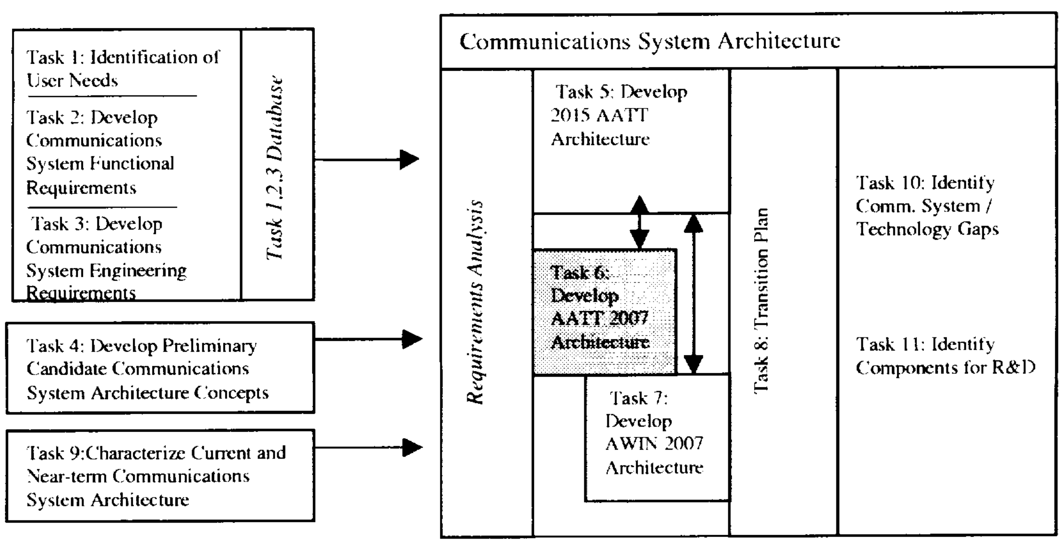

Figure 2.1-1. Relationship to Other Tasks

Task 6 began with a review of the relevant user needs and functional communications requirements collected in Tasks 1 and 2. This review was followed by the development of concepts of operation for 2007. Next, we analyzed the 2015 AATT Architecture to provide the top-down desired end state perspective, and the NAS Architecture for its bottoms-up perspective and to assess ability to meet these needs. The Task 6 AATT 2007 Architecture was developed from this analysis.

To ensure data availability to meet the needs of all users of the Air Traffic Services, three classes of users were defined as follows:

- Class 1: Operators who are required to conform to FAR Part 91 only, such as low-end General Aviation (GA) operating normally up to 10,000 ft. This class includes operators of rotorcraft, gliders, and experimental craft and any other user desiring to operate in controlled airspace below 10,000 ft. The primary distinguishing factor of this class is that the aircraft are smaller and that the operators tend to make minimal avionics investments. A small number of aircraft are not equipped with radios, but these aircraft are outside the realm of a communications architecture.
- Class 2: Operators who are required to conform to FAR Parts 91 and 135, such as air taxis and commuter aircraft. It is likely that high-end GA and business jets and any other users desiring to operate in controlled airspace will invest in the necessary avionics to be able to achieve the additional benefits.
- Class 3: Operators who are required to conform to FAR Parts 91 and 121, such as Commercial Transports. This class includes passenger and cargo aircraft and any other user desiring to operate in controlled airspace. These users will invest in the avionics necessary to achieve the additional benefits.

Table 2.1-1 presents the high level objectives to be met by the resulting communications architecture. These user goals and operational requirements have been grouped according to user class.

Table 2.1-1. User Goals and Operational Requirements

Class 1 User Goals	**Class 2 User Goals**	**Class 3 User Goals**
• Minimize/streamline interaction with ATM system • Make communications transparent and seamless for the pilot • Expand access to more airports in IMC conditions (High-end GA)	• Reduce limitations and delays caused by weather • Provide instrument approaches to more airports	• Expand the use of user preferred routes and trajectories • Increase airport capacity in IMC • Increase system predictability • Reduce weather related delays • Minimize time and path length for routing around hazardous weather
Class 1 Operational Requirements	**Class 2 Operational Requirements**	**Class 3 Operational Requirements**
Class 1 users require: • On demand weather • Weather at more sites • User friendly formats ("user friendly" is TBD but could include graphical, oriented to flight path, uncluttered, easy to interpret by solo pilot, etc.) • More real-time updates	Class 2 users require: • Weather at a greater number of sites • More real-time weather at remote sites	The Class 3 users, desiring a combination of preferred routes and increased capacity, require: • More precise weather information for routing • Weather information consistent with that seen by controllers and operations centers • Higher density grids at higher update rates to support decision support systems like CTAS and wake vortex prediction systems

The preceding information emphasizes a flow of information that generally is ground-to-air. Aircraft will be required, however, to down link a greater number of aircraft parameters and intent information to feed automation and decision support systems (e.g., CTAS, wake vortex prediction, etc.).

The Task 6 effort identifies the criteria and provides an assessment of the suitability of each mode of communications and communications link for each potential aviation application. These assessments concentrate on engineering requirements and address the benefits to specific types of users, thereby positioning them to drive user equipage decisions. From a CSA perspective, the implications of airspace users that have varying levels of capability are considered, so airspace mix also is considered. The resulting recommended 2007 AATT Architecture is defined in section 3.3.3, with supporting technical detail appearing in section 4.

2.2 Overview of the Document

Section 1 is an executive summary that provides a high-level synopsis of this document.

Section 2 introduces the task and provides the necessary background and context, including the relationship of Task 6 to other RTO 24 tasks.

Section 3 provides architecture concepts, characteristics, and considerations and develops the 2007 AATT Architecture. It discusses the following topics in order:

- Section 3.1 describes our approach and identifies the architectural concepts that drove that approach, and it describes the functional, analytical, and technical concepts that drove the solution.
- Section 3.2 presents a high-level description of the 2015 AATT Communications Architecture developed under Task 5. The description includes a high-level concept of operations and a physical data flow diagram.
- Section 3.3 presents a description of the 2007 AATT Architecture component links. Candidate communications link alternatives for each identified category of message are discussed.
- Section 3.4 describes the recommended 2007 AATT Architecture from an architecture (i.e., system of communication links) perspective. It also provides a mapping to the technical detail (SOW Section 4.6.1) for each link contained in section 5.

Section 4 presents the technical detail of the communication load analysis.

- Section 4.1 discusses the inputs provided by earlier tasks and scenarios developed to put those in context.
- Section 4.2 discusses the methodology used to map the messages defined in Task 3 with the scenarios to calculate the link loading by aircraft class and phase of flight. The numerical results of the message load calculations are presented and implications and conclusions drawn from the numbers are discussed.
- Section 4.3 discusses the traffic loading of messages suitable for non-addressed broadcast.
- Section 4.4 presents two-way message loading.
- Section 4.5 presents a summary of message category loading by domain.

Section 5 provides the technical details of the individual communications links.

- Section 5.2 provides the SOW 4.6.1 characteristics for each communications link in the 2007 architecture.
- Section 5.3 discusses significant points and tradeoffs considered in link selection.

3 Defining the 2007 AATT Architecture

3.1 Introduction

The analysis leading to the definition of the 2007 communications architecture involved three primary tasks shown in Figure 3.1-1: (1) defining an overall functional architecture to satisfy the desired services, (2) defining the information to be exchanged while providing the services (i.e., communication loading), and (3) identifying the enabling mechanisms (i.e., communication links) that meet the requirements for exchanging the information. Note that the technical concepts presented in this section are not unique to Task 6 (2007 AATT Architecture); rather, they apply equally well to Tasks 5 (2015 AATT Architecture) and Task 7 (2007 AWIN Architecture).

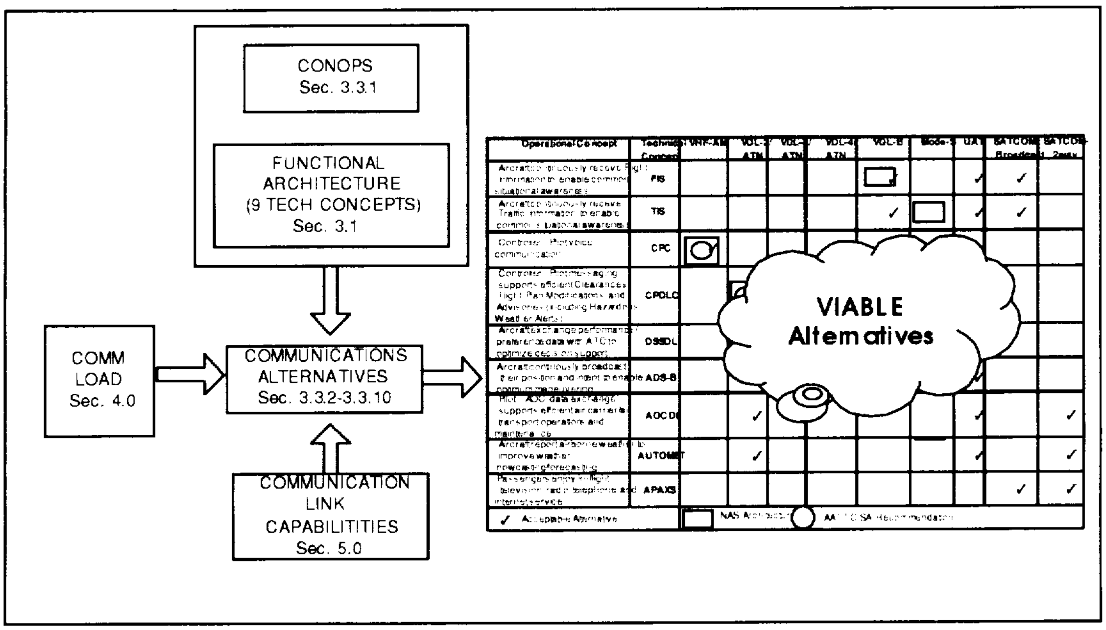

Figure 3.1-1. Architecture Development Method

Definition of the functional architecture required an understanding of the desires of the aviation community. To gain this understanding, we reviewed and integrated a wide range of user requirements as documented in Tasks 1, 2, and 3 and drew upon knowledge gained through our team's in-depth involvement in the development of the NAS Architecture. We organized our results by air traffic services and the functional capabilities and then matched the message type requirements from Task 2 with this service/functional capability structure. The result is a *service-driven view of the message types* that had been identified. [Note that, for our purposes, a message type is a logical grouping representing all data forms within that type, including raw data, commands, images, etc.]. We then focused these message types further by aligning them with crosscutting technical concepts. The technical concepts were derived from the CONOPS for the purpose of defining the functional architecture. Finally, by applying the appropriate enabling communication links to the functional architecture, we transformed it into the physical communications architecture. These relationships are illustrated in Figure 3.1-2.

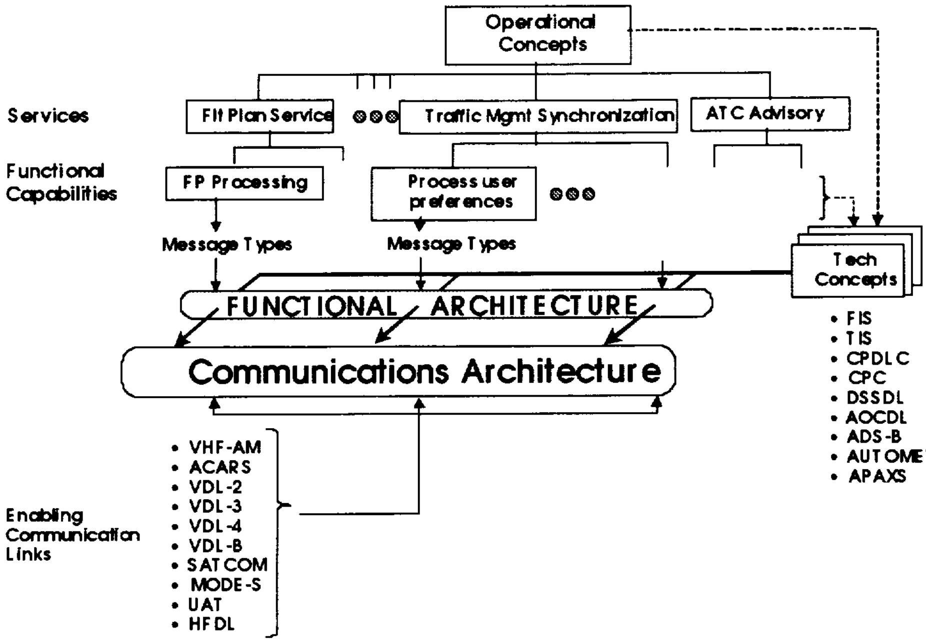

Figure 3.1-2. Operational Concepts to Communications Architecture

At the highest level are the operational concepts that provide the top down vision for what is desired. In the 2007 timeframe, the operational concept drivers are the need for increased user flexibility with operating efficiencies and increased levels of capacity and safety to meet the growing demand for air transportation. These concepts are characterized by: (1) removal of constraints and restrictions to flight operations, (2) better exchange of information and collaborative decision making among users and service providers, (3) more efficient management of airspace and airport resources, and (4) tools and models to aid air traffic service providers.

The operational concepts provide a context for measuring progress and for assessing whether or not the infrastructure is being provided to support the vision. The vision provided by the operational concepts draws upon the efforts such as the ATS Concept of Operations for the National Airspace System in 2005, the Concept Definition for Distributed Air/Ground Traffic Management (DAG-TM), and current and emerging industry trends. Context for the 2007 AATT Architecture is provided from two perspectives. The first perspective provides a view of the desired AATT 2015 architecture necessary to assess whether or not the 2007 architecture is viable on the transition path to 2015. The second perspective provides the broader vision necessary to integrate the 2007 architecture into the overall NAS.

From a communication architecture perspective, it is important to understand the services that will enable the operational concepts along with their supporting functions and the various message types associated with the functions. The services identified for this task and their related functional capabilities were identified in Tasks 1, 2, and 3 and are summarized in Table 3.1-1. The table also includes the Message Type Identifiers for the information exchange to support these functional capabilities.

Table 3.1-1. Services and Associated Functional Capabilities

Service	Function Name (Functional Capability)	Msg ID (M#)
Aeronautical Operational Control (AOC)	Collaborate with ATM on NAS Projections and User Preferences	M25
	Monitor Flight Progress - AOC	M23
		M33
		M6
	Airline Maintenance and Support	M8-M12
	Schedule; Dispatch; and Manage Aircraft Flights	M30
ATC Advisory Service	Provide In-flight NAS Status Advisories	M17
	Provide In-flight or Pre-flight Traffic Advisories	M32
	Provide In-flight or Pre-flight Weather Advisories	M13
		M14
		M15
		M18
		M20
		M21
		M22
		M26
		M27
		M28
		M29
		M35
		M37
		M39
		M4
		M43
		M44
Flight Plan Services	File Flight Plans and Amendments	M22
		M24
		M32
	Process Flight Plans and Amendments	M16
		M32
		M34
		M40
On-Board Service	Provide Administrative Flight Information	M5
		M7
	Provide Public Communications	M31

Service	Function Name (Functional Capability)	Msg ID (M#)
Traffic Management Strategic Flow Service	Provide Future NAS Traffic Projections	M38
Traffic Management Synchronization Service	Process User Preferences	M2
	Project Aircraft In-flight Position and Identify Potential Conflicts	M1
		M3
	Provide In-flight Sequencing; Spacing; and Routing Restrictions	M36
	Provide Pre-flight Runway; Taxi Sequence; and Movement Restrictions	M32
		M36

Table 3.1-2 below provides a textual description of the Message Type corresponding to each Message Type Identifier. These messages may be voice, text, or graphical images.

Table 3.1-2. Message Types and Message Type Identifiers

Message Type Identifier	Message Type
M1	ADS
M2	Advanced ATM
M3	Air Traffic Information
M4	Aircraft Originated Meteorological Observations
M5	Airline Business Support: Electronic Database Updating
M6	Airline Business Support: Passenger Profiling
M7	Airline Business Support: Passenger Re-Accommodation
M8	Airline Maintenance Support: Electronic Database Updating
M9	Airline Maintenance Support: In-Flight, Emergency Support
M10	Airline Maintenance Support: Non-Routine Maintenance/ Information Reporting
M11	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)
M12	Airline Maintenance Support: Routing Maintenance/ Information Reporting
M13	Arrival ATIS
M14	Not used – See M43, M44
M15	Convection
M16	Delivery of Route Deviation Warnings
M17	Departure ATIS
M18	Destination Field Conditions
M19	Diagnostic Data
M20	En Route Backup Strategic General Imagery
M21	FIS Planning – ATIS
M22	FIS Planning Services
M23	Flight Data Recorder Downlinks
M24	Flight Plans
M25	Gate Assignment
M26	General Hazard
M27	Icing
M28	Icing/ Flight Conditions
M29	Low Level Wind Shear

Message Type Identifier	Message Type
M30	Out/ Off/ On/ In
M31	Passenger Services: On Board Phone
M32	Pilot/ Controller Communications
M33	Position Reports
M34	Pre-Departure Clearance
M35	Radar Mosaic
M36	Support Precision Landing
M37	Surface Conditions
M38	TFM Information
M39	Turbulence
M40	Winds/ Temperature
M41	System Management and Control
M42	Miscellaneous Cabin Services
M43	Aircraft Originated Ascent Series Meteorological Observations
M44	Aircraft Originated Descent Series Meteorological Observations

Given a definition of the message types that require air-ground communication, the next step was to organize the message types further in a logical fashion that supports the development of a functional communication architecture. To accomplish this organizational construct, we examined the operational concepts and the service functional capabilities to identify ways to focus the functional architecture. Based on that examination, we defined nine unique technical concepts related to air-ground communications that incorporate the functional capabilities and drive the definition of the functional architecture. These technical concepts are defined in Table 3.1-3 below:

Table 3.1-3. Air-Ground Communications Technical Concepts

Technical Concept Definition	Technical Concept Name
Aircraft continually receive Flight Information to enable common situational awareness of weather and NAS status	Flight Information Services (FIS)
Aircraft continually receive Traffic Information to enable common situational awareness of the traffic in the area	Traffic Information Services (TIS)
Controller-Pilot data messaging supports efficient Clearances, Flight Plan Modifications, and Advisories	Controller-Pilot Data Link Communications (CPDLC)
Controller-Pilot voice communication to support ATC operations	Controller-Pilot Communications (CPC)
Aircraft exchange performance / preference data with ATC to optimize decision support	Decision Support System Data Link (DSSDL)
Pilot-AOC data messaging supports efficient air carrier/air transport operations and maintenance	Airline Operational Control Data Link (AOCDL)
Aircraft broadcast data on their position and intent continuously to enable optimum maneuvering	Automated Dependent Surveillance-Broadcast (ADS-B)
Aircraft report airborne weather data to improve weather nowcasting/forecasting	Automated Meteorological Reporting (AUTOMET)
Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service	Aeronautical Passenger Services (APAXS)

Using these technical concepts as drivers, we next defined the functional architecture for air-ground communications as shown in Figure 3.1-3.

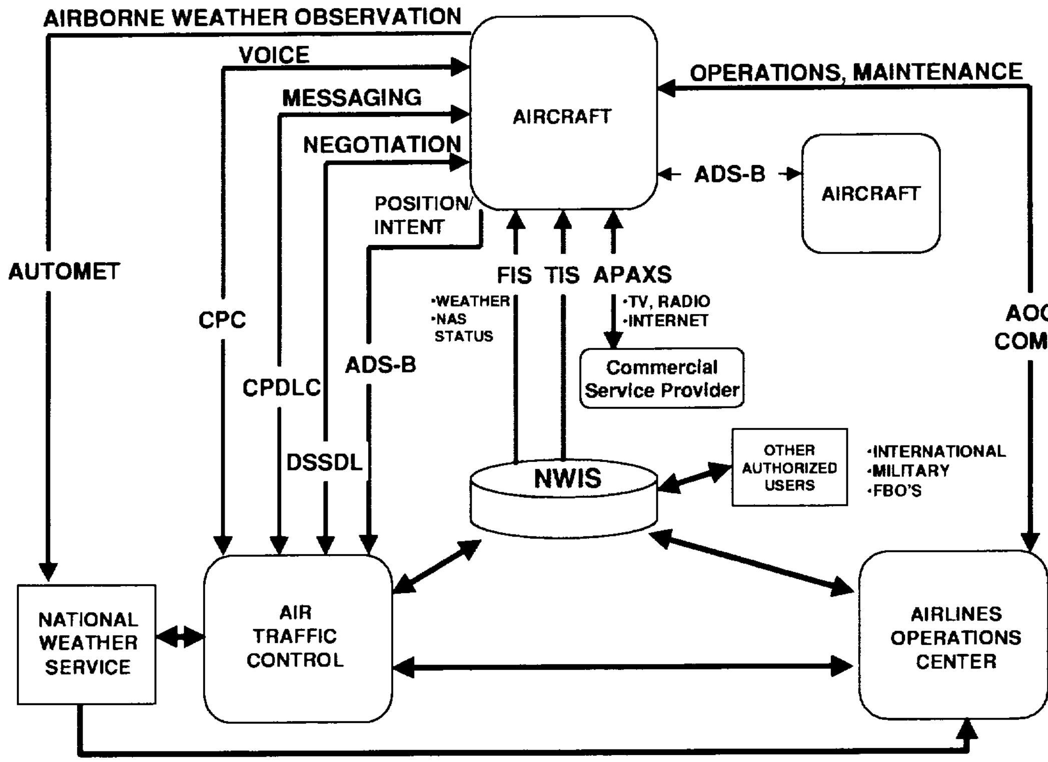

Figure 3.1-3. Functional Architecture for Air-Ground Communications

Our next step was to organize the functional capability message types into categories that are associated with each technical concept. Table 3.1-4 shows the resulting message categories, including message content for each category, mapped to the individual technical concepts listed in Table 3.1-3 above.

Table 3.1-4. Message Categories Mapped to Technical Concepts

Category.	Technical Concept	Description of Concept
1	Flight Information Services (FIS)	Aircraft continually receive Flight Information to enable common situational awareness
2	Traffic Information Services (TIS)	Aircraft continuously receive Traffic Information to enable common situational awareness
3	Controller-Pilot Data Link Communications (CPDLC)	Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories
4	Controller Pilot Communications (CPC) Voice	Controller - Pilot voice communication
5	Decision Support System Data Link (DSSDL)	Aircraft exchange performance / preference data with ATC to optimize decision support
6	Airline Operational Control Data Link (AOCDL)	Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance
7	Automated Dependent Surveillance (ADS) Reporting	Aircraft continuously transmit data on their position and intent to enable optimum maneuvering

Category.	Technical Concept	Description of Concept
8	Automated Meteorological Reporting (AUTOMET)	Aircraft report airborne weather data to improve weather nowcasting and forecasting
9	Aeronautical Passenger Services (APAXS)	Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service

The organization of message types into the categories listed above is listed in Table 3.1-5 below.

Table 3.1-5. Organization of Message Types into Message Categories

Message Category	Message Category Identifier	Message Type Identifier	Message Type
FIS	1	M13	Arrival ATIS
	1	M15	Convection
	1	M17	Departure ATIS
	1	M18	Destination Field Conditions
	1	M20	En Route Backup Strategic General Imagery
	1	M21	FIS Planning – ATIS
	1	M22	FIS Planning Services
	1	M26	General Hazard
	1	M27	Icing
	1	M28	Icing/ Flight Conditions
	1	M29	Low Level Wind Shear
	1	M35	Radar Mosaic
	1	M37	Surface Conditions
	1	M38	TFM Information
	1	M39	Turbulence
	1	M40	Winds/ Temperature
TIS	2	M3	Air Traffic Information
CPDLC	3	M24	Flight Plans
	3	M29	Low Level Wind Shear
	3	M32	Pilot/ Controller Communications
	3	M33	Position Reports
	3	M34	Pre-Departure Clearance
	3	M41	System Management and Control
DSSDL	5	M2	Advanced ATM
	5	M16	Delivery of Route Deviation Warnings
	5	M24	Flight Plans
AOCDL	6	M9	Airline Maintenance Support: In-Flight Emergency Support
	6	M10	Airline Maintenance Support: Non-Routine Maintenance/ Information Reporting
	6	M11	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)
	6	M12	Airline Maintenance Support: Routing Maintenance/ Information Reporting
	6	M19	Diagnostic Data
	6	M23	Flight Data Recorder Downlinks
	6	M25	Gate Assignment

Message Category	Message Category Identifier	Message Type Identifier	Message Type
AOCDL	6	M30	Out/ Off/ On/ In
	6	M8	Airline Maintenance Support: Electronic Database Updating
ADS-B	7	M1	ADS
AUTOMET	8	M43	Aircraft Originated Ascent Series Meteorological Observations
	8	M44	Aircraft Originated Descent Series Meteorological Observations
APAX	9	M5	Airline Business Support: Electronic Database Updating
	9	M6	Airline Business Support: Passenger Profiling
	9	M7	Airline Business Support: Passenger Re-Accommodation
	9	M31	Passenger Services: On Board Phone
	9	M42	Miscellaneous Cabin Services

Note that there are no message category 4 messages in the 2007 timeframe as the installed NEXCOM radios emulate VHF AM radios at this time.

At this point, having established a functional architecture and a corresponding relationship to the message types, we can use the communication load analysis (section 4) and the communication link analysis (section 5) to develop suitable alternative physical communication architectures. This development of AATT Architecture and its deviations from the baseline NAS Architecture is discussed in Section 3.3.

3.2 2007 AATT Communication System Architecture Development

In 2007, there still will be a range of users who will choose to participate at various levels of equipage. All users are accommodated and will receive benefits commensurate with their levels of equipage.

The remainder of this section develops the 2007 AATT communications system architecture based on the set of technical concepts presented in Figure 3.1-1 and briefly outlined above. These concepts are further highlighted in Figure 3.2-1 which depicts the range of equipage and tactical control in addition to the level of air ground communication. Each subsection begins with a description of the technical concept and the introduction of a concept single line drawing. The purpose of the single line drawing is to highlight the end-to-end connectivity required at the concept level necessary to execute the technical concept. This provides a structure that allows us to determine technical as well as concept gaps. Next, the communication load requirements for the concept are discussed followed by an identification of the communication link alternatives that could satisfy the load requirements. Finally, the NAS Architecture approach for the concept is identified. The NAS Architecture is the FAA's fifteen-year strategic plan for modernization of the NAS. The objective of NAS modernization is to add new capabilities that will improve efficiency, safety and security while sustaining existing services.

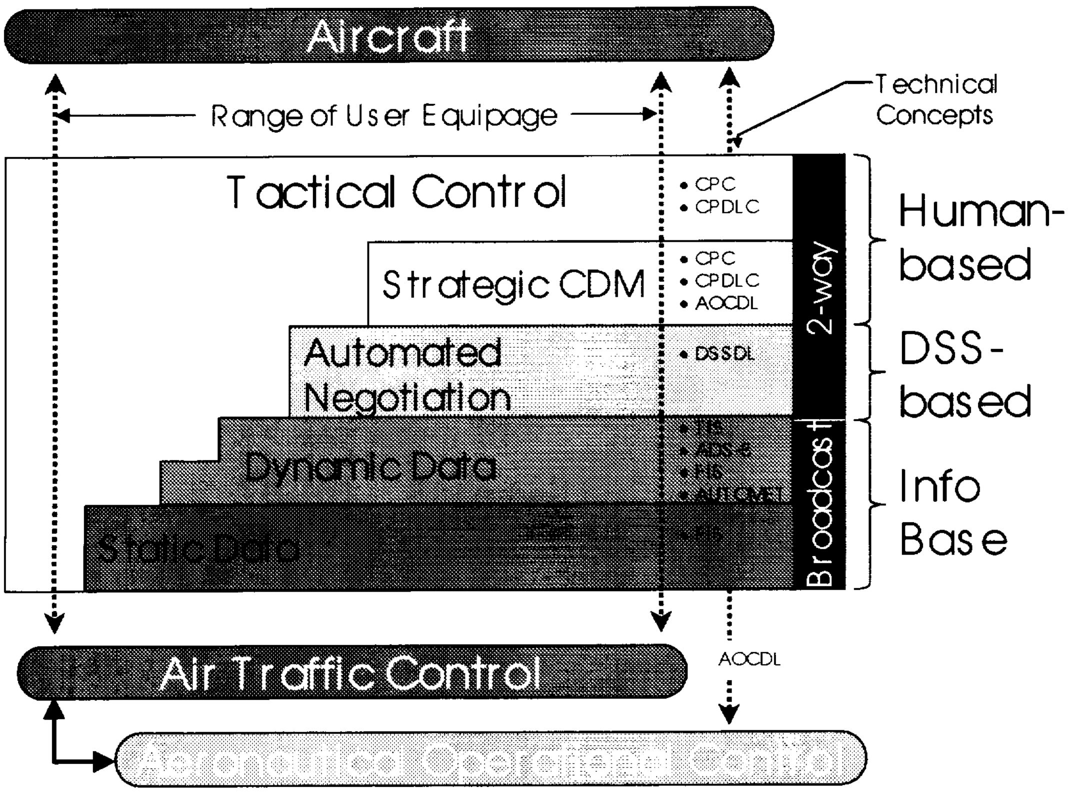

Figure 3.2-1. Air-Ground Communications Levels

3.2.1 Flight Information Services (FIS)

The FIS technical concept does not change from that projected for 2015. FIS provides one of the foundation functions for maintaining the static and dynamic data requirements for the information base of the NAS. In this concept, aircraft receive flight information continuously in order to enable common situational awareness for pilots that supports their ability to operate safely and efficiently within the NAS. Flight information consists of NAS weather information, NAS status information and NAS traffic flow information. Flight information is considered advisory and for the purposes of air-ground communications is classified as routine (see section 4.2 for further details). FIS information is intended for transmission to all classes of users. Thus, any selected link alternative must be capable of installation and use in most any aircraft regardless of class. The single line diagram for FIS is shown in Figure 3.2-2.

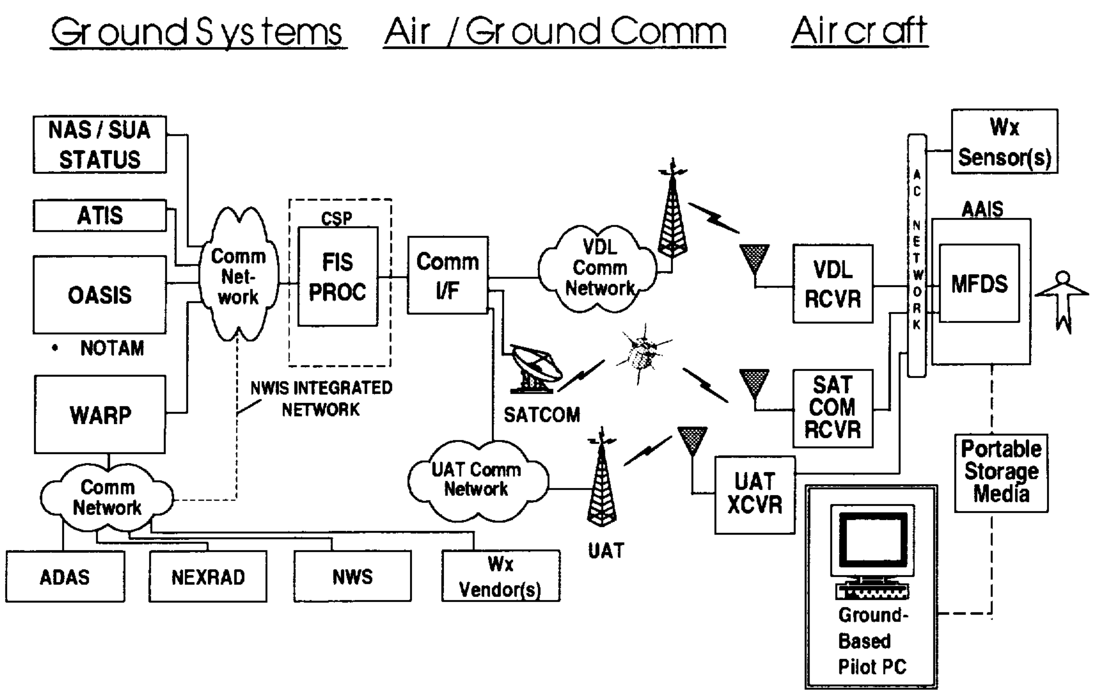

Figure 3.2-2. Flight Information Service in 2007

The Weather products transmitted via FIS may include observations and forecasts, weather radar data, winds and temperature aloft, and gridded forecast data. The NAS status information may include NOTAMs, airport conditions and configurations, and active/inactive status of special use airspace. NAS traffic flow information may include active and pending restriction data, and other traffic flow initiative information.

During the requirements analysis conducted in Tasks 1 through 3, it was thought that some types of FIS products might be tailored for a specific flight and delivered only to an aircraft that requested it, while other FIS products were not flight specific and would be suitable for broadcasts. In this form the messages require conversion from 2-way to broadcast or vice versa for our analysis. These message types are shown in Table 4.3-5 and Table 4.3-6.

For FIS, the NAS Architecture plans to rely on commercial service providers to supply products regionally to the aircraft via four allocated 25kHz VHF frequencies using VDL-B.

Our communication load estimate for broadcast FIS is the same for 2007 as for 2015 as we were unable to identify any additional products. The FIS load data is derived from Table 4.5-6 and Table 4.5-7.

For the initial analysis, the architecture was evaluated with FIS data transmitted to the aircraft using a two-way (request/reply) data link or a transmit-only broadcast data link, depending on the message type, as identified in Tasks 2 and 3.

In order to get a domain broadcast estimate we combine the FIS flight specific and non-flight specific data (Table 4.3-10) and make the appropriate unit conversions to produce Table 3.2-1. For purposes of estimation, if we assume a region consisting of one en route center, a consolidated terminal area and four airports, then the total communication requirement for the region would be 7.2 kbps on the broadcast link and 66 kbps on the two-way link. This greatly exceeds the capacity of a VDL channel, precluding the use of this approach on the channels currently allocated for FIS. In addition, this approach would require the use of separate radios for broadcast and two-way FIS and complicated avionics to combine the results on a display.

Table 3.2-1. FIS 2-way + broadcast Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
FIS – Domain	9.9	9.4	17.2	
Region (x) [1]	39.6 (4)	9.4 (1)	17.2 (1)	66
FIS - Regional Broadcast		0.6	6.6	7.2

Note: (x) is domain multiplier

Even for information of a general nature, it could be delivered to every flight over two-way links. Given the dynamic nature of FIS data, however, a two-way data link would require a constant request/reply method that is inefficient in terms of channel overhead and suffers in performance directly proportional to the number of aircraft (see Section 4.3.2). Our estimate of the two-way communication loading for FIS (if all messages were two-way) identifies the need for uplinks ranging 1265 kbps for 2007 in a geographic area covering airspace for four airports, a consolidated TRACON, and en route. This far exceeds any VDL link capacities and would require a move to Broadband links. Detailed analysis included applying overhead factors for two-way communications to all non-flight specific messages; since this is not considered a viable solution, the details analysis is not included here.

From a communication standpoint, broadcast communication is considered desirable for FIS because it is the most efficient in terms of overhead and component design. This is the method currently being employed by the FIS service providers in selected areas.

If the messages identified in Table 4.4-3 as two-way messages for FIS were instead broadcast, at the same frequencies as shown in the table, the total communication load would be reduced to the loads shown in Table 3.2-2. Note that the communication load is reduced not only because products are transmitted only once for all aircraft to receive, but also because the protocol overhead for broadcast is less than the overhead for two-way communication.

Table 3.2-2. FIS Communication Load Requirements (kilobits per second) to Broadcast all FIS Message Types

	Airport	Terminal	En Route	Total
FIS - Domain	0.2	0.9	6.9	
FIS - Region	1.0 (5)	4.5 (5)	6.9 (1)	12.4
FIS - National				248 (20)

Note: (x) is domain multiplier

Using the same example of a region including en route airspace and five airports and terminals, the total load requirement is 12.4 kbps. This is within the capacity of a VDL-B channel. One disadvantage of regional coverage is that the pilot can only receive FIS data for the region that they are flying in. In some situations this can limit the pilots ability to perform strategic planning.

Aggregation of this data to a national level can conservatively be estimated by multiplying the regional estimate by 20 (the number of CONUS centers). This yields a national broadcast load of 248 kbps. This would exceed the capacity of any VDL link but could be supported by UAT or SATCOM links.

Technology Gap

One of the greatest challenges to national implementation of FIS (including region by region) is establishment of the A/G ground network. From this aspect, the establishment of a multi-use broadband data exchange network becomes more appealing. Our analysis indicates that VDL-B can accommodate the delivery of FIS data to the aircraft if performed on a regional basis and given the assumptions for data size and compression ratios identified in Section 4.3. National broadcast or two-way FIS implementations will require the higher capacity solutions that are in the early stages of implementation. A summary of the possible FIS communication links is shown in Table 3.2-3.

The government should explore innovative methods for establishing a national air-ground broadband data exchange network. This effort should cover all aspects of the air-ground network from location to physical access to operation and maintenance. For example, the government could make their terrestrial air-ground communication sites accessible to commercial service providers, even potentially turning them over to third parties for operation and maintenance. As many wireless telecommunication providers are doing today.

Table 3.2-3. FIS Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Flight Information to enable common situational awareness	FIS					✓ (boxed)		✓	✓	
✓ Acceptable Alternative		□ NAS Architecture	○ AATT CSA Recommendation							

3.2.2 Traffic Information Services (TIS)

The TIS technical concept is another of the foundation functions necessary for maintaining the dynamic data requirements for the information base of the NAS. In this concept, aircraft receive trajectory information of all aircraft continuously in order to enable common situational awareness for pilots that enhances their ability to operate safely and efficiently within the NAS. TIS information consists of real time aircraft position data that is received by ATC from their ground-based surveillance sensor network consisting of primary and secondary radars and dependent surveillance receivers. The received aircraft position data is combined with trajectory and intent data and then broadcast to participating aircraft. TIS information is provided without any ground controller involvement. TIS information is used onboard the aircraft to support tactical maneuvering and trajectory planning decisions by the pilot. The performance requirements for transmission of TIS data to support tactical maneuvering are much more stringent (0.5 seconds) than for support of trajectory planning (120 seconds). To be useful for trajectory planning for ten or twenty minutes ahead, the TIS information needs to cover a large volume of airspace. The recommended architecture supports tactical maneuvering and trajectory planning, so the communication loading is much higher than if only tactical maneuvering were supported. The end-to-end connectivity diagram for TIS is shown in Figure 3.2-3.

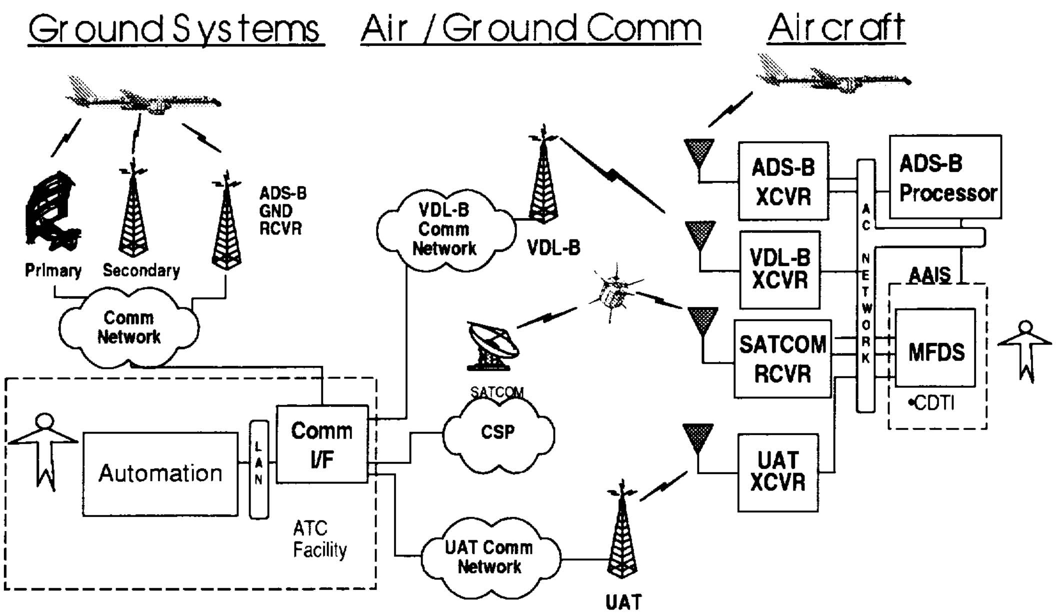

Figure 3.2-3. TIS Connectivity Diagram in 2015

TIS is a principal enabler of ADS-B maneuvering and trajectory planning. Hence, the deployment of TIS will parallel that of ADS-B. The current ADS-B deployment strategy calls for implementation in "local pockets." This strategy would allow the use of VDL-B to support TIS in the interim, although VDL-B as a long-term solution will require a large number of VHF frequencies.

Implementing a VDL-B solution, however, is problematical in that each VDL channel would require an additional 25kHz VHF frequency in each sector or region of implementation to avoid interference. This could not be supported under the current frequency allocation scheme meaning that implementation of a multi-channel VDL-B solution would need to wait until frequencies have been reallocated as a part of the NEXCOM implementation. This will begin in 2010 and will be complete by 2015. One implication of waiting until the 2010-2015 time frame, however, would be the restriction of early maneuvering benefits for ADS-B since without TIS (or 100% ADS-B equipage) the pilot has no assurance of complete traffic situational awareness while conducting a maneuver. An additional, and potentially even more problematic implication, is that these frequencies are the same ones that would be required for the DSSDL concept, which would be using VDL-3. Given these considerations it is not recommended that TIS be implemented nationally within the 118MHz – 137MHz aviation spectrum.

The volume of traffic information depends on the number of aircraft, since data must be included in the TIS broadcast for each aircraft in the airspace. Table 3.2-4 shows the peak data rate volumes. For a volume of airspace including five airports, five terminal and en route, the peak volume would be 50.5 kbps.

Table 3.2-4. TIS Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
TIS - Domain	21.3	6.4	18.5	
TIS - Region	N/A	32.0 (5) [1]	18.5	50.5
TIS - National	N/A	52.7 [1139] [2]	153.2 [4140]	205.9

Note 1: Region defined as 1 En Route, 5 Terminal
Note 2: National Peak Total number of aircraft per domain

In our analysis there are only 2 other links to consider that offer enough performance to support TIS: UAT and SATCOM. UAT offers link performance in the range of 1 Mbps, which would easily support the TIS requirement. SATCOM offers link performance in the range of 2 Mbps, which would also easily support the TIS requirement. Table 3.2-5 provides an overview of UAT and SATCOM. One potential advantage of using UAT would be that the majority of aircraft would already have a UAT radio (if it were the technology chosen for ADS-B) and a UAT terrestrial network would have been established. An advantage of SATCOM would be the wide area access provided without the need for a terrestrial network and the ability to use a commercial service provider. Each of these links is currently in the developmental stages and requires further research to establish their viability.

Table 3.2-6 provides a summary of the TIS communication links. The NAS Architecture currently identifies Mode-S as the recommended communications link for TIS. Based on our load analysis, however, we do not feel that Mode-S will be capable of supporting TIS in the long term. Further, we feel that Mode-S should not be pursued as a short-term solution as its use would most likely inhibit transition to a national solution by 2015

Table 3.2-5. UAT and SATCOM overview

	UAT	Ka SATCOM
Base	• Terrestrial • FAA Radar, Navigation and/or Air-Ground Communication sites	• Space • Assume desirable CONUS coverage • Commercial service providers
Capacity	1Mbps	> 2Mbps
PRO's	• If selected as ADS-B link, all aircraft would eventually have UAT radio • Use of FAA sites • Avionics design complete – standards in development	• CONUS coverage without maintenance of terrestrial network • Higher data rates • Most likely will be available from commercial service providers
CON's	• Maintenance of terrestrial network • Additional radio required if not selected as part of ADS-B • Most likely will require FAA ownership and operation – currently no funding identified	• Immature avionics design - no standards – unproven for small GA aircraft • Additional radio required

Table 3.2-6. TIS Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Traffic Information to enable common situational awareness	TIS					✓	☐ (NAS Architecture)	✓	✓	
✓ Acceptable Alternative		☐ NAS Architecture ◯ AATT CSA Recommendation								

Technology GAPS

Again, the government should explore innovative methods for establishing a national air-ground broadband data exchange network. The gaps associated with the implementation of TIS via UAT or SATCOM are the identification of suitable spectrum (independent of that used for ADS-B, in the case of UAT) and the development of antennas and avionics that are suitable for use on all aircraft.

Initial UAT avionics design is complete with field testing due to begin in the fall of 2000 as part of the Safe Flight 21 CAPSTONE program. Use of satellite communication links requires the demonstration of aeronautical mobile technologies for antenna, receivers, link algorithms, protocols, and standards. A major technology focus for broadband communications services is the need to provide more bandwidth (with a focus on Ka-band). Given the migration to these frequencies, the need exists for higher efficiency transmitters (both space and terrestrial), more adaptive bandwidth versus power efficient modulation, forward error correction coding (including turbo codes and bit/modulation symbol interleaving), and much expanded use of variable bit rate formats and dynamic multiplexing techniques such as asynchronous transfer mode (ATM) based technologies. Antennas and receivers must be adapted for the aviation market (size, weight, cost) and must overcome the problems of rain attenuation for broadcast TIS over satellite.

3.2.3 Controller-Pilot Communications (CPC)

Voice remains unchanged in 2007, except for implementation of digital radios that will continue to operate in the VHF-AM mode. Voice communication is the foundation of air traffic control. Thus, even as we move toward a higher utilization of data exchange for routine communications, it is critical to maintain a high quality, robust voice communication service. The implementation of NEXCOM will provide both digital voice and data capabilities. New multi-mode radios will be able to emulate the existing VHF-AM analog modulation and other selected modulation techniques using software programming.

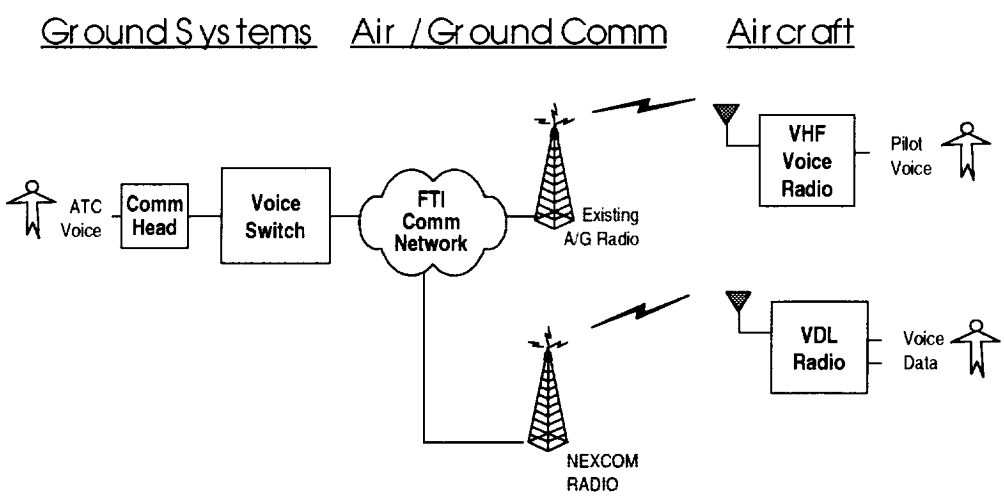

Figure 3.2-4. CPC Air/Ground Voice Communication in 2007

The CPC communication links are shown in Table 3.2-8. The NAS Architecture plans to transition controller pilot voice communication to an FAA supported VDL-3 network in the 2010-2015 time frame. Our VDL-3 link analysis indicates that a single VDL-3 sub-channel supports 4.8 kbps. Our communication load analysis indicates that a single VDL-3 sub-channel is sufficient to support controller pilot communication under worst case loading conditions. We therefor recommend that the AATT CSA maintain the NAS Architecture recommendation.

Table 3.2-7. CPC Load Analysis Results

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	2.6	1.2	1.0	1.0	3.0	0.8
2	0.8	0.4	0.8	0.8	0.4	0.2
3	1.0	0.4	0.8	0.8	0.5	0.2
Total	6.3		5.3		5.2	
Voice Channels Required (P=0.2)	9		8		8	

The CPC communication links are shown in Table 3.2-8. The NAS Architecture plans to transition controller pilot voice communication to an FAA supported VDL-3 network in the 2010-2015 time frame.

Table 3.2-8. CPC Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Controller - Pilot voice communication	CPC	✓								

✓ Acceptable Alternative ☐ NAS Architecture ◯ AATT CSA Recommendation

Technology Gap

None identified

3.2.4 Controller-Pilot Data Link Communications (CPDLC)

The objective of CPDLC is to provide a data messaging capability between controllers and pilots that will reduce voice frequency congestion and provide a more precise and efficient means of communicating instructions and requests. CPDLC begins with the creation and initiation of a message by a controller or pilot. In the 2007 time frame CPDLC will employ a limited message set primarily focused on controller clearance delivery and transfer of communications.

In the 2007 time frame, the NAS Architecture projects the use of a commercial service provider VDL-2 network for CPDLC. Our communication load analysis (see Table 4.5-6) identifies load requirements by domain as indicated in Table 3.2-9. The data in Table 3.2-9 is developed by adding the uplink and downlink loads for each domain.

Table 3.2-9. CPDLC Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route
CPDLC- Domain	1.7	0.5	0.6
CPDLC- (Estimate per Sector)	0.4 (4)	0.1 (7)	0.03 (20)

In the 2007 time frame, there is only one ATN compliant communication link available for providing CPDLC service; the AOCDL VDL-2 network. The current plan for the AOCDL network is to use four allocated frequencies to provide national support. Each frequency has an effective capacity of 19.2 kbps. Using our communication load projections from Table 3.2-9 above we can estimate the number of

AOCDL frequencies required for a high-density area with four airport/terminal domains within a single en route domain. This would require capacity for 9.4 kbps in addition to the capacity allocated for AOCDL. This would also make it possible to dedicate separate frequencies to AOC and CPDLC with only one additional frequency for CPDLC applications.

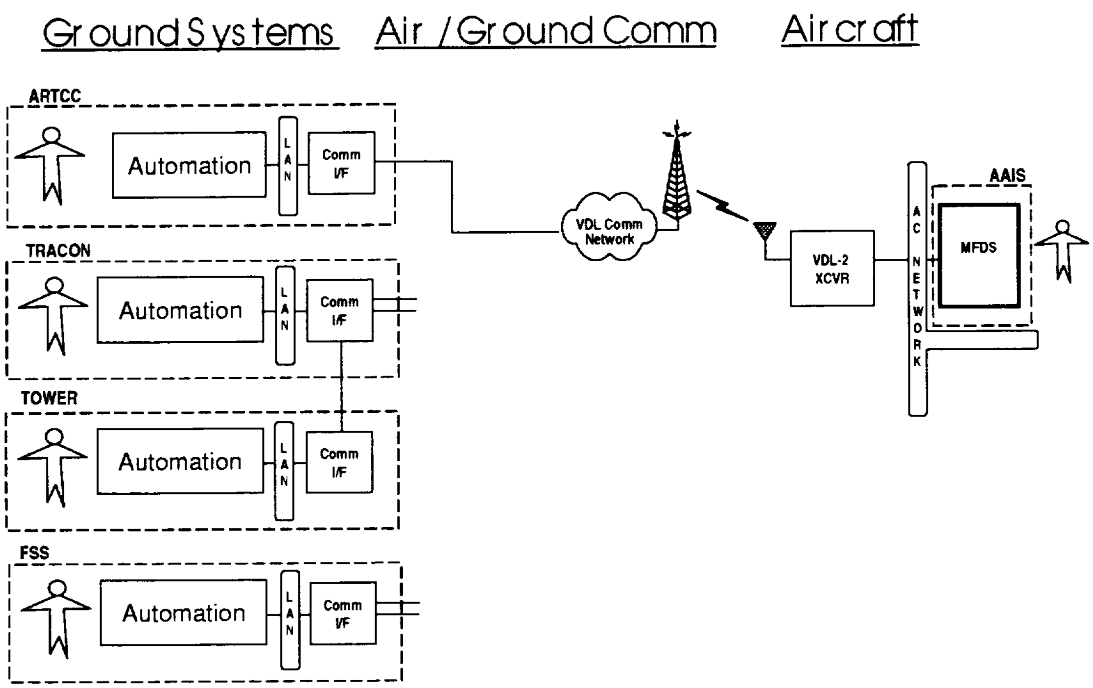

Figure 3.2-5. CPDLC Controller/Pilot Data Link Communications in 2007

The CPDLC communication links are shown in Table 3.2-10.

Table 3.2-10. CPDLC Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	CPDLC		✓ (NAS Architecture, AATT CSA Recommendation)							
✓ Acceptable Alternative		□ NAS Architecture	○ AATT CSA Recommendation							

Technology Gap

There are no technology gaps identified for CPDLC via VDL-2.

3.2.5 Decision Support System Data Link (DSSDL)

The DSSDL capability is in its initial stages in the 2007 time frame. Initially, data exchange is not fully automated in that the controller or pilot must authorize its use by the aircraft DSS/ATC DSS, which is similar to the exchange and use of pre-departure clearance data today. Figure 3.2-6 depicts the major elements of DSSDL.

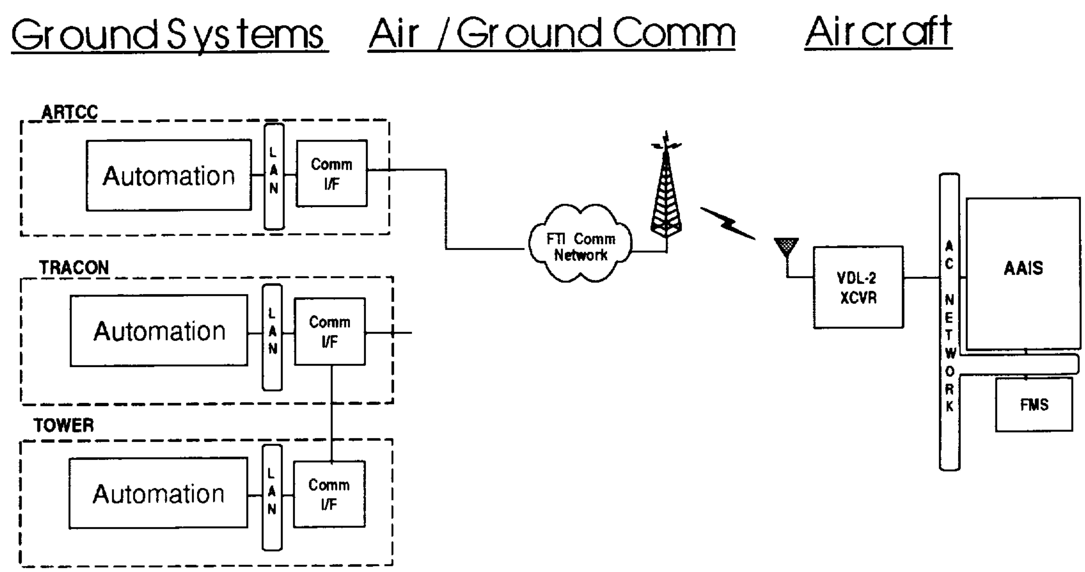

Figure 3.2-6. Decision Support System Data Link in 2007

DSSDL preferences that result in clearance changes (i.e. flight plan or trajectory updates) will be provided to the aircraft via CPDLC message. For example, an aircraft preference for turbulence avoidance eventually may result in an ATC originated CPDLC message to CLIMB TO (*level*).

DSSDL is applicable only to aircraft that have an advanced FMS that supports integration with an onboard data link. Initial DSSDL messages most likely will be aircraft-to-ATC only, indicating preferences for routes or arrival times.

DSSDL ASSUMPTIONS for 2007

- Only aircraft with avionics that allow integration of data link information into the flight management system can use DSSDL
- Data can be processed directly by ATC automation or aircraft avionics, but the results must be accepted by controller/pilot prior to use by automation in air traffic control or flight operations.
- DSSDL is an essential service

The DSSDL communication links in 2007 are shown in Table 3.2-11.

Table 3.2-11. DSSDL Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft exchange performance / preference data with ATC to optimize decision support	DSSDL		✓ (boxed, circled)		✓		✓	✓		✓
✓ Acceptable Alternative		☐ NAS Architecture ◯ AATT CSA Recommendation								

Table 3.2-12. DSSDL Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route
DSSDL- Domain	0.13	0.06	0.03
DSSDL- (Estimate per Sector)	0.03 (4)	0.01 (7)	0.0 (20)

In the 2007 time frame, there is only one ATN compliant communication link available for providing DSSDL service; the AOCDL VDL-2 network. The current plan for the AOCDL network is to use four allocated frequencies to provide national support. Each frequency has an effective capacity of 19.2 kbps. As noted above for CPDLC, the planned AOCDL VDL-2 network will have sufficient capacity to support CPDLC and DSSDL for the communication loads expected in 2007. As shown in Table 3.2-12 we can accommodate DSSDL without the need for additional frequencies.

Technology Gap

The following items require further definition in order to implement a DSSDL capability. These areas are currently under study by the FAA so they are not included in the gaps addressed in Task 10/11.

- Ground automation that can accept data input via direct data link and allow controller authorization
- Protocols that support routing and prioritization
- Data integrity / error correction algorithms
- Avionics that can accept data input via direct data link and allow pilot authorization

3.2.6 Automated Dependent Surveillance-Broadcast (ADS-B)

ADS-B aircraft continuously broadcast their position, velocity, and intent information using GPS as the primary source of navigation data to enable optimum maneuvering. ADS-B will support both air-ground and air-air surveillance. The major operational environments improved by ADS-B include "gap-filler" surveillance for non-radar areas, surface operations, pair-wise maneuvers, and approach/departure maneuvers. ADS-B equipped aircraft with CDTI equipment will provide enhanced visual acquisition of other ADS-B equipped aircraft to pilots for situational awareness and collision avoidance. Pilots and controllers will have common situational awareness for shared separation responsibility to improve safety and efficiency. When operationally advantageous, pilots in ADS-B equipped aircraft may obtain approval from controllers for pair-wise or approach/departure maneuvers. In the future, en route controllers in centers with significant radar coverage gaps will provide more efficient tactical separation to ADS-B equipped aircraft in non-radar areas. The received ADS-B surveillance data will enable controllers to "see" ADS-B equipped aircraft and reduce separation standards in areas where they previously used procedural control. The end-to-end connectivity diagram for ADS-B is shown in Figure 3.2-7.

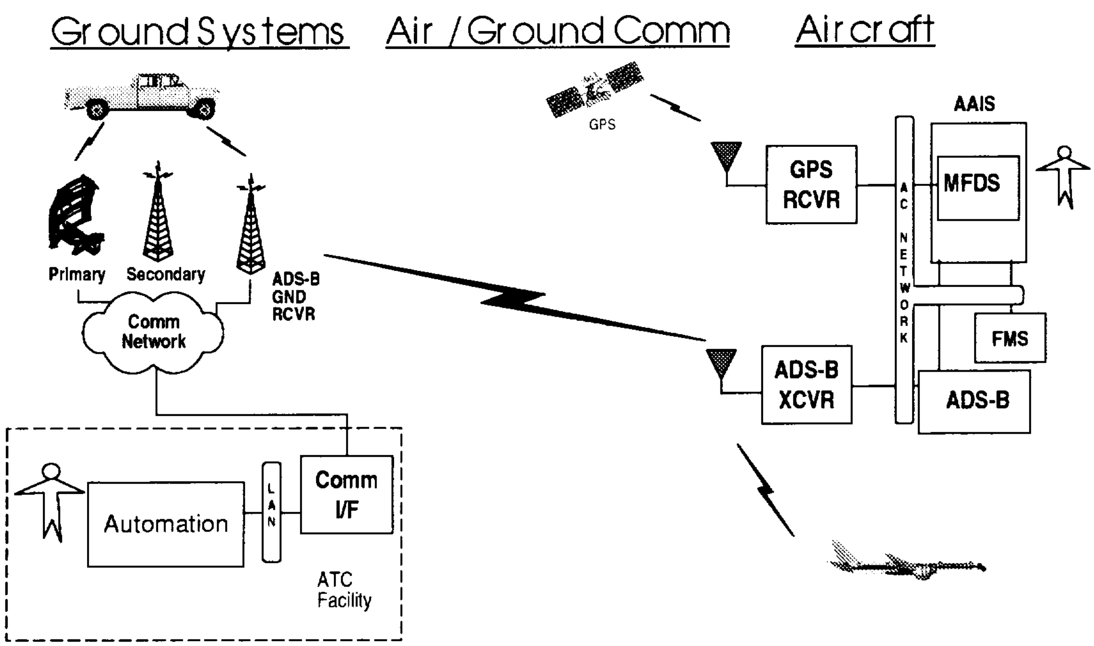

Figure 3.2-7. ADS-B Connectivity Diagram in 2007

ADS-B messages containing identification, state vector, intent, status and other information are assembled by aircraft avionics. ADS-B equipped aircraft broadcast the assembled messages over the ADS-B link twice per second (worst case) for reception by other ADS-B equipped aircraft or ATC ground stations. ADS-B equipped aircraft receive the messages over an air-air communication link, process the data, and display it on the cockpit display for improving situational awareness of the pilot. The aircraft automation function processes the intent and track data for other aircraft, performs collision management, and displays traffic and DSS information to the pilot to support air-air operations such as pair-wise maneuvers and collision avoidance.

ATC ground stations receive messages from ADS-B equipped aircraft over the air-ground communication link, process the messages, and send them to the responsible ATC facility. ADS-B and other primary and secondary surveillance data are processed by ATC automation along with ADS-B intent data to provide controllers with the necessary displays and controls to perform separation assurance and other ATC services. The ADS-B message content is consistent with the MASPS for ADS-B (RTCA/DO-242). ADS-B messages are designed to be flexible and expandable to accommodate potential ADS-B applications that are not yet designed. The surveillance data portion of an ADS-B message is used to support tactical and advisory ATC services, while the intent and other portions of an message supports more strategic services such as traffic synchronization.

While the emphasis in this architecture is on ADS-B, Automatic Dependent Surveillance - Addressable (ADS-A) is used in the oceanic domain and other remote areas such as Alaska. ADS-A will provide surveillance of intercontinental flights in oceanic airspace using a HF data link or satellite communications. Aircraft equipped with future navigation systems such as FANS-1A or ATN avionics will exchange information such as identification, flight level, position, velocity, and short-term intent with ADS-A ground equipment in oceanic Air Route Traffic Control Centers. Ground equipment and automation will display the aircraft position and track to oceanic controllers that will allow current oceanic lateral and longitudinal separation standards to be reduced for properly equipped aircraft.

Additionally, controller will permit aircraft pairs equipped with ADS-B avionics to perform pair-wise maneuvers such as in-trail climbs or descents in selected oceanic airspace.

As part of the NAS Architecture, ADS-B will be deployed in a phased approach consistent with aviation community needs, FAA priorities, and projected budgets. In general, for each ADS-B operational environment, experiments and prototype demonstrations conducted as part of Safe Flight 21 lead to operational key site deployments. Key site deployments represent the increment where operational procedures and certified systems are used to deliver daily service. Following key site deployment, additional "pockets" of ADS-B will be deployed on a benefits-driven basis. These deployments eventually could result in national deployment. In the 2007 time frame initial deployment will be started for the "pocket" areas. Much of the initial ADS-B deployment will enable air-to-air use of ADS-B in selected airspace to demonstrate operational feasibility and achievement of estimated benefits. The extent of aircraft equipage and demand from the aviation community will be a factor in determining the strategy for deployment of ADS-B ground stations.

Our communication load analysis for ADS-B is shown in Table 3.2-13 and Section 4.6. Note that ADS-B is broadcast to all aircraft and ground stations within the range of the transmitter, so the communication requirement is not domain specific.

Table 3.2-13. ADS-B Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
ADS-B	4.3	0.9	0.4	5.6

The ADS-B communication link options are shown in Table 3.2-14. The FAA is engaged in a program to evaluate three candidate ADS-B technologies (Mode-S Squitter, UAT, VDL-4) with a link decision expected in 2001. 1090 MHz Extended Squitter is derived from existing Secondary Surveillance Radar (SSR) Mode-S technology. This technology operates on a single frequency (i.e., 1090 MHz) operating at a data rate of 1 Mbps shared with other secondary surveillance radar users. Baseline ICAO standards for 1090 MHz extended squitter exist and RTCA/EUROCAE standards are under development, as well as updates to the existing ICAO standards.

Table 3.2-14. ADS-B Communication Link Options

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continously broadcast their position and intent to enable optimum maneuvering	ADS-B				✓		[✓]	✓		
✓ Acceptable Alternative		[ ] NAS Architecture	○ AATT CSA Recommendation							

Universal Access Transceiver (UAT) is a technology developed by the Mitre Corporation supporting both uplink and downlink broadcast services. UAT would operate on an as-yet-undetermined single dedicated frequency near 1000 MHz (966 MHz is being used for test purposes) at a data rate of 1 Mbps. UAT has been selected as the ADS-B technology in the Alaskan CAPSTONE initiative. Initiation of UAT standards development by RTCA is currently under consideration.

VDL Mode 4 is a technology operating on multiple dedicated VHF channels with a nominal data rate of 19.2 kbps per channel. VDL Mode 4 employs time division multiple access with both a self-organizing mode and a ground managed mode. VDL Mode 4 standards currently are under development by ICAO and EUROCAE.

The FAA, in close cooperation with the aviation community and international organizations, is working to define the operational concepts for ADS-B, evaluate the three candidate ADS-B link technologies, and plan for the transition to ADS-B in the NAS. The most important factor in the successful implementation of ADS-B is the Link Technology Decision scheduled for 2001. The goal is to have a single global ADS-B technology. This goal may not be achieved, but global standards for ADS-B technologies must be developed so ADS-B aircraft can operate both in CONUS and internationally. The Link Technology Decision could result in a combination of the ADS-B technologies. The ADS-B communication links used in the 2007 to 2015 time frame will depend on the link decision.

Technology Gap

A potential ADS-B technology gap is the human factors for display of ADS-B aircraft. A human factors study should be performed to define the symbology and content of controller and pilot displays. The symbology should indicate the source and quality of the positional data to support different operations and separation standards for normal or degraded operations.

Another potential gap is the availability of ADS-B communication avionics compatible with the technology or combination of technologies that result from the Link Technology Decision. Standards are already in work for the three potential ADS-B technologies. There could be additional work to define integrated standards if a combination of ADS-B technologies is selected.

3.2.7 Airline Operational Control Data Link (AOCDL)

Aircraft Operational Control (AOC) – Pilot/Aircraft – AOC data exchange supports efficient air carrier/air transport operations and maintenance. The AOC's prime responsibility is to ensure the safety of flight and to operate the aircraft fleet in a legal and efficient manner. The AOC's business responsibility requires that the dispatcher conduct individual flights (and the entire schedule) efficiently to enhance the business success and profitability of the airline. Most major airlines operate a centralized AOC function at an operations center that is responsible for worldwide operations. Typical AOC data exchange supports airline operations (OOOI, flight data, position reporting, etc.) and maintenance (performance, diagnostic, etc.) Figure 3.2-8 depicts the major elements of AOCDL. The AOCDL communication links are shown in Table 3.2-15.

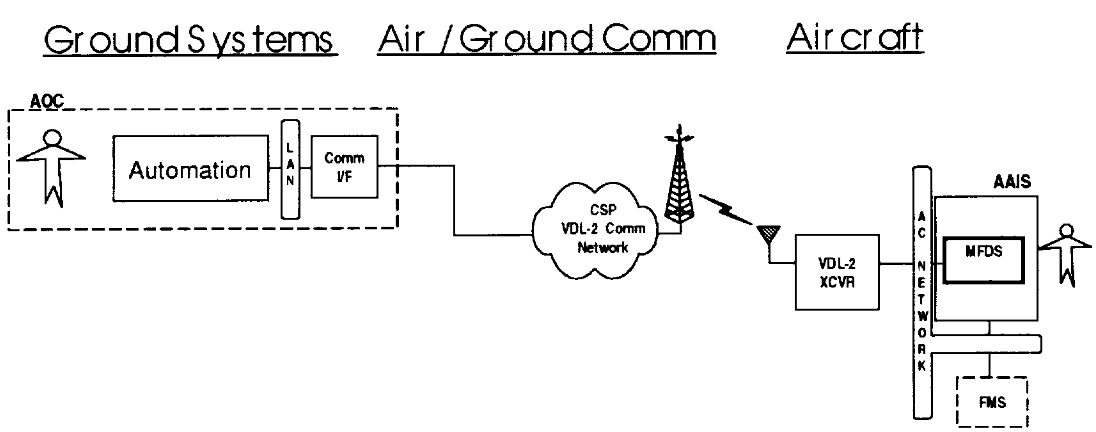

Figure 3.2-8. AOC Data Link in 2007

ASSUMPTION

A majority of current ACARS users will migrate to VDL-2 use by 2007.

Table 3.2-15. AOCDL Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Pilot - AOC data exchange supports efficient air carrier/air transport operations and maintenance	AOCDL		✓					✓		✓

✓ Acceptable Alternative   ☐ NAS Architecture   ◯ AATT CSA Recommendation

In the 2007 time frame, the AOC data link is the only ATN compliant link available. Our communication loading analysis for AOCDL by domain is shown in Table 3.2-16.

Table 3.2-16. AOCDL Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
AOCDL	7.4	7.6	0.6	
Worst Case	29.4 (4)	7.6 (1)	0.6 (1)	37.6

Note: (x) is domain multiplier

Our communication load analysis, summarized in Table 3.2-16, projects peak loading for AOCDL from 0.6-7.6 kbps. Because frequency assignments for AOCDL are not based on domain (although volume of messages is), it is necessary to consider the communication load generated in a worst case area, such as one including en route airspace, a consolidated TRACON, and four airports. This environment requires 37.6 kbps. The current plan for AOCDL is to use four 25kHz frequencies to support AOCDL. Each frequency when used in a VDL-2 mode provides an effective data rate of 19.2 kbps. Thus we can expect 76.8 kbps from four channels. This is sufficient to support the projected demand in any environment in 2007. This merits more detailed analysis, since only four VDL-2 channels are expected to support the AOCDL communications load and the CPDLC/DSSDL loads as mentioned earlier; this combined load would require a capacity of 51.2 kbps. Our projected demand justifies serious consideration of other high performance communication links, most especially SATCOM. Costs for two-way SATCOM service may be attractive for the AOCs if it is coupled with some form of APAXS that make it cost competitive with VDL-2.

Technology Gap

Given our projections for communications loading it is likely that some of the channels may operate near saturation. Research should be conducted to establish a means to sense channel overload and provide for a controlled degradation of service. There are no technology gaps for implementation of AOC data link via VDL-2. Technology gaps would exist however, should implementation over another communication link be chosen. Use of satellite communication links requires the demonstration of aeronautical mobile technologies for antenna, receivers, link algorithms, protocols, and standards. A major technology focus for broadband communications services is the need to provide more bandwidth (with a focus on Ka-band). Given the migration to these frequencies, the need exists for higher efficiency transmitters (both space and terrestrial), more adaptive bandwidth versus power efficient modulation, forward error correction coding (including turbo codes and bit/modulation symbol interleaving), and much expanded use of variable bit rate formats and dynamic multiplexing techniques such as asynchronous transfer mode

(ATM) based technologies. Antennas and receivers must be adapted for the aviation market (size, weight, cost) and must overcome the problems of rain attenuation.

3.2.8 Automated Meteorological Transmission (AUTOMET)

AUTOMET definition is currently under the auspices of the RTCA SC 195 which has developed Minimum Interoperability Standards (MIS) for Automated Meteorological Transmission (RTCA DO-252) for wind, temperature, water vapor and turbulence. Conceptually, aircraft participating in an AUTOMET service program must be able to respond to AUTOMET commands issued by a ground-based command and control system. Downlink message parameters (e.g., frequency, type, etc) are changed by uplink commands from the ground-based systems and are triggered by various conditions (agreed to in advance by the airline, service provider and NWS), or by a request from an end user. Goals of the AUTOMET system are: 1) Increase the amount of usable weather data that is provided to the weather user community; 2) Increase the resolution of reports, forecast products and hazardous weather warnings to make providers of weather information more operationally efficient; 3) Increase the knowledge of the state of the atmosphere and decrease controller workload by automatically transmitting hazardous weather conditions to the ground and other aircraft to improve the ATC system.

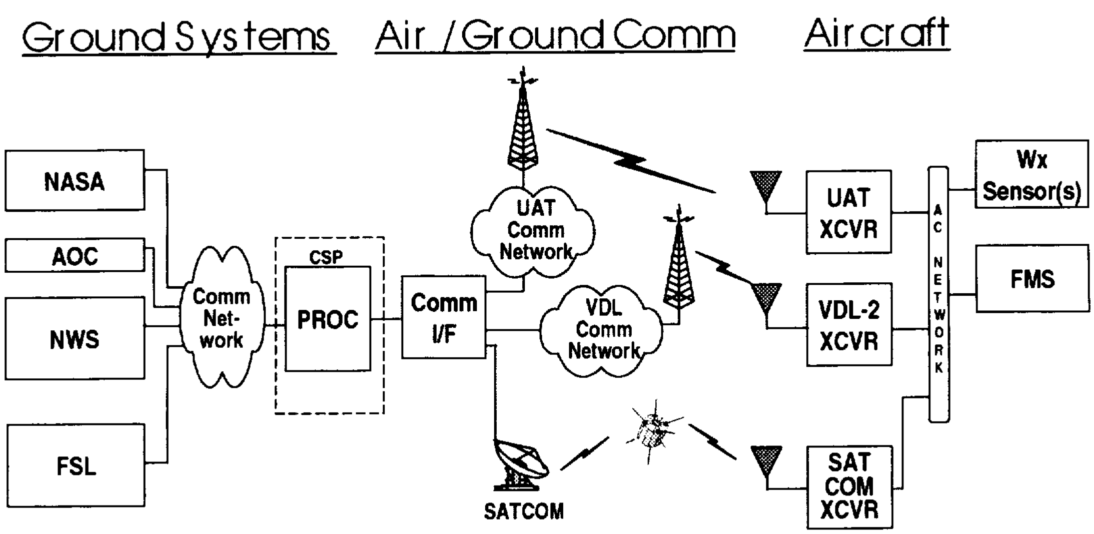

Figure 3.2-9. Automated Meteorological Transmission (AUTOMET) in 2007

The AUTOMET communication links are shown in Table 3.2-17. For aircraft weather reporting using AUTOMET, a number of aircraft collect wind, temperature, humidity, and turbulence information in flight and automatically relay the information to a commercial service provider using VDL Mode 2. The service provider collects and reformats the information and then forwards the information to the National Weather Service (NWS). The NWS uses this AUTOMET information and weather data from other sources to generate gridded weather forecasts. The improved forecasts are distributed to airlines and the FAA to assist in planning flight operations. The gridded weather data, based on AUTOMET data, is also provided to WARP, for use by FAA meteorologists and by several ATC decision support system tools to improve their predictive performance.

Table 3.2-17. AUTOMET Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft report airborne weather to improve weather nowcasting/forecasting	AUTOMET		✓					✓		✓
✓ Acceptable Alternative		☐ NAS Architecture ◯ AATT CSA Recommendation								

Our communication loading analysis for AUTOMET is shown in Table 3.2-18 for each domain. The data in this table indicates that the downlink of all potential AUTOMET products in all domains could potentially saturate the capacity of a VDL-2 channel (19.2 kbps) in conjunction with other messages on the link. In all likelihood AUTOMET data will be downlinked on whatever data link is used to support AOCDL. Thus, if both AOCDL and AUTOMET are combined, along with CPDLC, the capacity of VDL-2 may be exceeded. Methods to filter or compress the amount of data sent to the ground to limit the probability of saturating the VDL-2 channel may be needed. If AOCDL moves to SATCOM, however, there will be sufficient capacity to handle all projected AUTOMET data. As AUTOMET is mainly focused on GA aircraft though a move to SATCOM would bring with it the technology gaps associated with SATCOM.

Table 3.2-18. AUTOMET Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
AUTOMET	N/A	1.2	1.7	
Worst Case	N/A	1.2 (1)	1.7 (1)	2.9

Note: (x) is domain multiplier

Technology Gap

With the potential gaps notes above, from an air/ground communications standpoint, work is currently underway to develop standards for the implementation of AUTOMET. From an avionics perspective, further research could be performed to develop a sensor package that requires no calibration by the pilot or aircraft owner. It is essential to ensure that the data delivered from an AUTOMET sensor be accurate at all times in order to maintain the integrity of the forecast model.

3.2.9 Aeronautical Passenger Services (APAXS)

Passengers enjoy in-flight television, radio, entertainment, telephone, and Internet services. Our analysis of communication trends indicates that there will be a commercial demand for real-time television, radio, and Internet service to airline passengers. Industry surveys have shown that while prerecorded programs and movies are a lower priority for passengers than reading, sleeping, and working, there always has been a high interest in live television. One service provider had surveys conducted that indicated 50% of respondents were interested, and 35% would be willing to pay $3-5 per flight for live television – the principal interest being in Cable News Network (CNN). This demand for service most likely will be satisfied through digital, high-data-rate satellite channels. Figure 3.2-10 depicts the major elements of APAXS.

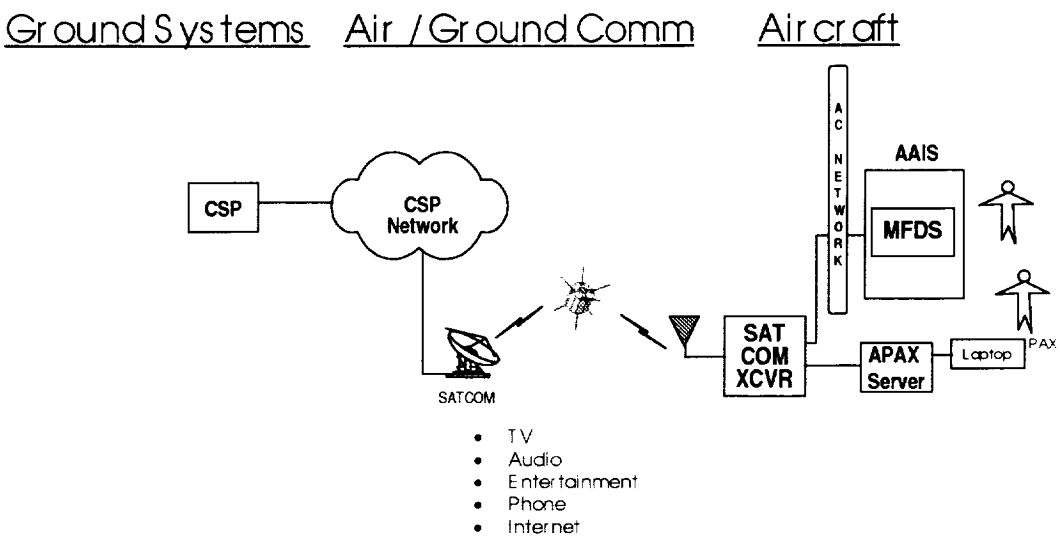

Figure 3.2-10. Aeronautical Passenger Services in 2007

ASSUMPTION

Commercial demand will drive satellite service for the aircraft.

While APAXS is not a service associated with any air traffic management function, it is likely that commercial demand will have driven direct broadcast satellite service to be available in the cabin as early as 2007. This availability is particularly important to note since it may provide an opportunity to support air traffic services that would not be possible otherwise. The APAXS communication links are shown in Table 3.2-20. Note, there are no plans for this in the current NAS architecture.

Table 3.2-19. APAXS Load Analysis Results (kilobits per second)

	En Route Uplink	En Route Downlink
APAXS – Domain	33	29
APAXS – CONUS	669	587

Table 3.2-20. APAXS Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Passengers enjoy in-flight television, radio, telephone, and internet service	APAXS								✓	✓
✓ Acceptable Alternative		☐ NAS Architecture ◯ AATT CSA Recommendation								

Accordingly, we recommend that further study be conducted to determine the possibility for innovative partnerships or incentives that may leverage the involvement of commercial service providers in the delivery of selected air traffic services. For example, providers of broadcast entertainment channels to aircraft could be required to provide an air traffic services channel that is freely accessible by all aircraft.

This example is similar to the requirement that cable television providers have with respect to public access channels.

A freely accessible high-data-rate channel could be used to provide FIS and TIS (strategic only) for all aircraft operating in the CONUS region.

Technology Gap

Suitable antenna/receiver design to resolve rain attenuation and provide a suitable (cost, size, weight) solution for all aircraft types.

3.3 2007 Communication System Architecture Link Alternatives Summary

This section provides a summary of the communication links that can be available to support the 2007 CSA. Each link is described in detail in Section 5 of this document and is summarized below in Table 3.3-1.

Table 3.3-1. Capacity Provided by Various Communication Links

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
	kbps	Channels	Channels	Aircraft	
HFDL	1.8	2	1	50	Intended for Oceanic
ACARS	2.4	10	1	25	ACARS should be in decline as users transition to VDL Mode 2
VDL Mode 2	31.5	4+	1	150	System can expand indefinitely as user demand grows
VDL Mode 3	31.5*	~300	1	60	Assumes NEXCOM will deploy to all phases of flight
VDL Mode 4	19.2	1-2	1	500	Intended for surveillance
VDL – B	31.5	2	1	Broadcast	Intended for FIS
Mode-S	1000**	1	1	500	Intended for surveillance
UAT	1000	1	1	500	Intended for surveillance/FIS
SATCOM	-	-	-	-	Assumes satellites past service life
Future SATCOM	384	15	1	~200	Planned future satellite
Future Ka Satellite	2,000	~50	~50	~200	Estimated capability - assumes capacity split for satellite beams
Fourth Generation Satellite	>100,000	>100	>100	Unknown	Based on frequency license filings

* Channel split between voice and data.

** The Mode-S data link is limited to a secondary, non-interference basis with the surveillance function and has a capacity of 300 bps per aircraft in track per sensor (RTCA/DO-237).

A summary of the peak communication loads for 2007 is provided in Table 3.3-2.

Table 3.3-2. **Summary of Peak Communication Loads for 2007 (kbps)**

	Airport Uplink	Airport Downlink	Terminal Uplink	Terminal Downlink	En Route Uplink	En Route Donwlink
FIS	0.2	0.0	0.9	0.0	6.9	0.0
TIS	21.3	0.0	6.4	0.0	18.5	0.0
CPDLC	0.9	0.8	0.3	0.2	0.3	0.3
DSSDL	0.0	0.1	0.0	0.0	0.0	0.0
AOC	0.4	7.0	0.5	7.1	0.2	2.9
ADS Reporting	0.0	4.3	0.0	0.9	0.0	0.4
AUTOMET	0.0	0.0	0.0	1.2	0.0	1.7
APAX	0.0	0.0	0.0	0.0	29.2	25.6

The NAS requires a voice capability, a two-way data messaging capability, and a broadcast data exchange capability. The broadcast data exchange capability supports the establishment of an air-ground information base. The technical concepts that support this information base are FIS, TIS, ADS-B, and AUTOMET. For FIS, a commercial service provider will supply FIS products via VDL-2 to the aircraft. TIS is a principal enabler of ADS-B maneuvering and trajectory planning. Hence, the deployment of TIS will parallel that of ADS-B. The current ADS-B deployment strategy calls for implementation in "local pockets" in the 2007 time frame. This strategy would allow the use of VDL-B to support TIS in the interim, although VDL-B is not a viable solution for the long term given the number of VHF frequencies required.

In the current planning described above, a solution for each of these concepts is developed from one of the VHF data links identified in Table 3.3-1. These must be interim solutions, however, as VDL cannot support these concepts at the national level. Clearly, VDL is not the link needed to support an integrated data exchange capability. Candidate links that could meet this integrated data exchange need should be capable of supporting data rates on the order of hundreds of kilobits per second. The absence of a recognized requirement for an integrated broadcast data exchange capability represents the greatest deficiency in today's NAS modernization planning. This capability potentially could be supported by terrestrial- or space-based solutions, each of which would emerge from one of the following paths. A terrestrial-based solution most likely will emerge if UAT is chosen for ADS-B; this solution would drive the establishment of a terrestrial network of UAT transceivers that, given proper planning, could support FIS, TIS, and AUTOMET. A space-based solution most likely will emerge from the demand to place real time television and Internet service in commercial airline cabins. Once again, given proper planning, this could support FIS, TIS, and AUTOMET.

We cannot make a recommendation for FIS, TIS, or ADS-B, because we feel that there is additional research required to provide data sufficient to support a recommendation. An integrated data exchange capability as we discuss in this analysis is not currently envisioned in the NAS Architecture. Additionally, the link decision currently underway on ADS-B can have a significant influence on the overall communication system architecture.

In 2007 there still is a primary reliance on VHF-AM for controller pilot voice communication in the terminal and airport domains. However, we anticipate that as a result of successful Preliminary Eurocontrol Tests of Air/Ground Data Link (PETAL-II) trials in Europe and CPDLC trials in the US, a majority of class 2/3 aircraft operators will modify their multi-mode radios to take advantage of CPDLC in the En Route domain.

Unfortunately, in the 2007 time frame there is only one viable two-way data link to support the CPDLC, DSSDL, AOCDL (and potentially AUTOMET) needs: The VDL-2 service provided on the AOC allocated frequencies. Our communication load analysis, summarized in Table 3.3-2, projects the sum of peak loading for AOCDL of 40.3 kbps. This loading by itself would require three VDL-2 channels to serve a single worst-case geographic area, which raises the question of how the demand for this limited resource will be managed. We know from our analysis in Task 5 that after the FAA converts its air-ground voice network to VDL-3, it will be capable of satisfying the CPDLC and DSSDL demands. Thus, the challenge in the near term is to develop an effective transition strategy that is focused on the desired 2015 goal. From a CPDLC and DSSDL standpoint, our recommendation would be to develop a plan for allocation of additional frequencies (on a temporary basis) to support the interim demand. From an AOCDL standpoint, given the projected demand, serious consideration of other high performance communication links, most especially SATCOM, should be made. Costs for two-way SATCOM service may be attractive for the AOCs if it is coupled with some form of APAXS that make it cost competitive with VDL-2.

Finally, for APAXS, the use of SATCOM will be driven by the commercial industry desire to provide high-data-rate services to passengers. Such services include real time television and Internet access. Air Traffic Service providers should stay aware of these efforts and look for opportunities to exploit this method of data transmission. Accordingly, we recommend that further study be conducted to determine the opportunities for innovative partnerships or incentives that may leverage the involvement of commercial service providers in the delivery of selected air traffic services via SATCOM. For example, providers of broadcast entertainment channels to aircraft could be required to provide an air traffic services channel that is freely accessible by all aircraft. This example is similar to the requirement that cable television providers have with regard to providing public access channels. A summary of the technical concepts and the recommended communication links is shown in Table 3.3-3.

In summary, for the 2007 time frame, a majority of Class 1 aircraft is still equipped with a VHF-AM radio for voice communications. Flight information is provided via a commercial service provider using VDL-B for those aircraft that are equipped.

Class 2 users differ from Class 1 users in that some Class 2 users have access to AOCDL that provides operations and maintenance data via VDL-2. Some Class 2 users will choose to equip for ADS-B based on benefits that they can receive in the areas that they fly. Flight information is provided via a commercial service provider using VDL-B for those aircraft that are equipped.

The Class 3 users will be equipping with multimode radios that support two-way data link communications via VDL-2. Some Class 3 users will choose to equip for ADS-B based on benefits that they can receive in the areas that they fly. Flight information is received via AOCDL using VDL-2 or SATCOM. Two-way SATCOM will be available to support passenger Television and Internet services and may begin to support aircraft-AOC data exchange.

The 2007 AATT Architecture alternatives are shown in Figure 3.3-1 and Figure 3.3-2.

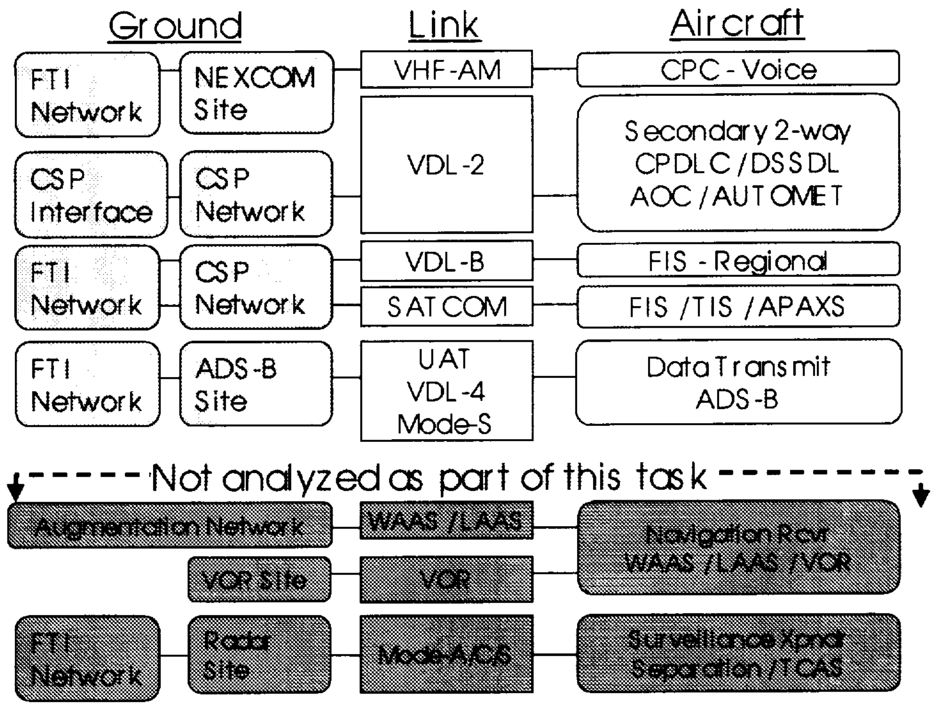

Figure 3.3-1. 2007 AATT Architecture - SATCOM Alternative

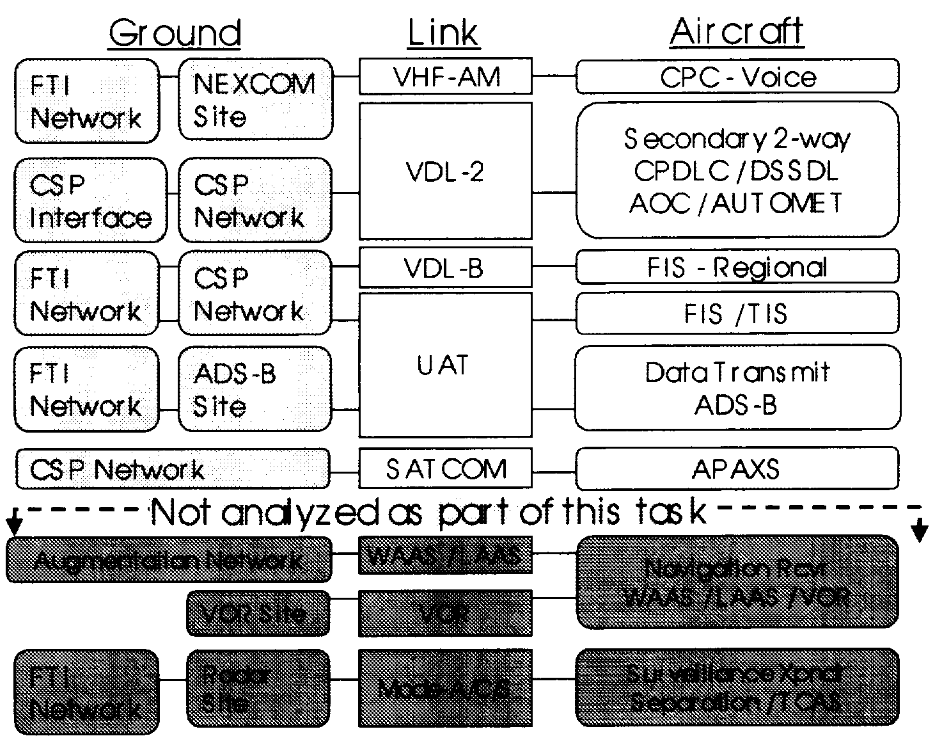

Figure 3.3-2. 2007 AATT Architecture - UAT Alternative

Table 3.3-3. 2007 AATT Technical Concepts to Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Flight Information to enable common situational awareness	FIS					[✓]		✓	✓	
Aircraft continuously receive Traffic Information to enable common situational awareness	TIS					✓	[ ]	✓	✓	
Controller - Pilot voice communication	CPC	[(✓)]								
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	CPDLC		[(✓)]							
Aircraft exchange performance / preference data with ATC to optimize decision support	DSSDL		[(✓)]							
Aircraft continously broadcast their position and intent to enable optimum maneuvering	ADS-B				✓		[✓]	✓		
Pilot - AOC data exchange supports efficient air carrier/air transport operations and maintenance	AOCDL		✓					✓		✓
Aircraft report airborne weather to improve weather nowcasting/forecasting	AUTOMET		✓					✓		✓
Passengers enjoy in-flight television, radio, telephone, and internet service	APAXS								✓	✓

✓ Acceptable Alternative   [ ] NAS Architecture   ( ) AATT CSA Recommendation

4 Communication Loading Analysis

4.1 Air-Ground Communications

The overall approach to the air-ground communications load analysis is illustrated in Figure 4.1-1 and presented in detail in the following sections. Air-ground communications service requirements are addressed in Section 1.2. Air-ground messages and messages per flight are calculated in Section 1.3. Voice message traffic per flight is calculated in section 1.4. Projections for the peak number of flights in 2007 and the total traffic load are calculated in Section 1.5. Section 1.6 addresses air-to-air message traffic.

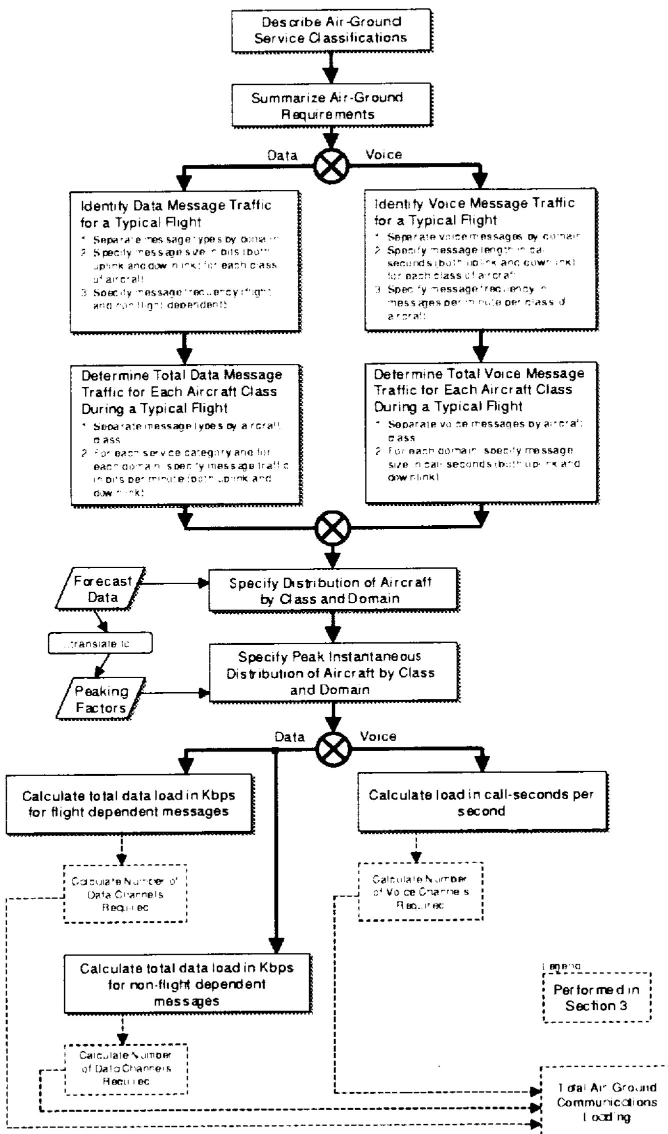

Figure 4.1-1. Communications Load Analysis Method

In this analysis, the term air-ground is used when the direction of the transmission is not relevant. Whenever direction is important, the terms uplink (ground-to-air) and downlink (air-to-ground) are used. The terms message and message traffic are used when the distinction between voice and data messages is not important. Otherwise, the term voice message or data message is used.

All message traffic is assigned to one of nine technical concept categories to simplify calculations and to provide insights that guide the architectural solutions presented in Chapter 3. The technical concept categories are shown in Table 4.1-1 and represent logical groupings of message types based on application and similar communications service requirements.

Table 4.1-1. Air-Ground Technical Concept Classifications

Category.	Technical Concept	Description of Concept
1	Flight Information Services (FIS)	Aircraft continually receive Flight Information to enable common situational awareness
2	Traffic Information Services (TIS)	Aircraft continuously receive Traffic Information to enable common situational awareness
3	Controller-Pilot Data Link Communications (CPDLC)	Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories
4	Controller Pilot Communications (CPC) Voice	Controller - Pilot voice communication
5	Decision Support System Data Link (DSSDL)	Aircraft exchange performance / preference data with ATC to optimize decision support
6	Airline Operational Control Data Link (AOCDL)	Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance
7	Automated Dependent Surveillance (ADS) Reporting	Aircraft continuously transmit data on their position and intent to enable optimum maneuvering
8	Automated Meteorological Reporting (AUTOMET)	Aircraft report airborne weather data to improve weather nowcasting and forecasting
9	Aeronautical Passenger Services (APAXS)	Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service

Throughout the analysis, traffic is segregated by airspace domain and class of aircraft. The domains consist of airport, terminal, en route, and oceanic as defined in Table 4.1-2. By separating traffic loads according to domain, the air-ground communication architecture can be optimized to meet unique regional requirements. The three classes of aircraft are low-end general aviation (Class 1), high-end general aviation and commuter aircraft (Class 2), and commercial carriers (Class 3), as described in Table 4.1-3. The classification by domain and aircraft class gives a more precise traffic load estimate since the number, frequency, and type of message in many cases depends on where the aircraft is and what type of equipage it has. Table 4.1-4 shows the estimated aircraft population in each class that is equipped for a particular technical concept. The percentages in Table 4.1-4 were developed using FAA forecasts and engineering judgement. The values are only approximate but have been specified to the nearest percent to maintain internal consistency.

Table 4.1-2. Airspace Domains

Domain	Definition and Comment*
En route	Airspace in which en route air traffic control services are normally available. The average duration in this domain is 25 minutes per en route center.
Terminal	Airspace in which approach control services are normally available. The average duration in this domain is 10 minutes.
Airport	Airspace, including, runways and other areas used for taxiing, takeoff, and landing, in which tower control services are normally available. The average duration in this domain is 10 minutes.
Oceanic	Airspace over the oceans of the world, considered international airspace, where oceanic separation and procedures per the International Civil Aviation Organization are applied. The average duration in this domain is 180 minutes.

*Average duration of flights are taken from *Aeronautical Spectrum Planning for 1997-2010*, RTCA/DO-237, January 1997, p. F-4.

Table 4.1-3. Aircraft Classes

Class of Aircraft	Definition and Comment
Class 1	Operators who are required to conform to FAR Part 91 only, such as low-end General Aviation (GA) operating normally up to 10,000 ft. This class includes operators of rotorcraft, gliders, and experimental craft and any other user desiring to operate in controlled airspace below 10,000 ft. The primary distinguishing factor of this class is that the aircraft are smaller and that the operators tend to make minimal avionics investments.
Class 2	Operators who are required to conform to FAR Parts 91 and 135, such as air taxis and commuter aircraft. It is likely that high-end GA and business jets and any other users desiring to operate in controlled airspace will invest in the necessary avionics to be able to achieve the additional benefits.
Class 3	Operators who are required to conform to FAR Parts 91 and 121, such as Commercial Transports. This class includes passenger and cargo aircraft and any other user desiring to operate in controlled airspace. These users will invest in the avionics necessary to achieve the additional benefits.

Table 4.1-4. Percent of Aircraft Equipped for Each Technical Concept in 2007

Technical Concept	Class 1	Class 2	Class 3
FIS	16%	22%	24%
TIS	16%	20%	27%
CPDLC	14%	23%	29%
CPC (voice)	100%*	100%	100%
DSSDL	3%	10%	21%
AOCDL	0%	5%	51%
ADS Reporting	16%	20%	27%
AUTOMET	16%	22%	24%
APAXS	1%	1%	14%

*Aircraft that are not equipped with a radio are excluded from the CSA

4.2 Air-Ground Communications Service Requirements

General communications service requirements include priority, call setup time, latency, availability, restoration times, and NAS interfaces. Availability and restoration times depend on NAS priority level.

which in turn drive the level of link redundancy needed. Table 4.2-1 shows requirements for each technical concept.

Table 4.2-1. Air-Ground Service Requirements

Technical Concept.	Priority	Availability Restoration Time	Call Setup Time	Latency End to End	Aircraft Interface
FIS	Routine	0.99 1.7 hour	≤10 sec	~10 sec	FAA NWIS Network
TIS	Critical, Essential	0.99999 6 seconds	≤ 5 sec	~1 sec	FAA Surveillance Network
CPDLC	Critical	0.99999 6 seconds	≤ 5 sec	~1 sec	FAA Air-Ground Com Network
CPC	Critical	0.99999 6 seconds	≤ 5 sec	~400 msec	FAA Air-Ground Com Network
DSSDL	Essential	0.999 10 minutes	≤ 5 sec	~1 sec	ATC Automation
AOCDL	Routine	0.99 1.7 hour	≤ 10 sec	~10 sec	Commercial Service Provider
ADS	Critical	0.99999 6 seconds	≤ 5 sec	~1 sec	Surveillance Network
AUTOMET	Routine	0.99 1.7 hour	≤ 30 sec	~10 sec	Commercial Service Provider
APAXS	Routine	0.99 1.7 hour	≤ 30 sec	~10 sec	Commercial Service Provider

The NAS System Requirements Specification defines priority levels as follows:

- Critical services are those which, if lost, would prevent the NAS from exercising safe separation and control of aircraft. For critical services the availability goal is 0.99999 and the goal for service restoral time is 6 seconds.
- Essential services are those which, if lost, would reduce the capability of the NAS to exercise safe separation and control of aircraft. For essential services the availability goal is 0.999 and the goal for service restoral time is 10 minutes.
- Routine services are those which, if lost, would not significantly degrade the capability of the NAS to exercise safe separation and control of aircraft. For routine services the availability goal is 0.99 and the goal for service restoral time is 1.68 hours.

Coverage requirements for air-ground services are assumed to be:

- Fully redundant coverage for continental United States (CONUS), Hawaii, Alaska, Caribbean islands, Canada, Mexico, and Central and South America.
- Single coverage over the Pacific and Atlantic Ocean regions (redundant coverage is assumed to be provided by other CAAs and by commercial service providers
- Single coverage over the polar regions

All voice traffic in 2007 is assumed to be analog.

Oceanic communications requirements are somewhat relaxed from en route requirements. Availability for critical communications is assumed to be 0.9999 with a restoral time of 6 seconds and a message latency of 10 seconds.

These service requirements are used in the load analysis for purposes of grouping messages with similar service and delivery requirements. They are also used to select communications link technologies and develop of the overall architecture presented in Chapter 3. The latency requirement in Table 4.2-1, for example, would appear to preclude the use of geosynchronous satellites for critical voice services (CPC voice) due to satellite propagation delays, which exceed 200 milliseconds. Although latency is considered a "soft" requirement in this analysis, the architecture solution in Chapter 3 does not use geosynchronous satellites for CPC voice service because of the excessive propagation delay.

4.3 Air-Ground Data Message Traffic Requirements

Information on message sizes and frequencies came from a number of sources. A unique message identifier (Msg ID), shown in Table 4.3-1, is assigned to the various message types to simplify the analysis. In some cases, these message types represent specific messages with a fixed length and repetition rate. In general, however, message types are merely representative of the type and the characteristics are simply an average.

Table 4.3-1. Message Types and Message Type Identifiers

Message Type Identifier	Message Type
M1	ADS
M2	Advanced ATM
M3	Air Traffic Information
M4	Not used – See M43, M44
M5	Airline Business Support: Electronic Database Updating
M6	Airline Business Support: Passenger Profiling
M7	Airline Business Support: Passenger Re-Accommodation
M8	Airline Maintenance Support: Electronic Database Updating
M9	Airline Maintenance Support: In-Flight Emergency Support
M10	Airline Maintenance Support: Non-Routine Maintenance/ Information Reporting
M11	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)
M12	Airline Maintenance Support: Routing Maintenance/ Information Reporting
M13	Arrival ATIS
M14	Not used – See M43, M44
M15	Convection
M16	Delivery of Route Deviation Warnings
M17	Departure ATIS
M18	Destination Field Conditions
M19	Diagnostic Data
M20	En Route Backup Strategic General Imagery
M21	FIS Planning – ATIS
M22	FIS Planning Services
M23	Flight Data Recorder Downlinks
M24	Flight Plans
M25	Gate Assignment

Message Type Identifier	Message Type
M26	General Hazard
M27	Icing
M28	Icing/ Flight Conditions
M29	Low Level Wind Shear
M30	Out/ Off/ On/ In
M31	Passenger Services: On Board Phone
M32	Pilot/ Controller Communications
M33	Position Reports
M34	Pre-Departure Clearance
M35	Radar Mosaic
M36	Support Precision Landing
M37	Surface Conditions
M38	TFM Information
M39	Turbulence
M40	Winds/ Temperature
M41	System Management and Control
M42	Miscellaneous Cabin Services
M43	Aircraft Originated Ascent Series Meteorological Observations
M44	Aircraft Originated Descent Series Meteorological Observations

Each message type is mapped to an aircraft class and airspace domain based on information in the reference source and expert knowledge. The messages are further assigned to technical concept categories to aid in the presentation of data and to simplify the communications architecture design process.

Some message types are extremely large and compression is required in order to reduce communications loads. The compression ratios assumed in this analysis are shown in Table 4.3-2. In some cases, the same message is sent with different compression ratios because the required resolution is not the same in all domains (e.g., M15 and M28). Note that all traffic loading data presented in this chapter has been compressed according to Table 4.3-2 and no further compression should be applied.

Throughout the analysis voice and data traffic are treated separately to deal with the unique requirements each imposes on the communications architecture.

Table 4.3-2. Data Compression Factors Used (1:1 assumed for all other messages)

Domain	Msg ID	Compression*
Terminal Tactical	M18	10:1
	M20	10:1
	M27	10:1
	M29	10:1
	M37	20:1
Terminal Strategic	M15	50:1
	M28	50:1
	M35	10:1
En Route Tactical	M39	50:1

Domain	Msg ID	Compression*
En Route Near Term Strategic	M15 M26 M28 M37 M39	20:1 20:1 20:1 20:1 20:1
En Route Far Term Strategic	M15 M26 M28	50:1 50:1 50:1

**Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase I Report, Aviation Weather Communications Requirements*, Lockheed Martin Aeronautical Systems

4.3.1 Data Message Traffic per Flight

Data message traffic tables are developed for each class of aircraft based on the particular set of messages required by that class in a given domain. Note that frequency units are expressed in terms of messages per flight or messages per minute per flight, depending on the nature of the communications. For messages that occur on a periodic basis and are independent of the number of aircraft, frequencies are expressed in terms of messages per minute. These non-flight dependent messages are listed in a separate table (see Table 4.3-6) and only added the total communications load after other calculations are completed. The largest common unit used to express message frequencies and flight times was a minute; this time unit was chosen as the basic unit for all calculations because it helps to distinguish between traffic loads channel data rates.

Data message traffic by flight for each class of aircraft is summarized in Table 4.3-3, Table 4.3-4, and Table 4.3-5. These tables do not represent peak traffic, but rather the expected traffic with departures and arrivals evenly distributed within each domain. All message sizes are expressed in bits.

Table 4.3-3. Data Message Traffic for Class 1 Aircraft (flight dependent)*

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
FIS	M17	En Route	1 msg/flt	3200	1 msg/flt	64
	M21	Terminal	1 msg/flt	400	1 req/flt	56
	M22	Airport	1 msg/10 sec	2100	1 req/flt	64
	M22	Terminal	1 msg/10 sec	2000	6 req/flt	64
	M22	En Route	1 msg/10 sec	2000	4 req/flt	64
	M28	En Route	1 msg/flt	45000	N/A	N/A
CPDLC	M32	Airport	10 msg/flt	123	10 msg/flt	32
	M32	Terminal	9.6 msg/flt	123	13.1 msg/flt	32
	M32	En Route	10.2 msg/flt	118	17.4 msg/flt	34
	M34	Airport	1.25 msg/flt	1800	2.25 msg/flt	304
	M41	Airport	5 msg/flt	720	4 msg/flt	720
	M41	Terminal	2 msg/flt	720	1 msg/flt	720
	M41	En Route	6 msg/flt	720	5 msg/flt	720
DSSDL	M16	Airport	1 msg/5 flts	800	1 msg/5 flts	800
	M16	Terminal	1 msg/5 flts	800	1 msg/5 flts	800
	M16	En Route	1 msg/5 flts	800	1 msg/5 flts	800
	M2	Airport	1 msg/flt	40	1 msg/flt	960

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
DSSDL	M2	Terminal	1 msg/flt	40	1 msg/flt	960
	M2	En Route	1 msg/flt	40	1 msg/flt	960
	M38	Airport	2 msg/flt	800	2 msg/flt	800
	M38	Terminal	1 msg/2 flt	800	1 msg/2 flt	100
	M38	En Route	1 msg/flt	800	1 msg/flt	100
ADS Reporting	M1	Airport	1 msg/flt	128	1 msg/1.1 sec	144
	M1	Terminal	1 msg/flt	128	1 msg/5.33 sec	144
	M1	En Route	1 msg/flt	128	1 msg/12.1 sec	144
AUTOMET	M14	Airport	N/A	N/A	10 msg/flt	430
	M14	Terminal	N/A	N/A	3 msg/minute	430
	M14	En Route	N/A	N/A	1 msg/15 minutes	430
	M4	Terminal	1 msg/flt	56	1 msg/5 minutes	1760
	M4	En Route	1 msg/flt	56	1 msg/5 minutes	1760
	M43	Terminal	1 msg/flt	56	3 msg/min	512
	M43	En route	1 msg/flt	56	1 msg/6 min	2152
	M44	En Route	1 msg/flt	56	1 msg/2min	3544

*Compressed per Table 4.3-2

Table 4.3-4. Data Message Traffic for Class 2 Aircraft (flight dependent)*

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
FIS	M17	En Route	1 msg/flt	3200	1 msg/flt	64
	M21	Terminal	1 msg/flt	400	1 req/flt	56
	M22	Airport	1 msg/10 sec	2100	1 req/flt	64
	M22	Terminal	1 msg/10 sec	2000	6 req/flt	64
	M22	En Route	1 msg/10 sec	2000	4 req/flt	64
	M28	En Route	1 msg/flt	45000		
CPDLC	M32	Airport	10 msg/flt	123	10 msg/flt	32
	M32	Terminal	9.6 msg/flt	123	13.1 msg/flt	32
	M32	En Route	10.2 msg/flt	118	17.4 msg/flt	34
	M34	Airport	1.25 msg/flt	1800	2.25 msg/flt	304
	M41	Airport	5 msg/flt	720	4 msg/flt	720
	M41	Terminal	2 msg/flt	720	1 msg/flt	720
	M41	En Route	6 msg/flt	720	5 msg/flt	720
DSSDL	M16	Airport	1 msg/5 flts	800	1 msg/5 flts	800
	M16	Terminal	1 msg/5 flts	800	1 msg/5 flts	800
	M16	En Route	1 msg/5 flts	800	1 msg/5 flts	800
	M2	Airport	1 msg/flt	40	1 msg/flt	960
	M2	Terminal	1 msg/flt	40	1 msg/flt	960
	M2	En Route	1 msg/flt	40	1 msg/flt	960
	M38	Airport	2 msg/flt	800	2 msg/flt	800
	M38	Terminal	1 msg/2 flt	800	1 msg/2 flt	100
	M38	En Route	1 msg/flt	800	1 msg/flt	100

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
AOCDL	M10	Terminal	3 msg/flt	480	3 msg/flt	10400
	M11	Airport	6 msg/flt	480	6 msg/flt	10080
	M11	Terminal	6 msg/flt	480	6 msg/flt	10080
	M11	En Route	6 msg/flt	480	6 msg/flt	10080
	M12	Airport	3 msg/flt	480	3 msg/flt	10400
	M12	Airport	3 msg/flt	480	3 msg/flt	5200
	M12	Terminal	3 msg/flt	480	3 msg/flt	5200
	M12	En Route	3 msg/flt	480	3 msg/flt	10400
	M12	En Route	3 msg/flt	480	3 msg/flt	5200
	M19	Terminal	N/A	N/A	1 msg/min	50
	M19	En Route	N/A	N/A	1 msg/min	50
	M23	En Route	N/A	N/A	1 msg/flt	3000
	M25	Airport	1 msg/flt	10	1 msg/flt	10
	M30	Airport	1 msg/flt	10	1 msg/flt	10
	M30	Terminal	1 msg/flt	10	1 msg/flt	10
	M33	En Route	2 msg/flt	10	2 msg/flt	80
	M8	Airport	3 msg/flt	480	3 msg/flt	10400
	M8	Terminal	3 msg/flt	480	3 msg/flt	10400
	M8	En Route	3 msg/flt	480	3 msg/flt	10400
	M9	Terminal	1 msg/flt	2600	4 msg/flt	240
	M9	En Route	1 msg/flt	2600	4 msg/flt	240
ADS Reporting	M1	Airport	1 msg/flt	128	1 msg/1.1 sec	144
	M1	Terminal	1 msg/flt	128	1 msg/5.33 sec	144
	M1	En Route	1 msg/flt	128	1 msg/12.1 sec	144
AUTOMET	M14	Airport	N/A	N/A	10 msg/flt	430
	M14	Terminal	N/A	N/A	3 msg/minute	430
	M14	En Route	N/A	N/A	1 msg/15 minutes	430
	M4	Terminal	1 msg/flt	56	1 msg/5 minutes	1760
	M4	En Route	1 msg/flt	56	1 msg/5 minutes	1760
	M43	Terminal	1 msg/flt	56	3 msg/min	512
	M43	En route	1 msg/flt	56	1 msg/6 min	2152
	M44	En Route	1msg/flt	56	1 msg/2min	3544

*Compressed per Table 4.3-2

Table 4.3-5. Data Message Traffic for Class 3 Aircraft (flight dependent)*

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
FIS	M17	En Route	1 msg/flt	3200	1 msg/flt	64
	M21	Terminal	1 msg/flt	400	1 req/flt	56
	M22	Airport	1 msg/10 sec	2100	1 req/flt	64
	M22	Terminal	1 msg/10 sec	2000	6 req/flt	64
	M22	En Route	1 msg/10 sec	2000	4 req/flt	64
	M28	En Route	1 msg/flt	45000	N/A	N/A
CPDLC	M32	Airport	10 msg/flt	123	10 msg/flt	32
	M32	Terminal	9.6 msg/flt	123	13.1 msg/flt	32
	M32	En Route	10.2 msg/flt	118	17.4 msg/flt	34
	M34	Airport	1.25 msg/flt	1800	2.25 msg/flt	304
	M41	Airport	5 msg/flt	720	4 msg/flt	720
	M41	Terminal	2 msg/flt	720	1 msg/flt	720
	M41	En Route	6 msg/flt	720	5 msg/flt	720

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
DSSDL	M16	Airport	1 msg/5 flts	800	1 msg/5 flts	800
	M16	Terminal	1 msg/5 flts	800	1 msg/5 flts	800
	M16	En Route	1 msg/5 flts	800	1 msg/5 flts	800
	M2	Airport	1 msg/flt	40	1 msg/flt	960
	M2	Terminal	1 msg/flt	40	1 msg/flt	960
	M2	En Route	1 msg/flt	40	1 msg/flt	960
	M38	Airport	2 msg/flt	800	2 msg/flt	800
DSSL	M38	Terminal	1 msg/2 flt	800	1 msg/2 flt	100
	M38	En Route	1 msg/flt	800	1 msg/flt	100
AOCDL	M10	Terminal	3 msg/flt	480	3 msg/flt	10400
	M11	Airport	6 msg/flt	480	6 msg/flt	10080
	M11	Terminal	6 msg/flt	480	6 msg/flt	10080
	M11	En Route	6 msg/flt	480	6 msg/flt	10080
	M12	Airport	3 msg/flt	480	3 msg/flt	10400
	M12	Airport	3 msg/flt	480	3 msg/flt	5200
	M12	Terminal	3 msg/flt	480	3 msg/flt	5200
	M12	En Route	3 msg/flt	480	3 msg/flt	10400
	M12	En Route	3 msg/flt	480	3 msg/flt	5200
	M19	Terminal	N/A	N/A	1 msg/min	50
	M19	En Route	N/A	N/A	1 msg/min	50
	M23	En Route	N/A	N/A	1 msg/flt	3000
	M25	Airport	1 msg/flt	10	1 msg/flt	10
	M30	Airport	1 msg/flt	10	1 msg/flt	10
	M30	Terminal	1 msg/flt	10	1 msg/flt	10
	M33	En Route	2 msg/flt	10	2 msg/flt	80
	M8	Airport	3 msg/flt	480	3 msg/flt	10400
	M8	Terminal	3 msg/flt	480	3 msg/flt	10400
	M8	En Route	3 msg/flt	480	3 msg/flt	10400
	M9	Terminal	1 msg/flt	2600	4 msg/flt	240
	M9	En Route	1 msg/flt	2600	4 msg/flt	240
ADS Reporting	M1	Airport	1 msg/flt	128	1 msg/1.1 sec	144
	M1	Terminal	1 msg/flt	128	1 msg/5.33 sec	144
	M1	En Route	1 msg/flt	128	1 msg/12.1 sec	144
AUTOMET	M14	Airport	N/A	N/A	10 msg/flt	430
	M14	Terminal	N/A	N/A	3 msg/minute	430
	M14	En Route	N/A	N/A	1 msg/15 minutes	430
	M4	Terminal	1 msg/flt	56	1 msg/5 minutes	1760
	M4	En Route	1 msg/flt	56	1 msg/5 minutes	1760
	M43	Terminal	1 msg/flt	56	3 msg/min	512
	M43	En route	1 msg/flt	56	1 msg/6 min	2152
	M44	En Route	1msg/flt	56	1 msg/2min	3544
APAXS	M31	En Route	5 10-min/flt	1440000	5 10-min/flt	1440000
	M42	En Route	1 msg/flt	1000000	20 msg/flt	1000
	M5	En Route	3 msg/flt	5200	6 msg/flt	480
	M6	En Route	2 msg/flt	5200	2 msg/flt	480
	M7	En Route	2 msg/flt	5200	2 msg/flt	480

*Compressed per Table 4.3-2

Table 4.3-6. **Non Flight Dependent Data Message Traffic (all aircraft classes)***

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)
FIS	M15	En Route	4 products/60 minutes	252000
	M15	En Route	6 products/60 minutes	306000
	M15	Terminal	6 products/60 minutes	252000
	M18	Terminal	60 products/60 minutes	1300
	M20	En Route	4 products/60 minutes	2800000
	M26	En Route	2 product/60 min	144000
	M26	En Route	6 products /60 min	350000
FIS	M27	Terminal	60 products /60 min	5510
	M28	En Route	6 products /60 min	219000
	M28	En Route	2 products/60 min	27000
	M40	En Route	1 product/60 minutes	54000
	M40	En Route	6 product/60 minutes	262500
	M29	Terminal	6 products/60 min	480
	M35	Terminal	31 products/60 minutes	7350
	M37	En Route	4 products/60 minutes	28800
	M39	En Route	1 product/60 minutes	27000
	M39	En Route	6 product/60 minutes	131000
	M39	En Route	4 product/60 minutes	252000
TIS	M3	Airport	1 msg/2 sec	224
	M3	En Route	1 msg/6 sec	224
	M3	Terminal	1 msg/4.8 sec	224

*Compressed per Table 4.3-2; all downlink traffic is flight dependent and therefore excluded from this table

Non-flight dependent products usually are large messages that are identical for all recipients. They can be sent on a periodic basis and the number of times they are sent is not dependent on the number of flights. The message characteristics are assumed to be the same for all classes and domains, with the exception of TIS messages. The size of TIS messages varies depending on the number of aircraft being reported. The total communications load will therefore depend on whether the message is being transmitted nationwide or just to the aircraft in a small region.

4.3.2 Data Message Load Per Flight

In order to convert messages per flight to communications channel loading, several assumptions are required regarding the duration of flights, communications protocol overheads, and message characteristics:

- ATN protocol overheads are applied to all connection-oriented messages, i.e., CPDLC, DSSDL, AOCDL, and AUTOMET messages, plus flight dependent FIS messages.
- The ATN protocol network layer overhead varies according to message context and message size; the actual overhead spans a wide range of documented values. RTCA/DO-237, for example, uses a protocol overhead of 136% for uplink messages and 1376% for downlink messages. (These values are biased toward the maxima that can be expected; the average overhead on downlink traffic is likely to be far less in practice.) For very short messages (i.e., CPDLC), this analysis assumes an average uplink overhead of 100% and an average downlink overhead of 200%. For longer messages (i.e., all other ATN traffic), the average overhead is assumed to 20% in both directions. These assumptions are in general agreement with the results of ARINC overhead predictions for various AOC messages.
- Non-flight dependent FIS messages and all TIS messages include a network layer overhead of 10% for error detection and synchronization.
- A physical layer overhead of 50% is assumed on all data messages (RTCA/DO-237).

- Modulation efficiency for D8PSK is assumed to be 1.25 bps per Hertz (RTCA/DO-237).
- The average time a flight spends in each airport domain is 10 minutes (RTCA/DO-237).
- The average time a flight spends in each terminal domain is 10 minutes (RTCA/DO-237).
- The average time a flight spends in each en route domain is 25 minutes per center; an average flight spans two centers.
- The average time a flight spends in the oceanic domain is 180 minutes.
- Only AUTOMET message types M43 and M44 are included in the data communications loading calculations; these messages are assumed to contain all the information found in other AUTOMET messages that are smaller in size. Message sizes and frequencies are based on the 1999 draft RTCA Minimum Interoperability Standard for AUTOMET.
- 8 bits per character is used to convert messages size in characters to message size in bits for AUTOMET messages M43 and M44; all other messages were expressed as bits in the source documents used.
- All AUTOMET traffic is suppressed in the airport domain to reduce channel requirements: the data is highly redundant and duplicates what is available from fixed airport weather sensors.

These assumptions are used to convert data message traffic in Tables 4.3-3, 4.3-4 and 4.3-5 into bits per flight per minute for each Technical Concept and class of aircraft. To get bits per minute per flight, the message size in bits is multiplied by the frequency in messages per minute times the proportion of aircraft equipped (Table 4.1-4). If the messages are on a per flight basis, the conversion requires multiplying the message size in bits times the number of messages per flight in a particular domain divided by the time a flight spends in that domain to obtain bits per minute per flight. This number is then multiplied by the proportion of aircraft equipped (Table 4.1-4) to arrive at the estimates shown in Table 4.3-7, Table 4.3-8, and Table 4.3-9.

Table 4.3-7. Data Message Traffic for Aircraft Class 1 (bits per min per flight)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	296.1	0.2	282.9	1.0	515.3	0.3
CPDLC	24.3	20.0	9.0	5.9	7.6	8.6
DSSDL	0.8	1.2	0.3	0.5	0.2	0.2
AOCDL	0.0	0.0	0.0	0.0	0.0	0.0
ADS Reporting	0.2	128.2	0.2	26.5	0.1	11.7
AUTOMET	0.0	0.0	0.1	36.1	0.1	50.1
APAXS	0.0	0.0	0.0	0.0	168.0	147.4

*Compressed per Table 4.3-2

Table 4.3-8. Data Message Traffic for Aircraft Class 2 (bits per min per flight)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	131.7	0.1	125.9	0.5	229.2	0.1
CPDLC	12.9	10.6	4.8	3.1	4.0	4.6
DSSDL	0.9	1.3	0.3	0.6	0.2	0.2
AOCDL	1.7	32.9	2.3	33.3	0.9	13.7
ADS Reporting	0.1	51.8	0.1	10.7	0.0	4.7
AUTOMET	0.0	0.0	0.1	16.1	0.0	22.3
APAXS	0.0	0.0	0.0	0.0	87.0	76.3

*Compressed per Table 4.3-2

Table 4.3-9. Data Message Traffic for Aircraft Class 3 (bits per min per flight)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	165.5	0.1	158.1	0.6	288.0	0.2
CPDLC	17.1	14.8	6.9	4.5	5.8	6.7
DSSDL	1.1	2.2	0.7	1.3	0.5	0.6
AOCDL	20.1	386.5	27.4	390.6	11.0	160.6
ADS Reporting	0.1	80.6	0.1	16.6	0.1	7.3
AUTOMET	0.0	0.0	0.1	20.2	0.1	28.0
APAXS	0.0	0.0	0.0	0.0	1,752.7	1,537.4

*Compressed per Table 4.3-2

4.3.3 Non Flight Dependent Data Message Traffic

The total number of FIS and TIS messages transmitted does not vary with the number of flights or the instantaneous airborne count. For these non-flight dependent messages, the message size in bits is multiplied by the frequency in messages per minute and listed separately in Table 4.3-10. Note that the length of a TIS message is directly proportional to the number of aircraft reporting in a local, regional, or national area, depending on the communications architecture assumed. The values in Table 4.1-4 (Percent of Aircraft Equipped for Each Technical Concept) are not used in this calculation since number of aircraft equipped to receive TIS messages does not affect the channel loading.

Table 4.3-10. Non-Flight Dependent Data Message Traffic (bits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	0.0	0.0	0.0	0.0	0.0	0.0
TIS	176.9	0.1	52.7	0.1	153.2	0.2

*Compressed per Table 4.3-2

4.3.4 Oceanic Data Message Load Per Flight

In the oceanic domain, data message traffic includes en route messages plus certain messages unique to oceanic flights. It is assumed that users in 2007 will want to receive the full complement of en route messages in the oceanic domain, if the communications links can support it. Using the same messages and message frequencies in the oceanic domain would provide seamless communications when transiting the NAS. Table 4.3-11 is only presented for Class 3 aircraft since the other classes are used primarily for domestic flights.

Table 4.3-11. Oceanic Data Message Traffic for Aircraft Class 3 (bits per min per flight)*

Technical Concept	Airport		Terminal		Oceanic	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	N/A	N/A	N/A	N/A	6,912.0	0.0
CPDLC	N/A	N/A	N/A	N/A	361.6	515.8
DSSDL	N/A	N/A	N/A	N/A	6.7	8.5
AOCDL	N/A	N/A	N/A	N/A	47.0	865.9
ADS Reporting	N/A	N/A	N/A	N/A	1.0	41.5
AUTOMET	N/A	N/A	N/A	N/A	0.9	3,068.2
APAXS	N/A	N/A	N/A	N/A	40,260.0	40,032.0

*Compressed per Table 4.3-2

4.4 Voice Traffic

ATC voice traffic is not included with data message traffic even though it can be digitized and sent as a data message. This is because CPC voice communications are highly interactive and require immediate acknowledgement. For reasons of safety, ATC voice services must also meet stringent availability, reliability, and diversity requirements that exceed what is required for most data messages. The premium paid for this type of service dictates that its use be limited to critical communications. By 2007, it is assumed that terminal and en route voice communications to high-end aircraft will have transferred completely to CPDLC.

APAXS voice messages are routine and are not included in airport and terminal domains where it is assumed that on-board telephones must remain stowed for reasons of safety. Predicted passenger telephone calls are based on the assumption that 5% of the passengers place a 5 minute call in a one-hour period. The time is equally divided between uplink (listening) and downlink (talking) channels. For purposes of this analysis, only Class 3 aircraft are assumed to have passenger telephony. Note that voice traffic is expressed in call-seconds, i.e., the amount of time an uplink or downlink channel is in use.

Table 4.4-1. Voice Message Traffic in 2007 (call-seconds)

Message	Domain	Class	Uplink	Downlink	Msgs. per Flight
CPC Clearances	Airport	1	5 sec	5 sec	1/flt
CPC Clearances		1	5 sec	1 sec	2/flt
CPC Clearances		2	5 sec	5 sec	1/flt
CPC Clearances		2	5 sec	1 sec	2/flt
CPC Clearances		3	5 sec	5 sec	1/flt
CPC Clearances		3	5 sec	1 sec	2/flt
CPC Clearances	Terminal	1	5 sec	10 sec	1/flt
CPC TOC*		1	5 sec	5 sec	1/flt

Message	Domain	Class	Uplink	Downlink	Msgs. per Flight
CPC Advisories	En Route	1	20 sec	5 sec	1/flt
APAXS	En Route	1	150 sec	150 sec	0.05 passngr/hr

* Transfer of Communications

The total voice traffic per flight is calculated by multiplying the duration of the voice message by the number of times the message occurs and dividing by the time spent in the domain. The results are summed for each domain and class of aircraft to get the total per flight requirements.

Table 4.4-2. CPC Voice Message (call-seconds per min per flight)

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	1.5 sec	0.7 sec	1.0 sec	1.5 sec	0.8 sec	0.2 sec
2	1.5 sec	0.7 sec	N/A	N/A	N/A	N/A
3	1.5 sec	0.7 sec	N/A	N/A	N/A	N/A

The APAXS passenger telephony calculations assume an average flight has 90 passengers and that 5% of the passengers in a given hour will talk for 150 seconds and listen for 150 seconds. Since the time spent in en route per flight is 50 minutes, the uplink and downlink load is 0.05 calls per passengers per hour x 90 passengers per flight x 5/6 hour per flight x 150 seconds per call / 50 minutes per flight = 11.3 call-seconds per minute per flight while en route.

Table 4.4-3. APAXS Voice Message (call-seconds per min per flight)

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
3	N/A	N/A	N/A	N/A	11.3	11.3

4.5 Traffic Load Analysis

4.5.1 Flight Forecasts

The average traffic load is developed from the per flight message traffic multiplied by the expected number of flights in 2007. Communications links, however, are generally designed for peak loads to avoid increased delays or blocking when traffic is heaviest. Peak flights by domain for 1998 are therefore projected out to 2007 to estimate the peak load. The projections shown in Table 4.5-1 represent a 12.6% increase in operations between 1998 and 2007 for the aircraft classes of interest. FAA forecasts for terminal area itinerant aircraft operations are used because they correspond closely to the number of flights and are readily available from FAA forecast data by class of aircraft. For simplicity, it is assumed that the percent growth within each aircraft class and domain is the same as the percent growth in total aircraft operations.

Table 4.5-1. Peak Number of Flights (Aircraft) by Domain in 2007

Year	Operations*	Airport	Terminal	En Route
1998	73,169,228	154	110	400
2007	82,392,277	173	125	450

*APO Terminal Area Forecast Summary Report, TAF System Model

Applying the forecast distribution of operations for each class of aircraft to the number of flights in each domain provides the approximate distribution of flights by class and domain for 2007 as shown in Table 4.5-2.

Table 4.5-2. Estimated Peak Distribution of Flights by Class and Domain in 2007

Class	Operations*	Airport	Terminal	En Route
1	48,452,403	102	73	265
2	15,629,983	33	24	85
3	18,309,891	38	28	100
Total	82,392,277	173	125	450

*APO Terminal Area Forecast Summary Report, TAF System Model

4.5.2 Data Traffic Load

Multiplying the peak number of flights in Table 4.5-2 by the messages per flight in Table 4.3-7, Table 1.3-8, and Table 4.3-9 results in the estimated peak loads shown in Table 4.5-3, Table 4.5-4, and Table 4.5-5.

Table 4.5-3. Peak Data Message Traffic for Aircraft Class 1 in 2007 (kilobits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	296.1	0.2	282.9	1.0	515.3	0.3
CPDLC	24.3	20.0	9.0	5.9	7.6	8.6
DSSDL	0.8	1.2	0.3	0.5	0.2	0.2
ADS Reporting	0.2	128.2	0.2	26.5	0.1	11.7
AUTOMET	N/A	N/A	0.1	36.1	0.1	50.1
APAXS	N/A	N/A	N/A	N/A	168.0	147.4

*Compressed per Table 4.3-2

Table 4.5-4. Peak Data Message Traffic for Aircraft Class 2 in 2007 (kilobits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	131.7	0.1	125.9	0.5	229.2	0.1
CPDLC	12.9	10.6	4.8	3.1	4.0	4.6
DSSDL	0.9	1.3	0.3	0.6	0.2	0.2
AOCDL	1.7	32.9	2.3	33.3	0.9	13.7
ADS Reporting	0.1	51.8	0.1	10.7	0.0	4.7
AUTOMET	N/A	N/A	0.1	16.1	0.0	22.3
APAXS	N/A	N/A	N/A	N/A	87.0	76.3

*Compressed per Table 4.3-2

Table 4.5-5. Peak Data Message Traffic for Aircraft Class 3 in 2007 (kilobits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	165.5	0.1	158.1	0.6	288.0	0.2
CPDLC	17.1	14.8	6.9	4.5	5.8	6.7
DSSDL	1.1	2.2	0.7	1.3	0.5	0.6
AOCDL	20.1	386.5	27.4	390.6	11.0	160.6
ADS Reporting	0.1	80.6	0.1	16.6	0.1	7.3
AUTOMET	N/A	N/A	0.1	20.2	0.1	28.0
APAXS	N/A	N/A	N/A	N/A	1,752.7	1,537.4

*Compressed per Table 4.3-2

Combining the peak data message load for each aircraft class and converting to kilobits per second gives the aggregate loads shown in Table 4.5-6. Here it is seen that APAXS, FIS, and AOCDL, in that order, account for most of the traffic.

Table 4.5-6. Combined Peak Data Message Traffic for All Aircraft Classes in 2007 (kilobits per second)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	9.9	0.0	9.4	0.0	17.2	0.0
CPDLC	0.9	0.8	0.3	0.2	0.3	0.3
DSSDL	0.0	0.1	0.0	0.0	0.0	0.0
AOCDL	0.4	7.0	0.5	7.1	0.2	2.9
ADS Reporting	0.0	4.3	0.0	0.9	0.0	0.4
AUTOMET	N/A	N/A	0.0	1.2	0.0	1.7
APAXS	N/A	N/A	N/A	N/A	33.5	27.4

*Compressed per Table 4.3-2

Aggregate non-flight dependent traffic loads are shown in Table 4.5-7 for regional coverage and in Table 4.5-8 for national coverage. The two tables are different because uplink TIS message size increases according to the number of aircraft in the area of interest. Regional TIS message sizes are based on the peak number of aircraft that would be found in a given domain (the smallest region of interest). The TIS traffic in Table 4.5-7 is calculated by multiplying traffic in Table 4.3-10 by the peak domain traffic in Table 4.5-2. The results are divided by 60 x 1000 to express the load in kilobits per second. From this table it can be seen that the combined FIS and TIS en route peak load would require a 25.0 kbps uplink channel and the peak airport load would require a 21.4 kbps uplink channel.

Table 4.5-7. Regional Non-Flight Dependent peak Data Message Traffic for All Aircraft Classes in 2007 (kilobits per sec)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	N/A	N/A	0.6	N/A	6.5	N/A
TIS	21.4	0.0	6.4	0.0	18.5	0.0

*Compressed per Table 4.3-2

TIS message sizes in Table 4.5-8 for national coverage are based on estimates of the peak instantaneous airborne count for all domains. The peak instantaneous nationwide count in 2000 is roughly 5,500 aircraft. By 2007 it is assumed this will grow 12.6% to a total of 6,193 peak airborne aircraft. These aircraft are assumed to be distributed within the three domains in the same proportions found in Table 4.5-1, i.e., 1,436 in airport domains, 1,026 in terminal domains, and 3,731 in en route domains. Table 4.3-10 is multiplied by these flights to get the peak loads shown in Table 4.5-8. The table shows that nationwide (the largest area of interest), a TIS uplink channel has to carry 383 kilobits per second to meet peak loads. Approximately half of this load results from the combined operations of all airport domains.

Table 4.5-8. National Non-Flight Dependent Peak Data Message Traffic for All Aircraft Classes in 2007 (kilobits per sec)*

Technical Concept	Airport		Terminal		En Route		National
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink	Uplink
FIS	N/A	N/A	0.6	N/A	6.5	N/A	7.1
TIS	177.0	0.0	52.7	0.0	153.2	0.0	382.9

*Compressed per Table 4.3-2

4.5.3 Oceanic Traffic Load

Peak oceanic flights are estimated based on peak hour contacts by Oakland and New York centers. Of the two, New York is slightly higher with 84 flights en route in the peak hour in 2000. Assuming 12.6% growth by 2007, the messages rates per flight in Table 4.3-11 are multiplied by 95 peak flights in 2007 and divided by 60 x 1000 to get kilobits per second. The table shows that a 11.6 kbps uplink and 7.2 kbps down link is sufficient for peak air traffic services, and a 63.7 kbps channel is sufficient in each direction for passenger services.

Table 4.5-9. Total Oceanic Data Message Traffic in 2007 (kilobits per second)*

Technical Concept	Airport		Terminal		Oceanic	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	N/A	N/A	N/A	N/A	10.9	0.0
CPDLC	N/A	N/A	N/A	N/A	0.6	0.8
DSSDL	N/A	N/A	N/A	N/A	0.0	0.0
AOCDL	N/A	N/A	N/A	N/A	0.1	1.4
ADS Reporting	N/A	N/A	N/A	N/A	0.0	0.1
AUTOMET	N/A	N/A	N/A	N/A	0.0	4.9
APAXS	N/A	N/A	N/A	N/A	63.7	63.4

*Compressed per Table 4.3-2

4.5.4 Voice Traffic Load

Peak CPC voice traffic is shown in Table 4.5-10. The number of call-seconds per minute per flight from Table 4.4-2 is multiplied by the peak number of flights in Table 4.5-2 and then divided by 60 seconds per minute to get channel occupancy in call-seconds per second. The total for each domain represents the number of full-period uplink or downlink analog voice channels required. To minimize the chance of all channels being in use at the same time, extra capacity can be added to the system. Assuming a multiserver queque with exponentially distributed call durations as a worst-case queuing model for air-ground communications, the number of channels needed for a given probability of blocking can be calculated. In this analysis, it is assumed that there should be no more than one chance in five of finding all channels busy. Under peak traffic conditions with a 0.2 probability of all channels being busy, it is seen that the busiest airport domain in 2007 requires 7 voice channels. The busiest terminal domain requires 6 voice channels and the busiest en route domain requires 6 channels.

Table 4.5-10. Peak CPC Voice Messages in 2007 (call-seconds/second)

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	2.6	1.2	1.0	1.0	3.0	0.8
2	0.8	0.4	0.8	0.8	0.4	0.2
3	1.0	0.4	0.8	0.8	0.5	0.2
Total	6.3		5.3		5.2	
Voice Channels Required (P=0.2)	7		6		6	

Peak passenger APAXS calls are estimated by multiplying the call-seconds per minute per flight in Table 4.4-3 times the peak number of flights in Table 4.5-2 (11.3 call-seconds per minute per flight x 100 en route flights = 1130 call-seconds per minute). This quantity is then divided by 60 seconds per minute to get channel occupancy in call-seconds per second as shown in Table 4.5-11. A multi-server queuing model is again used to calculate the number of voice channels needed for there to be no more than one chance in five that all channels are in use. The table shows that the peak passenger load in the busiest en route domain would require 33 voice channels. The total number of voice channels required nationwide might have approximately 10 times the traffic for about 305 voice channels since other en route domains are below the peak en route domain and do not all peak simultaneously.

Table 4.5-11. Peak APAXS Voice Messages in 2007 (call-seconds/sec)

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
3	N/A	N/A	N/A	N/A	18.8	18.8
Total	N/A		N/A		37.6	
Voice Channels Required (P=0.2)	N/A		N/A		33	

4.6 Air-Air Traffic

Air-to-air broadcasts originate from individual aircraft so the message load is directly proportional to the number of aircraft. It is assumed that aircraft originated data messages are for ADS-B surveillance applications, with minimal use of other applications proposed for ADS-B. From Table 4.5-6, it can be seen that the peak ADS-B traffic in the airport, terminal, and en route domains is 4.3 kbps, 0.9 kbps, and 0.4 kbps respectively. Postulating a "worst case" scenario where one aircraft is receiving peak ADS-B data from four airport domains, one terminal domain, and one en route domain (e.g., New York center), the total traffic would be 4 x 4.3 kbps plus 1 x 0.9 kbps plus 1 x 0.4, or 18.5 kilobits per second as the maximum required air-to-air link capacity in 2007. This represents approximately 144 ADS-B equipped aircraft on the ground or in the air that might be using an air-to-air link.

5 Communication Links Analysis

This section provides the technical detail of the data links available for the 2007 architecture. Much of this information is also presented in the Task 9 Report, *Characterize the Current and Near-Term Communications System Architectures,* which provides additional information on applications, standards, protocols, and networks. The links discussed in this section are:

- Voice - DSB-AM
- VHF Digital Link Mode 2 (VDLM2)
- VHF Digital Link Mode3 (VDLM3)
- VHF Digital Link Broadcast (VDL-B)
- Mode S
- Universal Access Transceiver (UAT)
- Example Geosynchronous (GEO) Satellite (Recommended SATCOM)
- Example Medium Earth Orbit (MEO) Satellite
- Example Low Earth Orbit (LEO) Satellite
- High Frequency Data Link (HFDL)

5.1 Standard Description Template

Each link is characterized according to section 4.6.1 of the Task Order and organized using the following template.

CHARACTERISTIC	Segment	DESCRIPTION
System Name		Name
Communication type	R/F Ground	HF, VHF, L-Band, SATCOM ...
Frequency/Spectrum of Operations	R/F Ground	Frequency
System Bandwidth Requirement	R/F Ground	Bandwidth for channel and system
System and Channel Capacity	R/F	Number of channels and channel size
Direction of communications	R/F	Simplex, broadcast, duplex....
Method of information delivery	R/F Ground	Voice, data, compressed voice
Data/message priority capability	R/F Ground	High, medium, low
System and component redundancy	R/F Ground	
Physical channel characteristics	R/F	Line of sight (LOS), other
Electromagnetic interference	R/F	Text description
Phase of Flight Operations	Ground	Pre-flight, departure, terminal ....
Channel Data Rate	R/F Ground	Signaling rate
Robustness of channel and system	R/F	Resistance to interference, fading...
System Integrity	R/F Ground	Probability
Quality of service	R/F Ground	Bit error rate, voice quality
Range/coverage	R/F Ground	Oceanic, global, regional...
Link and channel availability	R/F Ground	Probability
Security/encryption capability	R/F Ground	Text description
Degree/level of host penetration	R/F	Percentage or class of users
Modulation scheme	R/F	AM, FM, D8PSK,....
Access scheme	R/F	CSMA, TDMA, ...
Timeliness/latency, delay requirements	R/F Ground	Delay
Avionics versatility	R/F	Application to other aircraft
Equipage requirements	R/F	Mandatory, optional
Architecture requirements	R/F Ground	Open System or proprietary
Source documents		References

Integrity is the ability of a system to deliver uncorrupted information, and may include timely warnings that the information or system should not be used. Integrity is provided by the application, transport and network layers (rather than the link and physical layers), and is usually specified in terms of the probability of an undetected error. The integrity values in the following link descriptions thus reflect service integrity requirements rather than "link integrity" requirements. The only meaningful measure of "link integrity" is a bit error rate, which is shown under quality of service.

Comm Link	System integrity (probability)
Voice DSB-AM	No integrity requirement for 2007 voice services
VDL Mode 2	CPCLC and DSSDL will be ATN compliant services and require that the end -to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message be less than or equal to $10E^{-8}$ per message
VDL Mode 3	No integrity requirement for 2007 voice services
VDL-B	Some FIS products may require that the end-to end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message be less than or equal to $10E^{-8}$ per message.
Mode-S	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has be supplied to the ADS-B system. ADS-B system integrity is $10E^{-6}$ or better on a per report basis. [Note: Due to constraints imposed by the Mode-S squitter message length, multiple messages must typically be received before all required data elements needed to generate a particular ADS-B report are available.]
UAT	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has be supplied to the ADS-B system. ADS-B system integrity is $10E^{-6}$ or better on a per report basis. Currently, the UAT worst-case overall undetected error probability for an ADS-B message is $3.7x10E^{-11}$, which exceeds the minimum requirement. [Note: For UAT, ADS-B messages map directly (one-to-one correspondence) to ADS-B reports; they are not segmented as they are in Mode-S ADS-B.]
Inmarsat-3	No integrity requirement for 2007 data services
GEO Satellite	Some FIS products may require that the end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message be less than or equal to $10E^{-8}$ per message
MEO Satellite	No integrity requirement for 2007 data services
ICO Global Satellite	No integrity requirement for 2007 data services
Iridium Satellite	No integrity requirement for 2007 voice services
HFDL	No integrity requirement for 2007 data services

5.2 Near-Term Links Available

5.2.1 VHF DSB-AM

Virtually all air traffic control communications are currently based on the VHF, double-side band amplitude modulated (DSB-AM) radio. DSB-AM has been used since the 1940s, first in 100 kHz channels, then in 50 kHz channels, and now 25 kKz channels. Recently, Europe has further reduced channel spacing to 8.33 kHz channels in some air space sectors due to their critical need for more channels. In the United States, the FAA provides simultaneous transmission over UHF channels for military aircraft. In the oceanic domain beyond the range of VHF, aircraft use HF channels. Studies have shown that controller workload is directly correlated to the amount of voice communications required. Voice is subject to misinterpretation and human error and has been cited as having an error rate of 3% and higher. With the introduction of ACARS, AOC voice traffic dropped significantly although it is still used.

Table 5.2-1. Analog Voice/VHF DSB-AM Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Analog voice/VHF double sideband (DSB)—amplitude modulated (AM)**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	Leased telephone channels
Frequency/ Spectrum of Operations	RF	117.975 MHz—137 MHz
System Bandwidth Requirement	RF	Nominal 3 kHz per channel with audio input 350 - 2,500 Hz 760 channels total in VHF band @ 25 kHz spacing/channel
	Ground	N/A
System and Channel Capacity (number of channels and channel size)	RF	Nominal 3 kHz per channel with audio input 350 - 2,500 Hz 760 channels total in VHF band @ 25 kHz spacing/channel System is constrained by frequency allocation, not technical limits. Expansion to 112 MHz has been discussed if radionavigation systems are decommissioned.
	Ground	Telephone line per assigned radio frequency
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Simplex - Transmission or reception on a single frequency but not simultaneously.
	Ground	Voice telephone lines are duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Voice
	Ground	Voice
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	N/A
	Ground	N/A
System and component redundancy requirement (1/2, 1/3, etc):	RF	Airborne - One unit required for GA, two units for air carrier. Redundancy: GA typically equips with two units (1:1); air carrier equips with three units (1:2).
	Ground	1:1 plus some overlap of ground stations
Physical channel characteristics (LOS, OTH, etc.):	RF	Line of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics:	RF	RTCA DO-160C, Sections 15, 18, 19, 20, and 21.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	3 kHz
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Voice communications are error prone and highly variable. An error rate of 3% has been measured in high activity sectors.
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	VHF voice communications are generally considered poor due to system and background noise. (The human ear is VERY good at puling voice out of a noisy AM signal.) A standard voice quality metric has not been applied.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 250 nm at 30,000 feet 100 nm at 5,000 feet Coverage: United States including the Gulf of Mexico.
Link and channel availability	RF	Exceeds 99.7%

CHARACTERISTIC	SEGMENT	DESCRIPTION
Security/ encryption capability	RF	N/A
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	All commercial, all military and most GA aircraft equipped. All aircraft participating in IFR airspace are required to equip. Approximately 20,000 GA aircraft use only unrestricted airspace and do not equip with a radio.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Double sideband—Amplitude Modulation (DS-AM)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Normal signal propagation delay
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	System	Respond to 75% of calls within 10 seconds and 94% of calls within 60 seconds
	System	No measured data. Air Traffic Controllers determine access and priority based on traffic and situation.
Avionics versatility (applicability to other aircraft platforms)	Avionics	Any aircraft equipped with VHF transmitter and receiver.
Equipage requirements (mandatory for IFR, optional, primary, backup,	Avionics	Mandatory for IFR flight operations; not required in uncontrolled airspace.
	Ground	Ground stations required for coverage.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.)	RF/Avionics	Signal in space characteristics are set by National and International standards. Avionics are developed by vendors with proprietary designs. Some integration with navigation.
Level of integration with other aircraft avionics (independent data link, shares communications link with applications, etc.)	Ground	Vendors provide ground communications using proprietary hardware/software designs and commercial telecommunications standards.
Source documents		Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; ARINC Quality Management Reports, Air/Ground Voice Performance

5.2.2 VDL Mode 2

VDL Mode 2 is a 1990's concept for aeronautical data link. It has been designed by the international aviation community as a replacement for ACARS. Many of the limitations of ACARS have been overcome in the VDL Mode 2 system. The best known improvement is the increase in channel data rate from the ACARS 2.4 kbps rate to a 31.5 kbps rate. The improved rate is expected to increase user data rates ten to 15 times over the current ACARS. The variation is dependent upon user message sizes, channel loading assumptions, and service provider options. VDL Mode 2 can carry all message types carried by ACARS plus Air Traffic Service messages such as CPDLC, which require performance levels of latency and message assurance not possible with ACARS.

VDL Mode 2 is a subnetwork in the Aeronautical Telecommunication Network (ATN). ATN has been adopted by ICAO to provide a global air/ground and ground/ground network for all aviation related traffic. ATN addresses both the communications aspects and the applications.

Table 5.2-2. VDL Mode 2 Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**VHF Digital Link Mode 2** (VDL Mode 2)
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	ARINC Data Network System (ADNS) & ARINC Packet Network (APN)
Frequency/ Spectrum of Operations		136.975MHz, 136.950MHz, 136.925MHz, 136.900MHz currently approved for VDL in international frequency plans. The 136.500 - 137.0 MHz band (20 channels) is potentially assignable to VDL Mode 2 in the U.S. Additional frequencies are based on availability and sharing critieria.
System Bandwidth Requirement	RF	25KHz
	Ground	Primary 56 Kbps , dial backup 64 Kbps ISDN
System and Channel Capacity (number of channels and channel size)	RF	Unlimited system growth - primarily dependent on regulatory frequency allocation. Ground stations are capable of four independent frequencies. Initial deployment will be based on aircraft equipage and will only require 1-2 frequencies.
	Ground	APN X.25 packet switched services and IP and ATN protocols
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Simplex - Transmission or reception on a single frequency but not simultaneously.
	Ground	Simplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	data
	Ground	data
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
	Ground	The VDL Mode 2 ground network can prioritize messages over the wide area network and within the ground station in accordance with ATN priority schemes. Once presented to the radio for transmission, messages are not preempted.
Physical channel characteristics (LOS, OTH, etc.)		
	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	RTCA DO-160C, Sections 15, 18, 19, 20, and 21.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	First VDL Mode 2 usage expected in 2000 in En Route. Potentially applicable to all domestic phases of flight: Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	31.5 kbps/25KHz channel
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Design availability for Initial Operating Capability (IOC) is .9999. Higher availability will be achieved with additional ground stations and supporting network components for critical airports and applications.
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Within the VDL Mode 2 subnetwork, the probability of a lost packet is less than 10^{-7}. The subnetwork uses logical acknowledgements for packet delivery assurance. An additional end-to-end message assurance is applied to assure message delivery (all packets for a message).

CHARACTERISTIC	SEGMENT	DESCRIPTION
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 200 nm at 30,000 feet 80 nm at 5,000 feet Coverage: Implementation will begin in 2000 with U.S. En Route and high density airports (Airspace A and B). Coverage will expand as users equip.
Link and channel availability	RF	The availability of each ground station is 0.997. Ground station availability based on providing RF signal so radio and all components included. For typical applications, two ground stations will be available to achieve 0.9999 system availability.
Security/ encryption capability	RF	None at the RF level - VDL Mode 2 will support authentication and encryption of applications as planned by ATN.
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	None - system to be deployed in 2000. VDL Mode 2 is applicable to all user classes but is expected to be first implemented by air carriers and regional airlines operating in Class A airspace (above 18,000 feet) and associated Class B airspace airports.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Carrier Sense Multiple Access (CSMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	95% of messages delivered within 3.5 seconds within the VDL Mode 2 subnetwork. End-to-end delivery is estimated at 95% within 5 seconds.
Avionics versatility (applicability to other aircraft platforms)	System	VDL Mode 2 can be used for all applications.
	Avionics	VDL Mode 2 can be used on any class aircraft.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.)	Ground	Ground stations must be installed for coverage
	System	Signal in space characteristics are set by National and International standards. Avionics are developed by vendors with proprietary designs. Can share VHF equipment with other applications (VHF voice).
Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)		The digital radios used by VDL Mode 2 are capable of providing analog voice service and/or VDL Mode 3 service with appropriate software and hardware additions. Radio is dedicated to one Mode when installed.
Source documents		ARINC VDL Mode 2/ATN Briefing for FAA

5.2.3 VDL Mode 3

VDL Mode 3 is also an ATN subnetwork. VDL Mode 3 has been designed for Air Traffic controller-pilot communications for both voice and data. VDL Mode 3 uses time division to split each 25 kHz channel into four subchannels, which can be any combination of voice or data. This approach allows VDL Mode 3 to provide a traditional voice service and a data link service over a single system. Each subchannel operates at 4.8 kbps. For voice service, VDL Mode 3 includes a voice encoder/decoder (vocoder) which allows digital signals to be converted to voice. As a data channel, VDL Mode 3 can provide data service at 4.8 kbps in each data subchannel.

VDL Mode 3 is under development by the FAA as the NEXCOM program. Initially NEXCOM will provide voice service to replace the current 25 kHz, double side-band amplitude modulated (DSB-AM) voice service.

Table 5.2-3. VDL Mode 3 Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Very High Frequency Digital Link Mode 3 (VDL Mode 3)**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	Very High Frequency (VHF)
	Ground	Undetermined
Frequency/ Spectrum of Operations:	RF	118-137MHz
System Bandwidth Requirement:	RF	25KHz/channel; Radios are specified for 112-137 MHz tuning range.
	Ground	Undetermined
System and Channel Capacity (number of channels and channel size):	RF	As a system, VDL Mode 3 can be used for all frequencies in the VHF aeronautical band, pending frequency sharing criteria. VDL Mode 3 is planned as the replacement for all current ATC analog voice frequencies, approximately 500 channels. Each VDL Mode 3 frequency provides four subchannels per 25KHz channel.
	Ground	Fractional T-1 interfaces indicated in draft specification.
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Simplex - Transmission or reception on a single frequency but not simultaneously, within a subchannel. Subchannels can communicate independently with TDMA scheme.
	Ground	Undetermined
Method of information delivery (voice, voice recording, data, combination, etc.):	RF	Pulse code modulated voice or data in any given subchannel
	Ground	Data, ATN-compliant network protocols
System and component redundancy requirement (1/2, 1/3, etc):	Ground	Undetermined, 1:1 is current practice.
	RF	Ground components: 1:1 is current practice Airborne: 1:2
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	VDL Mode 3 will begin deployment for voice function in approximately 2005 for En Route phase of flight. Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight will be added as the system expands.
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	10,500 symbols/sec (3 bits per symbol) 31.5 Kbps/channel 4.8 Kbps/subchannel, 4 subchannels/channel
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Digital = BER of 10^{-3} for minimum, uncorrected signal BER of 10^{-6} daily average
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Voice: The PCM voice will be encoded using an 8 kHz sampling rate at a resolution of 16 bits per sample.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 200 nm at 30,000 feet 80 nm at 5,000 feet Coverage: Implementation will begin in 2005 with U.S. En Route. Coverage will expand to all U.S. phases of flight.
Link and channel availability	RF	Radio availability =.99999

CHARACTERISTIC	SEGMENT	DESCRIPTION
Security/ encryption capability	RF	No encryption at RF level. Should support ATN defined encryption and authentication at application level.
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	System is in implementation. Will be available to commercial, G/A, and military aircraft
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Time Division Multiple Access (TDMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	< 250 msec
	System	< 250 msec
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Ground	Ground stations required for service/coverage.
	Avionics	NEXCOM will initially be deployed in analog voice Mode to allow fielding and aircraft equipage. When switched to digital voice Mode, approximately 2006, equipage will be mandatory for high En Route.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)		Signal in space and protocols are defined by National and International standards. Ground equipment will be provided by vendors using proprietary designs. VDL data can support numerous applications.
Source documents		Implementation aspects for VDL Mode 3 system (version 2.0), VDL Circuit Mode MASPS and MOPS, Aeronautical Mobile Communications Panel (AMCP); Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; RTCA /DO-224.

5.2.4 VHF Digital Link—Broadcast (VDL-B)

VDL-B is a broadcast variation of VDL Mode 2. Currently intended for Flight Information Services, VDL-B provides weather information to suitably equipped aircraft. The broadcast approach can increase the throughput of data to the user since the protocol overhead of request/reply and confirmation is not required. Under the FAA's FIS Policy, two VHF band frequencies were provided to each of two vendors for implementation. As a condition at no cost to the user, each vendor is required to transmit a minimum set of weather products. The vendor is allowed to charge fees for additional optional products such as weather graphics. The protocols for the FIS-B systems are partially proprietary and may be specified by the vendor. The vendors are expected to use the D8PSK physical layer but the upper layers are not standardized.

VDL-B is not an ICAO SARPs recognized version of VDL. The VDL-B term has been used to describe a data link intended primarily or solely for broadcast of data one-way to aircraft. Weather and traffic information are the usual applications cited for broadcast functions. The description in this report is based on VDL Mode 2 and FIS, which is the most common usage of the term VDL-B. Other variations of VDL-B are possible since it is not an official term or definition.

Table 5.2-4. VDL Broadcast Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**VHF Data Link—Broadcast (VDL-B)**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	Leased telco for current implementation. VDL Mode 2 network possible in the future. Other proprietary solutions possible.
Frequency/ Spectrum of Operations		118-137MHz
System Bandwidth Requirement	RF	25KHz
	Ground	N/A
System and Channel Capacity (number of channels and channel size)	RF	Two frequencies per vendor, Total of four frequencies.
	Ground	Leased telco.
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Broadcast
	Ground	Duplex (return needed for ground station monitor and control)
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
	Ground	VDL-B is a proposed broadcast service that provides advisory and weather information to all aircraft monitoring the channel. The information provided contributes to the safety of flight. This service is similar to Flight information services (FIS)
System and component redundancy requirement (1/2, 1/3, etc)	RF	Since FIS is an advisory service, high availability is not required and redundancy will probably not be used.
	Ground	None expected.
Physical channel characteristics (LOS, OTH, etc.)	RF	Line of sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	The FIS-B information will be available in all phases of flight if the aircraft is within range of the ground station. En Route will have the most coverage while coverage on the ground will be limited. Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	31.5 kbps if D8PSK used 19.2 for GMSK Other data rates possible
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	RF is robust and resistant to interference, fading, multi-path, atmospheric attenuation, weather
System integrity (probability)	System	Based on non-critical service category, availability is estimated as 0.99
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Unknown
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	LOS (180 nautical miles for aircraft at 25,000 feet) 80 nm at 5,000 feet
Link and channel availability	RF	0.99

CHARACTERISTIC	SEGMENT	DESCRIPTION
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Intended for G/A market but available to all users.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK) or Gaussian Mean Shift Keying (GMSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Broadcast mode has not been defined
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Unkown
	System	> 5 seconds
	Avionics	Optional
	Ground	Required for message transmission
Avionics Versatility	Avionics	If D8PSK approach used, then the radio could be used for multiple applications.
Equipage Requirements	RF	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	Ground	Required for message transmission
	System	Proprietary hardware/software mix.
	Avionics	Can share VHF equipment with other applications
Source documents		None

5.2.5 Mode S

Mode S is an evolution of the traditional Secondary Surveillance Radar (SSR). For Mode S, each aircraft has a unique 24-bit address, which allows transmission selectively addressed to a single aircraft instead of broadcast to all aircraft in an antenna beam. The Mode S transponder has 56 bit registers which can be filled with airborne information such as aircraft speed, waypoint, meteorological information, and call sign. The information in the register can be sent either by an interrogation from the ground system or based on an event such as a turn. For ADS-B, equipped aircraft can exchange information without a master ground station. Although capable of sending weather and other information, the Mode S communications capability is allocated to support of its surveillance role and will consist of aircraft position and intent. ADS-B uses the Mode S downlink frequency (i.e., 1090 MHz) and link protocols to squitter (i.e., spontaneously broadcast) onboard derived data characterizing the status (current and future) of own aircraft or surface vehicle via various ADS-B extended squitter message types (e.g., State Vector [position/velocity], Mode Status [identification/type category/current intent], and On-Condition [future intent/coordination data]).

Table 5.2-5. Mode S Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**Mode S**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	
	Ground	L-Band (also known as D-Band)
Frequency/ Spectrum of Operations:		1090 MHz, +/- 1MHz
System Bandwidth Requirement:	RF	2 MHz (based on the existing Mode-S downlink)
	Ground	Leased telecommunications
System and Channel Capacity (number of channels and channel size):	RF	Single 2 MHz channel
	Ground	Leased telecommunications
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Broadcast from aircraft
	Ground	Ground stations transmit at 1030 MHz and receive at 1090 MHz. For ADS-B service, receive only stations have been proposed.
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	Surveillance function has priority over communications function
	Ground	None. The probability of successful message reception and report update are specified (see Table 3-4 of RTCA DO-242 ADS-B MASPS) depending upon the specific operational applications being supported by the ADS-B system. In this broadcast system more critical data (as determine by the operation being supported) are broadcast more frequently to improve the probability of message reception and report update.
System and component redundancy requirement (1/2, 1/3, etc):	RF	This depends on the ADS-B equipage class, its hardware implementation, and the specific operational applications being supported. The system level minimum availability requirements for equipage classes A1 through A3, for example, is 0.999. This, coupled with the minimum system level continuity of service requirement for the probability of being unavailable during an operation of no more than 2 x 10 –4 per hour of flight along with the specific availability requirements for the operation being performed (e.g., parallel approach), will determine whether equipment redundancy is needed to satisfy the operational requirement. This is expected to be part of the certification process and will be based on the intended use of the ADS-B equipment and the operational approval(s) being sought.
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics:	RF	ADS-B equipment has broad EMI requirements: transmitting and/or receiving equipment shall not compromise the operation of any co-located communication or navigation equipment (i.e., GPS, VOR, DME, ADF, LORAN) or ATCRBS and/or Mode-S transponders. Likewise, the ADS-B antenna shall be mounted such that it does not compromise the operation of any other proximate antenna.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Operational applications supported by ADS-B have been identified across all phases of flight, except possibly pre- and post-flight.
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	1 Mbps Mode-S provides data link capability as a secondary service to surveillance. Extended length message, ELM, format provides 80 user bits per 112 bit message. A typical rate is one ELM per four seconds (RTCA DO-181)

CHARACTERISTIC	SEGMENT	DESCRIPTION
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	The L-Band frequency is subject to fading and multi-path; Mode-S uses a 24-bit parity field and forward error detection and correction (FEDC) to help address this.
System integrity (probability)	System	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has been supplied to the ADS-B system. ADS-B system integrity is 10^{-6} or better on a per report basis. [Note: Due to constraints imposed by the Mode-S extended squitter message length, multiple messages must typically be received before all required data elements needed to generate a particular ADS-B report are available.]
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Mode-S system performance for undetected error rate is specified to be less than one error in 10^{-7} based on 112-bit transmissions.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Assuming LOS exists, range performance depends on traffic density and the 1090 MHz interference environment (i.e., ADS-B uses the same frequency as ATC transponder-based surveillance). In low-density environments (e.g., oceanic) range performance is typically 100+ nm, while in a high-traffic density and 1090 interference environments (e.g., LAX terminal area) the range performance is on the order of 50 to 60 nm with current receiver techniques (improved processing techniques have been identified that are expected to provide range performance to 90 nm in dense environments).
Link and channel availability	RF	100%, as ADS-B is a true broadcast system
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	TBD, since still being developed. However, a significant number of initial implementations are expected to occur in aircraft already equipped with TCASII/Mode-S transponders (commercial air transport and high-end business aircraft). This area of equipage (i.e., TCASII/Mode-S) is expected to increase as the ICAO mandate for TCASII Change 7 (called ACAS in the international community) starts to occur in 2003.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Pulse Position Modulation (PPM) Each ADS-B message consists of a four pulse preamble (0.5 microsecond pulses, with the 2nd, 3rd, and 4th pulses spaced 1.0, 3.5, and 4.5 microseconds after the 1st) followed by a data block beginning 8 microseconds after 1st preamble pulse. The data block consists of 112 one-microsecond intervals with each interval corresponding to a bit (a binary "1" if a 0.5 pulse is in the first half of the interval or a "0" if the pulse is in the second half of the interval.
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Random access; squitter transmissions are randomly distributed about their mean value between some fixed high and low limits (e.g., "one-second" squitters have a one second mean value and are randomly transmitted every 0.8 to 1.2 seconds). This done to minimize collisions on the link. When collisions do occur, the receiver uses the next available message (which in a broadcast system like ADS-B will arrive shortly) to obtain the data.
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	
	ADS-B System	ADS-B uncompensated latency must be less than 1.2 ms or 0.4 ms depending upon the uncertainty of the position data (error [95% probable]) being used to support a particular operational application. The error is categorized according to navigation uncertainty categories (NUCs) from 1 to 9, with the higher NUCs indicating more accurate position data. The 1.2 ms requirement applies to NUCs less than 8 (0.05 to 10 nm position error), while the 0.4 ms must be met for NUCs 8 or 9 (3 to 10 m error).

CHARACTERISTIC	SEGMENT	DESCRIPTION
Avionics versatility (applicability to other aircraft platforms)	Avionics	ADS-B as defined is intended to be applicable to all aircraft category types as well as surface vehicles operating in the aircraft movement area of an airport. A range of equipage classes have been defined to accommodate the various levels of user requirements from GA to air transport.
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Avionics	No mandate of the ADS-B system is planned. However, if ADS-B equipment is used to perform a particular operation (e.g., IFR), a specific ADS-B equipage class, with certain minimum performance characteristics (e.g., transmitter power), will be required.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.)	Ground	No mandate of the ADS-B system is planned. However, if FAA were to use ADS-B to monitor ground vehicles on the airport movement areas, all such vehicles would have to be equipped with at least a minimum (i.e., broadcast-only) ADS-B system.
Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	System	ADS-B uses the Mode-S architecture which is a sub-network of the ATN and is based on an open system architecture.
	Avionics	The signal in space characteristics are defined by national and international forums.
Source documents		RTCA DO-242 ADS-B MASPS, RTCA DO-181 Mode-S MOPS, draft material for 1090 MHz ADS-B MOPS

5.2.6 Universal Access Transceiver (UAT)

The Universal Access Transceiver concept is intended for distribution of surveillance and weather data. It uses a unique hybrid access method of TDMA and random access. The TDMA portion is used to transmit the traffic and weather information while the random access portion is used by aircraft to transmit their own location in conformance with the RTCA DO-242 broadcast approach. The system is experimental and currently operates on a UHF frequency of 966 MHz. The bandwidth of the system is 3 MHz and a suitable frequency assignment would be difficult. UAT has not been standardized and is not currently recognized by ICAO/ATN. The system is being evaluated in the Safe Flight 21 initiative and would become an open system architecture if developed. The UAT implementation of ADS-B functionality had as its genesis a Mitre IR&D effort to evaluate a multi-purpose broadcast data link architecture in a flight environment. Its use for ADS-B was seen as a capacity and performance driver of the link. The current evaluation system (no standard exists or is in process at this time) uses a single frequency (experimental frequency assigned), a binary FM waveform, and broadcasts with 50 W of power. The system provides for broadcast burst transmissions from ground stations and aircraft using a hybrid TDMA/random access scheme. The UAT message structure, net access scheme, and signal structure have been designed to support the RTCA DO-242 ADS-B MASPS (i.e., to transmit State Vector, Mode Status, and On-Condition messages and provide the corresponding ADS-B reports for use by operational applications). The UAT is also investigating support for other situational awareness services (e.g., TIS-B & FIS-B) through sharing of the channel resources with ADS-B.

Table 5.2-6. UAT Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**UAT**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	UHF
Frequency/ Spectrum of Operations	System	The UAT evaluation system operates on an experimental frequency assignment of 966 MHz. [Note: This band was selected due to the availability of spectrum. However, the system is not frequency specific and could operate in any suitable spectrum.]
System Bandwidth Requirement	RF	3 MHz
	Ground	$\geq$ 1 MHz

CHARACTERISTIC	SEGMENT	DESCRIPTION
System and Channel Capacity (number of channels and channel size)	RF	One channel, 2 MHz
	Ground	Single 1 MB/s channel
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Two part: Ground broadcasts information to aircraft, aircraft transmit position information.
	Ground System	Telco
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
System and component redundancy requirement (1/2, 1/3, etc)	Ground	None, broadcast system. The probability of successful message reception/report update are specified (see Table 3-4 of RTCA DO-242 ADS-B MASPS) depending upon the specific operational applications being supported by the ADS-B system. The more critical data (as determine by the operation being supported) have minimum requirements that broadcast more frequently to improve the probability of message reception and report update. [Note: The ground station TDMA access protocol (see access scheme description below) may have some capability for message prioritization. However, this could not be determined from the documentation available.]
	RF	This is still to be determined. It depends on the ADS-B equipage class, its hardware implementation, and the specific operational applications being supported. The system level minimum availability requirements for equipage classes A1 through A3, for example, is 0.999. This, coupled with the minimum system level continuity of service requirement for the probability of being unavailable during an operation of no more than 2 x 10 –4 per hour of flight, along with the specific availability requirements for the operation being performed (e.g., parallel approach), will determine whether equipment redundancy is needed to satisfy the operational requirement. This is expected to be part of the certification process and will be based on the intended use of the ADS-B equipment and the operational approval(s) being sought.
Physical channel characteristics (LOS, OTH, etc.)	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics	RF	UAT is being designed for operation on a clear channel. Interference to or from off-channel systems can only be assessed once an operational frequency is identified. DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Primarily En Route but operational applications supported by ADS-B have been identified across all phases of flight, except possibly pre- and post-flight. UAT is being designed to support all ADS-B applications (as defined by DO-242)
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	1 Mbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	In general, the UHF frequency is subject to fading and multipath; UAT uses a 48-bit Reed-Solomon forward error correction (FEC) code and a 24-bit cyclic redundancy code (CRC) (acts as a 24-bit parity code) to help address this.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System integrity (probability)	System	UAT will be judged according to ADS-B standards. ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has been supplied to the ADS-B system. ADS-B system integrity is 10–6 or better on a per report basis. Currently, the UAT worst-case overall undetected error probability for an ADS-B message is 3.7x10-11, which exceeds the minimum requirement. [Note: For UAT ADS-B messages map directly (i.e., one-to-one correspondence) to ADS-B reports (i.e., they are not segmented as they are in Mode-S ADS-B).]
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Worst-case overall undetected error probability for an UAT ADS-B message is 3.7x10-11
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	LOS. Similar to VHF: 200 nm at 30,000 feet, 80 nm at 5,000 feet. The UAT proposal is to establish a series of ground stations to provide coverage over the U.S. at low (5,000 feet) altitude.
Link and channel availability	RF	Estimated at 0.99 since it will be an advisory service.
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	None. This is a new system design that is not implemented. It currently has appeal and support from the GA community who perceive it to be a lower cost and possibly improved performance alternative to other ADS-B candidate systems (i.e., Mode-S and VDL Mode 4). However, frequency allocation, product development, and standardization/certification of a final design will have to occur before the validity of this perception can be determined.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	UAT uses both TDMA and Binary Continuous Phase Frequency Shift Keying in its signal cycle. The TDMA signal is used by the ground station for broadcast uplink. The Binary portion is used by aircraft to report position.
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	UAT uses multiple access techniques: time division multiple access (TDMA) in the first portion (e.g., 188 ms) of a one second "frame" (i.e., slots to separate ground station messages from the aircraft and surface vehicle messages) and random access in the second portion (e.g., 812 ms) of the frame for ADS-B messages from aircraft and surface vehicles.
Avionics versatility (applicability to other aircraft platforms)	RF	UAT is being designed to meet ADS-B requirements. ADS-B uncompensated latency must be less than 1.2 ms or 0.4 ms depending upon the uncertainty of the position data (error [95% probable]) being used to support a particular operational application. The error is categorized according to navigation uncertainty categories (NUCs) from 1 to 9, with the higher NUCs indicating more accurate position data. The 1.2 ms requirement applies to NUCs less than 8 (i.e., 0.05 to 10 nm position error), while the 0.4 ms must be met for NUCs 8 or 9 (i.e., 3 to 10 nm error).
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	RF	Optional

CHARACTERISTIC	SEGMENT	DESCRIPTION
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	Avionics	UAT is a new system design being developed from scratch to meet ADS-B requirements. Therefore, since ADS-B as defined is intended to be applicable to all aircraft category types as well as surface vehicles operating in the aircraft movement area of an airport, UAT should be expected to have the avionics versatility needed to address the set of ADS-B requirements. A range of ADS-B equipage classes have been defined to accommodate the various levels of user requirements from GA to air transport
	Ground	Design information available to all vendors
	System	UAT is a new system and currently does have any standards (e.g., RTCA MOPS or ICAO SARPS).
Source documents	UAT	UAT system information was obtained from various briefings to RTCA SC-186 Plenary meetings and private Mitre correspondence. The system description is largely for an evaluation system involved in the current Safe Flight 21 tests and can be expected to change.

5.2.7 Example Geosynchronous (GEO) Satellites (Recommended SATCOM)

Limited aviation communications are currently available via satellite. The InMarSat GEO satellite provides voice and low-speed data service to aircraft in the oceanic domain. The data service has been used to supplement HF voice air traffic control. Satellite voice for air traffic has been limited to emergency voice. The satellite services are installed on aircraft for commercial passenger voice service and the air traffic control services are provided as a secondary consideration. In an emergency, the pilot has priority access to the communication channel. The large dish size used for GEO satellites is expensive and difficult to install on smaller aircraft such as GA. Cargo aircraft do not have the passenger voice communications support and therefore, have not traditionally been equipped with satellite communications equipment.

The InMarSat-4 (Horizons) satellites are proposed for 2001. Due to the crowded spectrum in L-band, Horizons may be deployed at S-band. Data rates of 144 kbps with an Aero-I aircraft terminal and 384 kbps with an Aero-H terminal are forecast. The Horizons satellites may have 150-200 spot beams and 15-20 wide area beams.

5.2.7.1 InMarSat-3

Table 5.2-7. InMarSat-3 Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Inmarsat-3**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	SATCOM – GEO satellite. Five satellites.
	Ground	Ground Earth Stations (GES)
Frequency/ Spectrum of Operations:		C Band ~ 4,000 to 8,000 MHz, and L Band ~1,000 to 2,000 MHz
System Bandwidth Requirement	RF	10 Mhz satellite 17.5 kHz for 21Kbps channel with A-QPSK modulation 10 kHz for 10.5 Kbps channel with A-QPSK 8.4 kHz for 8.4 Kbps channel with A-QPSK 5.0 kHz for 4.8 Kbps channel with A-QPSK 5.0 kHz for 2.4 Kbps channel with A-BPSK 5.0 kHz for 1.2 Kbps channel with A-BPSK 5.0 kHz for 0.6 Kbps channel with A-BPSK
	Ground	N/A

CHARACTERISTIC	SEGMENT	DESCRIPTION
System and Channel Capacity (number of channels and channel size)	RF	Six channels per aircraft for Aero H (High) for current equipage Voice at either 9.6 kbps or 4.8 kbps Data at 10.5 - to 0.6 kbps Maximum voice capacity with additional aircraft equipment is 24 voice channels.
	Ground	N/A
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Complex - see Access scheme block
	Ground	Half Duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Digitally encoded voice & data services
	Ground	Digitally encoded voice & data services
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None - Pilot can seize voice channel if needed
	Ground	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	2 ground stations per region; one satellite per region; Some aircraft may have redundant avionics
	Ground	2 ground stations per region
Physical channel characteristics (LOS, OTH, etc.):	RF	Geosynchronous Satellite LOS, with ~ 1/3 earth footprint
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Primarily Oceanic. Currently InMarSat is not allowed to operate in domestic airspace.
Channel data rate (digital) and/or occupied band width (analog) requirement:		Voice: 10.5 Kbps/with 0.5 Forward Error Correction; Data: Aero-H: 9.6 Kbps; Aero-I: 4.8 Kbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Highly robust
System integrity (probability)	System	BER of 10^{-3} for voice, 10^{-5} for data
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Voice is toll quality. Call blocking probability less than 1 per 50 attempts in busy hour
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	1/3 Earth Regional: Indian Ocean, Pacific Ocean, East Atlantic and West Atlantic regions overlap and cover the entire earth within +/- 85 degrees latitude.
Link and channel availability	RF	98.8% (spot beam) Satellite operates within the 10 MHz band assigned to AMS (R) S for satellite service by ICAO.
Security/ encryption capability	RF	N/A
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Commercial aircraft approximately 1,000 equipped out of estimated 2,000 oceanic fleet.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Aeronautical-Quadrature Phase Shift Key (A-QPSK), Aeronautical variation of QPSK

CHARACTERISTIC	SEGMENT	DESCRIPTION
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	P-Channel (Packet): Time Division Multiplexing (TDM) for signaling and user data (ground-to-air) R-Channel(Random): Slotted Aloha, aircraft-to-ground signaling T-Channel (Reservation): TDMA - used for reserving time slots C-Channel (Circuit-mode): Used for voice
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	8 seconds/95% for 380 octet user packet at 10.5 kbps 45 seconds/95% for 380 octet user packet at 600 bps
	System	End to end delay within acceptable limits for voice transmission
Avionics versatility (applicability to other aircraft platforms)		Size and weight of Avionics and antenna are prohibitive for small aircraft.
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Optional
	Ground	Ground Earth Stations (GES) required for receipt of satellite signals
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary hardware and software
	Avionics	Independent data link
Source documents		Inmarsat SDM; Nera System Summary; Inmarsat fact sheets; Annex 10, Aeronautical Telecommunications, International Civil Aviation Association (ICAO); ARINC Market Survey for Aeronautical Data Link Services; INMARSAT Aeronautical System Definition Manual

5.2.7.2 Potential GEO Satellites

Other GEO satellites have been proposed that are potentially applicable to the aviation market and which are described further in the Task 9 report. They include the AMSC/TMI satellites, Loral Skynet, CyberStar and Orion satellites, the ASC and AceS systems and the proposed Celestri combination GEO/LEO satellite system. They are not discussed further in this report due to their limited service offering or due to their limited remaining satellite life expectancy. Many details of proposed satellites are unavailable either because they are proprietary developments or the designs are still in development. A representative 2007 GEO system based on the LM/TRW Astrolink and Hughes Spaceway systems is presented below.

Table 5.2-8. GEO Satellite Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		LM/TRW Astrolink GEO, Hughes Spaceway GEO. (At least one of these or a similar system should be operational in 2007)
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	Ka-band
	Ground	Unknown
Frequency/ Spectrum of Operations:	RF	Ka-band, 20 GHz downlink from satellite, 30 GHz uplink to satellite
System Bandwidth Requirement:	RF	500 MHz or more, each direction, maybe split 4 or 7 ways for frequency reuse in each cell (spot beam)
	Ground	

CHARACTERISTIC	SEGMENT	DESCRIPTION
System and Channel Capacity (number of channels and channel size):	RF	16kbps to 2Mbps standard channels, hundreds of channels available. Over 100Mbps gateway or hub channels.
	Ground	Unknown
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	duplex, may be asymmetric
	Ground	Duplex
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	Multiple priorities available
	Ground	Unknown
System and component redundancy requirement (1/2, 1/3, etc):	RF	Design life of 10 to 15 years, high system availability (0.9999 goal)
	Ground	Unknown, typically multiple ground stations in view
Physical channel characteristics (LOS, OTH, etc.):	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	possible interference from terrestrial Ka-band systems (LMDS, fiber alternatives systems), regulated through spectrum licensing
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	All
Channel data rate (digital) and/or occupied band width (analog) requirement:		FDM/TDMA burst (packet) channels, variable bit rates, 1 to 100+ Mbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	variable rate coding and variable data rates to mitigate deep rain fades, many frequencies available to avoid fixed interference
System integrity (probability)	System	0.9999 availability typical goal
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	10^{-9} or better typical
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	global possible, but most systems do not intend to cover oceans and polar regions, GEO systems point spot beams to land masses and high population areas in particular
Link and channel availability	RF	0.9999 availability typical goal
Security/ encryption capability	RF	terminal authentication during access encryption can be overlaid, but not a basic feature
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Fixed ground terminal service beginning in 2003
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	digital, QPSK, burst (packets), FEC variable rates 1/2 or higher
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	FDM/TDMA

CHARACTERISTIC	SEGMENT	DESCRIPTION
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	latency: approx. 0.3 second for GEO
	System	
Avionics versatility (applicability to other aircraft platforms)		Not designed for fast moving terminals, can be achieved if business is identified and the developer designs capability.
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	optional
	Ground	
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
	Avionics	Independent
Source documents		FCC and ITU spectrum license applications, conference publications

5.2.7.3 MEO Satellites

MEO satellite systems have been proposed for the Aeronautical Mobile Service. MEO systems have several advantages over the GEO and LEO approaches. The reduced transmission distance of MEO systems provides a higher link margin. Compared to LEO systems, the MEO satellites are in view to an individual aircraft longer and experience less frequent handoffs. Boeing, ICO-Global, Celestri, and Teledesic are possible MEO satellites for the 2007 timeframe. The following table is based on the ICO-Global system. (Note: Segment is used only for characteristic with multiple descriptions)

Table 5.2-9. ICO Global Satellite Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**ICO Global**
Communications/link type (HF, VHF, L-Band, SATCOM, other):		SATCOM MEO satellites; 10 satellites in two planes of 5 each (plus 2 spares)
Frequency/ Spectrum of Operations:	Service Band, Uplink	2.170 – 2.200 GHz
	Service Band, Downlink	1.98 – 2.010 GHz
	Feeder Band, Uplink	6.725 – 7.025 GHz
	Feeder Band, Downlink	5 GHz (AMS(R)S)
	Crosslink Band	N/A
System Bandwidth Requirement:	System	Unknown
System and Channel Capacity (number of channels and channel size):	RF	24,000 circuits total/4.8 Kbps voice
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Duplex

CHARACTERISTIC	SEGMENT	DESCRIPTION
Method of information delivery (voice, voice recording, data, combination, etc.):	RF	GSM Voice
Data/message priority capability / designation (high, intermediate, low, etc.):	System	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	10 satellites in two planes of 5 each (plus 2 spares)
Physical channel characteristics (LOS, OTH, etc.):	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	Service Link Margin 8.5 dB, DO-160D for avionics
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	All
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	4.8 Kbps voice
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Moderate. Max one-satellite duration: 120 minutes Connectivity characteristics: Simultaneous fixed view required
System integrity (probability)	System	Not stated
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Unknown
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	System	Full earth coverage
Link and channel availability	RF	Not stated
Security/ encryption capability	System	Not stated
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	RF	None
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	QPSK
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	TDMA (implied that path diversity and combining will be used
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Latency: ~140ms path + sat switching + 100ms in 2 codecs
Avionics versatility (applicability to other aircraft platforms)	RF	No avionics available.
Equipage requirements (mandatory for IFR, optional, primary, backup)	RF	Optional

CHARACTERISTIC	SEGMENT	DESCRIPTION
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
Source documents		ARINC Satellite Study

5.2.7.4 LEO Satellites

The IRIDIUM system is shown in the following template to represent potential LEO systems although IRIDIUM has gone bankrupt and will not be available. The 66 satellite IRIDIUM LEO system was designed for mobile voice and low-speed data and has been proposed for aeronautical mobile users. FCC filings have indicated future IRIDIUM versions would provide higher speed data services. In addition to the low data rate, LEO systems must overcome the frequent handoff problem that occurs as a satellite transits the user location.

Table 5.2-10. IRIDIUM Satellite Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**Iridium**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	SATCOM; LEO satellites; 66 satellites in 6 planes of 11 each (plus 12 spares)
Frequency/ Spectrum of Operations	Service Band, Uplink	1.62135 – 1.62650 GHz (AMS(R)S)
	Service Band, Downlink	1.62135 – 1.62650 GHz (AMS(R)S)
	Feeder Band, Uplink	29 GHz
	Feeder Band, Downlink	19 GHz
	Crosslink Band	23 GHz
System Bandwidth Requirement	System	10.5 MHz
	Channel	31.5 kHz/50 kbps/12 users
System and Channel Capacity (number of channels and channel size)	RF	3840 circuits/sat; 56,000 circuits total
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	System	duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	System	Voice and data
Data/message priority capability / designation (high, intermediate, low, etc.)	System	None
System and component redundancy requirement (1/2, 1/3, etc)	RF	66 satellites in 6 planes of 11 each (plus 12 spares)
	Ground	Satellite-satellite switching for high ground system availability

CHARACTERISTIC	SEGMENT	DESCRIPTION
Physical channel characteristics (LOS, OTH, etc.)	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics	RF	Service link margin: 16.5 dB no combining min BER 10^{-2} DO 1600 for avionics
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	All
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	2.4 Kbps and 4.8 Kbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	High. Max one-satellite duration: 9 minutes Connectivity characteristics: Flex to any station at any location
System integrity (probability)	RF	$1x10^{-6}$
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Compressed voice, toll quality
Range/ Coverage/ footprint (oceanic, global, regional / line-of-sight	System	Full earth coverage
Link and channel availability	RF	99.5%
Security/ encryption capability	System	Proprietary protocol
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	RF	No aviation usage
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	QPSK, FEC rate ¾,
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	FDMA/TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	12 ms path; 175 ms total
Avionics versatility (applicability to other aircraft platforms)	RF	No avionics available
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Optional

CHARACTERISTIC	SEGMENT	DESCRIPTION
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
Source documents		ARINC Satellite Study

5.2.8 High-Frequency Data Link

HF data link provides an alternative to oceanic satellite data and HF voice communications. The aircraft changes are small, consisting primarily of a radio upgrade and a new message display capability. HF antenna and aircraft wiring can remain the same. HFDL is cheaper to install and operate than satellite. For cargo aircraft that do not need the passenger voice service of satellite, HFDL provides a cost effective data link. HFDL is adaptive to radio propagation and interference. It seeks the ground station with the best signal and adjusts the data-signaling rate to reduce errors caused by interference. HFDL service is faster, less error prone and more available than traditional HF voice communications. HFDL has not yet been approved for carrying air traffic messages and aircraft equipage is just beginning.

Table 5.2-11. HFDL Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		HIGH FREQUENCY DATA LINK (HFDL) (GLOBAlink/HF)
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	High Frequency (HF)
	Ground	ARINC Data Network System (ADNS) & ARINC Packet Network (APN)
Frequency/ Spectrum of Operations:		2.8 MHz to 22 MHz
System Bandwidth Requirement:	RF	3 kHz Single Side band, carrier frequency plus 1440 Hz. Each Station provides 2 channels
	Ground	N/A
System and Channel Capacity (number of channels and channel size):	RF	Two channels per ground station
	Ground	ADNS & APN X.25 packet switched services
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Half-duplex
	Ground	Full duplex with a separate channel for each transmit and receive path, however the communications equipment often blocks receive voice when the operator is transmitting resulting in a half-duplex operation.
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data

CHARACTERISTIC	SEGMENT	DESCRIPTION
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	N/A
	Ground	A ground based priority and preemption capability that enables Air Traffic Services (ATS) messages to be delivered ahead of Aeronautical Operational Control (AOC) messages. A higher priority single or multiblock ATS message will be serviced before lower priority multiblock messages. The transmission of lower priority multiblock messages will resume when the higher priority message is completed. Lower priority messages will be delivered in their entirety to the aircraft. Lower priority single-block messages are not preempted due to protocol and avionics implementation requirements. The immediate preemption by higher priority messages of lower priority multiblock messages is also supported.
System and Component Redundancy	RF	HFDL Ground Stations (HGS) are geographically located to provide a 1 / 2 equipment diversification with each site transmitting two frequencies to provide a 1 / 4 relationship for radio frequencies.
	Ground	ETE availability for HFDL through ADNS and APN provides redundancy with an availability of 1.00000. In the North Atlantic Region redundancy is also provided with an equipment availability of.99451 for the passport backbone Access Module. In the Pacific Region total redundancy is provided ETE.
Physical channel characteristics (LOS, OTH, etc.):	RF	Via ionosphere
Electromagnetic interference (EMI) / compatibility characteristics:	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	Adaptable to propagation conditions: 1800, 1200, 600, 300 bps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Signals in the HF band are influenced by the characteristics inherent in transmitting through the ionosphere, which include various emissions from the sun interacting with the earth's magnetic field, ionosphere changes, and the 11-year sunspot cycle which affects frequency propagation. HF is also affected by other unpredictable solar events. Frequency management techniques are used to mitigate these effects
System integrity (probability)	System	No integrity requirement for 2007 data services, Forward error detection
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	95% of uplink message blocks in 60 seconds (one-way); 95% of uplink message blocks in 75 seconds (round-trip); 99% of uplink message blocks in 180 seconds (round-trip
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	3,000 nm from each ground station. Ten stations deployed as of December 1999 with 3-4 more sites under consideration to complete Global coverage.
Link and channel availability	RF	≥99.8% End to End Operational Availability
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Commercial aircraft, 50-100 equipped. New service with potential 8,000 users

CHARACTERISTIC	SEGMENT	DESCRIPTION
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	M-Phase Shift Keying (M-PSK) 1800 (8-PSK); 1200(4-PSK); 600 (2-PSK); 300 (2-PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Slotted TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Uplink end-to-end: 2 minutes/95%, 6 minutes/99% of messages Downlinks end-to-end: 1 minute/95%, 3 minutes/99%
Avionics versatility (applicability to other aircraft platforms)	Avionics	Any aircraft equipped with HF transmit and receive equipment and the appropriate HFDL interface unit
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Avionics	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications, etc.)	System	Signal in space defined by national and international standards. HF Voice equipment may be shared with other HF applications (i.e., HF voice).
Source documents		Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; ARINC Quality Management Reports, Air/Ground Voice Performance; ARINC specification 635-2 ARINC Aeronautical Data Link Proposal, 1997; HFDL Ground Station System Segment Specification

5.3 Link Considerations

5.3.1 Ground based systems

All aviation communications systems based on ground stations have limitations of coverage and range. The majority of aviation communications systems are line of sight limited. The radio frequency power available permits operation at distances up to 200 nautical miles (nm). However, the curvature of the earth blocks the signal to aircraft unless the aircraft is at high altitude. At low altitudes such as 5,000 feet, the line of sight range is reduced to approximately 30 nm. Mountains also block signals and reduce potential coverage. Satellites are much less limited in coverage but do become constrained by available power. A geosynchronous satellite can cover one-third of the earth but the radio frequency power will be far less than for terrestrial systems. Traditionally satellite systems have used dish antennas to increase received power. Newer satellite concepts include low earth orbit (LEO) and medium earth orbit (MEO) systems which are closer to the earth which improves the available power while reducing the coverage for each satellite.

5.3.2 Frequency band

The aviation industry has traditionally used frequency spectrum allocated specifically to aviation applications and protected by national and international law from interference. Under international agreement, the aviation communications frequencies are limited to ATC and AOC use. Services such as entertainment and passenger communications have been prohibited. All of the VHF systems, voice

DSB-AM, ACARS, VDL Mode 2, Mode 3, and Mode 4 are designed to operate within the current 25 kHz channel spacing of the 118 - 137 MHz protected VHF band.

Three major configurations of satellite systems were considered. GEO systems depend on satellites in geosynchronous orbit. Usually a single satellite provides wide area coverage that is essentially constant. Coverage is not possible at the poles. MEO satellites move relative to the earth and their coverage shifts. A number of satellites are needed and earth coverage is virtually complete. A failure of a single satellite causes a short-term outage. LEO satellites move quickly relative to the earth and require numerous satellites for full earth coverage; therefore, an outage of a single satellite is short-term.

5.3.3 General Satellite Comments

Ka and extremely high frequency (EHF) systems are best for fixed or slowly moving terminals, not for aviation speed terminals (path delay variation, Doppler, frequent hand-off between spot beams). Coding and other link margin features may be used to compensate for speed when the aircraft is above atmospheric degradation (rain). The GEO and MEO systems avoid oceans by not pointing spot beams there (systems with phased array antennas will be capable of pointing at oceans) and LEO systems plan to power down the satellites while over the oceans or low population areas. These issues are not technological problems; they are design choices based on business cases. To insure capability for aeronautic use, economic opportunity needs to be communicated to the system developers (business cases supporting premium charges, particularly over unpopulated areas).

Alternatives to these systems will likely be provided by established service providers, such as Inamoratas (at Ku-band, and possibly new systems at Ka-band), and Boeing, which is aggressively pursuing multimedia to the passenger with asymmetrical return link. There will be a premium charge for this type system relative to fixed-ground terminals, particularly when outside of populated areas.

Boeing has already demonstrated direct video broadcast (DVB) standard communication to the aircraft. The emerging DVB-RCS (return channel satellite) standard will probably be capable of asymmetric communication with aircraft and be available in 2007.

5.3.4 Summary of Links

The communications links are summarized in Table 5.3-1, which presents the key performance characteristics. The most significant consideration in our review has been the need to provide high bandwidth and capacity. As shown, existing and near term links are limited in bandwidth and capacity and will be unable to meet the future traffic load from FIS and TIS. Message latency is also a significant consideration, especially for the ATC critical message types. Considerations such as modulation scheme, frequency, integrity, range and protocol are important design considerations buy are not the major factors for selecting a future data link.

Table 5.3-1. Capacity Provided by Various Communication Links

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
	kbps	Channels	Channels	Aircraft	
HFDL	1.8	2	1	50	Intended for Oceanic
ACARS	2.4	10	1	25	ACARS should be in decline

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
					as users transition to VDL Mode 2
VDL Mode 2	31.5	4+	1	150	System can expand indefinitely as user demand grows
VDL Mode 3	31.5*	~300	1	60	Assumes NEXCOM will deploy to all phases of flight
VDL Mode 4	19.2	1-2	1	500	Intended for surveillance
VDL – B	31.5	2	1	Broadcast	Intended for FIS
Mode-S	1000**	1	1	500	Intended for surveillance
UAT	1000	1	1	500	Intended for surveillance/FIS
SATCOM	-	-	-	-	Assumes satellites past service life
Future SATCOM	384	15	1	~200	Planned future satellite
Future Ka Satellite	2,000	~50	~50	~200	Estimated capability - assumes capacity split for satellite beams
Fourth Generation Satellite	>100,000	>100	>100	Unknown	Based on frequency license filings

* Channel split between voice and data.

** The Mode-S data link is limited to a secondary, non-interference basis with the surveillance function and has a capacity of 300 bps per aircraft in track per sensor (RTCA/DO-237).

Appendix A Acronyms

AAC	Airlines administrative communications
AATT	Advanced Air Transportation Technologies
ACARS	aircraft communications addressing and reporting system
ADAS	AWOS data acquisition system
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance - Broadcast
AFSS	automated flight service station
AM	amplitude modulation
AMS	acquisition management system
AMS(R)S	Aeronautical Mobile Satellite (Route) Service
AOC	airline operations center
ARTCC	Air route traffic control center
ASIST	Aeronautics Safety Investment Strategy Team
ASOS	automated surface observing system
ASR-9	airport surveillance radar- nine
ASR-WSP	airport surveillance radar- weather system processor
ATCSCC	Air traffic Control System Command Center
ATIS	Automatic Terminal Information Service
ATM	air traffic management
ATN	Aeronautical Telecommunication Network
ATS	air traffic services
ATSP	air traffic service provider
AvSP	Aviation Safety Program
AWIN	Aviation Weather Information
AWOS	automated weather observing system
BER	bit error rate
CD	compact disk
CONOPS	concept of operations
CONUS	Continental United States
CP	conflict probe
CPU	central processing unit
CSA	communications system architecture
CTAS	Center-TRACON Automation system
DA	descent advisor
DAG-TM	Distributed Air/Ground Traffic Management

DoD	Department of Defense
DOT	Department of Transportation
DOTS	dynamic ocean tracking system
DSR	Display System Replacement
FAA	Federal Aviation Administration
FANS 1/A	future air navigation system
FAR	Federal Aviation Regulation
FBWTG	FAA bulk weather telecommunications gateway
FCC	Federal Communications Commission
FDM	flight data management
FDP	flight data processor
FFP1	Free Flight Phase 1
FIS	Flight Information Service
FL	flight level
FP	flight plan
FSS	flight service station
GA	general aviation
GPS	Global Positioning System
HARS	high altitude route system
HF	high frequency
IF	interface
IFR	Instrument flight rules
IMC	instrument meteorological conditions
IOC	initial operating capability
ITWS	Integrated terminal weather system
LLWAS	Low-level wind shear alert system
MDCRS	Meteorological Data Collection and Reporting System
METAR	meteorological aviation report
MOPS	minimum operational performance standards
NAS	National Airspace System
NAS RD	NAS Requirements Document
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NESDIS	national environmental satellite, data, and information service
NEXRAD	next generation radar
NLDN	national lightning detection network
NWS	National Weather Service

NWS/OSO	National Weather Service/Office of Systems Operations
OASIS	operational and supportability implementation system
OAT	Office of Advanced Technology
ODAPS	oceanic display and planning system
PFAST	passive final approach spacing tool
PIREPS	pilot reports
RA	resolution advisory
RD	requirements document
RTCA	RTCA, Incorporated
RTO	Research Task Order
RVR	runway visual range
STC	supplemental type certificate
TAF	Terminal Aerodrome Forecast
TBD	to be determined
TDWR	terminal Doppler weather radar
TFM	traffic flow management
TM	traffic management
TMS	traffic management system
TRM	Technical Reference Model
TWIP	terminal weather information for pilots
VDL	very high frequency digital link
VFR	visual flight rules
VHF	very high frequency
WARP	weather and radar processor
WMSCR	weather message switching center replacement
WJHTC	William J. Hughes Technical Center
WxAP	weather accident prevention

Appendix B Glossary for Architectural and Operational Terms

Term	Definition
Additional Services	Advisory information provided by ATC which includes but is not limited to the following: a. Traffic advisories. b. Vectors, when requested by the pilot, to assist aircraft receiving traffic advisories to avoid observed traffic. c. Altitude deviation information of 300 feet or more from an assigned altitude as observed on a verified (reading correctly) automatic altitude readout (Mode C.) d. Advisories that traffic is no longer a factor. e. Weather and chaff information. f. Weather assistance. g. Bird activity information. h. Holding pattern surveillance. Additional services are provided to the extent possible contingent only upon the controller's capability to fit them into the performance of higher priority duties and on the basis of limitations of the radar, volume of traffic, frequency congestion, and controller workload. The controller has complete discretion for determining if he/she is able to provide or continue to provide a service in a particular case. The controller's reason not to provide or continue to provide a service in a particular case is not subject to question by the pilot and need not be made known to him/her.
Air Traffic Control	A service operated by appropriate authority to promote the safe, orderly and expeditious flow of air traffic.
Air Traffic Service	A generic term meaning: a. Flight Information Service b. Alerting Service c. Air Traffic Advisory Service d. Air Traffic Control Service 1. Area Control Service, 2. Approach Control Service, or 3. Airport Control Service.
Architecture	The structure of NAS components, their interrelationships, and the principles and guidelines governing their design and evolution over time.
Capability	NAS Architecture component consisting of a set of functions, systems, and/or related activities that enables or supports the delivery of a service.
Flight Object	The flight object is a virtual collection of all applicable data for a specific flight. It contains the "pointers" for all logical subsets. For example, the flight object would contain the "pointer" to the current flight plan data within the FAA NWIS as well as "pointers" to other flight data, such as gate preference, possibly within airline databases.

Term	Definition
Flight Phase	• The PRE-FLIGHT phase of flight encompasses all activities prior to initial aircraft movement. During the Pre-Flight phase of flight Pilots plan their flight, submit a flight plan to Air Traffic Control, and conduct aircraft checks (Pilots flying VFR are not required to file a flight plan, however, it is encouraged by the FAA). • The SURFACE Movement phase of flight begins encompasses aircraft and SURFACE vehicle movement on the airport SURFACE. • The ARRIVAL / DEPARTURE phases of flight represent the climb and descent transition periods between the airport SURFACE and CRUISE. • The CRUISE phase of flight encompasses all flight activities (generally level flight) between departure climb out and initial descent for arrival. The CRUISE phase of flight generally relates to the En Route, Oceanic, and—in the future—Space domains but also has applicability to the Terminal domain for some flight activities. • The Cross-Cutting "phase of flight" encompasses those activities that support one or more phases of flight. These activities are generally related to the provision of Traffic Management, Navigation, Emergency and Alerting, Airspace Management, or Infrastructure/Information Management Services.
Implementation Step	NAS Architecture component consisting of operational scenarios and the mechanisms necessary to enable the delivery of a capability.
Mechanism	People, systems, or support activities.
Operational Scenario	Narrative description of the interaction of mechanisms necessary to perform a specific portion of a capability.
Service	High-level activities performed by the FAA for the aviation community that contribute to the safe and efficient flow of aircraft throughout the NAS.

Communications System Architecture Development For Air Traffic Management & Aviation Weather Information Dissemination

Research Task Order 24

Subtask 4.8, Develop AWIN 2007 Architecture

(Task 7.0)

Prepared By

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Table of Contents

Table of Figures

Table of Tables

1 Executive Summary

1.1 Background

Aviation Weather Information (AWIN) and Weather Information Communications (WINCOMM) are elements of the National Aeronautics and Space Administration's (NASA's) Aviation Safety Program (AvSP). The AvSP will address the Office of Advanced Technology (OAT) goal of "reducing the aircraft accident rate by a factor of five within 10 years, and by a factor of 10 within 20 years." In 1997, an Aeronautics Safety Investment Strategy Team (ASIST) defined the objectives of AvSP in the following way:

> The team recognized that weather was a major contributing factor in aviation accidents and incidents. A key recommendation of the ASIST activity was for a significant effort in weather accident prevention. As a result, weather accident prevention (WxAP) has been incorporated as a key element of the AvSP. Furthermore, the ASIST weather team produced a prioritized list of investment areas under weather accident prevention. Weather data dissemination was considered the most critical and highest ranked priority on the list.[1]

The AvSP officially launches in fiscal year 2000. The specific activity (Task 7) addressed in this document is a pre-AvSP development effort. It is a sub-element under the Advanced Air Transportation Technologies (AATT) Research Task Order (RTO) 24, Communications System Architecture Development for Air Traffic Management and Aviation Weather Information Dissemination.

1.2 Objectives

The objective of Task 7 is to develop a 2007 AWIN Architecture; i.e., to develop a communication system architecture (CSA) with the potential for implementation by 2007 that "can fulfill the goal of providing the collection and dissemination of aviation weather information and distribution of advanced weather products to the various aviation platform classes."[2]

1.3 Technical Approach

While the specific Task 7 objective addresses collection and dissemination of weather information, weather information and distribution must be viewed within the context of the overall National Airspace System (NAS) Architecture. For example, NASA's office of Aerospace Technologies has identified a technology objective stating:

> While maintaining safety, triple the aviation system throughput, in all weather conditions, within 10 years.

The FAA's stated NAS weather architecture goal is to:

> Convert existing weather architecture—consisting of separate, stand-alone systems—to one where future weather systems are fully integrated into the NAS.

These statements clearly indicate the need to view the weather architecture in the full context of the NAS; in particular, the Air Traffic Management (ATM) component of the NAS. To provide that context, we

[1] Background from the "Communications System Architecture Development For Air Traffic Management Aviation Weather Information Dissemination" Request for Task Plan.
[2] "Communications System Architecture Development For Air Traffic Management Aviation Weather Information Dissemination" Request for Task Plan.

extracted user needs and high-level goals (Task 1) from a wide variety of sources, including other NASA and FAA programs, RTCA activities, and industry. From these needs and goals, we developed a consensus vision and concept of operations for the 2015 architecture (Task 5) to provide a "top down" perspective. We further refined the operational concept into nine communication technical concepts that formed our functional communication architecture. For AWIN, the functional communication architecture can be further simplified to those highlighted in Figure 1.3-1.

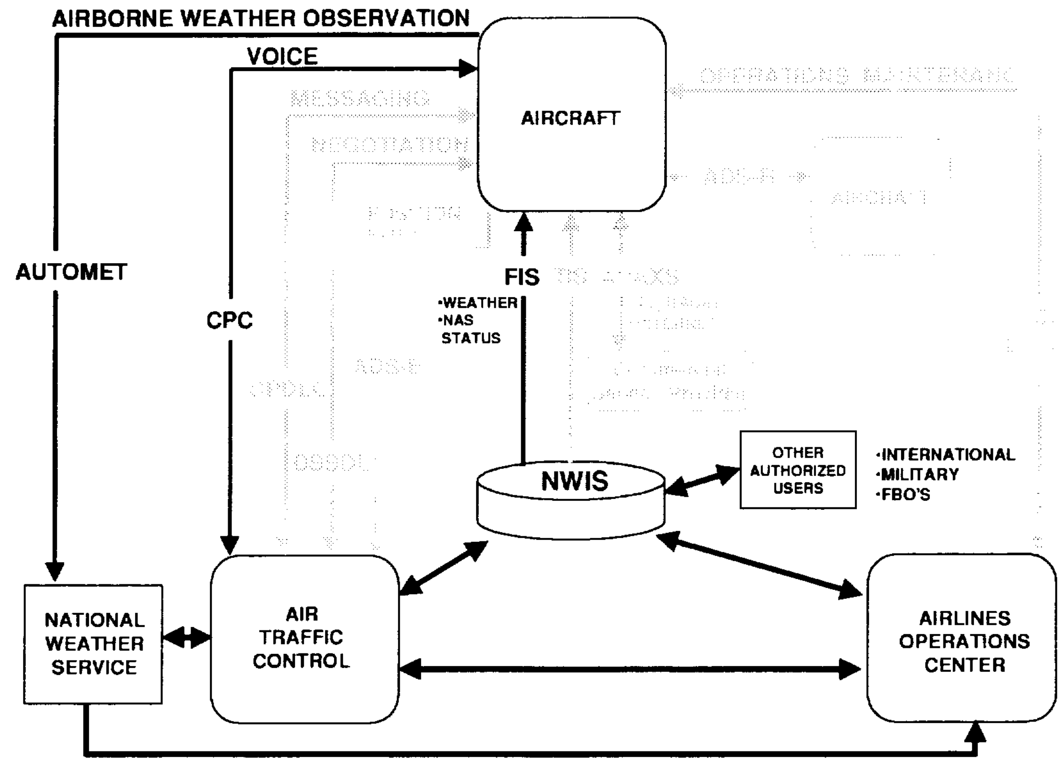

Figure 1.3-1. AWIN Functional Architecture

The functional communication architecture was used to formulate the physical architecture alternatives based on the results of our communication loading analysis (Section 4) and on our determination of communication link capabilities (Section 5). This process is illustrated in Figure 1.3-2.

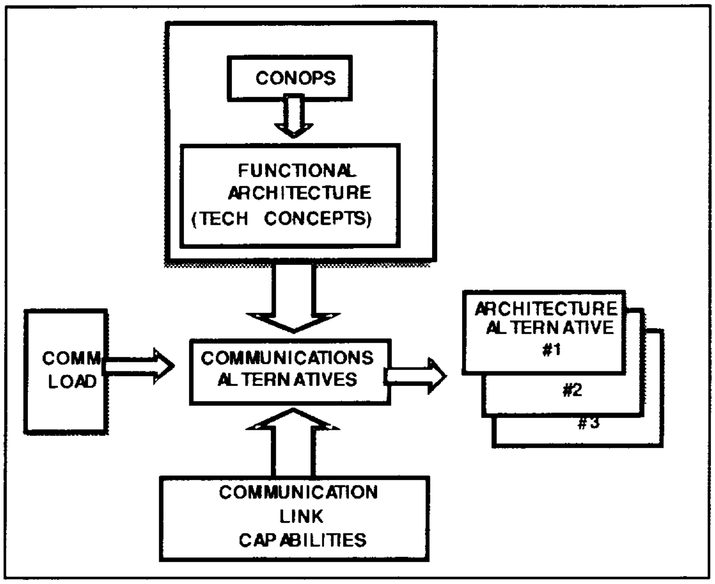

Figure 1.3-2. AWIN Architecture Alternative Development Method

1.4 Results of This Task

The results of this Task produced three alternative architectures as shown in the figure below

Category	Technical Concept	VDL-B	VDL-2/ATN	VHF-AM	UAT	SATCOM-2 way
1	FIS	▭ ◇			○◇	△◇
4	CPC (voice)			▭ △○◇		
8	AUTOMET		▭ △○◇		◇	◇

◇ Technically Feasible
▭ Alternative 1 - NAS Architecture
○ Alternative 2 – Terrestrial-Based
△ Alternative 3 – Space – Based

Figure 1.4-1. AWIN Architecture Alternative

As is shown in the table the only variations in the AWIN architecture alternatives are in the Flight Information Services (FIS) category. Given the communication link technologies that we determined could be available in 2007 and considering the 2015 architecture recommendation, we could not find a compelling reason to recommend a departure from the current NAS Architecture path for CPC or AUTOMET.

For FIS, our communication load analysis indicated that we can support regional data dissemination. However, we will exceed the capacity of any VHF data link for national broadcast in the 2007 time frame. The 2015 AATT communication architecture (Task 5 of this report) recommends that a national FIS data broadcast capability be provided using a broadband data link. (UAT or SATCOM).

This being the case, the choices are:

- Reduce the data requirements to fit within existing capabilities
- Create new compression or data packaging techniques that will support additional data with existing capabilities
- Develop multi-channel strategies that rely on avionics processing and storage capabilities to create the desired products from multiple data streams
- Move to a new communication system that supports the data requirements
- A hybrid of the above.

In summary, for the 2007 AWIN communication architecture, we conclude that the NAS Architecture provides the best solutions for controller-pilot voice communication (VHF-AM digital radios) and for AUTOMET (VDL-2). There are no acceptable solutions in this time frame for automated real-time delivery of hazardous weather information to the cockpit so this function must continue to be performed by the controller. Finally, for delivery of FIS data, the use of VDL-B will support regional dissemination of weather products and is sufficient for the 2007 time frame. However, national deployment of FIS should be accomplished through the implementation of a broadband data exchange capability. With this objective, further research should be conducted (as outlined in Tasks 5, 10, and 11) to determine whether a terrestrial-based, (UAT), space-based (SATCOM), or hybrid solution is most suitable.

2 Introduction

In 1995, NASA began the Advanced Air Transportation Technologies (AATT) initiative to support definition, research, and selected high-risk technology development. In fiscal year 2000, NASA will officially launch its Aviation Safety Program (AvSP). This report responds to a specific task (Develop AWIN 2007 Architectures), which is a pre-AvSP activity being conducted under AATT.

2.1 Overview of Task 7

The objective of Task 7 is to develop a 2007 AWIN Architecture; i.e., to develop a communication system architecture (CSA) with the potential for implementation by 2007 that can fulfill the goal of providing the collection and dissemination of aviation weather information and distribution of advanced weather products to the various aviation platform classes.

Task 7 is one of eleven related tasks in the AATT RTO 24, Communications System Architecture Development for Air Traffic Management and Aviation Weather Information Dissemination. The relationships among these tasks are depicted in Figure 2.1-1. Task 5 develops the 2015 AATT Architecture, and Task 6 develops the 2007 AATT Architecture. Task 7 builds upon the communications system concepts developed in Task 4 and uses the definition of the 2015 CSA from Task 5 and requirements from Task 3 to define the recommended AWIN architecture. Elements of Task 9 define and determine what is achievable in 2007. The results of these tasks feed Tasks 8, 10, and 11.

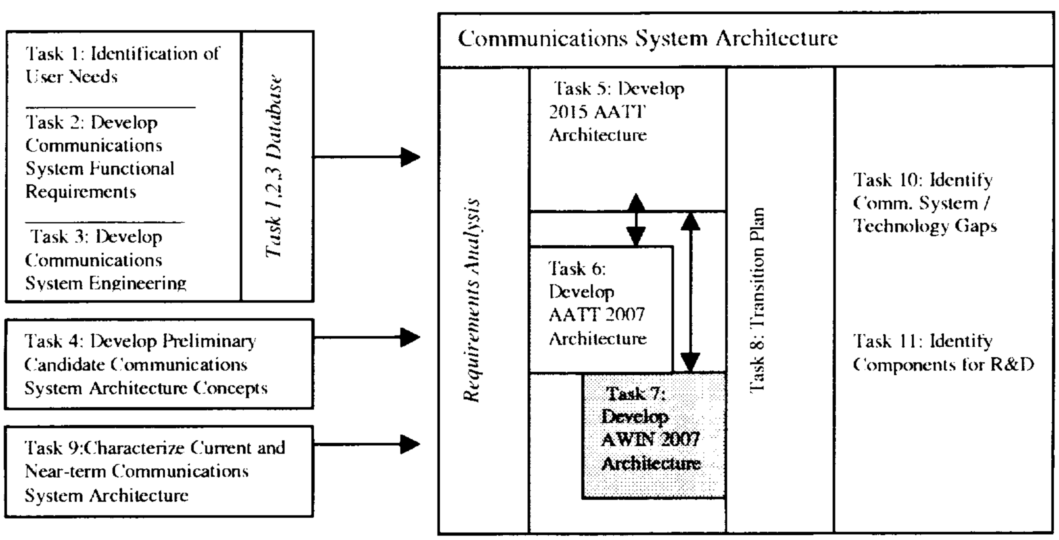

Figure 2.1-1. Relationship to Other Tasks

Task 7 began with a review of the relevant user needs and functional communications requirements collected in Tasks 1 and 2 of this RTO (RTO 24). This review was followed by the development of concepts of operation for 2007. Next, we analyzed the current CSA for weather products and the NAS Architecture for their ability to meet these needs. The Task 7 2007 AWIN Architecture was developed from this analysis and will be used to identify gaps for inclusion in Task 10.

To ensure weather data availability to meet the needs of all users of the Air Traffic Services, three classes of users were defined as follows:

- Class 1: Operators who are required to conform to FAR Part 91 only, such as low-end General Aviation (GA) operating normally up to 10,000 ft. This class includes operators of rotorcraft, gliders, and experimental craft and any other user desiring to operate in controlled airspace below 10,000 ft. The primary distinguishing factor of this class is that the aircraft are smaller and that the operators tend to make minimal avionics investments.

- Class 2: Operators who are required to conform to FAR Parts 91 and 135, such as air taxis and commuter aircraft. It is likely that high-end GA and business jets and any other users desiring to operate in controlled airspace will invest in the necessary avionics to be able to achieve the additional benefits.

- Class 3: Operators who are required to conform to FAR Parts 91 and 121, such as Commercial Transports. This class includes passenger and cargo aircraft and any other user desiring to operate in controlled airspace. These users will invest in the avionics necessary to achieve the additional benefits.

Based on the user needs and functional communications requirements presented in Tasks 1 and 2, the table below presents the high level goals and operational requirements to be met by the resulting communications architecture. These user goals and operational requirements have been grouped according to user class.

Table 2.1-1. User Goals and Operational Requirements

Class 1 User Goals	**Class 2 User Goals**	**Class 3 User Goals**
• Minimize/streamline interaction with ATM system • Make communications transparent and seamless for the pilot • Expand access to more airports in IMC conditions (High-end GA)	• Reduce limitations and delays caused by weather • Provide instrument approaches to more airports	• Expand the use of user preferred routes and trajectories • Increase airport capacity in IMC • Increase system predictability • Reduce weather related delays • Minimize time and path length for routing around hazardous weather
Class 1 Operational Requirements	**Class 2 Operational Requirements**	**Class 3 Operational Requirements**
Class 1 users require: • On demand weather • Weather at more sites • User friendly formats ("user friendly" is TBD but could include graphical, oriented to flight path, uncluttered, easy to interpret by solo pilot, etc.) • More real-time updates	Class 2 users require: • Weather at a greater number of sites • More real-time weather at remote sites	The Class 3 users, desiring a combination of preferred routes and increased capacity, require: • More precise weather information for routing • Weather information consistent with that seen by controllers and operations centers • Higher density grids at higher update rates to support decision support systems like CTAS and wake vortex prediction systems

The information above emphasizes a flow of information that generally is ground-to-air. However, the system will require more air-to-ground weather information to populate the higher density grids and enable near real-time updates.

2.2 Overview of the Document

Section 1 is an executive summary that provides a high-level synopsis of the document.

Section 2 introduces the task and provides background and context, including the relationship of Task 7 to other RTO 24 tasks.

Section 3 provides architecture concepts, characteristics, considerations and develops alternatives for the 2007 AWIN Architecture. It discusses the following topics in order:

- Our approach to developing architecture alternatives
- A summary of the 2015 AATT communication system architecture
- Development of the 2007 AWIN functional architecture
- Definition of the alternative architectures
- Technology gaps for the alternative architectures
- Transition path for the 2007 AWIN architecture

Section 4 presents the technical detail of the communication load analysis. It discusses the following topics in order:

- Inputs provided by earlier tasks
- The use of scenarios to organize the information
- Calculation methodology
- Numerical results of the message load calculations
- Implications and conclusions drawn from the numbers.

Section 5 provides the technical details of the individual communications links. For each communications link it presents:

- The link characteristics
- Significant points and tradeoffs considered in link selection.

3 Defining the 2007 AWIN Architecture

3.1 Introduction

The analysis leading to the definition of the 2007 AWIN communications architecture alternatives involved the three primary tasks shown in Figure 3.1-1: (1) defining an overall functional architecture to satisfy the desired services, (2) defining the information to be exchanged while providing the services (i.e., communication loading), and (3) identifying the enabling mechanisms (i.e. communication links) that are suitable for exchanging the information. Based on these tasks, we developed communications alternatives that were reflected in three distinct 2007 AWIN communications architecture alternatives and transition strategies. Note that the concepts presented in this section are not unique to Task 7 (2007 AWIN Architecture); rather, they apply equally well to Task 5 (2015 AATT Architecture) and Task 6 (2007 AATT Architecture).

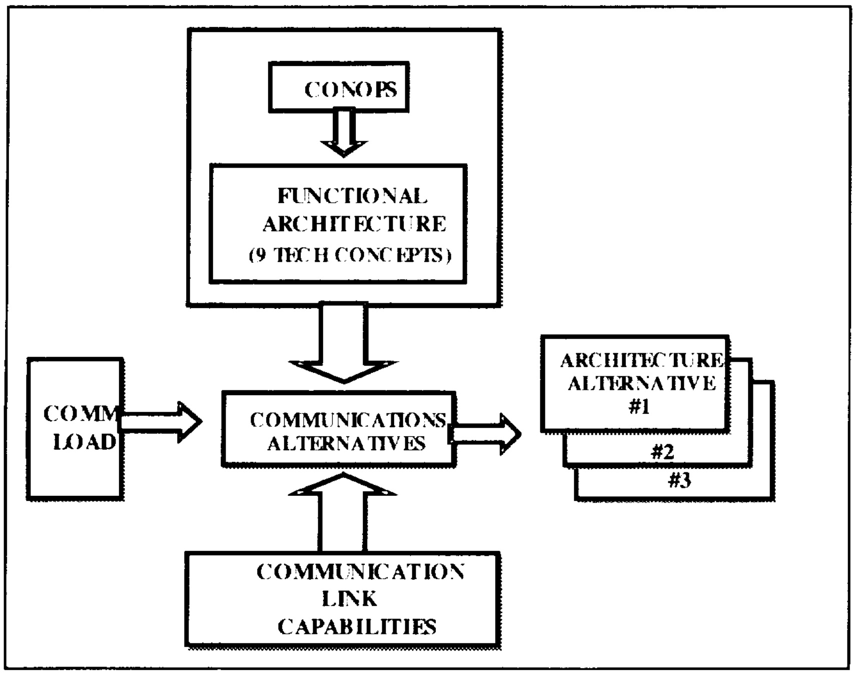

Figure 3.1-1. AWIN Architecture Alternative Development Method

Definition of the functional architecture first requires an understanding of the desires of the aviation community. To gain this understanding, we reviewed a wide range of user requirements as documented in Tasks 1, 2, and 3 and drew upon knowledge gained through our team's in-depth involvement in the development of the NAS Architecture. We organized our results by air traffic services and the functional capabilities into which the services logically divide, and then matched the message type requirements that were identified in Task 2 with this service/functional capability structure. The result was a *service-driven view of the message types* that had been identified. [Note that, for our purposes, a message type is a logical grouping of information that represents all data forms within that type, including raw data, commands, images, etc.]. We then focused these message types further with cross-cutting technical concepts derived from the CONOPS for the purpose of defining the functional architecture. Finally, by applying the appropriate enabling communication links to the functional architecture, we transformed it into the physical communications architecture. These relationships are illustrated in Figure 3.1-2.

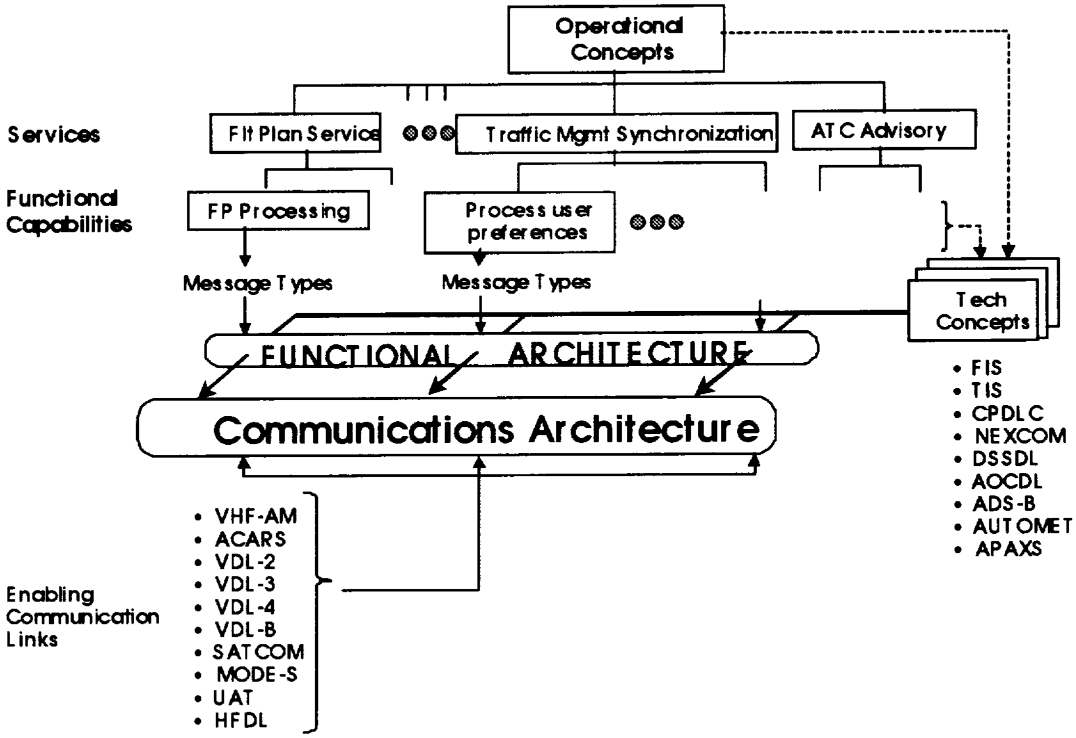

Figure 3.1-2. Operational Concepts to Communications Architecture

At the highest level are the operational concepts that provide the top down vision for what is desired. In the 2015 time frame, the drivers for the operational concepts are born out of the need for increased user flexibility with operating efficiencies and increased levels of capacity and safety to meet the growing demand for air transportation. These concepts are characterized by: (1) removal of constraints and restrictions to flight operations, (2) better exchange of information and collaborative decision making among users and service providers, (3) more efficient management of airspace and airport resources, and (4) tools and models to aid air traffic service providers.

The operational concepts provide a context for measuring progress and for assessing whether or not the infrastructure is being provided to support the vision. The vision provided by the operational concepts draws upon the results of efforts such as the ATS Concept of Operations for the National Airspace System in 2005, the Concept Definition for Distributed Air/Ground Traffic Management (DAG-TM), and current and emerging industry trends. It provides context for the 2007 AWIN Architecture from two perspectives. The first perspective provides a view of the desired 2015 architecture necessary to assess whether or not the 2007 architecture is correctly positioned on the path to 2015. The second perspective provides the broader vision necessary to integrate the 2007 architecture into the overall NAS.

From a communication architecture perspective, it is important to understand the services that will enable the operational concepts along with their supporting functions and the various message types that are the products of those functions. The services identified for this task and their related functional capabilities were identified in Tasks 1, 2, and 3 and are summarized in Table 3.1-1, which also includes the Message Type Identifiers for the information exchange to support these functional capabilities.

Table 3.1-1. Services and Associated Functional Capabilities

Service	Function Name (Functional Capability)	Msg ID (M#)
Aeronautical Operational Control (AOC)	Collaborate with ATM on NAS Projections and User Preferences	M25
	Monitor Flight Progress - AOC	M23
		M33
		M6
	Airline Maintenance and Support	M8-M12
	Schedule; Dispatch; and Manage Aircraft Flights	M30
ATC Advisory Service	Provide In-flight NAS Status Advisories	M17
	Provide In-flight or Pre-flight Traffic Advisories	M32
	Provide In-flight or Pre-flight Weather Advisories	M13
		M14
		M15
		M18
		M20
		M21
		M22
		M26
		M27
		M28
		M29
		M35
		M37
		M39
		M4
		M43
		M44
Flight Plan Services	File Flight Plans and Amendments	M22
		M24
		M32
	Process Flight Plans and Amendments	M16
		M32
		M34
		M40
On-Board Service	Provide Administrative Flight Information	M5
		M7
	Provide Public Communications	M31
Traffic Management Strategic Flow Service	Provide Future NAS Traffic Projections	M38
Traffic Management Synchronization Service	Process User Preferences	M2
	Project Aircraft In-flight Position and Identify Potential Conflicts	M1
		M3
	Provide In-flight Sequencing; Spacing; and Routing Restrictions	M36
	Provide Pre-flight Runway; Taxi Sequence; and Movement Restrictions	M32
		M36

Table 3.1-2 below provides a textual description of the Message Type corresponding to each Message Type Identifier. These messages may be voice, text, or graphical images.

Table 3.1-2. Message Types and Message Type Identifiers

Message Type Identifier	Message Type
M1	ADS
M2	Advanced ATM
M3	Air Traffic Information
M4	Not used – See M43, M44
M5	Airline Business Support: Electronic Database Updating
M6	Airline Business Support: Passenger Profiling
M7	Airline Business Support: Passenger Re-Accommodation
M8	Airline Maintenance Support: Electronic Database Updating
M9	Airline Maintenance Support: In-Flight, Emergency Support
M10	Airline Maintenance Support: Non-Routine Maintenance/ Information Reporting
M11	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)
M12	Airline Maintenance Support: Routing Maintenance/ Information Reporting
M13	Arrival ATIS
M14	Not used – See M43, M44
M15	Convection
M16	Delivery of Route Deviation Warnings
M17	Departure ATIS
M18	Destination Field Conditions
M19	Diagnostic Data
M20	En Route Backup Strategic General Imagery
M21	FIS Planning – ATIS
M22	FIS Planning Services
M23	Flight Data Recorder Downlinks
M24	Flight Plans
M25	Gate Assignment
M26	General Hazard
M27	Icing
M28	Icing/ Flight Conditions
M29	Low Level Wind Shear
M30	Out/ Off/ On/ In
M31	Passenger Services: On Board Phone
M32	Pilot/ Controller Communications
M33	Position Reports
M34	Pre-Departure Clearance
M35	Radar Mosaic
M36	Support Precision Landing
M37	Surface Conditions
M38	TFM Information
M39	Turbulence
M40	Winds/ Temperature
M41	System Management and Control
M42	Miscellaneous Cabin Services

Message Type Identifier	Message Type
M43	Aircraft Originated Ascent Series Meteorological Observations
M44	Aircraft Originated Descent Series Meteorological Observations

Given a definition of the message types that require air-ground communication, the next step was to organize them further in a logical fashion that supports the development of a functional communication architecture. To accomplish this organizational construct, we examined the operational concepts and the service functional capabilities to identify ways to focus the functional architecture. Based on that examination, we defined nine unique technical concepts related to air ground communications that span the functional capabilities and that can be used to drive the definition of the functional architecture. These technical concepts are defined in Table 3.1-3 below:

Table 3.1-3. Air-Ground Communications Technical Concepts

Technical Concept Definition	Technical Concept Name
Aircraft continually receive Flight Information to enable common situational awareness of weather and NAS status	Flight Information Services (FIS)
Aircraft continually receive Traffic Information to enable common situational awareness of the traffic in the area	Traffic Information Services (TIS)
Controller-Pilot data messaging supports efficient Clearances, Flight Plan Modifications, and Advisories	Controller-Pilot Data Link Communications (CPDLC)
Controller-Pilot voice communication to support ATC operations	Controller-Pilot Communications (CPC)
Aircraft exchange performance / preference data with ATC to optimize decision support	Decision Support System Data Link (DSSDL)
Pilot-AOC data messaging supports efficient air carrier/air transport operations and maintenance	Airline Operational Control Data Link (AOCDL)
Aircraft broadcast data on their position and intent continuously to enable optimum maneuvering	Automated Dependent Surveillance-Broadcast (ADS-B)
Aircraft report airborne weather data to improve weather nowcasting/forecasting	Automated Meteorological Reporting (AUTOMET)
Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service	Aeronautical Passenger Services (APAXS)

Using these technical concepts as drivers, we next defined the functional architecture for air ground communications as shown in Figure 3.1-3

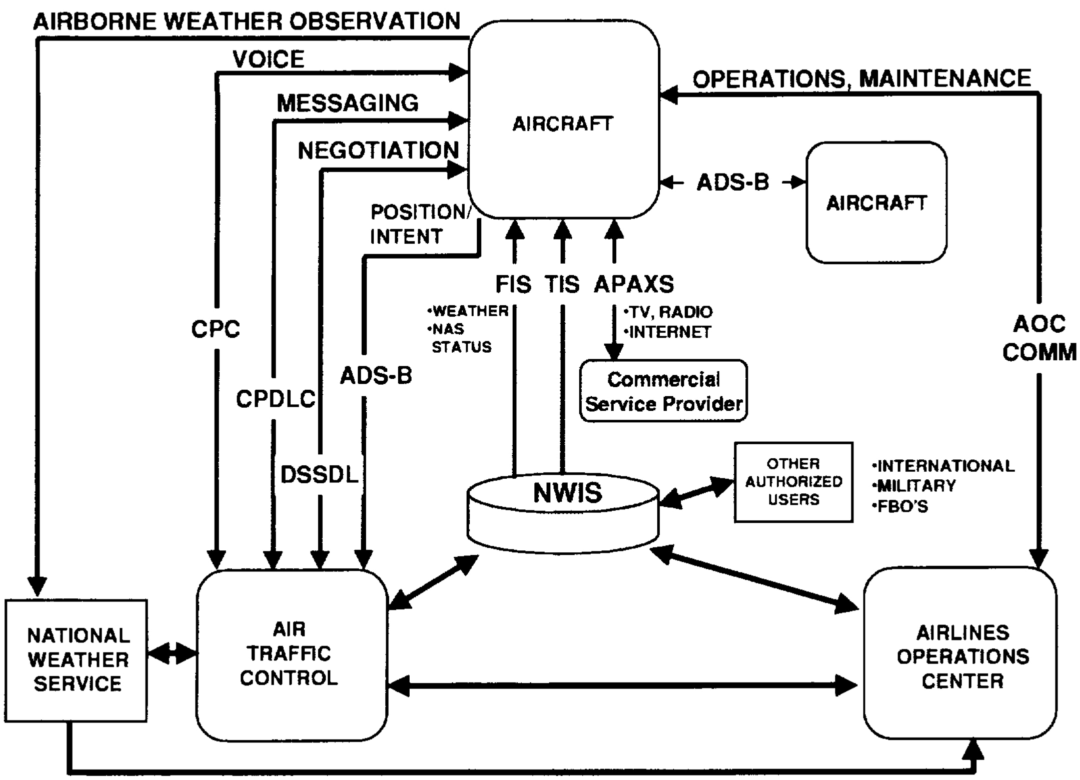

Figure 3.1-3. Functional Architecture for Air-Ground Communications

Our next step was to organize the functional capability message types into categories that are associated with each technical concept. The following table shows the resulting message categories, including message content for each category, mapped to the individual technical concepts listed in Table 3.1-4.

Table 3.1-4. Message Categories Mapped to Technical Concepts

Category.	Technical Concept	Description of Concept
1	Flight Information Services (FIS)	Aircraft continually receive Flight Information to enable common situational awareness
2	Traffic Information Services (TIS)	Aircraft continuously receive Traffic Information to enable common situational awareness
3	Controller-Pilot Data Link Communications (CPDLC)	Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories
4	Controller Pilot Communications (CPC) Voice	Controller - Pilot voice communication
5	Decision Support System Data Link (DSSDL)	Aircraft exchange performance / preference data with ATC to optimize decision support
6	Airline Operational Control Data Link (AOCDL)	Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance
7	Automated Dependent Surveillance (ADS) Reporting	Aircraft continuously transmit data on their position and intent to enable optimum maneuvering
8	Automated Meteorological Reporting (AUTOMET)	Aircraft report airborne weather data to improve weather nowcasting and forecasting
9	Aeronautical Passenger Services (APAXS)	Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service

The organization of message types into the categories listed above is listed in Table 3.1-5 below.

Table 3.1-5. Organization of Message Types into Message Categories

Message Category	Message Category Identifier	Message Type Identifier	Message Type
FIS	1	M13	Arrival ATIS
	1	M15	Convection
	1	M17	Departure ATIS
	1	M18	Destination Field Conditions
	1	M20	En Route Backup Strategic General Imagery
	1	M21	FIS Planning – ATIS
	1	M22	FIS Planning Services
	1	M26	General Hazard
	1	M27	Icing
	1	M28	Icing/ Flight Conditions
	1	M29	Low Level Wind Shear
	1	M35	Radar Mosaic
	1	M37	Surface Conditions
	1	M38	TFM Information
	1	M39	Turbulence
	1	M40	Winds/ Temperature
TIS	2	M3	Air Traffic Information
CPDLC	3	M24	Flight Plans
	3	M29	Low Level Wind Shear
	3	M32	Pilot/ Controller Communications
	3	M33	Position Reports
	3	M34	Pre-Departure Clearance
	3	M41	System Management and Control
DSSDL	5	M2	Advanced ATM
	5	M16	Delivery of Route Deviation Warnings
	5	M24	Flight Plans
AOCDL	6	M9	Airline Maintenance Support: In-Flight Emergency Support
	6	M10	Airline Maintenance Support: Non-Routine Maintenance/ Information Reporting
	6	M11	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)
	6	M12	Airline Maintenance Support: Routing Maintenance/ Information Reporting
AOCDL	6	M19	Diagnostic Data
	6	M23	Flight Data Recorder Downlinks
	6	M25	Gate Assignment
	6	M30	Out/ Off/ On/ In
	6	M8	Airline Maintenance Support: Electronic Database Updating
ADS-B	7	M1	ADS
AUTOMET	8	M43	Aircraft Originated Ascent Series Meteorological Observations
	8	M44	Aircraft Originated Descent Series Meteorological Observations
APAX	9	M5	Airline Business Support: Electronic Database Updating
	9	M6	Airline Business Support: Passenger Profiling
	9	M7	Airline Business Support: Passenger Re-Accommodation
	9	M31	Passenger Services: On Board Phone
	9	M42	Miscellaneous Cabin Services

At this point, having established a functional architecture and a corresponding relationship to the message types, we can combine it with the results of the communication load analysis (section 4.0) and the communication link analysis (Section 5.0) to develop suitable alternative physical communication architectures. This must be performed within the context of the 2015 AATT communications architecture, however, to ensure that the alternatives selected are on a reasonable path to provide a summary of the 2015 AATT architecture (See task 5 for details). The development of alternative architectures for 2007 is the subject of section 3.3.

3.2 2015 AATT Architecture

The 2015 time frame represents the final phases of transition from the era of analog voice communication and islands of diverse information to the new era of digital data exchange through integrated networks using common data. The results of this transition are an integrated collection of systems and procedures that efficiently use the capacity of the NAS while balancing access to all user classes and maintaining the highest levels of safety. As depicted in Figure 3.2-1, efficient collaboration among users is built on a foundation of common data that composes the information base. This data can be logically divided into a static component, representing data that changes infrequently such as maps, charts, etc., and a dynamic component, representing data that changes frequently such as the weather, traffic flow status, and aircraft position. This information base provides common situational awareness to all users who choose to participate. In this time frame, there a variety of users who will choose to participate at various levels of equipage ranging from voice only through multi-mode radios and fully modular avionics. All users are accommodated, however, and will receive benefits commensurate with their levels of equipage.

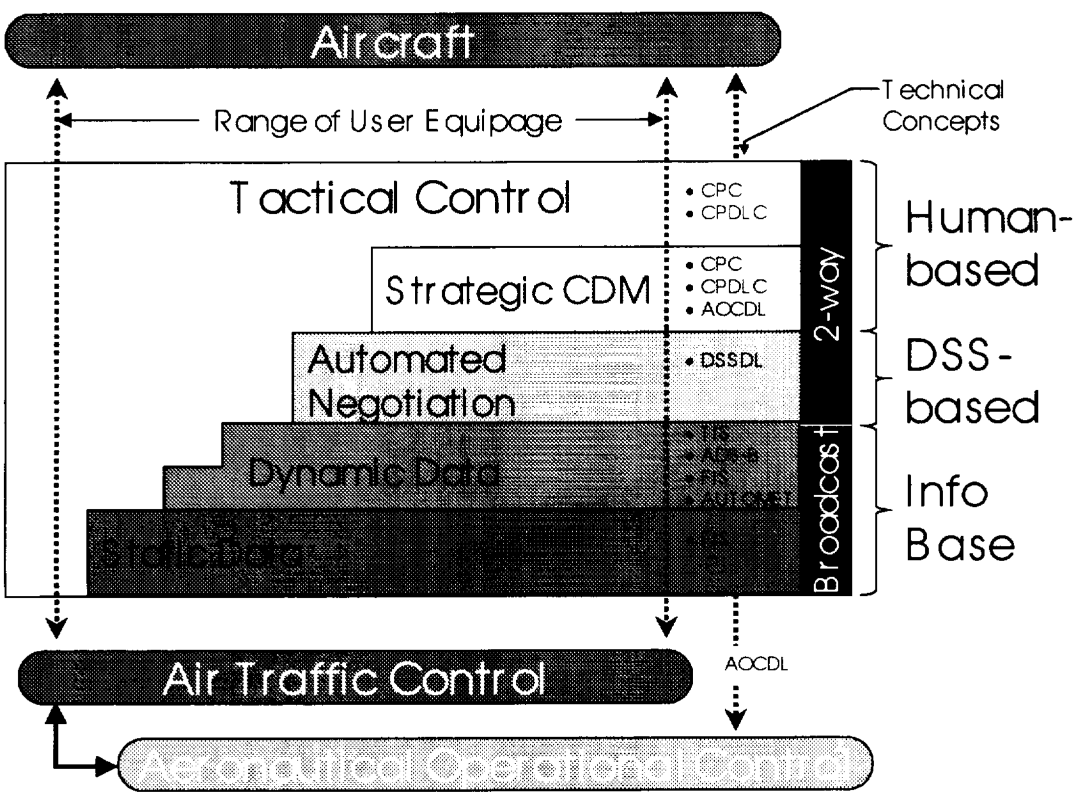

Figure 3.2-1. Air-Ground Communication Levels

The challenge in maintaining the information base is to keep the dynamic data current for all participating users so that optimum decisions can be made. Given a common information base, decision support systems can analyze this data continuously to develop optimum solutions for individual aircraft trajectories as well as trajectories for groups of aircraft. This negotiation takes place between aircraft Decision Support System (DSS) tools and between aircraft and ATC DSS tools. When optimum solutions (or inability to find a solution) are determined, pilots and controllers are notified for confirmation (or other appropriate action). This action takes the form of strategic collaborative decision making or tactical control. In either event, data exchange continues using specified data link messages with voice communication used when it is the only practical means.

For 2015, two alternative architectures are recommended for further study. These alternatives are focused on the selection of a terrestrial or space-based broadband data exchange link (UAT or SATCOM). The 2015 AATT Architecture alternatives are shown in Figure 3.2-2 and Figure 3.2-2.

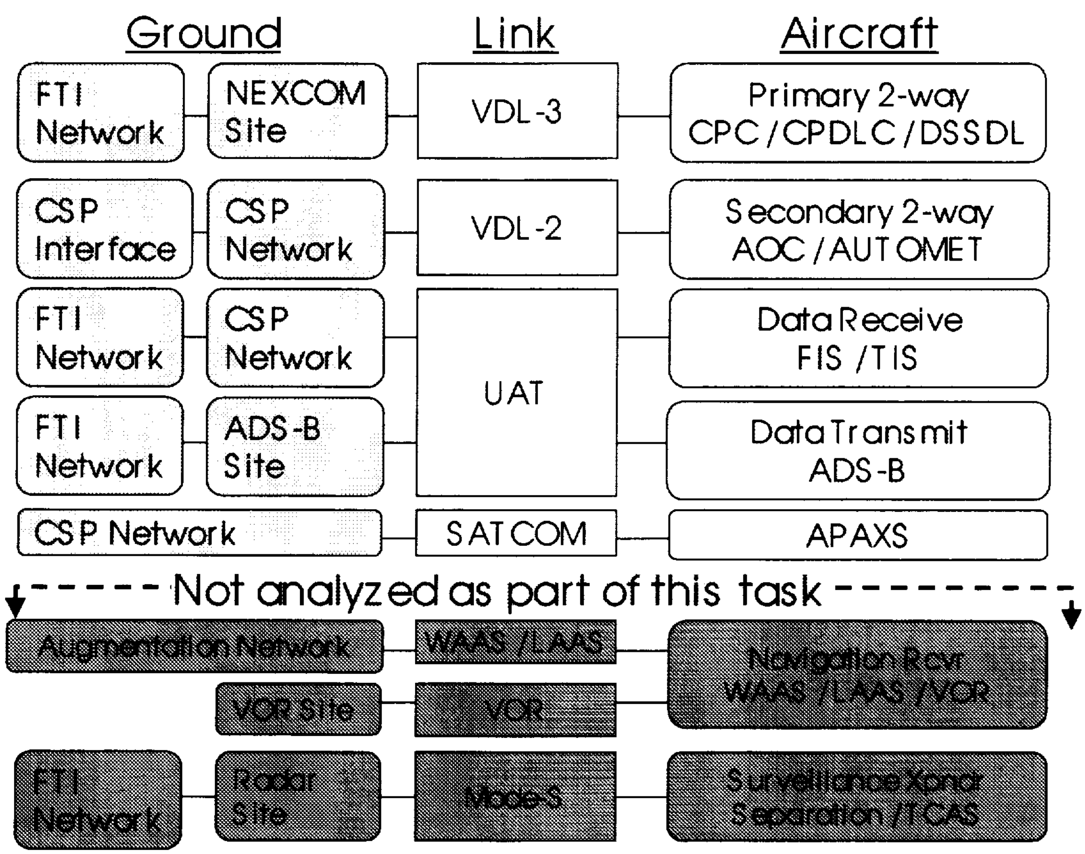

Figure 3.2-2. 2015 AATT Architecture-Terrestrial Based

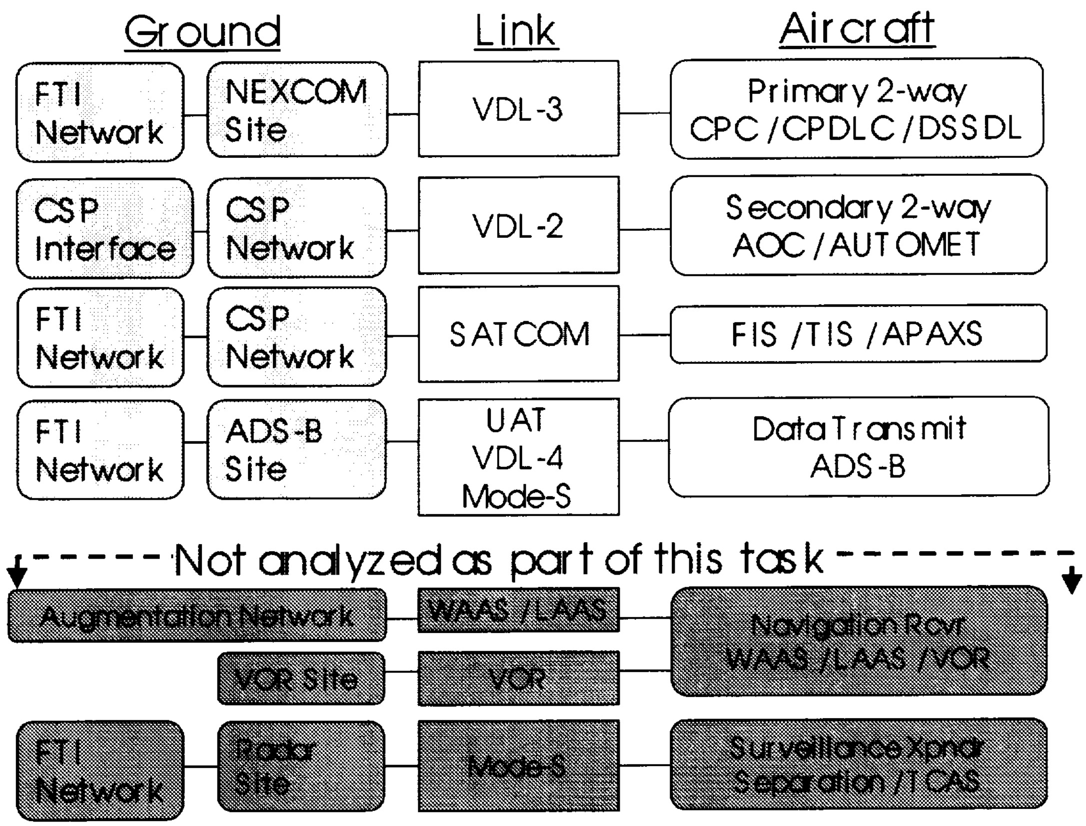

Figure 3.2-3. 2015 AATT Architecture- Space Based

3.3 2007 AWIN Architecture

This section focuses on the definition and development of the weather-related portion of the AATT architecture in the 2007 time frame. Section 3.3.1 describes the operational concept. Section 3.3.2 describes the AWIN-related technical concepts. Section 3.3.3 describes the architecture alternatives developed to satisfy the technical concepts. Finally, Section 3.3.4 identifies the technology gaps that require further research.

3.3.1 AWIN Related Operational Concepts for 2007

The NAS weather architecture was developed to optimize the capability to collect and process weather data, provide current and forecast conditions of hazardous and routine weather, and disseminate that information in text and/or graphical formats to all NAS users and service providers. NAS users include pilots who receive preflight and in-flight weather information, flight planners, air traffic controller specialists, airline and vendor meteorologists, and airline dispatchers.

In 2007, the NAS is in transition toward the establishment of common data sharing among service providers and users that form the basis for collaborative management of the air traffic control system. Concepts such as Free Flight and DAG-TM call for more distributed control of aircraft movement and less dependence on government services. From a communication perspective, these paradigm shifts result in the need for greater communication throughput, as the volumes of data increase.

The NAS infrastructure has evolved to an integrated weather system supported by WARP and ITWS. These systems convert "raw" weather data into meaningful information and act as weather servers for the NAS wide information system. This allows near simultaneous delivery of weather data and products to both users and service providers, resulting in an enhanced common situation awareness.

In addition to supplying weather information to the cockpit, some aircraft operators choose to equip their aircraft with weather sensors that can report data to the ground, including temperature, winds aloft, humidity, and turbulence. This data is used by the NWS to supplement forecast models, resulting in more accurate forecast data for use by ATC decision support systems.

In addition to data linked ATIS, clearance delivery, and taxi instructions, basic meteorological information, such as current and forecast weather and pilot reports (PIREPs), is available in the cockpit, as are current weather maps. Additionally, in this time frame, there is increasingly accurate weather information available to the service provider and user, including hazardous weather alerts for wind shear, microbursts, gust fronts as well as areas of precipitation, icing, and low visibility.

From a pilot's perspective, this data is provided through commercial flight information service providers. These providers receive weather and NAS status information from the FAA (and other sources) and provide it (using FAA and Commercial spectrum) to pilots for a subscription fee. As part of the FAA's flight information services policy, the FAA will approve the basic weather data that a commercial service provider will provide to the cockpit. This has the greatest impact on the Class 1 users, since this information is already available to Class 2 and 3 users through their AOCs.

An increase in collaboration among users and service providers for both planning and strategic problem resolution emerges as a result of increased information exchange. Databases and decision support systems that use these databases enable a shared view of traffic and weather among all parties so that proposed strategies can be evaluated. For example, in a severe weather situation, increased collaboration among users and service providers enables shared decisions on how to avoid the severe weather and deal with the resultant short-term capacity shortage.

The weather related portions of the technical concepts identified in Section 3.1 are as follows:

Technical Concept Definition	Technical Concept Name
Aircraft continuously receive Flight Information to enable common situational awareness	Flight Information Services (FIS)
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	Controller-Pilot Data Link Communications (CPDLC)
Controller - Pilot voice communication	Next Generation Communications (NEXCOM)
Aircraft report airborne weather data to improve weather nowcasting/forecasting	Automated Meteorological Reporting (AUTOMET)

Accordingly, the functional architecture for AWIN is a shown in Figure 3.3-1.

Category	Technical Concept	VDL-B	VDL-2/ATN	VHF-AM	UAT	SATCOM-2 way
1	FIS	◇			◇	◇
4	CPC (voice)			◇		
8	AUTOMET		◇		◇	◇

◇ Technically Feasible

□ NAS Architecture

Figure 3.3-1. AWIN Functional Architecture

Each technical concept associated with the AWIN architecture is described in Section 3.3.2. Figures showing the end-to-end systems and communication links for the technical concepts are provided as part of the description. The figures identify the significant ground systems, air-ground communication links, and aircraft systems.

3.3.2 Technical Concepts

3.3.2.1 Flight Information Services (FIS)

The FIS technical concept does not change from that projected for 2015. FIS provides one of the foundation functions for maintaining the static and dynamic data requirements for the information base of the NAS. In this concept, aircraft receive flight information continuously in order to enable common situational awareness for pilots that support their ability to operate safely and efficiently within the NAS. Flight information consists of NAS weather information, NAS status information and NAS traffic flow information. Flight information is considered advisory and for the purposes of air-ground communications is classified as routine (see section 4.2 for further details). FIS information is intended for transmission to all classes of users. Thus, any selected link alternative must be capable of installation and use in most any aircraft regardless of class. The single line diagram for FIS is shown in Figure 3.3-2.

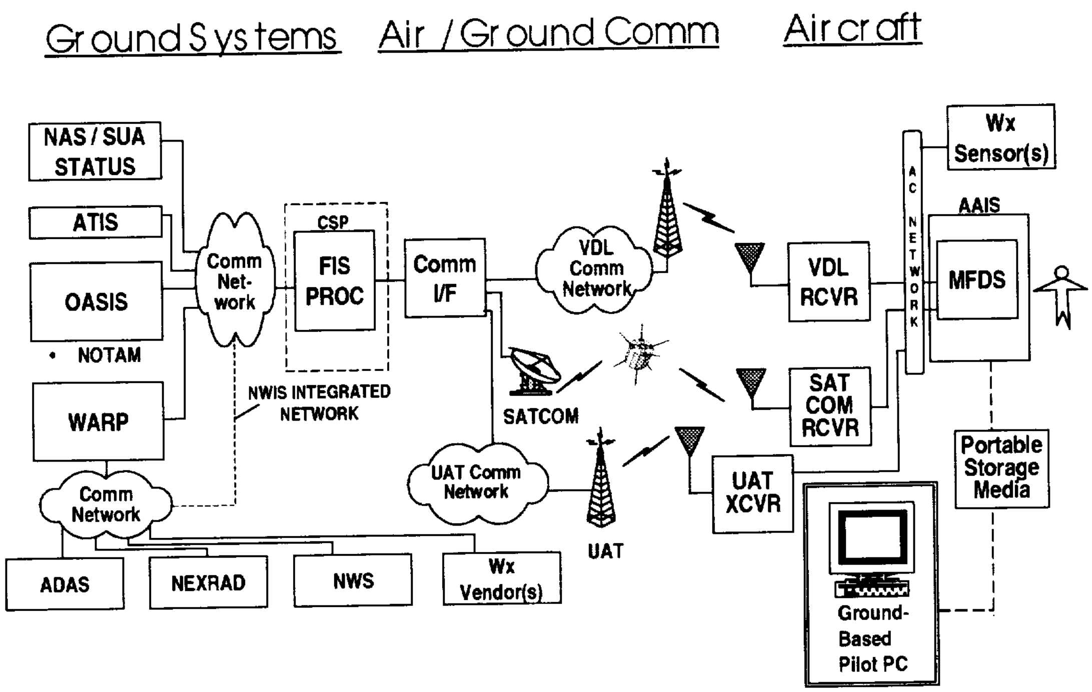

Figure 3.3-2. Flight Information Service in 2007

The Weather products transmitted via FIS may include observations and forecasts, weather radar data, winds and temperature aloft, and gridded forecast data. The NAS status information may include NOTAMs, airport conditions and configurations, and active/inactive status of special use airspace. NAS traffic flow information may include active and pending restriction data, and other traffic flow initiative information.

During the requirements analysis conducted in Tasks 1 through 3, it was thought that some types of FIS products might be tailored for a specific flight and delivered only to an aircraft that requested it, while other FIS products were not flight specific and would be suitable for broadcasts. In this form the messages require conversion from 2-way to broadcast or vice versa for our analysis. These message types are shown in Table 4.3-3 and Table 4.3-4 respectively.

For FIS, the NAS Architecture plans to rely on two commercial service providers to supply products regionally to the aircraft, via two allocated 25kHz VHF frequencies each, using VDL-B.

Our communication load estimate for broadcast FIS is the same for 2007 as for 2015 as we were unable to identify any additional products that could be added after 2007. The FIS load data is derived from Table 4.5-6 and Table 4.5-7.

For the initial analysis, the architecture was evaluated with FIS data transmitted to the aircraft using a two-way (request/reply) data link or a transmit-only broadcast data link, depending on the message type. This was based on the requirements identified in Tasks 2 and 3.

In order to get a domain broadcast estimate we combine the FIS flight specific and non-flight specific data (Table 4.3-3, Table 4.3-4) and make the appropriate unit conversions to produce Table 3.3-1. For purposes of estimation, if we assume a region consisting of one en route center, a consolidated terminal area and four airports, then the total communication requirement for the region would be 7.2 kbps on the broadcast link and 66 kbps on the two-way link. This greatly exceeds the capacity of a VDL channel, precluding use of this approach on the channels currently allocated for FIS. In addition, this approach would require the use of separate radios for broadcast and two-way FIS and complicated avionics to combine the results on a display.

Table 3.3-1. FIS 2-Way + Broadcast Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
FIS – Domain	9.9	9.4	17.2	
Region (x) [1]	39.6 (4)	9.4 (1)	17.2 (1)	66
FIS - Regional Broadcast		0.6	66	7.2

Note: (x) is domain multiplier

Even for information of a general nature, it could be delivered to every flight over two-way links. Given the dynamic nature of FIS data, however, a two-way data link would require a constant request/reply method that is inefficient in terms of channel overhead and suffers in performance directly proportional to the number of aircraft (see Section 4.3.2). Our estimate of the two-way communication loading for FIS (if all messages were two-way) identifies the need for uplinks ranging up to 1265 kbps in 2007 for a geographic area covering the airspace of; four airports, a consolidated TRACON, and encompassing en route airspace. This far exceeds any VDL link capacities and would require a move to broadband links. Detailed analysis included applying overhead factors for two-way communications to all non-flight specific messages; since this is not considered a viable solution, the details analysis is not included here.

From a communication standpoint, broadcast communication is considered desirable for FIS because it is the most efficient in terms of overhead and component design. This is the method currently being employed by the FIS service providers in selected areas.

If the messages identified in Table 4.3-3 as two-way messages for FIS were instead broadcast, at the same frequencies as shown in the table, the total communication load would be reduced to the loads shown in Table 3.3-2. Note that the communication load is reduced not only because products are transmitted only once for all aircraft to receive, but also because the protocol overhead for broadcast is less than the overhead for two-way communication.

Table 3.3-2. FIS Communication Load Requirements (kilobits per second) to Broadcast all FIS Message Types

	Airport	Terminal	En Route	Total
FIS - Domain	0.2	0.9	6.9	
FIS - Region	1.0 (5)	4.5 (5)	6.9 (1)	12.4
FIS - National				248 (20)

Note: (x) is domain multiplier

Using the same example of a region (en route airspace including five airports and their related terminals) the total load requirement is 12.4 kbps. This is within the capacity of a VDL-B channel. One disadvantage of regional coverage is that the pilot can only receive FIS data for the region that they are flying in. In some situations, this can limit the pilot's ability to perform strategic planning.

Aggregation of this data to a national level can conservatively be estimated by multiplying the regional estimate by 20 (the number of CONUS centers). This yields a national broadcast load of 248 kbps. This would exceed the capacity of any VDL link but could be supported by the broadband UAT or SATCOM links.

Table 3.3-3. FIS Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Flight Information to enable common situational awareness	FIS					[✓]		✓	✓	
✓ Acceptable Alternative		[ ] NAS Architecture	( ) AATT CSA Recommendation							

3.3.2.2 Controller-Pilot Communications (CPC)

Voice communication is the foundation of air traffic control. Thus, even as we move toward a higher utilization of data exchange for routine communications, it is critical to maintain a high quality, robust voice communication service. Voice communications remain unchanged from the pilots and controllers perspective in 2007. From a technical perspective, the implementation of digital technology radios (that continue to operate in the DSB-AM mode) provide higher reliability, ease of maintenance, and are the first step toward implementation of VDL-3. The concept for CPC is shown in Figure 3.3-3.

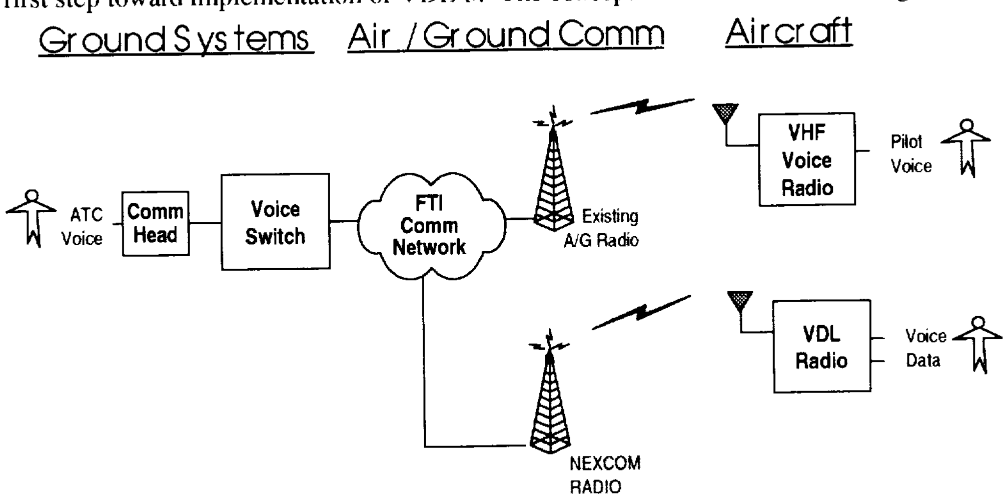

Figure 3.3-3. CPC Air/Ground Voice Communication in 2007

The CPC communication links are shown in Table 3.3-5. The NAS Architecture plans to transition controller pilot voice communication to an FAA supported VDL-3 network in the 2010-2015 time frame. Our VDL-3 link analysis indicates that a single VDL-3 sub-channel supports 4.8 kbps. Our communication load analysis indicates that a single VDL-3 sub-channel is sufficient to support controller pilot communication under worst case loading conditions. We therefor recommend that the AATT CSA maintain the NAS Architecture recommendation.

Table 3.3-4. CPC Load Analysis Results

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	2.6	1.2	1.0	1.0	3.0	0.8
2	0.8	0.4	0.8	0.8	0.4	0.2
3	1.0	0.4	0.8	0.8	0.5	0.2
Total	6.3		5.3		5.2	
Voice Channels Required (P=0.2)	9		8		8	

The CPC communication links are shown in Table 3.3-5. The NAS Architecture plans to transition controller pilot voice communication to an FAA supported VDL-3 network in the 2010-2015 time frame.

Table 3.3-5. CPC Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Controller - Pilot voice communication	CPC	✓ (boxed, circled)								
✓ Acceptable Alternative		☐ NAS Architecture	◯ AATT CSA Recommendation							

3.3.2.3 Automated Meteorological Transmission (AUTOMET)

The definition of AUTOMET is currently under the auspices of RTCA Special Committee 195 which has developed Minimum Interoperability Standard (MIS) for Automated Meteorological Transmission of wind, temperature, water vapor and turbulence (RTCA DO-252). Conceptually, aircraft participating in the AUTOMET service must be able to respond to AUTOMET commands issued by a ground-based command and control system. Downlink message parameters (e.g., frequency, type, etc) are changed by uplink commands from the ground-based systems and are triggered by various conditions (agreed to in advance by the aircraft operator, commercial service provider, and AUTOMET product user). Goals of the AUTOMET system are: 1) Increase the amount of usable weather data that is provided to the weather user community; 2) Increase the resolution of reports, forecast products and hazardous weather warnings to make providers of weather information more operationally efficient; 3) Increase the knowledge of the state of the atmosphere and decrease controller workload by automatically transmitting hazardous weather conditions to the ground and other aircraft to improve the ATC system. The AUTOMET single line drawing is shown in Figure 3.3-4.

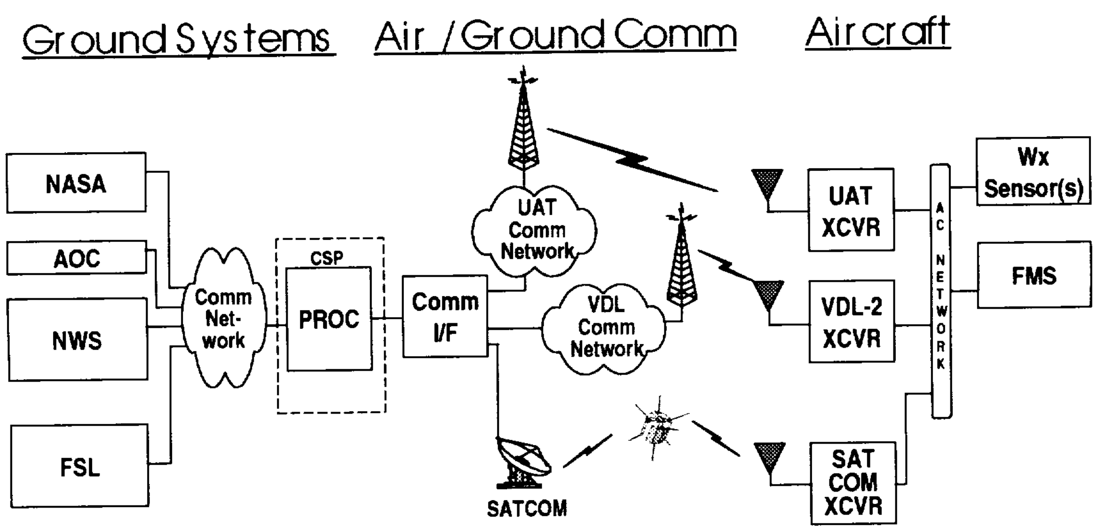

Figure 3.3-4. Automated Meteorological Transmission (AUTOMET) in 2007

In our AUTOMET concept aircraft collect wind, temperature, humidity, and turbulence information in flight and automatically relay the information to a commercial service provider. The service provider collects (and for some users reformats) the information and then forwards it to the AUTOMET product users. Functionally, there are a number of users of "AUTOMET" data today, albeit under different names. Some examples are:

Name	User
MDCARS, E-MDCRS	NOAA, NWS
ACARS	NOAA, FSL AOC
EPIREPS	NASA

For our analysis, these are treated as functional equivalents under the name AUTOMET. The NWS uses AUTOMET information and weather data from other sources to generate gridded weather forecasts. The improved forecasts are distributed to airlines and the FAA to assist in planning flight operations. The gridded weather data, based on AUTOMET data, is also provided to WARP, for use by FAA meteorologists and by several ATC decision support system tools to improve their predictive performance.

Our communication loading analysis for AUTOMET is shown in Table 3.3-6 for each domain. For AUTOMET we assume that no data will be transmitted in the airport domain since there are other sensors that provide that data and it is poor use of a communication channel to have many aircraft transmitting the same data. The worst case load for AUTOMET should occur in a high-density terminal domain within a high-density en route domain. Thus, we use our worst case terminal and en route aircraft forecast to develop the communication load estimate.

AUTOMET equivalent data is transmitted today over the ACARS network. We believe that this data transmission will migrate to the VDL-2 network by 2007. Given that the effective data rate of a single VDL-2 channel is 19.2 kbps, there is sufficient capacity on the VDL-2 network to support AUTOMET. The UAT or SATCOM links could also support AUTOMET, but we believe that this would be unlikely to occur given current plans. A summary of the viable communication links for AUTOMET is shown in Figure 3.3-7

Table 3.3-6. AUTOMET Communication Load Requirements (kilobits per second)

	Airport	Terminal	En Route	Total
AUTOMET	N/A	1.2	1.7	
Worst Case	N/A	1.2 (1)	1.7 (1)	2.9

Note: (x) is domain multiplier

Table 3.3-7. AUTOMET Communication Links

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft report airborne weather to improve weather nowcasting/forecasting	AUTOMET		✓					✓		✓
✓ Acceptable Alternative		☐ NAS Architecture	◯ AATT CSA Recommendation							

3.3.3 2007 AWIN Architecture Alternatives

The applicable communication links described in the previous section can be summarized in the following table:

Category	Technical Concept	VDL-2/ ATN	VDL-B	VHF-AM	UAT	SATCOM
1	FIS		✔		✔	✔
4	CPC			✔		
8	AUTOMET	✔			✔	✔

In theory, any combination of links that address all technical concept areas will form a valid communication architecture. Our approach to creating architecture alternatives was to begin with the NAS Architecture and then consider terrestrial and space-based alternatives.

3.3.3.1 Architecture Alternative 1 - NAS Architecture

The NAS Architecture is the aviation community's comprehensive, 15-year (strategic) plan to modernize the NAS. The objective of NAS modernization is to add new capabilities to improve efficiency, safety and security while sustaining existing services. The NAS Architecture is unique in that it combines the technical aspects of a traditional architecture with their related programmatic aspects (i.e. cost and schedule). It is this combination of programmatic and technical aspects, in the context of the NAS as a whole, that results in a baseline consistent with FAA priorities and schedules.

The communication portion of the NAS Architecture for 2007 was selected as AWIN Architecture Alternative 1 because it reflects the current thinking, priorities, and funding by the FAA and aviation community. This NAS communication architecture baseline has allocated funding consistent with the planning, acquisitions, and implementation of communication and weather systems. The other AWIN architecture alternatives will use this alternative as their reference for comparison.

The NAS Architecture recognizes that weather conditions interfere with flight operations and are a significant contributor to aviation accidents. Therefore the NAS Architecture baseline provides for improved ways to collect, process, transmit, and display weather information to users and service providers during flight planning and while in-flight. The key to reducing weather -related accidents is to improve pilot decision-making through increased exchange of timely weather information.

The NAS weather architecture for 2007 will evolve from today's stand-alone systems to one where weather systems are integrated into a weather server concept (wherein common weather information is available to all authorized participants) to enhance safety and efficiency by promoting common situational awareness. The NAS weather architecture attempts to optimize the capability to collect and process weather data, provide current and forecast conditions of hazardous and routine weather, and disseminate information in text and or graphical formats. NAS users include pilots who receive preflight and in-flight weather information, flight planners, airline and vendor meteorologists, and airline dispatchers. Service providers include ATC personnel, traffic management specialists, and flight service specialists.

The NAS weather systems are briefly described to provide the context to understand the air-ground and ground-ground communications necessary to support AWIN. The NAS weather systems are categorized into 1) weather sensor and/or data sources and 2) processing and display systems. Improved weather sensors and data sources include the Next Generation Weather Radar (NEXRAD), Terminal Doppler Weather Radar (TDWR), and ground and aircraft-based sensors. NEXRAD processing and dissemination capabilities will be improved to provide higher resolution weather information such as wind speed and direction for precipitation, convective activities, tornadoes, hail, and turbulence. TDWR provides alerts of hazardous weather conditions in the terminal area and advanced notice of changing wind conditions to permit timely change of active runways. Other sensors will be upgraded or replaced to take advantage of evolving sensor technology. Aircraft functioning as sensors for weather data will become a key element in improving the accuracy of weather forecasts and will support validation of new weather algorithms. The airborne sensors will collect real-time information such as winds aloft, temperature, and humidity for downlink to ground facilities for distribution.

The key processing and display systems for 2007 are the deployment of the Integrated Terminal Weather System (ITWS) and the Weather and Radar Processor (WARP). These systems act as weather servers that convert multiple sources of weather data into meaningful information. ITWS acquires, processes, and disseminates weather products to other systems and users in the terminal domain and WARP in the en route domain. ITWS provides NEXRAD and TDWR data and improved forecasts to the controller's traffic displays at TRACONs and air traffic control towers (ATCT) and terminal weather information to ARTCCs. At an ARTCC, WARP provides a mosaic of NEXRAD data for controller's traffic displays and improved weather data to meteorologists and traffic managers. Decision support tools such as conflict probe and traffic management advisor also benefit from improved weather data. The Operational and Supportability Implementation System (OASIS) receives weather information from WARP and provides weather products to the flight service specialists to assist in flight planning. Pilots access weather products at the FSS using OASIS or use Direct User Access Terminals (DUATS) for self-briefing and filing of flight plans.

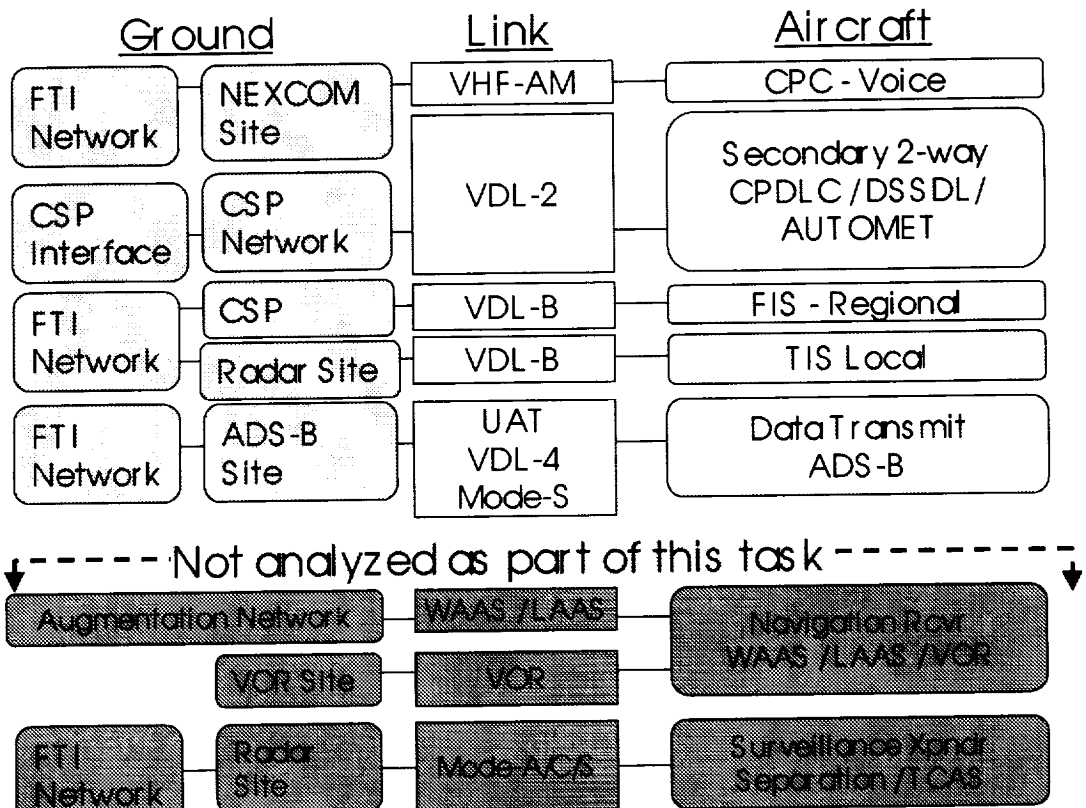

Figure 3.3-5. 2007 AWIN Architecture Alternative 1 - NAS Architecture

A diagram of the 2007 AWIN Air-Ground Communication Architecture consistent with the baseline NAS Architecture is shown in Figure 3.3-5. The current NAS Architecture baseline is terrestrial-based and focused on the use of VHF data links. There are no plans in the current NAS architecture to explore the use of SATCOM for any applications beyond ground-ground communications, oceanic communications, or GPS augmentation. It is assumed that the FAA Telecommunication Infrastructure (FTI) will provide the necessary bandwidth and routing/switching services to support ground-ground communications.

The NAS Architecture baseline for FIS in the 2007 timeframe is to allocate two VHF frequencies to each of two commercial service providers to deliver weather information to the cockpit via VDL-B. Users will need to equip their aircraft with a VHF data radio (likely multi-mode radios) and a color multifunction display to receive and display the information.

Controllers at FSSs, ARTCCs and other ATC facilities will continue to use voice communications to provide weather information to aircraft either directly when requested or via broadcast. Voice communications are also used for pilot reports (PIREPs) of weather conditions. In the 2007 timeframe, NEXCOM digital technology radios will replace many of the existing analog technology radios. In this time frame, however, these radios will emulate the existing DSB-AM modulation. Transition to digital voice will begin in 2010.

Aircraft participating in AUTOMET collect wind, temperature, humidity, and turbulence information in-flight and automatically relay the information to a commercial service provider using VDL Mode 2. The service provider collects and — in some cases — reformats the information and forwards it to the National Weather Service (NWS) and other participating organizations. The NWS uses this AUTOMET information and weather data from other sources to generate nowcast/forecast products. The improved forecasts are distributed to airlines and the FAA to assist in planning flight operations. The gridded weather data based on AUTOMET data is also provided to the WARP weather network for use by FAA meteorologists and ATC decision support system tools.

A summary of the 2007 AWIN architecture alternative contained in the baseline NAS Architecture is provided in Table 3.3-8 below.

Table 3.3-8. AWIN Architecture Alternative 1 - NAS Architecture Summary

Technical Concept	2007 NAS Weather Architecture
Flight Information Service (FIS)	• Regional weather products delivered by commercial service provider using VDL broadcast • Controllers or flight service specialist continue to provide weather services using existing VHF analog voice communications
Controller-Pilot Communications (CPC)	• Weather advisories, PIREPs and other information still passed between aircraft users and ground ATC by voice communications • NEXCOM digital technology radios replace existing VHF analog technology radios (emulate DSB-AM Modulation)
Automated Meteorological Transmission (AUTOMET)	• Participating aircraft collect in-flight meteorological data and automatically transmit data to commercial service provider using VDL Mode 2 • Service provider forwards–and in some cases, reformats– weather information to participating organizations

3.3.3.2 Architecture Alternative 2 - Terrestrial-Based Architecture

A diagram of the 2007 AWIN Alternative 2 Architecture shown in Figure 3.3-6. The major change from Alternative 1 is the addition of a broadband UAT link to support FIS.

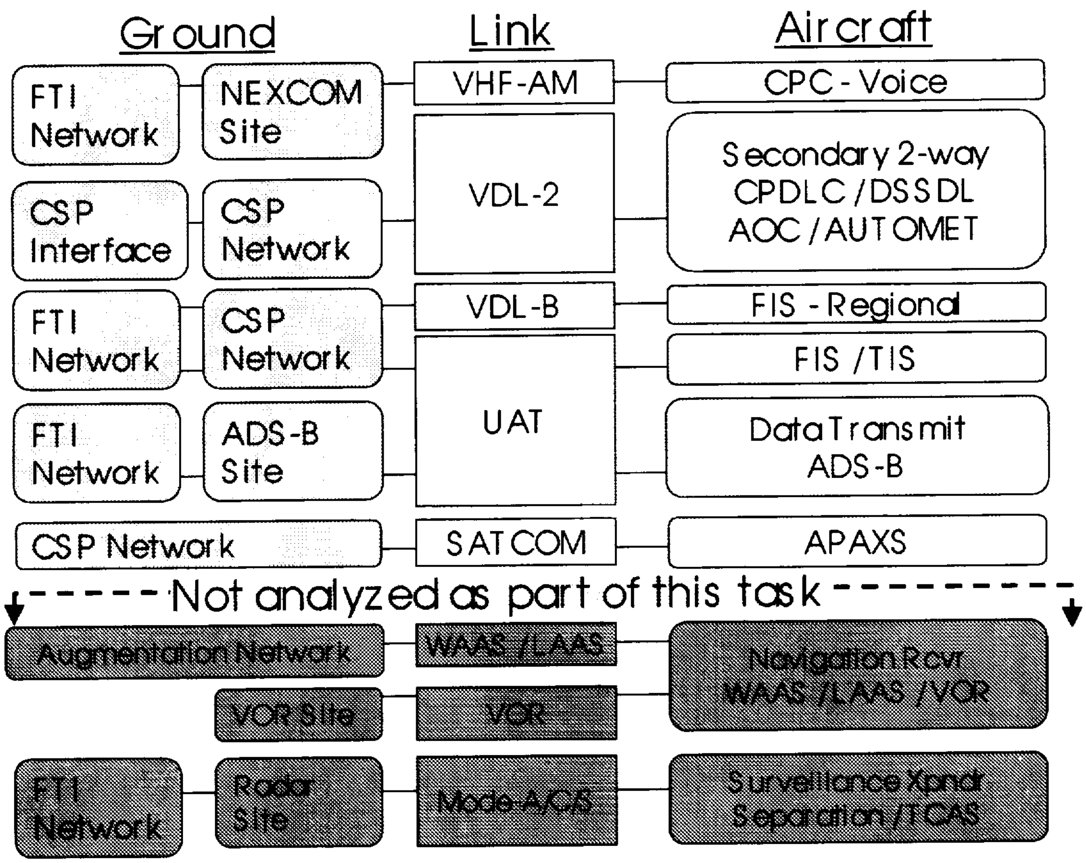

Figure 3.3-6. 2007 AWIN Architecture Alternative 2 - Terrestrial-Based Architecture

The implementation of UAT in a terrestrial network that provides CONUS coverage would most likely result from the selection of UAT as the communication link for ADS-B. The FAA and EUROCONTROL are expected to make an ADS-B link decision in 2001. If UAT is selected the FAA would begin deployment of UAT in "local pockets" beginning in the 2004/2005 time frame, with National deployment complete in the 2010-2012 time frame. It is assumed that these UAT sites will be established with broadband connectivity to the FTI network either directly or via a commercial service provider —and that dedicated frequencies will be allocated for FIS. These FIS frequencies (and potentially the operation of the communication sites) may be allocated to commercial service providers with similar provisions as the current FIS policy. A terrestrial broadband UAT network provides the capacity to transmit regional and national FIS data. This extends the situational awareness of the pilot and supports strategic flight planning in the cockpit. The UAT link is currently being tested as part of the Safe Flight 21 program in Alaska and the Ohio River Valley.

The comparison of AWIN Architecture Alternative 2 to the baseline NAS Architecture for 2007 is summarized in Table 3.3-5 below.

Table 3.3-9. **2007 AWIN Architecture Alternative 2 Comparison to NAS Architecture**

Technical Concept	SATCOM Broadcast Architecture Differences
Flight Information Service (FIS)	• National FIS data set broadcast using non addressed UAT communications to properly equipped aircraft • Commercial service providers continue to make weather products available to users using VDL broadcast during transition to UAT
Controller-Pilot Communications (CPC)	• Same as baseline 2007 NAS Architecture alternative described in Section 3.3.1.
Automated Meteorological Transmission (AUTOMET)	• Same as baseline 2007 NAS Architecture alternative described in Section 3.3.1.

3.3.3.3 Architecture Alternative 3 - Space-Based SATCOM

A diagram of the 2007 AWIN Alternative 3 Architecture is shown in Figure 3.3-7. This alternative is identical to Architecture Alternative 2 with the exception that FIS data is provided via SATCOM.

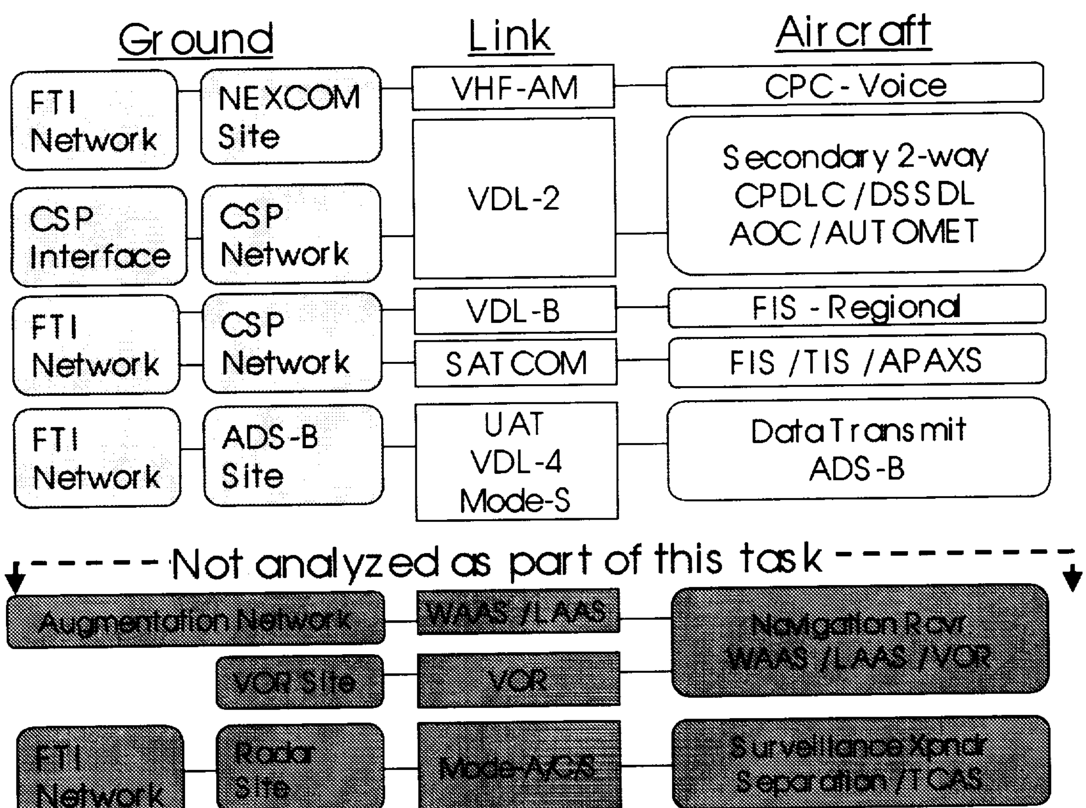

Figure 3.3-7. 2007 AWIN Architecture Alternative 3 - SATCOM Two-way

This AWIN architecture alternative implements a two-way satellite request/reply architecture to disseminate routine and flight specific weather data as part of the FIS concept. The volume of weather data today and its inevitable increase in the future along with the desire to include multi-regional or national data does not lend itself to distribution via VDL. Furthermore, the emergence of satellite technology – with data transmission rates hundreds of times that of VDL and broader coverage – in the near term offers the promise of a full collection of weather products available to the pilot throughout the flight. If UAT is not chosen for ADS-B there will be n motivation for the FAA to establish a terrestrial broadband air-ground network. Absent a terrestrial network, SATCOM is the only viable method for providing CONUS-wide broadband data. We believe that broadband satellite technology satisfies the requirements, and could be demonstrated by 2004. Further, we believe that commercial demand for broadband aeromobile services will be the primary driver for SATCOM implementation.

The comparison of AWIN Architecture Alternative 3 to the baseline NAS Architecture for 2007 is summarized in Table 3.3-10 below.

Table 3.3-10. 2007 AWIN Architecture Alternative 3 Comparison to NAS Architecture

Technical Concept	SATCOM Two-way Architecture Differences
Flight Information Service (FIS)	• FIS data set sent to properly equipped aircraft using two-way satellite communications • Commercial service providers continue to make weather products available to users using VDL broadcast during transition to SATCOM
Controller-Pilot Communications (CPC)	• Same as baseline 2007 NAS Architecture alternative described in Section 3.3.1.
Automated Meteorological Transmission (AUTOMET)	• Same as baseline 2007 NAS Architecture alternative described in Section 3.3.1.

3.3.4 Technology Gaps

To determine if technology gaps existed in any of our architecture alternatives we created "single line" drawings for each of the technology concepts. The purpose of the single line drawing is to highlight the end-to-end connectivity required at the concept level to be able to execute the technical concept. This provides a structure that allows us to determine technical as well as concept gaps.

For gap consideration, the technologies must have the potential to be implemented by 2007. Furthermore, activities to close the gap must be demonstrable no later than 2004. To determine if a gap exists we used the following criteria:

- Invention required - no technology exists
- Experimentation required - no demonstrated application exists
- Focused research required - no aviation-related integration exists
- Standards development required – no International aeronautical standards exist
- Certification and engineering required - no certified systems exist

Each single line drawing contains all of the communication links that were identified in any of the architecture alternatives so that any gap associated with a particular technical concept can be seen. The following paragraphs address the technology gaps identified for each technical concept.

3.3.4.1 Flight Information Services

Flight information services is the most significant technology concept for AWIN. As discussed in the previous architecture alternatives section, the NAS Architecture relies on a commercial service provider(s) to disseminate weather products via VDL-B. Our analysis of future FIS data exchange requirements in section 4 indicates that the imagery and weather data requirements will exceed the capabilities of a VDL-B link as described in section 4.3. To remain a viable alternative, higher data compression schemes for VDL-B must be researched as a means to keep up with expanding data demands.

Use of satellite communication links requires the demonstration of aeronautical mobile technologies for antenna, receivers, link algorithms, protocols, and standards. A major technology focus for broadband communications services is the need to provide more bandwidth (i.e., a focus on Ka-band). Given the migration to these frequencies, the need exists for higher efficiency transmitters (both space and terrestrial), more adaptive bandwidth versus power efficient modulation, forward error correction coding (including turbo codes and bit/modulation symbol interleaving), and much expanded use of the variable bit rate formats of dynamic multiplexing techniques such as asynchronous transfer mode (ATM) based technologies. Antennas and receivers must be adapted for the aviation market (size, weight, cost) and must overcome the problems of rain attenuation for broadcast FIS over satellite.

In addition to the communication gaps identified for FIS, there are ground and aircraft gaps that must also be addressed, these are: common data standards, NWIS security and routing protocols for delivery of FIS data, and data display standards for the cockpit.

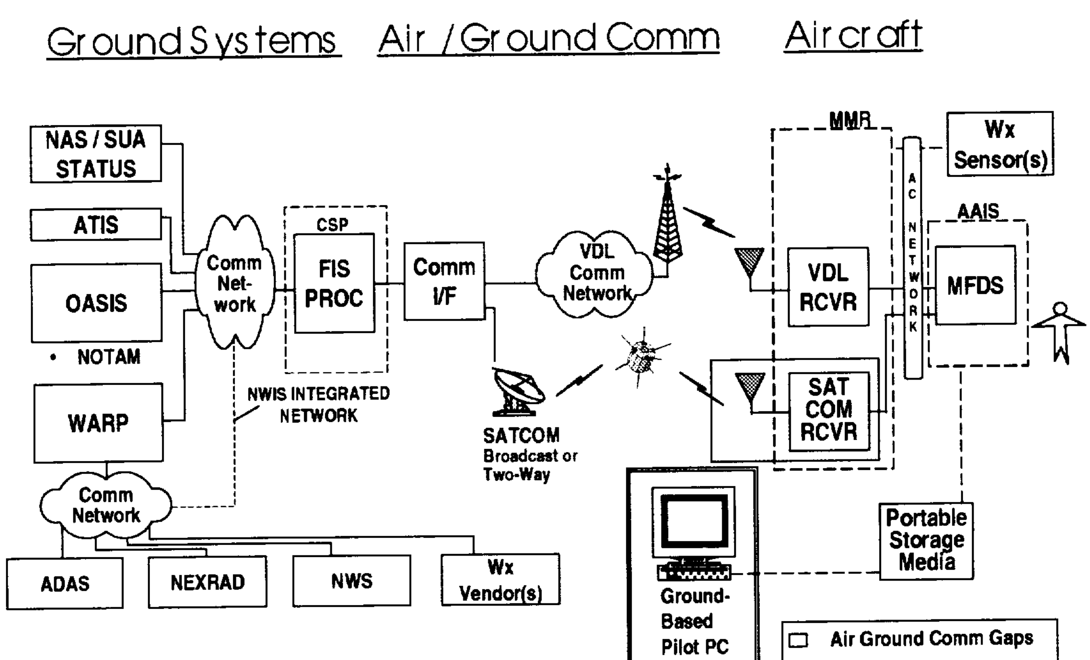

Figure 3.3-8. Flight Information Service - Gaps

3.3.4.2 Controller- Pilot Data Link Communications (CPDLC)

CPDLC has been identified as the means for automated delivery of hazardous weather alerts to the cockpit. However, it is unlikely that this capability can be implemented on VDL-2 (which is the only datalink available in the 2007 time frame). The gap that exists in this case is one of time, not technology. It is unlikely that the NEXCOM implementation of VDL-3 for data can be accelerated into the 2007 time frame. In the interim, however, research could be performed to determine if a satisfactory priority message scheme could be developed and integrated into the VDL-2 link. Also, standards work can be performed to add hazardous weather messages to the CPDLC message set for use when VDL-3 is implemented. Finally, research could be performed to promote a standard for a cockpit voice synthesis capability that would provide audio delivery of CPDLC messages to the pilot.

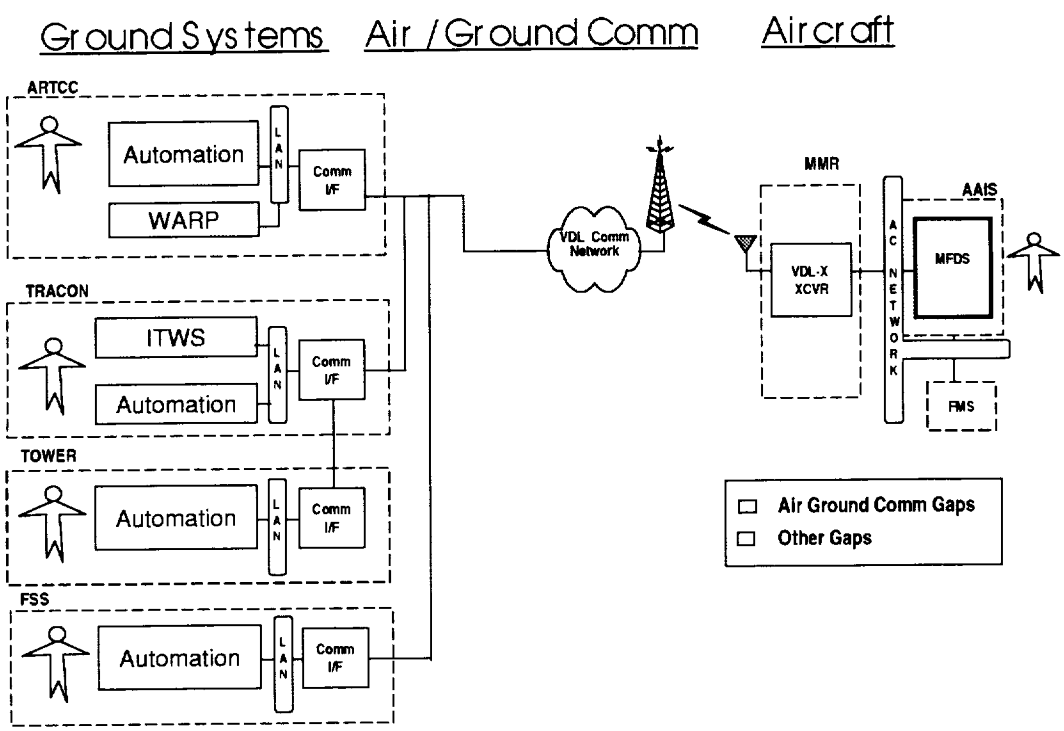

Figure 3.3-9. CPDLC Controller/Pilot Data Link Communications - Gaps

3.3.4.3 CPC Air/Ground Voice Communications

NEXCOM provides the voice communications capability for the NAS. From a technology gap standpoint, NEXCOM/VDL-3 has the implementation time line problems mentioned in the CPDLC gaps above. There are concerns, however, in the area of voice digitization. Further research can be performed to improve the digital voice compression techniques at rates of 4800 bps. Also, improved speech recognition systems are being deployed in a number of commercial areas. Speech recognition technology will continue to be used in automation systems. The research and development focus should be to reduce the effects of background noise which leads to errors in every environment[3].

[3] **Joel Stratte-McClure, Continental Magazine, March 2000**

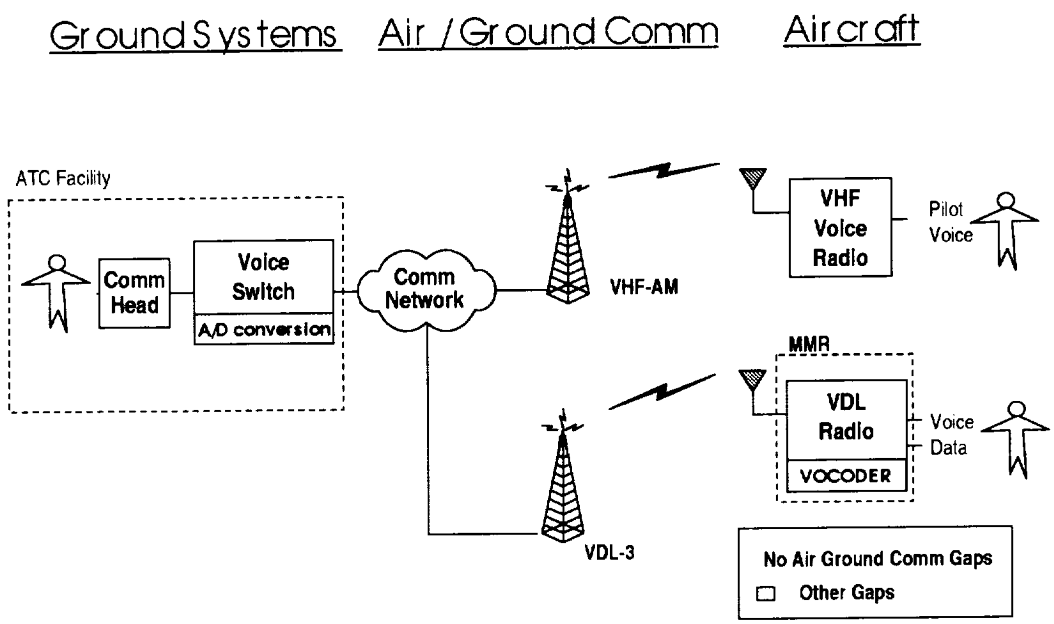

Figure 3.3-10. CPC Air/Ground Voice Communication - Gaps

3.3.4.4 Automated Meteorological Reporting (AUTOMET)

From an air/ground communications standpoint, work is currently underway to develop standards for the implementation of AUTOMET. From an avionics perspective, with this in mind it is essential to ensure that the data delivered from an AUTOMET sensor be accurate at all times in order to maintain the integrity of the forecast model.

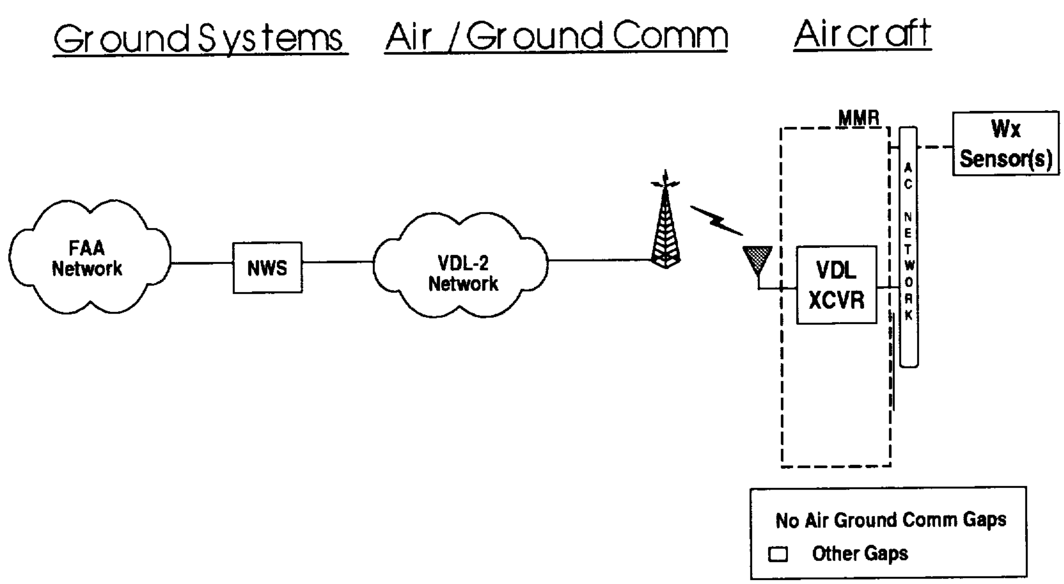

Figure 3.3-11. Automated Meteorological Transmission (AUTOMET)

In summary, the most significant communications technology gaps for AWIN reside in the potential of developing satellite communications capabilities that can be integrated onto all aircraft platforms.

3.4 AWIN Communication Architecture Transition

This section describes the primary schedule of activities that we have identified to support a transition from today's communication architecture to an AWIN communications architecture in the 2007 time frame. The activities identified were grouped into ground, air, and avionics communications and then were further divided into research, standards, and systems areas with certification also identified for avionics. The AWIN communication architecture schedule is shown in figure 3.4-1. We will discuss these activities for each technical concept.

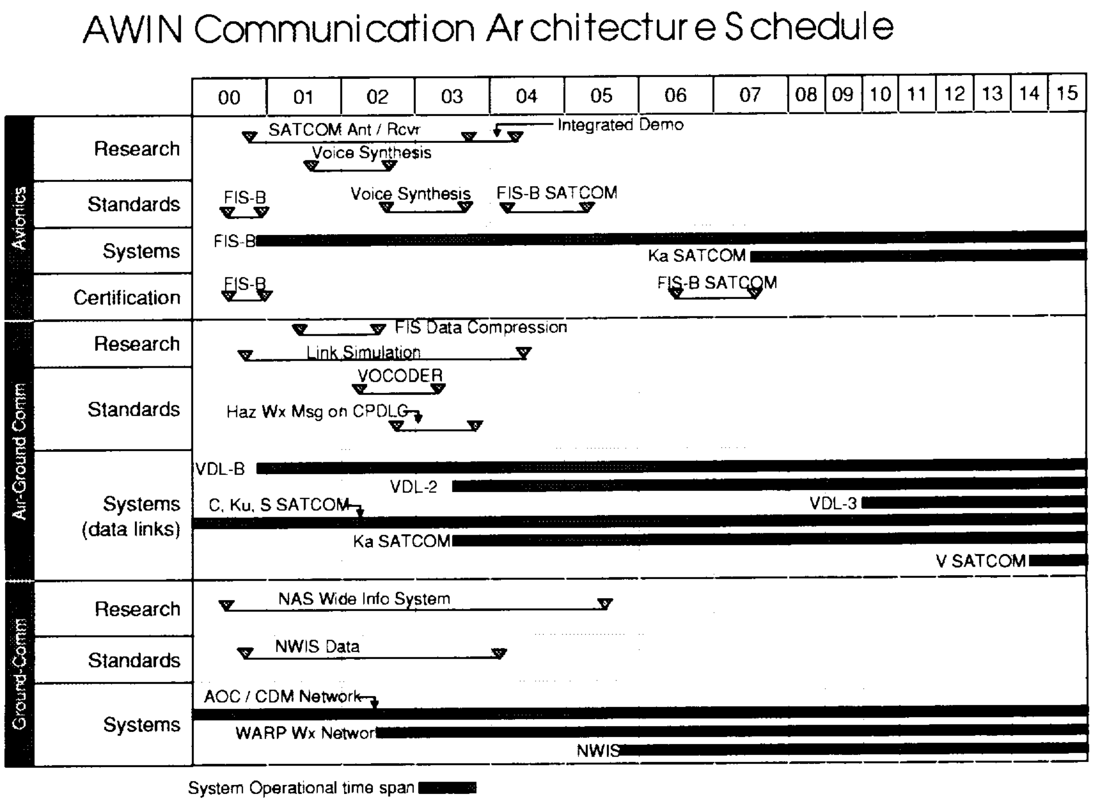

Figure 3.4-1. AWIN Schedule

Flight Information Services

An FIS-B MASPS (Minimum Aviation System Performance Standards) is being drafted by RTCA SC-195 with an anticipated completion date near the end of calendar year 2000. It is in this time frame that the service providers will begin to provide service via their preferred VDL-B technology in selected areas of the NAS. Deployment of FIS throughout the NAS will proceed based on the demand for service. If the demand for service and the amount of FIS data continue to grow as anticipated and the deployment of next generation Ka band satellites also continues, there will most likely be a market for aero-mobile SATCOM FIS. In order to support a deployment of satellite based FIS in 2007, research on aircraft suitable antennas, receivers, encoding schemes, etc must begin in the near term. This research would culminate in an integrated demonstration for each class of aircraft in the first and second quarters of FY2004. Additionally, on the ground, research and standards development is required to establish the data structure for the NAS-wide information system. Establishment of the NWIS will be the primary driver for the sharing of additional data with the aircraft.

Controller Pilot Data Link Communications

For CPDLC, research should begin in the near term to determine if a standard can be developed for the timely, automated distribution of hazardous weather alerts over VDL-2. Also, near term research should be conducted on the application and use of voice synthesis in the cockpit for audio delivery of CPDLC messages.

CPC Voice Communications

While VCODER standards exist today, there is a need for a next generation of standards that concentrate on the elimination of background noise, especially in the cockpit. Additionally, efforts should be focused on establishing compatibility of digitization schemes between the avionics and ground to ensure high quality voice communication.

AUTOMET

Research should continue on aircraft weather sensors with an emphasis on the development of sensors that support the ability to remotely determine accuracy and that do not require calibration by the aircraft owner/operator. Link simulations should be conducted to determine the peak performance requirements for download of sensor data.

4 Communication Loading Analysis

4.1 Air-Ground Weather Communications

The overall approach to the air-ground weather communications load analysis is illustrated in Figure 4.1-1 and presented in detail in the following sections. Air-ground weather communications service requirements are addressed in Section 4.2. Air-ground weather messages and messages per flight are calculated in Section 4.3. Voice message traffic per flight is calculated in section 4.4. Projections for the peak number of flights in 2007 are estimated and the total traffic load is calculated in Section 4.5.

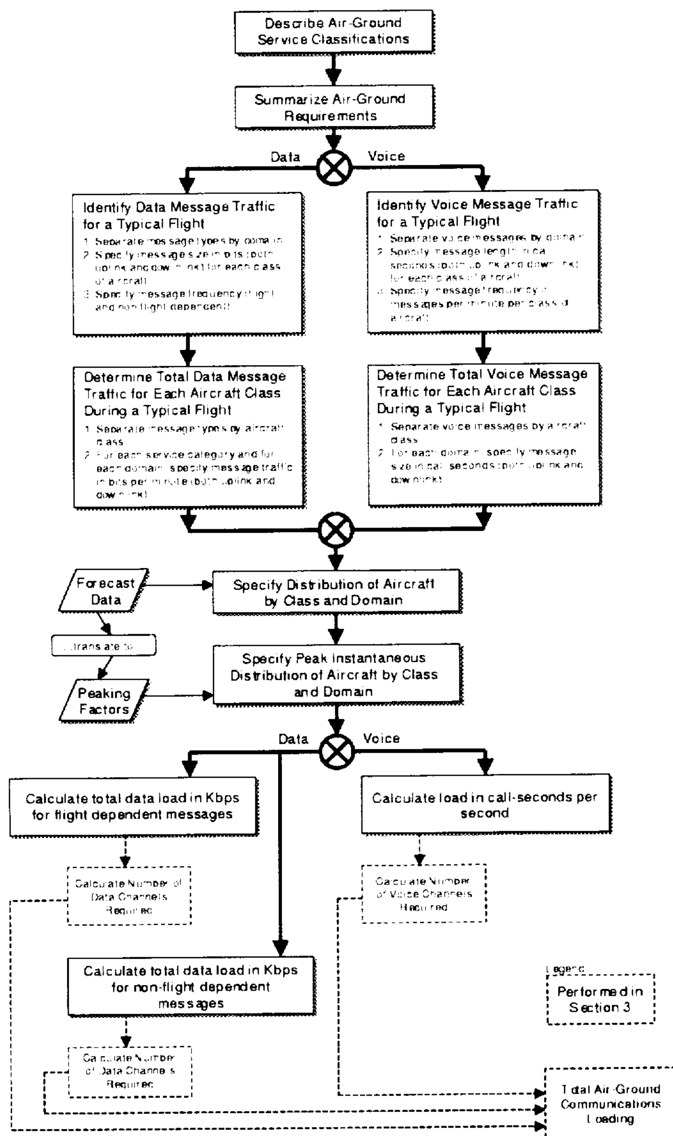

Figure 4.1-1. Communications Load Analysis Method

In this analysis, the term air-ground is used when the direction of the transmission is not relevant. Whenever direction is important, the terms uplink (ground-to-air) and downlink (air-to-ground) are used. The terms message and message traffic are used when the distinction between voice and data messages is not relevant. Otherwise, the term voice message or data message is used.

Throughout the analysis, communications traffic is separated by airspace domains and classes of aircraft. The domains consist of airport, terminal, en route, and oceanic. The three classes of aircraft are low-end general aviation (Class 1), high-end general aviation and commuter aircraft (Class 2), and commercial carriers (Class 3). The classification by domain and airspace gives a more precise traffic load estimate since the number, frequency, and type of message in many cases depends on where the aircraft is and what type of equipage it has. Also, by separating traffic loads according to domain, the air-ground communication architecture can be optimized to meet unique regional requirements. For this analysis, the aircraft classes and domains are defined as shown in Table 4.1-1 and Table 4.1-2.

Table 4.1-1. Aircraft Classes

Class of Aircraft	Definition and Comment
Class 1	Operators who are required to conform to FAR Part 91 only, such as low-end General Aviation (GA) operating normally up to 10,000 ft. This class includes operators of rotorcraft, gliders, and experimental craft and any other user desiring to operate in controlled airspace below 10,000 ft. The primary distinguishing factor of this class is that the aircraft are smaller and that the operators tend to make minimal avionics investments.
Class 2	Operators who are required to conform to FAR Parts 91 and 135, such as air taxis and commuter aircraft. It is likely that high-end GA and business jets and any other users desiring to operate in controlled airspace will invest in the necessary avionics to be able to achieve the additional benefits.
Class 3	Operators who are required to conform to FAR Parts 91 and 121, such as Commercial Transports. This class includes passenger and cargo aircraft and any other user desiring to operate in controlled airspace. These users will invest in the avionics necessary to achieve the additional benefits.

Table 4.1-2. Airspace Domains

Domain	Definition and Comment*
En route	Airspace in which en route air traffic control services are normally available. The average duration in this domain is 25 minutes per en route center.
Terminal	Airspace in which approach control services are normally available. The average duration in this domain is 10 minutes.
Airport	Airspace, including, runways and other areas used for taxiing, takeoff, and landing, in which tower control services are normally available. The average duration in this domain is 10 minutes.
Oceanic	Airspace over the oceans of the world, considered international airspace, where oceanic separation and procedures per the International Civil Aviation Organization are applied. The average duration in this domain is 180 minutes.

Average duration of flights are taken from *Aeronautical Spectrum Planning for 1997-2010*, RTCA/DO-237, January 1997, p. F-4.

All message traffic is assigned to technical concept categories to simplify calculations and provide insights that guide the architectural solutions presented in Chapter 3. The only two categories used for weather messages are shown in Table 4.1-3 and represent logical groupings of messages based on application and similar service requirements. Table 4.1-4 shows the estimated aircraft population in each class that is equipped for a particular technical concept. The percentages in Table 4.1-4 were developed using FAA forecasts and engineering judgement. The values are only approximate but have been specified to the nearest percent to maintain internal consistency. The percentages were assumed to be the same for FIS and AUTOMET.

Table 4.1-3. **Air-Ground Technical Concept Classifications**

Category.	Technical Concept	Description of Concept
1	Flight Information Services (FIS)	Aircraft continually receive Flight Information to enable common situational awareness
8	Automated Meteorological Reporting (AUTOMET)	Aircraft report airborne weather data to improve weather nowcasting and forecasting

Table 4.1-4. **Percent of Aircraft Equipped for Each Technical Concept in 2007**

Technical Concept	Class 1	Class 2	Class 3
FIS	16%	22%	24%
AUTOMET	16%	22%	24%

4.2 Air-Ground Communications Service Requirements

Communications service requirements include priority, availability and restoral times, call setup time, latency, and interfaces. Availability and restoration times depend on NAS priority level, which in turn drive the level of link redundancy needed. Table 4.2-1 shows requirements for the two technical concepts of interest.

Table 4.2-1. **Air-Ground Service Requirements**

Technical Concept.	Priority	Availability Restoration Time	Call Setup Time	Latency End to End	Aircraft Interface
FIS	Routine	0.99 1.68 hour	≤10 sec	~10 sec	FAA NWIS Network
AUTOMET	Routine	0.99 1.68 hour	≤ 30 sec	~10 sec	Commercial Service Provider

FIS and AUTOMET messages are considered to have routine priority. The NAS System Requirements Specification defines routine services as those which, if lost, would not significantly degrade the capability of the NAS to exercise safe separation and control of aircraft. For routine services the availability goal is 0.99 and the goal for service restoral time is 1.68 hours.

Coverage requirements for air-ground services are assumed to be:

- Fully redundant coverage for continental United States (CONUS), Hawaii, Alaska, Caribbean islands, Canada, Mexico, and Central and South America.
- Single coverage over the Pacific and Atlantic Ocean regions (redundant coverage is assumed to be provided by other CAAs and by commercial service providers
- Single coverage over the polar regions

All voice traffic in 2007 is assumed to be analog.

These service requirements are used in the load analysis for purposes of grouping messages with similar service and delivery requirements. They are of greater importance, however, in selecting communications link technologies and in the development of the overall architecture presented in Section 3.

4.3 Air-Ground Data Message Traffic Requirements

Information on weather message sizes and frequencies came from a number of sources. A unique message identifier (Msg ID), shown in Table 4.3-1, is assigned to the various messages to simplify later reference. In most cases, message types represent specific messages with a constant length and repetition rate. In some cases, however, message types are merely representatives of the type, and the characteristics are simply an average.

Table 4.3-1. Message Types and Message Type Identifiers

Message Type Identifier	Message Type
M4	Aircraft Originated Meteorological Observations
M13	Arrival ATIS
M14	AUTOMET
M15	Convection
M16	Delivery of Route Deviation Warnings
M17	Departure ATIS
M18	Destination Field Conditions
M20	En Route Backup Strategic General Imagery
M21	FIS Planning – ATIS
M22	FIS Planning Services
M26	General Hazard
M27	Icing
M28	Icing/ Flight Conditions
M29	Low Level Wind Shear
M35	Radar Mosaic
M37	Surface Conditions
M39	Turbulence
M40	Winds/ Temperature
M43	Aircraft Originated Ascent Series Meteorological Observations
M44	Aircraft Originated Descent Series Meteorological Observations

Each weather message type is mapped to an aircraft class and airspace domain based on information in the reference source and expert knowledge. The messages are further assigned to one of the technical concept categories to simplify subsequent calculations and facilitate communications architecture decisions.

Some message types are extremely large and compression is assumed in order to reduce communications loads. The compression ratios are shown in Table 4.3-2. In some cases, the same message is sent with different compression ratios because the required resolution is not the same in all domains (e.g., M15 and M28). Note that all traffic data presented in this chapter is compressed according to Table 4.3-2 and no further compression should be applied.

Throughout the analysis voice and data traffic are treated separately to deal with any unique requirements they impose on the communications architecture.

Table 4.3-2. Data Compression Factors Used (1:1 assumed for all other messages)

Domain	Msg ID	Compression*
Terminal Tactical	M18	10:1
	M20	10:1
	M27	10:1
	M29	10:1
	M37	20:1
Terminal Strategic	M15	50:1
	M28	50:1
	M35	10:1
En Route Tactical	M39	50:1
En Route Near Term Strategic	M15	20:1
	M26	20:1
	M28	20:1
	M37	20:1
	M39	20:1
En Route Far Term Strategic	M15	50:1
	M26	50:1
	M28	50:1

**Data Communications Requirements, Technology and Solutions for Aviation Weater Information Systems, Phase I Report, Aviation Weather Communications Requirements*, Lockheed Martin Aeronautical Systems

Data message tables are developed for each class of aircraft based on the particular set of weather messages required by that class in a given domain. Note that frequency units are expressed in terms of messages per flight or messages per minute per flight, depending on the nature of the communications. For messages that occur on a periodic basis and are independent of the number of aircraft, frequencies are expressed in terms of messages per minute. These messages are listed in a separate table (see Table 4.3-4) and only added the total communications load after per-flight calculations are completed. The largest common unit used to express message frequencies and flight times was a minute; this time unit was chosen to express weather message traffic in consistent terms for all calculations and to avoid confusing traffic loads with channel data rates.

4.3.1 Data Message Traffic per Flight

Data message traffic by flight for each class of aircraft is summarized in Table 4.3-3. This table does not represent peak traffic, but rather the expected traffic with departures and arrivals evenly distributed within each domain. All message sizes are in bits.

Table 4.3-3. Data Message Traffic For All Classes of Aircraft (flight dependent)*

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
FIS	M17	En Route	1 msg/flt	3200	1 msg/flt	64
	M21	Terminal	1 msg/flt	400	1 req/flt	56
	M22	Airport	1 msg/10 sec	2100	1 req/flt	64
	M22	Terminal	1 msg/10 sec	2000	6 req/flt	64
	M22	En Route	1 msg/10 sec	2000	4 req/flt	64
	M28	En Route	1 msg/flt	45000	N/A	N/A
AUTOMET	M14	Airport	N/A	N/A	10 msg/flt	430
	M14	Terminal	N/A	N/A	3 msg/minute	430
	M14	En Route	N/A	N/A	1 msg/15 minutes	430
	M4	Terminal	1 msg/flt	56	1 msg/5 minutes	1760

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)	Frequency	Downlink Size (bits)
AUTOMET	M4	En Route	1 msg/flt	56	1 msg/5 minutes	1760
	M43	Terminal	1 msg/flt	56	3 msg/min	512
	M43	En route	1 msg/flt	56	1 msg/6 min	2152
	M44	En Route	1 msg/flt	56	1 msg/2min	3544

* Compressed per Table 4.3-2

Non-flight dependent products shown in Table 4.3-4 usually are large messages that are identical for all recipients. They can be sent on a periodic basis and the number of times they are sent is not dependent on the number of flights. The message characteristics are assumed to be the same for all classes and in all domains.

Table 4.3-4. Non Flight Dependent Data Message Traffic (all aircraft classes)*

Technical Concept	Msg. ID	Domain	Frequency	Uplink Size (bits)
FIS	M15	En Route	4 products/60 minutes	252000
	M15	En Route	6 products/60 minutes	306000
	M15	Terminal	6 products/60 minutes	252000
	M18	Terminal	60 products/60 minutes	1300
	M20	En Route	4 products/60 minutes	2800000
	M26	En Route	2 product/60 min	144000
	M26	En Route	6 products /60 min	350000
	M27	Terminal	60 products /60 min	5510
	M28	En Route	6 products /60 min	219000
	M28	En Route	2 products/60 min	27000
	M40	En Route	1 product/60 minutes	54000
	M40	En Route	6 product/60 minutes	262500
	M29	Terminal	6 products/60 min	480
	M35	Terminal	31 products/60 minutes	7350
	M37	En Route	4 products/60 minutes	28800
	M39	En Route	1 product/60 minutes	27000
	M39	En Route	6 product/60 minutes	131000
	M39	En Route	4 product/60 minutes	252000

*Note that all downlink traffic is flight dependent; compressed per Table 4.3-2

4.3.2 Data Message Load Per Flight

In order to convert messages per flight to an actual data load, several assumptions are required regarding the duration of flights communications protocol overheads, and message characteristics:

- ATN protocol overheads are applied to all connection oriented messages, i.e., AUTOMET messages and flight dependent FIS messages.
- The ATN protocol network layer overhead varies according to message context and message size; the actual overhead spans a wide range of documented values. RTCA/DO-237, for example, uses a protocol overhead of 136% for uplink messages and 1376% for downlink messages. (These values are biased toward the maxima that can be expected; the average overhead on downlink traffic is likely to be far less in practice.) This analysis assumes an average network overhead of 20% in both directions for FIS and AUTOMET messages. This figure is in general agreement with the results of ARINC overhead predictions for various AOC messages.

- Non-flight dependent FIS messages include a network layer overhead of 10% for error detection and synchronization.
- A physical layer overhead of 50% is assumed on all data messages (RTCA/DO-237).
- Modulation efficiency for D8PSK is assumed to be 1.25 bps per Hertz (RTCA/DO-237).
- The average time a flight spends in each airport domain is 10 minutes (RTCA/DO-237).
- The average time a flight spends in each terminal domain is 10 minutes (RTCA/DO-237).
- The average time a flight spends in each en route domain is 25 minutes per center; an average flight spans two centers.
- The average time a flight spends in the oceanic domain is 180 minutes.
- Only AUTOMET message types M43 and M44 are included in the data communications loading calculations; these messages are assumed to contain all the information found in other AUTOMET messages that are smaller in size. Message sizes and frequencies are based on the 1999 draft RTCA Minimum Interoperability Standard for AUTOMET.
- 8 bits per character is used to convert messages size in characters to message size in bits for AUTOMET messages M43 and M44; all other messages are given as bits in the source documents used.
- AUTOMET traffic is suppressed in the airport domain to reduce channel requirements; the data is highly redundant and duplicates what is available from fixed airport weather sensors.

These assumptions are used to convert data message traffic in Table 4.3-3 into bits per flight per minute for each technical concept and class of aircraft. To get bits per minute per flight, the message size in bits is multiplied by the frequency in messages per minute. If the messages are on a per flight basis, the conversion requires multiplying the message size in bits times the number of messages per flight in a particular domain divided by the time a flight spends in that domain to obtain bits per minute per flight as shown in Table 4.3-5, Table 4.3-6, and Table 4.3-7.

Table 4.3-5. Data Message Traffic for Aircraft Class 1 (bits per min per flight)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	2903.0	1.5	2774.0	10.1	5052.2	2.9
AUTOMET	N/A	N/A	1.3	353.9	1.0	490.9

*Compressed per Table 4.3-2

Table 4.3-6. Data Message Traffic for Aircraft Class 2 (bits per min per flight)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	3991.7	2.0	3814.3	13.9	6946.8	4.1
AUTOMET	N/A	N/A	1.8	486.6	1.4	675.0

*Compressed per Table 4.3-2

Table 4.3-7. Data Message Traffic for Aircraft Class 3 (bits per min per flight)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	4354.6	2.2	4161.0	15.2	7578.3	4.4
AUTOMET	N/A	N/A	1.9	530.8	1.5	736.4

*Compressed per Table 4.3-2

4.3.3 Non Flight Dependent Data Message Traffic

Many FIS messages are not dependent on the number of flights or the instantaneous airborne count. For messages that do not increase in number as the number of aircraft increase, the message size in bits is multiplied by the frequency in messages per minute and aggregated in Table 4.3-8.

Table 4.3-8. Non-Flight Dependent Data Message Traffic (bits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	N/A	N/A	38,154.1	0.0	391,695.3	N/A

*Compressed per Table 4.3-2

4.3.4 Oceanic Data Message Load Per Flight

In the oceanic domain, weather message traffic consists of FIS and AUTOMET as shown in Table 4.3-9. It is assumed that users in 2007 will want to receive the full complement of en route messages in the oceanic domain, if the communications links can support it. Using the same messages and message frequencies in the oceanic domain would provide seamless communications when transiting the NAS. Only Class 3 aircraft are included since the other classes are used primarily for domestic flights.

Table 4.3-9. Oceanic Data Message Traffic for Aircraft Class 3 (bits per min per flight)*

Technical Concept	Airport		Terminal		Oceanic	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	N/A	N/A	N/A	N/A	6,912.0	0.0
AUTOMET	N/A	N/A	N/A	N/A	0.9	3,068.2

*Compressed per Table 4.3-2

4.4 Voice Traffic

In 2007, the only weather related voice traffic is assumed to be CPC advisories. It is assumed that voice will be used in the airport domain by all aircraft classes but CPDLC will be used in lieu of voice in the terminal and en route domains by aircraft that are suitably equipped.

Table 4.4-1. Voice Message Traffic in 2007 (call-seconds)

Message	Domain	Class	Uplink	Downlink	Msgs. per Flight
CPC Advisories	En Route	1	20 sec	5 sec	1/flt
CPC Advisories	En Route	2	10 sec	5 sec	1/flt
CPC Advisories	En Route	3	10 sec	5 sec	1/flt

The total voice traffic per flight is calculated by multiplying the duration of the voice message by the number of times the message occurs and dividing by the time spent in the domain. The results are summed for each domain and class of aircraft to get the total per flight requirements then discounted based on the percentage of aircraft in each class that will be sending this information via CPDLC.

Table 4.4-2. CPC Voice Message (call-seconds per min per flight)

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	N/A	N/A	N/A	N/A	0.7	0.2
2	N/A	N/A	N/A	N/A	0.3	0.2
3	N/A	N/A	N/A	N/A	0.3	0.1

4.5 Traffic Load Analysis

4.5.1 Flight Forecasts

The average traffic load is developed from the per flight message traffic multiplied by the expected number of flights in 2007. Communications links, however, are generally designed for peak loads to avoid increased delays or blocking when traffic is heaviest. Peak flights by domain for 1998 are therefore projected out to 2007 to estimate the peak load. The projections shown in Table 4.5-1 represent a 12.6% increase in operations between 1998 and 2007 for the aircraft classes of interest. FAA forecasts for terminal area itinerant aircraft operations are used because they correspond closely to the number of flights and are available from FAA forecast data by class of aircraft. For simplicity, it is assumed that the percent growth within each aircraft class and domain is the same as the percent growth in total aircraft operations.

Table 4.5-1. Peak Number of Flights (Aircraft) by Domain in 2007

Year	Operations*	Airport	Terminal	En Route
1998	73,169,228	154	110	400
2007	82,392,277	173	125	450

*APO Terminal Area Forecast Summary Report, TAF System Model

Applying the forecast distribution of operations for each class of aircraft to the number of flights in each domain provides the approximate distribution of flights by class and domain for 2007 as shown in Table 4.5-2.

Table 4.5-2. Estimated Peak Distribution of Flights by Class and Domain in 2007

Class	Operations*	Airport	Terminal	En Route
1	48,452,403	102	73	265
2	15,629,983	33	24	85
3	18,309,891	38	28	100
Total	82,392,277	173	125	450

*APO Terminal Area Forecast Summary Report, TAF System Model

4.5.2 Data Traffic Load

Multiplying the peak number of flights in Table 4.5-2 by the messages per flight in Table 1.3-5, Table 1.3-6, and Table 1.3-7 results in the estimated peak loads shown in Table 4.5-3, Table 4.5-4, and Table 4.5-5.

Table 4.5-3. Peak Data Message Traffic for Aircraft Class 1 in 2007 (kilobits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	296.1	0.2	282.9	1.0	515.3	0.3
AUTOMET	N/A	N/A	0.1	36.1	0.1	50.1

*Compressed per Table 4.3-2

Table 4.5-4. Peak Data Message Traffic for Aircraft Class 2 in 2007 (kilobits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	131.7	0.1	125.9	0.5	229.2	0.1
AUTOMET	N/A	N/A	0.1	16.1	0.0	22.3

*Compressed per Table 4.3-2

Table 4.5-5. Peak Data Message Traffic for Aircraft Class 3 in 2007 (kilobits per min)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	165.5	0.1	158.1	0.6	288.0	0.2
AUTOMET	N/A	N/A	0.1	20.2	0.1	28.0

*Compressed per Table 4.3-2

Combining the peak data message load for each aircraft class and converting to kilobits per second provides the aggregate load shown in Table 4.5-6. The table shows that addressing FIS messages to individual aircraft in the NAS would require a peak uplink bandwidth of 9.9 kbps in the busiest airport domains, 9.4 kbps in the busiest terminal domains, and 17.2 kbps in the busiest en route domains. The largest AUTOMET load is1.7 kbps in the peak terminal domain.

Table 4.5-6. Combined Peak Data Message Traffic for All Aircraft Classes in 2007 (kilobits per second)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	9.9	N/A	9.4	N/A	17.2	N/A
AUTOMET	N/A	N/A	0.0	1.2	0.0	1.7

*Compressed per Table 4.3-2

Non flight dependent traffic loads are shown in Table 4.5-7 for national coverage. The numbers in Table 4.5-7 are calculated by dividing the traffic in Table 1.3-8 by 60 x 1000 to express the load in kilobits per second. From this table it can be seen that the FIS en route peak load would require a 6.5 kbps uplink channel and the peak terminal load would require a 0.6 kbps uplink channel.

Table 4.5-7. National Non-Flight Dependent peak Data Message Traffic for All Aircraft Classes in 2007 (kilobits per sec)*

Technical Concept	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	0.0	N/A	0.6	N/A	6.5	N/A

*Compressed per Table 4.3-2

4.5.3 Oceanic Traffic Load

Peak oceanic flights are estimated based on peak hour contacts by Oakland and New York centers. Of the two, New York is slightly higher with 84 flights en route in the peak hour in 2000. Assuming 12.6% growth by 2007, the messages rates per flight in Table 1.3-9 are multiplied by 95 peak flights in 2007 and divided by 60*1000 to get kilobits per second. The table shows that a 21.5 kbps uplink is sufficient for peak loads.

Table 4.5-8. Total Oceanic Data Message Traffic in 2007 (kilobits per second)*

Technical Concept	Airport		Terminal		Oceanic	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
FIS	N/A	N/A	N/A	N/A	10.9	0.0
AUTOMET	N/A	N/A	N/A	N/A	0.0	4.9

*Compressed per Table 4.3-2

4.5.4 Voice Traffic Load

Peak CPC voice weather advisory traffic is shown in Table 4.5-9. The number of call-seconds per minute per flight from Table 4.4-2 is multiplied by the peak number of flights in Table 4.5-2 and then divided by 60 seconds per minute to get channel occupancy in call-seconds per second. The total for each domain represents the number of full-period uplink or downlink analog voice channels required. To minimize the chance of all channels being in use at the same time, extra capacity can be added to the system. Assuming a multiserver queue with exponentially distributed call durations as a worst-case model for air-ground communications, the number of channels needed for a given probability of blocking can be calculated. In this analysis, it is assumed that there should be no more than one chance in five of finding all channels busy. Under peak traffic conditions with a 0.2 probability of all channels being busy, it is seen that the busiest en route domain in 2007 requires 6 voice channels. It is assumed that voice weather advisories do not occur in the other domains.

Table 4.5-9. Peak CPC Voice Messages in 2007 (call-seconds/second)

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	N/A	N/A	N/A	N/A	3.0	0.8
2	N/A	N/A	N/A	N/A	0.4	0.2
3	N/A	N/A	N/A	N/A	0.5	0.2
Total	N/A		N/A		5.2	
Voice Channels Required (P=0.2)	N/A		N/A		6	

5 Communications Links Analysis

This section provides the technical detail of the data links available for the 2007 architecture. Much of this information is also presented in the Task 9 Report, *Characterize the Current and Near-Term Communications System Architectures,* which provides additional information on applications, standards, protocols, and networks. The links discussed in this section are:

- Voice - DSB-AM
- VHF Digital Link Mode 2 (VDLM2)
- VHF Digital Link Mode3 (VDLM3)
- VHF Digital Link Broadcast (VDL-B)
- Mode S
- Universal Access Transceiver (UAT)
- Example Geosynchronous (GEO) Satellite (Recommended SATCOM)
- Example Medium Earth Orbit (MEO) Satellite
- Example Low Earth Orbit (LEO) Satellite
- High Frequency Data Link (HFDL)

5.1 Standard Description Template

Each link is characterized according to section 4.6.1 of the Task Order and organized using the following template.

CHARACTERISTIC	Segment	DESCRIPTION
System Name		Name
Communication type	R/F Ground	HF, VHF, L-Band, SATCOM ...
Frequency/Spectrum of Operations	R/F Ground	Frequency
System Bandwidth Requirement	R/F Ground	Bandwidth for channel and system
System and Channel Capacity	R/F	Number of channels and channel size
Direction of communications	R/F	Simplex, broadcast, duplex....
Method of information delivery	R/F Ground	Voice, data, compressed voice
Data/message priority capability	R/F Ground	High, medium, low
System and component redundancy	R/F Ground	
Physical channel characteristics	R/F	Line of sight (LOS), other
Electromagnetic interference	R/F	Text description
Phase of Flight Operations	Ground	Pre-flight, departure, terminal ....
Channel Data Rate	R/F Ground	Signaling rate
Robustness of channel and system	R/F	Resistance to interference, fading...
System Integrity	R/F Ground	Probability
Quality of service	R/F Ground	Bit error rate, voice quality
Range/coverage	R/F Ground	Oceanic, global, regional...
Link and channel availability	R/F Ground	Probability
Security/encryption capability	R/F Ground	Text description
Degree/level of host penetration	R/F	Percentage or class of users
Modulation scheme	R/F	AM, FM, D8PSK,....
Access scheme	R/F	CSMA, TDMA, ...
Timeliness/latency, delay requirements	R/F Ground	Delay
Avionics versatility	R/F	Application to other aircraft
Equipage requirements	R/F	Mandatory, optional
Architecture requirements	R/F Ground	Open System or proprietary
Source documents		References

Integrity is the ability of a system to deliver uncorrupted information, and may include timely warnings that the information or system should not be used. Integrity is provided by the application, transport and network layers (rather than the link and physical layers), and is usually specified in terms of the probability of an undetected error. The integrity values in the following link descriptions thus reflect service integrity requirements rather than "link integrity" requirements. The only meaningful measure of "link integrity" is a bit error rate, which is shown under quality of service.

Comm Link	System integrity (probability)
Voice DSB-AM	No integrity requirement for 2007 voice services
VDL Mode 2	CPCLC and DSSDL will be ATN compliant services and require that the end -to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message be less than or equal to $10E^{-8}$ per message
VDL Mode 3	No integrity requirement for 2007 voice services
VDL-B	Some FIS products may require that the end-to end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message be less than or equal to $10E^{-8}$ per message.
Mode-S	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has be supplied to the ADS-B system. ADS-B system integrity is $10E^{-6}$ or better on a per report basis. [Note: Due to constraints imposed by the Mode-S squitter message length, multiple messages must typically be received before all required data elements needed to generate a particular ADS-B report are available.]
UAT	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has be supplied to the ADS-B system. ADS-B system integrity is $10E^{-6}$ or better on a per report basis. Currently, the UAT worst-case overall undetected error probability for an ADS-B message is $3.7x10E^{-11}$, which exceeds the minimum requirement. [Note: For UAT, ADS-B messages map directly (one-to-one correspondence) to ADS-B reports; they are not segmented as they are in Mode-S ADS-B.]
Inmarsat-3	No integrity requirement for 2007 data services
GEO Satellite	Some FIS products may require that the end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message be less than or equal to $10E^{-8}$ per message
MEO Satellite	No integrity requirement for 2007 data services
ICO Global Satellite	No integrity requirement for 2007 data services
Iridium Satellite	No integrity requirement for 2007 voice services
HFDL	No integrity requirement for 2007 data services

5.2 Near-Term Links Available

5.2.1 VHF DSB-AM

Virtually all air traffic control communications are currently based on the VHF, double-side band amplitude modulated (DSB-AM) radio. DSB-AM has been used since the 1940s, first in 100 kHz channels, then in 50 kHz channels, and now 25 kKz channels. Recently, Europe has further reduced channel spacing to 8.33 kHz channels in some air space sectors due to their critical need for more channels. In the United States, the FAA provides simultaneous transmission over UHF channels for military aircraft. In the oceanic domain beyond the range of VHF, aircraft use HF channels. Studies have shown that controller workload is directly correlated to the amount of voice communications required. Voice is subject to misinterpretation and human error and has been cited as having an error rate of 3% and higher. With the introduction of ACARS, AOC voice traffic dropped significantly although it is still used.

Table 5.2-1. Analog Voice/VHF DSB-AM Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Analog voice/VHF double sideband (DSB)—amplitude modulated (AM)**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	Leased telephone channels
Frequency/ Spectrum of Operations	RF	117.975 MHz—137 MHz
System Bandwidth Requirement	RF	Nominal 3 kHz per channel with audio input 350 - 2,500 Hz 760 channels total in VHF band @ 25 kHz spacing/channel
	Ground	N/A
System and Channel Capacity (number of channels and channel size)	RF	Nominal 3 kHz per channel with audio input 350 - 2,500 Hz 760 channels total in VHF band @ 25 kHz spacing/channel System is constrained by frequency allocation, not technical limits. Expansion to 112 MHz has been discussed if radionavigation systems are decommissioned.
	Ground	Telephone line per assigned radio frequency
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Simplex - Transmission or reception on a single frequency but not simultaneously.
	Ground	Voice telephone lines are duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Voice
	Ground	Voice
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	N/A
	Ground	N/A
System and component redundancy requirement (1/2, 1/3, etc):	RF	Airborne - One unit required for GA, two units for air carrier. Redundancy: GA typically equips with two units (1:1); air carrier equips with three units (1:2).
	Ground	1:1 plus some overlap of ground stations
Physical channel characteristics (LOS, OTH, etc.):	RF	Line of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics:	RF	RTCA DO-160C, Sections 15, 18, 19, 20, and 21.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	3 kHz
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Voice communications are error prone and highly variable. An error rate of 3% has been measured in high activity sectors.
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	VHF voice communications are generally considered poor due to system and background noise. (The human ear is VERY good at puling voice out of a noisy AM signal.) A standard voice quality metric has not been applied.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 250 nm at 30,000 feet 100 nm at 5,000 feet Coverage: United States including the Gulf of Mexico.
Link and channel availability	RF	Exceeds 99.7%
Security/ encryption capability	RF	N/A

CHARACTERISTIC	SEGMENT	DESCRIPTION
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	All commercial, all military and most GA aircraft equipped. All aircraft participating in IFR airspace are required to equip. Approximately 20,000 GA aircraft use only unrestricted airspace and do not equip with a radio.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Double sideband—Amplitude Modulation (DS-AM)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Normal signal propagation delay
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	System	Respond to 75% of calls within 10 seconds and 94% of calls within 60 seconds
	System	No measured data. Air Traffic Controllers determine access and priority based on traffic and situation.
Avionics versatility (applicability to other aircraft platforms)	Avionics	Any aircraft equipped with VHF transmitter and receiver.
Equipage requirements (mandatory for IFR, optional, primary, backup,	Avionics	Mandatory for IFR flight operations; not required in uncontrolled airspace.
	Ground	Ground stations required for coverage.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications, etc.)	RF/Avionics	Signal in space characteristics are set by National and International standards. Avionics are developed by vendors with proprietary designs. Some integration with navigation.
	Ground	Vendors provide ground communications using proprietary hardware/software designs and commercial telecommunications standards.
Source documents		Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; ARINC Quality Management Reports, Air/Ground Voice Performance

5.2.2 VDL Mode 2

VDL Mode 2 is a 1990's concept for aeronautical data link. It has been designed by the international aviation community as a replacement for ACARS. Many of the limitations of ACARS have been overcome in the VDL Mode 2 system. The best known improvement is the increase in channel data rate from the ACARS 2.4 kbps rate to a 31.5 kbps rate. The improved rate is expected to increase user data rates ten to 15 times over the current ACARS. The variation is dependent upon user message sizes, channel loading assumptions, and service provider options. VDL Mode 2 can carry all message types carried by ACARS plus Air Traffic Service messages such as CPDLC, which require performance levels of latency and message assurance not possible with ACARS.

VDL Mode 2 is a subnetwork in the Aeronautical Telecommunication Network (ATN). ATN has been adopted by ICAO to provide a global air/ground and ground/ground network for all aviation related traffic. ATN addresses both the communications aspects and the applications.

Table 5.2-2. VDL Mode 2 Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**VHF Digital Link Mode 2** (VDL Mode 2)
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	ARINC Data Network System (ADNS) & ARINC Packet Network (APN)
Frequency/ Spectrum of Operations		136.975MHz, 136.950MHz, 136.925MHz, 136.900MHz currently approved for VDL in international frequency plans. The 136.500 - 137.0 MHz band (20 channels) is potentially assignable to VDL Mode 2 in the U.S. Additional frequencies are based on availability and sharing critieria.
System Bandwidth Requirement	RF	25KHz
	Ground	Primary 56 Kbps , dial backup 64 Kbps ISDN
System and Channel Capacity (number of channels and channel size)	RF	Unlimited system growth - primarily dependent on regulatory frequency allocation. Ground stations are capable of four independent frequencies. Initial deployment will be based on aircraft equipage and will only require 1-2 frequencies.
	Ground	APN X.25 packet switched services and IP and ATN protocols
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Simplex - Transmission or reception on a single frequency but not simultaneously.
	Ground	Simplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	data
	Ground	data
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
	Ground	The VDL Mode 2 ground network can prioritize messages over the wide area network and within the ground station in accordance with ATN priority schemes. Once presented to the radio for transmission, messages are not preempted.
Physical channel characteristics (LOS, OTH, etc.)		
	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	RTCA DO-160C, Sections 15, 18, 19, 20, and 21.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	First VDL Mode 2 usage expected in 2000 in En Route. Potentially applicable to all domestic phases of flight: Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	31.5 kbps/25KHz channel
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Design availability for Initial Operating Capability (IOC) is .9999. Higher availability will be achieved with additional ground stations and supporting network components for critical airports and applications.
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Within the VDL Mode 2 subnetwork, the probability of a lost packet is less than 10^{-7}. The subnetwork uses logical acknowledgements for packet delivery assurance. An additional end-to-end message assurance is applied to assure message delivery (all packets for a message).
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 200 nm at 30,000 feet 80 nm at 5,000 feet Coverage: Implementation will begin in 2000 with U.S. En Route and high density airports (Airspace A and B). Coverage will expand as users equip.

CHARACTERISTIC	SEGMENT	DESCRIPTION
Link and channel availability	RF	The availability of each ground station is 0.997. Ground station availability based on providing RF signal so radio and all components included. For typical applications, two ground stations will be available to achieve 0.9999 system availability.
Security/ encryption capability	RF	None at the RF level - VDL Mode 2 will support authentication and encryption of applications as planned by ATN.
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	None - system to be deployed in 2000. VDL Mode 2 is applicable to all user classes but is expected to be first implemented by air carriers and regional airlines operating in Class A airspace (above 18,000 feet) and associated Class B airspace airports.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Carrier Sense Multiple Access (CSMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	95% of messages delivered within 3.5 seconds within the VDL Mode 2 subnetwork. End-to-end delivery is estimated at 95% within 5 seconds.
Avionics versatility (applicability to other aircraft platforms)	System	VDL Mode 2 can be used for all applications.
	Avionics	VDL Mode 2 can be used on any class aircraft.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.)	Ground	Ground stations must be installed for coverage
	System	Signal in space characteristics are set by National and International standards. Avionics are developed by vendors with proprietary designs. Can share VHF equipment with other applications (VHF voice).
Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)		The digital radios used by VDL Mode 2 are capable of providing analog voice service and/or VDL Mode 3 service with appropriate software and hardware additions. Radio is dedicated to one Mode when installed.
Source documents		ARINC VDL Mode 2/ATN Briefing for FAA

5.2.3 VDL Mode 3

VDL Mode 3 is also an ATN subnetwork. VDL Mode 3 has been designed for Air Traffic controller-pilot communications for both voice and data. VDL Mode 3 uses time division to split each 25 kHz channel into four subchannels, which can be any combination of voice or data. This approach allows VDL Mode 3 to provide a traditional voice service and a data link service over a single system. Each subchannel operates at 4.8 kbps. For voice service, VDL Mode 3 includes a voice encoder/decoder (vocoder) which allows digital signals to be converted to voice. As a data channel, VDL Mode 3 can provide data service at 4.8 kbps in each data subchannel.

VDL Mode 3 is under development by the FAA as the NEXCOM program. Initially NEXCOM will provide voice service to replace the current 25 kHz, double side-band amplitude modulated (DSB-AM) voice service.

Table 5.2-3. VDL Mode 3 Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Very High Frequency Digital Link Mode 3 (VDL Mode 3)**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	Very High Frequency (VHF)
	Ground	Undetermined

CHARACTERISTIC	SEGMENT	DESCRIPTION
Frequency/ Spectrum of Operations:	RF	118-137MHz
System Bandwidth Requirement:	RF	25KHz/channel; Radios are specified for 112-137 MHz tuning range.
	Ground	Undetermined
System and Channel Capacity (number of channels and channel size):	RF	As a system, VDL Mode 3 can be used for all frequencies in the VHF aeronautical band, pending frequency sharing criteria. VDL Mode 3 is planned as the replacement for all current ATC analog voice frequencies, approximately 500 channels. Each VDL Mode 3 frequency provides four subchannels per 25KHz channel.
	Ground	Fractional T-1 interfaces indicated in draft specification.
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Simplex - Transmission or reception on a single frequency but not simultaneously, within a subchannel. Subchannels can communicate independently with TDMA scheme.
	Ground	Undetermined
Method of information delivery (voice, voice recording, data, combination, etc.):	RF	Pulse code modulated voice or data in any given subchannel
	Ground	Data, ATN-compliant network protocols
System and component redundancy requirement (1/2, 1/3, etc):	Ground	Undetermined, 1:1 is current practice.
	RF	Ground components: 1:1 is current practice Airborne: 1:2
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	VDL Mode 3 will begin deployment for voice function in approximately 2005 for En Route phase of flight. Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight will be added as the system expands.
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	10,500 symbols/sec (3 bits per symbol) 31.5 Kbps/channel 4.8 Kbps/subchannel, 4 subchannels/channel
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Digital = BER of 10^{-3} for minimum, uncorrected signal BER of 10^{-6} daily average
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Voice: The PCM voice will be encoded using an 8 kHz sampling rate at a resolution of 16 bits per sample.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 200 nm at 30,000 feet 80 nm at 5,000 feet Coverage: Implementation will begin in 2005 with U.S. En Route. Coverage will expand to all U.S. phases of flight.
Link and channel availability	RF	Radio availability =.99999
Security/ encryption capability	RF	No encryption at RF level. Should support ATN defined encryption and authentication at application level.
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	System is in implementation. Will be available to commercial, G/A, and military aircraft

CHARACTERISTIC	SEGMENT	DESCRIPTION
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Time Division Multiple Access (TDMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	< 250 msec
	System	< 250 msec
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Ground	Ground stations required for service/coverage.
	Avionics	NEXCOM will initially be deployed in analog voice Mode to allow fielding and aircraft equipage. When switched to digital voice Mode, approximately 2006, equipage will be mandatory for high En Route.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)		Signal in space and protocols are defined by National and International standards. Ground equipment will be provided by vendors using proprietary designs. VDL data can support numerous applications.
Source documents		Implementation aspects for VDL Mode 3 system (version 2.0), VDL Circuit Mode MASPS and MOPS, Aeronautical Mobile Communications Panel (AMCP); Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; RTCA /DO-224.

5.2.4 VHF Digital Link—Broadcast (VDL-B)

VDL-B is a broadcast variation of VDL Mode 2. Currently intended for Flight Information Services, VDL-B provides weather information to suitably equipped aircraft. The broadcast approach can increase the throughput of data to the user since the protocol overhead of request/reply and confirmation is not required. Under the FAA's FIS Policy, two VHF band frequencies were provided to each of two vendors for implementation. As a condition at no cost to the user, each vendor is required to transmit a minimum set of weather products. The vendor is allowed to charge fees for additional optional products such as weather graphics. The protocols for the FIS-B systems are partially proprietary and may be specified by the vendor. The vendors are expected to use the D8PSK physical layer but the upper layers are not standardized.

VDL-B is not an ICAO SARPs recognized version of VDL. The VDL-B term has been used to describe a data link intended primarily or solely for broadcast of data one-way to aircraft. Weather and traffic information are the usual applications cited for broadcast functions. The description in this report is based on VDL Mode 2 and FIS, which is the most common usage of the term VDL-B. Other variations of VDL-B are possible since it is not an official term or definition.

Table 5.2-4. VDL Broadcast Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**VHF Data Link—Broadcast (VDL-B)**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	Leased telco for current implementation. VDL Mode 2 network possible in the future. Other proprietary solutions possible.
Frequency/ Spectrum of Operations		118-137MHz
System Bandwidth Requirement	RF	25KHz
	Ground	N/A
System and Channel Capacity (number of channels and channel size)	RF	Two frequencies per vendor, Total of four frequencies.
	Ground	Leased telco.
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Broadcast
	Ground	Duplex (return needed for ground station monitor and control)
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
	Ground	VDL-B is a proposed broadcast service that provides advisory and weather information to all aircraft monitoring the channel. The information provided contributes to the safety of flight. This service is similar to Flight information services (FIS)
System and component redundancy requirement (1/2, 1/3, etc)	RF	Since FIS is an advisory service, high availability is not required and redundancy will probably not be used.
	Ground	None expected.
Physical channel characteristics (LOS, OTH, etc.)	RF	Line of sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	The FIS-B information will be available in all phases of flight if the aircraft is within range of the ground station. En Route will have the most coverage while coverage on the ground will be limited. Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	31.5 KBPS if D8PSK used 19.2 for GMSK Other data rates possible
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	RF is robust and resistant to interference, fading, multi-path, atmospheric attenuation, weather
System integrity (probability)	System	Based on non-critical service category, availability is estimated as 0.99
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Unknown
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	LOS (180 nautical miles for aircraft at 25,000 feet) 80 nm at 5,000 feet
Link and channel availability	RF	0.99
Security/ encryption capability	RF	None

CHARACTERISTIC	SEGMENT	DESCRIPTION
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Intended for G/A market but available to all users.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK) or Gaussian Mean Shift Keying (GMSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Broadcast mode has not been defined
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Unkown
	System	> 5 seconds
	Avionics	Optional
	Ground	Required for message transmission
Avionics Versatility	Avionics	If D8PSK approach used, then the radio could be used for multiple applications.
Equipage Requirements	RF	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	Ground	Required for message transmission
	System	Proprietary hardware/software mix.
	Avionics	Can share VHF equipment with other applications
Source documents		None

5.2.5 Mode S

Mode S is an evolution of the traditional Secondary Surveillance Radar (SSR). For Mode S, each aircraft has a unique 24-bit address, which allows transmission selectively addressed to a single aircraft instead of broadcast to all aircraft in an antenna beam. The Mode S transponder has 56 bit registers which can be filled with airborne information such as aircraft speed, waypoint, meteorological information, and call sign. The information in the register can be sent either by an interrogation from the ground system or based on an event such as a turn. For ADS-B, equipped aircraft can exchange information without a master ground station. Although capable of sending weather and other information, the Mode S communications capability is allocated to support of its surveillance role and will consist of aircraft position and intent. ADS-B uses the Mode S downlink frequency (i.e., 1090 MHz) and link protocols to squitter (i.e., spontaneously broadcast) onboard derived data characterizing the status (current and future) of own aircraft or surface vehicle via various ADS-B extended squitter message types (e.g., State Vector [position/velocity], Mode Status [identification/type category/current intent], and On-Condition [future intent/coordination data]).

Table 5.2-5. Mode S Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**Mode S**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	
	Ground	L-Band (also known as D-Band)
Frequency/ Spectrum of Operations:		1090 MHz, +/- 1MHz

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Bandwidth Requirement:	RF	2 MHz (based on the existing Mode-S downlink)
	Ground	Leased telecommunications
System and Channel Capacity (number of channels and channel size):	RF	Single 2 MHz channel
	Ground	Leased telecommunications
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Broadcast from aircraft
	Ground	Ground stations transmit at 1030 MHz and receive at 1090 MHz. For ADS-B service, receive only stations have been proposed.
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	Surveillance function has priority over communications function
	Ground	None. The probability of successful message reception and report update are specified (see Table 3-4 of RTCA DO-242 ADS-B MASPS) depending upon the specific operational applications being supported by the ADS-B system. In this broadcast system more critical data (as determine by the operation being supported) are broadcast more frequently to improve the probability of message reception and report update.
System and component redundancy requirement (1/2, 1/3, etc):	RF	This depends on the ADS-B equipage class, its hardware implementation, and the specific operational applications being supported. The system level minimum availability requirements for equipage classes A1 through A3, for example, is 0.999. This, coupled with the minimum system level continuity of service requirement for the probability of being unavailable during an operation of no more than 2 x 10 –4 per hour of flight along with the specific availability requirements for the operation being performed (e.g., parallel approach), will determine whether equipment redundancy is needed to satisfy the operational requirement. This is expected to be part of the certification process and will be based on the intended use of the ADS-B equipment and the operational approval(s) being sought.
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics:	RF	ADS-B equipment has broad EMI requirements: transmitting and/or receiving equipment shall not compromise the operation of any co-located communication or navigation equipment (i.e., GPS, VOR, DME, ADF, LORAN) or ATCRBS and/or Mode-S transponders. Likewise, the ADS-B antenna shall be mounted such that it does not compromise the operation of any other proximate antenna.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Operational applications supported by ADS-B have been identified across all phases of flight, except possibly pre- and post-flight.
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	1 Mbps Mode-S provides data link capability as a secondary service to surveillance. Extended length message, ELM, format provides 80 user bits per 112 bit message. A typical rate is one ELM per four seconds (RTCA DO-181)
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	The L-Band frequency is subject to fading and multi-path; Mode-S uses a 24-bit parity field and forward error detection and correction (FEDC) to help address this.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System integrity (probability)	System	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has been supplied to the ADS-B system. ADS-B system integrity is 10^{-6} or better on a per report basis. [Note: Due to constraints imposed by the Mode-S extended squitter message length, multiple messages must typically be received before all required data elements needed to generate a particular ADS-B report are available.]
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Mode-S system performance for undetected error rate is specified to be less than one error in 10^{-7} based on 112-bit transmissions.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Assuming LOS exists, range performance depends on traffic density and the 1090 MHz interference environment (i.e., ADS-B uses the same frequency as ATC transponder-based surveillance). In low-density environments (e.g., oceanic) range performance is typically 100+ nm, while in a high-traffic density and 1090 interference environments (e.g., LAX terminal area) the range performance is on the order of 50 to 60 nm with current receiver techniques (improved processing techniques have been identified that are expected to provide range performance to 90 nm in dense environments).
Link and channel availability	RF	100%, as ADS-B is a true broadcast system
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	TBD, since still being developed. However, a significant number of initial implementations are expected to occur in aircraft already equipped with TCASII/Mode-S transponders (commercial air transport and high-end business aircraft). This area of equipage (i.e., TCASII/Mode-S) is expected to increase as the ICAO mandate for TCASII Change 7 (called ACAS in the international community) starts to occur in 2003.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Pulse Position Modulation (PPM) Each ADS-B message consists of a four pulse preamble (0.5 microsecond pulses, with the 2nd, 3rd, and 4th pulses spaced 1.0, 3.5, and 4.5 microseconds after the 1st) followed by a data block beginning 8 microseconds after 1st preamble pulse. The data block consists of 112 one-microsecond intervals with each interval corresponding to a bit (a binary "1" if a 0.5 pulse is in the first half of the interval or a "0" if the pulse is in the second half of the interval.
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Random access; squitter transmissions are randomly distributed about their mean value between some fixed high and low limits (e.g., "one-second" squitters have a one second mean value and are randomly transmitted every 0.8 to 1.2 seconds). This done to minimize collisions on the link. When collisions do occur, the receiver uses the next available message (which in a broadcast system like ADS-B will arrive shortly) to obtain the data.
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	
	ADS-B System	ADS-B uncompensated latency must be less than 1.2 ms or 0.4 ms depending upon the uncertainty of the position data (error [95% probable]) being used to support a particular operational application. The error is categorized according to navigation uncertainty categories (NUCs) from 1 to 9, with the higher NUCs indicating more accurate position data. The 1.2 ms requirement applies to NUCs less than 8 (0.05 to 10 nm position error), while the 0.4 ms must be met for NUCs 8 or 9 (3 to 10 m error).
Avionics versatility (applicability to other aircraft platforms)	Avionics	ADS-B as defined is intended to be applicable to all aircraft category types as well as surface vehicles operating in the aircraft movement area of an airport. A range of equipage classes have been defined to accommodate the various levels of user requirements from GA to air transport.

CHARACTERISTIC	SEGMENT	DESCRIPTION
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Avionics	No mandate of the ADS-B system is planned. However, if ADS-B equipment is used to perform a particular operation (e.g., IFR), a specific ADS-B equipage class, with certain minimum performance characteristics (e.g., transmitter power), will be required.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.)	Ground	No mandate of the ADS-B system is planned. However, if FAA were to use ADS-B to monitor ground vehicles on the airport movement areas, all such vehicles would have to be equipped with at least a minimum (i.e., broadcast-only) ADS-B system.
Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	System	ADS-B uses the Mode-S architecture which is a sub-network of the ATN and is based on an open system architecture.
	Avionics	The signal in space characteristics are defined by national and international forums.
Source documents		RTCA DO-242 ADS-B MASPS, RTCA DO-181 Mode-S MOPS, draft material for 1090 MHz ADS-B MOPS

5.2.6 Universal Access Transceiver (UAT)

The Universal Access Transceiver concept is intended for distribution of surveillance and weather data. It uses a unique hybrid access method of TDMA and random access. The TDMA portion is used to transmit the traffic and weather information while the random access portion is used by aircraft to transmit their own location in conformance with the RTCA DO-242 broadcast approach. The system is experimental and currently operates on a UHF frequency of 966 MHz. The bandwidth of the system is 3 MHz and a suitable frequency assignment would be difficult. UAT has not been standardized and is not currently recognized by ICAO/ATN. The system is being evaluated in the Safe Flight 21 initiative and would become an open system architecture if developed. The UAT implementation of ADS-B functionality had as its genesis a Mitre IR&D effort to evaluate a multi-purpose broadcast data link architecture in a flight environment. Its use for ADS-B was seen as a capacity and performance driver of the link. The current evaluation system (no standard exists or is in process at this time) uses a single frequency (experimental frequency assigned), a binary FM waveform, and broadcasts with 50 W of power. The system provides for broadcast burst transmissions from ground stations and aircraft using a hybrid TDMA/random access scheme. The UAT message structure, net access scheme, and signal structure have been designed to support the RTCA DO-242 ADS-B MASPS (i.e., to transmit State Vector, Mode Status, and On-Condition messages and provide the corresponding ADS-B reports for use by operational applications). The UAT is also investigating support for other situational awareness services (e.g., TIS-B & FIS-B) through sharing of the channel resources with ADS-B.

Table 5.2-6. UAT Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**UAT**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	UHF
Frequency/ Spectrum of Operations	System	The UAT evaluation system operates on an experimental frequency assignment of 966 MHz. [Note: This band was selected due to the availability of spectrum. However, the system is not frequency specific and could operate in any suitable spectrum.]
System Bandwidth Requirement	RF	3 MHz
	Ground	≥ 1 MHz
System and Channel Capacity (number of channels and channel size)	RF	One channel, 2 MHz
	Ground	Single 1 MB/s channel

CHARACTERISTIC	SEGMENT	DESCRIPTION
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Two part: Ground broadcasts information to aircraft, aircraft transmit position information.
	Ground System	Telco
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
System and component redundancy requirement (1/2, 1/3, etc)	Ground	None, broadcast system. The probability of successful message reception/report update are specified (see Table 3-4 of RTCA DO-242 ADS-B MASPS) depending upon the specific operational applications being supported by the ADS-B system. The more critical data (as determine by the operation being supported) have minimum requirements that broadcast more frequently to improve the probability of message reception and report update. [Note: The ground station TDMA access protocol (see access scheme description below) may have some capability for message prioritization. However, this could not be determined from the documentation available.]
	RF	This is still to be determined. It depends on the ADS-B equipage class, its hardware implementation, and the specific operational applications being supported. The system level minimum availability requirements for equipage classes A1 through A3, for example, is 0.999. This, coupled with the minimum system level continuity of service requirement for the probability of being unavailable during an operation of no more than 2 x 10^{-4} per hour of flight, along with the specific availability requirements for the operation being performed (e.g., parallel approach), will determine whether equipment redundancy is needed to satisfy the operational requirement. This is expected to be part of the certification process and will be based on the intended use of the ADS-B equipment and the operational approval(s) being sought.
Physical channel characteristics (LOS, OTH, etc.)	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics	RF	UAT is being designed for operation on a clear channel. Interference to or from off-channel systems can only be assessed once an operational frequency is identified. DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Primarily En Route but operational applications supported by ADS-B have been identified across all phases of flight, except possibly pre- and post-flight. UAT is being designed to support all ADS-B applications (as defined by DO-242)
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	1 Mbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	In general, the UHF frequency is subject to fading and multipath; UAT uses a 48-bit Reed-Solomon forward error correction (FEC) code and a 24-bit cyclic redundancy code (CRC) (acts as a 24-bit parity code) to help address this.
System integrity (probability)	System	UAT will be judged according to ADS-B standards. ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has been supplied to the ADS-B system. ADS-B system integrity is 10^{-6} or better on a per report basis. Currently, the UAT worst-case overall undetected error probability for an ADS-B message is 3.7×10^{-11}, which exceeds the minimum requirement. [Note: For UAT ADS-B messages map directly (i.e., one-to-one correspondence) to ADS-B reports (i.e., they are not segmented as they are in Mode-S ADS-B).]

CHARACTERISTIC	SEGMENT	DESCRIPTION
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Worst-case overall undetected error probability for an UAT ADS-B message is 3.7×10^{-11}
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	LOS. Similar to VHF: 200 nm at 30,000 feet, 80 nm at 5,000 feet. The UAT proposal is to establish a series of ground stations to provide coverage over the U.S. at low (5,000 feet) altitude.
Link and channel availability	RF	Estimated at 0.99 since it will be an advisory service.
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	None. This is a new system design that is not implemented. It currently has appeal and support from the GA community who perceive it to be a lower cost and possibly improved performance alternative to other ADS-B candidate systems (i.e., Mode-S and VDL Mode 4). However, frequency allocation, product development, and standardization/certification of a final design will have to occur before the validity of this perception can be determined.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	UAT uses both TDMA and Binary Continuous Phase Frequency Shift Keying in its signal cycle. The TDMA signal is used by the ground station for broadcast uplink. The Binary portion is used by aircraft to report position.
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	UAT uses multiple access techniques: time division multiple access (TDMA) in the first portion (e.g., 188 ms) of a one second "frame" (i.e., slots to separate ground station messages from the aircraft and surface vehicle messages) and random access in the second portion (e.g., 812 ms) of the frame for ADS-B messages from aircraft and surface vehicles.
Avionics versatility (applicability to other aircraft platforms)	RF	UAT is being designed to meet ADS-B requirements. ADS-B uncompensated latency must be less than 1.2 ms or 0.4 ms depending upon the uncertainty of the position data (error [95% probable]) being used to support a particular operational application. The error is categorized according to navigation uncertainty categories (NUCs) from 1 to 9, with the higher NUCs indicating more accurate position data. The 1.2 ms requirement applies to NUCs less than 8 (i.e., 0.05 to 10 nm position error), while the 0.4 ms must be met for NUCs 8 or 9 (i.e., 3 to 10 nm error).
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	RF	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	Avionics	UAT is a new system design being developed from scratch to meet ADS-B requirements. Therefore, since ADS-B as defined is intended to be applicable to all aircraft category types as well as surface vehicles operating in the aircraft movement area of an airport, UAT should be expected to have the avionics versatility needed to address the set of ADS-B requirements. A range of ADS-B equipage classes have been defined to accommodate the various levels of user requirements from GA to air transport
	Ground	Design information available to all vendors
	System	UAT is a new system and currently does have any standards (e.g., RTCA MOPS or ICAO SARPS).
Source documents	UAT	UAT system information was obtained from various briefings to RTCA SC-186 Plenary meetings and private Mitre correspondence. The system description is largely for an evaluation system involved in the current Safe Flight 21 tests and can be expected to change.

5.2.7 Example Geosynchronous (GEO) Satellites (Recommended SATCOM)

Limited aviation communications are currently available via satellite. The InMarSat GEO satellite provides voice and low-speed data service to aircraft in the oceanic domain. The data service has been used to supplement HF voice air traffic control. Satellite voice for air traffic has been limited to emergency voice. The satellite services are installed on aircraft for commercial passenger voice service and the air traffic control services are provided as a secondary consideration. In an emergency, the pilot has priority access to the communication channel. The large dish size used for GEO satellites is expensive and difficult to install on smaller aircraft such as GA. Cargo aircraft do not have the passenger voice communications support and therefore, have not traditionally been equipped with satellite communications equipment.

The InMarSat-4 (Horizons) satellites are proposed for 2001. Due to the crowded spectrum in L-band, Horizons may be deployed at S-band. Data rates of 144 kbps with an Aero-I aircraft terminal and 384 kbps with an Aero-H terminal are forecast. The Horizons satellites may have 150-200 spot beams and 15-20 wide area beams.

5.2.7.1 InMarSat-3

Table 5.2-7. InMarSat-3 Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		Inmarsat-3
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	SATCOM – GEO satellite. Five satellites.
	Ground	Ground Earth Stations (GES)
Frequency/ Spectrum of Operations:		C Band ~ 4,000 to 8,000 MHz, and L Band ~1,000 to 2,000 MHz
System Bandwidth Requirement	RF	2.5, 5.0, 7.5, AND 17.5 KHZ
	Ground	N/A
System and Channel Capacity (number of channels and channel size)	RF	Six channels per aircraft for Aero H
	Ground	
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Simplex
	Ground	Half Duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Digitally encoded voice
	Ground	Digitally encoded voice
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
	Ground	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	Two ground stations per region; one satellite per region; Some aircraft may have redundant avionics
	Ground	Two ground stations per region
Physical channel characteristics (LOS, OTH, etc.):	RF	Geosynchronous Satellite, ~ 1/3 earth footprint
Electromagnetic interference (EMI) / compatibility characteristics	RF	N/A

CHARACTERISTIC	SEGMENT	DESCRIPTION
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Pre-flight, departure surface operations, terminal, en-route/cruise, landing, and post flight
Channel data rate (digital) and/or occupied band width (analog) requirement:		Voice: 20 kbps; Data: Aero-H: 9.6 kbps; Aero-I: 4.8 kbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Highly robust
System integrity (probability)	System	No integrity requirement for 2007 data services.
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Voice is toll quality.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	1/3 Earth Regional: Indian Ocean, Pacific Ocean, East Atlantic and West Atlantic regions overlap and cover the entire earth within +/- 85 degrees latitude.
Link and channel availability	RF	Satellite operates within the 10 MHz band assigned to AMS (R) S for satellite service by ICAO.
Security/ encryption capability	RF	N/A
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Commercial aircraft
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Aeronautical-Quadriture Phase Shift Key (A-QPSK), Aeronautical variation of QPSK
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Voice: Time Division Multiplexing (TDM) to aircraft; Time Division Multiplexing Access (TDMA) from aircraft. Data: Frequency Division Multiplexing Access (FDMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Satellite signal propagation delay
	System	End to end delay within acceptable limits for voice transmission
Avionics versatility (applicability to other aircraft platforms)	Avionics	Size and weight of Avionics and antenna are prohibitive for small GA aircraft. Aero-I may fit in some business jet GA a/c
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Optional
	Ground	Ground Earth Stations (GES) required for receipt of satellite signals
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary hardware and software
	Avionics	Independent data link
Source documents		InMarSat SDM; Nera System Summary; InMarSat fact sheets; Annex 10, Aeronautical Telecommunications, International Civil Aviation Association (ICAO); ARINC Market Survey for Aeronautical Data Link Services

5.2.7.2 Potential GEO Satellites

Other GEO satellites have been proposed that are potentially applicable to the aviation market and which are described further in the Task 9 report. They include the AMSC/TMI satellites, Loral Skynet, CyberStar and Orion satellites, the ASC and AceS systems and the proposed Celestri combination GEO/LEO satellite system. They are not discussed further in this report due to their limited service offering or due to their limited remaining satellite life expectancy. Many details of proposed satellites are unavailable either because they are proprietary developments or the designs are still in development. A representative 2007 GEO system based on the LM/TRW Astrolink and Hughes Spaceway systems is presented below.

Table 5.2-8. GEO Satellite Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		LM/TRW Astrolink GEO, Hughes Spaceway GEO. (At least one of these or a similar system should be operational in 2007)
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	Ka-band
	Ground	Unknown
Frequency/ Spectrum of Operations:	RF	Ka-band, 20 GHz downlink from satellite, 30 GHz uplink to satellite
System Bandwidth Requirement:	RF	500 MHz or more, each direction, maybe split 4 or 7 ways for frequency reuse in each cell (spot beam)
	Ground	
System and Channel Capacity (number of channels and channel size):	RF	16kbps to 2Mbps standard channels, hundreds of channels available. Over 100Mbps gateway or hub channels.
	Ground	Unknown
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	duplex, may be asymmetric
	Ground	Duplex
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	Multiple priorities available
	Ground	Unknown
System and component redundancy requirement (1/2, 1/3, etc):	RF	Design life of 10 to 15 years, high system availability (0.9999 goal)
	Ground	Unknown, typically multiple ground stations in view
Physical channel characteristics (LOS, OTH, etc.):	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	possible interference from terrestrial Ka-band systems (LMDS, fiber alternatives systems), regulated through spectrum licensing
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	All
Channel data rate (digital) and/or occupied band width (analog) requirement:		FDM/TDMA burst (packet) channels, variable bit rates, 1 to 100+ Mbps

CHARACTERISTIC	SEGMENT	DESCRIPTION
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	variable rate coding and variable data rates to mitigate deep rain fades, many frequencies available to avoid fixed interference
System integrity (probability)	System	0.9999 availability typical goal
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	10^{-9} or better typical
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	global possible, but most systems do not intend to cover oceans and polar regions, GEO systems point spot beams to land masses and high population areas in particular
Link and channel availability	RF	0.9999 availability typical goal
Security/ encryption capability	RF	terminal authentication during access encryption can be overlaid, but not a basic feature
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Fixed ground terminal service beginning in 2003
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	digital, QPSK, burst (packets), FEC variable rates 1/2 or higher
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	FDM/TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	latency: approx. 0.3 second for GEO
	System	
Avionics versatility (applicability to other aircraft platforms)		Not designed for fast moving terminals, can be achieved if business is identified and the developer designs capability.
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	optional
	Ground	
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
	Avionics	Independent
Source documents		FCC and ITU spectrum license applications, conference publications

5.2.7.3 MEO Satellites

MEO satellite systems have been proposed for the Aeronautical Mobile Service. MEO systems have several advantages over the GEO and LEO approaches. The reduced transmission distance of MEO systems provides a higher link margin. Compared to LEO systems, the MEO satellites are in view to an individual aircraft longer and experience less frequent handoffs. Boeing, ICO-Global, Celestri, and Teledesic are possible MEO satellites for the 2007 timeframe. The following table is based on the ICO-Global system. (Note: Segment is used only for characteristic with multiple descriptions)

Table 5.2-9. ICO Global Satellite Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**ICO Global**
Communications/link type (HF, VHF, L-Band, SATCOM, other):		SATCOM MEO satellites; 10 satellites in two planes of 5 each (plus 2 spares)
Frequency/ Spectrum of Operations:	Service Band, Uplink	2.170 – 2.200 GHz
	Service Band, Downlink	1.98 – 2.010 GHz
	Feeder Band, Uplink	6.725 – 7.025 GHz
	Feeder Band, Downlink	5 GHz (AMS(R)S)
	Crosslink Band	N/A
System Bandwidth Requirement:	System	Unknown
System and Channel Capacity (number of channels and channel size):	RF	24,000 circuits total/4.8 Kbps voice
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Duplex
Method of information delivery (voice, voice recording, data, combination, etc.):	RF	GSM Voice
Data/message priority capability / designation (high, intermediate, low, etc.):	System	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	10 satellites in two planes of 5 each (plus 2 spares)
Physical channel characteristics (LOS, OTH, etc.):	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	Service Link Margin 8.5 dB, DO-160D for avionics
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	All
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	4.8 Kbps voice
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Moderate. Max one-satellite duration: 120 minutes Connectivity characteristics: Simultaneous fixed view required
System integrity (probability)	System	Not stated
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Unknown
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	System	Full earth coverage
Link and channel availability	RF	Not stated
Security/ encryption capability	System	Not stated

CHARACTERISTIC	SEGMENT	DESCRIPTION
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	RF	None
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	QPSK
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	TDMA (implied that path diversity and combining will be used
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Latency: ~140ms path + sat switching + 100ms in 2 codecs
Avionics versatility (applicability to other aircraft platforms)	RF	No avionics available.
Equipage requirements (mandatory for IFR, optional, primary, backup)	RF	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
Source documents		ARINC Satellite Study

5.2.7.4 LEO Satellites

The IRIDIUM system is shown in the following template to represent potential LEO systems although IRIDIUM has gone bankrupt and will not be available. The 66 satellite IRIDIUM LEO system was designed for mobile voice and low-speed data and has been proposed for aeronautical mobile users. FCC filings have indicated future IRIDIUM versions would provide higher speed data services. In addition to the low data rate, LEO systems must overcome the frequent handoff problem that occurs as a satellite transits the user location.

Table 5.2-10. IRIDIUM Satellite Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**Iridium**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	SATCOM; LEO satellites; 66 satellites in 6 planes of 11 each (plus 12 spares)
Frequency/ Spectrum of Operations	Service Band, Uplink	1.62135 – 1.62650 GHz (AMS(R)S)
	Service Band, Downlink	1.62135 – 1.62650 GHz (AMS(R)S)
	Feeder Band, Uplink	29 GHz
	Feeder Band, Downlink	19 GHz
	Crosslink Band	23 GHz

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Bandwidth Requirement	System	10.5 MHz
	Channel	31.5 kHz/50 kbps/12 users
System and Channel Capacity (number of channels and channel size)	RF	3840 circuits/sat; 56,000 circuits total
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	System	duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	System	Voice and data
Data/message priority capability / designation (high, intermediate, low, etc.)	System	None
System and component redundancy requirement (1/2, 1/3, etc)	RF	66 satellites in 6 planes of 11 each (plus 12 spares)
	Ground	Satellite-satellite switching for high ground system availability
Physical channel characteristics (LOS, OTH, etc.)	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics	RF	Service link margin: 16.5 dB no combining min BER 10^{-2} DO 160D for avionics
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	All
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	2.4 Kbps and 4.8 Kbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	High. Max one-satellite duration: 9 minutes Connectivity characteristics: Flex to any station at any location
System integrity (probability)	RF	1×10^{-6}
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Compressed voice, toll quality
Range/ Coverage/ footprint (oceanic, global, regional / line-of-sight	System	Full earth coverage
Link and channel availability	RF	99.5%
Security/ encryption capability	System	Proprietary protocol
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	RF	No aviation usage
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	QPSK, FEC rate ¾,
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	FDMA/TDMA

CHARACTERISTIC	SEGMENT	DESCRIPTION
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	12 ms path; 175 ms total
Avionics versatility (applicability to other aircraft platforms)	RF	No avionics available
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
Source documents		ARINC Satellite Study

5.2.8 High-Frequency Data Link

HF data link provides an alternative to oceanic satellite data and HF voice communications. The aircraft changes are small, consisting primarily of a radio upgrade and a new message display capability. HF antenna and aircraft wiring can remain the same. HFDL is cheaper to install and operate than satellite. For cargo aircraft that do not need the passenger voice service of satellite, HFDL provides a cost effective data link. HFDL is adaptive to radio propagation and interference. It seeks the ground station with the best signal and adjusts the data-signaling rate to reduce errors caused by interference. HFDL service is faster, less error prone and more available than traditional HF voice communications. HFDL has not yet been approved for carrying air traffic messages and aircraft equipage is just beginning.

Table 5.2-11. HFDL Characteristics

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		HIGH FREQUENCY DATA LINK (HFDL) (GLOBAlink/HF)
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	High Frequency (HF)
	Ground	ARINC Data Network System (ADNS) & ARINC Packet Network (APN)
Frequency/ Spectrum of Operations:		2.8 MHz to 22 MHz
System Bandwidth Requirement:	RF	3 kHz Single Side band, carrier frequency plus 1440 Hz. Each Station provides 2 channels
	Ground	N/A
System and Channel Capacity (number of channels and channel size):	RF	Two channels per ground station
	Ground	ADNS & APN X.25 packet switched services
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Half-duplex
	Ground	Full duplex with a separate channel for each transmit and receive path, however the communications equipment often blocks receive voice when the operator is transmitting resulting in a half-duplex operation.
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data

CHARACTERISTIC	SEGMENT	DESCRIPTION
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	N/A
	Ground	A ground based priority and preemption capability that enables Air Traffic Services (ATS) messages to be delivered ahead of Aeronautical Operational Control (AOC) messages. A higher priority single or multiblock ATS message will be serviced before lower priority multiblock messages. The transmission of lower priority multiblock messages will resume when the higher priority message is completed. Lower priority messages will be delivered in their entirety to the aircraft. Lower priority single-block messages are not preempted due to protocol and avionics implementation requirements. The immediate preemption by higher priority messages of lower priority multiblock messages is also supported.
System and Component Redundancy	RF	HFDL Ground Stations (HGS) are geographically located to provide a 1 / 2 equipment diversification with each site transmitting two frequencies to provide a 1 / 4 relationship for radio frequencies.
	Ground	ETE availability for HFDL through ADNS and APN provides redundancy with an availability of 1.00000. In the North Atlantic Region redundancy is also provided with an equipment availability of.99451 for the passport backbone Access Module. In the Pacific Region total redundancy is provided ETE.
Physical channel characteristics (LOS, OTH, etc.):	RF	Via ionosphere
Electromagnetic interference (EMI) / compatibility characteristics:	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	Adaptable to propagation conditions: 1800, 1200, 600, 300 bps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Signals in the HF band are influenced by the characteristics inherent in transmitting through the ionosphere, which include various emissions from the sun interacting with the earth's magnetic field, ionosphere changes, and the 11-year sunspot cycle which affects frequency propagation. HF is also affected by other unpredictable solar events. Frequency management techniques are used to mitigate these effects
System integrity (probability)	System	No integrity requirement for 2007 data services, Forward error detection
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	95% of uplink message blocks in 60 seconds (one-way); 95% of uplink message blocks in 75 seconds (round-trip); 99% of uplink message blocks in 180 seconds (round-trip
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	3,000 nm from each ground station. Ten stations deployed as of December 1999 with 3-4 more sites under consideration to complete Global coverage.
Link and channel availability	RF	≥99.8% End to End Operational Availability
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Commercial aircraft, 50-100 equipped. New service with potential 8,000 users

CHARACTERISTIC	SEGMENT	DESCRIPTION
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	M-Phase Shift Keying (M-PSK) 1800 (8-PSK); 1200(4-PSK); 600 (2-PSK); 300 (2-PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Slotted TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Uplink end-to-end: 2 minutes/95%, 6 minutes/99% of messages Downlinks end-to-end: 1 minute/95%, 3 minutes/99%
Avionics versatility (applicability to other aircraft platforms)	Avionics	Any aircraft equipped with HF transmit and receive equipment and the appropriate HFDL interface unit
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Avionics	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications, etc.)	System	Signal in space defined by national and international standards. HF Voice equipment may be shared with other HF applications (i.e., HF voice).
Source documents		Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; ARINC Quality Management Reports, Air/Ground Voice Performance; ARINC specification 635-2 ARINC Aeronautical Data Link Proposal, 1997; HFDL Ground Station System Segment Specification

5.3 Link Considerations

5.3.1 Ground based systems

All aviation communications systems based on ground stations have limitations of coverage and range. The majority of aviation communications systems are line of sight limited. The radio frequency power available permits operation at distances up to 200 nautical miles (nm). However, the curvature of the earth blocks the signal to aircraft unless the aircraft is at high altitude. At low altitudes such as 5,000 feet, the line of sight range is reduced to approximately 30 nm. Mountains also block signals and reduce potential coverage. Satellites are much less limited in coverage but do become constrained by available power. A geosynchronous satellite can cover one-third of the earth but the radio frequency power will be far less than for terrestrial systems. Traditionally satellite systems have used dish antennas to increase received power. Newer satellite concepts include low earth orbit (LEO) and medium earth orbit (MEO) systems which are closer to the earth which improves the available power while reducing the coverage for each satellite.

5.3.2 Frequency band

The aviation industry has traditionally used frequency spectrum allocated specifically to aviation applications and protected by national and international law from interference. Under international agreement, the aviation communications frequencies are limited to ATC and AOC use. Services such as entertainment and passenger communications have been prohibited. All of the VHF systems, voice

DSB-AM, ACARS, VDL Mode 2, Mode 3, and Mode 4 are designed to operate within the current 25 kHz channel spacing of the 118 - 137 MHz protected VHF band.

Three major configurations of satellite systems were considered. GEO systems depend on satellites in geosynchronous orbit. Usually a single satellite provides wide area coverage that is essentially constant. Coverage is not possible at the poles. MEO satellites move relative to the earth and their coverage shifts. A number of satellites are needed and earth coverage is virtually complete. A failure of a single satellite causes a short-term outage. LEO satellites move quickly relative to the earth and require numerous satellites for full earth coverage; therefore, an outage of a single satellite is short-term.

5.3.3 General Satellite Comments

Ka and extremely high frequency (EHF) systems are best for fixed or slowly moving terminals, not for aviation speed terminals (path delay variation, Doppler, frequent hand-off between spot beams). Coding and other link margin features may be used to compensate for speed when the aircraft is above atmospheric degradation (rain). The GEO and MEO systems avoid oceans by not pointing spot beams there (systems with phased array antennas will be capable of pointing at oceans) and LEO systems plan to power down the satellites while over the oceans or low population areas. These issues are not technological problems; they are design choices based on business cases. To insure capability for aeronautic use, economic opportunity needs to be communicated to the system developers (business cases supporting premium charges, particularly over unpopulated areas).

Alternatives to these systems will likely be provided by established service providers, such as Inamoratas (at Ku-band, and possibly new systems at Ka-band), and Boeing, which is aggressively pursuing multimedia to the passenger with asymmetrical return link. There will be a premium charge for this type system relative to fixed-ground terminals, particularly when outside of populated areas.

Boeing has already demonstrated direct video broadcast (DVB) standard communication to the aircraft. The emerging DVB-RCS (return channel satellite) standard will probably be capable of asymmetric communication with aircraft and be available in 2007.

5.3.4 Summary of Links

The communications links are summarized in Table 5.3-1, which presents the key performance characteristics. The most significant consideration in our review has been the need to provide high bandwidth and capacity. As shown, existing and near term links are limited in bandwidth and capacity and will be unable to meet the future traffic load from FIS and TIS. Message latency is also a significant consideration, especially for the ATC critical message types. Considerations such as modulation scheme, frequency, integrity, range and protocol are important design considerations buy are not the major factors for selecting a future data link.

Table 5.3-1. Capacity Provided by Various Communication Links

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
	kbps	Channels	Channels	Aircraft	
HFDL	1.8	2	1	50	Intended for Oceanic
ACARS	2.4	10	1	25	ACARS should be in decline as users transition to VDL Mode 2

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
VDL Mode 2	31.5	4+	1	150	System can expand indefinitely as user demand grows
VDL Mode 3	31.5*	~300	1	60	Assumes NEXCOM will deploy to all phases of flight
VDL Mode 4	19.2	1-2	1	500	Intended for surveillance
VDL – B	31.5	2	1	Broadcast	Intended for FIS
Mode-S	1000**	1	1	500	Intended for surveillance
UAT	1000	1	1	500	Intended for surveillance/FIS
SATCOM	-	-	-	-	Assumes satellites past service life
Future SATCOM	384	15	1	~200	Planned future satellite
Future Ka Satellite	2,000	~50	~50	~200	Estimated capability - assumes capacity split for satellite beams
Fourth Generation Satellite	>100,000	>100	>100	Unknown	Based on frequency license filings

* Channel split between voice and data.

** The Mode-S data link is limited to a secondary, non-interference basis with the surveillance function and has a capacity of 300 bps per aircraft in track per sensor (RTCA/DO-237).

Appendix A. Acronyms

AAC	Airlines administrative communications
AATT	Advanced Air Transportation Technologies
ACARS	aircraft communications addressing and reporting system
ADAS	AWOS data acquisition system
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance - Broadcast
AFSS	automated flight service station
AM	amplitude modulation
AMS	acquisition management system
AMS(R)S	Aeronautical Mobile Satellite (Route) Service
AOC	airline operations center
ARTCC	Air route traffic control center
ASIST	Aeronautics Safety Investment Strategy Team
ASOS	automated surface observing system
ASR-9	airport surveillance radar- nine
ASR-WSP	airport surveillance radar- weather system processor
ATCSCC	Air traffic Control System Command Center
ATIS	Automatic Terminal Information Service
ATM	air traffic management
ATN	Aeronautical Telecommunication Network
ATS	air traffic services
ATSP	air traffic service provider
AvSP	Aviation Safety Program
AWIN	Aviation Weather Information
AWOS	automated weather observing system
CD	compact disk
CONOPS	concept of operations
CONUS	Continental United States
CP	conflict probe
CPU	central processing unit
CSA	communications system architecture
CTAS	Center-TRACON Automation system
DA	descent advisor
DAG-TM	Distributed Air/Ground Traffic Management

DoD	Department of Defense
DOT	Department of Transportation
DOTS	dynamic ocean tracking system
DSR	Display System Replacement
FAA	Federal Aviation Administration
FANS 1/A	future air navigation system
FAR	Federal Aviation Regulation
FBWTG	FAA bulk weather telecommunications gateway
FCC	Federal Communications Commission
FDM	flight data management
FDP	flight data processor
FFP1	Free Flight Phase 1
FIS	Flight Information Service
FL	flight level
FP	flight plan
FSS	flight service station
GA	general aviation
GPS	Global Positioning System
GWS	graphical weather service
HARS	high altitude route system
HF	high frequency
IF	interface
IFR	Instrument flight rules
IMC	instrument meteorological conditions
IOC	initial operating capability
ITWS	Integrated terminal weather system
LLWAS	Low-level wind shear alert system
MDCRS	Meteorological Data Collection and Reporting System
METAR	meteorological aviation report
MOPS	minimum operational performance standards
NAS	National Airspace System
NAS RD	NAS Requirements Document
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NESDIS	national environmental satellite, data, and information service
NEXRAD	next generation radar

NLDN	national lightning detection network
NWS	National Weather Service
NWS/OSO	National Weather Service/Office of Systems Operations
OASIS	operational and supportability implementation system
OAT	Office of Advanced Technology
ODAPS	oceanic display and planning system
PFAST	passive final approach spacing tool
PIREPS	pilot reports
RA	resolution advisory
RD	requirements document
RTCA	RTCA, Incorporated
RTO	Research Task Order
RVR	runway visual range
TAF	Terminal Aerodrome Forecast
TBD	to be determined
TDWR	terminal Doppler weather radar
TFM	traffic flow management
TM	traffic management
TMS	traffic management system
TRM	Technical Reference Model
TWIP	terminal weather information for pilots
VDL	very high frequency digital link
VFR	visual flight rules
VHF	very high frequency
WARP	weather and radar processor
WMSCR	weather message switching center replacement
WJHTC	William J. Hughes Technical Center
WxAP	weather accident prevention

Communications System Architecture Development For Air Traffic Management & Aviation Weather Information Dissemination

Research Task Order 24

Subtask 4.9, Develop Transition Plan

(Task 8.0)

Prepared By

ARINC
Science Applications International Corporation (SAIC)
TRW

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Under
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May 2000

Table of Contents

Table of Figures

Table of Tables

1 Executive Summary

1.1 Background

The Advanced Air Transportation Technologies (AATT) initiative has a number of project sub-elements ranging from advanced ATM concept development to aircraft systems and operations. It also has an Advanced Communications for Air Traffic Management (AC/ATM) task with a goal of enabling an aeronautical communications infrastructure through satellite communications that provides the capacity, efficiency, and flexibility necessary to realize the benefits of the future ATM system and the mature Free-Flight (F/F) environment. Specifically, the AC/ATM task is leveraging and developing advanced satellite communications technology to enable F/F and provide global connectivity to all aircraft in a global aviation information network. The task directly addresses the Office of Aerospace Technology (OAT) Enterprise Pillar One Enabling Technology Goal of increasing aviation throughput as part of the AATT Project. The objectives of the AC/ATM task are to:

1. Identify the current communication shortfalls of the present ATM system
2. Define communications systems requirements for the emerging AATT concept(s)
3. Demonstrate AATT concepts and hardware
4. Develop select high-risk, high payoff advanced communications technologies.

The technical focus of the AC/ATM task has centered on the development of advanced satellite communications technology as a select high-risk, high payoff technology area in support of ATM communications (objective 4 above). Although the thrust of the task has been satellite communications (SATCOM), aeronautical air-ground communications will be provided for the foreseeable future by a number of different communications systems/data links, including VHF, L-band, and SATCOM. Relevant advanced technology development for any of these systems requires that a comprehensive technical communications architecture exist. In satisfaction of objectives 1 and 2, a comprehensive technical communications system architecture must be defined and developed. That architecture must address the user communications requirements of the future mature ATM system that the various data links mentioned can support.

1.2 Objectives

The objective of Task 8 is to develop a transition plan for achievement of the 2015 AATT communications architecture as defined in Task 5 of this report. The transition plan will highlight the key milestones and interdependencies that are necessary to achieve this goal.

1.3 Technical Approach

The 2015 communications architecture defined in Task 5 is described functionally as a collection of technical concepts and physically as a collection of communication links. Our approach to describing a transition plan for the communication architecture was to define the key milestones and activities for implementation of each of the technical concepts and each of the communication links, followed by a summary of the system-wide cross-cutting activities that apply to the integrated systems. This approach provides a view of the activities necessary to deliver a service as well as a view of the activities necessary to establish a specific communications link to support one or more services.

1.4 Results of This Task

A collection of schedules was produced for each of the communication architecture technical concepts and for each communication link highlighting the key milestones and activities necessary for implementation. Additionally, an integrated system level schedule was produced to depict the cross-cutting milestones and activities that apply to all communication architecture efforts.

2 Introduction

2.1 Overview of Task 8

Task 8 provides a transition plan for the 2015 communications architecture identified in task 5. The transition plan identifies key milestones, activities, and interdependencies necessary to implement the communication architecture.

2.2 Relationship to Other Tasks

Task 8 is one of eleven related tasks in the AATT RTO 24, Communications System Architecture Development for Air Traffic Management and Aviation Weather Information Dissemination. The relationships among these tasks are depicted in Figure 2.2-1. Task 8 provides the transition plan for achieving the 2015 AATT communications architecture defined in Task 5 and identifies the research and standards activities that are necessary to address the technology gaps identified in Task 10.

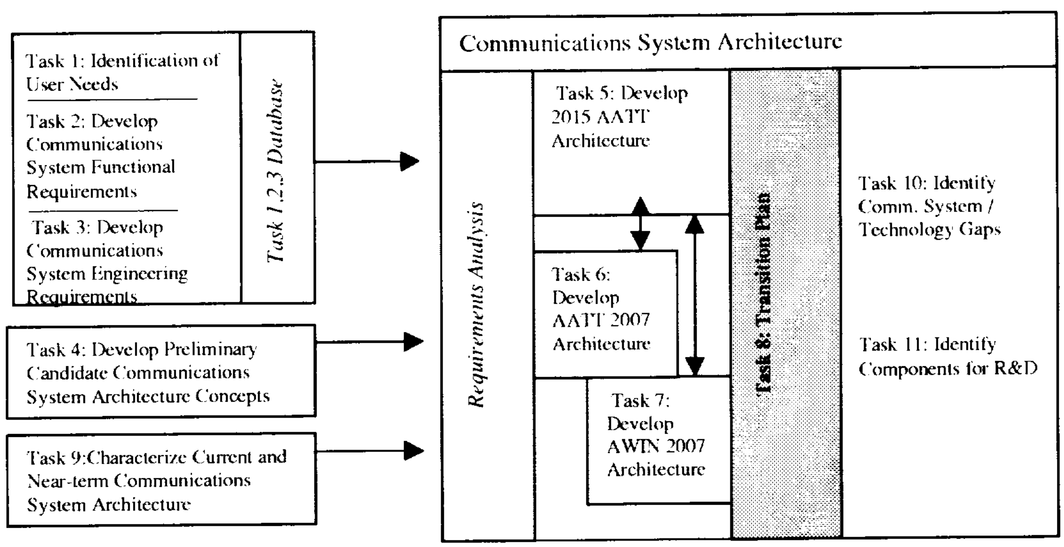

Figure 2.2-1. Relationship to Other Tasks

Overview of the Document

Sections 1 and 2 provide an executive summary and overview of the document. Section 3 presents the transition schedules for each of the technical concept areas and provides an integrated transition schedule for each communication link.

3 Transition Plan

3.1 Introduction

The NAS is in a constant state of transition. Significant changes will occur in air-ground communications between today and 2007. Many of the systems that will begin implementation just prior to 2007 will be fully deployed by 2015. Table 3.1-1 below summarizes the significant changes that will occur in making the transition from today to 2007 and then from 2007 to 2015. Transitions that reflect the current path of the NAS Architecture are indicated as such. Those not indicated are recommended deviations from the NAS Architecture path. The Aeronautical Operation Control Data Link (AOCDL) and Airline Passenger Communication Service (APAXS) are not part of the NAS Architecture.

Transition schedules are provided first for each technical concept area and then for each communication link. Each schedule is organized into ground communications, air-ground communications, and avionics in order to highlight the activities in each of these areas necessary to deliver the service. Within each of these areas are sections for research, standards, and systems.

Table 3.1-1. Summary of Technical Concept Transition

Technical concept	Today - 2007	2007 - 2015
FIS	• Provided by commercial service provider over VDL-B [NAS Architecture] • Possible introduction of SATCOM broadcast	• Migrate to SATCOM broadcast if not established by 2007
TIS	• Possible "local pockets" on UAT/Mode-S [NAS Architecture] • Possible introduction of SATCOM broadcast	• Establish VDL-B or continue SATCOM broadcast if established by 2007
CPDLC	• Initial service on VDL-2 for En Route airspace [NAS Architecture]	• Migrate to VDL-3, transition complete for all but uncontrolled airspace by 2015 [NAS Architecture]
CPC	• Transition existing analog radios to digital radios broadcasting VHF-AM [NAS Architecture]	• Migrate to VDL-3, transition complete for all but uncontrolled airspace by 2015 [NAS Architecture]
DSSDL	• Begin initial service for aircraft to ATC data on VDL-2 [NAS Architecture]	• Migrate to VDL-3 [NAS Architecture]
AOCDL	• Migrate from ACARS (VDL-1) to VDL-2	• Continue service on VDL-2
ADS-B	• Implement "local pockets" on Mode-S / UAT/VDL-4 based on link decision [NAS Architecture]	• Evolve to national implementation on Mode-S / UAT/VDL-4 [NAS Architecture]
AUTOMET	• Evolve MDCRS from ACARS to VDL-2 [NAS Architecture] • Implement AUTOMET for class 1 users on VDL-2	• Continue service on VDL-2 [NAS Architecture]
APAXS	• Evolve to next generation e.g., Ka-band SATCOM services	• Continue SATCOM services • Experiment with V-band services

Table 3.1-2 below identifies the links that will be used by each technical concept area for each time frame. This table also illustrates the interdependencies of the technical concept areas for each communications link.

Table 3.1-2. Technical Concept Time Frame

Technical Concept	VHF-AM	VDL-2 / ATN	VDL-3 / ATN	VDL-4 / ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
FIS					2007 2015		2007* 2015*	2007* 2015*	
TIS					2007 2015	2007*	2007* 2015*	2007* 2015*	
CPDLC		2007	2015						
CPC	2007 2015		2015						
DSSDL		2007	2015						
AOCDL		2007 2015					2007* 2015*		2007* 2015*
ADS-B				2007* 2015*		2007* 2015*	2007* 2015*		
AUTOMET		2007 2015					2007* 2015*		2007* 2015*
APAXS								2007* 2015	2007* 2015
	* Possible Implementation								

Table 3.1-3 provides a summary of functionality provided by each communications link.

Table 3.1-3. Transition Summary by Communications Link

Communication Link	Today - 2007	2007 - 2015
VHF-AM	• Support NAS-wide air-ground voice communication	• Support air-ground communication in selected uncontrolled airspace
VDL-2	• Support En Route CPDLC messaging • Support Initial aircraft to ATC DSSDL data exchange • Support AOC operations and maintenance data exchange • Support AUTOMET reporting to NWS	• Support AOC operations and maintenance data exchange • Support AUTOMET reporting to NWS
VDL-3	• No service in 2007	• Support CPDLC messaging in all domains • Support DSSDL data exchange for aircraft-ATC and aircraft-aircraft

Communication Link	Today - 2007	2007 - 2015
VDL-4	• Possible support for ADS-B in local pockets	• Possible support for ADS-B
VDL-B	• Support commercial delivery of FIS data	• Support commercial delivery of FIS data • Support delivery of TIS tactical data
Mode-S	• Support aircraft surveillance (not considered as a part of data communication function) • Possible support for TIS tactical data delivery to aircraft • Possible support for ADS-B in "local pockets"	• Support aircraft surveillance (not considered as a part of data communication function) • Possible support for ADS-B
UAT	• Possible support for TIS tactical data delivery to aircraft • Possible support for ADS-B in "local pockets"	• Possible support for ADS-B
SATCOM-broadcast	• Possible support for FIS • Possible support for TIS • Possible support for APAXS	• Support for FIS • Possible support for TIS
SATCOM-2way	• Possible support for APAXS	• Support for APAXS

3.2 Transition Plans

Each of the nine technical concept areas is addressed in terms of major activities and milestones that must be met to achieve the objectives of the 2015 environment.

3.2.1 Flight Information Systems (FIS) Transition

In the FIS concept aircraft receive flight information continuously to enable common situational awareness and allow pilots to operate safely and efficiently. Flight information consists of weather and NAS status information. The objective of FIS is to provide to the aircraft the most current information available. In our concept, the FAA makes flight information available to commercial service providers, who then transmit that information to aircraft that subscribe to their service.

Currently, the NAS Architecture baseline for FIS in the 2007 and 2015 time frames is to allocate up to four VHF frequencies to allow commercial service providers to deliver weather information to the cockpit via data link. As part of the FAA's FIS policy, the FAA will make NAS status and existing weather data available to commercial service providers for development of FIS products. The commercial service provider will use VDL broadcast to transmit text and graphical weather, special use airspace information, NOTAMs, and traffic flow data directly to the aircraft. Users will need to equip their aircraft with a VHF data radio (multimode radio) and a multifunction color display to receive the information.

In the 2015 time frame, we believe that non-addressed broadcast satellite technology will be the most desirable for providing flight information. This is based on our forecast that the exchange of data between the ground nodes and aircraft will increase exponentially (as it has for the past 10 years). This increase will drive the requirement for data exchange from the kilobit range to the megabit range. Given this forecast, we must look beyond the VHF spectrum toward broadband solutions that are provided via SATCOM. While dedicated ATC SATCOM solutions are most likely unaffordable, we believe that consumer demand for broadcast services in the cabin will provide the incentive for system providers to develop the receivers, antenna, and other components necessary to provide this service. Without cooperative research from the government, these designs will support high-end aircraft only.

Given the migration to broadband frequencies, the need exists for higher efficiency transmitters (both space and terrestrial), more adaptive bandwidth versus power efficient modulation, forward error correction coding (including turbo codes and bit/modulation symbol interleaving), and much expanded use of variable bit rate formats and dynamic multiplexing techniques such as asynchronous transfer mode (ATM) based technologies. Antennas and receivers must be adapted for the aviation market (size, weight, cost) and must overcome the problems of rain attenuation for broadcast FIS over satellite.

In addition to the communication gaps identified for FIS, there are ground and aircraft gaps that also must be addressed, including the development of common data standards, NWIS security routing protocols for delivery of FIS data, and data display standards for the cockpit.

The transition schedule for FIS is shown in Figure 3.2-1.

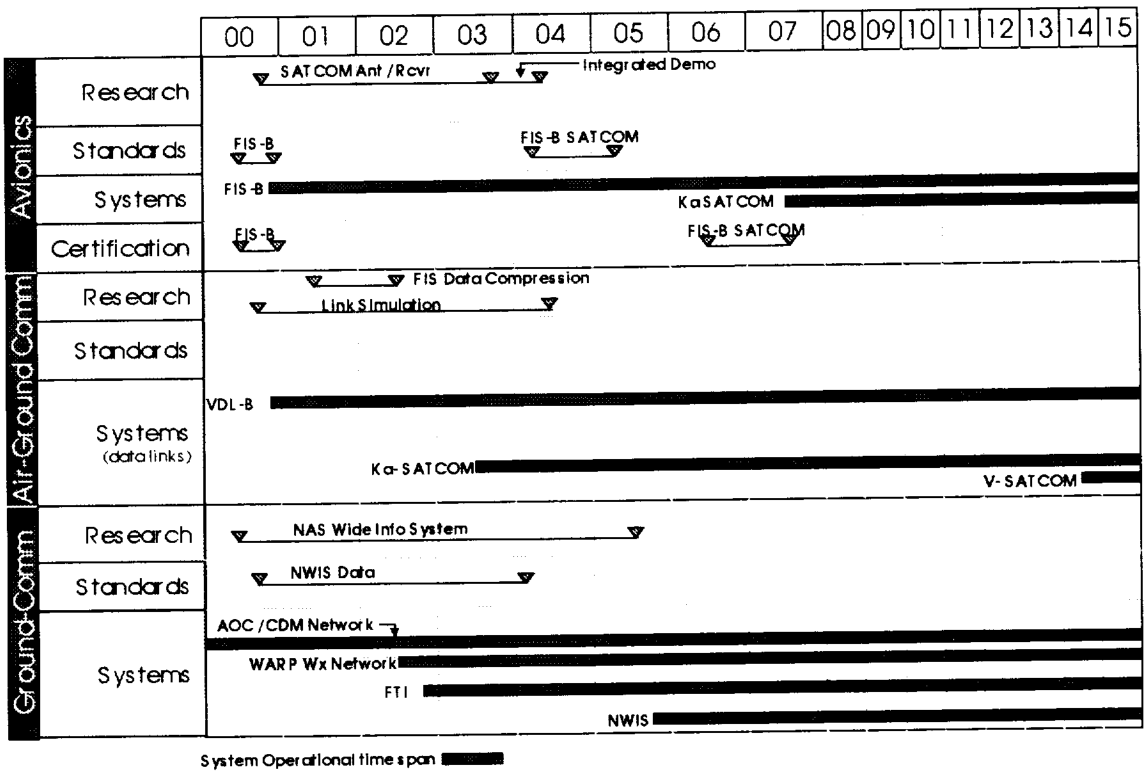

Figure 3.2-1. AATT Communication Architecture Schedule-FIS

FIS Avionics

For FIS avionics, standards development within RTCA is currently underway in SC-195. Completion of the standard is anticipated for the end of 2000. The FIS commercial service providers are anticipated to have VDL-B avionics available for aircraft installation in the fall of 2000.

Research should begin on SATCOM solutions for FIS in the fall of 2000 with the goal of beginning an integrated demonstration of FIS delivery to the cockpit via SATCOM in the fall of 2003. Data gathered from this research would be used to develop a FIS standard for SATCOM in the 2004/2005 time frame. This standard would drive the development and certification of SATCOM avionics in the 2006/2007 time frame.

FIS Air-Ground Communications

It is anticipated that an initial ground-based VDL-B network will be in place in the fall of 2000 in selected areas. This network will utilize the FAA allocated frequencies and will grow to national coverage based on user demand.

Initial deployment of Ka-band satellites will begin in the 2003 time frame. Efforts should be made to secure channel space in order to support an integrated FIS SATCOM demonstration.

Research should be conducted in the 2001/2002 time frame to determine the improvements that can be made in the effective FIS data transfer rates through the use of data compression schemes. Additionally, link simulation research should be conducted in conjunction with the SATCOM avionics research to determine the most effective link usage/access methods required to support data transfer.

FIS Ground Communications

The structure of FIS data will be influenced by the information architecture efforts for the NAS-wide information system. NWIS efforts will include the development of data standards for all operational data used within the NAS. These efforts will begin in the mid 2000 time frame. FIS data is provided to the commercial service providers via the WARP weather network that is supported by the FAA Telecommunications Infrastructure.

3.3 Traffic Information Service (TIS) Transition

The TIS function is intended to improve the safety and efficiency of aircraft by providing pilots with automatic display of surrounding traffic and warning of any potentially threatening conditions. The source of the information is aircraft tracks maintained by the ground for a region of airspace. Traffic information consists of real time aircraft position data that is received by ATC from their ground-based surveillance sensor network consisting of primary and secondary radars and dependent surveillance receivers. The received aircraft position data is combined with trajectory and intent data and re-sent to aircraft. TIS information supports Cockpit Display of Traffic Information (CDTI) to provide pilots with complete traffic situational awareness. In our concept, the FAA provides traffic information to commercial service providers who then transmit that information to the aircraft.

SATCOM Broadcast may be available in the 2007 time frame due to the commercial demand for APAXS direct broadcast satellite or other services in aircraft. This availability could provide an additional benefit of supporting air traffic services such as TIS-B that would not otherwise be available. Assuming it was available, SATCOM could support the strategic portion (data latency of five minutes acceptable) of TIS for aircraft operating in the CONUS in 2007. It is expected that SATCOM will be available in the 2015 time frame.

The transition schedule for TIS is shown in Figure 3.3-1.

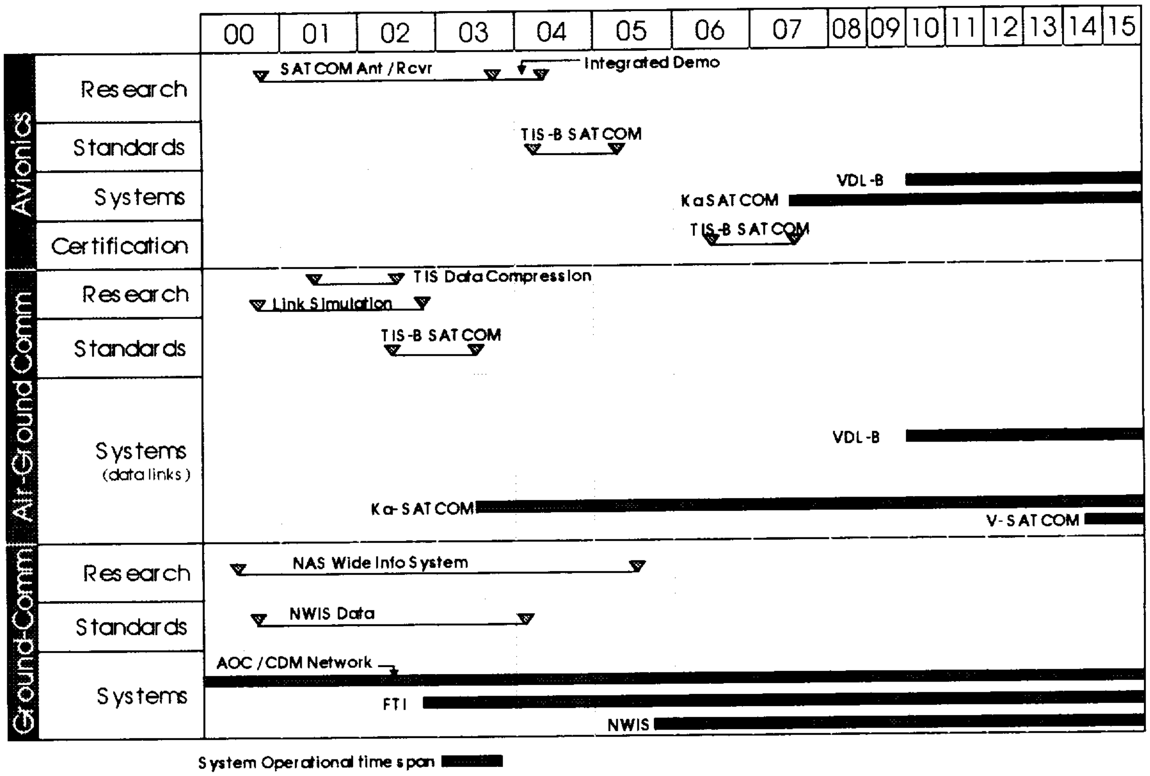

Figure 3.3-1. AATT Communication Architecture Schedule-TIS

TIS Avionics

Some initial standards for TIS-B have been developed but they will need to be modified to be compatible with the standards that will be revised following the ADS-B link decision. With a link decision anticipated in the end of 2001, this standards work should begin shortly thereafter but no later than 2003. Avionics standards should consider the use of SATCOM based on the results of research to develop suitable SATCOM avionics and demonstrations conducted in the 2003/2004 time frame.

TIS Air-Ground Communications

Barring successful demonstration of SATCOM capability for TIS, a terrestrial-based solution will be required. This will most likely be some form of VDL-B using VHF spectrum that is made available as a result of efficiencies realized through implementation of VDL-3.

Research should be conducted in the 2001/2002 time frame in cooperation with FIS to determine the improvements that can be made in effective data transfer rates through the use of data compression schemes. Additionally, link simulation research should also be conducted cooperatively in conjunction with the SATCOM avionics research to determine the most effective link usage/access methods required to support data transfer.

TIS Ground Communications

The structure of TIS data will be influenced by the information architecture efforts for the NAS-wide information system. NWIS efforts will include the development of data standards for all operational data used within the NAS. These efforts will begin in the mid 2000 time frame. TIS data will be provided through the FAA Telecommunications Infrastructure.

3.4 Controller-Pilot Communications (CPC) Transition

Voice communication is the foundation of air traffic control. Thus, even as we move toward a higher utilization of data messaging for routine communications, it is critical to maintain a high quality, robust voice communication service. The implementation of NEXCOM will provide both digital voice and data capabilities. Radios will be able to emulate the existing analog system and select modulation techniques using software programming. As the users equip with new avionics, NEXCOM will evolve to an ATN compliant VDL-3 voice and data capability implementing Time Division Multiple Access (TDMA). TDMA uses four time slots or sub-channels within each 25 kHz channel, with an effective data transfer rate of 4.8 Kbps each.

The transition schedule for CPC is shown in Figure 3.4-1.

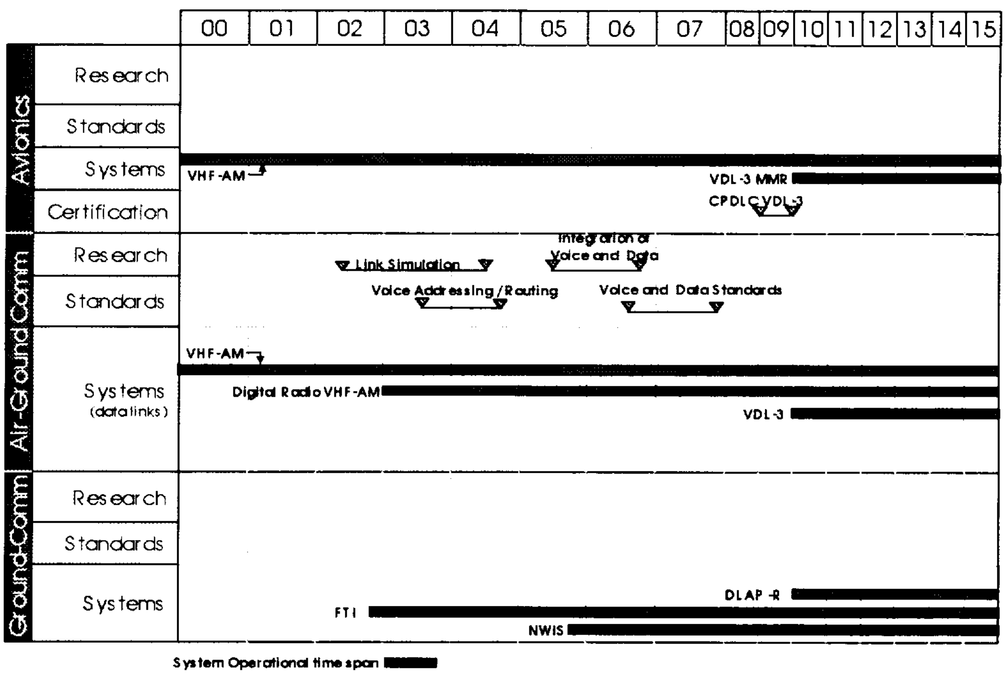

Figure 3.4-1. AATT Communication Architecture Schedule-NEXCOM

CPC Avionics

Aircraft avionics for voice communication remain unchanged from today's systems until the introduction of VDL-3 in the 2010 time frame. It is anticipated that the majority of users will transition to a VDL multi-mode radio in the 2010 to 2015 time frame in conjunction with the cut-over of sectors from VHF-AM to VDL-3 operation.

CPC Air-Ground Communications

As part of the NEXCOM program, the current VHF-AM radios will be replaced with digital radios (that continue to broadcast VHF-AM) in the 2003 time frame. These radios will be configured for VDL-3 operation beginning in the 2010 time frame.

We recommend that research be performed to develop standards for addressing and routing schemes that would support the creation of a virtual voice/data network. Furthermore, research should be conducted to determine whether standards could be developed to support the integration of voice and data. If this is possible, if would allow maximum utilization of the VHF spectrum.

CPC Ground Communications

No change is required to the ground communications systems until the deployment of VDL-3. At that time, digitization of controller voice will be required. To support this, we recommend that research be done to create improved standards for voice compression.

3.5 Controller Pilot Data Link Communication (CPDLC) Transition

The objective of CPDLC is to provide a data messaging capability between controllers and pilots that will reduce voice frequency congestion and provide a more precise and efficient means of communicating clearances and advisories. CPDLC begins with the creation and initiation of a message by a controller or pilot. CPDLC messages are ATN compliant, which accommodates message prioritization. Fixed or free-text messages are supported. For operations in the continental US, CPDLC will initially utilize a commercial service provider with VDL-2 communications.

CPDLC has been identified as the means for automated delivery of hazardous weather alerts to the cockpit. Given the urgency associated with providing these alerts the current belief is that these messages must be prioritized for delivery. The VDL-2 implementation, does not support message prioritization at the RF level and it is unlikely that the NEXCOM implementation of VDL-3 for data can be accelerated into the 2007 time frame. In the interim, however, research could be performed to determine if priority messages could be integrated into the VDL-2 link. Standards work also can be performed to add hazardous weather messages to the CPDLC message set for use when NEXCOM/VDL-3 is implemented. Finally, research could be performed to promote a standard for a cockpit voice synthesis capability that would provide audio delivery of CPDLC messages.

The transition schedule for CPDLC is shown in Figure 3.5-1

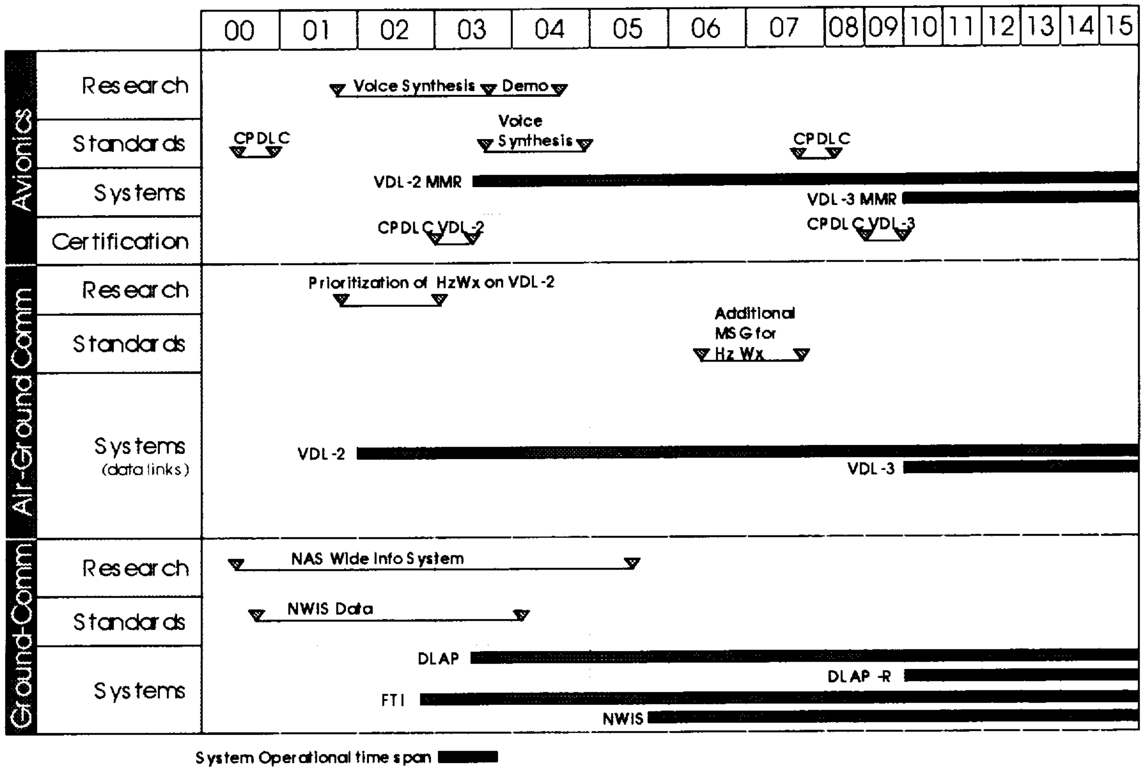

Figure 3.5-1. AATT Communication Architecture Schedule-CPDLC

CPDLC Avionics

The exchange of controller pilot messages will begin in the mid 2003 time frame with a limited number of messages available in selected en route airspace using a commercial service provider's VDL-2 network. The available message set will continue to grow through transition to the FAA VDL-3 network based on demand. Aircraft operators that equip their aircraft for CPDLC via VDL-2 will be required to upgrade their radios for CPDLC via VDL-3 to be able to use the enhanced message set.

We believe that the use of synthesized voice (for delivery of selected CPDLC messages) in the cockpit would enhance safety by eliminating some pilot "head-down" time. Accordingly, we recommend research and demonstration of this capability that would lead to the development of a standard for the use of synthesized voice.

CPDLC Air-Ground Communications

The VDL-2 network necessary to support initial CPDLC will be available in the 2002 time frame. We have recommended that CPDLC messages be used to support the delivery of hazardous weather advisories to pilots. As discussed above, these are considered priority messages that would only be suitable for delivery via VDL-3. Accordingly, we believe that research should be performed to determine the viability of sending hazardous weather advisories via VDL-2, given that VDL-2 ground networks support ATN priority. If successful, this would accelerate the benefits to both pilots and controllers.

Regardless of whether hazardous weather messages can be integrated into the VDL-2 message set, standards work will be required to establish the message set(s) for delivery via VDL-3.

CPDLC Ground Communications

The processing of CPDLC messages on the ground requires a data link applications processor (DLAP) that must be kept up to date with the latest message set. Messages are delivered from the air-ground communications site to the appropriate ATC facility via the FTI network. An upgrade to the DLAP will be required to support the CPDLC message set when the transition to VDL-3 occurs in the 2010 time frame.

3.6 Decision Support System Data Link (DSSDL) Transition

As we establish the NAS-Wide Information System and promote the exchange of common data among participating nodes of the NAS, a data exchange method must be created that allows aircraft to participate as if they were "ground-based" nodes (i.e., they would have the same access and integrity of information as ground nodes). This is the objective of DSSDL. DSSDL provides a capability for the transfer of data between aircraft avionics and ATC automation (or other aircraft). Its purpose is to accommodate real time exchange of data that does not require human intervention or acknowledgement. The data transferred by DSSDL supports calculations by DSS algorithms that will be used by controllers and pilots to make decisions. Initially, this data exchange is not fully automated in that the controller or pilot must authorize its use by the aircraft DSS/ATC DSS, which is similar to the exchange and use of pre-departure clearance data today. In time, however, with system experience and the acceptance of controllers and pilots, DSSDL will become a fully automated method of negotiating/notifying change among participating users of the NAS.

DSSDL is applicable only to aircraft that have an advanced FMS that supports integration with an onboard data link. In the 2007 time frame, the NAS will be in the initial stages of implementing DSSDL and only a small portion of class 3 users are expected to be equipped. Initial DSSDL messages most likely will be aircraft-to-ATC only, indicating preferences for routes or arrival times.

In the 2007 time frame, the NAS Architecture will be in the initial implementation stages of DSSDL. In this time frame, only aircraft preference data will be sent to ATC automation for controller use and for input to DSS tools. In fact, in the early stages of DSSDL the data exchange could be performed as message additions to AOCDL (using the extended message format) with routing to ATC. DSSDL data exchange will be via VDL-2.

The transition schedule for DSSDL is shown in Figure 3.6-1.

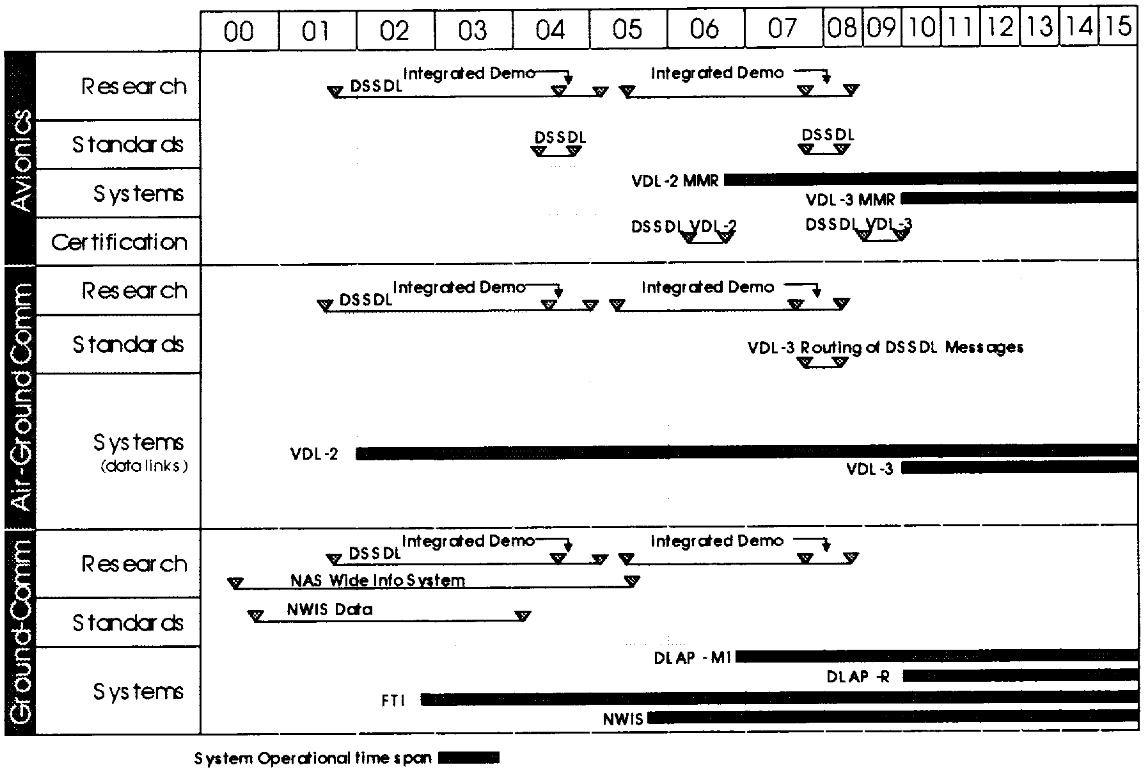

Figure 3.6-1. AATT Communication Architecture Schedule-DSSDL

DSSDL Avionics

Deployment of an initial aircraft to ATC DSSDL capability in the 2006/2007 time frame will require research and demonstration of an integrated avionics, air-ground communications, and ground communications system. The results of this research and demonstration will be used to establish standards for the initial deployment of DSSDL. Following this initial research, further research should be conducted to establish the aircraft to aircraft data exchange standard using VDL-3 with the goal of establishing a syntax for negotiation based on a defined information base shared by each party to the negotiation. Transition to DSSDL via VDL-3 will occur in the 2010 time frame in conjunction with the transition of NEXCOM and CPDLC.

DSSDL Air-Ground Communications

DSSDL will utilize the existing commercial service provider VDL-2 network and will transition to the FAA VDL-3 network in the 2010 time frame. Integrated research must be conducted to support the deployment of this capability as discussed above.

DSSDL Ground Communications

A modification to the DLAP will be required in the 2006 time frame in order to support the initial DSSDL data exchange. Messages are delivered from the air-ground communications site to the appropriate ATC facility via the FTI network.

3.7 Aeronautical Operational Control Data Link (AOCDL) Transition

Aircraft Operational Control (AOC) – Pilot/Aircraft – AOC data exchange supports efficient air carrier/air transport operations and maintenance. The AOC's prime responsibility is to ensure the safety of flight and to operate the aircraft fleet in a legal and efficient manner. The AOC's business responsibility requires that the dispatcher conduct individual flights (and the entire schedule) efficiently to enhance the business success and profitability of the airline. Most major airlines operate a centralized AOC function at an operations center that is responsible for worldwide operations. Typical AOC data exchange supports airline operations (OOOI, flight data, position reporting, etc.) and maintenance (performance, diagnostic, etc.).

In the 2007 time frame the AOCDL begins to take on increasing significance as a part of the collaborative decision making process between ATC, AOC, and the aircraft. A majority of current ACARS users will migrate to VDL-2 because of the additional data capacity provided.

In 2015, the AOCDL continues to provide operations and maintenance data exchange service via VDL-2.

The AOCDL transition schedule mirrors that of the VDL-2 communications link described in Section 4.2 of this document.

3.8 Automatic Dependent Surveillance (ADS-B) Transition

ADS-B aircraft continuously broadcast their position, velocity, and intent information using GPS as the primary source of navigation data to enable optimum maneuvering. ADS-B will support both air-ground and air-air surveillance. The major operational environments improved by ADS-B include "gap-filler" surveillance for non-radar areas, surface operations, pair-wise maneuvers, and approach/departure maneuvers. ADS-B equipped aircraft with CDTI equipment will provide enhanced visual acquisition of other ADS-B equipped aircraft to pilots for situational awareness and collision avoidance. Pilots and controllers will have common situational awareness for shared separation responsibility to improve safety and efficiency. When operationally advantageous, pilots in ADS-B equipped aircraft may obtain approval from controllers for pair-wise or approach/departure maneuvers. In the future, en route controllers in centers with significant radar coverage gaps will provide more efficient tactical separation to ADS-B equipped aircraft in non-radar areas. The received ADS-B surveillance data will enable controllers to "see" ADS-B equipped aircraft and reduce separation standards in areas where they previously used procedural control.

ADS-B will be deployed in a phased approach consistent with aviation community needs, FAA priorities, and projected budgets. In general, for each ADS-B operational environment, experiments and prototype demonstrations conducted as part of Safe Flight 21 lead to operational key site deployments. Key site deployments represent the increment where operational procedures and certified systems are used to deliver daily service. Following key site deployment, additional "pockets" of ADS-B will be deployed on a benefits-driven basis. These deployments eventually could result in national deployment. In the 2007 time frame, initial deployment will be started for the "pocket" areas. Much of the initial ADS-B deployment will enable air-to-air use of ADS-B in selected airspace to demonstrate operational feasibility and achievement of estimated benefits. The extent of aircraft equipage and demand from the aviation community will be a factor in determining the strategy for deployment of ADS-B ground stations.

The FAA is engaging in a program to evaluate three candidate ADS-B communication technologies (Mode S Squitter, UAT, VDL-4) with an expected link decision in 2001.

The transition schedule for ADS-B is shown in Figure 3.8-1.

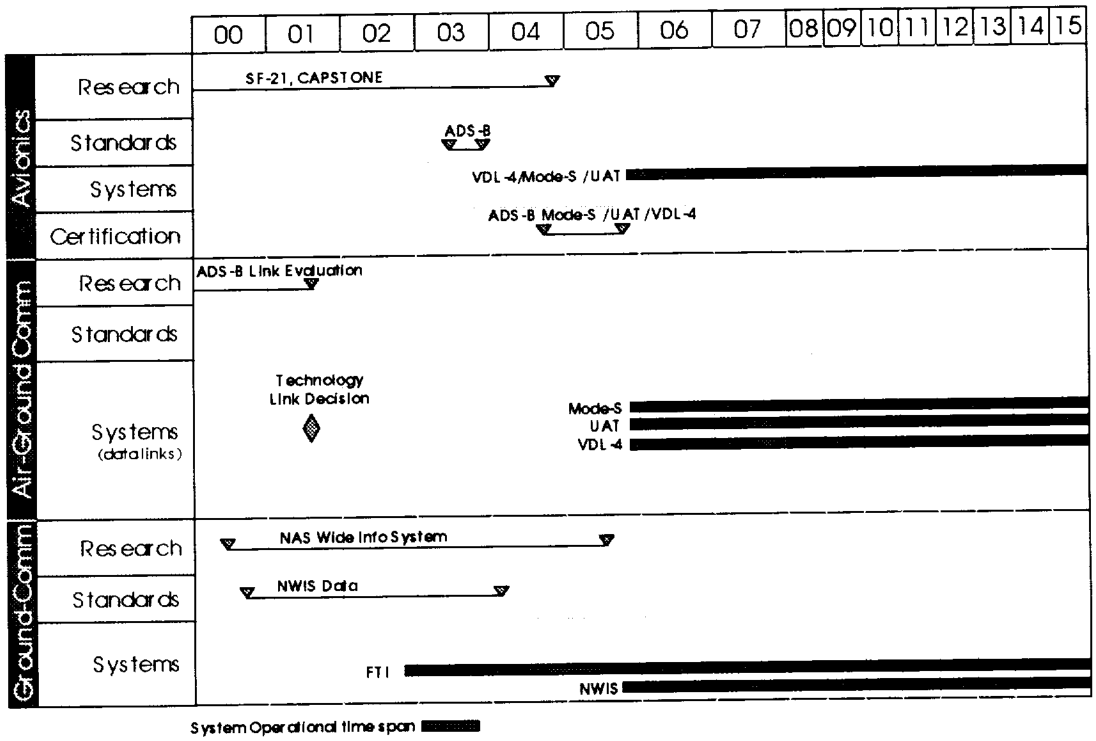

Figure 3.8-1. AATT Communication Architecture Schedule-ADS-B

ADS-B Avionics, Air-Ground Communications, and Ground Communications

The transition of ADS-B is being conducted by the Safe Flight 21 program office with field evaluations being conducted in Alaska and the Ohio Valley region. The results of these ongoing field trials will be input to a link decision in the late 2001 time frame. The result of the link decision will begin a series of "local pocket" implementations throughout the NAS beginning in the 2005/2006 time frame. Research in this area is mature and well defined.

3.9 Automated Meteorological Transmission (AUTOMET) Transition

AUTOMET is being defined under the auspices of the RTCA SC 194, which established the Minimum Interoperability Standard (MIS) for Automated Meteorological Transmission for wind, temperature, water vapor and turbulence. Conceptually, aircraft participating in an AUTOMET service program must be able to respond to AUTOMET commands issued by a ground-based command and control system. Downlink message parameters (e.g., frequency, type, etc) are changed by uplink commands from the ground-based systems and are triggered by various conditions (agreed to in advance by the airline, service provider and NWS), or by a request from an end user. Goals of the AUTOMET system are: 1) Increase the amount of usable weather data that is provided to the weather user community; 2) Increase the resolution of reports, forecast products and hazardous weather warnings to make providers of weather information more operationally efficient; 3) Increase the knowledge of the state of the atmosphere and decrease controller workload by automatically transmitting hazardous weather conditions to the ground and other aircraft to improve the ATC system.

Participating aircraft that report weather using AUTOMET collect wind, temperature, humidity, and turbulence information in flight and automatically relay the information to a commercial service provider using VDL Mode 2. The service provider collects and reformats the information and then forwards the information to the National Weather Service (NWS) and the FAA. The NWS uses this AUTOMET information and weather data from other sources to generate gridded weather forecasts. The improved forecasts are distributed to airlines and the FAA to assist in planning flight operations. The gridded weather data, based on AUTOMET data, is also provided to WARP for use by FAA meteorologists and is used by several ATC decision support system tools to improve their performance.

The transition schedule for AUTOMET is shown in Figure 3.9-1.

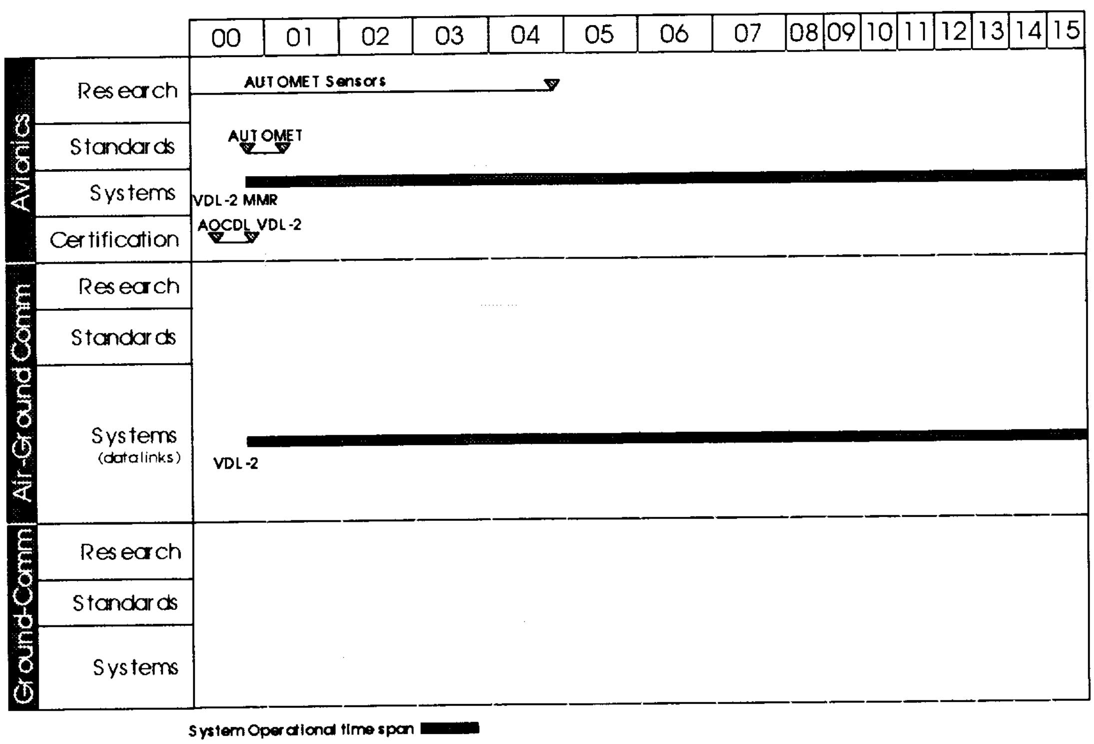

Figure 3.9-1. AATT Communication Architecture Schedule-AUTOMET

AUTOMET Avionics

There is ongoing research on AUTOMET avionics sensors in addition to the standards work described above. Calibration requirements for sensors on low end GA aircraft is seen as an obstacle for widespread implementation. The amount of data that is required and how the data will be used is yet to be determined.

3.10 Aeronautical Passenger Services (APAXS) Transition

Passengers enjoy in-flight television, radio, entertainment, telephone, and Internet services. Our analysis of communication trends indicates that there will be a commercial demand for real-time television, radio, and Internet service to airline passengers. Industry surveys have shown that while prerecorded programs and movies are a lower priority for passengers than reading, sleeping, and working, there always has been a high interest in live television. One service provider had surveys conducted that showed some 50% of respondents were interested, and 35% would be willing to pay S3-5 per flight for live television--the principal interest being in CNN. This demand for service most likely will be satisfied through digital, high-data-rate satellite channels.

While APAXS is not a service associated with any air traffic management function, it is likely that in the 2007 time frame commercial demand will have driven direct broadcast satellite service to be available in the cabin. This availability is particularly important to note since it may provide an opportunity to support air traffic services that would not be possible otherwise.

The transition schedule for APAXS is expected to follow the SATCOM schedule described in Section 4.6 of this document.

4 Communication Link Transitions

The previous section addressed the transition issues from the perspective of the major service concepts. This section addresses the transition milestones and activities from the data link technology point of view.

4.1 VHF-AM Transition

In 2007 there is still total reliance on VHF-AM for controller pilot voice communication in the terminal and airport domains. However, we anticipate that as a result of successful PETAL-II trials in Europe and CPDLC trials in the US, a majority of class 2 and 3 aircraft operators will upgrade their communication avionics to VDL-2 multimode radios to take advantage of CPDLC in the En Route domain.

In 2015 the NAS will have transitioned from VHF-AM for controller pilot voice communication to VDL-3 digital voice communication in all but selected areas of uncontrolled airspace. Additionally, for Class 2 and 3 users, the majority of controller pilot communication occurs through CPDLC via VDL-3.

The transition schedule for VHF-AM is shown in Figure 4.1-1.

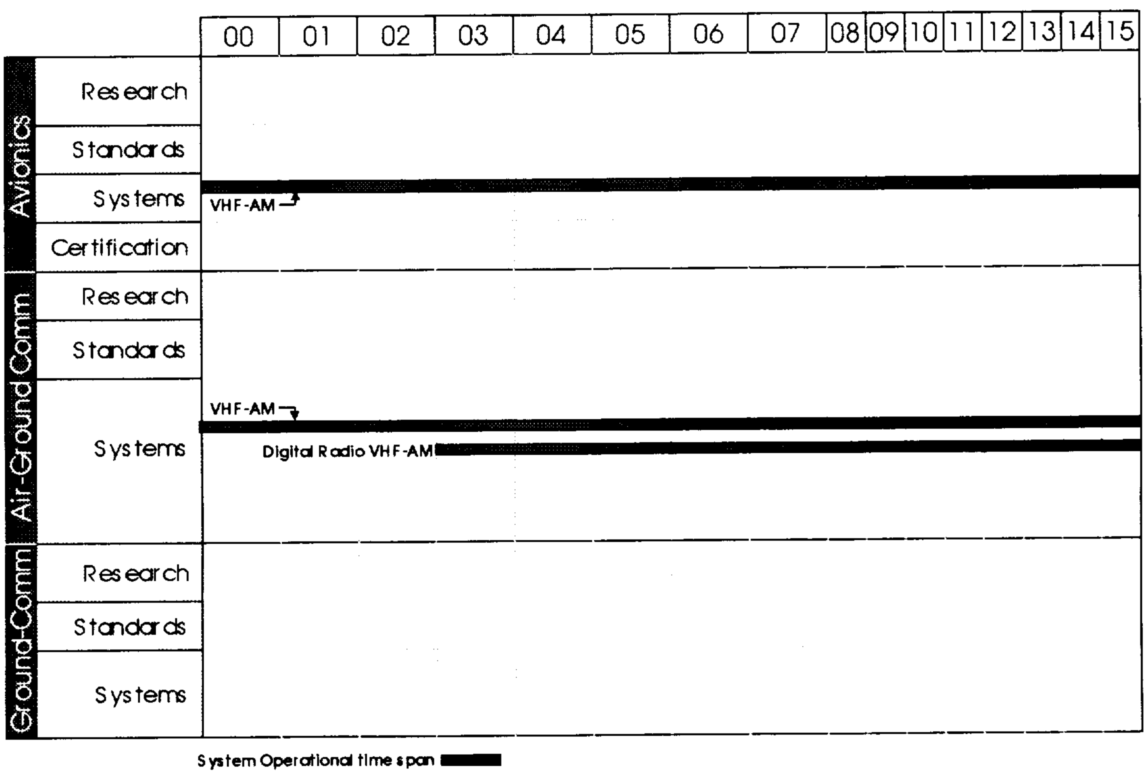

Figure 4.1-1. AATT Communication Architecture Schedule-VFH-AM

4.2 VDL-2 Transition

In addition to CPDLC, the benefit of data link also increases the use of VDL-2 for DSSDL and AUTOMET in addition to supporting its original service of AOCDL. In this time frame, all VDL-2 data is transmitted via the AOC frequencies. The anticipated number of channels assigned for VDL-2 AOC use is four. This provides an effective total data rate of 126Kbps. Our worst case estimate for VDL-2 data in this time frame is 104Kbps (see section 4). Based on that estimate, we believe that there is sufficient margin available to support the interim use of the AOC VDL-2 network for CPDLC, DSSDL, and AUTOMET. This data loading will shift to the FAA VDL-3 network in the 2015 architecture. AOC data is not permitted on the Government-owned ATC Communications links.

There will continue to be a need to maximize the communication capacity of VHF data links operating in the protected aviation spectrum. Accordingly we recommend further research in the areas of link modulation and data compression to increase the overall bit transfer rate, and network prioritization schemes that combine voice and data, and the development of designs for virtual air ground links that will maximize the use of available frequencies.

The transition schedule for VDL-2 is shown in Figure 4.2-1.

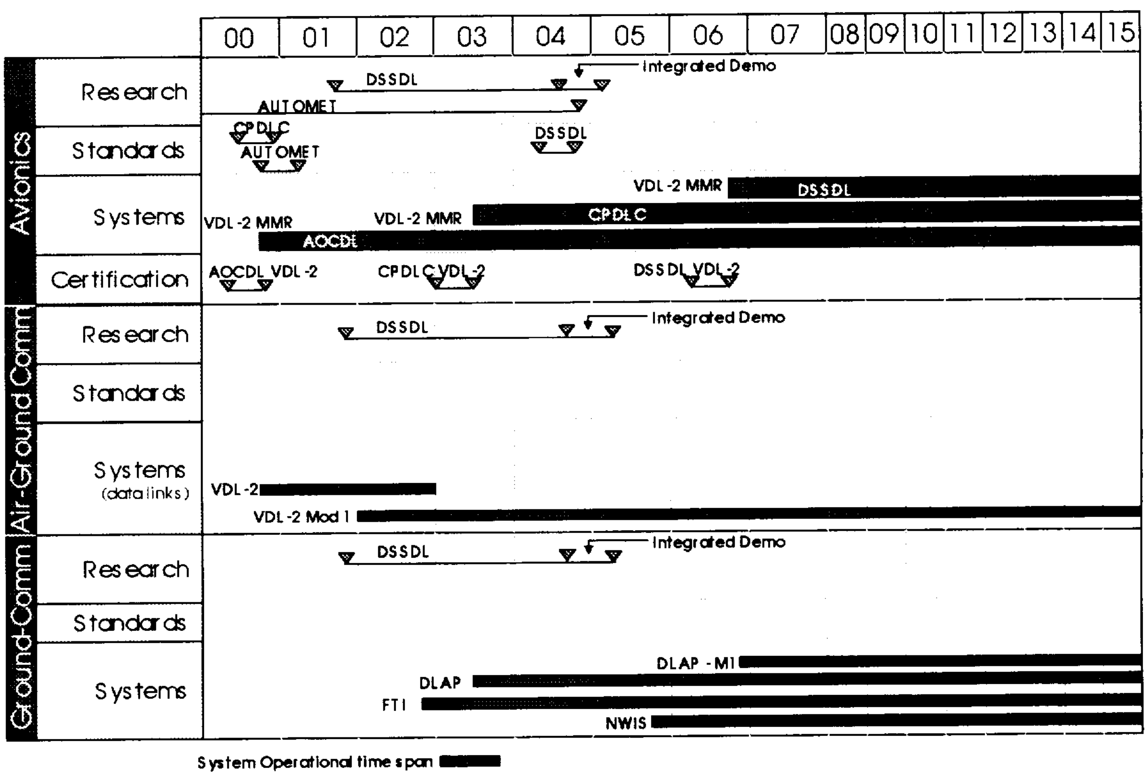

Figure 4.2-1. AATT Communication Architecture Schedule-VDL-2

4.3 VDL-3 Transition

VDL-3 provides a time division access scheme that accommodates message prioritization and provides subchannels that can be dedicated to either voice or data exchange. VDL-3 will be deployed by the FAA beginning in the 2010 time frame at their existing air-ground communication sites. Selected airspace will be cut-over from VHF-AM to VDL-3 for voice (NEXCOM) and from VDL-2 to VDL-3 for data (CPDLC, DSSDL) through 2015.

There will continue to be a need to maximize the communication capacity of VHF data links operating in the protected aviation spectrum. Accordingly we recommend further research in the areas of link modulation and data compression to increase the overall bit transfer rate, and network prioritization schemes that combine voice and data, and the development of designs for virtual air ground links that will maximize the use of available frequencies.

The transition schedule for VDL-3 is shown in Figure 4.3-1.

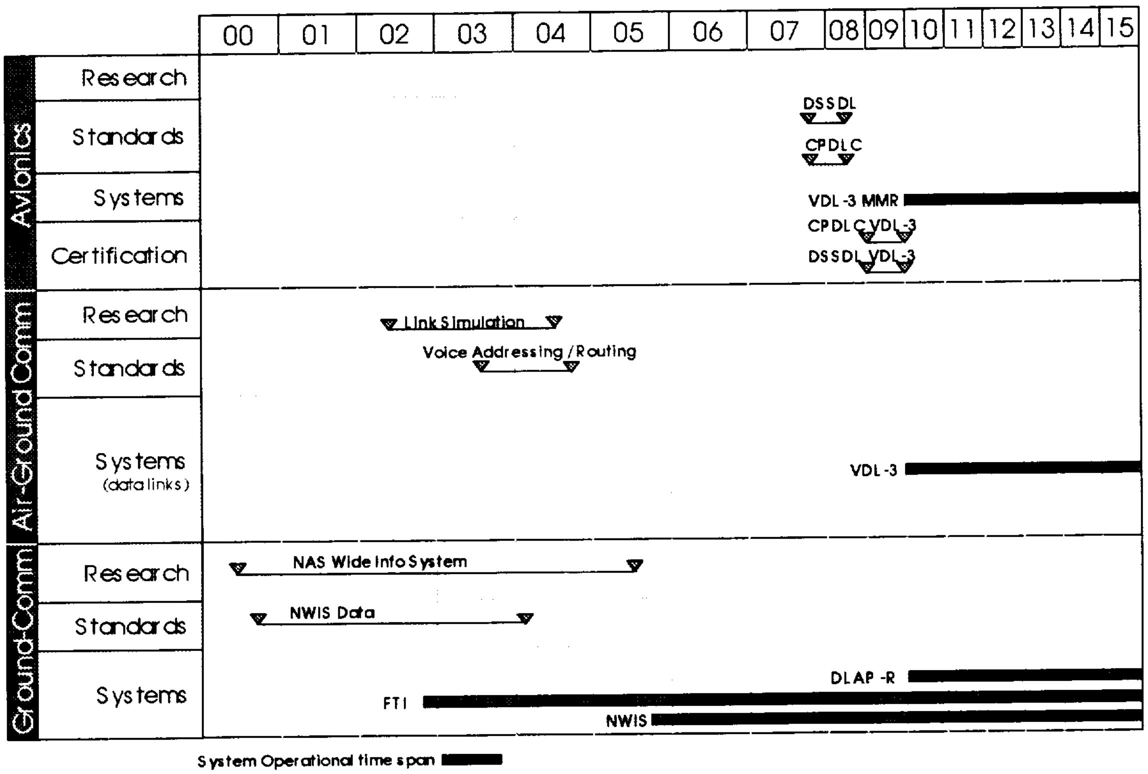

Figure 4.3-1. AATT Communication Architecture Schedule-VDL-3

4.4 VDL-B Transition

Commercial service providers are anticipated to employ some form of VDL Broadcast for support of FIS. Research should be conducted to determine the suitability of VDL-B for support of TIS. This research should also consider the use of single or multiple VDL-3 subchannels for data broadcast in both air-to-air and air-to-ground applications. Additionally, research should be conducted to determine the improvements that can be made in the effective data transfer rates for FIS (and possibly TIS) through the use of data compression schemes.

The transition schedule for VDL-B is shown in Figure 4.4-1.

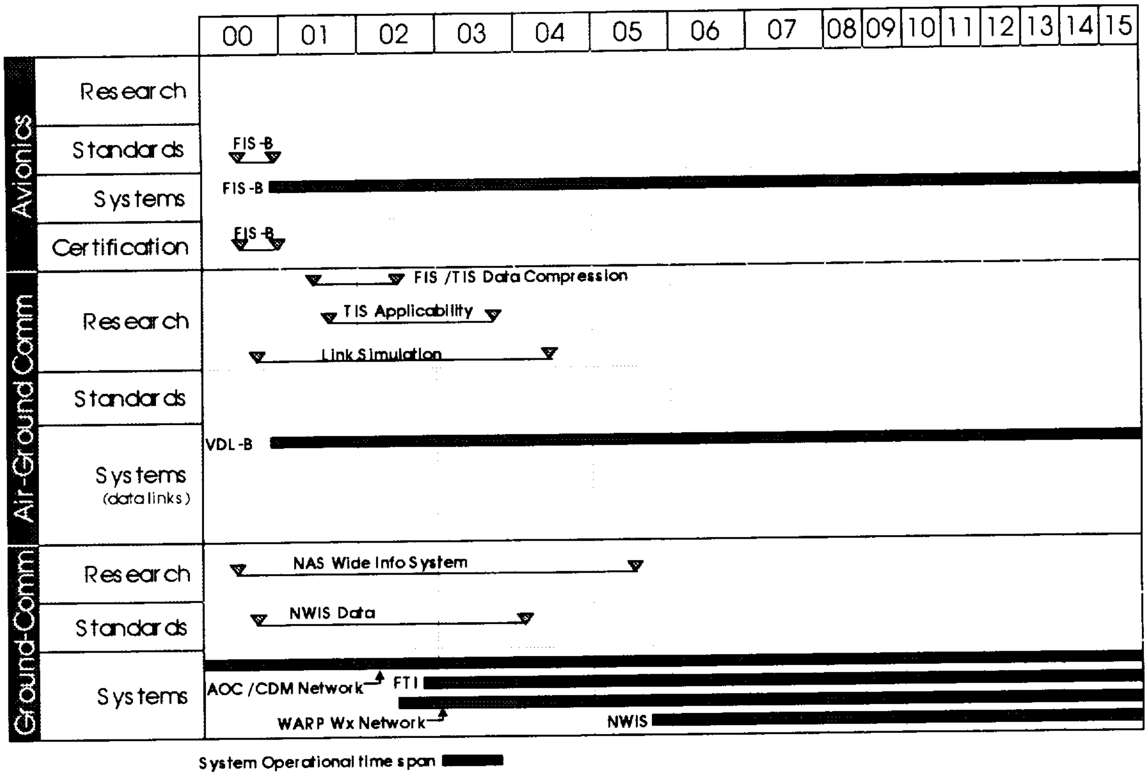

Figure 4.4-1. AATT Communication Architecture Schedule-VDL-B

4.5 VDL-4, UAT, Mode-S Transition

The use of Mode-S and VDL-4 as data links should—in our opinion—be dedicated solely to the support of surveillance in order to optimize the use of these links for that purpose. This would limit these links to the support of ADS-B (in addition to the secondary surveillance function in the case of Mode-S). While these links could arguably support any data exchange between air and ground, we do not feel that it makes sense to burden these links with non-surveillance data when there is sufficient (and more suitable) broadband capacity on other links. While UAT provides a broadband data link capacity, we would also recommend that, if selected for ADS-B, consideration be given to use of a dedicated frequency for ADS-B with additional frequencies allocated for broadband data exchange. The FAA and EUROCONTROL are currently in the process of making a link decision for support of ADS-B.

The transition schedule for VDL-4/UAT/Mode-S is shown in Figure 4.5-1.

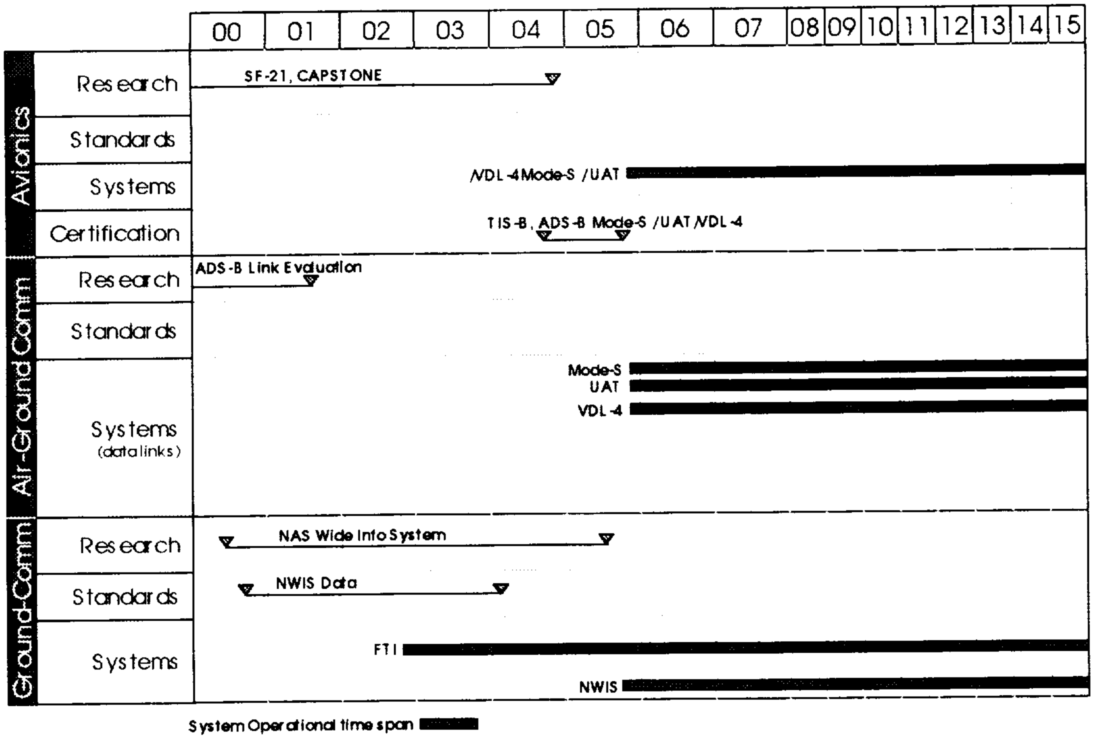

Figure 4.5-1. AATT Communication Architecture Schedule-UAT/Mode-S/VDL-4

4.6 SATCOM Transition

Finally, the use of SATCOM will be driven by the commercial sectors desire to provide high-data-rate services to passengers such as real time television and Internet. Air Traffic Service providers should stay aware of these efforts and look for opportunities to exploit this method of data transmission to support the broadcast needs of TIS and FIS.

Accordingly, we recommend that further study be conducted to determine the possibility for innovative partnerships or incentives that may leverage the involvement of commercial service providers in the delivery of selected air traffic services via SATCOM. For example, providers of broadcast entertainment channels to aircraft could be required to provide an air traffic services channel that is freely accessible by all aircraft. This example is similar to the requirement that cable television providers have with regard to providing public access channels.

The transition schedule for SATCOM is shown in Figure 4.6-1.

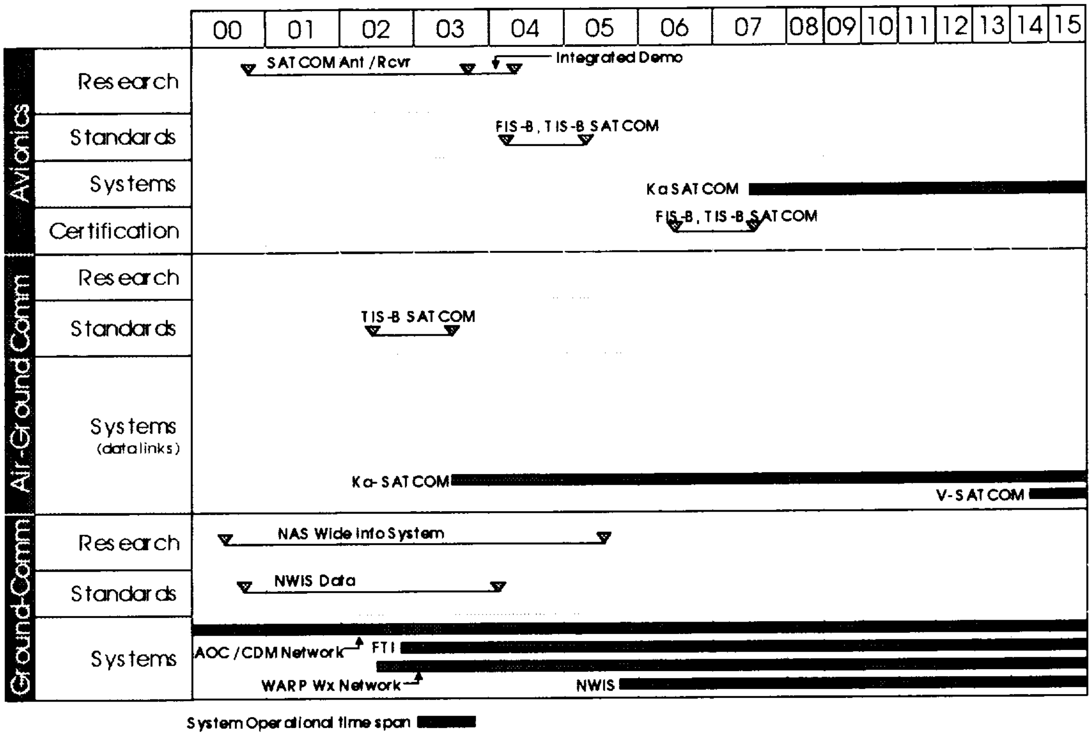

Figure 4.6-1. AATT Communication Architecture Schedule-SATCOM

5 Communication System Cross-cutting Transition activities

The integration of tools, services, technologies, procedures and information will provide the necessary foundation to support the 2015 AATT concept. A comprehensive communications system architecture must facilitate the interaction and integration of multiple services. The cross-cutting technology issues that will impact the communications architecture apply to more than one service and are media independent. These include the detailed definitions of the NAS-wide Information System, Information Security and Information Display.

NAS-wide Information System

- Definition of a common data set
- Standardized interfaces to promote interoperability
- Performance parameters

Information Security

- Encryption techniques (as applicable to various types of data)
- Performance requirements
- Protection from unauthorized access
- Protection from interference

Information Display

- Fused display of flight, traffic, taxi information
- Standard symbology
- Low cost, multifunction displays

The transition schedule for Communication System Cross-cutting activities is shown in Figure 5-1. The schedule includes a summary of the air-ground and ground communication systems that are affected by these cross-cutting activities.

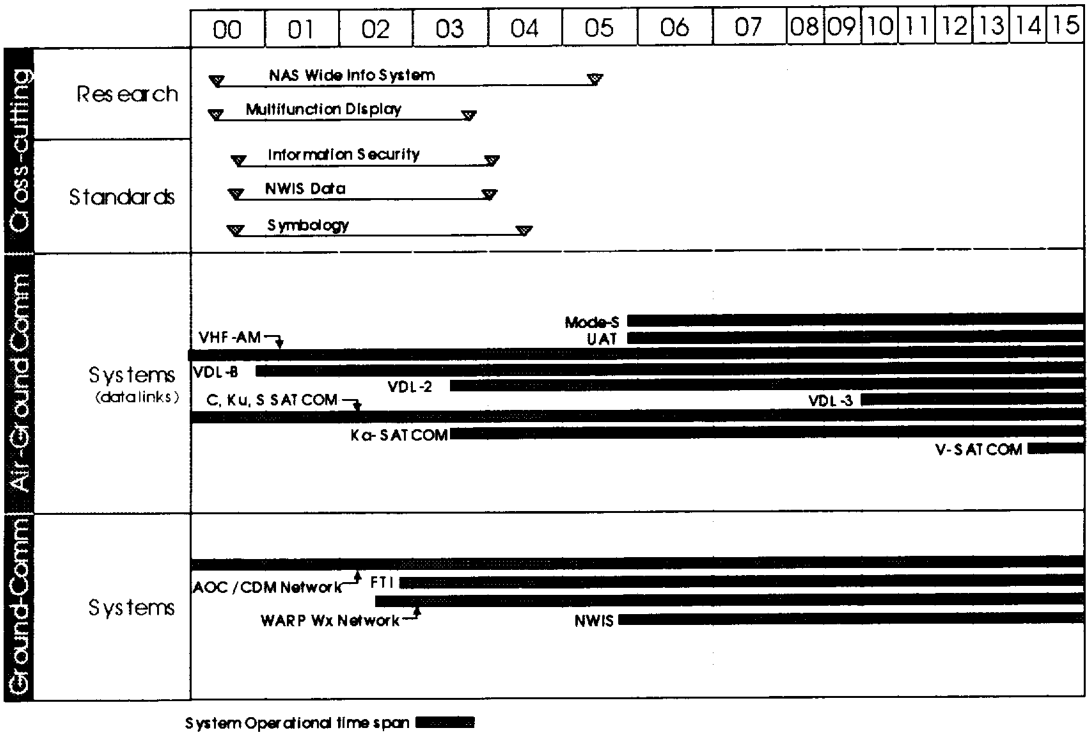

Figure 5-1. AATT Communication Architecture Schedule-Cross-Cutting Transition Activities

6 Summary

When applicable, the milestones and associated activities discussed in this transition plan are based on the current implementation schedules for products and services identified in the NAS Architecture. For services that are outside of the NAS transition plan (AOC, Onboard Passenger/Crew) and new transmission links (Ka-band SATCOM) the schedules have been derived from knowledge of FCC filings and current research and development efforts by commercial service providers. The gaps identified in this section are addressed in further detail in task 10 and task 11.

Communications System Architecture Development For Air Traffic Management & Aviation Weather Information Dissemination

Research Task Order 24

Subtask 4.11, Identify Communications Systems and Technology Gaps

(Task 10.0)

Prepared By

ARINC
Science Applications International Corporation (SAIC)
TRW

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Under
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Table of Contents

Table of Figures

Table of Tables

1 Introduction

1.1 Overview

This report identifies communications technology gaps resulting from an analysis of the recommended 2007 and 2015 Communication System Architecture (CSA). The gaps reflect the communications systems, data links and components that are not addressed by present and near term development programs. The gaps are presented in sufficient detail to enable consideration of technical solutions.

This report follows Task 8, which presented a transition plan for achievement of the 2015 AATT communications architecture as defined in Task 5. The transition plan will highlight the key milestones and interdependencies that are necessary to achieve this goal.

1.2 Approach

To meet the task objective, the communications technology gaps are summarized and categorized as system or component gaps and further identified according to the associated air, ground, and/or space platform.

1.3 Terms and Definitions

The following terms and definitions provide the framework for identifying and categorizing the gaps (Task 10) and candidate solutions (Task 11).

1.3.1 System Gaps

System gaps are concerned with the collection, processing, and distribution of information necessary for safe and efficient operations within the NAS. System gaps fall under one of three categories defined below:

- New systems: An entirely new method of collecting, processing, and distributing data is required to meet the new requirements of the proposed 2015 Communications System Architecture.
- New or improved data link: The protocols and hardware necessary to distribute data through the network are inadequate for the expanded requirements and need improvement.
- Improved network: The protocols are adequate for the expanded requirements; however, the physical configuration (number and location of network nodes) can be improved to provide improved access, response time, and availability.

1.3.2 Component Gap

Component gaps are specified at the following level (applicable to air, ground, and space platforms):

- Radio Frequency (RF) Technology (receivers, transmitters, RF converters, etc.): The hardware that enables wireless transmissions between nodes in such a manner that it may be transmitted and received via antenna technology.

- Antenna Technology: The hardware by which a node in the network receives and transmits RF signals.
- Network/switching and routing technology: The software used to connect the various network nodes and ensure that information is properly routed to the correct destination.

1.4 Relationship to Other Tasks

Task 10 is based on the summary and conclusions drawn from the recommended AATT and AWIN Communications System Architectures (CSA). The purpose of the document is to present a clear picture of the technological gaps in the current or planned communications systems and components. These gaps must be addressed to meet the projected requirements for the 2007 and 2015 CSA. For this purpose, we identify the basic building blocks of a system or component that will form the required communications infrastructure. Such systems or components, if targeted for future research and development (see Task 11), will reduce the implementation risk for the aeronautical industry and facilitate efficient and effective aeronautical communication. Figure 1.4-1 Task Relationship shows the relationship of Task 10 to the other Advanced Air Transportation Technologies (AATT) TO24 Tasks.

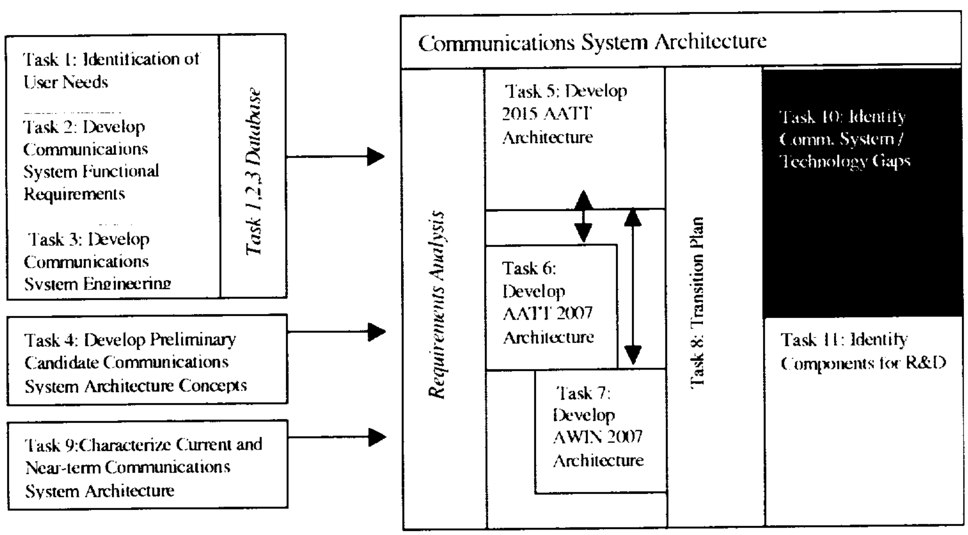

Figure 1.4-1. Task Relationship

2 Gap Identification

Figure 2-1 shows the conceptual communications architecture for 2015. The shaded areas represent the communications system technology gap areas addressed in this report. The ground segment gaps include the interface to the NAS-Wide Information System (NWIS) and to commercial passenger services. It is believed that this is the area where standards for data, security and inter-network (ATN/Non-ATN) communications are needed. In addition, the interface between commercial service providers and the FAA systems will require selection and agreement in national and international forums (i.e. - ICAO) on numerous communications-related standards and performance metrics. In the air segment, shown on the right of the chart, the avionics must support multiple communications links, high-speed data rates and communications between various data communications processors and displays. In the space segment (indicated by the satellite icon), it is assumed that commercial service providers will have the satellites in place, by 2007, to offer broadcast services to airspace users via Ka-band. The gaps include the availability of suitable antennas and receivers for all classes of aircraft that resolve the problems associated with rain attenuation, weight, flexibility and end-user cost. Gaps in the architecture will result in a subset of user needs not being appropriately addressed.

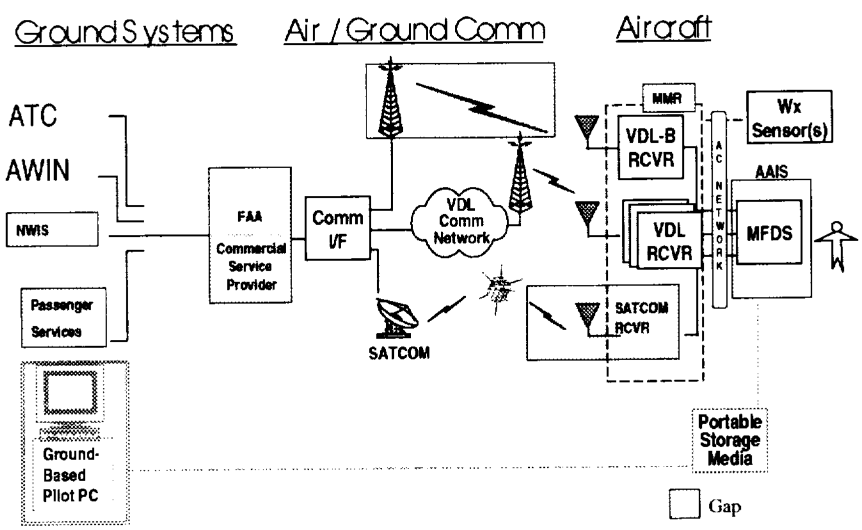

Figure 2-1. 2015 Communications Architecture

2.1 Service Provisions Concepts vs Communication Architectures

The process of defining the 2015 AATT and 2007 AATT and AWIN architectures discussed in Tasks 5-7 involved an analysis of the operational concepts versus the infrastructure provided to support those concepts. To do this, a list of services (concept enablers) along with their supporting functions and associated message types was used as the basis for evaluation for each of the possible communications link alternatives. The resulting recommendations are based on the premise that the technology already exists in the current NAS environment, is planned, or is technically feasible for the timeframe considered. The gap analysis identifies the communications system and or components that are not in the current NAS plan, but must be in place to support our recommended architecture. If the technology is targeted for 2007, it must be demonstrable by 2003.

The services discussed above have been consolidated into nine technical concepts each with distinct communications requirements. The nine technical concepts are listed below along with the related communications gap areas. The entries on the table below are as follows:

- "Required": indicates that the gap must be addressed to adequately meet the objectives of the associated technical concept
- "Useful": indicates that improvements in these areas are not required to meet the technical concept but are useful to achieve the service objective in an efficient manner.

In addition to these communications technology system and component gaps, we have identified several crosscutting issues that will impact data distribution in the NAS including common data definitions and interfaces for the NAS Wide Information System (NWIS), and information security.

Table 2.1-1. Communications Technology Gaps Related to NAS Service Technological Concepts

ID	Service Description	Technical Concept	Gap Areas and Solution Alternatives		
			A. Advanced Aircraft Information System	B. VHF Improvements	C. SATCOM
1	Aircraft continually receive Flight Information to enable common situational awareness	Flight Information Service	Required	Useful	Required
2	Aircraft continuously receive Traffic Information to enable common situational awareness	Traffic Information Service	Required	Useful	Required
3	Controller - Pilot voice communication	Controller-pilot communication (voice)	Useful	Useful	
4	Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	Controller-Pilot Data Link Communications (data)	Useful	Useful	
5	Aircraft exchange performance / preference data with ATC to optimize decision support	Decision Support	Useful	Useful	Useful
6	Aircraft continuously broadcast data on their position and intent to enable optimum maneuvering	ADS Reporting	Useful		
7	Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance	AOC	Useful		
8	Aircraft report airborne weather data to improve weather nowcasting/forecasting	Weather Reporting	Useful		
9	Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service	Passenger Service	Required		Required

2.2 Communications Technological Gaps

Analysis of the communications system gaps includes the identification of user needs that will not adequately be met. User needs, in this context, encompass the requirements of all NAS airspace users (ATC, aircrew, AOC and other service providers). In Task 1 and 2 of this RTO, user needs and functional communications requirements were collected from various FAA and industry documents. These requirements are contained in the User Requirements Database submitted as a Task 1, 2, 3 Deliverable. The user needs included in the gap summary below are representative of user requirements that will not adequately be met if action is not taken to fill the gaps detailed in this report. The solution candidates are summarized in this section and presented in greater detail in Task 11.

2.2.1 Aircraft Communications Network Gap

With more data being sent to the cockpit, an aircraft network similar to ground local area networks will be needed. Higher data rates, increasing exchanges between on-board processors, and the combined need for high reliability and ease of installation drive the need for an aircraft network. This section focuses on the need for development of the Advanced Aircraft Information System (AAIS) consisting of high speed network (Flight Deck/Cabin), airborne server, multifunctional displays, and intelligent router. This is considered a communications technology system gap because it is not addressed in the current NAS plan but is an integral part of the recommended AATT 2015 Architecture as well as the 2007 AATT and AWIN Architectures.

Fusion of data, use of common symbology, and other techniques are needed to support heads-up and situational awareness requirements for the pilot. With present technology, the integration and installation of displays in GA airplanes is expensive. New technologies that allow affordable installations in small cockpits are necessary.

User Needs Impacted:

- Graphical weather to the cockpit
- Common situational awareness
- Self separation
- Ability to display, in the cockpit, real-time weather and surrounding traffic
- Capability to support the use of graphical weather products and aeronautical information in accordance with the RTCA MOPS
- Data link control and display units integrated in the cockpit within, easy reach and forward field of view of the aircrew
- Data link message formatting function that ensures that the sender's message and intent is fully and accurately represented on the receiver's display.

Summary of Solution Candidates:

Advanced Aircraft Information System (AAIS)

AAIS will aid the exchange of information by providing a standard and uniform communication media for data transmission. Otherwise, numerous custom interfaces will be needed, adding to aircraft complexity and cost. The proposed solution candidates are discussed in further detail in Task 11.

- The aircraft avionics subsystems, including the communication components, should be networked using high-speed Commercial Off-the-Shelf (COTS) hardware and software.
- COTS technologies for high-speed digital data transfer applicable to terrestrial LANs should be adapted for use in the airborne environment.
- COTS technologies for multi-protocol routers applicable to terrestrial LANs should be adapted for use in the airborne environment.
- COTS technologies for servers applicable to terrestrial LANs should be adapted for use in the airborne environment.
- Development of low-cost displays for the following applications:
  - Airborne Collision Avoidance System (ACAS) symbology
  - Taxi symbology generated from data transmitted by airport ground traffic control
  - Heads-up symbology with uplinked taxi directions
  - Information fusion on pilot's tactical displays
  - Fusion of information (terrain, tower obstacles, and proximate aircraft) techniques applicable to commercial airplanes should be examined.
- Development of high quality voice synthesis technology should be pursued for CPDLC message applications.

2.2.2 VHF Communications Gaps

Increasing the capacity of the VHF band will support two-way services and will help ease the transition to higher data exchanges proposed for the satellite broadcast solution. Improvements in the antenna design, modulation schemes, compression techniques, voice over data and voice synthesis technologies will allow for more efficient transmission of data.

2.2.2.1 Directional VHF Antenna

Multiple VHF links are expected for future aircraft including combinations of 25 kHz DSB-AM voice, ACARS, VDL Mode 2, and VDL Mode 3. Installing multiple systems on large aircraft is difficult but usually manageable. Installation of multiple systems on small aircraft is more difficult due to the limited space available and may increase interference between systems. Reducing interference typically requires frequency separation, which consequently reduces the spectrum available for use.

2.2.2.2 Modulation

The optimum modulation for large FIS broadcast messages has not been condsidered. The D8PSK modulation scheme selected by ICAO for VDL Mode 2 and VDL Mode 3 was based on the existing 25 kHz spacing in the VHF band, relatively short messages, and two-way communications. Modulation schemes considered were Differential Eight-Phase Shift Keying (D8PSK), Eight-Level Frequency Modulation (8LFM), 4-ary Quadrature Amplitude Modulation (4QAM), and 16-ary QAM (16QAM). ICAO working paper AMCP/WG-C/5 summarized the modulation analysis as follows:

- 4QAM has insufficient throughput and was primarily considered to improve range and fading performance
- 16QAM is the most complex scheme and is significantly more costly than the others. It has a less certain performance at longer ranges and under fading conditions.
- 8LFM with a nonlinear transmitter that can provide more RF power on the channel and provides more margin than D8PSK
- D8PSK has greatly superior Adjacent Channel Interference (ACI) performance for digital modulation against digital (mode 2/ mode 3) and
- provides a channel data rate of 31.5 kb/s with a baud rate of 10.5 kbaud and three bits per symbol.

The detailed discussion indicated that 16QAM could yield a throughput of 37.8 kb/s for longer (1024 octet) messages based on a 25 kHz bandwidth. FIS and other services using large message sizes could benefit from the greater throughput.

If the VHF band and 25kHz constraints for FIS-B are changed, a more efficient modulation scheme may be possible and appropriate. Possible changes include: 1) Increase the 25 kHz bandwidth, 2) Assign FIS to another band besides VHF, 3) Revise the modulation analysis based on broadcast only transmission.

Virtual Network

The current spectrum allocation is not optimized for digital communication. As discussed in detail in Task 11, an automated channel assignment or virtual channel concept would allow more efficient use of the VHF spectrum. Instead of assigning frequencies on a sector basis, automatic message routing to aircraft would be done by the ground network, relieving the controller and pilot of frequent tuning and also optimizing the use of frequencies.

2.2.2.3 Compression

Compression has not been considered for all of the data types identified for aeronautical communications. As further discussed in Task 11, compression techniques can reduce the volume of data required for transmission, increasing the capacity of the data link. Compression is independent of the link and can be applied equally to the VHF band or the SATCOM band.

User Needs Impacted:

- Delivery of FIS
- Delivery of two-way ATC-Pilot communications.

Summary of Solution Candidates:

The following solution candidates are discussed in more detail in Task 11.

1. Efficient modulation schemes will allow more data over limited channel
2. Onboard processing could allow weather images to be reduced to aggregate measurements without the need to send the entire image. New compression schemes (Wavelet, Fractal, Principal Component Analysis (PCA) would increase the available bandwidth of current transmission links.
3. Automated channel assignment (roaming). Transparent change of frequency could optimize frequency layout.
4. Vocoder standards should be adopted to ensure global interoperability and high quality.
    - Compatibility of NEXCOM Vocoders with Commercial satellite service providers
    - Compatibility of NEXCOM Vocoders with current FAA ground infrastructure (Voice Switching Control System) VSCS
5. Development of directional VHF Antennas

2.2.3 Spectrum Availability for Increased Data Traffic

Ka-band satellite service offers increased link capacity of at least two orders of magnitude over the current and near term VHF data links (approximately 10Kbps now to at least 1 Mbps over Ka-Band). We believe commercial service providers will apply Ka-band technology to the cabin passenger services and this represents an opportunity for leveraging the technology for delivery of broadcast FIS and TIS data to all classes of aircraft. Eventually two-way satellite communication will support request reply applications. Satellite delivery of FIS and TIS data is not in the NAS 4.0 Architecture.

A major technology focus for generation-after-next broadband satellite communications services (deployed in the 2003-to-2010 timeframe) is on the need to provide more bandwidth, i.e., a focus on Ka-band (30/20 GHz) and the 50/40 GHz band.

The need exists for higher efficiency transmitters, more adaptive bandwidth versus power efficient modulation, forward error correction coding and much expanded use of the variable bit rate formats of dynamic multiplexing techniques such as Asynchronous Transfer Mode (ATM) based technologies.

User Needs Impacted:

The use of Ka-band technology requires improvements in antenna and receiver technology to support the wide range of aviation users and aircraft types. Interface standards must be determined.

Summary of Solution Candidates:

The following solution candidates are discussed in more detail in Task 11.

- Development of low cost, stabilized, steerable Ka-band antennas suitable for all aircraft
- Development of Ka-band transceivers suitable for aeromobile use
- Multimode Radio with Ka-band Interface
- SATCOM aeromobile Standards.

2.2.4 Traffic Information System Definition

The NAS architecture indicates that local vicinity traffic information will be gathered on the ground and provided to aircraft via a data link. The data link is not specified and the interface to the TIS is not defined. Communications requirements such as volume of data, data formats, data integrity, and domains for distribution (i.e. within TRACON, ARTCC, or sector) have not been defined. The timeliness of TIS information is estimated at 10 seconds from target aircraft location, through the ground processing and uplink to the receiving aircraft for display. Ground processing will be required to fuse the data from numerous sources and reduce the information transmitted to the aircraft.

User Needs Impacted:

- Pilot situational awareness of traffic
- Loss of pilot aid for locating other aircraft in VFR conditions
- Support for self-separation concepts.

Summary of Solution Candidates:

The following issues are discussed in more detail in Task 11:

The proposed solution for TIS is satellite broadcast. The information does not require acknowledgement, does not have low latency requirements, is constantly changing, and is needed by all users in the NAS. In the absence of a broadcast satellite link, VHF links may provide the service if the data can be constrained to the data rates of proposed links.

2.2.5 Cross-Cutting Technology Issues

Cross-cutting technology gaps are issues that are transmission media independent and that effect multiple service areas

2.2.5.1 NAS-Wide Information System Definition

Users have expressed the need for increased flexibility, along with operating efficiencies and increased levels of capacity and safety in order to meet the growing demand for air transportation. These needs are further characterized by: (1) removal of constraints and restrictions to flight operations, (2) better exchange of information and collaborative decision making among users and service providers, (3) more efficient management of airspace and airport resources, and (4) tools and models to aid air traffic service providers.

The ability to meet these needs will hinge on the development of a NAS-wide information system. The NAS-wide information system is a core technology that enables the access and exchange of information among all participating NAS users. The result is a virtual information base that provides common situational awareness to all users who choose to participate. This information base also provides the foundation for efficient collaboration among users.

The challenge in maintaining the information base is to keep the dynamic data current for all participating users so that optimum decisions can be made. From a communications architecture point of view, an optimum design can only be achieved through the development of a standardized communications interface, data set, and access protocols. Other considerations include data refresh rates and communications performance parameters. These decisions must be made in conjunction with accurate simulation of the NWIS concept in a representative environment

User Needs Impacted:

NWIS is not yet defined. The users needs, however, are centered around the efficient access and exchange of information among all participants. Failure to implement the NWIS will have an adverse impact on the ability to maintain an information base that supports the ability to make efficient decisions that ultimately affect the capacity of the NAS.

Summary of Solution Candidates:

The NAS-wide Information System is pivotal for meeting the capacity and safety needs of the aviation community. If provides the foundation for common situational awareness and enables collaborative decisions. It is also essential that an efficient interface is developed between NWIS and the CSA that incorporates common data definitions and standard protocols. These issues are discussed in more detail in Task 11.

2.2.5.2 Information Security

Current aeronautical voice and data services do not typically employ security techniques. ATC commands and AOC air/ground data are transmitted without encryption and can be received by anyone suitably equipped. The change to greater dependence on data makes ATC communications more vulnerable to security threats unless appropriate security measures are taken. AOC users are expected to employ security techniques to ensure reliable service and maintain company proprietary data.

User Needs Impacted

The items below include security-related functional communications requirements contained in the User Requirements Database:

- A Security Management Program shall be an integral part of the design, manufacture, test, installation, operation and maintenance of a data link system.
- The Security Management Program shall identify the means of containing the effects of security breaches internally and externally to the data link system, identify recovery actions and also identify mitigation procedures to prevent re-occurrence.
- A security policy shall be developed for data link systems.

- The data link system shall be protected against security violations in accordance with performance requirements as described in the service descriptions.
- The airborne and ground systems shall be able to detect security breaches and alert the users with appropriate data security warnings.
- Ground databases and recordings of data communications shall be protected against access by unauthorized persons.
- The system shall be secured from outside tampering.

Summary of Solution Candidates:

The following issues are discussed in more detail in Task 11:

Authentication, source validation, data privacy, and prevention of deliberate interference are issues that have become increasingly troublesome for all communications service providers. The Research and development in the information security area by commercial service providers and by EUROCONTROL should be conducted and appropriate measures developed for use in the NAS.

2.3 Summary of Gaps by Segment

The tables below list the gaps by ground, air and space segment and indicates whether the gap is a system or component level gap. This report (Task 10) is directly tied to the solution candidate and areas for research and development discussed in Task 11. It is also closely aligned with the transition discussions in Task 8.

Table 2.3-1. Communications Technology Gaps by Segment

Architecture Requirement	*Communications Technology Gap Areas*	System or Component	Segment		
2007/2015			Ground	Air	Space
2007	**Advanced Aircraft Information System**	New System Required			
	High Speed Network (Flight Deck/Cabin)	Improved Component		x	
	Server	Improved Component		x	
	Multifunctional Displays	Improved Component		x	
	Intelligent Router	Improved Component		x	
2007	**VHF Improvements**				
	Directional VHF Antennas	Improved Component		x	
	Modulation	Improved System	x		
	Virtual Network	Improved System	x		
	Compression	Improved Technology	x		
	Voice synthesis	Data Link	x		

Architecture Requirement	*Communications Technology Gap Areas*	System or Component	Segment		
2007/2015			Ground	Air	Space
2007	**SATCOM**	New System, Component and Datalink Required			
	Multi-mode Radio with Ka-band Interface	Improved Component		x	
	Development of efficient modulation techniques for Ka satellite bands	Improved Component		x	x
	Mobile Standards	Improved System			x
	Ka-band Receiver Improvements	Improved Component		x	
	Ka-band Antenna Improvements	Improved Component		x	
2015	**Traffic Information System**	New System Required			
	Com. Interface to TIS (standard data set, access protocol, user verification)	New System	x	x	

Table 2.3-2. Cross-Cutting Technology Issues

Architecture Requirement	*Cross-Cutting Technology Issues*	System or Component	Segment		
2007/2015			Ground	Air	Space
2015	**NAS-Wide Information System**	New System Required			
	Com. Interface to Distributed NAS Wide Database (standard data set, access protocol, user verification)	New System	x	x	
2007	**Information Security**	Improved Datalink Required			
	Authentication	New System	x	x	
	Data Validation	Improved System	x	x	
	Protection from Interference	Improved System	x	x	x

3 Acronyms

Term	*Meaning*
AAC	Airline Administrative Control
AATT	Advanced Air Transportation Technologies
AAIS	Advanced Aircraft Information System
AMSRS	Aeronautical Mobile Satellite (Route) Service
AOC	Airline Operational Control
ARINC	Aeronautical Radio Inc.
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
AWIN	Aviation Weather Information
BER	Bit Error Rate
COTS	Commercial Off-The-Shelf
EMC	Electromagnetic Capability
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration
FEC	Frame error check
FOQA	Flight Operational Quality Assurance
FMS	Flight Management System
FSS	Fixed Satellite Service
GA	General Aviation
GPS	Global Positioning System
G/T	Gain to System Noise Temperature Ratio
HF	High Frequency
IFE	In-Flight Entertainment
IFR	Instrument Flight Rules
IP	Internet Protocol
LAN	Local Area Network
MFD	Multifunctional Display
NAS	National Airspace System
PSK	Phase Shift Keying
QAM	Quadrature Modulation
QoS	Quality of Service
RF	Radio Frequency
SAIC	Science Applications International Corporation

SATCOM	Satellite Communications
SOW	Statement of Work
SSR	Secondary Surveillance Radar
VHF	Very High Frequency
WAN	Wide Area Network

Communications System Architecture Development

for

Air Traffic Management & Aviation Weather Information Dissemination

Research Task Order 24

Subtask 4.12, Identify Communications Components, Systems and Technologies for Research & Development

(Task 11.0)

Prepared By

ARINC
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Table of Contents

Table of Figures

Table of Tables

1. Introduction

1.1. Overview

This document presents the candidate technology solutions to fill the communications system and technology gaps identified in Task 10. This information is useful for future technology development and planning purposes.

1.2. Terms and Definitions

The following terms and definitions provide the framework for identifying and categorizing the gaps (Task 10) and candidate solutions (Task 11).

1.1.1 System Gaps

System gaps are concerned with the collection, processing, and distribution of information necessary for safe and efficient operations within the NAS. System gaps fall under one of the following categories defined below:

- New systems: An entirely new method of collecting, processing, and distributing data is required to meet the new requirements of the proposed 2015 Communications System Architecture.
- New or improved data link: The protocols and hardware necessary to distribute data through the network are inadequate for the expanded requirements and need improvement.
- Improved network: The protocols are adequate for the expanded requirements; however, the physical configuration (number and location of network nodes) can be improved to provide improved access, response time, and availability.

1.1.2 Component Technology Gaps

Component gaps are specified at the following level (applicable to air, ground, and space platforms):

- Radio Frequency (RF) Technology (receivers, transmitters, RF converters, etc.): The hardware that enables wireless transmissions between nodes in such a manner that it may be transmitted and received via antenna technology.
- Antenna Technology: The hardware by which a node in the network receives and transmits RF signals.
- Network/switching and routing technology: The software used to connect the various network nodes and ensure that information is properly routed to the correct destination.

1.3. Relationship to Other Tasks

Task 11 is based on the summary and conclusions drawn from the recommended AATT and AWIN Communications System Architectures (CSA). The purpose of the document is to present candidate solutions to the technological gaps identified in Task 10. Figure 1.3-1 shows the relationship of Task 11 to the other Advanced Air Transportation Technologies (AATT) TO24 Tasks.

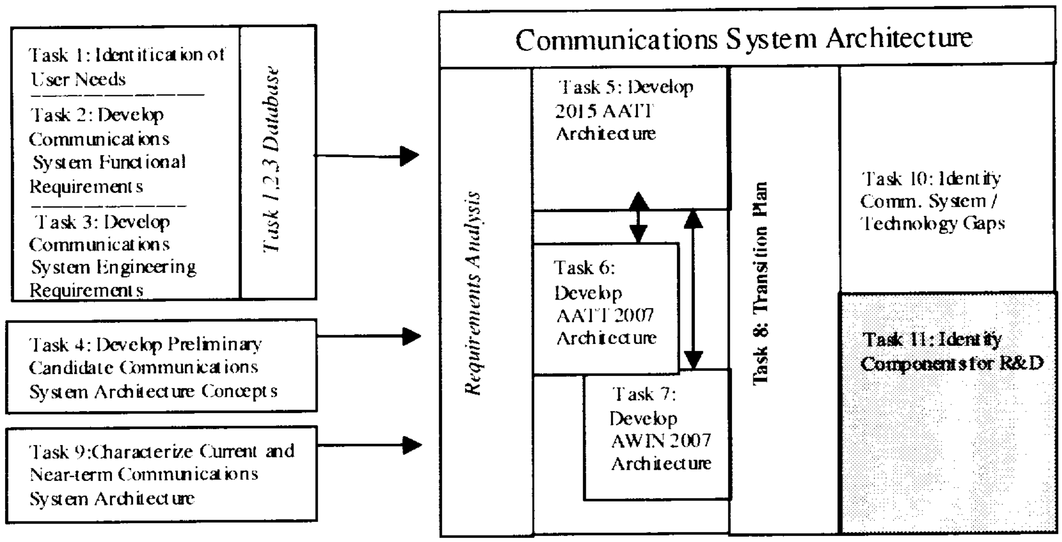

Figure 1.3-1. Relationship of Tasks

1.4. Summary Of Communications System and Technology Gaps

The shaded areas in Figure 1.4-1 below represent the communications system technology gap areas addressed in the Task 10 Report. The ground segment gaps include the interface to the NAS-Wide Information System (NWIS) and to commercial passenger services. It is believed that this is the area where standards for data, security and inter-network (ATN/Non-ATN) communications need further definition. In addition, the interface between commercial service providers and the FAA systems will require selection of numerous communications related standards and performance metrics. In the air segment (shown on the right of the chart) the avionics must support multiple communications links, high-speed data rates, and communications between various data communications processors and displays. In the space segment (indicated by the satellite icon), it is assumed that commercial service providers will have the satellites in place by 2007 to offer broadcast services to airspace users via Ka-band. The gap is in the availability of suitable antennas and receivers for all classes of aircraft that resolve the problems associated with rain attenuation, weight, flexibility and end-user cost.

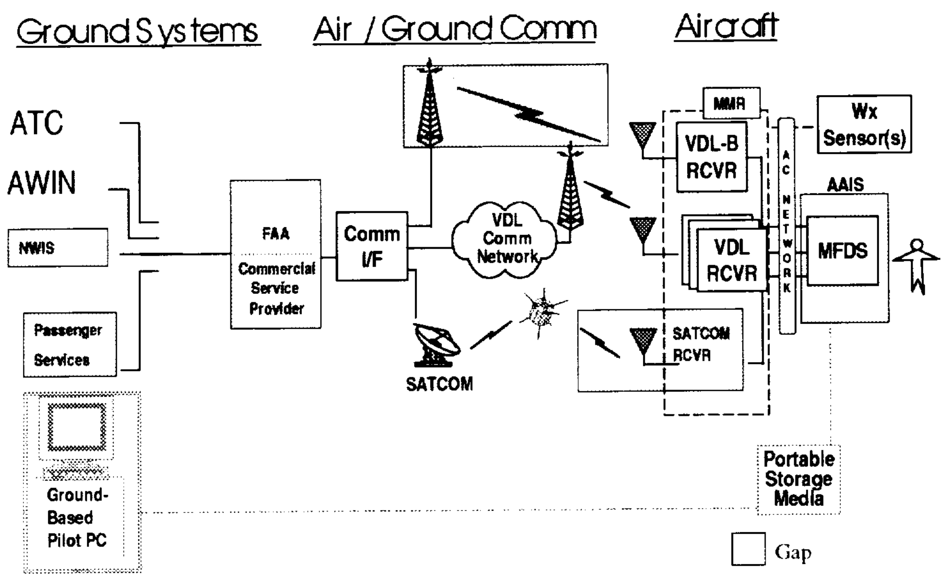

Figure 1.4-1. Communications Technology Gaps

An analysis of the recommended architecture revealed a number of gaps related to communications systems and components, which are summarized below. The potential solutions may include systems and components that are readily available (commercial off-the-shelf) as well as new systems and components that must be developed or adapted for use in the aeronautical environment. Task 10 focused on details related to the gaps. Task 11 focuses on the potential solutions and areas that require further research and development. It is with some reservation that we use the term "research" and offer the following qualifier:

> The communications technology discussed in this section is already in various stages of development or is commercially available with few exceptions. However, work must be done in all cases to adapt the technology to the various classes of aircraft and ensure that it meets the certification requirements imposed by the FAA at the appropriate level.

1.2 Summary of Gaps by Segment

The table below lists the gaps by ground, air and space segment and indicates whether the gap is a system or component level gap.

Table 1.2-1. **Communications Technology Gaps by Segment**

Architecture Requirement	*Communications Technology Gap Areas*	System or Component	Segment		
2007/2015			Ground	Air	Space
2007	**Advanced Aircraft Information System**	New System Required			
	High Speed Network (Flight Deck/Cabin)	Improved Component		x	
	Server	Improved Component		x	
	Multifunctional Displays	Improved Component		x	
	Intelligent Router	Improved Component		x	
2007	**VHF Improvements**				
	Directional VHF Antennas	Improved Component		x	
	Modulation	Improved System	x		
	Virtual Network	Improved System	x		
	Compression	Improved Technology	x		
	Voice synthesis	Data Link	x		
2007	**SATCOM**	New System, Component and Datalink Required			
	Multi-mode Radio with Ka-band Interface	Improved Component		x	
	Development of efficient modulation techniques for Ka satellite bands	Improved Component		x	x
	Mobile Standards	Improved System			x
	Ka-band Receiver Improvements	Improved Component		x	
	Ka-band Antenna Improvements	Improved Component		x	
2015	**Traffic Information System**	New System Required			
	Com. Interface to TIS (standard data set, access protocol, user verification)	New System	x	x	

Table 1.2-2. **Cross-Cutting Technology Issues**

Architecture Requirement	*Cross-Cutting Technology Issues*	System or Component	Segment		
2007/2015			Ground	Air	Space
2015	**NAS-Wide Information System**	New System Required			
	Com. Interface to Distributed NAS Wide Database (standard data set, access protocol, user verification)	New System	x	x	
2007	**Information Security**	Improved Datalink Required			
	Authentication	New System	x	x	
	Data Validation	Improved System	x	x	
	Protection from Interference	Improved System	x	x	x

2 Communications Solution Alternatives for Research & Development

2.1 Communications Technology Gap Areas

The Free Flight and Distributed Air/Ground Traffic Management, (DAG-TM) concepts are predicated on a common situational awareness among the air traffic controller, the pilot, and service providers such as air carrier dispatchers. Based on this common view of the situation, all users can negotiate on traffic management problems (such as hazardous weather, airport closures, equipment failures), and can exchange information such as observed weather, flight plan modifications, and deviations. The amount of data required to support the Free Flight and DAG concepts including graphical FIS and TIS products is expected to greatly increase the demands on the aircraft communications system and VHF spectrum. The following sections discuss the need for an Advanced Aircraft Information Systems (AAIS), VHF improvements and a satellite data link to accommodate future air/ground data distribution.

2.1.1 Advanced Aircraft Information System

With more data being sent to the cockpit, an aircraft network similar to ground local area networks will be needed. Higher data rates, increasing exchanges between on-board processors, and the combined need for high reliability and ease of installation drive the need for an aircraft network.

This section focuses on the need for development of the Advanced Aircraft Information System (AAIS) consisting of a high speed network (Flight Deck/Cabin), aircraft server, multifunctional displays, and intelligent router. This is considered a communications technology system gap because it is not addressed in the current NAS plan but is an integral part of the recommended AATT 2015 Architecture as well as the 2007 AATT and AWIN Architectures.

2.1.1.1 High Speed Network

This section discusses the need for an aircraft network similar to terrestrial LAN designs but suitable for aircraft environments. The current aircraft network is described for comparison.

Present aircraft flight deck communications are supported by a variety of audio and data link transceivers that operate in the Very High Frequency (VHF), High Frequency (HF), and Satellite Communications (SATCOM) (L-band) frequency. Historical functionality requirements placed the analog audio and the data link in the same units to minimize the number of on-board radios. Each radio is capable of either voice or data but typically is switched to only one mode. Figure 2.1-1 shows the configuration of current multiple radio installations for air carriers (Class 3 and 2). The wiring from the antenna to the Communications Management Unit (CMU) is independent for each radio. Radios are considered critical for flight operations and commercial airplanes have dual and triple redundancy.

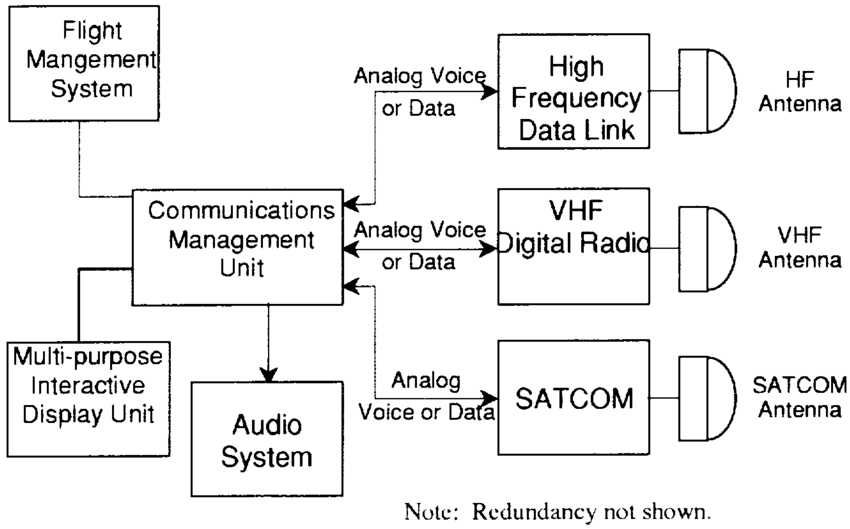

Figure 2.1-1. Present Configuration of Aircraft Communication Systems

In addition to distribution of information among on-board equipment, future aircraft cabin services such as In-Flight Entertainment (IFE), e-commerce, and Internet applications will require a flow of information to and from aircraft that will approach 10 Mbps during flight. Distribution within the aircraft will require a high speed bus or local area network (LAN). Existing terrestrial LANs achieve 100 Mbps, which would provide sufficient performance and growth potential for the proposed aircraft environment.

Aircraft networks will have additional requirements beyond those of terrestrial LANs. Aircraft installations require FAA certification including consideration of EMI, fire safety, redundancy, failure modes, security and maintenance. If the network carries ATC, AOC and passenger traffic, it will require information security, quality of service provisions and a priority scheme. Adaptation of existing commercial LANs will need to address these requirements.

Current technologies such as Fiber Distributed Data Interface (FDDI), are potentially applicable to the aircraft network requirements. FDDI is designed to handle synchronous data for voice and video, provides high capacity, is immune to EMI, has redundancy features, and is lightweight.

As previously stated, existing radios are operated in either a voice or data mode. In contrast, the future aircraft communications system will carry both voice and data over the same wiring as shown in Figure 2.1-2, Notional Block Diagram for 2015 Aeronautical Communication System (ACS) Integrating Data and Digitized Voice).

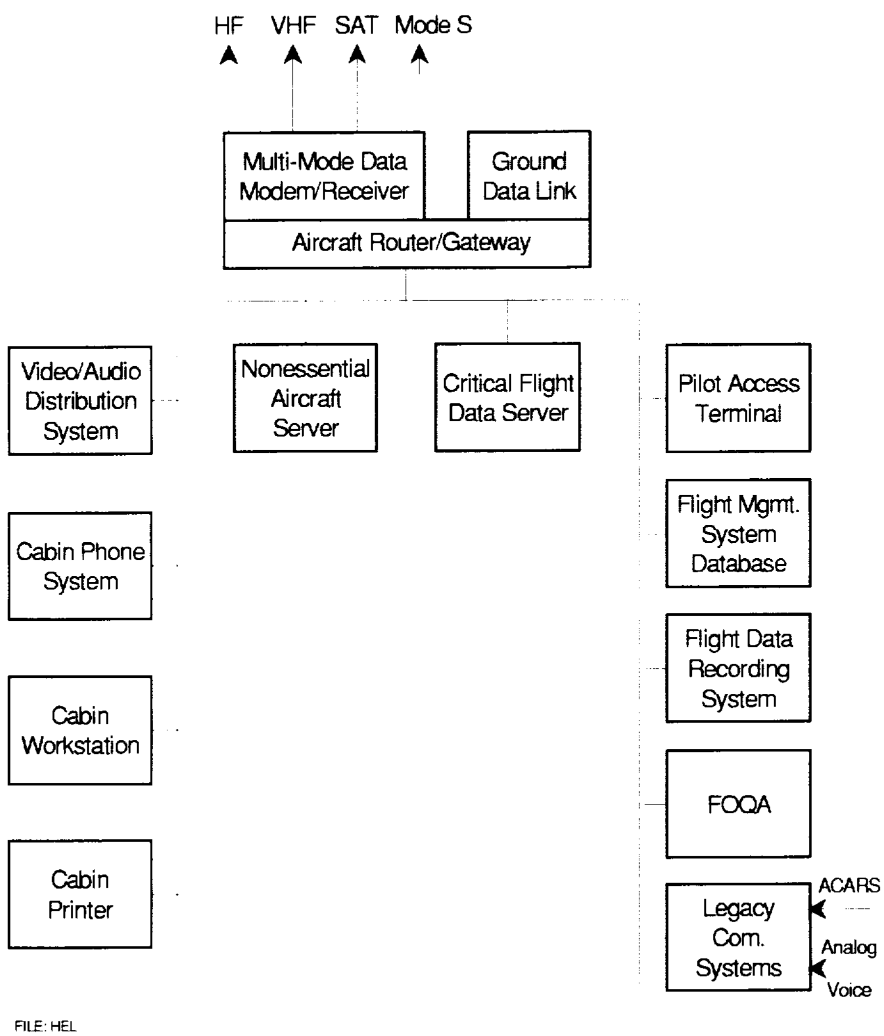

Figure 2.1-2. Notional Block Diagram for 2015 Aeronautical Communication System (ACS) Integrating Data and Digitized Voice

2.1.1.2 Aircraft Servers

In 2015, each aircraft will access the NAS-Wide Information System (NWIS) to determine the impact of changes on the flight. Information regarding current and predicted weather, traffic density, restrictions, and status of Special Use Airspace (SUA) will be available, through NWIS to all aviation service providers and airplane crews. The communications interface has not yet been determined.

The network architecture will require an aircraft server that takes advantage of shared media and can route all NWIS information. The architecture, operating system, major applications, and the NAS-wide database management needs of that server must be defined. Further, the server must be integrated into distributed architectures to support priority of critical traffic and meet availability and other performance criteria.

2.1.1.3 Multifunctional Displays

The volume of new information available to the pilot will require an effective means of presentation. Most studies and efforts have assumed a multifunction display will be used to present a wide variety of text and graphics. Suitable displays that are reliable and readable in the sunlight of a cockpit are currently high cost. An additional issue is the ability of the display to simultaneously support numerous applications from simple text messages to detailed weather graphics, other aircraft positions, navigation information and terrain. Generally, each application has developed its own display approach. The pilot needs fused applications and potentially symbolic representations in order to quickly understand and react to information. The approaches used for solving the display issues will drive requirements for the AAIS, including the network and server components.

Types of information for the pilot display are:

- Flight symbology graphics showing boundaries based on weather such as in Instrument Flight Rules (IFR), Instrumented Meteorological Rules (IMRs), or Marginal Visual Flight Rules (MVFRs)
- Heads-up display symbology with uplinked taxi information
- Fused display information about terrain, tower obstacles, and proximate aircraft
- Hazardous weather contours such as wind shear in terminal area, and icing, hail, turbulence and lightning areas
- Taxi instructions including active runways and airport layout

Display alternatives include the use of Liquid Crystal Diode (LCD) displays , synthesized voice and direct projection to the eye. LCDs may be useful for small aircraft with cost or size limitations. Military pilots have used helmet-mounted projection techniques to provide data to the pilot without obscuring the view. Commercial applications are also being developed for personal computer users. A projected view approach would assist GA pilots since it would not require heads-down and it should also be easier to fit into small aircraft.

Research is recommended to investigate display technologies for use in aircraft, identify the most suitable means of presenting information to the pilot and to address human factors issues associated with the presentation of information.

2.1.1.4 Intelligent Router

The ATN concept includes an aircraft router function that will allow the aircraft to communicate with a number of different ground applications such as CPDLC, ADS, and AOC. Research will be needed to define the router function and determine how to implement it with sufficient redundancy, security, and priority for the additional services such as FIS and TIS.

General specifications and the internal architecture for such a router should, if possible, correlate with high-speed routers supporting terrestrial internetworking (single board computer, configurable and modular). The router should also be able to manage multiple air/ground links employing policy-based routing to optimize the link selection for each message or condition such as out of range or radio failures. Furthermore, the router must handle all data in and out of the airplane, including telephony, video, audio, digitized voice, text and graphics.

One approach is a multiprotocol aircraft router, applicable to both the cockpit and the cabin that would enhance reliability and lower the cost. Protocols supported include legacy protocols such as Aircraft Communications Addressing and Reporting System (ACARS), the transition protocol of ACARS over Aviation VHF Link Communication (AVLC), commercial protocols such as TCP/IP, and ATN protocols such as TP4/CLNP.

There are three possible implementations to consider: 1) The protocols could exist in the same router. Current ATN implementations are using this approach for the "dual stack" of ATN and ACARS legacy protocols. 2) Multiple routers could be used, each dedicated to a separate protocol or stack but able to be reconfigured in the event of failure. 3) Gateway or conversion approaches could be used to change legacy protocols into ATN or future commercial protocols either in the ground network or within the aircraft system. Although the dual stack approach is being developed today, it may not offer the configuration flexibility and speed necessary for the expected traffic loads (see Task 5).

2.1.2 VHF Link Improvements

Certain measures should be taken to improve the VHF infrastructure proposed by the NAS 4.0 Architecture. These improvements include a new antenna design, new modulation and compression techniques, and improvement to components used for voice transmission.

2.1.2.1 Directional VHF Antenna

Multiple VHF links are expected for future aircraft including combinations of 25 kHz DSB-AM voice, 8.33 kHz DSB-AM voice, ACARS, VDL Mode 2, VDL Mode 3, and VDL Mode 4. Installing multiple systems on large aircraft is difficult but usually manageable. Installation of multiple systems on small aircraft is difficult due to the limited space available and the risk of interference between systems. Reducing interference typically requires frequency separation as well as physical separation. Frequency separation reduces the spectrum available for use.

VHF aircraft antennas are currently omni-directional, which are low-cost and allow simple installation. The power gain of directional antennas is not needed for the communication ranges (200 nm maximum) of aircraft. However, directional antennas provide increased protection from unwanted signals outside the pointing angle of the antenna. A directional VHF antenna may be useful for the VHF data link problem if it is low cost and reliable. Electrically steerable antennas have been designed for other bands and services and the technology may be transferable to aviation. A combination of antennas or a switchable configuration of the antenna from omni to directional could allow initial operation in an omni mode to find a station, then switch to the directional mode once the station is located.

2.1.2.2 Modulation

The D8PSK modulation scheme selected by ICAO for VDL Mode 2 and VDL Mode 3 was based on the existing 25 kHz spacing in the VHF band, relatively short messages, and two-way communications. Modulation schemes considered were Differential Eight-Phase Shift Keying (D8PSK), Eight-Level Frequency Modulation (8LFM), 4-ary Quadrature Amplitude Modulation (4QAM), and 16-ary QAM (16QAM). ICAO working paper, AMCP/WG-C/5 summarized the modulation analysis as follows:

- 4QAM has insufficient throughput and was primarily considered to improve range and fading performance.

- 16QAM is the most complex scheme and is significantly more costly than the others. It has less certain performance at longer ranges and under fading conditions.
- 8LFM has a nonlinear transmitter that can provide more RF power on the channel and provides more margin than D8PSK.
- D8PSK has greatly superior adjacent channel interference performance for digital modulation against digital modulation (Mode 2, Mode 3, or combinations)
- D8PSK provides a channel data rate of 31.5 kb/s with a baud rate of 10.5 kbaud and three bits per symbol.

The detailed discussion in the ICAO paper indicated that 16QAM could yield a throughput of 37.8 kb/s for longer (1024 octet) messages based on a 25 kHz bandwidth. FIS and other services using large message sizes could benefit from the greater throughput. However, the Adjacent Channel Interference (ACI) would be a significant factor if a weather service is proposed in the aeronautical VHF band.

If the original assumptions and constraints for FIS-B are changed, a more efficient modulation scheme may be possible and more appropriate. Possible changes include: 1) Increase the 25 kHz bandwidth, 2) Assign FIS to another band, 3) Revise the modulation analysis based on broadcast only transmission.

2.1.2.3 Virtual Network

Current frequency allocation practices are based on analog voice radio techniques and assign a single frequency to each ATC control sector on a non-interference basis. With the advent of digital communications such as VDL Mode 3, more efficient frequency usage is possible. Figure 2.1-3 Frequency Usage, illustrates the transition from existing analog assignments to future VDL Mode 3 assignments. VDL Mode 3 will provide more virtual channels and enable growth or additional services.

A new national frequency assignment strategy that maximizes the capability of Mode 3 should be developed. The application of virtual network approaches used in systems such as cellular telephone, which maintains the connection as the vehicle moves through the various frequency service areas should be considered. The virtual network approach could be applied to shared services such as FIS but can not be applied to controller services such as CPDLC without changing the one frequency/one sector/one controller criteria.

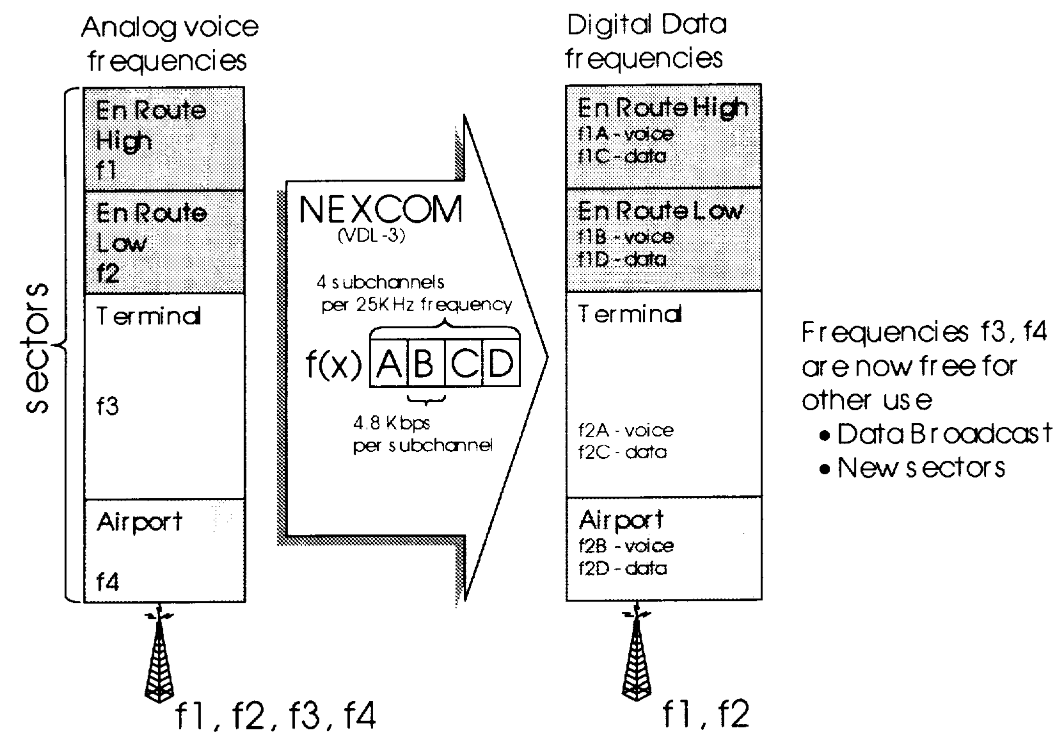

Figure 2.1-3. Frequency Usage - Analog to VDL-3

2.1.2.4 Compression

Compression techniques were envisioned for some of the air-ground information transmission in this study. Highly critical information such as navigation, surveillance, and air traffic control commands can not typically be compressed to a significant degree. Graphic products such as TIS and FIS can be compressed, perhaps as high as 100:1 depending on the resolution needed for the product. Compression of the information is desirable in order to reduce the bandwidth required.

A related approach to saving bandwidth is to minimize data at the application layer by text or symbol compression; example being the use of predefined messages in CPDLC. Instead of sending the text characters, each message is represented by a number with associated fields for variable information such as altitude, speed, and heading. Since the set of ATC messages has been refined over the years, a standardized set can be used to represent the most common messages. Free text formats are available for unusual situations. Weather products may also lend themselves to reduction at the application layer. It may not be necessary to send a large weather graphic to the aircraft - a symbolic representation may be sufficient. Optimizing applications has significant benefits to the data link including reducing the bandwidth requirement and allowing checksum and reasonableness checks (certain values should never occur for a given field).

Research and analysis is needed to determine how much is acceptable, which information or products can be compressed, and how the pilot will cope with missing or incomplete information that may be lost by combinations of compression, interference, and/or outages.

2.1.2.5 Voice Synthesis

Pilots of Class 3 aircraft are familiar with data link because they have been using it for a number of years. In two-pilot cockpits, data link messages are frequently handled by the non-flying pilot to avoid "heads-down" by the primary pilot. GA (Class 1 aircraft) are typically single pilot and they have expressed concern that it will be difficult for a pilot to use data link because of the heads-down issue. A voice synthesis capability on the aircraft would allow pilots to listen to their data messages rather than having to read them. Voice synthesis has been used for Digital-ATIS messages and is well established outside of aeronautical communications. It could be applied to CPDLC messages and any current text message including current weather text messages.

Although voice synthesis is not a new technology, applying it to the cockpit will require additional effort. A large number of voice synthesis products exist and all products may not be acceptable for conversion of ATC and weather information. Research should be conducted to apply voice synthesis technology to the cockpit and to develop acceptability standards to support testing and certification of products both for the aircraft and for associated ground based systems.

2.1.3 SATCOM

The use of Ka-band satellite is suggested for broadcast FIS and TIS data distribution. This section describes the required research associated with the use of Ka-band Satellite including multi-mode radio with Ka-band interface, modulation techniques, mobile standards, receiver improvements, and antenna improvements.

2.1.3.1 Multi-mode Radio with Ka-band Interface

Current air/ground radio designs are based on multi-mode radios that can provide AM, VDL Mode 2 and VDL Mode 3 modulations. The multi-mode approach lowers the number of total radios required on the aircraft, eases the transition problems of establishing the new modulations, and enables aircraft to operate in numerous geographic regions without changing equipage. A Ka-band interface to the existing multi-mode radios would be desirable to permit satellite communication to be integrated with other radio operations.

2.1.3.2 Modulation Techniques

Communications links at the frequencies in the Ka-band are degraded by rain and blocked by obstacles in the line-of-sight. Attenuation caused by oxygen and water vapor in the Ka-band is in the neighborhood of 0.1 dB/km to 0.2 dB/km. A study in 1993 by the NASA ACTS Program shows that typical rain attenuation in the Ka-band is in the neighborhood of 7 dB. To mitigate this severe attenuation during rain, several approaches such as alternate path to avoid rain and coding have been proposed. Viterbi coding can improve the satellite link margin; using PSK modulation with the rate 1/3 and 1/2 Viterbi decoders (Clark, G. and Cain, J., "Error-Correction Coding for Digital Communications," Plenum, 1988) and an error rate of 10-5 with constraint length of 7, one can expect a processing gain of 7 dB. Since the data were taken using fixed stations, further analysis and research is recommended to establish the effectiveness in flight situations.

Higher efficiency modulation techniques of 8-PSK and QAM appear appropriate to Ka-band satellite applications. To optimize satellite power and bandwidth utilization, 8-PSK or 16-QAM modulation together with a Turbo code can be used. As compared to QPSK or BPSK (the two most used digital modulations in satellite communications) 8-PSK uses two-thirds of the bandwidth required by QPSK and only one-third of the bandwidth required by BPSK. The use of Turbo codes is a new forward error correction (FEC) technology that also offers significant improvement over common conventional convolutional FEC techniques. It is recommended that their performance be evaluated based on the proposed aeronautical data and high to low speed platforms.

2.1.3.3 Mobile Standards

We have recommended the Ka-band primarily because of its relative availability of radio spectrum. Lower bands are technically feasible but are already crowded with existing users and applications. Use of satellite communications links requires the demonstration of aeronautical mobile technologies for antenna, receivers, link algorithms, protocols, and standards. In addition, satellite usage for Ka-band requires a number of political and economic initiatives. Satellite spectrum is internationally allocated. If a dedicated aeronautical band is required, the frequency will have to be proposed and accepted in a process that traditionally requires many years. If the proposed "industry partnership" approach is followed, a near term satellite allocation could be used. This approach would not provide the frequency protection of existing aeronautical bands and additional consideration should be given to priority schemes, procedures to mitigate failure or blockage of signals, and redundancy.

As previously mentioned, the Ka-band is attenuated by rain, water vapor and oxygen at certain frequencies. Coding methods provide additional gain that can offset rain attenuation. Satellite diversity may also be applicable if the space segment includes multiple satellites. LEO, MEO and HEO constellations and combination of LEO/MEO/GEO/HEO constellations could provide diversity to the aircraft. GEO constellations might provide diversity if multiple satellites are in view since each satellite signal would pass through different amounts of atmospheric attenuation.

It is recommended that the potential of LEO, MEO, HEO and GEO constellations to provide communications diversity to aircraft in order to overcome rain attenuation effects be studied.

2.1.3.4 Receiver Improvements

Existing Ka-band receivers are made for high bandwidth, fixed or broadcast services. None are currently intended for mobile service. An aircraft receiver should be lightweight, low cost, and must work with the antenna, and modulation scheme to provide operation throughout the dynamic maneuvers of the aircraft. A receive-only radio can be less expensive than a radio with transmitting capability. Achieving low cost for the user may require a tradeoff in performance between the bandwidth and modulation scheme. Modulation schemes with lower throughput may be used to increase range, decrease fading, reduce interference, lower antenna cost, or to adapt to dynamic performance. Research should be conducted to develop an effective design for a low cost aircraft receiver that addresses all of the mobile factors.

2.1.3.5 Ka-band Antenna Improvements

The requisite future aircraft antenna must be a high-performance subsystem that maximizes gain while minimizing system temperature. Such an antenna must be capable of electronically tracking the satellite with a pointing error of less than 0.25°, while permitting a small profile of less than 20 centimeters (8 inches) to minimize its impact on the airplane aerodynamics. The required aircraft antenna system must contain a two-way (receiving and transmitting) antenna, low-noise amplifier, down/up converter, high-power amplifier, diplexer, and associated RF cables and aircraft wiring.

The antenna system must fit into a radome installed on the aircraft fuselage no higher than 15 centimeters (6 inches). The antenna system figure of merit gain to system voice temperature (G/T) must be better than 10 dB/K. The frequencies that allow such high performance from small antennas are in the Ku band and above (Ku, Ka, Q, and V bands). The antenna would require high directivity supported by an electronic steering system (based on aircraft position and attitude and RF reception maxima) that orients the antenna toward the satellite to optimize reception. The antenna system half power beam-width must be below 5 degrees in both directions to minimize interference and comply with Federal Communications Commission (FCC) regulations. Research is required to develop antennas that meet these characteristics for all classes of aircraft.

2.1.4 TIS Interface

Pilots are currently limited in their ability to perceive other aircraft. Even in clear weather, aircraft speeds limit the time available for pilots to detect and recognize an aircraft and determining relative speed, direction and altitude is difficult. Aircraft frequently encounter each other without prior warning in uncontrolled airspace and weather conditions and darkness can increase the difficulty. The TIS service will provide traffic information processed on the ground to the aircraft for display to the pilot. A graphical format on a multi-function display is the most common display approach although other methods have been postulated.

The proposed Ka-band data link appears to be an appropriate medium for distributing the TIS data to all users of the NAS. Known performance requirements are within the ability of a satellite. TIS data could be combined in the uplink feed with FIS and NWIS data.

It is recommended that standards, protocols, and some performance characteristics be defined for a TIS communications interface and satellite distribution approach.

2.2 Cross Cutting Technology Gaps

In Task 10, certain gaps have been identified that affect the communication system architecture but are independent of communication media or apply to more than one service. Because these gaps cut across multiple services, they are discussed separately below.

2.2.1 Communications Interface to NAS-Wide Information System (NWIS)

The NAS-wide information system is not yet defined but in all probability can be thought of as a collection of information sources that — logically combined — form the information base of static and dynamic data of the NAS (see Figure 2.2-1). This is the data that feeds the FIS and TIS technical concepts that are a part of our CSA. The challenge faced by the CSA in interfacing with a distributed information source such as the NWIS is one of access to all the necessary data required.

From a CSA point of view, a NWIS logical mapping of data locations will be required in order to be able to collect and disseminate broadcast data. This could be similar to the domain name server approach used on the Internet today.

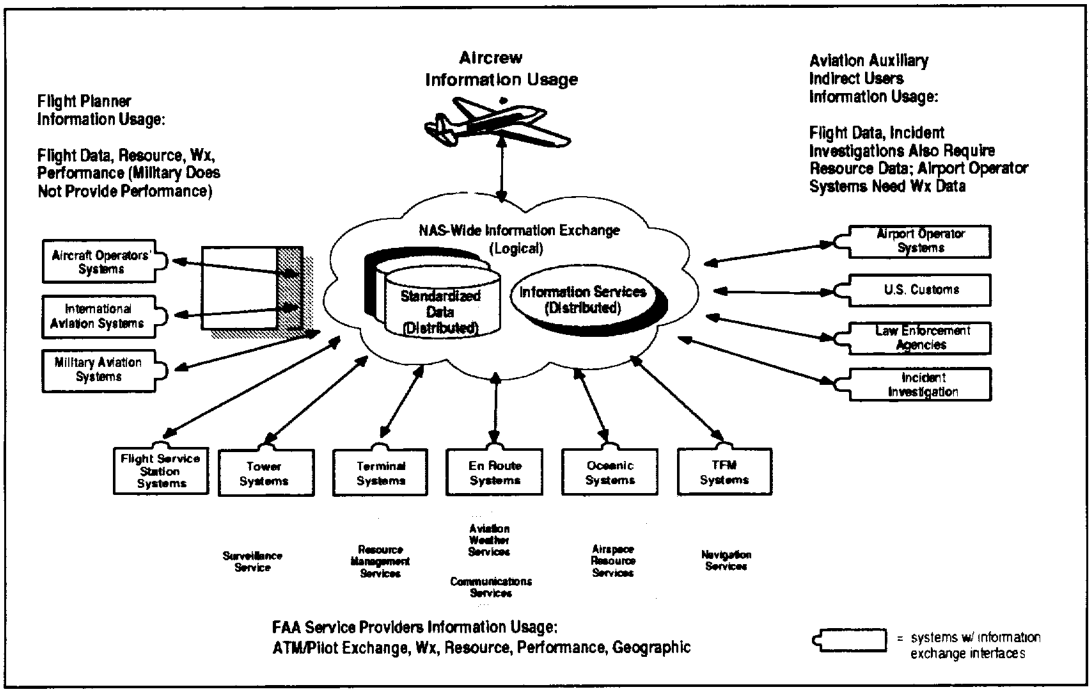

Figure 2.2-1. NAS-Wide Information System[1]

The wide variety of data exchanged via the NWIS will need a consistent set of standards such as data field formats, time stamping, integrity checking, updating, security classification, and compression categorization. The data standards will impact the communications requirements of latency, capacity, integrity, availability and information security.

Research is recommended to define the implementation of the NWIS and how it interfaces with the elements of the communications system recommended by this task order.

2.2.2 Information Security

Information security is considered as a cross-cutting system gap.

ICAO is studying aspects of security and has reached agreement on the following approach for the ATN (See Figure 2.2-2 ATN Security Approaches). ATN security services are provided at the application layer for both the air-ground data link and ground-ground ATC Message Handling Services. This provides integrity protection of ATN message contents. Security services are required at the network level for Inter-domain (between countries) IDRP messages that are transmitted between routers on each side of the domain boundary. Security services are optional (i.e. a local issue) at the network level for Intra-domain (within a country) and IS-IS protocol messages. Security services are optional (i.e. a local issue) at the network level for ES-IS protocol message connections.

[1] NAS Architecture Version 4.0, Figure 19-2.

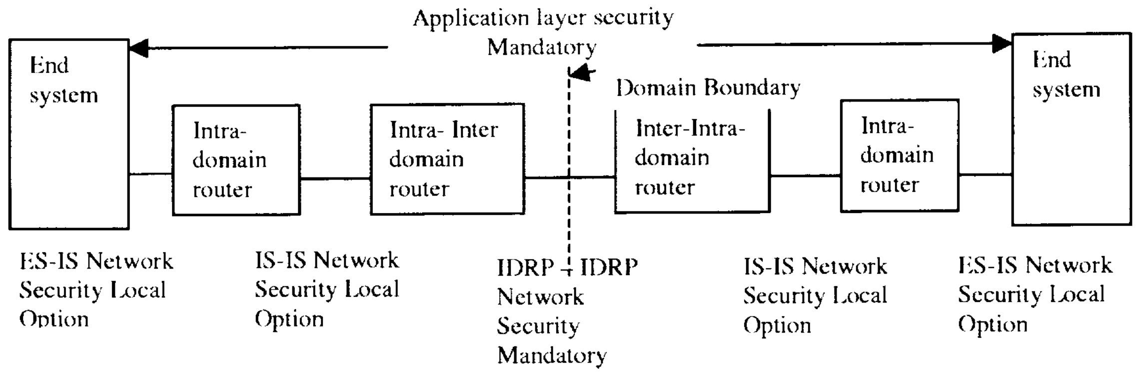

Figure 2.2-2. ATN Security Approaches

We recommend that NASA actively participate with ICAO and the industry to establish ATN security requirements and standards in the areas discussed below.

2.2.2.1 Authentication

A key concern for air traffic control applications such as CPDLC is the assurance that control messages are from a legitimate source (i.e. - controllers). In information security terms, this function is termed authentication and is based on secure means of identifying the sender of a message. ICAO is defining an authentication approach for ATN applications. Authentication adds processing delay and overhead to messages that will need to be considered in the traffic loading and analysis of future links. Authentication for non-ATN systems will require definition if commercial technologies are applied and proposed for air traffic services.

2.2.2.2 Data validation

In this context, data validation is the ability of the user to receive data that is correct and uncorrupted. Data validation would prevent the changing of data by a third party. This is distinct from the integrity of the data which refers to the error correction and message assurance capabilities of the protocols. The reliance on a wide variety of data from NWIS and other sources increases the need for a data validation approach, which is not currently being studied.

2.2.2.3 Deliberate Interference/Sabotage

A number of means exist to cause interference to the communications systems and to deliberately sabotage them. For all radio frequency (RF) links, deliberate and accidental interference is possible. The aeronautical frequency bands such as VHF are allocated on a non-interference or protected basis. If someone causes interference, the damage is usually localized to a single station and frequency and actions are taken to eliminate the interference. Commercial systems outside the aeronautical protected bands such as the proposed Ka-band, may be allocated on a shared basis which increases the potential for accidental interference. As the aircraft fleet is increasingly dependent on the data provided by TIS, FIS and other ATS applications, interference could cause major traffic disruption.

Deliberate interference can be caused at both the RF link and on the ground network. Deliberate interference or jamming, is similar to the accidental interference described above but is more difficult to determine and resolve since the perpetrator must be forced to cease interference.

Ground networks are becoming more vulnerable to deliberate attack as widely used protocols such as Internet Protocol (IP) are used. IP is vulnerable to denial of service attacks.

The mixture of air traffic control and commercial technologies and services proposed for the 2007 time frame require a means to protect the communications links and data sources from deliberate and accidental attacks. Procedures to maintain safe air traffic operations in the event of service interruption are required.

For data links, security is needed at both the application layer and network layer. Firewall software developed for terrestrial networks may be applicable to airborne environments.

3 Acronyms

Term	*Meaning*
AAC	Airline Administrative Control
AATT	Advanced Air Transportation Technologies
AAIS	Advanced Aircraft Information System
AMSRS	Aeronautical Mobile Satellite (Route) Service
AOC	Airline Operational Control
ARINC	Aeronautical Radio Inc.
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
AWIN	Aviation Weather Information
BER	Bit Error Rate
COTS	Commercial Off-The-Shelf
EMC	Electromagnetic Capability
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration
FEC	Frame error check
FOQA	Flight Operational Quality Assurance
FMS	Flight Management System
FSS	Fixed Satellite Service
GA	General Aviation
GPS	Global Positioning System
G/T	Gain to System Noise Temperature Ratio
HF	High Frequency
IFE	In-Flight Entertainment
IFR	Instrument Flight Rules
IP	Internet Protocol
LAN	Local Area Network
MFD	Multifunctional Display
NAS	National Airspace System
PSK	Phase Shift Keying
QAM	Quadrature Modulation
QoS	Quality of Service
RF	Radio Frequency
SAIC	Science Applications International Corporation

SATCOM	Satellite Communications
SOW	Statement of Work
SSR	Secondary Surveillance Radar
VHF	Very High Frequency
WAN	Wide Area Network

A/A	Air to Air
A/G	Air to Ground
AAC	Airlines administrative communications
AAIS	Advanced Aircraft Information System
AATT	Advanced Air Transportation Technologies
ACARS	aircraft communications addressing and reporting system
ADAS	AWOS data acquisition system
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance - Broadcast
AFSS	automated flight service station
AIM	Aeronautical Information Manual
AIRMET	Airman's Information Manual
AM	amplitude modulation
AMS	acquisition management system
AMS(R)S	Aeronautical Mobile Satellite (Route) Service
AMSRS	Aeronautical Mobile Satellite (Route) Service
AMSS	Aeronautical Mobile Satellite System
AOC	airline operations center
ARINC	Aeronautical Radio Inc.
ARTCC	Air route traffic control center
ASIST	Aeronautics Safety Investment Strategy Team
ASOS	automated surface observing system
ASR-9	airport surveillance radar- nine
ASR-WSP	airport surveillance radar- weather system processor
ATC	Air Traffic Control
ATC DSS	Air Traffic Control Decision Support Systems
ATCSCC	Air traffic Control System Command Center
ATCT	Air Traffic Control Tower
ATIS	Automatic Terminal Information Service
ATM	air traffic management
ATN	Aeronautical Telecommunication Network
ATS	air traffic services
ATSP	air traffic service provider
AvSP	Aviation Safety Program
AWIN	Aviation Weather Information Services
AWIN	Aviation Weather Information
AWOS	automated weather observing system
BER	bit error rate
BER	Bit Error Rate
CD	compact disk
CDM	Collaborative Decision Making
CDMA	Code Division Multple Access
CDTI	Cockpit Display of Traffic Information
CNS	Communications, Navigation and Surveillance
CONOPS	concept of operations
CONUS	Continental United States
COTS	Commericial Off-The-Shelf
CP	conflict probe
CPDLC	Controller-Pilot Data Link Communications System

CPU	central processing unit
CSA	communications system architecture
CSMA	Carrier Sense Multiple Access
CTAS	Center-TRACON Automation system
CWA	Center Weather Advisory
D8PSK	Differential Eight-Level Phase Shift Keying
DA	descent advisor
DAG-TM	Distributed Air/Ground Traffic Management
DoD	Department of Defense
DOT	Department of Transportation
DOTS	dynamic ocean tracking system
DSR	Display System Replacement
EMC	Electromagnetic Capability
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FANS 1/A	future air navigation system
FAR	Federal Air Regulations
FAR	Federal Aviation Regulation
FBO	Fixed Base Operator
FBWTG	FAA bulk weather telecommunications gateway
FCC	Federal Communications Commission
FDM	flight data management
FDP	flight data processor
FEC	Frame error check
FEDSIM	Federal Systems Integration and Management Center
FFP1	Free Flight Phase 1
FIS	Flight Information Service
FL	flight level
FMS	Flight Management System
FOQA	Flight Operational Quality Assurance
FP	flight plan
FSS	flight service station
FSS	Fixed Satellite Service
G/G	Ground-to-Ground
G/T	Gain to System Noise Temperature Ratio
GA	General Aviation
GEO	Geostationary Earth Orbit
GPS	Global Positioning System
HARS	high altitude route system
HF	high frequency
HF	High Frequency
ICAO	International Civil Aviation Organization
IF	interface
IFE	In-Flight Entertainment
IFR	Instrument flight rules
IFR	Instrument Flight Rules
IMC	instrument meteorological conditions
IOC	initial operating capability

IP	Internet Protocol
ITWS	Integrated terminal weather system
IWF	Integrated Weather Forecast
KBPS	Kilobites Per Second
LAN	Local Area Network
LEO	Low Earth Orbit
LLWAS	Low-level wind shear alert system
MBO	Military Base Operations
MDCRS	Meteorological Data Collection and Reporting System
MEO	Medium Earth Orbit
METAR	meteorological aviation report
MFD	Multifunctional Display
MOC	Mission Operational Control
MOPS	minimum operational performance standards
MSS	Mobile Satellite Service
MTBF	Mean Time Between Failure
N/A	Not Applicable
NAS	National Airspace System
NAS RD	NAS Requirements Document
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NAWIS	National Aeronautics and Space Administration
NESDIS	national environmental satellite, data, and information service
NEXCOM	Next Generation A/G Communications System
NEXRAD	next generation radar
NLDN	national lightning detection network
NOTAM	Notice to Airman
NWS	National Weather Service
NWS/OSO	National Weather Service/Office of Systems Operations
OASIS	operational and supportability implementation system
OAT	Office of Advanced Technology
ODAPS	oceanic display and planning system
PFAST	passive final approach spacing tool
PIREP	Pilots Report
PIREPS	pilot reports
PSK	Phase Shift Keying
QAM	Quadrature Modulation
QoS	Quality of Service
RA	resolution advisory
RCP	Required Communications Performance
RD	requirements document
RF	Radio Frequency
RTCA	RTCA, Incorporated
RTO	Research Task Order
RVR	runway visual range
SAIC	Science Applications International Corporation
SAR	Search and Rescue
SARP	Standards and Recommended Practices
SATCOM	Satellite Communications

SIGMET	Significant Meteorological Information
SOW	Statement of Work
SPECI	Special Weather Report
SSR	Secondary Surveillance Radar
STC	supplemental type certificate
SUA	Special Use Air Space
TAF	Terminal Aerodrome Forecast
TBD	to be determined
TDWR	terminal Doppler weather radar
TFM	traffic flow management
TIS	Traffic Information Services
TM	traffic management
TMS	traffic management system
TRACON	Terminal Radar Approach Control Facility
TRM	Technical Reference Model
TWDL	Two-Way Data Link
TWEB	Transcribed Weather Broadcast
TWIP	terminal weather information for pilots
VDL	very high frequency digital link
VFR	visual flight rules
VHF	very high frequency
VOR	VHF-Omni Directional Range
WAAS	Wide Area Augmentation System
WAN	Wide Area Network
WARP	weather and radar processor
WJHTC	William J. Hughes Technical Center
WMSCR	weather message switching center replacement
Wx	Weather
WxAP	weather accident prevention

Communications System Architecture Development For Air Traffic Management & Aviation Weather Information Dissemination

Research Task Order 24

Subtask 4.2, Identify of User Needs
Subtask 4.3, Communications System Functional Requirements
Subtask 4.4, Communications System Engineering Requirements

(Tasks 1, 2, 3)

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Table of Contents

Table of Figures

1 Introduction

The first three subtasks of RTO 24 are concerned with the collection and cataloging of user needs, functional system requirements, and engineering system requirements. The objective of Task 1 is to develop a comprehensive list of user needs derived from industry and government documentation. Task 2 is concerned with the creation of a comprehensive list of functional system requirements while Task 3 is focused on the generation of a complete list of system engineering requirements.

A relational database was created to serve as a repository for Tasks 1, 2 and 3 data. Each record in the list of requirements generated for these tasks has associated with it, a source document (shown in Attachment 3) as well as one or more functional capabilities (shown in Attachment 1) allowing for comparison and traceability between the user needs, functional requirements, and system requirements. Without the use of the functional capability and the source document, the ability to establish any sort of traceablity would be lost as the two types of requirements and the user needs are not directly related to each other. Instead, they are applicable to general activities in the NAS. These activities are captured in the list of functional requirements and, as a result, provide a means of comparison.

The lists resulting from the three tasks provide a large amount of information, but, as so many records exist for each of the three tasks, a reader would find it difficult to find specific information and, therefore, derive any real value from the work performed. To manage the output of the first three tasks and to create an index of records from which a user may quickly access any information necessary, the lists were incorporated into a relational database tool. This allows a user to create queries for specific information, and it creates a framework for any additional information that may be included in the future. The Task 1,2, and 3 database also has in it user forms which allow a user with no working knowledge of databases, to access specific information. From these forms, a user may query any number of fields and will receive information in an easy to understand format.

This document explains the outputs of Tasks 1, 2, and 3 in the context of the database displays. Field definitions are given, and user display screens are shown to ensure the reader is given the necessary information in context.

2 Identification of User Needs

The first subtask of TO 24 involved the collection of user needs from industry accepted documentation pertaining to ATM and AWIN data communications in the present, 2007, and 2015 state.

2.1 Task 1 Approach

The user needs presented for delivery were pulled from the source documentation required by NASA as well as from a collection of other document (shown in the appendices) to ensure adequate coverage of the diverse viewpoints of aviation's participants and leaders. The needs were then put into the database and were categorized by a number of parameters which allow for user defined sorts. Of particular importance are the functional capability, the ATM, and the AWIN parameters. The functional capability assignment of a user need allows it to be compared to the system engineering requirements, specific message characteristics, and link analyses carried out in later tasks, thereby allowing for a unified effort over the course of the entire task order. The ATM and AWIN fields provide the ability to sort the needs into those that are concerned with weather, air traffic management, or both. When using these three parameters as well as the others provided and discussed in more depth below, the database provides the ability to quickly reference multiple data sources for user needs relating to specific criteria.

2.2 User Needs Captured in the Database

The user needs view screen is shown below with field definitions following.

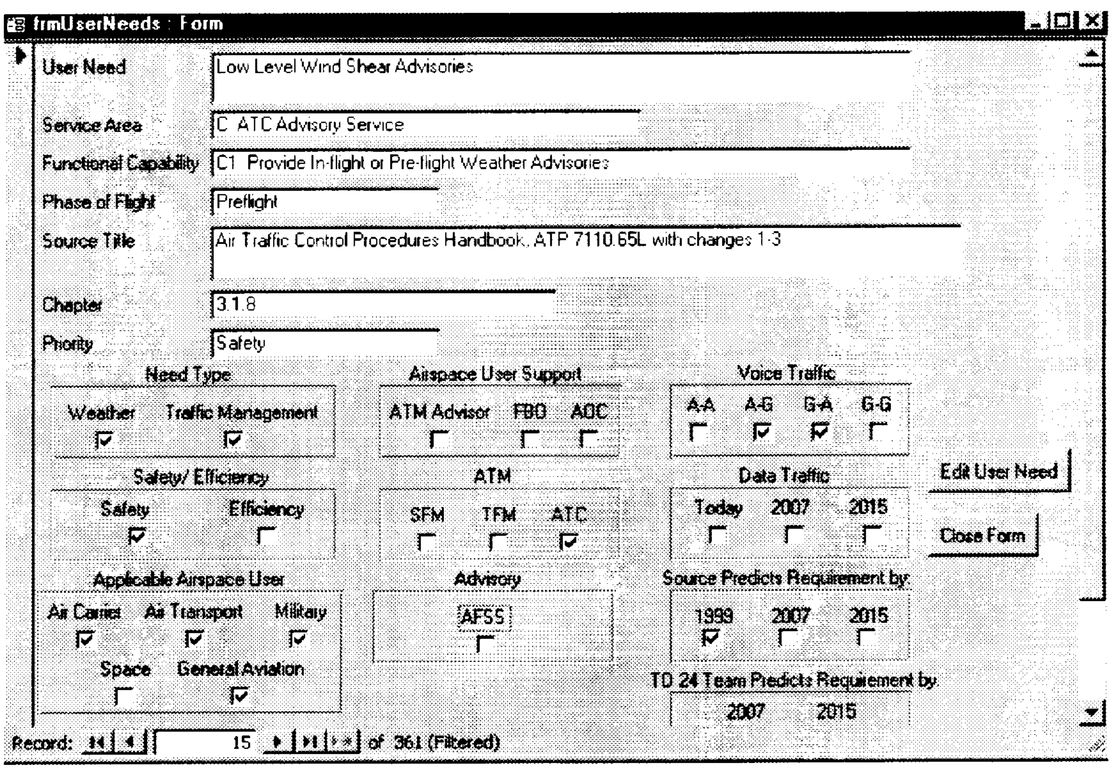

Figure 2.2-1. User Needs

User Need: This field shows the user need which all other fields on the form support.

Service Area: This field refers to the NAS services as defined in the NAS Architecture documentation. Attachment 2 has a complete description of each service.

Functional Capability: This field shows which functional capabilities affect the user need. The classification of needs allows their comparison with the outputs of the other TO24 Subtasks. The complete list of functional capabilities is shown in Attachment 1.

Phase of Flight: The phase of flight associated with the need. The options are preflight, arrival/ departure, enroute, and oceanic.

Source Title: Field displays the source document from which the user need was pulled. When documents are duplicative and contain the same user needs, the need is recorded only once with the document of higher precedence going into the source field. The other documents containing references to the user need, however, are mentioned in the "Comments" field.

Chapter: Field shows where in the source document the user need was found.

Priority: The relative level of importance assigned to the user need. Seven options exist for this field. From the highest to lowest priority they are: safety, regulatory, essential, important, relative, beneficial, and value added. Priority assignments for user needs other than those categorized as AWIN-related have been made subjectively. AWIN-related user needs were prioritized using techniques developed by MITRE, reviewed by industry, and then adopted by the FAA.

Need Type: This group allows the user to see whether the need is related to AWIN, ATM, or a combination of both activities.

Safety/ Efficiency: The need is shown here to be related to safety, efficiency, or both.

Applicable Airspace User: The user type to which the need applies. The type of user is defined primarily through the Federal Air Regulations under which the operations are conducted: general flight rules (FAR 91), certificated scheduled air carrier operations (FAR 121); certificated non-scheduled commercial operations (FAR 135), military operations, and space operations.

During the document review, it was found that specific user needs for military users were not included. Therefore, military requirements were assumed to be similar to those of other users.

Airspace User Support: Indicates which user support services are concerned with the need.

ATM: Fields show which ATM providers are affected by the specified user need. Strategic Flow Management (SFM), Tactical Traffic Management (TFM), and Air Traffic Control (ATCT, TRACON, ARTCC) are the possibilities.

Advisory: Determines whether the need pertains to services provided by Flight Service Station Specialists or others supporting the ATC function in an advisory capacity only.

Voice Traffic: These boxes show the flow of voice traffic that is affected by the need.

Data Traffic: These boxes indicate the year in which the source document says the necessary information flows concerning the need will occur via data instead of via voice.

Source Predicts Requirement by: A check in one of these fields indicates the source document says that the capabilities to service the user need specified will be available by the given year. When a document references data links, particularly those related to weather, the values for these fields was adjusted knowing that the FAA's data link program schedule has slipped. So, if the document were to say that a certain capability would be available by 2007, yet given FAA delays, such is known to be false. The 2015 field will be populated, and 2007 will be left blank.

TO 24 Team Predicts Requirement by: A check in one of these fields indicates that while the source document does not necessarily say that the capability to service the need will be available, the TO 24 team does feel the capability will be available by the given year.

Comments: This field contains additional information.

The electronic copy of the Task 1, 2, 3 Database is submitted as Attachment 5.

3 Communications System Functional Requirements

Task 2 identifies functional communications requirements associated with the user need identified in Task 1 and provides traceability back to them by way of the common mapping to functional capabilities. The task is divided into two separate subtasks which help to define "The Message" portion on the chart below showing the interactions between the three initial tasks of TO 24. The first subtask (Subtask 2.1) captures the characteristic data of a set of messages which are commonly used in aviation. The second (Subtask 2.2) involves the capture of message independent requirements relating to overall function, procedures, human factors, transition and security.

It is believed that the outputs from Task 2, used in conjunction with those of Tasks 1 and 3 provide all of the top-level requirements necessary for the development of the communications network architecture presented in later tasks.

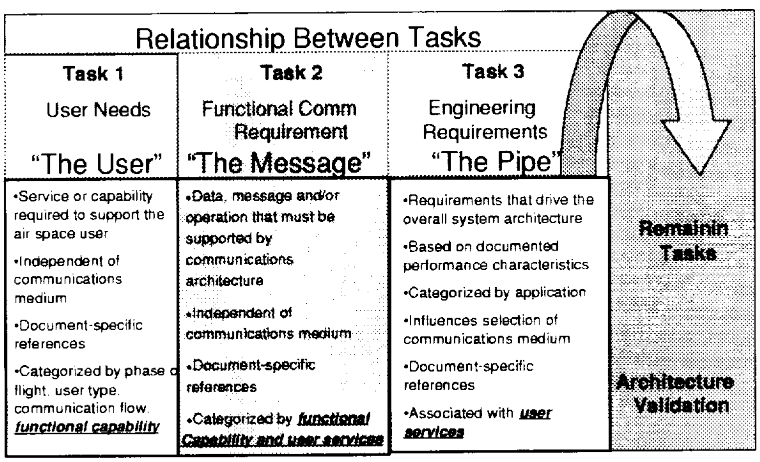

Figure 3-1. Task Relationships (Task 2)

3.1 Subtask 2.1: Message Characteristics

3.1.1 Subtask 2.1 Approach

This subtask serves as a collection point for all message requirements that are medium independent. These requirements bridge the gap between the user needs previously identified in Task 1 and the detailed system engineering requirements found in both Task 3 and discussed later in this document. The connection to the Task 1 output is through the functional capabilities providing a many-to-many relationship where all messages pertaining to a certain functional capability are related to all user needs pertaining to a functional capability. The link to the Task 3 output, however, is much tighter as each message is related to an engineering requirement in a one-to-one relationship. This means that each message can be shown in the database with not only its own characteristic data, but also with an associated system engineering requirement. This is better illustrated within the context of the database in the next section.

The reader of this document must remember that the primary focus of TO 24 is to establish traceability of functional requirements, specifically those pertaining to message traffic, back to user needs by way of the functional capabilities. Validation of these requirements is considered outside the scope of this task. However, validation by the user community is strongly recommended.

3.1.2 Message Characteristics in the Database

The Message Characteristics/ System Engineering Requirements view screen shot is shown below. Descriptions of those fields pertaining only to message characteristics (Subtask 1.1.1) and those fields pertaining to both message characteristics and to system engineering requirements are discussed in this section. Fields concerned only with engineering requirements are discussed in later sections.

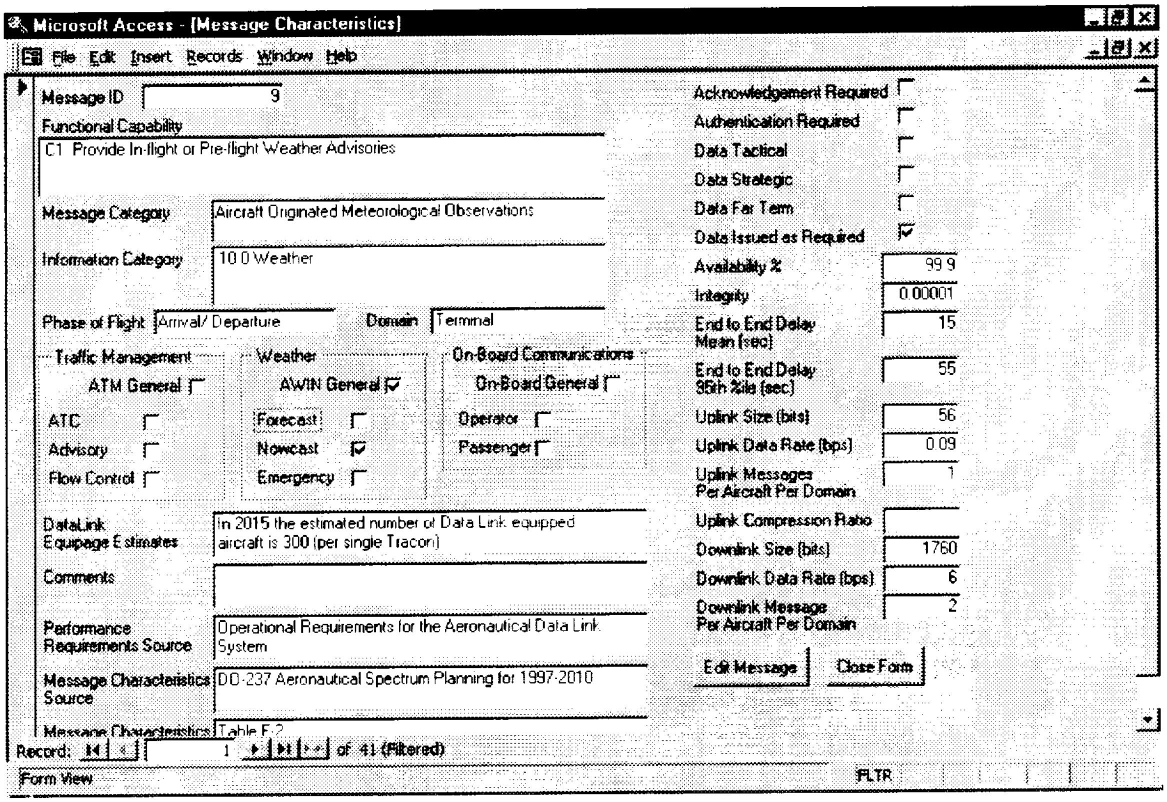

Figure 3.1-1. Message Characteristics Screen

Service Area: This field refers to the NAS services as defined in the NAS Architecture documentation. Attachment 2 has a complete description of each service.

Functional Capability: Functional capabilities, derived from the User Services definition used throughout the rest of TO-24, allow for a more granular classification of activities accomplished in the NAS. A complete list of functional capabilities and their associated user services can be found in Attachment 1.

Message Categories: Estimates of message traffic based on basic application areas as defined in the FAA Operational Requirements for the Aeronautical Datalink System source document. Note that in order to capture the projected weather products expected to be delivered under broadcast FIS, weather messages have been defined at a more detailed level.

Information Exchange Categories: Refers to eleven categories of traffic derived from NAS 4.0 and defined as part of TO-19 (AATT). An example of an information exchange is Category 1, Aeronautical, which consists of PIREPS, NOTAMS, and charts. A complete list of information exchange categories can be found in Attachment 5.

Phase of Flight: Breakdown of NAS operational domains into the following segments: preflight, arrival/departure, en route domestic and en route oceanic.

Domain: Breakdown of flight profiles into the following segments: Airport, Terminal, En route, and En route Oceanic.

Traffic Management: Air Traffic Management (ATM) refers to all aspects of communication and control of aircraft in the NAS. It can be divided into specific Air Traffic Control (ATC), Advisory, and Flow control communications categories.

- ATC – control of aircraft movements though controlled airspace including terminal, enroute, and oceanic routes
- Advisory – general information provided by the air traffic control function to aircraft operating within a specific airspace
- Flow Control – predictive (strategic) and real-time (tactical) actions on the part of air traffic and the NAS users to facilitate smooth and even traffic flow through the NAS
- ATM General – message conforms to any one or more of the three ATM categories listed above.

Weather: Aeronautical Weather (AWIN) refers to all aspects of communication designed to provide NAS users with atmospheric data along their intended flight path. Data communication can be characterized temporally as forecast, current conditions (now-cast), or imminent danger to the aircraft (emergency).

- Forecast – generally refers to conditions predicted along the intended aircraft route
- Now-cast – current conditions being encountered immediately ahead of the aircraft or pilot reports of conditions being encountered at the time of transmission
- Emergency – dangerous conditions such as severe convective activity including severe lightning, icing, and windshear
- AWIN General – message conforms to any one or more of the three AWIN catogories listed above

Onboard Communication: Non-control information that relates to airline operations, administrative concerns, passenger communications, and passenger entertainment (e.g., broadcast TV, internet, etc.)

Data Link Equipage Estimates: Information provided by the defining source as to the predicted growth in a particular type of message traffic

Source of Message Characteristics: Industry or regulatory source document. In compiling the message characteristic data, only a subset of source documents was used as primary sources. The remainder of the source documents either did not address specific message requirements or restated the message characteristic data from the primary sources.

Acknowledgement Required: Indicator that either the current definition of the message or predicted use of the message will require active acknowledgement on the part of the message's recipient. Note that automatic acknowledgement inherent in the underlying transmission protocol are not included here.

Authentication Required: Indicator that some form of active authentication is to be employed in conjunction with a particular message type.

Data: The data fields provide a measure of the timeliness of the message. There is an indirect relationship between this field and both phase of flight and domain since the aircraft spends limited time in each phase of flight or domain.

- Tactical (0-15 minutes) – Messages needed for near-term decision making
- Strategic (15-60 minutes) – Messages, often predictive in nature, for strategic decision-making
- Far Term (60+ minutes) – Messages, often advisory in nature, relating to conditions or actions still quite far away
- Issue as Required – Data that is only sent when required

Average Uplink Message Size (bits): Message size (excluding error correction and protocol overhead).

Uplink Data Rate per Aircraft (bps): Bits per second measure of transmit time (excluding error correction and protocol overhead).

Uplink Message Frequency per Aircraft: Number of messages sent to an aircraft during its flight in a specific domain, i.e., number of messages uplinked in the terminal domain (terminal domain flight length is typically ten minutes).

Uplink Compression Ratio: The ratio of the uncompressed uplink message to the one that is actually sent. A value of 10 in this field would indicate a message is compressed to one tenth of its original size before being passed to the aircraft.

Average Downlink Message Size (bits): Message size (excluding error correction and protocol overhead).

Downlink Data Rate per Aircraft (bps): Bits per second measure of transmit time (excluding error correction and protocol overhead).

Downlink Message Frequency per Aircraft: Number of messages expected from each aircraft during its flight in a specific domain, i.e., number of messages downlinked in the terminal domain (terminal domain flight length is typically ten minutes).

3.2 Subtask 2.2, Functional Requirements

The second subtask (2.2) contains message independent functional communications requirements. These "shall" statements were found in industry-related documentation and address the current, planned and potential services projected for the 2007 to 2015 timeframe. As in Subtask 2.1, the data is traced back to functional capabilities to provide the traceability throughout TO 24. The view screen of for Subtask 2.2 data is shown below along with field definitions.

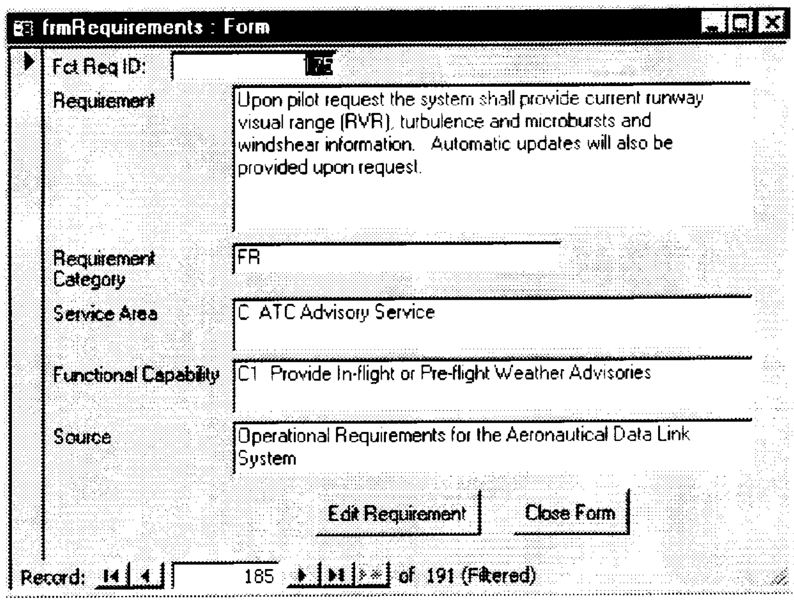

Figure 3.2-1. Requirements View Screen

FctReq ID: This field is used only for database management and has no bearing on the requirements presented within.

Requirement –Communications Requirement, specific "shall" statement

Requirement Category: The following classifications were used to capture these requirements:

FR:	Functional requirements capture requirements relating to the datalink system.
HFR:	Human factor requirements capture requirements that describe and specify the man-machine interface.
OPR:	Operational and procedural requirements capture requirements that govern the air-ground datalink.
SECR:	Security requirements are those requirements relating to the protection of data being communicated from malicious attack or from being divulged to unknown or unauthorized parties.
TRANSR:	Transition requirements are those requirements imposed due to the need to inter-operate seamlessly during the migration from existing communication infrastructure to a new infrastructure architecture.
COMR:	Communications requirements capture generic requirements relating to the communication media or mechanism to be employed across a particular link.
SLR:	System level requirements capture requirements that affect all communications regardless of transmission media or application including availability, integrity, reliability, and capacity requirements.

Service Area: This field refers to the NAS services as defined in the NAS Architecture documentation. Attachment 1 has a complete description of each service.

Functional Capability: Functional capabilities, derived from the User Services definition used throughout the rest of TO-24, allow for a more granular classification of activities accomplished in today's air traffic environment. A complete list of functional capabilities and their associated user services can be found the attachments.

Source Document - Industry or regulatory source document from which the requirement was derived.

The electronic copy of the Task 1, 2, 3 Database is submitted as Attachment 5.

4 Communications System Engineering Requirements

Task 3 builds upon the work done in Tasks 1, 2, and 4. It serves as the collection point for "hard" system engineering requirements independent of the transmission medium and provides traceability back to user needs by way of a common mapping to functional capabilities. Its relationship with the two previous Tasks is shown in the following figure.

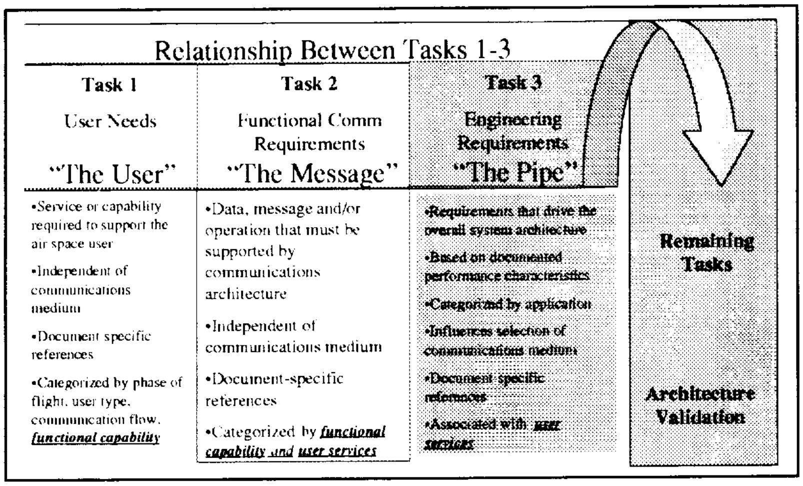

Figure 3.2-1. Task Relationships (Task 3)

Task 3 is divided into two primary subtasks. The first (Subtask 3.1) maps each potential communications link developed in Task 4 to a user service and functional capability. This information is contained in the "Link Analysis" in the database. The second (Subtask 3.2) involves the capture of system independent requirements concerning availability, reliability, and integrity as they relate to the message categories identified in Task 2. The Subtask 3.2 outputs are shown in the database under "Requirements".

It is believed that the outputs from Task 3, used in conjunction with those of Tasks 1 and 2 provide all of the system engineering requirements necessary for the development of the preferred architecture.

4.1 Sub-task 3.1: Development of Link Matrix

4.1.1 Subtask 3.1 Approach

As will be shown in further depth in Task 4, the basic Candidate System Architecture (CSA) Concept identifies six users/consumers of information. This is diagrammed in the following figure.

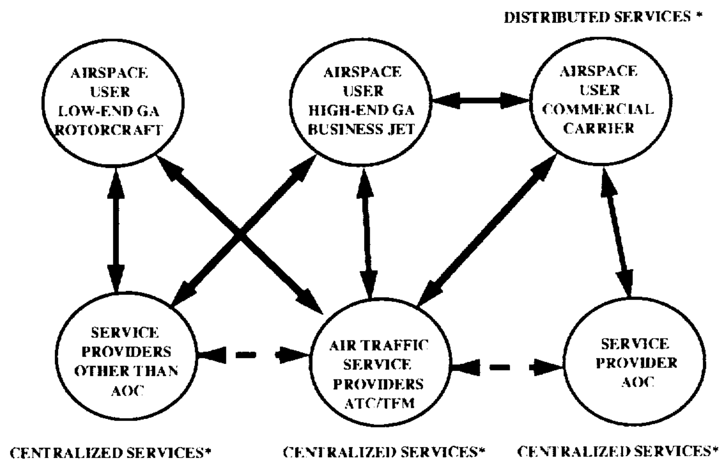

Figure 4.1-1. Basic CSA

At the Spring 1999 Quarterly review with NASA, it was agreed to modify this structure by using the FAR designations governing aircraft categories as the discriminator between airborne user classes. The new definition is as follows:

- Class 1: General Aviation Users required to follow Part 91 only.
- Class 2: Air Taxi and Commercial Users required to follow Parts 91 and 135.
- Class 3: Air Carrier Users required to follow Parts 91 and 121.

Adopting these definitions produces the following updated figure.

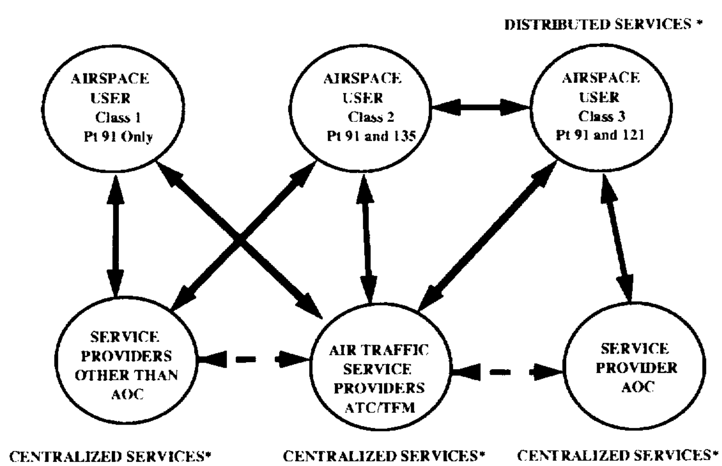

Figure 4.1-2. Basic CSA with FAR designations

Close examination of this figure indicates that there are thirty-six possible links in the system (includes the case where users are speaking with other users in the same class). These thirty-six links are as follows:

1. Class 1 to Class 1
2. Class 1 to Class 2
3. Class 1 to Class 3
4. Class 1 to Non-AOC Service Provider
5. Class 1 to ATS
6. Class 1 to AOC
7. Class 2 to Class 1
8. Class 2 to Class 2
9. Class 2 to Class 3
10. Class 2 to Non-AOC Service Provider
11. Class 2 to ATS
12. Class 2 to AOC
13. Class 3 to Class 1
14. Class 3 to Class 2
15. Class 3 to Class 3
16. Class 3 to Non-AOC Service Provider
17. Class 3 to ATS
18. Class 3 to AOC
19. Non-AOC Service Provider to Class 1
20. Non-AOC Service Provider to Class 2
21. Non-AOC Service Provider to Class 3
22. Non-AOC Service Provider to Non-AOC Service Provider
23. Non-AOC Service Provider to ATS
24. Non-AOC Service Provider to AOC
25. ATS to Class 1
26. ATS to Class 2
27. ATS to Class 3
28. ATS to Non-AOC Service Provider
29. ATS Provider to ATS
30. ATS to AOC
31. AOC to Class 1
32. AOC to Class 2
33. AOC to Class 3
34. AOC to Non-AOC Service Provider
35. AOC to ATS
36. AOC to AOC

Excluding direction of communications flow reduces the number of links to be considered to twenty-one. Removing the purely ground to ground links reduces the list to fifteen. These are:

1. Class 1 to/from Class 1
2. Class 1 to/from Class 2
3. Class 1 to/from Class 3
4. Class 1 to/from Non-AOC Service Provider
5. Class 1 to/from ATS
6. Class 1 to/from AOC
7. Class 2 to/from Class 2
8. Class 2 to/from Class 3
9. Class 2 to/from Non-AOC Service Provider
10. Class 2 to/from ATS
11. Class 2 to/from AOC
12. Class 3 to/from Class 3
13. Class 3 to/from Non-AOC Service Provider
14. Class 3 to/from ATS
15. Class 3 to/from AOC

Determination of whether a link is utilized for a specific service or functional capability was accomplished using the following criteria:

1. If the link is commonly used to provide that service, include it.
2. If NAS 4.0 projects use of that link in the future for the provision of that service, include it.
3. If no use of the link for provision of a service can be identified, exclude it.
4. If a corner condition is identified whereby the service could be provided, but it would be extremely rare or out of the ordinary, exclude it. In this case, a comment should be added to the comment field describing the circumstances where such use might occur.

In today's environment, a number of the links are uni-directional. However, in consideration of a 2015 end-state, it is likely that most links will provide bi-directional capability. This was the rationale for collapsing the links to bi-directional flow only.

4.1.2 Link Analysis in the Database

As with all other data groups in Tasks 1,2, and 3, the Link Analysis is accessed through three screens: query, view, and edit. The view screen is shown below to show the meanings of all fields in the link analysis. Field explanations then follow.

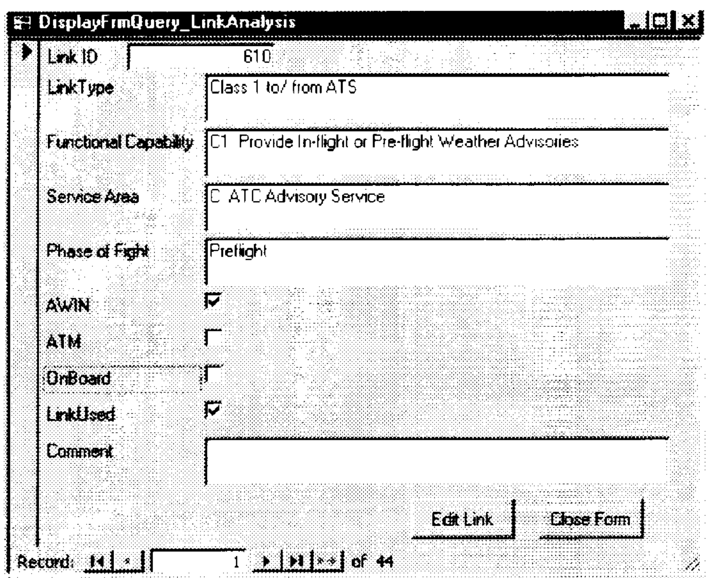

Figure 4.1-3. Link Analysis view screen

Link ID: This field shows the ID number assigned to the link shown. It is used for database management; its does not help to describe the communications link.

Link Type: This field shows the type of link. Its values can only be one of the 15 possible communications links described in the previous section. "Class 1 to/ from ATS" is the example shown here.

Functional Capability: This field shows which functional capabilities are supported by this communication link. The complete list of functional capabilities is shown in Attachment 1.

Service Area: This field shows which services areas are supported by this communications link. The complete list of service areas is shown in Attachment 2.

Phase of Flight: The field shows the applicable phase of flight for the link. The phases of flight in this study are preflight, arrival/departure, enroute, and oceanic.

AWIN: A checked box in this field shows that the link is used to communicate weather information.

ATM: A checked box here shows the link is used to communicate air traffic control instructions.

On Board: A box with a check shows that the link is used to provide on-board communications related to flight administration or passenger services.

Link Used: A checked box says that the link is used in the present architecture. A box without a check says that the link is not used.

Comment: The "Comment" field holds any extra information concerning the link not shown within the other fields.

4.2 Subtask 3.2: System Engineering Requirements

4.2.1 Subtask 3.2 Approach

The second portion of Task 3 serves as a collection point for all system engineering requirements that are medium independent. These requirements build on the message characteristics collected in Subtask 2.2 by providing overall availability, integrity, and delay values for each of the message types identified. Each system engineering requirement is tied directly to a single message type.

4.2.2 System Engineering Requirements in the Database

The system engineering requirements view screen is shown below along with field definitions. As most of the fields have already been discussed in previous sections, only the new fields which relate to the engineering requirements and have not been previously covered are discussed below.

Information Exchange Categories – Refers to eleven categories of traffic derived from NAS 4.0 and defined as part of TO-19 (AATT). An example of an information exchange is Category 1, Aeronautical, which consists of PIREPS, NOTAMS, and charts. A complete list of information exchange categories can be found in Attachment 5.

Phase of Flight – Breakdown of flight profiles into the following segments: preflight, arrival/departure, domestic, and oceanic

Domain – Breakdown of flight profiles into the following segments: Airport, Terminal, Enroute, and Enroute Oceanic

Performance Requirement Source: This field shows the source from which the performance requirement values come.

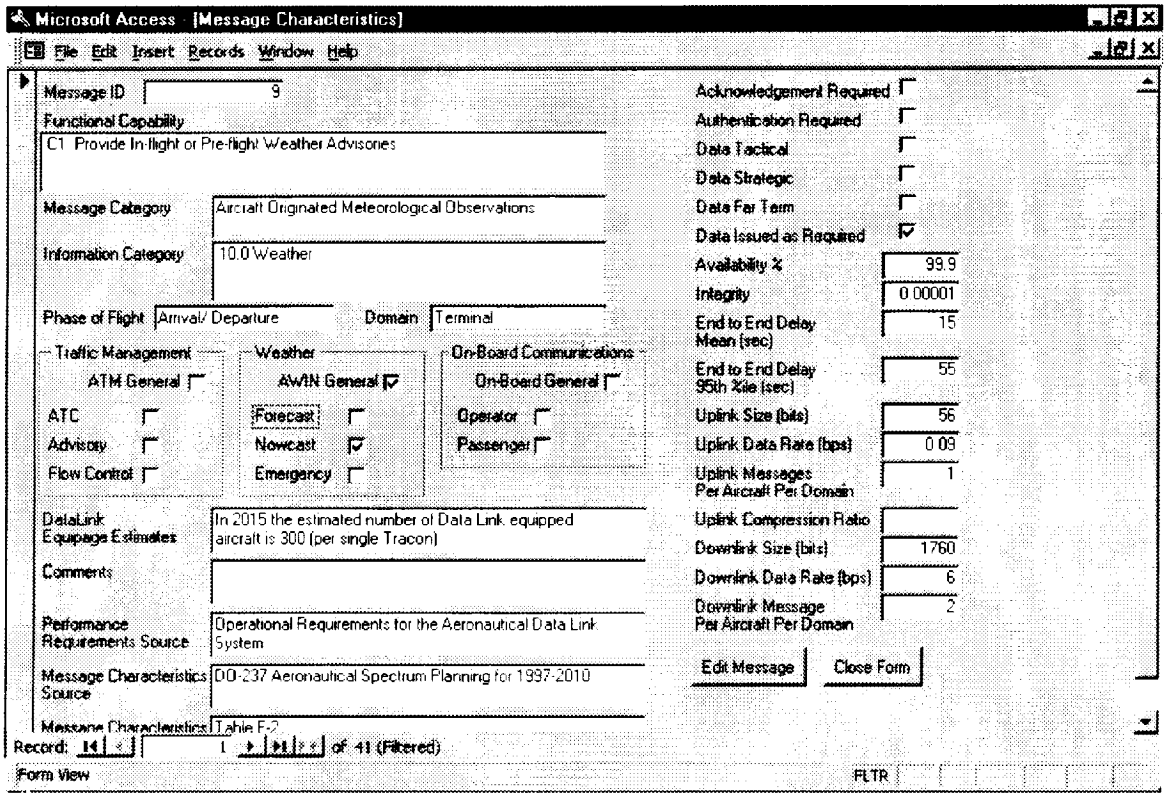

Figure 4.2-1. Message Characteristics/ System Engineering Requirements

Availability: The probability that the system, or a specific subsystem, is in an operable state and capable of performing its required functions to a specified level of performance during any and all required operating time.

Integrity: The absence of errors induced in a message by the system.

End-to-End Delay: Elapsed time between the initial presentation of speech or data to a channel for transmission and receipt of that speech or data at the receiver.

- Mean – Average measure of delay (seconds)
- 95% - Statistical measure indicative of the point at which 95% of messages can be expected to be received

The electronic copy of the Task 1, 2, and 3 Database is submitted as Attachment 5.

Attachment 1. Service/Functional Capabilities Matrix

All Subtasks in TO 24 are associated with a functional capability and user service to allow for traceability to each output of each subtask of the task order

USER SERVICES	FUNCTIONAL CAPABILITIES
Flight plan service	• File flight plans and amendments • Process flight plans and amendments • Provide information for flight plans
ATC separation assurance service	• Separate IFR aircraft • Avoid potential hazards and collisions • Maintain minimum distance from special use airspace (SUA) • Monitor flight progress
ATC advisory service	• Provide in-flight or pre-flight weather advisories • Provide in-flight or pre-flight traffic advisories • Provide in-flight NAS status advisories
Traffic management - Synchronization service	• Provide in-flight sequencing, spacing, and routing restrictions • Provide pre-flight runway, taxi sequence, and movement restrictions • Project aircraft in-flight position and identify potential conflicts • Process user preferences
Traffic management - strategic flow service	• Provide future NAS traffic projections • Collaborate with airspace users/user support on NAS projections and user preferences • Monitor NAS traffic status • Assess NAS traffic performance
Emergency and alerting Service	• Provide emergency assistance and alerts • Support search and rescue (SAR)
Navigation service	• Provide airborne navigation guidance • Provide surface navigation guidance
Airspace management service	• Manage design and use of NAS airspace • Manage use of SUA
Infrastructure/information management service	• Monitor and maintain NAS infrastructure • Manage radio spectrum for u.s. aviation community
On-board service Aircraft/airline operational services Passenger onboard services	• Schedule, dispatch, and manage aircraft flights • Monitor flight progress • Collaborate with ATM on NAS projections and user preferences • provide administrative flight information • Provide in-flight entertainment • Provide public communications

Attachment 2. User Service Definitions

Below are the definitions of Air Traffic user services from the latest draft FAA NAS Architecture document jointly developed by the FAA AT Requirements (ARS) and Systems Engineering and Architecture (ASD) organizations. For the purposes of AATT Task Order 24, a user service definition has been added for the Onboard services covering both passenger and aircraft/airline operational information.

Flight Planning Service

The flight planning service provides both flight plan support and flight plan data processing to support the safe and efficient use of the nation's airspace through the development and use of coordinated flight plans. This includes preparing and conducting pre-flight and in-flight briefings, filing flight plans and amendments, managing flight plan acceptance and evaluation, preparing flight planning broadcast messages, and maintaining flight-planning data archives. This service offers preparation to conduct a flight within the NAS and allows changes to flight profiles while operating within the NAS.

Flight Plan Support

Flight plan support provides NAS users essential weather and aeronautical information. Flight planning requires information such as expected route, altitude, time of flight, available navigation systems, available routes, special use airspace (SUA) restrictions, daily demand conditions and anticipated flight conditions including weather and sky conditions (e.g. volcanic ash, smoke, birds). There is an exchange of a variety of data to support flight planning including NAS operational and maintenance status, weather, FAA facility status, with numerous NAS users to include, fixed base operators, pilots and flight planners, airline operations centers, Department of Defense (DOD) operations offices, and inter alia. Planning and pre-flight briefings contain current and forecast weather including winds and temperatures, surface conditions, and any significant meteorological condition. Aeronautical information includes notices to airmen containing information concerning the establishment, condition, or change in any NAS component (facility, service, or procedure of, or hazard in the NAS) the timely knowledge of which is essential to flight.

Flight Plan Processing

Flight plan processing provides acceptance and processing of flight plan data from all users (e.g., general aviation, commercial, military, customs, law enforcement, etc.); validates the flight plans; notifies users of any problems; and processes amendments, cancellations and flight plan closures. NAS flight plan processing provides evaluation and feedback for both domestic and international flight plans. Flight plan amendments both pre-flight and in-flight are also processed including cancellations, and closures. The NAS disseminates flight plan information as necessary.

4.3 Air Traffic Control Separation Assurance Service

The separation assurance service ensures that aircraft maintain a safe distance from other aircraft, terrain, obstacles, and certain airspace not designated for routine air travel. Separation assurance involves the application of separation standards to ensure safety. Standards are defined for aircraft operating in different environments.

4.3.1 Aircraft to Aircraft Separation.

Aircraft to aircraft separation prevents collision between airborne aircraft. A variety of methodologies are employed to apply the defined separation standards. These methodologies include the use of visual and automated means.

4.3.2 Aircraft to Terrain/Obstacles Separation

NAS employs defined separation standards to prevent collision between aircraft, terrain, and obstacles. Methods used include published safety zones and processing of position and intent information.

4.3.3 Aircraft to Airspace Separation.

Aircraft are separated from special use airspace (SUA) such as prohibited, restricted, and warning areas. The SUA is designed to ensure safety for unique aircraft operations or to prohibit flight within a specified area. Separation standards ensure aircraft remain an appropriate minimum distance from the airspace. The standards are applied via methods including regulatory publications and specific control instructions.

4.3.4 Surface Separation

Surface separation accounts for activities such as vehicle movements on the airport movement area, taxiing aircraft, water vehicles, protection from designated critical zones, etc. Standards are employed to ensure safe operation on the surface.

4.4 Air Traffic Control Advisory Service

Air traffic control and other facilities provide advice and information to assist pilots in the safe conduct of flight and aircraft movement. These advisories include providing weather information, traffic, and NAS status information. These advisories and information may be directed to a specific location, broadcast to any user in an area, or provided to a specific user.

4.4.1 Weather Advisories

Weather advisories and information are available either automatically or on request through communication with ATC and other facilities. For example, pilots receive weather advisories from automated weather observing or other systems, ATC facilities, and aircraft operations centers (AOCs). Advisories provide hazardous weather and/or flight conditions at airports or along the route of flight.

4.4.2 Traffic Advisories

Traffic advisories are provided to alert aircraft to potential conflicts with others on the surface or in-flight. For example, traffic advisories are provided to aircraft or other flight objects that are in the proximity of hot air/gas balloons, missile launches or other potential hazards. Traffic advisories for aircraft on the surface include the number, type, position and intent of the ground traffic.

4.4.3 NAS Status Advisories

Information about NAS status that has changed or was not readily available during flight planning is provided to in-flight aircraft. This includes updates concerning the operational status of airspace, airports, navigational aids (NAVAIDs), in-flight or ground hazards, traffic management directives, and other information that is essential to the safety and efficiency of aircraft.

4.5 Traffic Management-Synchronization Service

Traffic synchronization supports expeditious flight for the large number of aircraft using the NAS during any given period of time. NAS processes operate to maximize efficiency and capacity in response to weather, NAS infrastructure, runway availability or other conditions. Traffic synchronization is the tactical portion of traffic management providing sequencing, spacing, and routing of aircraft. Traffic synchronization activities are accomplished while maintaining separation assurance and implementing strategic flow management directives. The traffic synchronization service provides tactical instructions to optimize operations while airborne and on the surface.

4.5.1 Airborne

Airborne synchronization involves sequencing of aircraft to maximize efficiency and capacity of the NAS through all phases of flight (arrival, departure, and cruise). Maximum efficiency, predictability and capacity are obtained through the application of processes, which reduce variability in application of the defined separation standards. These activities include prioritization including the input of user preferences.

4.5.2 Surface

The surface is managed by formulating taxi sequences and communicating instructions to pilots and vehicle operators for the safe and efficient flow of traffic on the airport surface. Surface synchronization involves processes intended to maximize surface efficiency, predictability and capacity. It includes activities such as runway assignment, taxi sequence and movement instructions.

4.6 Traffic Management-Strategic Flow Service

The strategic flow service provides for orderly flow of air traffic from a system perspective. NAS demand and capacity is analyzed and balanced to minimize delays, avoid congestion, and maximize overall NAS throughput, flexibility, and predictability. Actual and predicted demand is compared to the current and predicted capacity of the NAS airspace, airports and infrastructure to plan the overall NAS strategy. When necessary, traffic flow management (TFM) plans are developed collaboratively to optimize the flow of traffic while accommodating user requests and schedules, airspace, infrastructure, weather constraints, and other variables. The strategic flow services are comprised of long-term planning (more than one day in advance) and flight-day traffic management (current 24-hour period) and performance assessment.

4.6.1 Long-term Planning

Long term planning works to maximize efficiency by developing predictions of capacity and demand more than one day in advance. Inputs include capacity and demand models based on airport use data, airspace for special use schedules, airline flight schedules, infrastructure status, and historical flight traffic demand information. It also includes activities designed for continual improvement in the predictive capabilities such as model validation, assessment of specific planned and executed strategies trend analysis and recommended changes.

4.6.2 Flight Day Management

Flight day traffic management optimizes NAS traffic flow for the current 24-hour period. Demand profiles are compared with projections of NAS capacity for the current day and identify periods and locations where predicted demand exceeds predicted capacity. Specific responses to maximize efficiency are developed and implemented through collaboration across the NAS.

4.6.3 Performance Assessment

Performance assessment provides institutional memory by archiving information to support post-flight analyses of NAS traffic flow. The effectiveness of NAS performance is analyzed to propose future improvements. Air traffic trends and activities are analyzed, problems identified and alternatives for improvement developed and evaluated. Long-term improvements to NAS performance include recommended changes to schedules, airspace design, ATC procedures, and the NAS infrastructure.

4.7 Emergency and Alerting Service

The emergency and alerting service monitors the NAS for distress or urgent situations, evaluates the nature of the distress, and provides an appropriate response to the emergency. Applicable situations include those that occur on the ground or in-flight. Emergency services include emergency assistance and alerting support.

4.7.1 Emergency Assistance

Emergency assistance provides direct support in the protection of individuals and property both in the air and on the ground. Examples of the wide variety of circumstances under which direct support is provided include location and navigation assistance for orientation, guidance to emergency airports, and generation of alternative courses of action.

4.7.2 Alerting Support

Alerting support provides indirect assistance for those events/circumstances in which the response is external to the system. For example, when information is received that an aircraft is overdue or missing, ELT signals are received, or search and rescue services may be required, alerting support provides the relevant information and coordinates with the appropriate international, military, federal, state, and local agencies. The appropriate organization(s) then provide direct response(s).

4.8 Navigation Service

The service provides navigational guidance to enable NAS users with suitable avionics to operate their aircraft safely and efficiently under different weather conditions. The service includes both ground and space-based networks of navigational aids for the NAS. These navigational aids broadcast electronic signals or provide guidance in accordance with international standards. The navigation service provides guidance during airborne operations (such as cruise, approach and landing), and during surface operations to appropriately equipped aircraft.

4.8.1 Airborne Guidance

NAS provides mechanisms and aids for point-in-space navigation through a variety of operating environments. These environments include structured routes, random routings and transitions. Guidance is provided for position determination in both vertical and lateral planes in all phases of flight. Additionally, visual aids provide guidance to aircraft transitioning to and from the surface.

4.8.2 Surface Guidance

NAS provides mechanisms and aids for maneuvering on the airport surface safely and efficiently. For example, references are provided to determine present position both electronic and/or visual.

4.9 Airspace Management Service

Airspace management service ensures the safe and efficient use of the national airspace resource. This includes the design, allocation, and stewardship of the airspace. Maximum safety and efficiency in the use of airspace results from coordinating airspace user needs and available capacity. Effective airspace management requires the seamless integration of airspace design and the management of airspace for special use.

4.9.1 Airspace Design

Airspace design provides maximum utilization of the national resource while ensuring safety to the public at large. This includes a cohesive plan for managing airspace changes, establishing and directing a financial plan to meet airspace priorities, establishing standards for modeling and analysis, and developing strategies to ensure environmental compatibility. Airspace planning and analysis considers, among other elements, the existing design, current and projected traffic usage, radio frequency congestion, effects of airport construction, proposed and existing surface structures, and environmental factors such as noise abatement and others. It provides the aviation community with the description, operational composition and status of airspace/airport components of the NAS.

4.9.2 Airspace for Special Use

Airspace for special use provides support to the national defense mission, fosters the development of commercial space enterprises, protects sensitive areas, and ensures the protection of other natural resources. Designation and management of special use airspace ensures optimal access.

4.10 Infrastructure/Information Management Service

Infrastructure management ensures a safe and efficient NAS through management and operation of the infrastructure and optimal use of resources. Infrastructure resources include systems such as radar, communication links, navigation aids and automation, while infrastructure management includes monitoring and maintenance of the NAS.

4.10.1 Monitoring and Maintenance

Monitoring and maintenance includes the activities necessary to monitor the NAS status, detect and isolate failures and outages, and perform corrective and preventive maintenance to ensure the operational readiness of the NAS. Maintaining, operating, and managing the infrastructure requires a variety of planning, engineering, analysis, repair and maintenance functions. It also includes monitoring status, real time assessments and systems implementations in the NAS.

4.10.2 Spectrum Management

Spectrum management secures, protects, and manages the radio spectrum for the FAA and the U.S. aviation community. It is the focal point for management policy and plans, engineering, frequency assignment, radio interference resolution, radiation hazard, obstruction evaluation, electronic counter measures, and other national/international spectrum activities.

Government/agency support provides information and coordination services. Examples of the agencies and organizations supported include, military air defense operations, law enforcement, government land management, drug interdiction, state aviation, Customs, National Transportation Safety Board, and inter alia.

4.11 Aerospace Operational Control Service

Aerospace Operational Control Services are non-ATC, safety-related functions performed by AOC, FBO, Military or other aircraft operations support personnel that include the scheduling, dispatch and management of aircraft flights, monitoring of flight progress and collaboration on ATM and NAS projections and user preferences.

4.11.1 Onboard Services

Onboard services are either associated with the aircraft, airline, or passengers. In most cases it is potentially a two-way exchange. Since some of these services are driven more by market (Profit/Loss) considerations versus Air Traffic considerations, it is likely that the use of more advanced communications techniques may be justified and therefore provide additional alternative implementations beyond those provided by the NAS.

4.12 Aircraft/Airline Operational Onboard Services

These services potentially include information relative to the state, intent, and status of the aircraft. Typical examples include engine status, heading, speed, timing for gate departure/arrival, wheels up/down, etc. It also includes information relative to the airline operations such as, schedule changes, airport status, fuel estimates, gate availability/assignments, etc. This information is presently transmitted via ACARS and is used by the Airline for scheduling and dispatching aircraft.

4.12.1 Passenger Onboard Services

These services potentially include broadcast services for entertainment (e.g., sporting events or other television), information services such as Internet access, business services such as fax or e-mail, and voice or data passenger communications. Some of these services, such as passenger telephony, are likely to use communications links that can also be used for ATM or FIS.

Attachment 3. Tasks 1-3 Source Document List

Source ID	Title	Author	Task 1	Task 2	Task 3
4	Aeronautical Digital Communication Architecture Utilizing LEO/ MEO Satellite Capability	AATT/ AWIN			
5	Aeronautical Satellite Communications for Automatic Dependent Surveillance	David H. Featherstone		S	
6	Aeronautical Information Manual	FAA	P	S	
7	Affordable, Flexible Communication Control Systems	Al Henry			
8	Air Traffic Management Concept Baseline Definition	Boeing Commercial Airplane Group		P	P
9	Air Traffic Service Plan, 1996-2005	FAA ATO-1		S	S
10	Air Traffic Weather Needs and Requirements, Order 7032.15	FAA	P	S	S
11	Air Traffic Weather Requirements Report	FAA/ Air Traffic Plans and Requirements Service	P	P	S
15	Aviation System Capacity Program, Advanced Air Transportation Technologies, ATM Concept Definition, Volume 1, Current and Future Operational Concepts for the National Airspace System	NASA Ames Research Center		S	S
16	Aviation System Capacity Program, Advanced Air Transportation Technologies, ATM Concept Definition, Volume 2, Coverage of Future National Airspace System Operational Requirements	NASA Ames Research Center		S	S
18	Avionics Transition Issues: User Motivations to Equip with Advanced Communication, Navigation, and Surveillance (CNS) Avionics	Rovinsky, Robert			
19	Aviation Weather (00-6A)	FAA	S	S	
20	Aviation Weather Services (00-45D)	FAA	P	S	
21	Aviation Weather Systems Plan	FAA NAS System Engineering Service		S	
22	Aviation Weather System: A Vision of the Future	FAA		S	
28	Comprehensive ATN Manual (CAMAL): Part I Introduction and Overview	Aeronautical Telecommunications Network (ATN)		S	
29	Comprehensive ATN Manual (CAMAL): Part II System Level Considerations	Aeronautical Telecommunication Network (ATN)		S	
30	Concept of Operations for the National Airspace System in 2005	FAA Traffic Services	S	S	
31	Concept of Operations for the National Airspace System in 2005, Addendum 1: Operational Tasks & Scenarios	FAA Traffic Services	P	S	
32	Concept of Operations in the National Airspace System in 2005 Version 1.0	FAA Office of Commercial Space Transportation		S	
33	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Lockheed Martin Aeronautical Systems, AWIN	S	P	P
34	Demonstrating an Improved Weather Awareness System for CDM	Falcone, Rich; Kevin Kollman; Bill Leber; John Moffatt; Lorraine Sandusky; Art Shantz; Mike Wambsganss; Jim Wetherly	S		
35	Evolutionary Operational Concept for Users of the National Airspace System, Draft V2.1	RTCA Select Committee on Free Flight Implementation	S	S	S
36	FAA Aviation Forecasts - Fiscal Years 1995-2006	FAA	S	S	S

Source ID	Title	Author	Task 1	Task 2	Task 3
37	FAA Terminal Area Forecasts - Fiscal Years 1993-2005	FAA	S	S	S
38	FAR: Federal Aviation Regulations (including FAR Parts 71, 125, 129, 189)	FAA	P	S	S
39	Final Report of RTCA Task Force 3: Free Flight Implementation	RTCA	P	S	S
40	Free Flight Action Plan	RTCA	S	S	S
41	Free Flight Satellite Communication Study Final Report	Lockheed Martin Aeronautical Systems, AATT	S	S	S
42	Flight Management System - Air Traffic Management Next Generation (FANG) Operational Concept	DOT/FAA	P	S	S
43	Flight Management System - Air Traffic Management Next Generation (FANG) Required Capabilities	DOT/FAA	P	S	S
44	Future FAA Communications Plan (Fuchsia Book)	Telecommunications Network Planning and Engineering Division		S	S
45	Global MET Solutions	Cech, Petr			
46	Integrated Plan for Air Traffic Management Research and Technology Development, Version 2.0	FAA/ NASA Inter-agency Air Traffic Management Integrated Product Team			
48	Joint Government/ Industry Operational Concept for the Evolution of Free Flight	RTCA Select Committee on Free Flight Implementation	P	S	S
49	Milestone 1.0.0: Consolidate and Assess Operations Concepts for the Future NAS	NASA/ AATT			
50	Mobile Satellite Service (MSS) Study Final Report	Federal Systems Integration and Management Center; Stanford Communications		P	P
52	National Airspace System Architecture, Version 4.0	DOT/ FAA	P	P	
53	National Airspace System Stakeholder Needs	Boeing Commercial Airplane Group		P	
54	Next Generation AMHS for AFTN Communications	Misra, Ramesh			
58	Operational Requirements for the Aeronautical Data Link System	FAA/ AFS/ ATR/ AND/ ARD/ ASE	P	P	P
59	Operational Windshear Warning System for Hong Kong's New Airport	Mahoney, William P. and Bruce Donaldson			
61	Potential Benefits and Costs of Free Flight to General Aviation	Burgess, Malcolm A. and Stuart W. Law (Research Triange Institute)			
62	Proposed Aviation Weather System Architecture	FAA		S	S
65	SATCOM Links Speed Weather Forecasts	Asker, James R			S
74	Weather Related Federal Aviation Regulations: General Aviation, Air Carrier, Air Taxi, and Commercial Operations	Glover, Graham K. (MITRE)	S	S	
78	Airline Operational Control Overview	FMS-ATM Next Generation (FANG) Team for FAA	P	S	
79	DO-219 Minimum Operational Performance Standards for ATC Two-Way Data Link Communications	RTCA SC-169		S	S
80	DO-237 Aeronautical Spectrum Planning for 1997-2010	RTCA SC-185		S	P
81	DO-239 MASPS for Traffic Information Service Data Link Communications	RTCA SC-169		P	P
82	DO-238 Human Engineering Guidance for Data Link Systems	RTCA SC-169		S	P

Source ID	Title	Author	Task 1	Task 2	Task 3
83	DO-136 Universal Air-Ground Digital Communication System Standards	SC-110 & SC-111		S	
84	DO-162 Report on Air-Ground Communications - Operational Considerations for 1980 and Beyond	RTCA SC-120			
85	DO-169 VHF Air-Ground Communication Technology and Spectrum Utilization	RTCA SC-140			S
86	DO-175 Minimum Operational Performance Standards for Ground-Based Automated Weather Observation Equipment	RTCA SC-143			S
87	DO-193 User Requirements for Future Communications, Navigation, and Surveillance Systems, Including Space Technology Applications	RTCA SC-155		S	
91	DO-209 Minimum Operational Performance Standards for Devices that Prevent Blocked Channels Used in Two-Way Radion Communications Due to Simultaneous Transmissions	RTCA SC-163		S	
92	DO-210C Minimum Operational Performance Standards for Aeronautical Mobile Satellite Services (AMSS)	RTCA SC-165		S	
94	DO-212 Minimum Operational Performance Standards for Airborne Automatic Dependent Surveillance (ADS) Equipment	RTCA SC-170		S	
95	DO-214 Audio Systems Characteristics and Minimum Operational Performance Standards for Aircraft Audio Systems and Equipment	RTCA SC-164		S	
96	DO-215A Guidance on Aeronautical Mobile Satellite Service (AMSS) End-to-End System Performance	RTCA SC-165		P	P
97	DO-218 Minimum Operational Performance Standards for Mode S Airborne Data Link Processor (Change 1)	RTCA SC-142		S	
98	DO-222 Guidelines on AMS(R)S Near Term Voice Implementation and Utilization	RTCA SC-165		S	S
99	DO-223 Minimum Operational Performance Standards for Context Management (CM) Equipment	RTCA SC-169		S	
100	DO-224 Signal-in-Space Minimum Aviation System Performance Standards (MASPS) for Advanced VHF Digital Data Communications Including Compatibility with Digital Voice Techniques	RTCA SC-172		S	S
101	DO-225 VHF Air-Ground Communications System Improvements Alternatives Study and Selection of Proposals for Future Action	RTCA SC-172		S	S
103	DO-231 Design Guidelines and Recommended Standards for the Implementation and Use of AMS(R)S Voice Services in a Data Link Environment	RTCA SC-165		S	S
104	DO-232 Operations Concept for Data Link Applications of Flight Information Services	RTCA SC-169		P	P
106	DO-237 Aeronautical Spectrum Planning for 1997-2010	RTCA SC-185		P	P
107	DO-240 Minimum Operational Performance Standards for Aeronautical Telecommunication Network (ATN) Avionics	RTCA SC-162		S	P

Source ID	Title	Author	Task 1	Task 2	Task 3
108	DO-241 Operational Concepts and Information Elements Required to Improve Air Traffic Management (ATM) - Aeronautical Operational Control (AOC) Ground-Ground Information Exchange to Facilitate Collaborative Decision Making	RTCA SC-169	S	S	
109	DO-242 Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B)	RTCA SC-186		S	P
110	DO-243 Guidance for Initial Implementation of Cockpit Display of Traffic Information	RTCA SC-186		S	
111	DO-244 Government/ Industry Guidelines and Concept for National Airspace Analysis and Redesign	RTCA SC-192		S	
112	DO-245 Minimum Aviation System Performance Standards for Local Area Augmentation System (LAAS)	RTCA SC-159		S	
113	DO-247 The Role of Global Navigation Satellite System (GNSS) in Supporting Airport Surface Operations	RTCA SC-159		S	
114	Operations Requirements for ATM Air/Ground Communications Services, OPR.ET1.ST05.1000-ORD-01-00	Eurocontrol		P	P
115	Inventory and Analysis of A/G Applications and Data Networks, Phase 1 Report, COM.ET2.ST15.1000-REP-xx-xx (Draft)	Eurocontrol		P	P
116	Aeronautical Safety Services Network Study	ARINC		S	
117	Code of Federal Regulations, 14 CFR Part 121	FAA	P	S	
118	Code of Federal Regulations, 14 CFR Part 129	FAA	P	S	
119	Code of Federal Regulations, 14 CFR Part 135	FAA	P	S	
120	Code of Federal Regulations, 14 CFR Part 91	FAA	P	S	
121	Air Traffic Control Procedures Handbook, ATP 7110.65L with Changes 1-3	DOT/ FAA	P		
122	Air Traffic Specialist Handbook, 7110.10M with changes 1-2	DOT/ FAA	P		
123	AATT Integrated Concept Volume 2	AATT	P	S	
124	FAA Air Traffic System Vision of the Future (1995-2015)		P	S	
125	FAA Flight 2000 Initial Program Plan		S		
126	AOPA Preliminary Assessment of General Aviation User Needs	RTCA SC-169, WG-3	P		
127	User Weather Requirements	FAA	P	S	
128	Digital A/G Communications System Operational Concept, FAA ASD-100	FAA	P	S	
129	FAR: Federal Aviation Regulations Part 125	FAA	P	S	S
130	FAR: Federal Aviation Regulations Part 189	FAA	P	S	S
131	FAR: Federal Aviation Regulations Part 25	FAA	P	S	S
132	FAR: Federal Aviation Regulations Part 23	FAA	P	S	S
133	Operations Concept for Data Link Applications of Flight Information Services	RTCA 081-96/ TMC 212			S
134	Initial/ Final Requirements Documents for En-Route Controller - Pilot Data Link Communications, Builds 1 and 1A	DOT/ FAA		S	S
135	Alternatives Analysis Report for Next Generation Air/ Ground System (NEXCOM)	DOT/ FAA		S	S
137	Requirements and Desirable Features of a Future VHF Air Ground Communications System	FAA		S	S

Attachment 4. List of Acronyms

AATT	Advanced Air Transportation Technology
A/A	Air to Air
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance-Broadcast
AFSS	Automated Flight Service Station
A/G	Air to Ground
AIM	Aeronautical Information Manual
AIRMET	Airmen's Meteorological Information
AMSS	Aeronautical Mobile Satellite System
AOC	Airline Operational Control
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATC DSS	Air Traffic Control Decision Support Systems
ATCT	Air Traffic Control Tower
ATIS	Automated Terminal Information System
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services (organization in the FAA)
AWIN	Aviation Weather Information Services
BER	Bit Error Rate
CDM	Collaborative Decision Making
CDMA	Code Division Multiple Access
CDTI	Cockpit Display of Traffic Information
CNS	Communications, Navigation and Surveillance
CPDLC	Controller-Pilot Data Link Communications System
CSMA	Carrier Sense Multiple Access
CWA	Center Weather Advisory
D8PSK	Differential Eight-Level Phase Shift Keying
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FAR	Federal Air Regulations
FBO	Fixed Base Operator
FEDSIM	Federal Systems Integration and Management Center
FIS	Flight Information Services
FMS	Flight Management System
G/G	Ground-to-Ground
GA	General Aviation
GEO	Geostationary Earth Orbit
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ITWS	Integrated Terminal Weather System
IWF	Integrated Weather Forecast
KBPS	Kilobits Per Second

LEO	Low Earth Orbit
MBO	Military Base Operations
METAR	International standard code format for hourly surface weather observations
MDCRS	Meteorological Data Collection and Reporting System
MEO	Medium Earth Orbit
MOC	Mission Operational Control
MSS	Mobile Satellite Service
MTBF	Mean Time Between Failure
N/A	Not Applicable
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NAWIS	National Airspace Weather Information Service
NEXCOM	Next Generation A/G Communications System
NEXRAD	Next Generation Weather RADAR
NOTAM	Notice to Airman
NWS	National Weather Service
PIREP	Pilots Report
RCP	Required Communications Performance
RF	Radio Frequency
RTCA	RTCA, Inc. Before shortening its name to RTCA, the organization was named the Radio Technical Commission for Aeronautics.
SAR	Search and Rescue
SARP	Standards and Recommended Practices
SATCOM	Satellite Communications
SIGMET	Significant Meteorological Information
SPECI	Special Weather Report
SUA	Special Use Airspace
TAF	Terminal Aerodrome Forecast
TDWR	Terminal Doppler Weather RADAR
TIS	Traffic Information Services
TRACON	Terminal Radar Approach Control Facility
TWDL	Two-way Data Link
TWEB	Transcribed Weather Broadcast
VDL	VHF Digital Link
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	VHF Omni-Directional Range
WAAS	Wide Area Augmentation System
WARP	Weather and Radar Processor
Wx	Weather

Category	Requirement	Source Document	Date	Section/ Paragraph
COMR	ATM data communications shall have priority over all other air/ground data communications	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	01/03/1995	4.2
COMR	The capacity of the data link system shall be such that the Quality of Service for each service is maintained in the case of simultaneous use of all services for all predicted traffic	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	01/03/1995	4.2
COMR	The data link system shall meet quality of service requirements, as described for every service.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	01/03/1995	4.5
COMR	The data link system should have the capability to manage message routing to flight deck and ATS end-user applications, to order queues of pending messages, and to vary operator notification according to established alerting schemes.	RTCA DO 238, Human Engineering Guidance For Data Link Systems	01/03/1995	4.5
COMR	The data link system should have the capability to unambiguously identify the source and destination all transmitted messages.	RTCA DO 238, Human Engineering Guidance For Data Link Systems	01/03/1995	4.5
COMR	The future air-ground communications system shall support area coverage requirements taking into account spectrum efficiency. Any new system will have the capability to satisfy this requirement in an acceptable manner without increasing pilot or controller workload or reducing the reliability of communications.	RTCA DO-225, "VHF Air-ground Communications System Improvements Study and Selectof Proposals for Future Actions", Prepared by: SC-172	06/22/1998	1
COMR	Throughput estimate of 90kbps to provide periodic download of flight data recorders and onboard diagnostic info including engine telemetry	RTCA DO 237, Aeronautical Spectrum Planning For 1997-2010	01/29/1998	1.3
COMR	Passenger communications shall not interfere with ATM message traffic.	Suggested format for functional requirement	04/02/1997	4.4
COMR	The ATN addressing and naming plans shall allow States and organizations to assign addresses and names within their own administrative domains.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	04/02/1997	3.8
COMR	The ATN shall accommodate routing based on a pre-defined routing policy.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	04/02/1997	7.2.2
COMR	The ATN shall enable an aircraft intermediate system to be connected to a ground intermediate system via concurrent mobile subnetworks	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	06/22/1998	5
COMR	The ATN shall enable an aircraft intermediate system to be connected to multiple ground intermediate systems.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	06/22/1998	5
COMR	The ATN shall enable exchange of application information when one or more authorized paths exist.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	06/22/1998	3
COMR	The ATN shall enable the exchange of address information between application entities.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	06/22/1998	2
COMR	The ATN shall enable the recipient of a message to identify the originator of that message.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	06/22/1998	1
COMR	The ATN shall make provisions for the efficient use of limited bandwidth subnetworks.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	06/22/1998	2
COMR	The ATN shall notify the appropriate application processes when no authorized path exists.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	06/22/1998	3
COMR	The ATN shall offer ATSC classes in accordance with the criteria in Table 1-1 of the ATN SARPS which defines the requirement for the 95% probability, maximum, end-to-end, one-way transit delay.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	08/01/1997	4.2
COMR	The ATN shall operate in accordance with the communication priorities defined in Table 1-2 and Table 1-3 of the ATN SARPS which defines the requirements for ATN communications priorities and mobile network priorities.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements		3.4.1
COMR	The ATN shall provide means to define data communication that can be carried only over authorized paths for the traffic type and category specified by the user.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements		3.4.1
COMR	The ATN shall provide means to unambiguously address all ATN end and intermediate systems.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	04/02/1997	4.21
COMR	The ATN shall support data communication to fixed and mobile systems.	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	04/02/1997	4.11
COMR	The ATN shall use International Organization for Standardization(ISO) communication standards for open systems interconnect(OSI).	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	04/02/1997	4.15
COMR	The data link end-systems shall have the capability to notify the originator when a transmitted message has not successfully reached its addressee or has not been responded by the latter within a defined time frame.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	01/03/1995	4.5
COMR	The data link system shall ensure correct addressing of messages.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services EuroControl 6/22/98	06/22/1998	2
COMR	The data link system shall support the exchange of ATM messages to all suitably equipped aircraft receiving air traffic services.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	04/02/1997	4.16
COMR	The end system shall make provisions to ensure that the probability of not detecting a 255-octet message being mis-delivered, non-delivered or corrupted by the internet communications service is less than or equal to 10 -8 per message Note — It is assumed that ATN subnetworks will ensure data integrity consistent with this system level requirement	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	04/02/1997	7.1.2

Requirements Capture Matrix
TO-24, Task #2

Category	Requirement	Source Document	Date	Section/ Paragraph
COMR	The system should facilitate interoperability and seamless transmission across international boarders	RTCA 081-96/TMC-212, Operations Concept for Data Link Applications of Flight InformatServices	06/22/1998	2
COMR	The system will provide the capability for users to access and maintain voice and data link communications without conflict or interference. This must be possible without degradation of service (to include meeting acceptable delay and voice quality requirements)	Flight Management Systems-Air Traffic Management Next Generat(FANG) Required Capabilities, DOT/FAA/AND-98-13	06/22/1998	6
COMR	Where the absolute time of day is used within the ATN it shall be based on coordinated universal time (UTC)	"The ATN SARPS", Sub-Volume 1, Introductand System Level Requirements	06/22/1998	1
COMR	In 2015 the data communications system shall support simultaneous data communications up to a peak number of data link equipped aircraft (or vehicles)	Operational Requirements for the Aeronautical Data Link System, FAA/AFS/ATR/ANC/ARD/ASE,	06/22/1998	2
FR	A manual override should be provided for the automatic management of subnetworks	RTCA DO 238, Human Engineering Guidance For Data Link Systems	06/22/1998	3
FR	A positive indication of failures of the data link system and each of its functions should be provided	RTCA DO 238, Human Engineering Guidance For Data Link Systems	06/22/1998	3
FR	Aircrew shall be provided with information the surrounding traffic using the appropriate technology (e.g. CDTI)	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	06/22/1998	2
FR	All data link messages should contain a message send time that is generated by the sender's action to transmit the message.	RTCA DO 238, Human Engineering Guidance For Data Link Systems		1.2.2.2
FR	All times contained in data link messages should be referenced to Universal Coordinated Time	RTCA DO 238, Human Engineering Guidance For Data Link Systems	06/22/1998	2
FR	An indication of message send time or age based on send time should be available for display on the message display to help operators estimate data validity and for coordination	RTCA DO 238, Human Engineering Guidance For Data Link Systems	01/03/1995	2.4.7
FR	Any unrecognized or unreasonable entry should prompt an error message from the system and should not result in any data changes.	RTCA DO 238, Human Engineering Guidance For Data Link Systems	06/22/1998	2
FR	ATM data link services will depend on the end-to-end performance and quality of the entire chain of components contributing to a data link system, from the ground to the aircraft via the communication networks. An end-to-end approach must therefore apply at every level of design, manufacture, test, installation, certification, operation maintenance of a data link system.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	06/22/1998	3
FR	Downlinked selected aircraft parameters (e.g. auto flight system panel settings and FMS target values) should not be used in integrated co-operative ATM applications and in safety critical systems without establishing their absolute validity and their relevance to the intended flight profile of the aircraft prior to their transmissions	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	06/22/1998	3
FR	Ground end systems supporting the delivery of flight information services shall not deny access from aircraft end systems.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	04/02/1997	7.3.1
FR	If all pending messages are not displayed, information should be provided to notify the operator of the existence of a queue of these messages	RTCA DO 238, Human Engineering Guidance For Data Link Systems	06/22/1998	3
FR	If an error is detected in the data link message, the system should notify the sender with an informative, diagnostic error message.	RTCA DO 238, Human Engineering Guidance For Data Link Systems	06/22/1998	2
FR	In the event of link abortion, system shutdown, the ground and the airborne systems should support retention messages.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	06/22/1998	1
FR	Operational compatibility shall be maintained for all new data link services.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	06/22/1998	2
FR	Provisions should be made for automatic storage, and retrieving of data link messages. The crew should be able to edit old messages and send them as new messages. A facility to produce hard-copies should be provided in the cockpit.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98		8.3.1
FR	The <data link> sequence should be based on time at which the message was originated, i.e., sent. If a data link system detects an out of sequence situation, the receiver should be notified of the problem and the situation should be clarified as soon as possible	RTCA DO 238, Human Engineering Guidance For Data Link Systems		3.11.1.4
FR	The <data link> system should provide the information needed to assist the operator in determining the nature of the error and how the error could be corrected.	RTCA DO 238, Human Engineering Guidance For Data Link Systems	06/22/1998	2
FR	The data link message formatting function should ensure that the sender's message and intent is fully and accurately represented on the receiver's display.	RTCA DO 238, Human Engineering Guidance For Data Link Systems	06/22/1998	2
FR	The data link should automatically manage the communication subnetworks (e.g. HF, VHF, Satellite, Mode S) to ensure system availability, integrity, and acceptable performance.	RTCA DO 238, Human Engineering Guidance For Data Link Systems	02/01/1996	6.1.2 (9)
FR	The data link should ensure the data integrity of all received messages before making them available for display to the operator.	RTCA DO 238, Human Engineering Guidance For Data Link Systems		2.2.1.2
FR	The data link system shall adjust to changes in communication media (notably, VHF, Mode-S and Satellite) depending on technical availability	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98		6.1.1

Requirements Capture Matrix
TO-24, Task #2

Category	Requirement	Source Document	Date	Section/ Paragraph
FR	The data link system shall have the capability to inform its user on its current operational status and configuration(including the status of all automatic functions).	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98		1.2.3
FR	The data link system shall have the capability to receive, maintain, and manage a queue of incoming messages, to notify the user of its presence and to distribute them to flight deck and ground system displays and output devices.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	06/22/1998	2
FR	The data link system shall provide automatic error checking of user-composed, system-generated, and received messages, as well as informative error messages.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	01/03/1996	3.3.1
FR	The data link system shall provide the capability for the user to shut down a data link equipment where applicable.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	02/01/1996	6.1.1
FR	The data link system shall provide the capability to display the reception Logical Acknowledgment (LACK) messages	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	06/22/1996	3
FR	The data link system shall provide the capability to unambiguously identify and validate the source and destination end systems for each message transmitted through it	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	06/22/1998	1
FR	The data link system shall provide user access to data link message history	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	06/22/1998	5
FR	The data link system shall support distress and emergency functions. This includes a covert capability to deal with acts of unlawful interference.	Operational Requirements for Air Traffic Management (ATM) Air/Ground Data Communications Services, EuroControl 6/22/98	06/22/1998	3

Message Characteristics

Message Char. ID	Service	Function Name (Functional Capability)	ATM ATC	ATM Advisory	ATM Flow Control	AWIN Forecast	AWIN Nowcast	AWIN Emergency	Onboard Operator	Onboard Passenger	Ack Req	Auth Req	Data Sec	Data Strat	Data Pri Type	Data Naked Ack Req	Phase of Flight	Message Category	Uplink Msg Per Aircraft Per Domain	Downlink Msg Per Aircraft Per Domain	Uplink Size Bits	Uplink Compression Ratio	Downlink Size Bits
8	Traffic Management Synchronization Service	Process User Preferences	X								X	X				X	Arrival/ Departure	Advanced ATM	1	1	40		960
12	Traffic Management Synchronization Service	Project Aircraft In-flight Position and Identify Potential Conflicts	X								X	X	X				Arrival/ Departure	Air Traffic Information	300	1	224		56
3	Traffic Management Synchronization Service	Project Aircraft In-flight Position and Identify Potential Conflicts	X								X	X	X				Oceanic	ADS	1	129	128		144
4	Traffic Management Synchronization Service	Project Aircraft In-flight Position and Identify Potential Conflicts	X								X	X	X				Arrival/ Departure	ADS	1	112	128		144
5	Traffic Management Synchronization Service	Process User Preferences	X								X	X				X	Arrival/ Departure	Advanced ATM	1	1	40		960
6	Traffic Management Synchronization Service	Process User Preferences	X								X	X		X		X	Enroute	Advanced ATM	1	1	40		960
52	Flight Plan Services	Process Flight Plans and Amendments	X								X	X		X			Enroute	Pilot Controller Communications	10.2	17.4	118		34
7	Traffic Management Synchronization Service	Process User Preferences	X								X	X			X		Enroute	Advanced ATM	1	1	40		960
50	ATC Advisory Service	Provide In-flight or Pre-flight Traffic Advisories	X								X	X		X			Enroute	Pilot Controller Communications	10.2	17.4	118		34
24	Flight Plan Services	Process Flight Plans and Amendments	X													X	Arrival/ Departure	Delivery of Route Deviation Warnings	0.2	0.2	800		800
23	Flight Plan Services	Process Flight Plans and Amendments	X													X	Enroute	Delivery of Route Deviation Warnings	0.2		800		800
22	Flight Plan Services	Process Flight Plans and Amendments	X													X	Arrival/ Departure	Delivery of Route Deviation Warnings	0.2	0.2	800		800
15	Traffic Management Synchronization Service	Project Aircraft In-flight Position and Identify Potential Conflicts	X								X	X	X				Arrival/ Departure	Air Traffic Information	128	1	224		56
14	Traffic Management Synchronization Service	Project Aircraft In-flight Position and Identify Potential Conflicts	X								X	X			X		Oceanic	Air Traffic Information	250	1	224		56
13	Traffic Management Synchronization Service	Project Aircraft In-flight Position and Identify Potential Conflicts	X								X	X		X			Enroute	Air Traffic Information	250	1	224		56

Message Characteristics

Message Char. ID	Service	Function Name (Functional Capability)	ATM ATC	ATM Advisory	ATM Flow Control	AWIN Forecast	AWIN Nowcast	AWIN Emergency	Onboard Operator	Onboard Passenger	Ack Req	Auth Req	Data Tac	Data Scrn	Data Per Term	Data Issued As Req	Phase of Flight	Message Category	Uplink Msg Per Aircraft Per Domain	Downlink Msg Per Aircraft Per Domain	Uplink Size Bits	Uplink Compression Ratio	Downlink Size Bits
1	Traffic Management Synchronization Service	Project Aircraft In-flight Position and Identify Potential Conflicts	X								X	X	X				Arrival/ Departure	ADS	1	516	128		144
54	Flight Plan Services	Process Flight Plans and Amendments	X								X	X	X				Arrival/ Departure	Pilot Controller Communications - Initial	5	5	123		32
66	Traffic Management Strategic Flow Service	Provide Future NAS Traffic Projections	X								X	X					Oceanic	TFM Information	1	1	440		100
65	Traffic Management Strategic Flow Service	Provide Future NAS Traffic Projections	X								X	X					Enroute	TFM Information	1	1	880		100
64	Traffic Management Strategic Flow Service	Provide Future NAS Traffic Projections	X								X	X	X				Arrival/ Departure	TFM Information	2	2	880		800
60	Traffic Management Synchronization Service	Provide In-flight Sequencing, Spacing, and Routing Restrictions	X										X				Arrival/ Departure	Support Precision Landing	200		180		
59	Traffic Management Synchronization Service	Provide Pre-flight Runway, Taxi Sequence, and Movement Restrictions	X										X				Arrival/ Departure	Support Precision Landing	200		180		
57	Flight Plan Services	Process Flight Plans and Amendments	X								X	X		X			Preflight	Pre-Departure Clearance	1.25	2.25	1800		304
2	Traffic Management Synchronization Service	Project Aircraft In-flight Position and Identify Potential Conflicts	X								X	X	X				Enroute	ADS	1	129	128		144
54	ATC Advisory Service	Provide In-flight or Pre-flight Traffic Advisories	X								X	X	X				Arrival/ Departure	Pilot Controller Communications - Initial	6	6	123		32
53	Traffic Management Synchronization Service	Provide Pre-flight Runway, Taxi Sequence, and Movement Restrictions	X								X	X		X			Arrival/ Departure	Pilot Controller Communications - Full	10	10	123		32
63	Flight Plan Services	File Flight Plans and Amendments	X								X	X		X			Arrival/ Departure	Pilot Controller Communications - Full	10	10	123		32
52	ATC Advisory Service	Provide In-flight or Pre-flight Traffic Advisories	X								X	X	X				Arrival/ Departure	Pilot Controller Communications	9.8	13.1	123		32
62	Flight Plan Services	Process Flight Plans and Amendments	X								X	X	X				Arrival/ Departure	Pilot Controller Communications	9.8	13.1	123		32
51	ATC Advisory Service	Provide In-flight or Pre-flight Traffic Advisories	X								X	X			X		Oceanic	Pilot Controller Communications	10.2	17.6	118		34

Message Characteristics

Message Char. ID	Service	Function Name (Functional Capability)	ATM ATC	ATM Advisory	ATM Flow Control	AWIN Forecast	AWIN Nowcast	AWIN Emergency	Onboard Operator	Onboard Passenger	Ack Req	Auth Req	Data Tac	Data Strat	Data Far Term	Data Issued As Req	Phase of Flight	Message Category	Uplink Msg Per Aircraft Per Domain	Downlink Msg Per Aircraft Per Domain	Uplink Size Bits	Uplink Compression Ratio	Downlink Size Bits
51	Flight Plan Services	Process Flight Plans and Amendments	X								X	X			X		Oceanic	Pilot/Controller Communications	10.2	17.4	118		34
33	ATC Advisory Service	Provide In-flight or Pre-flight Traffic Advisories		X			X						X			X	Arrival/ Departure	FIS Planning - ATIS	1	600	460		56
10	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X			X									X	Enroute	Aircraft Originated Meteorological Observations	1	6	56		1760
11	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X			X									X	Oceanic	Aircraft Originated Meteorological Observations	1	5	56		1760
25	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X		X							X				Preflight	Departure ATIS	1	1	3200		64
26	ATC Advisory Service	Provide In-flight NAS Status Advisories		X		X							X				Preflight	Departure ATIS	1	1	3200		64
28	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X		X								X			Enroute	Arrival ATIS	1	1	3200		64
31	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X			X						X			X	Arrival/ Departure	FIS Planning ATIS	1	600	400		56
34	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X			X						X				Arrival/ Departure	FIS Planning Services	1	1	2100		64
35	Flight Plan Services	File Flight Plans and Amendments		X			X							X		X	Enroute	FIS Planning Services	150	6	2000		64
36	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X			X						X			X	Arrival/ Departure	FIS Planning Services	60	6	2000		64
27	ATC Advisory Service	Provide In-flight NAS Status Advisories		X		X								X			Enroute	Arrival ATIS	1	1	3200		64
67	Traffic Management Strategic Flow Service	Provide Future NAS Traffic Projections			X						X	X	X	X			Arrival/ Departure	TFM Information	0.5	0.5	500		100
61	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories				X							X				Enroute	Surface Conditions			28800	20	
32	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories				X											Arrival/ Departure	En Route Backup Strategic General Imagery			2880000	10	

Message Characteristics

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31	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories				X								X			Enroute	En Route Backup Strategic General Imagery			2800000	10	
27	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories				X									X		Arrival Departure	Destination Field Conditions			1300	10	
26	ATC Advisory Service	Provide In-flight NAS Status Advisories		X		X								X			Enroute	Arrival ATIS	1	1	3200		64
26	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X		X								X			Enroute	Arrival ATIS	1	1	3200		64
25	ATC Advisory Service	Provide In-flight NAS Status Advisories		X		X							X				Preflight	Departure ATIS	1	1	3200		64
25	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X		X							X				Preflight	Departure ATIS	8	1	3200		64
67	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories				X							X				Enroute	Surface Conditions			23400	20	
63	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories				X								X			Arrival Departure	Surface Conditions			28800	20	
36	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X			X						X			X	Arrival Departure	FIS Planning Services	60	6	2000		64
21	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	Connection				20	306000
33	ATC Advisory Service	Provide In-flight or Pre-flight Traffic Advisories		X			X						X			X	Arrival Departure	FIS Planning ATIS	1	600	400		56
19	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	Connection				60	362000
18	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X		X				X				Arrival Departure	AUTOMET		30			430
17	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X		X					X			Enroute	AUTOMET		1.6			430

Message Characteristics

Message Char. ID	Service	Function Name (Functional Capability)	ATM ATC	ATM Advisory	ATM Flow Control	AWIN Forecast	AWIN Nowcast	AWIN Emergency	Onboard Operator	Onboard Passenger	Ack Req	Auth Req	Data Tag	Data Sized	Data For Term	Data Issued As Req	Phase of Flight	Message Category	Uplink Msg Per Aircraft Per Domain	Downlink Msg Per Aircraft Per Domain	Uplink Size Bits	Uplink Compression Ratio	Downlink Size Bits
16	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X		X				X				Arrival/ Departure	AUTOMET		100			1430
28	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X				X			X			Enroute	En Route Backup Strategic General Imagery			2560000	10	
30	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X				X			X			Enroute	En Route Backup Strategic General Imagery			2000000	10	
11	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X			X									X	Oceanic	Aircraft Originated Meteorological Observations	1	9	56		1792
10	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X			X									X	Enroute	Aircraft Originated Meteorological Observations	1	9	56		1760
23	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X			X						X			X	Arrival/ Departure	FIS Planning - ATIS	1	800	406		56
21	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Arrival/ Departure	Convection				50	212000
46	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Arrival/ Departure	Icing/ Flight Conditions			45000	50	
74	Flight Plan Services	Process Flight Plans and Amendments					X								X		Arrival/ Departure	Winds/ Temperature			64000	60	
73	Flight Plan Services	Process Flight Plans and Amendments					X							X			Enroute	Winds/ Temperature			283000	20	
72	Flight Plan Services	Process Flight Plans and Amendments					X							X			Enroute	Winds/ Temperature			64000	56	
71	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	Turbulence			252000	60	
70	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	Turbulence			131000	20	

Message Characteristics

Message Char. ID	Service	Function Name (Functional Capability)	ATM ATC	ATM Advisory	ATM Flow Control	AWIN Forecast	AWIN Nowcast	AWIN Emergency	Onboard Operator	Onboard Passenger	Ack Req	Auth Req	Data Tx	Data Start	Data For Term	Data Issued As Req	Phase of Flight	Message Category	Uplink Msg Per Aircraft Per Domain	Downlink Msg Per Aircraft Per Domain	Uplink Size Bits	Uplink Compression Ratio	Downlink Size Bits
69	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	Turbulence			27000	50	
68	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	Turbulence			27000	50	
58	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X								X		Arrival/ Departure	Radar Mosaic			7350	10	
34	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories		X			X						X				Arrival/ Departure	FIS Planning Services	1	1	2100		64
47	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	Icing/ Flight Conditions			27000	50	
9	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Arrival/ Departure	Aircraft Originated Meteorological Observations	1	2	96		1760
45	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	Icing/ Flight Conditions			21000	20	
44	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	Icing/ Flight Conditions			45000	50	
43	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Arrival/ Departure	Icing			5513	10	
42	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	General Hazard			350000	20	
41	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Enroute	General Hazard			144000	50	
40	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X									X	Oceanic	General Hazard			144000	50	

Message Char. ID	Service	Function Name (Functional Capability)	ATM ATC	ATM Advisory	ATM Flow Control	AWIN Forecast	AWIN Nowcast	AWIN Emergency	Onboard Operator	Onboard Passenger	Ack Req	Auth Req	Data Tac	Data Strat	Data Per Term	Data Issued As Req	Phase of Flight	Message Category	Uplink Msg Per Aircraft Per Domain	Downlink Msg Per Aircraft Per Domain	Uplink Size Bits	Uplink Compression Ratio	Downlink Size Bits
75	Flight Plan Services	Process Flight Plans and Amendments					X								X		Arrival/ Departure	Winds/ Temperatures			64000	50	
35	Flight Plan Services	File Flight Plans and Amendments		X			X							X		X	Enroute	FIS Planning Services	150	4	2000		64
46	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories						X								X	Arrival/ Departure	Low Level Wind Shear			480	10	
105	On-Board Service	Provide Public Communications							X	X	X	X			X		Enroute	Passenger Services On Board Phone	0	34.2	432000	432000	432000
56	Aeronautical Operational Control (AOC)	Monitor Flight Progress - AOC							X					X			Oceanic	Position Reports	8		10		80
16	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X		X				X				Arrival/ Departure	AUTOMET		100			430
83	On-Board Service	Provide Administrative Flight Information							X		X	X			X		Arrival/ Departure	Airline Business Support Passenger Re-Accomodation	80	80	3200	480	480
82	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Arrival/ Departure	Airline Business Support Passenger Profiling	8	2	5200	480	480
81	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Oceanic	Airline Business Support Passenger Profiling	2	2	5200	480	480
80	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Enroute	Airline Business Support Passenger Profiling	2	2	5200	480	480
79	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Arrival/ Departure	Airline Business Support Passenger Profiling	2	2	5200	480	480
78	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Arrival/ Departure	Airline Business Support Electronic Database Updating	3	6	5200	480	480
76	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Enroute	Airline Business Support Electronic Database Updating	3	6	5200	480	480

Message Char. ID	Service	Function Name (Functional Capability)	ATM ATC	ATM Advisory	ATM Flow Control	AWIN Forecast	AWIN Nowcast	AWIN Emergency	Onboard Operator	Onboard Passenger	Ack Req	Auth Req	Data Tac	Data Strat	Data Far Term	Data Issued As Req	Phase of Flight	Message Category	Uplink Msg Per Aircraft Per Domain	Downlink Msg Per Aircraft Per Domain	Uplink Size Bits	Uplink Compression Ratio	Downlink Size Bits
86	On Board Service	Provide Administrative Flight Information							X		X	X			X		Arrival/ Departure	Airline Business Support: Passenger Re-Accomodation	60	60	5200	480	480
59	Aeronautical Operational Control (AOC)	Monitor Flight Progress - AOC							X					X			Enroute	Position Reports	2		10		80
49	Aeronautical Operational Control (AOC)	Schedule, Dispatch, and Manage Aircraft Flights							X		X	X	X				Arrival/ Departure	Out/ Off/ On/ In	0.20	0.30	10		10
39	Aeronautical Operational Control (AOC)	Collaborate with ATM on NAS Projections and User Preferences							X		X	X		X			Arrival/ Departure	Gate Assignment	0.5	0.5	10		10
36	Flight Plan Services	File Flight Plans and Amendments							X		X	X		X			Preflight	Flight Plans	0.5	0.5	10		3000
37	Aeronautical Operational Control (AOC)	Monitor Flight Progress - AOC							X							X	Enroute	Flight Data Recorder		0.5			3000
28	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories							X							X	Enroute	Diagnostic Data		22			56
18	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X		X				X				Arrival/ Departure	AUTOMET		30			430
17	ATC Advisory Service	Provide In-flight or Pre-flight Weather Advisories					X		X					X			Enroute	AUTOMET		1.6			430
77	On Board Service	Provide Administrative Flight Information							X		X	X		X			Oceanic	Airline Business Support: Electronic Database Updating	3	6	5200	480	480
95	On Board Service	Provide Operational Flight Information							X		X	X			X		Oceanic	Airline Maintenance Support: Non-Routine Maintenance/ Information Reporting	3	3	480	10400	10400
104	On Board Service	Provide Administrative Flight Information							X		X	X		X			Arrival/ Departure	Airline Maintenance Support: Routing Maintenance/ Information Reporting	3	3	480	5200	5200
103	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Oceanic	Airline Maintenance Support: Routing Maintenance/ Information Reporting	3	3	480	5200	5200

Message Characteristics

Message Char. ID	Service	Function Name (Functional Capability)	ATM ATC	ATM Advisory	ATM Flow Control	AWIN Forecast	AWIN Nowcast	AWIN Emergency	Onboard Operator	Onboard Passenger	Ack Req	Auth Req	Data Tac	Data Strat	Data Per Term	Data Issued As Req	Phase of Flight	Message Category	Uplink Msg Per Aircraft Per Domain	Downlink Msg Per Aircraft Per Domain	Uplink Size Bits	Uplink Compression Ratio	Downlink Size Bits
102	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Enroute	Airline Maintenance Support: Routing Maintenance/ Information Reporting	3	2	480	5200	5200
101	On Board Service	Provide Administrative Flight Information							X		X	X		X			Preflight	Airline Maintenance, Support: Routing Maintenance/ Information Reporting	3	3	480	5200	5200
100	On-Board Service	Provide Operational Flight Information							X		X	X			X		Arrival/ Departure	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)	6	6	480	10400	10400
99	On-Board Service	Provide Operational Flight Information							X		X	X			X		Oceanic	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)	6	6	480	10400	10400
98	On-Board Service	Provide Operational Flight Information							X		X	X			X		Enroute	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)	6	6	480	10400	10400
97	On-Board Service	Provide Administrative Flight Information							X		X	X			X		Enroute	Airline Business Support: Passenger Re-Accomodation	80	80	5200	480	480
96	On-Board Service	Provide Operational Flight Information							X		X	X			X		Arrival/ Departure	Airline Maintenance Support: (Non-Routine Maintenance/ Information Reporting	3	3	480	10400	10400
95	On-Board Service	Provide Administrative Flight Information							X		X	X			X		Oceanic	Airline Business Support: Passenger Re-Accomodation	80	80	5200	480	480
94	On-Board Service	Provide Operational Flight Information							X		X	X			X		Enroute	Airline Maintenance Support: (Non-Routine Maintenance/ Information Reporting	3	3	480	10400	10400
93	On-Board Service	Provide Operational Flight Information							X		X	X			X		Preflight	Airline Maintenance Support: (Non-Routine Maintenance/ Information Reporting	3	3	480	10400	10400

Message Characteristics

Message Char. ID	Service	Function Name (Functional Capability)	ATM ATC	ATM Advisory	ATM Flow Control	AWIN Forecast	AWIN Nowcast	AWIN Emergency	Onboard Operator	Onboard Passenger	Ack Req	Auth Req	Data Tse	Data Evnt	Data Per Turn	Data Issued As Req	Phase of Flight	Message Category	Uplink Msg Per Aircraft Per Domain	Downlink Msg Per Aircraft Per Domain	Uplink Size Bits	Uplink Compression Ratio	Downlink Size Bits
92	On-Board Service	Provide Operational Flight Information							X		X	X			X		Arrival/ Departure	Airline Maintenance Support: In-Flight Emergency Support	1	4	2800	240	240
91	On-Board Service	Provide Operational Flight Information							X		X	X			X		Enroute	Airline Maintenance Support: In-Flight Emergency Support	1	4	2800	240	240
90	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Arrival/ Departure	Airline Maintenance Support: Electronic Database Updating	3	2	480	10400	10400
89	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Oceanic	Airline Maintenance Support: Electronic Database Updating	3	2	480	10400	10400
88	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Enroute	Airline Maintenance Support: Electronic Database Updating	3	3	480	10400	10400
87	On-Board Service	Provide Administrative Flight Information							X		X	X		X			Arrival/ Departure	Airline Maintenance Support: Electronic Database Updating	3	3	480	10400	10400
57	On-Board Service	Provide Operational Flight Information							X		X	X			X		Preflight	Airline Maintenance Support: On-Board Trouble Shooting (non-routine)	6	6	480	10080	10080

Message Characteristics

Uplink Data Rate BPS	Downlink Data Rate BPS	Domain Name	Domain Assumptions	Message Char. Source Title	Source Comment	Source Performance Reqs.	End To End Delay (Mean)	End To End Delay 95%	Availability %	Integrity	Data Link Equipage Comment ID	Comments
0.07	2	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	3	5	99.9	0.000001	1	
112	1	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	0.6	0.7	99.999	0.0000[illegible]	2	
0.08	12	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Derived from DO-237 en route	Operational Requirements for the Aeronautical Data Link System	10	20	99.999	0.000001	4	
0.2	27	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	3	5	99.999	0.000001	1	
0.07	2	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	3	5	99.9	0.000001	2	
0.02	1	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	10	13	99.999	0.000001	3	
0.8	0.39	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	10	13	99.9	0.000001	3	
0.03	1	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Derived from DO 237 en route	Operational Requirements for the Aeronautical Data Link System	10	13	99.9	0.000001	4	
0.8	0.39	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	10	13	99.9	0.000001	3	
0.3	2.3	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	5	5	99.9	0.0000[illegible]	1	
0.1	0.1	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	3	5	99.9	0.000001	3	
0.3	0.3	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	3	5	99.9	0.00001	1	
17	0.08	Terminal	Average flight duration is 10 minutes per terminal domain	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	0.6	0.7	99.999	0.00001	2	
37	0.04	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	0.2	0.7	99.999	0.000001	4	
37	0.04	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	5	10	99.999	0.000001	3	

Uplink Data Rate BPS	Downlink Data Rate BPS	Domain Name	Domain Assumptions	Message Char. Source Title	Source Comment	Source Performance Reqs.	End To End Delay (Mean)	End To End Delay 95%	Availability %	Integrity	Data Link Equipage Comment ID	Comments
0.2	131	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	2	2.2	99.999	0.000001	2	
1	0.3	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	3	5	99.2	0.00001	2	
1	0.1	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	10	20	99.8	0.000001	3	
1	0.1	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	15	55	98.9	0.000001	3	
3	3	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001	2	
33		Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	2	2.2	99.999	0.000001	1	
33		Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	5	7	95	0.000001	2	ILS and or marker beacon
13	3	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	96.2	0.00001	2	
0.09	12	En Route	Average flight duration is 25 minutes per en route center.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	10	20	99.039	0.000001	3	
1	0.3	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	3	5	99.9	0.00001	2	
2	0.5	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	3	5	99.9	0.00001	2	
2	0.5	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	3	5	99.8	0.00001	2	
2	0.22	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	3	5	99.9	0.000001	1	
2	0.22	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	3	5	99.9	0.000001	1	
0.8	0.39	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Derived from Table F-3	Operational Requirements for the Aeronautical Data Link System	10	13	99.9	0.000001	4	

Message Characteristics

Uplink Data Rate BPS	Downlink Data Rate BPS	Domain Name	Domain Assumptions	Message Char. Source Title	Source Comment	Source Performance Reqs.	End To End Delay (Mean)	End To End Delay 95%	Availability %	Integrity	Data Link Exchange Command ID	Comments
0.8	0.32	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Derived from Table F-3	Operational Requirements for the Aeronautical Data Link System	10	13	99.9	0.000001	4	
1	0.09	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001	1	
0.04	6	En Route	Average flight duration is 25 minutes per en route center.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	15	65	95	0.000001	3	
0.04	6	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Derived from DO 237 en route	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.000001	3	
37	1	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001	2	
32	1	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001	2	
32	1	En Route	Average flight duration is 25 minutes per en route center.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Derived from Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001	2	
1	0.09	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001	1	
230	0.1	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001	2	
34	0.17	En Route	Average flight duration is 25 minutes per en route center.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001	3	
217	8	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001	1	
32	8	En Route	Average flight duration is 25 minutes per en route center.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Derived from Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001	2	
8	2	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001	1	
		En Route	Average flight duration is 25 minutes per en route center.	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Far Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		Area of Regard (Area 1500nm, Surface, Time 120 min)
		Terminal	Average flight duration is 10 minutes per terminal domain.	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.6.3 (Terminal Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		1500nm(2) Single alt 10 pict

Uplink Data Rate BPS	Downlink Data Rate BPS	Domain Name	Domain Assumptions	Message Char. Source Title	Source Comment	Source Performance Reqs.	End To End Delay (Mean)	End To End Delay 95%	Availability %	Integrity	Data Link Equipage Comment ID	Comments
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Tactical)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		1800nm(2) Single Alt 10 pct
		Terminal	Average flight duration is 10 minutes per terminal domain.	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	3.5.3 (Terminal Tactical)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		5nm(2) surface 1 pct
32	1	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	Derived from Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001	2	
32	1	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	Derived from Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001	2	
32	1	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001	2	
32	1	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001	2	
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Tactical)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		1500nm(2) Surface 300 min
		Terminal	Average flight duration is 10 minutes per terminal domain.	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (Terminal Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		150nm(2) Surface 300 min
217	1	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001	1	
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Near Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		500nm(2) 50K ft 70min
1	8.09	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001	1	
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.4 (En Route Far Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		Area of Regard (Area 1500nm, Altitude 50K ft, Time 300 min)
	4300	Terminal	Average flight duration is 10 minutes per terminal domain	DO-237 Aeronautical Spectrum Planning for 1997-2010	5.1.2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001		
	19	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	5.1.2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001		

AAT TC24

5/21/2000

Uplink Data Rate BPS	Downlink Data Rate BPS	Domain Name	Domain Assumptions	Message Class, Source Title	Source Comment	Source Performance Reqs.	End To End Delay (Mean)	End To End Delay 95%	Availability %	Integrity	Data Link Equipage Comment ID	Comments
	7168	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	6.1.2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001		
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Far Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		Area of Regard (Area 1500nm, Single altitude, 10 pixl)
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Near Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		1500nm(2) Single Alt 10 pixl
0.04	6	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Derived from DO 237 en route	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.000001	3	
0.04	6	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001	3	
1	0.02	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001	1	
		Terminal	Average flight duration is 10 minutes per terminal domain.	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (Terminal Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		1500nm(2) 50K ft 300 min
		Terminal	Average flight duration is 10 minutes per terminal domain.	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (Terminal Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		1500nm(2) 50K ft 300 min
		Terminal	Average flight duration is 10 minutes per terminal domain.	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (Terminal Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		1500nm(2) 50K ft 300 min
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Near Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		500nm(2) 50K ft 70 min
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Far Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		Area of Regard (Area 1500nm, Altitude 50K ft, Time 300 min)
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Tactical)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		125nm(2) 20 K ft 5 pixl
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Near Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		500nm(2) 50K ft 70min

Message Characteristics

Uplink Data Rate BPS	Downlink Data Rate BPS	Domain Name	Domain Assumptions	Message Char. Source Title	Source Comment	Source Performance Reqs	End To End Delay (Mean)	End To End Delay 95%	Availability %	Integrity	Data Link Equipage Comment ID	Comments
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Far Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		Area of Regard (Area 1500nm, Altitude 50K ft, Time 300 min)
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Far Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		1500nm(2) 50K ft 300 min
		Terminal	Average flight duration is 15 minutes per terminal domain.	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	3.5.3 (Terminal Tactical)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		35nm(2) 15 k ft 1 pict
200	0.1	Airport	Average flight duration is 15 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001	2	
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Tactical)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		125nm(2) 20 K ft 5 pict
0.09	8	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001	1	
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Near Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		500nm(2) 50K ft 70min
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Far Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		Area of Regard (Area 1500nm, Altitude 50K ft, Time 300 min)
		Terminal	Average flight duration is 16 minutes per terminal domain.	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	3.5.3 (Terminal Tactical)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		35nm(2) 15 k ft 1 pict
		En Route	Average flight duration is 26 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Near Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		500nm(2) 50K ft 70min
82		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Far Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		Area of Regard (Area 1500nm, Altitude 50K ft, Time 300 min)
		En Route	Average flight duration is 25 minutes per en route center	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems, Phase 1 Report	Sect 3.5.3 (En Route Far Term Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		1500nm(2) 50K ft 300 min

Uplink Data Rate BPS	Downlink Data Rate BPS	Domain Name	Domain Assumptions	Message Char. Source Title	Source Comment	Source Performance Reqs	End To End Delay (Mean)	End To End Delay 95%	Availability %	Integrity	Data Link Equipage Comment ID	Comments
		Terminal	Average flight duration is 10 minutes per terminal domain	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems. Phase 1 Report	Sect 3.5.3 (Terminal Strategic)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		1500nmi(2) 50K 1 300 pos
84	0.17	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	Table F-3	Operational Requirements for the Aeronautical Data Link System	15	55	99.8	0.000001	3	
		Terminal	Average flight duration is 10 minutes per terminal domain	Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems. Phase 1 Report	3.5.3 (Terminal Tactical)	Operational Requirements for the Aeronautical Data Link System	15	55	95	0.00001		10nmi(2) surface 1 pos
4.8	4.8	En Route	Average flight duration is 25 minutes per en route center	SAIC Team		SAIC Team	15	55	95	0.00001		A/C capacity = 275 pass. Load factor = 85%. For on-board phone and own phone users, assume 5% of the time passengers are using the phone with call duration of 3 minutes and 4800 bps vocoder.
		En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	Mobile Satellite Service (MSS) Study Final Report	A-8	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001		
	7168	Airport	Average flight duration is 10 minutes per airport domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	5.1.2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001		
1258	118	Airport	Average flight duration is 19 minutes per airport domain.	SAIC Team		SAIC Team	15	55	95	0.00001		
1258	118	Terminal	Average flight duration is 10 minutes per terminal domain	SAIC Team		SAIC Team	15	55	95	0.00001		
1258	118	En Route	Average flight duration is 25 minutes per en route center	SAIC Team		SAIC Team	15	55	95	0.00001		
1258	118	En Route	Average flight duration is 25 minutes per en route center	SAIC Team		SAIC Team	15	55	95	0.00001		
1258	118	Airport	Average flight duration is 10 minutes per airport domain.	SAIC Team		SAIC Team	15	55	95	0.00001		
1258	118	Terminal	Average flight duration is 10 minutes per terminal domain.	SAIC Team		SAIC Team	15	55	95	0.00001		
1258	118	En Route	Average flight duration is 25 minutes per en route center	SAIC Team		SAIC Team	15	55	95	0.00001		

Uplink Data Rate BPS	Downlink Data Rate BPS	Domain Name	Domain Assumptions	Message Char. Source Title	Source Comment	Source Performance Reqs.	End To End Delay (Mean)	End To End Delay 95%	Availability %	Integrity	Data Link Equipage Comment ID	Comments
1758	116	Terminal	Average flight duration is 10 minutes per terminal domain	SAIC Team		SAIC Team	15	55	95	0.00001		
		En Route	Average flight duration is 25 minutes per en route center	Mobile Satellite Service (MSS) Study Final Report	A-8	Operational Requirements for the Aeronautical Data Link System	15	56	99.9	0.000001		
		Airport	Average flight duration is 10 minutes per airport domain.	Mobile Satellite Service (MSS) Study Final Report	A-8	Operational Requirements for the Aeronautical Data Link System	10	17	99.9	0.000001		
		Airport	Average flight duration is 10 minutes per airport domain.	Mobile Satellite Service (MSS) Study Final Report	A-8	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001		
		Airport	Average flight duration is 10 minutes per airport domain.	Mobile Satellite Service (MSS) Study Final Report	A-8	Operational Requirements for the Aeronautical Data Link System	15	56	99.9	0.00001		
	1.67	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	5.1.1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001		
	126	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	5.1.1	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.000001		
	4300	Terminal	Average flight duration is 10 minutes per terminal domain.	DO-237 Aeronautical Spectrum Planning for 1997-2010	5.1.2	Operational Requirements for the Aeronautical Data Link System	15	55	99.9	0.00001		
	181	En Route	Average flight duration is 25 minutes per en route center	DO-237 Aeronautical Spectrum Planning for 1997-2010	5.1.2	Operational Requirements for the Aeronautical Data Link System	15	65	99.9	0.00001		
1256	3168	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	SAIC Team		SAIC Team	15	55	95	0.00001		
2800	480	En Route Oceanic	Average flight duration is 3 hours per oceanic domain	SAIC Team		SAIC Team	15	55	95	0.00001		
2460	480	Terminal	Average flight duration is 10 minutes per terminal domain.	SAIC Team		SAIC Team	15	55	25	0.00001		
2400	480	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	SAIC Team		SAIC Team	15	55	95	0.00001		

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Message Characteristics

Uplink Data Rate BPS	Downlink Data Rate BPS	Domain Name	Domain Assumptions	Message Char. Source Title	Source Comment	Source Performance Reqs	End To End Delay (Mean)	End To End Delay 95%	Availability %	Integrity	Data Link Equipage Comment ID	Comments
2400	480	En Route	Average flight duration is 25 minutes per en route center.	SAIC Team		SAIC Team	15	55	95	0.00001		
2400	480	Airport	Average flight duration is 10 minutes per airport domain.	SAIC Team		SAIC Team	15	55	65	0.00001		
2400	2400	Terminal	Average flight duration is 10 minutes per terminal domain.	SAIC Team		SAIC Team	15	55	95	0.00001		
2400	2400	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	SAIC Team		SAIC Team	15	55	95	0.00001		
2400	2400	En Route	Average flight duration is 25 minutes per en route center	SAIC Team		SAIC Team	15	55	95	0.00001		
1236	118	En Route	Average flight duration is 25 minutes per en route center	SAIC Team		SAIC Team	15	55	95	0.00001		
2400	480	Terminal	Average flight duration is 10 minutes per terminal domain	SAIC Team		SAIC Team	15	55	95	0.00001		
1256	118	En Route Oceanic	Average flight duration is 3 hours per oceanic domain.	SAIC Team		SAIC Team	15	55	95	0.00001		
2400	480	En Route	Average flight duration is 25 minutes per en route center	SAIC Team		SAIC Team	15	55	95	0.00001		
2400	480	Airport	Average flight duration is 10 minutes per airport domain.	SAIC Team		SAIC Team	15	55	95	0.00001		

Message Characteristics

Uplink Data Rate BPS	Downlink Data Rate BPS	Domain Name	Domain Assumptions	Message Char. Source Title	Source Comment	Source Performance Reqs.	End To End Delay (Mean)	End To End Delay 95%	Availability %	Integrity	Data Link Equipage Component ID	Comments
2400	240	Terminal	Average flight duration is 10 minutes per terminal domain	SAIC Team		SAIC Team	15	55	95	0.0000		
2400	240	En Route	Average flight duration is 25 minutes per en route center	SAIC Team		SAIC Team	15	55	85	0.0000		
2400	480	Terminal	Average flight duration is 10 minutes per terminal domain.	SAIC Team		SAIC Team	15	55	95	0.0000		
2400	480	En Route Oceanic	Average flight duration is 8 hours per oceanic domain.	SAIC Team		SAIC Team	15	55	95	0.0000		
2400	480	En Route	Average flight duration is 25 minutes per en route center	SAIC Team		SAIC Team	15	55	95	0.0000		
2400	480	Airport	Average flight duration is 10 minutes per airport domain.	SAIC Team		SAIC Team	15	55	95	0.0000		
2400	2400	Airport	Average flight duration is 10 minutes per airport domain.	SAIC Team		SAIC Team	15	55	95	0.0000		

Communications System Architecture Development For Air Traffic Management & Aviation Weather Information Dissemination

Research Task Order 24

Subtask 4.5, Development of Preliminary/Candidate System Architectural Concepts

(Task 4.0)

Prepared By

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TRW

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NASA Glenn Research Center
Under
Contract NAS2-98002

July 14, 1999

Table of Contents

1 Executive Summary

This report provides a discussion of needed communication capabilities in 2015, outlines assessment criteria to apply to candidate architectures, and presents alternative concepts for an overall 2015 communication architecture. It serves as the foundation for continued work under NASA AATT RTO 24 to develop engineering-level detail for the architecture and transition plans from the current NAS architecture to a new architecture for 2015. It is based on the needs identified in Task 1, knowledge of communications and information technology advances, and projected changes in the FAA's NAS architecture.

Although the focus of these efforts is on documented user needs, these concepts recognize that user demands often derive from "wants" rather than needs. Awareness of what emerging technology can provide often stimulates a perception of needs. Assessing the quantitative benefits of satisfying specific needs will be left to Task 5. Similarly ranking and selection of specific architectural concepts is deferred to tasks 5 and 6. It is expected that 5 and 6 will serve as a synthesis of the work performed in tasks 1 through 4.

There are eleven fundamental services that any communication architecture for 2015 must support:

- Flight Planning Service
- ATC Separation Assurance Service
- ATC Advisory Service
- Traffic Management Synchronization Service
- Traffic Management Strategic Flow Service
- Emergency and Alerting Service
- Navigation Service
- Airspace Management Service
- Infrastructure/Information Management Service
- Aeronautical Operational Control
- Onboard Services

Each of these services is described by the drivers creating the need for the service and the constraints that limit the service. Candidate Communications System Architectures (CSAs) must address both the drivers and constraints to be viable. This report presents the opposing forces for each service and then derives a series of possible concepts for creating CSAs. These concepts are focused on the tradeoffs between a distributed functional allocation versus a centralized allocation and take into account the ideas of Free Flight, Distributed Air-Ground (DAG) communications, and Collaborative Decision Making (CDM). In addition, each concept must be viewed from the perspective of three separate user classes: air transport, high-end General Aviation (GA)/Business Aviation (BA), and low-end GA, as well as the service providers (e.g. AOC) and air traffic control (ATC). Finally, in keeping with the need to accelerate the introduction of weather information services, the candidate CSAs are characterized by both an AWIN and an ATM focus. It should be noted that ultimately a hybrid of these concepts would be needed based on industry-projected equipage rates and costs as well as the availability and advantages of various communication technologies.

Instead of presenting the CSAs in the form of block diagrams, focusing on an engineering view of the architecture, this report focuses on the users' perspective by presenting scenarios against which each of these concepts could be evaluated. The scenarios will depict how services are provided to users today, and how they could be provided to users in 2015.

Throughout the report, the eleven services are used to anchor the CSAs together and to provide a common thread throughout all TO24 subtasks. A network-centric focus has been maintained in keeping with the overall worldwide evolution of communication systems. Care has been taken to facilitate the combination and extraction of elements from the multiple CSAs. It is hoped that this approach will provide a solid foundation as well as maximum flexibility for follow-on work.

2 Introduction

2.1 Overview of Task Four

Task 4 is intended to develop a series of high-level Communications System Architecture (CSA) concepts to support the delivery of various services to all classes of users of the National Airspace System (NAS). These services are:

- Flight Planning Service
- ATC Separation Assurance Service
- ATC Advisory Service
- Traffic Management Synchronization Service
- Traffic Management Strategic Flow Service
- Emergency and Alerting Service
- Navigation Service
- Airspace Management Service
- Infrastructure/Information Management Service
- Aeronautical Operational Control
- Onboard Services

Each of these services can be viewed from the perspective of the different classes of users as well as from the point of view of the service providers. Communication between the users and service providers can be characterized by the type of traffic, direction of traffic, and the drivers and constraints affecting the service. In task four, a series of candidate Communication System Architectures (CSAs) are developed using these views. Subsequent tasks are defined to develop one of these architectures for both AWIN and ATM. Ultimately, the selected architecture will be defined "end-to-end" and will include ground systems, avionics, and the connecting networks.

The fundamental modes of communications that are likely to be available in 2015 are similar to those available today and include basic VHF or HF radio communications (voice or data), Satellite Communications (SATCOM), or data exchange via Mode-S. For the purposes of task four, very little attention has been paid to the specific mode of communication to be used in delivering a particular type of service. Rather, emphasis has been placed on who needs the data and how the data are employed in using the NAS. The key to answering these questions requires a review of the underlying drivers and constraints for each service.

Because of the concurrency of task one (identification of user needs) and the fact that task two (functional requirements) extends beyond task four, the findings of these two tasks do not feed directly into task four. For defining architectural concepts, though, it was necessary to gain a sense of the needs. This was done by collaboration between people working on the different tasks, rather than acquiring all the details.

Finally, task 4 identifies the criteria for the quantitative and qualitative assessments of candidate CSAs. The assessments, when completed as part of tasks five and six will concentrate on engineering requirements and will address the benefits to specific types of users, thereby driving user equipage decisions.

2.2 Overview of the Document:

Section one provides an executive summary of the overall report.

Section two provides an introduction to task four, the layout of the task four report, and a short description on the approach taken to develop the candidate CSAs.

Section three of this report provides a description of each service, the types of data and the directional flow of the data within that service offering, and a discussion of the drivers and restraining factors surrounding each service. It also describes which users are consumers and creators of the data.

Section four outlines the various concepts derived from the review of services and then discusses each in the context of overall concepts shaping the evolution of the NAS (e.g., Free Flight, Distributed Air Ground (DAG), Collaborative Decision Making (CDM), and the Small Aircraft Transportation System (SATS). Both present and future services are discussed.

Section five provides a discussion of the assessment criteria by which each CSA would need to be evaluated.

Appendix A provides service definitions according to NAS documentation, and appendix B further discusses trends and forecasting in technology.

2.3 Summary of Approach

Task one and task four were executed concurrently to allow for the development of a common set of services around which both the user needs identification process and the candidate CSA development could take place. Once the services were defined, the focus turned to identifying the various users and service providers that would need to use the candidate architecture. In parallel, work began on identifying the types of criteria that would be used to evaluate the architecture. Throughout these efforts, the team worked to separate those considerations that were technology or media based from those that were procedural in nature.

Brainstorming sessions were held with the overall team to postulate the various architectural concepts that appear in this report. Drawing on the extensive literature base collected for tasks one through three and the collective experience of the team, concepts were identified that married aspects of major initiatives such as Free flight, DAG, CDM, and SATS together with the current state of the art in communication technologies and capabilities. These capabilities were then extended and evolved based on various predictive factors such as rate of processor speed growth, the expected launch of data link capabilities, and the rate at which new equipment could be developed and fielded.

Care was taken throughout the development of the candidate CSAs to maintain flexibility for the follow-on tasks. The use of the categories the FAA utilized to structure the NAS technical architecture (i.e., user needs categorized by services and capabilities) will facilitate tasks five through seven and the consideration of transition plans in task eight.

3 Description of Needed Capabilities for 2015

All of the user needs identified in section one can be grouped around the eleven services used to provide ATM and AWIN capability. The figure below illustrates these services and provides example capabilities for each. The rest of this section outlines each service including the types and flow of data that will be used in any new communications architecture. The forces driving the need for a particular service in today's environment as well as the future are identified. Opposing or restraining factors are also noted that will impede the delivery of each service.

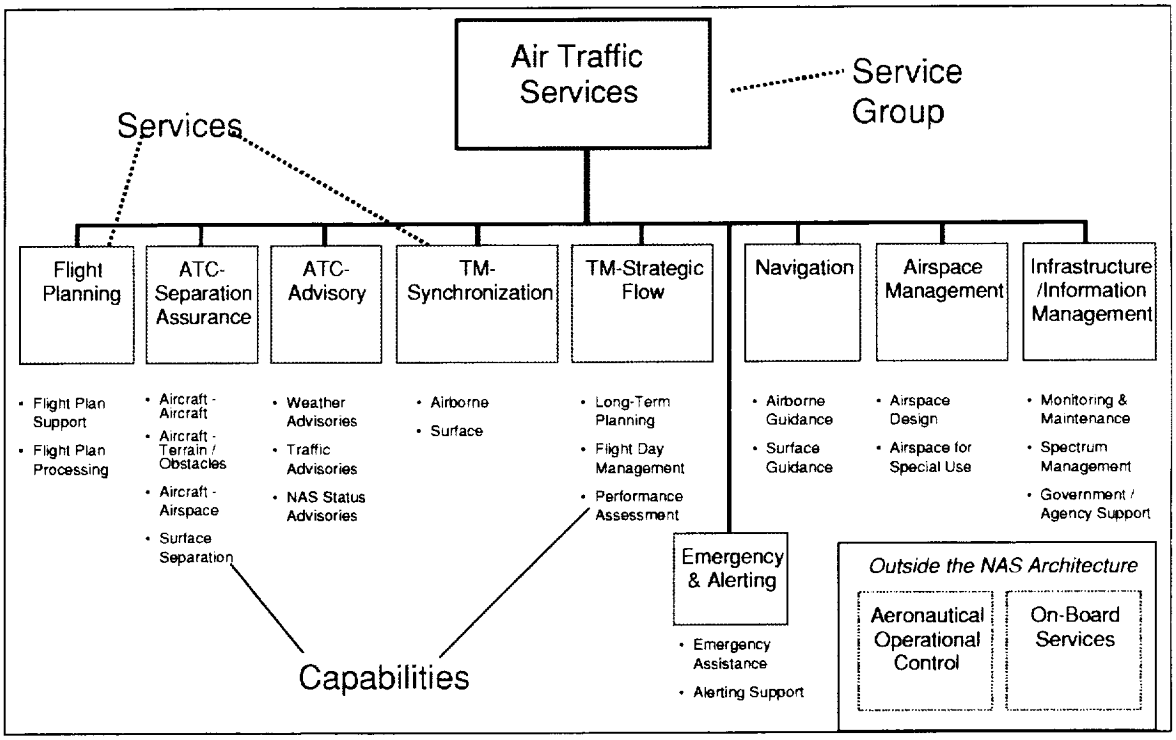


Figure 3-1. Air Traffic Services for ATM and AWIN

3.1 Flight Planning Service

Flight Planning Service includes both Flight Plan Support and Flight Plan Data Processing to support the safe and efficient use of the nation's airspace through the development and use of coordinated flight plans.

The capabilities described below comprise the Flight Planning Service. The first five of these capabilities support today's environment and are considered legacy capabilities. The remaining capabilities are necessary to support the CONOPS for the year 2005 and beyond. These capabilities are as follows:

Provide Aeronautical Information

Aeronautical information (e.g., information regarding special use airspace, preferred or fuel-efficient routes, traffic management, or the condition of selected NAS components) is required in support of flight planning. Such information is required to be easily and conveniently available to users for the total geographic area of NAS responsibility. Because of the large volume of aeronautical information there is a requirement to tailor the information presented to only that which is important to a specified route and time of flight or to specified locations or areas. Users require such information during all phases of flight.

Provide Weather Information

Weather conditions can significantly affect aircraft operations, performance and safety. Planning of flights requires the availability of timely and accurate weather information such as: upper air winds, upper air temperatures, and hazardous weather data. A capability is required to select and access weather information that could affect flight planning. Specialists and users require weather information.

Provide Pre-Flight Information

Pre-flight information includes the dissemination to users of aviation weather and aeronautical information for airports and proposed routes of flight.

Develop and Process Flight Plans

Developing and processing pre-flight and post-flight plans includes accepting and processing flight plans from all users (GA, airlines, military); validating the flight plans; notifying users of any problems; and processing amendments, cancellations and closures.

Implement Flight Plans

Implementation starts with the activation of a flight plan. It includes issuing of clearances for the flight, distributing flight plans to appropriate ATC facilities along the route, as well as processing in-flight changes.

Future User Services:

Collaborative Decision Making

Provides participating AOC's and the FAA with real-time access to current NAS status information, including infrastructure and operational factors. Increases predictability by allowing flight plan changes in response to NAS status and traffic demands through greater information sharing and automated decision aids. CDM will also provide more robust interactive feedback to NAS users' proposed flight plans based upon current constraints such as special use airspace, equipment and facility status, and weather conditions.

NAS-Wide Data Link

Allows controllers and pilots to directly exchange digital messages, such as FIS and TIS information, throughout the NAS.

Interactive Airborne Refile

Provides in-flight, electronic exchange and automated processing of flight plan change requests between pilots and controllers for entire route clearance.

Flight Plan Evaluation

Provides interactive feedback to NAS users proposed flight plans based upon current constraints such as special use airspace and equipment status.

Flight Plan Support provides NAS users with essential weather and aeronautical information such as available routes, special use airspace (SUA), daily demand conditions, anticipated flight conditions, NAS operational and maintenance status, and FAA facility status. Flight Plan Processing provides acceptance and processing of flight plan data, validation of flight plans; problem notification; processing of amendments, cancellations and flight plan closures.

Automated data link capabilities are needed to enable airspace users to conduct pre-flight and in-flight activities and receive information essential to flight without talking directly to control and/or flight service personnel.

Technical factors and user needs that tend to drive change for flight planning are listed below along with factors that may act as constraints.

Table 3.1-1. Flight Planning Service

Driving Forces →	← Constraints	Comments
Need for current route and other aeronautical information	• Access to information, DUATS, PATWAS, AFSS/FSS, TIBS, BASOPS and airline dispatch office. • Difficulty of using charts for some people using unfamiliar routes.	Large volume of information, from numerous sources and databases, must be customized for specified route, time and location/area.
Need for weather information	• Reliance on human weather observers • Difficulty understanding voice or data weather description • FAA reliance on meteorologists for weather information as primary source • Delays caused by manual receipt and entry of PIREPs by the Controller for operationally significant weather data • Controller weather data relay to pilots on a workload permitting basis	More efficient operations could be available with: • Complete automated surface observations • Increased use of data communications; reduced need for voice communications • Direct Automation support to pilots and FAA ATC personnel • Automated processing of real-time aircraft sensor data • Automatically generated tailored weather products • Direct dissemination of weather products to the cockpit. Controller provided weather services only on request, and only on a workload-permitting basis • Automated aircraft advisories
Reduction of delays while developing and processing flight plans	Rejection of flight plan by Host requires time-consuming resubmission	If Flight Service or the Host Computer rejects the flight plan, the flight plan must be amended or refiled. Improvement of the filing process to avoid rejection should be considered.

Driving Forces →	← Constraints	Comments
Ability to interactively refile or amend while airborne	• Insufficient interconnection of systems • Integrity and security of links • Bandwidth needed for interactive feedback • Limited "real estate" on cockpit screens	Constraints may require amending or filing another flight plan There is a need for better validation and automated transmission of flight plans, perhaps with some form of automated correction. More importantly, there a need to support upload of the approved flight plan to the FMS because manual uploads is time consuming and error prone.

3.2 ATC Separation Assurance Service

Separation Assurance Service ensures that aircraft maintain a safe distance from other aircraft, terrain, obstacles, and certain airspace not designated for routine air travel. Separation assurance involves the application of separation standards to ensure safety. Standards are defined for aircraft operating in different environments. These standards are based on both aircraft performance (the ability to know and maintain location) and surveillance equipment performance (the ability to receive and display aircraft position).

Aircraft-to-Aircraft Separation

Aircraft to aircraft separation prevents collision between airborne aircraft. Advancements in conflict detection and resolution systems may make it possible for aircraft to maintain separation without ATC intervention. Avionics will provide dependent surveillance reports to proximate aircraft and will be able to receive data link messages directly from the ATC automation system regarding other aircraft positions.

Both pilots and controllers will have an increasing need for situational awareness. Adequate communications coverage, including (up-link/down link) data link capability with the users, will reduce controller workload in locations where separation standards are currently procedural due to inadequate surveillance. Equipment limitations will be reduced in the future with the availability of Traffic Information Service, TIS, which will allow pilots to perceive other aircraft.

Aircraft-to-Terrain/Obstacles Separation

NAS employs separation standards to prevent collision between aircraft, terrain, and obstacles. Methods used include published safety zones and processing of position and intent information. Automated aural and visual indications of obstacle dimensions and location, as well as terrain proximity, available to all users, will enhance aviation safety. Pilots need the ability to obtain relevant, current charts with minimal expense and inconvenience. Terrain and Obstacle separation will be part of pilot situational awareness just like aircraft separation.

Aircraft-to-Airspace Separation

Aircraft are separated from Special Use Airspace (SUA) such as prohibited, restricted, and warning areas. Aircraft are either restricted or prohibited from SUAs depending on the type and status of the airspace. Automated aural and visual indications of SUA dimensions and location, available to all users, should reduce violation of SUA.

With the future implementation of commercial space, there may be an increase in SUAs (and more frequent use of those SUAs). The SUA schedule will be more accurate and better integrated with overall planning of ATC operations. Aircraft access to SUAs will be increased by the ability to share schedule information.

Surface Separation

Surface separation applies to vehicle movements on the airport movement area, taxiing aircraft, and protection from designated critical zones. Depending on local practices, tower controllers manage and control the surface of the airport including the taxiways, runways, and movement areas designated as controlled area. In other cases, controllers manage the optimized queues of arrival and departure aircraft. Pilots are responsible for separation of their aircraft from other aircraft, vehicles, obstructions, and designated critical zones while in transit to and from the airport movement areas.

While not yet sharing the responsibility for separation, pilots need on board systems that provide valuable assistance to the Ground Control Manager (GCM). Automation enhancement increases the margin of safety for aircraft, as surveillance and tracking of movement on the surface is much more precise. Airports will also be equipped with tracking radar and data transmitting systems that provide both pilots and the GCM with accurate information regarding the movement of all vehicles on the airport surface, a safety enhancement, especially in low visibility situations. A Surface Management System (SMS) can provide a collaborative decision making capability among ATC, the airlines, and airport operators to reduce delays in surface operations. Read and acknowledge messages will be expanded beyond pre-departure clearances and taxi routes to include best gate, gate time arrival, gate time pushback, etc.

At busy, local general aviation airports, the pilot will have more responsibility for surface separations or be restricted to certain airports. Busy airports are not often suitable for pilots with limited experience or with the minimal mandated equipage. Busy GA airports will need to support moving maps, automated clearance capabilities, automated weather warnings, and surface departure automation.

At the smallest GA airports, the procedural separations – one in/one out – will change when all aircraft operating at the aircraft are equipped to "see" each other. This will be especially helpful in remote areas with minimal low altitude radar coverage.

In 2015, separation will be managed mainly by data communications for airlines and predominantly by voice communications for low-end GA. By 2015, some GA users will choose to equip with a data capability, and some airlines may choose not to equip. Similarly, some users may choose to equip with technology that supports self-separation.

Air traffic controllers separate aircraft in the NAS using either procedural (non-radar) or surveillance (radar) techniques. Surveillance techniques provide more efficient separation of aircraft than procedural techniques. Controllers can also use the surveillance information to provide aircraft identification and location, navigation assistance, instrument approaches, traffic advisories, and unsafe condition alerts.

Surveillance systems such as radar can locate and identify aircraft, whether IFR or VFR. Radar surveillance systems are classified as either primary or secondary. Primary radar surveillance requires no cooperation from the aircraft targets. The aircraft position and velocity are determined by reflecting surveillance (radar) signals off the aircraft skin and using algorithms to process the received signals. Secondary radar surveillance takes advantage of cooperative aircraft equipped with transponders that respond to interrogation. The response signal is processed and displayed at the controller's station. This allows aircraft trajectory (active track) information to be determined. In addition, aircraft may be equipped with dependent equipment that continuously broadcasts trajectory and other information.

For aircraft to aircraft separation using surveillance techniques, controllers analyze the aircraft intent (from flight plans) and the actual and predicted trajectories (surveillance track data) to determine and resolve conflicts. For procedural separation, the pilot's flight plan and reported position, altitude, and estimated time to the next reporting point are used to control aircraft. A combination of time, distance, altitude, routes and visual methods separate aircraft, as appropriate, for departure/arrival and en route flight conditions.

Aircraft-to-SUA Separation

The controller needs to know the aircraft's intent and actual position as well as the location and status of the airspace. Surveillance track and flight plan information provide the actual and intent information needed by the controller to ensure that the aircraft flight trajectory remains an appropriate minimum distance from the SUA boundary. The controller either assigns altitudes to keep aircraft out of airspace or vectors aircraft around the airspace. Procedural separation assigns route and/or altitudes and monitors pilot reports to ensure that the aircraft remains an appropriate minimum distance from the boundary of the SUA.

Aircraft-to-Obstacle Separation

Air traffic controllers use aircraft intent and/or actual trajectory and known obstacle locations to separate aircraft from obstacles. Aircraft can be tracked using surveillance to ensure that the aircraft's trajectory maintains minimum lateral or vertical separation from the obstacle. Procedural techniques rely on aircraft route and/or altitude assignment and pilot reports to ensure the aircraft remain clear of all obstructions in accordance with appropriate separation standards.

Data Link Delivery of Expected Taxi Clearances (DDTC)

Terminal controllers are responsible for maintaining separation between aircraft, airspace and obstructions appropriate to operational conditions and types of aircraft in the system. The trajectories of controlled aircraft in the terminal airspace, SUA location and status, and obstacle locations are analyzed to determine potential conflicts. The controllers provide instructions for pilots to maneuver the aircraft to resolve situations that result in less than approved minimum separation. Separation assurance is provided through procedural and surveillance techniques.

En route controllers at ARTCCs are required to maintain separation between aircraft, SUAs, and obstructions appropriate to the en route airspace, operational conditions and types of aircraft. The en route facility maintains flight trajectory information for all participating aircraft in its airspace, SUA location and status, and the location of any obstacles. The en route controllers determine potential conflicts and provide instructions to pilots to maneuver the aircraft to avoid or remedy any conditions that result in less than approved minimum separation. Separation is provided and maintained through a combination of procedural and surveillance techniques.

Oceanic controllers, responsible for international airspace assigned to the NAS, are required to provide separation between aircraft, SUAs and obstacles appropriate to the oceanic airspace, operational conditions and types of aircraft. The responsible oceanic center maintains predicted aircraft trajectory information for controlled aircraft in its area. The aircraft trajectory information is used to determine when potential conflicts exist. Pilots maneuver the aircraft in response to controller instructions to avoid or remedy situations that result in less than approved minimum separation. Today controllers provide separation mainly using pilot reports with associated flight plans and procedures.

The separation of aircraft by air traffic controllers in the space domain is a future service. Space vehicles will be separated from aircraft, airspace, and obstacles by using corridors, reserving airspace or some other means, similar to the current procedures used for missile and Space Shuttle launches.

Technical factors and user requirements that tend to drive changes for Separation Assurance Service are listed below along with factors that may act as constraints.

Table 3.2-1. Drivers and constraints for Separation Assurance Service

Driving Forces →	← Constraints	Comments
More efficient movement on airport surface	• Position reporting on airport surface • Structures that obstruct line of sight	• DDTC at DTW has already been enhanced to provide positional information for aircraft using ACARS.
Flexibility for oceanic routes if separation standards can be reduced	• Situational awareness of pilots regarding nearby traffic • Situational awareness of controllers	• ADS-B has the potential for providing pilots with much better situational awareness than they currently have. • Improved communications is needed to show the controller the same picture as the pilot would have
Crowded airspace in East Coast corridor	• Off-shore areas lack radar surveillance • Off-shore areas go beyond VHF range	• Congestion in Atlantic corridor (e.g., DCA-BOS, MIA-JFK) could be diverted from crowded areas if flights could be routed over water. • Savings could also be realized in the Gulf, by using direct routes.
Free Flight	• Current route system	• There is substantial industry focus on this issue.

3.3 ATC Advisory Service

Today's aviation weather system is characterized by inefficient means of delivery to end-users, weather observations that are sparse, weather forecasts that are low resolution temporally and spatially, and products that provide quantities of cryptic data rather than the needed operationally significant decision aids.

Users need advisories including weather information, traffic, and NAS status information. Weather advisories and information need to be available to the user cockpit either automatically or on request through data link communications with ATC and other facilities. Advisories provide hazardous weather or flight conditions at airports, or along the flight route. Traffic advisories are provided to alert aircraft to potential conflicts with others on the surface or in-flight. These advisories are time critical and must be delivered to the aircraft in time to be applied. Information about the NAS status that has changed or was not readily available during flight planning is provided to in-flight aircraft. Availability of this information via data link to the cockpit will reduce voice communications and workload for both the user and ATC personnel.

Weather Advisories.

Of major importance to both pilots and controllers is the continued improvements in the area of weather tracking and forecasting. Improvements in communications and surveillance technologies facilitate a timely sharing of hazardous weather information between controllers and pilots. PIREPS provide a valuable source of "real-time" weather information. This information comes from pilots in the system reporting encounters with hazardous flying conditions such as thunderstorms, turbulence, icing, and wind shear (sudden changes in the direction of the wind relative to the direction of the aircraft). Enhancement in dissemination of PIREPs and easy-to-interpret weather information to the occasional pilot is needed for pre-flight and especially during in-flight. Additionally, pilots need more information about the severity of convective activity and cloud-to-cloud lightning often associated with thunderstorms.

Evolutionary strategy should focus on quickly developing prototypes with key related systems and ensure that interfaces and operations concepts are thoroughly validated by user evaluation teams in an operational environment. A flexible design can accommodate many levels of sophistication in automation capabilities, from simple separate weather displays to the display of integrated presentations of combined Doppler radar, weather satellite and other weather information suitable for the most sophisticated graphical display system.

Human factors considerations of information system design and sensory overload should seriously be examined. Weather information should be provided in standardized formats that can be quickly assimilated by the pilot and accommodate varying levels of meteorological skills. The pilot who flies daily gets proficient at reading textual weather; the pilot who makes an occasional weekend flight in a rented aircraft needs all the help he or she can get.

Pilot situational awareness can be increased through improved cockpit avionics. These avionics should display critical flight safety information such as weather, nearby traffic, terrain features, SUA status, notices to airmen, and significant weather advisories. Display of real-time weather information in the cockpit will help alleviate some of the hazards encountered during en route flight.

Both passenger and cargo Airlines need to have same picture of weather for decisions as ATC/TF in order to achieve collaboration. Businesses using the NAS need more predictive (i.e., accurate) weather, but for different purposes:

- Snow/ice – to adjust ground operations and schedules
- In air ice – to fly around (as is done for a thunderstorm)
- Thunderstorm at airport – to wait it out
- Thunderstorm en route – to work with ATC to fly around. The current communications sector setup is a potential impediment. It is necessary to be able to adjust the boundaries of sectors (with the accompanying change in frequencies) to accommodate an overwhelming number of aircraft flying through a relatively small hole in a storm. Changes in flight need to be accommodated for a specific aircraft rather than between airport pairs. Currently, thunderstorms in Kansas City can cause ATL, ORD, DFA, LGA, and LAX (for example) to shut down. With many major airports shut down, overall traffic in the NAS becomes light and the remaining operating airports to flow very well. The communications system needs to support dynamic reallocation of airspace, and making smaller sectors (to be able to reduce the

number of aircraft in the sector to manageable levels). The communications also needs to support the changing of a flight plan for a specific flight.

For most aircraft, weather advisories are provided via voice or digital ATIS. In either case, the information is broadcast (although controllers using voice can ask pilots for confirmation that the message has been received). Airlines often receive additional information using the ACARS link, which today is primarily for AOC data.

For those weather reports that are transmitted via data links, current reports are textual or use primitive graphics. Recent advances in compression algorithms have reduced message sizes, while new communication technologies have increased capacity. Some of the advances in compression techniques have resulted from the aviation industry's efforts to make "weather in the cockpit" more practical, but the tremendous growth in applications using the Internet has spawned more research and standardization in graphical compression techniques. Progress is being made on standards for providing weather in the cockpit.

In the next few years, more constellations of communications satellite in low or medium earth orbits will become operational. Preliminary marketing of downlinked broadcast entertainment services[1] is underway. Satellites could be used to broadcast basic weather data to equipped aircraft, with additional features for premium subscribers. Current CPUs are already powerful enough to selectively display broadcast data based on a pilot's profile. Such systems would need to be improved for ease use.

In the future, weather advisories can be automatically broadcast to pilots and controllers simultaneously. Both controllers and pilots need a system that could relay this time critical information so that alerting time is not delayed as the information is relayed by the controller to the pilot, and does not divert the controller from other important activities.

Pilots and controllers have different needs for information. Pilots need weather information that is tailored to their current course or planned route of flight. Controllers need access to a larger picture, extending to surrounding sectors and even other facilities, because weather conditions in neighboring areas can affect traffic conditions in their areas.

Although the planning styles of pilots vary, pilots should be able to request pre-flight and in-flight geographical weather data for anywhere in the NAS (or in the world, for longer-range aircraft).

With the FAA's policy on FIS, which reduces the role of the FAA for delivery of weather and shifts it to the private sector, there appears to be a viable market for for-profit weather service providers.

Military and civilian aircraft use different sources and transmission mechanisms for weather data.

<u>Traffic Advisories</u>

Traffic advisories need improved accuracy, with minimal human intervention by controllers. In today's environment the controller may be occupied with higher priority duties and unable to issue traffic information. In 2015, on-board computers and interfaces to the ATC surveillance and tracking systems will eliminate the role of the controller as the conduit for traffic advisories.

[1] CD-quality music broadcast to appropriately equipped automobiles or trucks.

Traffic advisories could be self-broadcast by aircraft, or rebroadcast by the ground system (expanded TIS—B). Accuracy would improve by having everyone on the same reference system. In the future, SUAs may be released more frequently (especially if space launches become more frequent). It may be desirable to have a combination traffic/NAS status advisory in the form of a broadcast message.

NAS Status Advisories

NAS status advisories are now available to pilots during pre-flight, on the Automated Terminal Information System (ATIS) via voice, and the D-ATIS system via digital means. With the appropriate avionics, computer software, interface and up-link capability, the pilot could automatically obtain NAS Status Advisories via the FAA's D-ATIS system.

The FAA maintains a National Airspace Performance Reporting System (NAPRS) database containing the status of key NAS systems, which may be available to the cockpit (with the appropriate avionics interface). Although NAPRS is not currently a real-time reporting system, it could be the basis of a database to provide pilots with NAS equipment status.

NAS Status Advisories can be expanded to have the RMM information translated to synthetic voice to handle some equipment outages. If the NAS is using dynamic resectorization, then there may be a desire to have some NAS configuration information broadcast from airports or have it available pre-flight via the Internet.

Technical factors and user requirements that tend to drive change for ATC weather, traffic, and NAS status advisories are listed in the table below, along with factors that tend to act as constraints.

Table 3.3-1. Drivers and Constraints for ATC Adviory Service

Driving Forces →	← Constraints	Comments
• Avoidance of hazardous weather • Possible fuel savings by taking winds aloft into consideration	• FIS weather policy • Shift to private sector may preclude some options of packaging FIS with TIS, ADS-B • Volume of data involved for maps	Weather information needs to be provided in a format which can easily be assimilated by the pilot and accommodate varying levels of meteorological skills
• Traffic, especially in congested airspace or airports	• Size of displays • Heads-down time • Latency	Information displayed in the cockpit needs to be easy to interpret

3.4 Traffic Management Synchronization Service

Today's current array of independent systems and varying standards will evolve to a shared environment connecting users and service providers for traffic flow management, flight services, and aviation weather. New decision support tools must be implemented to help users and service providers make collaborative decisions to prioritize and schedule flights and better organize air traffic locally and nationally. These tools will allow users and service providers to more efficiently direct flight paths, sequence departures and arrivals, change routes, and balance capacity and demand throughout the NAS. The objective is to reduce variability in services and optimize use of airspace and available runways.

Traffic synchronization supports expeditious flight for the large number of aircraft using the NAS during any given period of time. Airborne synchronization involves sequencing of aircraft to maximize efficiency and capacity of the NAS through all phases of flight (arrival, departure, and cruise). The surface is managed by formulating taxi sequences and communicating instructions to pilots and vehicle operators for the safe and efficient flow of traffic on the airport surface. Timely coordination between AOC and ATM on NAS projections and user preference, with appropriate data being available via data link, will be beneficial to the user.

Traffic synchronization needs to be able to deal with many types of input to adequately process user preferences – and user status – such as weight, optimal descent profile, optimal departure, and navigation capability. With improved Flight Management Systems, the aircraft should be able to relay data about the aircraft to the controller's Decision Support System (DSS) tools without pilot intervention.

Collaboration needs to be able to begin before the flight, using tools such as electronic whiteboards, AOCnet or bulk flight plan filing and refiling. Collaboration will occur during flights with the AOC acting in conjunction with the pilot to work with Traffic Management and ATC. The interactions need to be automated in such a way that the decisions made during the collaboration between pilots and controllers (and the related AOC and TM) are automatically stored into the various computers, unlike today's situation in which orally communicated agreements must then be inserted manually into computers. By 2015 (or much sooner), software assurance techniques will provide adequate assurance that the decisions endorsed by the pilots and controllers are correctly stored into the ground and airborne computers, but it is not likely that the computers will be trusted to make decisions without a "human in the loop."

Avionics will evolve to take advantage of the benefits found in the new communication, navigation and surveillance related technologies. With the new avionics and supporting ground infrastructure, enhanced services will be available to help users fly safer and more efficiently. The pace of modernization will be benefits-driven and dependent on users equipping with the new avionics.

Technical factors and user requirements that tend to drive change for traffic management synchronization are listed below, along with factors that may act as constraints to change.

Table 3.4-1. Drivers and Constraints for Traffic Management Synchronization Service

Driving Forces ➔	← Constraints	Comments
Traffic Management Synchronization Service	• Sustain critical NAS infrastructure • Continuity of ATC services	Changes to procedures, training, airspace design, and certification of both ground systems and avionics are will ensure users and service providers realize the new capabilities

3.5 Traffic Flow Management

Air traffic management (ATM) encompasses traffic flow management (TFM) and air traffic control (ATC) capabilities and is designed to minimize air traffic delays and congestion while maximizing overall NAS throughput, flexibility, and predictability.

The description of TFM functionality includes capabilities at the Air Traffic Control System Command Center (ATCSCC) with some functionality distributed to traffic management units

(TMUs) at air route traffic control centers (ARTCCs), at high-activity terminal radar approach control (TRACON) facilities, and at the highest-activity airport traffic control towers (ATCTs). To avoid duplication, only TFM functionality is described in this section.

TFM is the strategic planning and management of air traffic demand to ensure smooth and efficient traffic flow through FAA-controlled airspace. To support this mission, traffic management specialists (TMSs) at the ATCSCC and traffic management coordinators (TMCs) at local facilities (ARTCCs, TRACONs, and towers) use a combination of automation systems and procedures known collectively as the TFM decision support systems (DSSs).

Currently, the Traffic Management Strategic Flow Service concentrates on using ground delay programs to ensure that airports and airspace are not overloaded. This is not an efficient solution for allocation of air space.

Summary of Projected 2015 TFM Capabilities:

The NAS-wide information network is designed to facilitate collaboration and information sharing between users and service providers. NAS users will be involved in collaborative decision making by actively participating in flow strategy development, when appropriate, and by modifying their operations to meet air traffic flow initiatives. Collaboration and information exchange will reduce operational uncertainty, improve predictability, and enhance the decision making process by allowing user input into decisions that affect daily operations. Daily system performance data will be recorded to enable quantitative measurements concerning the effectiveness and efficiency of NAS operations from both the FAA and user perspectives. These capacity-related metrics will include delays, predictability, flexibility, and accessibility.

The collaborative process establishes the data exchange capability that will be used to implement ration-by-schedule procedures. The procedures modify the GDP, using the airline schedule, as defined in the OAG as the baseline for allocating actual departures and predicting arrival times, rather than the individual flight estimate. The ATCSCC consolidates the schedule information and transmits it with information on airport arrival capacity constraints.

Control by time of arrival (CTA) provides users with more flexibility in operational planning. CTA uses arrival- rather that departure-based decision making procedures, giving users more control over scheduling their own flights. Users will be assigned arrival times at destination airports and will be able to determine their departure and en route schedules to meet their designated arrival times.

Military scheduling agencies will provide real-time schedules for using SUA that allow sufficient time for service providers and users to incorporate it into their planning. As a SUA's status changes, the NAS is updated in real time, and commercial flights can be routed through it. [1]

Flight plan evaluation provides NAS users with immediate feedback about system constraints and options for their planned routes. This allows users to make timely revisions before submitting a flight plan. When a flight is airborne and operational factors dictate a reroute, the collaborative flight planning process will allow real-time changes, such as reroutes around severe weather or congested airspace. The airport configuration status will include active runway, equipment outages, weather, braking action, and visibility conditions. It will also include operational data, such as arrival and departure rates and types of approaches in use. The CDM process will also

1 Generally, the SUA must be clear of commercial flights 30 minutes prior to being restricted to military operations.

give users the opportunity to take part in deciding when equipment can be shut down for routine maintenance.

Modernized information systems will distribute timely, accurate, and consistent information in electronic format across the NAS, resulting in improved services to users, more efficient use of NAS resources, better flight planning, and more cost-effective systems development and acquisition. The information systems will provide users and service providers with a common view of the NAS for collaborative decision making. Common, standards-based data services will provide data collection, validation, processing, storage, and distribution of data to and from data sources that are both internal (e.g., traffic flow management) and external (e.g., the National Weather Service (NWS), airlines, DOD, and international traffic flow managers) to the FAA.

Data will be dynamically updated as situations change. Data types will include:

Flight Data: Such as the filed flight profile and all amendments, first movement of the aircraft, wheels-off time, in-flight position data, touchdown time, gate or parking assignment, and engine shutdown. The current flight plan will be expanded to become the flight object and will include the added information about the flight. The information will be standardized to be consistent with ICAO standards. The user is one of the main sources of this type of data.

Resource Data: Include static resource data, such as NAS boundaries, configurations, runways, and SUAs; and dynamic resource data, such as airport and airspace capacity constraints, current configuration of runways, system infrastructure status, schedule of SUA activity, and schedule of maintenance activity. The FAA is one of the main sources of this type of data.

Enhanced Weather Data: Include current and forecast weather, hazardous weather alerts for windshear events (microbursts and gust fronts) and other hazards such as icing, turbulence, etc.

Traffic Management Data: Include current and anticipated demand/capacity imbalances and planned strategies for managing them.

NAS Performance Measurement Data: Provide information on NAS performance in a meaningful and readily accessible format for better planning.

Geographic Data: Include terrain maps, obstruction locations, airspace boundaries, etc.

Surveillance Data: Include aircraft-position time and coordinates reports, velocity, and intent information.

The NAS is increasingly dependent on greater information exchange for better and shared planning and decision-making. The NAS will provide users and service providers with consistent, accurate, timely data to allow for future collaboration.

Technical factors and user requirements that tend to drive change for traffic flow management are listed in below along with factors that tend to act as constraints.

Table 3.5-1. Drivers and Constraints for Traffic Management Strategic Flow Service

Driving Forces →	← Constraints	Comments
Cost of delays to airlines and passengers	• Need for confidentiality of airlines information • Connectivity between FAA and AOCs • Less use of voice • Lack of standardized message formats	More precise tools to analyze flow control data, performance, and decision-making

3.6 Emergency and Alerting Services

Emergency assistance services are provided for aircraft in distress situations. ATC services range from assisting an aircraft low on fuel to the nearest airport to aircraft involved in a hijacking. Search and rescue activities include searching for missing aircraft and providing survival aid, rescue, and emergency medical help for occupants after an accident site is located.

Emergency Assistance Services

Emergency assistance services are provided for aircraft in distress situations. NAS ATC facilities provide urgent/distress declarations, aircraft, weather and traffic flow information, and flight plan information to support emergency situations. When emergency situations occur, the responsible ATC facility notifies rescue centers and aircraft operators, in addition to the appropriate foreign, military, federal, state, local and other agencies to help assist in handling the emergency or locating the aircraft.

The ATC facility in communication with the aircraft handles the emergency situation and coordinates the activities of the assisting facilities. The controller may transfer this responsibility to another ATC facility if it is better equipped to handle the emergency. Emergency assistance provided by ATC controllers and other specialists include:

- Providing alternative courses of actions such as distance, time to nearest airport, heading and recommended descent profile.
- Providing current flight information on the aircraft requesting assistance and other relevant information to the appropriate federal, state, local and other agencies.
- Alerting of crash, fire, and rescue services
- Attempting to reestablish aircraft communication using all appropriate means in the event two-way communication is lost with an aircraft under ATC control
- Responding to aircraft requests and notifying appropriate agencies when an aircraft is subject to unlawful interference (hijacking)
- Providing navigation assistance to orient aircraft, avoid or reroute for bad weather conditions, or guiding aircraft to emergency landings at appropriate airports.
- Directing aircraft dumping fuel to suitable dumping areas and notifying appropriate agencies
- Coordinating communications with foreign ATS units as needed

The ARTCCs serve as the central points in the NAS to collect and maintain detailed information for emergency situations. For aircraft operated by a foreign air carrier, the ARTCC responsible for the departure or destination point, when either point is within the United States, relays information to the operator of the aircraft. The ARTCC facilities responsible for the Flight

Information Regions (FIR) delegated to the FAA by ICAO provide emergency services to aircraft in oceanic or other airspace outside the NAS.

A terminal ATC facility alerts an ARTCC when an aircraft is considered to be in emergency status that may require Search and Rescue procedures, or an IFR aircraft is overdue. The ARTCC alerts and forwards pertinent information to the RCC whenever an aircraft in its airspace is in an emergency situation or overdue, or when alerted that an emergency situation exists at a terminal ATC facility. The responsible ARTCC or FSS facility coordinates with the RCC, and conducts a communications search to attempt to determine the location of the aircraft. The communication search checks the ATC facilities, airports and other facilities along the route usually from the last reported position to the destination to determine when the aircraft last contacted a facility. The communication search must be initiated before the RCC can began SAR procedures. The assistance of other aircraft known to be operating near the aircraft in distress is also solicited and the results forwarded to the RCC.

The FSSs are the central points for collecting and disseminating information on overdue or missing aircraft that are not on an IFR flight plan.

Terminal ATC facilities, ARTCCs and FSSs are also responsible for receiving and relaying pertinent ELT signal information to the appropriate authorities. When an ELT signal is heard or reported, the responsible ATC facility requests the applicable Direction Finding (DF) Facilities to determine fixes, bearings, and obtain any other pertinent information. Either the ARTCC or FSS collects the ELT information, coordinates with the RCC, and forwards fixes, bearings and other relevant information to the RCC. This information also includes the original and amended flight plan, last recorded or known position, last recorded heading, and the weather conditions for the last known position and projected flight path.

There are any number of circumstances that will result in the emergency service capability being invoked including:

- The pilot, ATC personnel, or officials responsible for the operation of an aircraft declare an emergency situation exists for an aircraft.
- Unexpected loss of radar contact and radio communication with any IFR or VFR aircraft.
- Reports indicate the aircraft either made a forced landing or its operating efficiency is so impaired that a forced landing will be necessary.
- Reports indicate that the crew has abandoned the aircraft or are about to do so.
- Intercept or escort aircraft services are needed
- Need for ground rescue appears likely
- An Emergency Locator Transmitter (ELT) signal is heard or reported.

Alerting Service

ARTCCs and Flight Service Stations (FSSs) alert Search and Rescue (SAR) agencies when information is received from any source that an aircraft is in difficulty, overdue, or missing. SAR is provided through the combined efforts of the federal agencies and the responsible agencies within each state. Operational resources are provided by the U.S. Coast Guard, military components, the Civil Air Patrol, state, county, and local law enforcement and other public safety agencies, and private volunteer organizations.

The SAR activities include searching for missing aircraft and providing survival aid, rescue, and emergency medical help for occupants after an accident site is located.

The U.S. Coast Guard is responsible for the coordination of SAR activities for the Maritime Regions, and the USAF is responsible for the Inland Region. Rescue Coordination Centers (RCC) established by the Coast Guard and the USAF directs the SAR activities within their regions.

When an aircraft is overdue or missing, a communications search is initiated to determine when the aircraft last contacted an ATC facility. The essential information is gathered for the aircraft (flight plan data, last known position, last recorded heading, search area conditions etc.) and distributed to the RCC prior to initiating the SAR effort. If ATC facilities hear or receive a report of an ELT signal, they attempt to determine the location of the signal. Direction finding facilities obtain fix bearings, and any other pertinent information from the ELT signal. This information is also forwarded to the RCC to support the SAR activities. A combination of Coast Guard, military, Civil Air Patrol, state, county and local law enforcement and other public agencies, and private volunteer organizations perform the actual SAR activities.

Technical factors and user requirements that tend to drive change for the emergency and alerting services are listed in the table below along with factors that may act as constraints to implementing the needed changes.

Table 3.6-1. Drivers and Constraints for Emergency and Alerting Service

Driving Forces →	← Constraints	Comments
Poor communication results in unnecessary searches	Communication tends to be poor where infrastructure is expensive to install and maintain (Alaska)	• LEO/MEO could become less expensive making aircraft equipage and ground infrastructure more cost effective. • Pilots would be able to advise ATC of changed plans (e.g. landing to wait out a storm) despite flying out of VHF voice radio coverage.
Lives can be saved if searches are fast	• Pilots may be injured or confused • ELT might be affected by crash	• Luxury automobiles now offer alerting services that report GPS location after an accident or user request; some boats can report location on maritime/aeronautical distress channels • Standalone feature is possibly too expensive, but most components would serve other functions

3.7 Navigation Services

The Navigation Service consists of the navigation guidance for en-route, surface, and approach and landing operations NAVAIDs for en-route enable the use of flight routes; terminal area NAVAIDs support operations near airports; and surface NAVAIDs provide airport surface guidance.

Cruise Navigation Guidance

Cruise NAVAIDs, both ground-based and satellite-based, enable airspace users to determine their position for the purpose of defining and utilizing flight routes.

Ground-base systems accomplish this by enabling position determination by bearing (theta) and range (rho) measurements relative to a predetermined aeronautical fix along established airways. These airways consist of series of regularly spaced, short-ranged NAVAIDs providing only limited lateral coverage. As a result, traffic is concentrated along these routes.

Space-based systems provide navigation services to properly equipped aircraft over a wide area. Such systems allow more efficient user-preferred routing and do not constrain users to established airways. These NAVAIDs also provide service in oceanic airspace delegated to NAS authority.

Approach and Landing Guidance

Terminal NAVAIDs enable aircraft users to navigate into and out of airports by, first, enabling an incoming pilot to determine the airport location and, second, by helping to correctly orient the aircraft with respect to the runway during approach, landing, and departure. These systems provide vertical, lateral, and distance navigational guidance allowing appropriately equipped aircraft to safely execute non-precision (course guidance only) and precision (course and glide path) landing approaches. Terminal NAVAIDs can be visual or electronic.

Visual NAVAIDs are utilized during approach when the pilot makes the final transition between instrument and visual flying. The NAVAIDs allow the pilot to determine airport locations; his position and orientation with respect to the runway, and provide vertical guidance during non-precision approaches. Different lighting requirements exist for airports rated for each of the three approach categories (I, II, III) with the more stringent requirements applying to Category III airports.

Electronic NAVAIDs are used to support instrument landings in each of the three approach categories. Category I landings are supported by electronic NAVAIDs delivering lateral, altitude (glide path), and distance guidance. Category II runways require another range marker, and Category III require the same guidance features with greater accuracy.

Surface Navigation Guidance

Surface guidance systems are primarily visual, based on lighting and signage. Pilots using these visual aids, with further assistance from detailed maps and tower controllers, maneuver on the airport surface.

Future Navigation Services

The use of GPS, LAAS, and WAAS will result in increased situational awareness in all phases of flight and, therefore, more efficient use of the airspace. The increase in airspace utility, however, will cause spectrum crowding as more users are in the air at the same time.

Areas now governed only by VFR and procedural flying will be opened to instrument flying. The pilot in this environment will use his improved navigational accuracy in conjunction with a land reference database for easier terrain avoidance. Eventually, this database will be available over the Internet and will have filtering capabilities to provide the pilot will all information pertinent to his flight without, at the same time, inundating him.

Surface operations will benefit from the use of LAAS as it will provide the pilot a better awareness of "unmarked" targets (movable and/ or unscheduled objects). LAAS data may flow automatically to the pilot or first through the controller.

The navigation improvements in already congested airspace will allow a further increase in traffic volume as well as the use of more direct routes. This, however, will result in a greater demand for separation services from ATC. Individual controllers may initially take responsibility for more aircraft to alleviate this new demand, but the need will eventually cause the addition of more controllers who will, in turn, further increase spectrum crowding. The use of "pre-made" data messages sent to aircraft when they arrive at certain points in the airspace may be one way of providing separation assurance services to more users while minimizing spectrum congestion.

Oceanic operations will improve as aircraft will be able to fly more precise routes. Better routing will allow more aircraft along each individual route and will allow the overtaking of slower aircraft along the route. In time, some parts of the current oceanic airspace will be treated like extensions of the domestic en-route, and, as a result, better real-time communication capability (both pilot-to-controller and pilot-to-pilot), more frequent position reporting, and pilot response to controller commands, all of which increase spectrum usage, will be needed.

Table 3.7-1. Drivers and Constraints for Navigation Services

Driving Forces →	← Constraints	Comments
Use of GPS for en route/ terminal navigation	▪ Frequency Spectrum ▪ Cost for users to update aircraft with new Avionics ▪ Concerns whether GPS can provide "sole service" ▪ Availability of voice and data communications for oceanic flights	U.S. Government is committed to provide a second and third signal to improve robustness and reliability of GPS for civilian Users. Also enables real-time determination of highly accurate position location anywhere on earth.
Deployment of WAAS to augment GPS to provide en route/ terminal navigation and CAT I approaches for airports	▪ Frequency Spectrum ▪ Cost Benefits of installing WAAS ▪ Availability of data and voice communications for flights in new en route airspace ▪ Cost for airports to upgrade lighting for new CAT I approaches	GEOSAT uplink stations and communication satellites provide frequency coverage throughout US airspace allowing more user preferred and direct routes. Sufficient accuracy to provide CAT I approaches at most airports.
Deployment of LAAS to augment GPS to provide CAT I/II/III approaches for airports	▪ Frequency Spectrum ▪ Cost Benefits of installing LAAS ▪ Cost for airports to upgrade lighting for new CAT I/II/III approaches	Precisely surveyed ground station, multiple GPS receivers, VHF link and broadcast GPS corrections with integrity messages to 20 to 30 nmi of airport.
Continued need for ground-based navigation as well as SAT navigation	▪ Capability of GPS to provide "sole service" ▪ Frequency Spectrum, availability, and interference concerns ▪ Timeline to transition GA and other Users from old equipment	Use of SAT navigation for "sole service" causes safety concerns about SAT availability, unintentional and intention interference, and other issues. The frequency spectrum will also be even more congested with concurrent use of ground and new SAT navigation systems.

3.8 Airspace Management Service

Airspace management service involves design, allocation, and stewardship of the national airspace resource in order to ensure its safe and efficient use. Effective airspace management is dependent upon the coordination of present and projected stakeholder (aviation and non-aviation) needs, traffic volumes, spectrum availability, effects of airport construction, surface structures, and environmental factors.

Future Airspace Management Services

The future will see shifts in airspace management practices.

- Sector management will become more dynamic in that controllers will have the ability to resize sectors to accommodate continuously changing traffic demands.
- The number of high altitude sectors will be minimized (possibly to only eight for complete national coverage) so that cross-country traffic need change sectors infrequently.
- The re-acquisition process of unused SUA will become more responsive. At present, this process is based on fax-type equipment and, as a result, is slow.
- In large metropolitan areas with multiple airports, low airspace will be managed as if it is serving one large airport with widely dispersed runways changing many communications requirements based on sector size and shape.
- Airspace will be managed as though position information is acquired with radar signal, but, instead, it will stream down from aircraft and their ADS sources.
- Oceanic routes for which demand is to increase, will likely be controlled in a manner consistent with en-route domestic flights instead of present oceanic methods.
- More airspace will be allocated for handling space launches.

Table 3.8-1. Drivers and Constraints for Airspace Management Services

Driving Forces →	← Constraints	Comments
Need to dynamically reconfigure airspace for flexibility and to accommodate increased traffic demands	▪ Automation and decision aids to support dynamically reconfiguring airspace ▪ Controller acceptance of the necessary procedure and paradigm changes • Additional communication requirements to support the different airspace configurations rather than the relatively rigid sectors used today	There is a limited capability to combine sectors of airspace in the ARTCCs today.
User demand for additional low altitude direct routes	▪ Users must be properly equipped with Avionics to fly direct routes ▪ Procedure changes and potential automation support needed to support new direct routes • Increased demand for data and voice communications in highly congested terminal airspace	Many existing low altitude routes cause the aircraft to fly increased distances due to ground navigation aid constraints.

3.9 Infrastructure/Information Management Service

Infrastructure management ensures flight safety and efficiency through the monitoring and maintenance of NAS supporting hardware, spectrum, and information services. Hardware, which includes radar, communication links, navigation aids, and automation, is continuously monitored. Failures are detected and isolated, and corrective and preventive maintenance is performed to ensure the operational readiness of the NAS. Spectrum management secures, protects, and manages the radio spectrum for the FAA and the U.S. aviation community. NAS support provides information and coordination services to the DOD, law enforcement, land grant agencies, state aviation managers, and disaster relief.

The monitoring and maintenance of NAS system performance is done only for systems operated and maintained directly by the FAA. NAS systems are continuously monitored, and anomalies are reported to the operations control center (OCC). The OCC itself also monitors facility key performance parameters and reports its findings to the National Operational Control Center (NOCC). When needed, an OCC may alter facility system controls to maintain facility and/or system optimization. All maintenance and system changes are reported in real-time to allow for expanded collaboration with NAS users.

Future Infrastructure Management

Although infrastructure does not directly support user needs, changes to the communications architecture that address user needs will have a significant effect on the infrastructure. In the current system, the FAA has software to manage the infrastructure it operates. Similarly, airlines manage their own corporate resources (although some have outsourced these activities). With the planned inclusion of network management in the next version of the ATN SARPs, the infrastructure may be able to manage airborne nodes, providing more information, but, at the same time, increasing the amount of network overhead. For both voice and data communications, it is likely that networks will be able to determine the status of other nodes on the network, whether these nodes are service providers (e.g., the CAAs of other States), airlines, or aircraft.

Information and coordination services will be faced with the fact that data sharing will be an issue with the maturation of the NAS network. Well defined methods of information dissemination will reduce costs as the FAA will not need to pay for or generate the same data multiple times; once the data is acquired, it is to remain available to all users. The data sharing will also aid in collaborative flight planning as users will be provided with an accurate picture of which portions of the NAS are functional and how to plan a flight given that certain portions are not.

Spectrum management will also change. At present it aids with the development of national policy governing spectrum allocation, and it provides guidance to all new and existing programs to ensure compliance with spectral standards and existing equipment. Spectral management will become more difficult in the future as new technology will require the use of spectrum previously unused for aeronautical communications. The economic value of spectrum in fields not related to aviation, however, will make it harder to protect for aeronautical mobile system route services [AMS(R)S]. In addition, aeronautical spectrum is currently allocated for specific purposes, such as navigation systems or communications systems. Any architecture that combines capabilities over a single communications pipe (e.g., using ADS-B to provide FIS services) may require changes to spectrum allocation – at both national (FCC, NTIA) and international (WRC, ITU-R) levels.

Table 3.9-1. **Drivers and Constraints for Infrastructure Management**

Driving Forces →	← Constraints	Comments
SARPs requirements to define and use managed objects, including on airborne nodes	Bandwidth	Requirements for network management
Use of commercial ground-ground networks	Network management tools custom built for FAA	Standardized protocols needed
Use of commercial air-ground networks	Service providers will use their own antenna farms	Changed role for spectrum engineering to protect spectrum, police interference, etc.
Service providers determine technology	ITU-R & FCC/NTIA spectrum allocations	Commercial providers get spectrum allocation. Spectrum is allocated for specific purposes; only aeronautical spectrum is protected.
• Service providers determine technology to satisfy commercial demand • Voice over IP is driving vocoder/ codec development	Clear transmission of voice is necessary	Acceptability criteria are needed for vocoders
Diversity; more types of links	Ability to manage multiple links and to failover when a link becomes unavailable; might require using a different provider	ATN routers are designed to handle multiple links
Security threats	System must accommodate public users, including non-U.S.	Network infrastructure requires protection mechanisms; topology might be affected
User demand for use of most economical, effective communication links	Cost of implementing and supporting multiple links; latency requirements	Current system is like the days of one telephone company; users had no choice as to who provided the service. PETAL II is using dual-stack to support FANS and ATN equipped aircraft.
Use of digital air-ground radios	Co-site interference	New modulation techniques (VDL, inter alia) have different interference characteristics and may require new placements of towers at antenna farms.
Increased use of non-FAA resources	As network management becomes more complicated, skills for problem resolution might be rare	Collaboration tools could make it possible for limited number of highly skilled, extensively trained experts to work on problems non-locally. • Need high-quality, secure links • But experts would not have to travel to job site

3.10 Aeronautical Operational Control (AOC) Service

Aeronautical Operational Control Services are provided by the major air carriers to schedule flight operations, monitor flight progress, and collaborate with FAA Traffic Flow Management on NAS projections and user preferences. AOC messages are those defined as necessary for the safe and orderly operation of an aircraft. While the majority of the messages are related to orderly operation, safety related messages are also significant in number. Typical safety messages include hazardous weather conditions or maintenance issues.

The original set of AOC data messages are the Out, Off, On, In (OOOI) messages. These messages are generated automatically via sensors and radio equipment on board the aircraft. By collecting these messages, airlines developed statistics on flight times and could maintain a rough estimate of aircraft location. Building on the success of the OOOI messages and the infrastructure to distribute them, airlines developed a variety of other messages.

The current AOC messages include the OOOI messages, crew information, fuel verification, delay reports, weight and balance, dispatch release, fuel remaining, gate assignment and coordination, engine parameters and a variety of weather information and maintenance messages. Flight plan information may be exchanged between the flight crew and the dispatch office in order to accommodate delays or rerouting. These planning messages include weather conditions at primary and secondary landing sites, air traffic control conditions and fuel analysis. The cabin crew need for AOC messaging include connecting flight gate information, special services for passengers such as a wheelchair request, and notification of an in-flight medical emergency.

Closely related to AOC messages are Airlines Administrative Communications (AAC). AAC messages have a lower priority than AOC messages but can be expected to increase significantly as data link capacity increases and per message costs decrease. Examples of AAC messages include passenger manifest, reporting crew hours, and in-flight passenger ticketing.

AOC traffic is growing rapidly and has created a commercial business case for an evolutionary bit-oriented system with higher speed, and modern internationally accepted protocols. The future needs for AOC include increasing amounts of engine performance data, flight plan data, and maintenance data. New uses include potential downlink of flight data recorder information and increased negotiations between aircraft crew and controllers for traffic flow management.

International spectrum allocations constrain AOC systems to existing allocations, necessitating greater spectrum efficiency. Future systems will feature common, compatible protocols in order to exchange messages via a variety of media including High Frequency (HF), Very High Frequency (VHF), and satellite. Messages will be routed through the lowest cost path consistent with latency delivery requirements.

Technical factors and user requirements that tend to drive change for aeronautical operational and administrative communications are listed below along with factors that tend to constrain that change.

Table 3.10-1. Drivers and Constraints for AOC and AAC

Driving Forces →	← Constraints	Comments
Need for aircraft maintenance data	• Bandwidth	Airlines can improve turnaround time by having right staff and equipment to service problems as soon as aircraft has landed.
Need for engine performance data	• Bandwidth • Confidentiality	Increasing demand for information. Data are provided, but airlines want more.
Flight plan data	• Bandwidth • Use of proprietary protocols	Needed for cost effective use of CDM

Driving Forces →	← Constraints	Comments
Efficient recovery from delays for passengers	• Bandwidth	Need improved gate information, possibly including expediting deplaning of passengers with tightest connections.
Desire for quicker financial and stock reporting	• Bandwidth • Confidentiality	Reports on beverage and duty-free sales for financial information as well as for replenishing stock

3.11 Onboard Services

Passengers have had few communication opportunities in the past. Voice service is available on a large number of aircraft today but has seen limited passenger use due to high cost. Passenger communications can be expected to increase substantially if costs are reduced.

Major increases in cabin services for passengers and cabin crew are envisioned. In the future passengers will have access to voice and data services and will be able to interact with automation systems for a variety of services including voice, in-flight entertainment, shopping, hotel and car reservations, and data exchange services such as electronic mail.

Cabin crewmembers will use the on board services to access their corporate automation to provide passenger services such as flight and travel planning. The same links can provide business functions such as load factor reports, cabin maintenance requirements, and crew availability.

Once connected to ground based automation services, passengers will be able to receive personal business communications.

Passenger communications will be provided by sharing transmission media thereby reducing the cost of all services for ATS, AOC, and the passenger. For shared service, the media must provide the ability to prioritize ATS and AOC messages over passenger messages. For the services that include financial transactions, secure links will be required.

Technical factors and user requirements that tend to drive change for aeronautical operational and administrative communications are listed below along with factors that tend to constrain that change.

Table 3.11-1. Drivers and Constraints for Onboard Services

Driving Forces →	← Constraints	Comments
Sporting events or other entertainment events	• High bandwidth for real-time television • EMI	A commercial firm has announced award of a contract to provide real-time television on A320s
Passengers want to conduct business (telephone, fax, laptop PCs)	• Equipage cost • Size of units • EMI • Interfaces to faxes, PCs • Power outlets • Security (for financial or personal transactions)	Passenger use of communications facilities can justify the installation of satellite or other communication equipment, which might also be useable for ATM, FIS, AOC, or other purposes.
Passengers bring their own equipment	• EMI	

Driving Forces →	**← Constraints**	**Comments**
Gambling	• Bandwidth • Latency • Security • U.S. law	• Already in place in flights that do not originate or terminate in the U.S., so some aircraft are equipped • Probably highly profitable

4 Candidate Communication System Architectures (CSAs) for Delivery of User Services

4.1 Communication System Architecture (CSA) Elements

Section 3 defined the user needs for delivery of the services necessary to support safe and efficient operations in the NAS Airspace. In addition, driving and restraining forces were identified, which characterize the differences between each class of service. This section defines candidate CSAs which actually deliver these or subset of these services to the airborne airspace users. Three classes of users are defined as follows:

- Class 1: Operators who are required to conform to FAR Part 91 only, such as low-end General Aviation (GA) operating normally up to 10,000 ft. This class includes operators of rotorcraft, gliders, and experimental craft and any other user desiring to operate in controlled airspace below 10,000 ft. The primary distinguishing factor of this class is that the aircraft are smaller and that the operators tend to make minimal avionics investments.
- Class 2: Operators who are required to conform to FAR Parts 91 and 135, such as air taxis and commuter aircraft. It is likely that high-end GA and business jets and any other users desiring to operate in controlled airspace will invest in the necessary avionics to be able to achieve the additional benefits.
- Class 3: Operators who are required to conform to FAR Parts 91 and 121, such as Commercial Transports. This class includes passenger and cargo aircraft and any other user desiring to operate in controlled airspace. These users will invest in the avionics necessary to achieve the additional benefits.

For purposes of developing candidate CSAs, it is assumed that all three classes of users either desires to or is required to operate under IFR rules. For a 2015 architecture, this will require a certain minimum equipage for aircraft in each class and will be a major cost and benefits (business) factor in assessing candidate CSAs.

The delivery of services traditionally have been provided by service providers; however, the proposed CSAs will address candidates that consider delivery of services by airborne users or delivery by user interaction with other remote data bases. Therefore, the CSAs will address the distribution of certain services to airborne users with the responsibility to deliver services to other users. All candidate CSAs will be developed consistent with the following figure which depicts the airspace users and service providers along with the information exchange paths used to deliver users services between airspace users (A-A) and between airspace users and service providers (A-G).

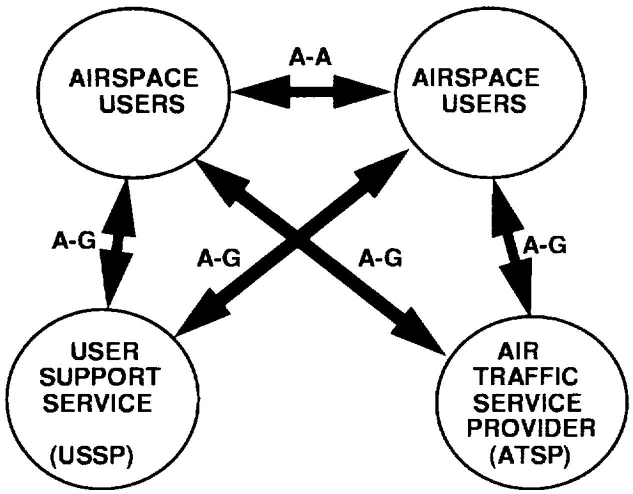


Figure 4.1-1. Baseline Communication System Architecture

The service providers can be categorized as either supporting the users in an advisory or operational fashion (User Support Service Provider) or as part of an air traffic organization (Air Traffic Service Provider). This distinction is critical as certain user services are uniquely provided by only one of the service providers. The following lists the specific organizations/systems that fall under each of the above categories.

User Support Service Providers (USSP)

- Fixed Base Operators
- Military Base Operators
- Airline Operations Centers
- Advisory Systems/organizations
  - ⇒ Flight Information System (FIS) Supplier
  - ⇒ D-ATIS
  - ⇒ National Weather Service; ETC..

Air Traffic Service Providers (ATSP)

- Automated Flight Service Station (AFSS)
- Traffic Management Units (TMUs)
- Air Traffic Control System Command Center (ATCSCC)
- Surface/Tower ATC
- Terminal ATC
- En Route ATC
- Oceanic ATC

As indicated above, the candidate CSAs for 2015 will address the distribution to airborne users of the responsibility to delivery certain services. Therefore two CSA Service Architectures will be evaluated consisting of:

1. **Centralized Service Provider Service Architecture** – the service providers would provide All services and processed information sent to the users who would utilize the information to maintain safe and efficient operations. The users would provide updates to the service providers and provide information to other users and service providers either mandated for safe operation (TCAS) or derived from observations in the user sphere of operation (PIREPS).
2. **Distributed User and Service Provider Service Architecture** – Certain services would be distributed to the airborne user who would have the responsibility to process information provided by the service providers not only to maintain its own safe and efficient flight but provide processed information to other airborne users and to service providers. Two potential areas of distribution include preparation of flight plans and distributed separation of IFR aircraft.

The distribution of the services or service architectures is a key in defining and selecting candidate CSAs as the distribution impacts the equipage of the airspace users affecting the cost and benefit decisions necessary to actually implement that CSA. The service architecture also affects the type and magnitude of information transferred between airspace users and service providers and the ultimate selection of the communications media.

The following section will evaluate each of the user service categories identified in section 3.0 for each of the two service architectures defined above. It is important to evaluate CSA service architectures at the service level due to the differences in service characteristics. For example, some services have more stringent performance requirements in terms of capacity and latency; or may not apply to either of the distributed or centralized service architectural schemes. The objective is to define a CSA concept that defines the distribution of services across the elements of the CSA as defined in Figure 4.1-1. The evaluation will consider the degree of that the delivery of services are driven by and support the following major Government/Industry/User initiatives such as:

1. AATT/Free Flight Concept
2. AWIN/Aviation Weather Safety Program
3. Distributed Air Ground (DAG) Concept
4. Collaborative Decision Making (CDM) Objectives
5. Small Aircraft Transportation System Concept

The evaluation will also address areas where delivery of services are restrained by:

1. Technology Availability
2. Program Availability
3. Resource Availability

The resulting CSA Concept will be used to define candidate CSAs by identifying different service delivery methods that can be applied to one or more information exchange paths in the CSA Concept. The three methods are defined as follows:

1. **Broadcast Method**- Information will be sent by service provider simultaneously to multiple airborne user subscribers containing the same set of information. Each subscriber must store and extract the information necessary to support their respective flight.
2. **Point-to Point (Addressable) Method** – Information is tailored for each subscriber based on subscriber needs and/or service provider determination and sent only to that specific subscriber. The subscriber must request changes to delivery.
3. **Query/Response Method** – The airborne user determines individual needs and remotely accesses the required information, retrieves the information, and uses the information in executing the particular flight. The databases being accessed could be either on the ground or on other aircraft.

4.2 Communication System Architecture (CSA) Concept Definition

The eleven (11) user service categories will be evaluated against the two (2) service architectures with the objective of identifying applicability of services to functional architectures, determining relative merit relative to supporting major user/industry drivers; i.e., Free Flight and Aviation Weather, and impact of constraining factors, such as, technology, other program dependencies, and resource limitations. The following evaluation will be utilized to (1) define the CSA Concept used for developing candidate CSAs and (20=) used to define critical restraining factors that may play a major part in selecting a CSA from the candidates.

Table 4.2-1. CSA User Service Category Versus Service Architecture

USER SERVICE CATEGORY	CENTRALIZED SERVICE PROVIDER SERVICE ARCHITECTURE	DISTRIBUTED AIRSPACE USER AND SERVICE PROVIDER SERVICE ARCHITECTURE
FLIGHT PLAN SERVICE	• Existing Service implementation • Cannot support full Free Flight or DAG concepts • Flight plan processing and Decision Support Tools relying on flight plans would be impacted as more flights fly direct routes under North American Route Program • CDM would impact processing of flight plans at AOCs and FAA Traffic Flow operations. • No major technology, program, or resource restraints	• Necessary to support AATT/Full Free Flight and DAG • Will improve support to CDM • Requires flight plan processing functions (preparation, modification, etc) to be conducted by onboard airspace user • Requires weather projections along entire route and probably trial planning function • Requires FMS equipage and link to flight plan processing • Significant, additional avionics required for GA users • Changes required for commercial avionics • Restrained by Availability of low cost GA avionics • Requires increases in flight plan data transmitted by airborne user

USER SERVICE CATEGORY	CENTRALIZED SERVICE PROVIDER SERVICE ARCHITECTURE	DISTRIBUTED AIRSPACE USER AND SERVICE PROVIDER SERVICE ARCHITECTURE
ATC SEPARATION ASSURANCE SERVICE	• Current service implementation except for TCAS operations, VFR operations, and Selected Oceanic maneuvers conducted by airborne users • Will support AATT/Free Flight Phase 1 and CDM capabilities but will result in increased processing (conformance checks, etc.) by service providers • Will not support AATT/Full Free Flight and DAG • Requires procedure for integration of pseudo-radar data (ADS, Flight Plans) with radar positional data by ATC Service providers • Requires the GA users have capability to receive and display aircraft positional information to fly IFR • Restrained by Availability of low cost GA avionics • Restrained by availability and capability of FAA ARTCC and TRACON automation systems to incorporate Decision Support Tools.	• Necessary to support AATT/Full Free Flight and DAG • Requires processing and display of traffic and weather information well beyond TCAS radius of operations and perhaps along entire route • Requires some form of conflict probe for airspace users • Requires much greater airspace user interaction with other airborne users • Requires FMS equipage and link to increased positional processing capabilities • Significant, additional avionics required for GA users • Changes required for commercial avionics • Restrained by Availability of low cost GA avionics • Restrained by availability and capability of FAA ARTCC and TRACON automation systems to incorporate Decision Support Tools • Restrained by lack of TCAS equipage on cargo transports and GA aircraft • Will increase amount of aircraft position and state information transmitted by airborne user
ATC ADVISORY SERVICE	• Current service implementation • Will support AATT/Free Flight and DAG concepts with increased quality and transmission capacity • Improved service restrained by FAA, NWS, and Commercial weather /flight information providers • Restrained by Availability of low cost GA avionics	• Same as centralized except that airborne users will have to issue traffic advisories to other users in their area of control beyond TCAS area. • Significant, additional avionics required for GA users • Changes required for commercial avionics • Will increase amount of advisory information transmitted from service providers and from airborne users to other airborne users.

USER SERVICE CATEGORY	CENTRALIZED SERVICE PROVIDER SERVICE ARCHITECTURE	DISTRIBUTED AIRSPACE USER AND SERVICE PROVIDER SERVICE ARCHITECTURE
TRAFFIC MANAGEMENT - SYNCHRONIZATION SERVICE	• Current service implementation • Most impact limited to CDM initiatives • Objectives of AATT/Free Flight are to reduce the occurrences of these Traffic Flow restrictions • No real impact on GA	• No potential impacts except that with distributed flight planning and separation assurance, airborne users will be in position to more efficiently react to restrictions and negotiate possible responses.
TRAFFIC MANAGEMENT - STRATEGIC FLOW SERVICE	• Current service implementation • Most impact limited to CDM initiatives • Objectives of AATT/Free Flight are to reduce the occurrences of these Traffic Flow restrictions • No real impact on GA	• No potential impacts except on preflight planning in conjunction with CDM initiatives.
EMERGENCY AND ALERTING SERVICE	• Current service implementation	• No potential impacts
NAVIGATION SERVICE	• Current service implementation • GA aircraft should have as a minimum the GPS navigational capability • Cost of GA avionics is not a major restraint	• Requires that all aircraft above FL180 have capability to utilize GPS navigational fixes as well as defined alternates • GA aircraft should have as a minimum the GPS navigational capability • Cost of GA avionics is not a major restraint
AIRSPACE MANAGEMENT SERVICE	• Current service implementation	• No major impacts except for increased transfer of information relative to SUA and any other restricted airspace to be used in distributed flight planning.
INFRASTRUCTURE/INFORMATION MANAGEMENT SERVICE	• Current service implementation	• Airborne users would need access to status information on ATC systems and airports to conduct flight planning.
AERONAUTICAL OPERATIONAL CONTROL (AOC) SERVICE	• Current service implementation	• Distributed airborne flight planning and CDM initiatives would increase amount of information exchanges between commercial pilots and dispatchers at AOC
ON-BOARD SERVICE	• Current service implementation	• No potential impacts

Based on the above tables, it is obvious that certain services are prime candidates for distribution to airborne users while others must be utilized by airborne users as a result of the distribution of the prime services. Together, they form the candidate set of distributed services to be used in definition of CSAs. Distributed services, by definition, are those that are utilized not only for the individual airborne user operation but generate information for use by other airborne users and service providers. The following table identifies those services supported by service providers and those distributed to airborne users.

Table 4.2-2. User Services Versus Service Providers and Distributed Airspace Users

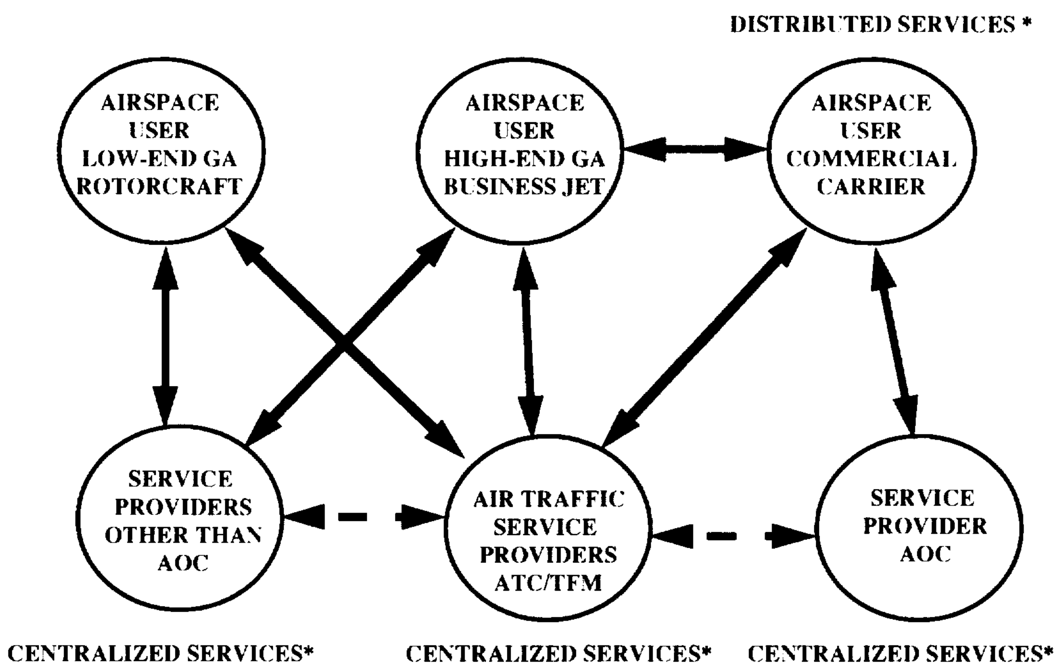
USER SERVICES	USSP (AOC)	USSP (OTHER)	ATSP (ATC)	ATSP (TFM)	DISTRIBUTED (NOTE)
FLIGHT PLAN SERVICE					P
ATC SEPARATION ASSURANCE SERVICE					P
ATC ADVISORY SERVICE					S
TRAFFIC MANAGEMENT - SYNCHRONIZATION SERVICE					S
TRAFFIC MANAGEMENT - STRATEGIC FLOW SERVICE					S
EMERGENCY AND ALERTING SERVICE					
NAVIGATION SERVICE					
AIRSPACE MANAGEMENT SERVICE					S
INFRASTRUCTURE/INFORMATION MANAGEMENT SERVICE					S
AERONAUTICAL OPERATIONAL CONTROL (AOC) SERVICE					S
ON-BOARD SERVICE					

NOTE: P = PRIMARY DISTRIBUTED SERVICE;
S = SECONDARY OR SUPPORTING SERVICE

It is assumed that GA aircraft considered in the development of CSAs are going to fly under IFR rules. As a minimum, all GA aircraft (including Rotorcraft) desiring to gain greater access to airspace under AATT/Free Flight and SATS concepts should be (1) equipped to receive and process weather data in both A/N and annotated (versus raw data) graphic formats, (2) have capability to receive augmented GPS signals for navigation, and (3) have capability to receive and display ADS-B position reports. Those High-end GA aircraft operating above 1000' should be equipped with the same capability as low-end GA but with added capability to broadcast ADS-B position reports.

In Table 4.2-1, there are several major restraints that must be overcome to achieve the objectives of the AATT/Free Flight, Aviation Weather, and SATS Concepts. The first is related to the above discussion and involves the availability of low cost GA avionics ($500 - $1,000) to include GPS navigation, weather display, ADS-B receive capabilities to under $2,500 to include expanded ADS-B broadcast capability. The benefits to GA airspace users have been documented (relative to gaining greater access to controlled airspace and should justify the above costs. The question is as to whether Industry can meet these cost goals for the avionics. At the other end of the user spectrum, the cost of modifying commercial avionics and equipping cargo transports with TCAS are another set of restraints that must be addressed. Finally, the most difficult restraint deals with revision of ATC orders, standards, and procedures to allow the integration of pseudo-radar position reports from ADS to be integrated with radar position reports and treated equally in separating IFR aircraft. The development of Candidate Communication System Architectures (CSAs) will be conducted assuming that the above restraining factors will be overcome.

The following figure depicts the Communication System Architecture (CSA) Concept derived from the previous tables, which forms the basis for definition of Candidate CSAs in the next section.



***:See Table 4.2-2 for Service Definitions**

Figure 4.2-1. Communication System Architecture (CSA) Concept

4.3 Candidate Communication System Architectures (CSAs) Definition

Candidate Communication System Architectures (CSAs) will be defined in terms of the method of service delivery for each of the air to ground and air to air information exchange path identified in Figure 4.2 -1. The methods of service delivery defined in 4.2 include:

1. **Broadcast Method(B)**
2. **Point-To-Point (Addressable) Method (A)**
3. **Query/Response Method (Q)**

These delivery modes can be applied to individual information exchange paths or groups of information exchange paths. Furthermore, several methods can be applied to a single path. Each method has characteristics which impact a wide range of factors including availability, capacity (bandwidth), avionics, safety, communications media (VHF, SATCOM, etc), therefore a wide range of candidates can be selected and evaluated. The following example represents an initial candidate CSA that will be used as the basis for determining other candidates.

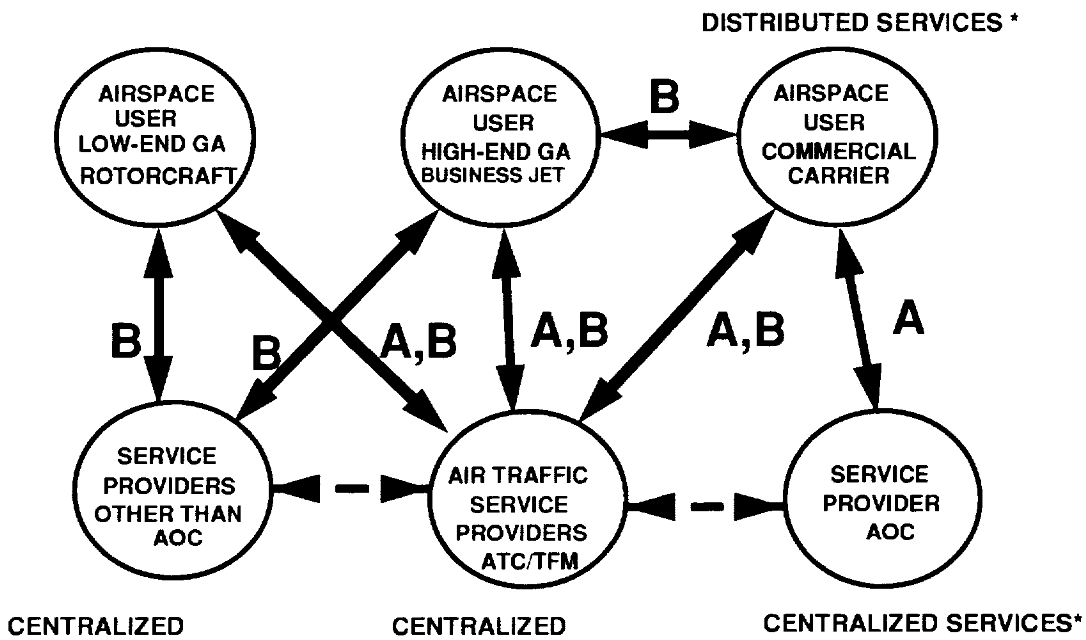


Figure 4.3-1. Baseline Candidate Communication System Architecture

The selection of the above service delivery method is based on the following rationale. For service providers other than the AOC, it makes sense to broadcast the advisories to provide a more cost-effective approach for GA users. The AOC would always use an addressable scheme for not only positive control but also protection of valuable operational information that would be of value to competitors. ATC Service providers would use a hybrid mode with traffic and weather data being broadcast to all aircraft flying in the controlled airspace with addressable mode used to transfer critical ATC and safety messages. It is likely due to cost constraints that Low-End GA would use a simpler and less costly media than either High-end GA or Commercial users. The broadcast air to air link between High-End GA and Commercial users is based on the assumption that both will be flying in the same airspace and will be employing full ADS-B capability.

Additional candidate CSAs can be developed by simply changing the methods of service delivery for individual information exchange paths. It is recommended that the baseline be modified to include the Query/Response Method for (a) GA users interacting with service provider databases and (b) Commercial users interacting with AOC databases. The introduction of this method of service delivery represents a major departure from traditional methods but does present a method that can incorporate both advanced information systems and communications technology. A demonstration of this method of service delivery relative to a wide range of information; including, weather, charting, and traffic is technically feasible at this time. Since the selection of a candidate CSA is linked closely to the selection of the method of service delivery, it is important that the relationship with communications technology be understood. The following discussion presented with that objective in mind.

Comparing candidate architectures – as alternatives – might obscure critical issues that are not easily packaged into a complete architecture but have profound impacts on the architecture.

Perhaps the clearest discriminator between concepts is the degree of linkage between the ATM and weather service providers. The current architecture is based on ATM and weather services being provided by the FAA, using FAA-operated communications links (with some links such as FANS or ACARS operated by commercial aeronautical service providers); airlines and some other users obtain weather from other sources, but the architecture is based on FAA provision of services.

In accordance with FAA policy established in June 1998, flight information services should be provided through commercial service providers. This has significant architectural implications. The current architecture leaves the communications decisions to the FAA. The alternative architecture leaves the decisions to the service providers and users, although the FAA would still have its regulatory role related to certification. In fact, users must pick a non-FAA link if they are to be able to receive these services.

The fact that this link decision might be made by users and weather providers does not take it out of the realm of the NAS architecture. The weather communication link and related avionics could be made totally independent of the links and avionics used for ATM. This, however, would have a profound impact on the economics of the avionics equipage and the amount of space needed for the avionics. If the link, processors, and displays acquired for FIS could also be used for delivery of other services, such as TIS or ADS-B, the level of equipage would change. Thus, the architecture needs to consider whether this non-ATM equipment must be dedicated to non-ATM use, or could also be shared with ATM functions.

This argument leads to a further consideration – whether services developed for commercial, non-aeronautical, applications should be adaptable for aeronautical use – and at what cost? To some extent, there has been a precedent. ACARS was developed to initially support largely administrative functions but has evolved to support AOC capabilities that affect safety and regularity of flight. Pre-departure clearances and ATIS have been delivered over ACARS for several years. In a few years, controller-pilot communications will be able to be conducted over a communications service developed for commercial use.

Aviation, like many other industries, has a critical need for more communications capacity and performance. Ground-based applications, using copper or fiber links, have enjoyed extensive improvements in performance; even without these improvements, capacity can be increased by establishing more circuits. Air-ground applications are not as fortunate; spectrum is a limited resource, although it has benefited from efficiency improvements. Most aeronautical communications, both voice and data, reside in the VHF band. Spectrum managers around the world have faced increasing challenges to manage the sparse capacity in VHF; other bands are needed if growth is to be accommodated.

One of the most effective areas for growth is in the bands suitable for satellite communications. The business case for satellite communications is being made based on general communications use, not just on aeronautical use. Projected high demand for these services has led to designs that provide very high capacity; with the expectation of many users, the satellite infrastructure costs can be spread across many users and types of applications, in order for the satellite communication providers to be able to compete with ground-based communications providers. For most users, ground-ground communications is an alternative and satellites have to be able to have competitive costs and performance in order to have a market. Aeronautical users, who must use radio communication, would be able to take advantage of this technology – probably at lower costs than previous satellite services.

Earlier, several modes of delivering services were described. The following discussion describes alternative ways in which one specific service could be provided, highlighting the characteristics of each of these delivery modes. The overall hierarchy of choices is shown in Figure 4.3-2, which portrays some of the alternative means for providing weather information to the cockpit.

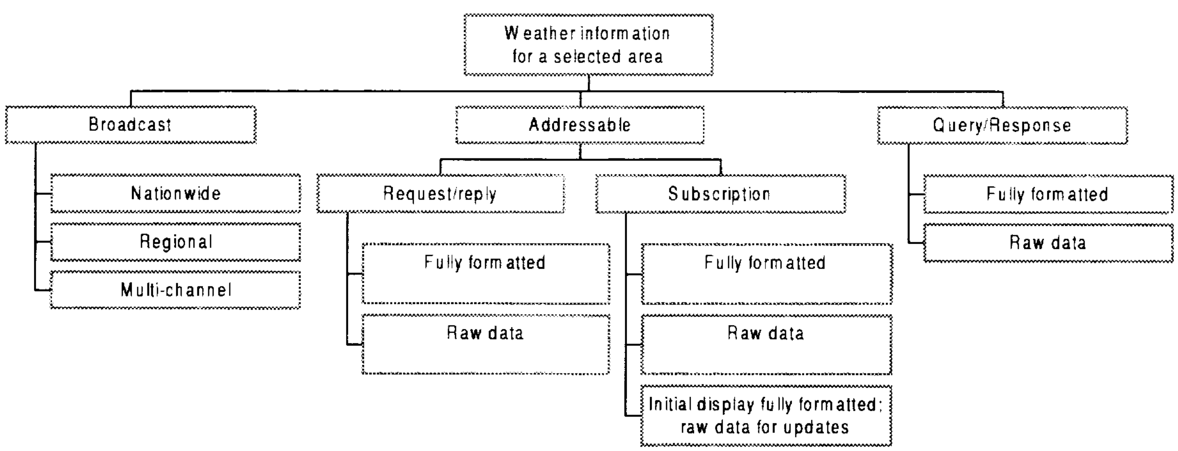


Figure 4.3-2. Service delivery Methods for a Weather Service Provider

When using a broadcast service, the user has no control over what is sent minimal control over what is received, and needs precise control over what is displayed. In terms of equipage, the aircraft needs a means for specifying the data of interest (e.g., via a menu) and a means for processing the request and displaying the results. The aircraft needs a receiver (and antenna suitable for reception), but does not need a transmitter. If the service provider is using broadband communications, it might be possible to have all of the provider's services on a single channel, with the data repeated at fairly frequent intervals to minimize latency to an acceptable range. This could be compared to a scroll of sports scores or stock ticker display on television news; you may have to wait several minutes before the information you want is available. In the case of aviation, it is not possible for the pilot to monitor the display, so automation is needed to select the desired information. It might be possible to subdivide the country into several regions, broadcasting weather of local interest. This could reduce the latency, but would also mean that pilots might have difficulty in obtaining weather for a destination or other portion of the flight. A service provider might also choose to offer multiple channels, in which case a channel selector could provide information for the area of interest, although it would require that the pilot have a simple interface to the channel selector (perhaps a touch screen with an interface that translated the airport symbol or map location into a channel.

This type of broadcast technology is easily achievable for satellites, and will be proven technology within a few years. Some automobiles are being equipped with satellite receivers that can receive multiple channels of CD-quality audio. New models of the Airbus A320 will be able to receive satellite television broadcasts.

Unlike broadcast, addressable point-to-point makes it possible to send user specific information to a single aircraft (or possibly groups of aircraft using a multicast). Point-to-point could be provided as a request/reply service, or on a subscription basis. This method provides many technology choices. Voice is already used for controllers to advise specific flights of weather conditions (although any other pilots on that channel will also hear the advisory). Pilots are able to request information from controllers on weather information, but this can occur only on a time-available basis. Besides the provision of weather information diverting the controller's attention from other tasks, it consumes part of the dedicated voice channel, making it unavailable for other communication.

Point-to-point data communication makes it possible to send considerably more data to the aircraft, including graphical weather displays. Graphical weather, even when compressed, requires a large amount of data. Modern CPUs have enough processing power to transform raw data into a suitable display, assuming that the avionics had appropriate map data. With point-to-point communications, users would be able to request delivery of specific products, possibly with some tailoring. If delivery is on a subscription basis, updates to the weather situation would be provided, either at regular intervals or when there were important changes to the situation. Simple request/reply requires that the service provider be able to remember the requestor's address only for as long as the transaction; subscription service requires that the service provider know the address and communications route to the aircraft for the duration of the subscription. If request/reply were used, it might be possible for a satellite to simply transmit the appropriate response, if the data were able to be stored on the satellite. Subscription service clearly requires that the data originate on the ground and be uplinked to the satellite for transmission to the requestor.

Point-to-point provision of the service requires that the airborne systems have the capability for specifying a request, processing the results (either from graphics ready to display or raw data), and display the data, as well as having a receiver and transmitter, and antenna suitable for transmission. With appropriate automation, the pilot could have a computer that formulated requests based on flight plan or current position, reducing the amount of human intervention to process requests. The service provider's ground systems need to be able to process and respond to requests, as well as having the raw data needed to respond to the requests.

A step beyond the point-to-point delivery mechanism is a query-response capability (although the underlying communication technology would probably be the same as for point-to-point, albeit with different performance requirements). This mode is analogous to some World Wide Web mapping applications, in which a user can query a database or service for information, and then refine the requests. For a weather application, a user might want to zoom in for more detail on potentially hazardous weather, might zoom out to be able to see the big picture to be able to evaluate going around the weather, or might query for information on an alternate airport. Unlike the point-to-point delivery mechanism, in which every user requesting a specific product gets the same product, the query-response mechanism requires tailoring to satisfy each request. Some form of automation is needed for the pilot in order to avoid having the query process be too cumbersome. This method imposes stringent communications requirements. Since the query is for more than a specific canned product, there must be a query language, which would need to be transmitted to the service provider. These queries would consume more bandwidth than the point-to-point service, and would also require shorter latency requirements in order to preserve the interactive nature of the session. Other than performance requirements, the communications equipage for this type of service would be the same as for the point-to-point mode, and could be considered an evolutionary service.

5 Assessment criteria

5.1 Definition of Assessment Criteria

The previous sections presented the set of user services to be supported in any future communications architecture and provided several alternative concepts. This section defines the criteria by which those architectures may be objectively evaluated. Assessment criteria are defined as those characteristics that differentiate among alternatives. In section three, drivers and constraints were introduced. In one sense, each driver or restraining force can be viewed as assessment criteria since they serve to differentiate the various architectures from one another.

The assessment criteria will also be applied during the research activities for Task 5, which develop the 2015 AATT Architecture; Task 6, Develop AATT 2007 Architecture; and Task 7, Develop AWIN 2007 Architecture. In addition, the assessment criteria have general applicability in the development of the transition plan (Task 8); identification of communications systems/technology gaps (Task 10); and the identification of components for future R&D (Task 11).

5.2 Types of Assessment Criteria

The most basic assessment criterion is the degree to which the proposed architecture meets the user's needs. This macro approach is extremely difficult to apply when dealing with multiple users, multiple service providers, and provisions of multiple services. It is also important to note that user's needs are dynamic, and that the derived functional and system requirements provide some flexibility based on the architecture being considered. For example, latency requirements applied to a LEO SATCOM versus a GEO SATCOM may be less and can allow for more flexibility in other parts of the communication path. This type of flexibility may impact decisions being made regarding whether to centralize or distribute a particular function.

A second type of assessment criteria to be considered are those that are non-technical in nature, but that often override the majority of technical considerations. The largest of these is economics. In the low-GA user segment, low-cost is simply a way of life. Requiring a more expensive communications package would have the direct effect of reducing the ranks of GA users. In the commercial air transport segment, the funds could be made available, but now the emphasis shifts to the business case. The adage in the avionics field is that any new equipment has to buy its way onto the airframe. Performing a cost-benefit analysis should be considered one of the most important criteria for any changes proposed in the communications infrastructure.

The next two sections provide a much finer breakout of various criteria that can be applied to differentiate between alternatives. As noted above, many of these items have previously appeared as either drivers or restraining forces in this report.

5.2.1 Quantitative Measures

Criteria can usually be evaluated with the use of an objective numeric metric. In this case, such metrics may still require some level of subjective prediction since the architectures being evaluated will be implemented over an extended period.

Schedule: A timeline for the overall development and fielding of any new communications architecture can be developed for each alternative. Such a schedule would need to consider other criteria listed here including the rate of market take-up for any new equipment, system capacity for production and installation across thousands of airframes and ground sites, and the certification of this new equipment.

Business Case: Business cases would need to be developed for each alternative that provide the cost and benefits to the user. The business case would need to consider opportunity costs, Return On Investment (ROI), and overall life-cycle costs.

System Performance: System performance covers a wide range of system characteristics. Two key concepts for measuring system performance are Required Communication Performance (RCP) and Installed Communications Performance (ICP). In both of these cases, criteria have been defined for system availability, latency, and reliability. Common measures include Bit Error Rate (BER); Mean Opinion Scoring (MOS) for vocoders, and percentages based on system availability (e.g. 99.95%). Another key system performance parameter is facilitation of safety communications through provision of priority message handling, data integrity, and end-to-end pipeline integrity.

Coverage: Coverage looks at overall access to the communications pipeline. That access can be geographic in nature (e.g., polar coverage), political (e.g., certain states opt not to equip their centers with a particular type of radio), or a resource limitation (e.g., insufficient spectrum over a terminal area).

5.2.2 Qualitative Measures

Qualitative measures rely on some degree of subjective evaluation usually based on a ranking scheme.

Technology: In the context of an assessment criterion, it is really the availability of technology that serves to discriminate between alternatives. If an architecture is dependent on "scheduled invention" to provide required throughput or speed, it is somewhat less attractive than one dependent on off the shelf technology. When assessing technology, product development cycles need to be considered as well.

Flexibility or adaptability: Architectures that allow for adaptability in terms of usage across user segments should be preferred over single use approaches. Note that flexibility is inherent in the subset/superset approach to architecture implementation.

Situational Awareness: With the increasing complexity of both ground systems and modern cockpits, special attention must be paid to situational awareness. Although this factor can be viewed as an element of human factors, our preference is to evaluate this criterion separately.

Human Factors: Any new architecture must be evaluated across a wide range of human factors considerations including workload issues and the cognitive limitations of human operators.

Transition: Consideration must be given to factors that will prohibit or delay installation of the new architecture. Phase-out periods, training, co-existence with legacy systems, and the ability of the support infrastructure to accommodate the ramp-up of a new communications infrastructure in the required timeframe must all be considered. Aircraft operators will face new equipment costs as well as additional training. A recent example of how difficult it is to incorporate communications changes can be found in the move to 8.33kHz.

5.3 Assessment as Risk Management

The majority of factors above will become measures of risks for the selected architecture. It is expected that no single architecture will fully address ALL user needs. Design tradeoffs will be needed as the resulting architecture is put together. A risk management plan for the actual development and rollout of the architecture for 2015 should be created early in the development phase and maintained by the FAA in their role as the air traffic manager.

Appendix A

This section provides the Air Traffic service descriptions for the NAS Architecture. A joint team of ASD, AT, and supporting contractors developed the Air Traffic service descriptions. These service descriptions will remain the same as the NAS is modernized unless there is a significant change in the NAS concept of operations or requirements.

A.1 Flight Planning Service

The flight planning service provides both flight plan support and flight plan data processing to support the safe and efficient use of the nation's airspace through the development and use of coordinated flight plans. This includes preparing and conducting pre-flight and in-flight briefings, filing flight plans and amendments, managing flight plan acceptance and evaluation, preparing flight planning broadcast messages, and maintaining flight-planning data archives. This service offers preparation to conduct a flight within the NAS and allows changes to flight profiles while operating within the NAS.

A.1.1 Flight Plan Support

Flight plan support provides NAS users essential weather and aeronautical information. Flight planning requires information such as expected route, altitude, time of flight, available navigation systems, available routes, special use airspace (SUA) restrictions, daily demand conditions and anticipated flight conditions including weather and sky conditions (e.g. volcanic ash, smoke, birds). There is an exchange of a variety of data to support flight planning including NAS operational and maintenance status, weather, FAA facility status, with numerous NAS users to include, fixed base operators, pilots and flight planners, airline operations centers, Department of Defense (DOD) operations offices, and inter alia. Planning and pre-flight briefings contain current and forecast weather including winds and temperatures, surface conditions, and any significant meteorological condition. Aeronautical information includes notices to airmen containing information concerning the establishment, condition, or change in any NAS component (facility, service, or procedure of, or hazard in the NAS) the timely knowledge of which is essential to flight.

A.1.2 Flight Plan Processing

Flight plan processing provides acceptance and processing of flight plan data from all users (e.g., general aviation, commercial, military, customs, law enforcement, etc.); validates the flight plans; notifies users of any problems; and processes amendments, cancellations and flight plan closures. NAS flight plan processing provides evaluation and feedback for both domestic and international flight plans. Flight plan amendments both pre-flight and in-flight are also processed including cancellations, and closures. The NAS disseminates flight plan information as necessary.

A.2 Air Traffic Control Separation Assurance Service

The separation assurance service ensures that aircraft maintain a safe distance from other aircraft, terrain, obstacles, and certain airspace not designated for routine air travel. Separation assurance involves the application of separation standards to ensure safety. Standards are defined for aircraft operating in different environments.

A.2.1 Aircraft to Aircraft Separation.

Aircraft to aircraft separation prevents collision between airborne aircraft. Varieties of methodologies are employed to apply the defined separation standards. These methodologies include the use of visual and automated means.

A.2.2 Aircraft to Terrain/Obstacles Separation.

NAS employs defined separation standards to prevent collision between aircraft, terrain, and obstacles. Methods used include published safety zones and processing of position and intent information.

A.2.3 Aircraft to Airspace Separation.

Aircraft are separated from special use airspace (SUA) such as prohibited, restricted, and warning areas. The SUA is designed to ensure safety for unique aircraft operations or to prohibit flight within a specified area. Separation standards ensure aircraft remain an appropriate minimum distance from the airspace. The standards are applied via methods including regulatory publications and specific control instructions.

A.2.4 Surface Separation

Surface separation accounts for activities such as vehicle movements on the airport movement area, taxiing aircraft, water vehicles, protection from designated critical zones, etc. Standards are employed to ensure safe operation on the surface.

<u>A.3 Air Traffic Control Advisory Service</u>

Air traffic control and other facilities provide advice and information to assist pilots in the safe conduct of flight and aircraft movement. These advisories include providing weather information, traffic, and NAS status information. These advisories and information may be directed to a specific location, broadcast to any user in an area, or provided to a specific user.

A.3.1 Weather Advisories

Weather advisories and information are available either automatically or on request through communication with ATC and other facilities. For example, pilots receive weather advisories from automated weather observing or other systems, ATC facilities, and aircraft operations centers (AOCs). Advisories provide hazardous weather or flight conditions at airports or along the route of flight.

A.3.2 Traffic Advisories

Traffic advisories are provided to alert aircraft to potential conflicts with others on the surface or in-flight. For example, traffic advisories are provided to aircraft or other flight objects that are in the proximity of hot air/gas balloons, missile launches or other potential hazards. Traffic advisories for aircraft on the surface include the number, type, position and intent of the ground traffic.

A.3.3 NAS Status Advisories

Information about NAS status that has changed or was not readily available during flight planning is provided to in-flight aircraft. This includes updates concerning the operational status of airspace, airports, navigational aids (NAVAIDs), in-flight or ground hazards, traffic management directives, and other information that is essential to the safety and efficiency of aircraft.

A.4 Traffic Management-Synchronization Service

Traffic synchronization supports expeditious flight for the large number of aircraft using the NAS during any given period. NAS processes operate to maximize efficiency and capacity in response to weather, NAS infrastructure, runway availability or other conditions. Traffic synchronization is the tactical portion of traffic management providing sequencing, spacing, and routing of aircraft. Traffic synchronization activities are accomplished while maintaining separation assurance and implementing strategic flow management directives. The traffic synchronization service provides tactical instructions to optimize operations while airborne and on the surface.

A.4.1 Airborne

Airborne synchronization involves sequencing of aircraft to maximize efficiency and capacity of the NAS through all phases of flight (arrival, departure, and cruise). Maximum efficiency, predictability and capacity are obtained through the application of processes, which reduce variability in application of the defined separation standards. These activities include prioritization including the input of user preferences.

A.4.2 Surface

The surface is managed by formulating taxi sequences and communicating instructions to pilots and vehicle operators for the safe and efficient flow of traffic on the airport surface. Surface synchronization involves processes intended to maximize surface efficiency, predictability and capacity. It includes activities such as runway assignment, taxi sequence and movement instructions.

A.5 Traffic Management-Strategic Flow Service

The strategic flow service provides for orderly flow of air traffic from a system perspective. NAS demand and capacity is analyzed and balanced to minimize delays, avoid congestion, and maximize overall NAS throughput, flexibility, and predictability. Actual and predicted demand is compared to the current and predicted capacity of the NAS airspace, airports and infrastructure to plan the overall NAS strategy. When necessary, traffic flow management (TFM) plans are developed collaboratively to optimize the flow of traffic while accommodating user requests and schedules, airspace, infrastructure, weather constraints, and other variables. The strategic flow services comprise long-term planning (more than one day in advance) and flight-day traffic management (current 24-hour period) and performance assessment.

A.5.1 Long-term Planning

Long term planning works to maximize efficiency by developing predictions of capacity and demand more than one day in advance. Inputs include capacity and demand models based on airport use data, airspace for special use schedules, airline flight schedules, infrastructure status, and historical flight traffic demand information. It also includes activities designed for continual improvement in the predictive capabilities such as model validation, assessment of specific planned and executed strategies trend analysis and recommended changes.

A.5.2 Flight Day Management

Flight day traffic management optimizes NAS traffic flow for the current 24-hour period. Demand profiles are compared with projections of NAS capacity for the current day and identify periods and locations where predicted demand exceeds predicted capacity. Specific responses to maximize efficiency are developed and implemented through collaboration across the NAS.

A.5.3 Performance Assessment

Performance assessment provides institutional memory by archiving information to support post-flight analyses of NAS traffic flow. The effectiveness of NAS performance is analyzed to propose future improvements. Air traffic trends and activities are analyzed, problems identified and alternatives for improvement developed and evaluated. Long-term improvements to NAS performance include recommended changes to schedules, airspace design, ATC procedures, and the NAS infrastructure.

A.6 Emergency and Alerting Service

The emergency and alerting service monitors the NAS for distress or urgent situations, evaluates the nature of the distress, and provides an appropriate response to the emergency. Applicable situations include those that occur on the ground or in-flight. Emergency services include emergency assistance and alerting support.

A.6.1 Emergency Assistance

Emergency assistance provides direct support in the protection of individuals and property both in the air and on the ground. Examples of the wide variety of circumstances under which direct support is provided include location and navigation assistance for orientation, guidance to emergency airports, and generation of alternative courses of action.

A.6.2 Alerting Support

Alerting support provides indirect assistance for those events/circumstances in which the response is external to the system. For example, when information is received that an aircraft is overdue or missing, ELT signals are received, or search and rescue services may be required, alerting support provides the relevant information and coordinates with the appropriate international, military, federal, state, and local agencies. The appropriate organization(s) then provide direct response(s).

A.7 Navigation Service

The service provides navigational guidance to enable NAS users with suitable avionics to operate their aircraft safely and efficiently under different weather conditions. The service includes both ground and space-based networks of navigational aids for the NAS. These navigational aids broadcast electronic signals or provide guidance in accordance with international standards. The navigation service provides guidance during airborne operations (such as cruise, approach and landing), and during surface operations to appropriately equipped aircraft.

A.7.1 Airborne Guidance

NAS provides mechanisms and aids for point-in-space navigation through a variety of operating environments. These environments include structured routes, random routings and transitions. Guidance is provided for position determination in both vertical and lateral planes in all phases of flight. Additionally, visual aids provide guidance to aircraft transitioning to and from the surface.

A.7.2 Surface Guidance

NAS provides mechanisms and aids for maneuvering on the airport surface safely and efficiently. For example, references are provided to determine present position both electronic and/or visual.

A.8 Airspace Management Service

Airspace management service ensures the safe and efficient use of the national airspace resource. This includes the design, allocation, and stewardship of the airspace. Maximum safety and efficiency in the use of airspace results from coordinating airspace user needs and available capacity. Effective airspace management requires the seamless integration of airspace design and the management of airspace for special use.

A.8.1 Airspace Design

Airspace design provides maximum utilization of the national resource while ensuring safety to the public at large. This includes a cohesive plan for managing airspace changes, establishing and directing a financial plan to meet airspace priorities, establishing standards for modeling and analysis, and developing strategies to ensure environmental compatibility. Airspace planning and analysis considers, among other elements, the existing design, current and projected traffic usage, radio frequency congestion, effects of airport construction, proposed and existing surface structures, and environmental factors such as noise abatement and others. It provides the aviation community with the description, operational composition and status of airspace/airport components of the NAS.

A.8.2 Airspace for Special Use

Airspace for special use provides support to the national defense mission, fosters the development of commercial space enterprises, protects sensitive areas, and ensures the protection of other natural resources. Designation and management of special use airspace ensures optimal access.

A.9 Infrastructure/Information Management Service

Infrastructure management ensures a safe and efficient NAS through management and operation of the infrastructure and optimal use of resources. Infrastructure resources include systems such as radar, communication links, navigation aids and automation, while infrastructure management includes monitoring and maintenance of the NAS.

A.9.1 Monitoring and Maintenance

Monitoring and maintenance includes the activities necessary to monitor the NAS status, detect and isolate failures and outages, and perform corrective and preventive maintenance to ensure the operational readiness of the NAS. Maintaining, operating, and managing the infrastructure requires a variety of planning, engineering, analysis, repair and maintenance functions. It also includes monitoring status, real time assessments and systems implementations in the NAS.

A.9.2 Spectrum Management

Spectrum management secures, protects, and manages the radio spectrum for the FAA and the U.S. aviation community. It is the focal point for management policy and plans, engineering, frequency assignment, radio interference resolution, radiation hazard, obstruction evaluation, electronic counter measures, and other national/international spectrum activities.

A.9.3 Government/Agency Support

Government/agency support provides information and coordination services. Examples of the agencies and organizations supported include, military air defense operations, law enforcement, government land management, drug interdiction, state aviation, Customs, National Transportation Safety Board, and inter alia.

A.10 Aeronautical Operational Control (AOC)

Airlines determine their own requirements for AOC. In those cases where the AOC service shares a communications resource with ATM or FIS applications, the AOC workload must be considered in assessing architectural alternatives.

A.11 On-board services

On-board services potentially include broadcast services for entertainment (e.g., sporting events or other television), information services such as Internet access, business services such as fax or email, and voice or data passenger communications. Some of these services, such as passenger telephony, are likely to use communications links that can also be used for ATM or FIS.

Appendix B – Technology Evolution and Forecasting

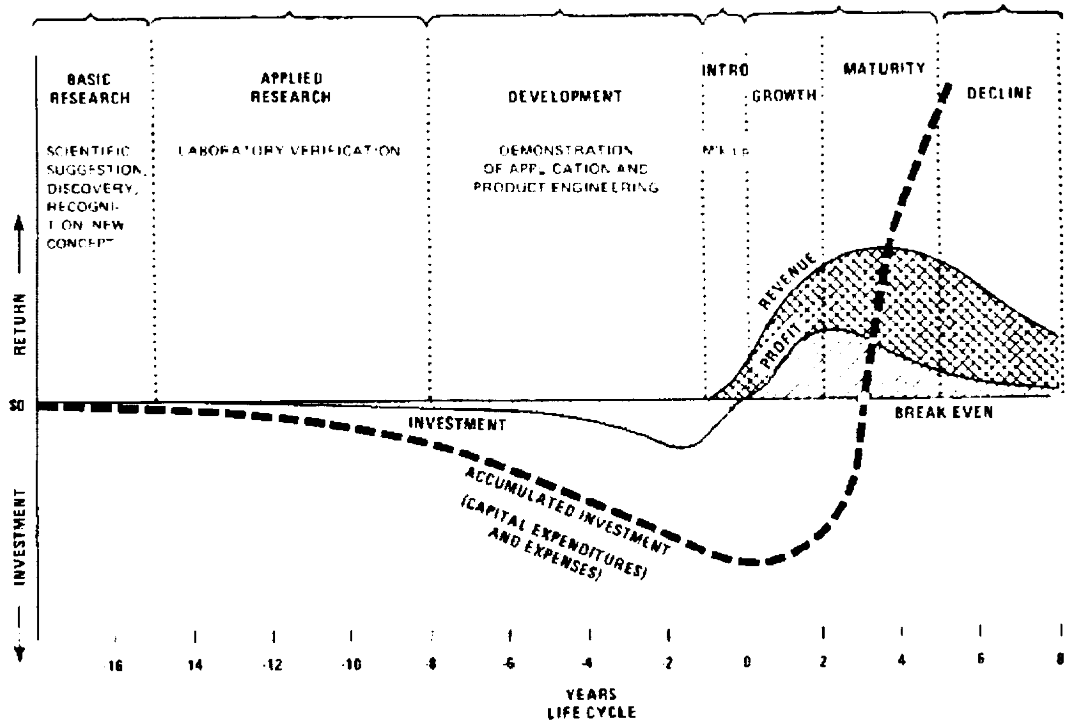
This appendix provides a brief discussion of enabling technology and the rate of its evolution. It identifies and documents the preliminary findings resulting from a brief review of selected forecasts of communication technologies, made approximately fifteen years ago, for their relative accuracy and potential applicability to the candidate communication architecture alternatives identified in section five.

B.1 The Technology Development Timeline

In developing candidate CSA's, we conducted a brief review of the application of technology development and implementation timelines. Technology projections and forecasts that were made approximately 15 years ago were assessed for their relative accuracy and potential applicability to this task. Both the timelines and the technology trend projections have broad applications in not only bounding the description of the range of ATM and AWIN services using a communications architecture, but also in assessing the architecture's flexibility and relative effectiveness and efficiency which result in user profits and benefits.

Figure B-1 shows a generic Product Development Lifecycle Timeline for Command, Control, and Communications (C3) technology. It can be applied to a wide range of aviation defense, and commercial technologies and provides a good view of the investment curve for the introduction of new technology. The elapsed time, or years in the life cycle, vary for each technology, but the approximately 15 – 20 year range was a reasonable estimate of the aggregate amount of time used to develop a "bundle" of technology, and "package" them into a complex product. Examples include a new model commercial passenger aircraft, an air traffic control radar system, a communications satellite system, or a sensor satellite system providing processing and disseminating weather data.

Capital Investment and Return in the Innovation

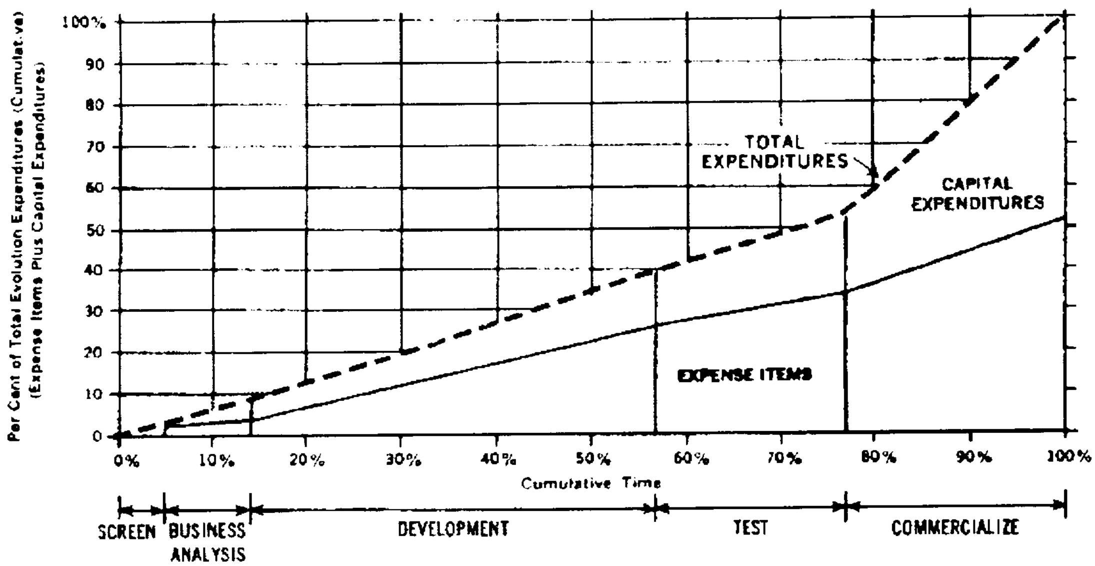


Source: A Methodology for Assessing Trends in the C3 Technology

Figure B-1. Capital Investment and Return in the Innovation

Figure A-2 provides another view of the cumulative investment expenditures by product development phase for commercial products. Both NASA and DOD have developed similar figures that show the effect of program decision as a percentage of system lifecycle costs, which have been applied by them in an approach similar to a business case analysis. The concepts are used to assess the effects of technology insertion, equipment upgrades, and other broad impacts on new system development decision processes.

Cumulative Expenditures and Time
(By Stage of Evolution - All-Industry Average)



Source: A Methodology for Assessing Trends in the C3 Technology Environment

Figure B-2. Product Development Lifecycle and Cumulative Expenditures

Compared to 15 – 20 years ago, significant time compression has occurred throughout the entire technology lifecycle. The development and product introduction timespan has decreased significantly, by at least half, and for many technologies even more. This time compression reduces the industry average from approximately eight years to four years or less. A number of factors seem to have contributed to this decrease. "New ways of doing business" continue to be implemented so that improved "profitability" (e.g., reduced costs) or increased "benefit" can be achieved more quickly in response to pressures from other competitive products and service providers. These 'new ways' have included concurrent engineering, process re-engineering, and outsourcing that allows companies to focus on their core competencies. All of this can be summarized as the mantra that has swept through the aerospace industry as "Faster, Cheaper, Better". It has also given rise to completely new business models that have the effect of creating new markets instead of simply evolving old ones (e.g. the internet and LEO-based global phone service.

The maturity period has similarly been shortened as the next "new thing" comes along to replace the incumbent technology. Much of the reason for this shortened mature phase is that the same technology is rolled back to create the next generation. Faster and more capable computers and manufacturing automation allow for each successive generation to improve on its predecessor. Nowhere is this process more evident than in basic communications infrastructure. Constant improvements in transmission media, switching technology, and spreading "open" standards ensure that communications systems are already obsolete once they reach their peak penetration into the market. Favorable economics has also played a role in the short maturity followed by sharp declines. Start-up companies have had a relatively easy time raising capital to bring new technology to market. Without the overhead and sunk cost of older development efforts to recover, they have been able to steal large pieces of market share. Their presence has forced the larger entrenched companies to cut short their efforts to extract as much profit from previous investments.

B.2 Technology Forecasts – Past History

Having looked at the compression of the development timeline, we then reviewed a number of technology projections and forecasts that were made 15 – 18 years ago. The continuing performance evolution in these technology categories will certainly have an impact on the candidate CSAs. These projections were assessed for their relative "accuracy" of the direction that the technology would evolve, the predicted timeframe, and the projected on products and services. Two of these projections are shown in Figures B-3 and B-4 below.

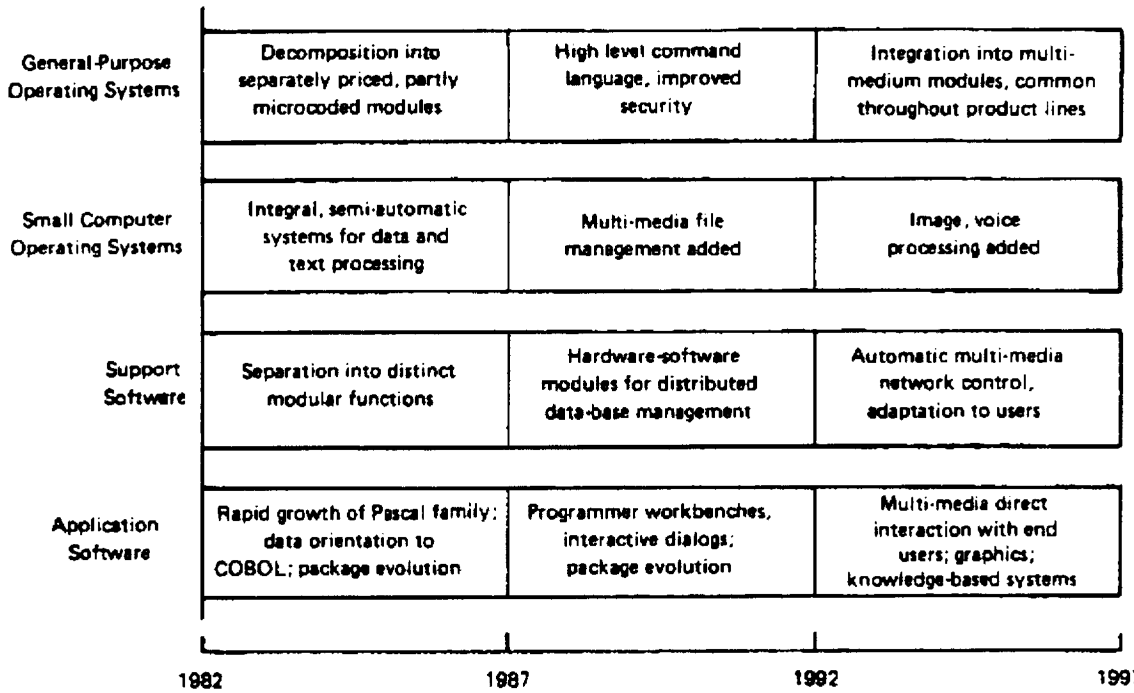
Sixth Generation...by 1990?
Why is computer technology so important? Because it is virtually the only major commodity on earth that is improving its price-performance ratio in absolute as well as relative terms. The following generalized chart shows computer progress since ENIAC, and anticipates—for the first time in print—the technology/price/performance equation that may be attained in the Sixth Generation

Year	1945	1955	1965	1975	1985	1990–95
Generation	1st	2nd	3rd	4th	5th	6th
Technology	Tubes	Transistors	ICs	VLSI	Parallel processors	Organics? Implants?
Cost factor	1,000	100	10	1	0.1	.01
Performance factor	1	10	100	1,000	10,000	100,000
Installed base	5	5,000	50,000	.5m	10m +	100m +

Source: John Joss/Technology Update

Aviation Week & Space Technology, August 22, 1983

Figure B-3. Projection of Price/Performance Ratios



Source: "Addendum to DoD Intelligence Information System Master Plan: Future Information Processing Technology" (Arthur D. Little, Inc.)

Figure B-4. Projection of Future Information Technology

Figure B-3 shows the projected price performance ratios over time related to key enabling processor technologies. Figure B-4 looks at the broader picture of computing platform and application software. None of the sources reviewed identified the substantial impact of digital signal processors (DSP). As expected, some enabling technologies were identified in the forecasts while others were clearly revolutionary in their appearance during the forecasted period. Few forecasts even hinted at the greatly improved price/performance and size of the processor chips that occurred during the forecasted timeframe. Nor did any of the forecasts project the rapid obsolescence of hardware and software systems and the need to continually upgrade to avoid compatibility problems when interfacing with the rest of an increasingly networked world.

As an aside, in a recent report from Lucent Technologies' Bell Laboratories, scientists projected that at the current rate of chip shrinkage and increased processor speed; silicon processor technologies could reach their limits by 2012. But processor capability and capacity will continue to double approximately every eighteen months. By that point science and industry will have to find new ways to build faster and more capable computers.

B.3 Conclusions – A Quandary

Our brief review of enabling technology and technology forecasting clearly illustrates the rate of technology evolution will continue to accelerate and lifecycles will shorten. It also points out some of the limitations to forecasting since new breakthroughs and new markets are constantly being identified. Unfortunately, the review has illustrated a quandary that will be faced for any new communications architecture. Airplanes and air traffic control systems have historically had very long mature phases. Avionics may be refurbished every five to eight years depending on the type of aircraft, but even this timeframe is long compared to the rate of development in computers and communications. Unlike the commercial world where business cases can be built for upgrading and replacing aging equipment on a regular basis, the cost of overhauling airplanes and control centers is prohibitive. It appears likely that a serious lag will always exist between the latest communication technologies available and those in widespread use in the NAS. This unfortunate reality must be considered in the evaluation of candidate CSAs.

Characterize the Current and Near-Term Communications System Architectures

Research Task Order 24

(Task 9.0)

Prepared By

ARINC
Science Applications International Corporation (SAIC)
TRW

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Table of Contents

1 Introduction and Overview

This document is the Final Report on the completion of Task 9 of Task Order 24 (TO24) of the Advanced Air Transportation Technologies (AATT) contract. The title of Task 9 is "Characterize the Current and Near-Term Communications System Architecture." The task is subdivided into four subtasks, dealing with applications; programs; systems; and networks, standards, and protocols. This report is organized as a short overview description of the NAS communications architecture, a description of the terminology developed to describe the architecture, and some conclusions about the utility of this document and the information contained herein.

1.1 Background

In 1995 NASA began the Advanced Air Transportation Technologies initiative to support definition, research, and selected high-risk technology development to enable the implementation of a new global Air Traffic Management (ATM) system. The AATT Project established, inter alia, tasking to investigate Advanced Communications for Air Traffic Management (AC/ATM) with the goal towards enabling an aeronautical communications infrastructure through satellite communications technology that provides the capacity, efficiency, and flexibility necessary to realize the benefits of the future ATM systems, and specifically the mature free flight environment. The technical focus of the AC/ATM task centers on the identification and characterization of high-risk, high-payoff satellite communications technologies that can satisfy the requirements of the 2015 NAS architecture.

1.2 Scope

The intent of Task 9 is to characterize the current and near-term NAS communications architecture by characterizing the applications that enable end users to operate and manage the ATM system, the programs to develop and deploy new applications and systems, the technical characteristics of the communications media themselves, and the networks, standards, and protocols which provide the framework within which the entire system operates. Because of the focus on satellite communications special attention is paid in these characterizations to the content or dependency on satellites. Because of the additional focus on weather products as contributors to the improvement of safety, special attention has also been paid to the weather content of each element of the current and near-term architecture description.

1.3 Characterization of Current and Near-term Architecture

The NAS Communication System, NASCS, of today consists of transport media, applications that ride the media, and end-systems which provide technical conversion from transport format to human-interpretable format. The transport media of the NAS CS are commonly referred to as communication systems themselves; VDL Mode 3, HF voice, etc.

1.4 Standards

A common characteristic of all communication systems is the adherence to standards that allow multiple types of equipment to interface, and multiple users with different end-systems to benefit from the connectivity. It is appropriate to characterize the NAS CS of today as one set of standards, and to describe the NAS CS of 2015 in terms of a set of standards, which may not be the same, but will be consistent with the standards of 1999. It is important that all systems and applications be based on open standards to facilitate interoperability now and in the future.

Relevant standards for the current and near-term NAS CS are described in Appendix 4.

1.5 Network and Protocols

Communication systems consist of a network, or family of networks, conforming to the standards. These networks employ standard protocols to manage the media, and the access to the media, in order to promote efficiency of operations and to provide access controls for security. It is appropriate to characterize the NAS CS of 1999 as a set of networks, using standard protocols, and to describe the NAS CS of 2015 in a similar manner. The aviation community has several international and national bodies involved with ensuring the standardization of aviation communications, such as ICAO and RTCA.

Relevant networks and protocols for the NAS CS of 1999—2005 are described in Appendix 4.

1.6 Communications Systems

The communications systems are the transport media which convey information between and among users. This information may be voice or data. The media are characterized by a number of quantitative technical elements such as frequency, data rate, modulation scheme, etc. The communications systems of the 2015 architecture must be described in the same terms to be able to measure improvement.

1.7 Applications and Development/Demonstration Programs

Applications are special arrangements of data which convey special meaning to users. These applications enable the intellectual interaction of users such as pilots and controllers to occur in a formal, standardized, unambiguous format.

Development and demonstration programs characterize the evolution of the current architecture, by describing activities and products intended to address current requirements.

1.8 Terminology

Objective

The objective of applications and programs is characterized by determining the "best fit " to the accepted list of user services and functional capabilities delineated in Table 1.8-1. The "best fit" may apply to multiple "user needs" and multiple "functional capabilities." Each "best fit" match is the subject of a complete table entry.

Table 1.8-1.

User Services	Functional Capabilities
Flight Plan Services	File flight plans and amendments
	Process flight plans and amendments
	Provide information for flight plans
ATC Separation Assurance Services	Separate IFR aircraft
	Avoid potential hazards and collisions
	Maintain minimum distance from special use airspace (SUA)
	Monitor flight progress
	Hand-off to controller—sector—facility
ATC Advisory Services	Provide in-flight or pre-flight weather advisories
	Provide in-flight or pre-flight traffic advisories
	Provide in-flight NAS status advisories
Tactical Traffic Management Services	Provide in-flight sequencing, spacing, and routing restrictions
	Provide pre-flight runway, taxi sequence, and movement restrictions
	Project aircraft in-flight position and potential conflicts
	Process user preferences

User Services	Functional Capabilities
Strategic Traffic Management Services	Provide future NAS traffic projections
	Collaborate with users on NAS projections and user preferences
	Monitor NAS traffic status
	Assess NAS traffic performance
Emergency and Alerting Services	Provide emergency assistance and alerts
	Support search and rescue (SAR)
Navigation Services	Provide airborne navigation guidance
	Provide surface navigation guidance
Surveillance Services	Provide aircraft position/ID
	Provide aircraft intent, state, and performance
Airspace Management Services	Manage design and use of NAS airspace
	Manage use of SUA
NAS Support Services	Monitor and maintain NAS infrastructure
	Manage aviation spectrum for U.S. aviation community
On-board Services	Provide administrative flight information
	Provide in-flight entertainment
	Provide public communications

1.9 Data Links Used

Each characterization for each application and program matches the application/ program to one of the data links in the following list. Subtask 9.3 then characterizes each data link by describing its technical characteristics.

Aircraft Communications, Addressing and Reporting System (ACARS)
VHF Digital Link Mode 2 (VDL Mode 2)
VHF Digital Link Mode3 (VDL Mode 3)
VHF Digital Link Mode4 (VDL Mode 4)
VHF Digital Link Broadcast (VDL-B)
Mode S
Universal Access Transceiver (UAT)
Satellite—Low Earth Orbiting (LEO)
Satellite—Geosynchronous (GEO)
Little LEO (Packet; store & forward)
Narrowband Big LEOs, MEOs
Narrowband GEOs
Any wideband satellite systems
Other current or potential media

1.10 End-application of Interest

The end-application of interest will be the "user service" from Table 1.8-1, expanded to include the end-system at an end-user facility.

1.11 Operational Domain

Networks are designed for, and applications and systems are used primarily in one or more phases of flight. The phases of flight and operational domain are as follows:

Pre-flight domain—activities which occur prior to aircraft movement.

Airport departure surface operations domain—activities that occur between commencement of aircraft movement and airborne departure from the end of the active runway used by the aircraft involved in the application.

Departure terminal domain—activities that occur between airborne departure from the end of the active runway and departure from terminal airspace.

En route/cruise—activities that occur between departure from terminal airspace at departure airport and entry into terminal airspace at arrival airport.

Arrival terminal domain—activities that occur between entry into terminal airspace at arrival airport and arrival at the threshold of the active runway to be used.

Airport arrival surface operations domain—activities that occur between airborne arrival at the threshold of the active runway and arrival at the position at which the aircraft will be parked and the flight terminated.

Post-flight domain—activities that occur after the aircraft has concluded the flight.

1.12 Targeted User Class

The targeted user class is the node of the end-to-end communications activity that applies. The nodes are:

Air traffic services provider—Any of the entities that provide control, direction, advice, or other ATC information to the pilot/aircrew/flight deck or aircraft operator management.

Flight services provider—Any of the entities that provide advisory information to the pilot/aircrew/flight deck domain or the aircraft operator management domain.

Pilot/aircrew/flight deck—The entities that control the movement of an aircraft through airspace and manage aircraft on-board systems.

Aircraft operator management—The entities that plan aircraft movements, perform dispatch functions, and otherwise provide management of operations (but not physical control of the aircraft).

Thus, as an example of operational domain and targeted user class, the PDC application occurs during the pre-flight phase as an interaction between the air traffic services provider and the pilot/aircrew/flight deck.

1.13 User Need Met

User need met is the benefit each targeted user class derives from the application.

1.14 Weather Involvement

For each data link the weather information or other weather relationship is identified and a description provided. The description will indicate what type of weather information is sent, how it is sent and any other information that may be of interest including involvement with the collection, analysis, or distribution of weather data or products.

1.15 Satellite Communications Requirements

For each application characterized, any satellite involvement or requirement is listed.

1.16 Status

The status of each application will be characterized as conceptual, developmental, or operational and some current details may be provided such as number of installations or major milestones.

Conceptual—the application has been defined, but development has not started. Details of the activities that led to the agreement to the application concept should be included.

Development—the application is under development. Additional information should be included to indicate the stage of development, for example, engineering development, preliminary testing, product demonstration, etc.

Operational—the application is in service today. A degree of operational status may also be included; for example, TDLS is operational today at 57 airports in the U.S.

1.17 Schedule

In contrast to the Status description, the Schedule section will provide significant dates. For conceptual or developmental applications, a schedule of implementation will be included if available. For operational applications, any available schedule of upgrades or improvements may be listed. Future intentions, including application termination or replacement, are included if available.

1.18 References

Documents used in developing the report as well as specifications and standards will be provided in this section.

A APPENDIX A—Communications/Datalink Applications

A.1 Characterize Current and Near-Term Communications System Architecture—Communications/Datalink Applications

A.1.1 Task Description

The purpose of this task is to survey, analyze, and document the current National Air Space (NAS) Communications System Architecture (CSA) to a sufficient level of detail for use as a baseline for the 2007—2015 CSA development.

A.1.2 Applications of Interest

The applications characterized are listed below. They have been identified in the two categories, AATT and AWIN. Note that D-ATIS and ACARS appear in both categories and are listed twice.

AATT:	CPDLC	A.2
	FANS1/A	A.3
	ACARS	A.4
	PDC	A.5
	DDTC	A.6
	TWDL	A.7
	D-ATIS	A.8
	ADS-A	A.9
	ADS-B	A.10
	TIS	A.11
	WAAS	A.12
	LAAS	A.13
	TCAS	A.14
	ILS LF/MF	A.15
	ILS VHF	A.16
	ILS L-band	A.17
	TDLS	A.18
	Decision Support Services (DSS)	A.19
AWIN:	FIS	A.20
	DUATS	A.21
	GWS	A.22
	TWIP	A.23
	D-ATIS	See A.8
	MDCRS	A.24
	ACARS	See A.4
	E-PIREPS	A.25

A.1.3 Standard Description Template

Each application is characterized using the following template. The description of the characteristic is provided in the section shown.

CHARACTERISTIC	DESCRIPTION
Application Name:	Section A1.2
Objective of Application:	Section A1.4
Data Links Used:	Section A1.5
End Application of Interest	Section A1.6
Operational Domain:	Section A1.7
Targeted User Class:	Section A1.8
User Need Met:	Section A1.9
How the Application Works:	Section A1.10
Weather Involvement:	Section A1.11
Satellite Communications:	Section A1.12
Status:	Section A1.13
Schedule:	Section A1.14
References	Section A1.15

A.1.4 Objective of Application

The objective of the application will be characterized by determining the "best fit" to the accepted list of user services and functional capabilities delineated in the following table. The "best fit" may apply to multiple "user needs" and multiple "functional capabilities." Each "best fit" match will be the subject of a complete table entry.

User Services	Functional Capabilities
Flight Plan Services	File flight plans and amendments Process flight plans and amendments Provide information for flight plans
ATC Separation Assurance Services	Separate IFR aircraft Avoid potential hazards and collisions Maintain minimum distance from special use airspace (SUA) Monitor flight progress Hand-off to controller—sector—facility
ATC Advisory Services	Provide in-flight or pre-flight weather advisories Provide in-flight or pre-flight traffic advisories Provide in-flight NAS status advisories
Tactical Traffic Management Services	Provide in-flight sequencing, spacing, and routing restrictions Provide pre-flight runway, taxi sequence, and movement restrictions Project aircraft in-flight position and potential conflicts Process user preferences
Strategic Traffic Management Services	Provide future NAS traffic projections Collaborate with users on NAS projections and user preferences Monitor NAS traffic status Assess NAS traffic performance
Emergency and Alerting Services	Provide emergency assistance and alerts Support search and rescue (SAR)
Navigation Services	Provide airborne navigation guidance Provide surface navigation guidance
Surveillance Services	Provide aircraft position/ID Provide aircraft intent, state, and performance
Airspace Management Services	Manage design and use of NAS airspace Manage use of SUA
NAS Support Services	Monitor and maintain NAS infrastructure Manage aviation spectrum for U.S. aviation community
On-board Services	Provide administrative flight information Provide in-flight entertainment Provide public communications

A.1.5 Data Links Used

Each entry for each application will match the application to one of the data links in the following list. These data links are characterized in Appendix C

ACARS
VDL Mode 2
VDL Mode 3
VDL Mode 4
VDL-B
Mode S
UAT
Satellite (LEO)
Satellite (GEO)
Little LEO (Packet; store & forward)
Narrowband Big LEOs, MEOs
Narrowband GEOs
Any wideband satellite systems

It is not necessary in this task to elaborate on how the data link supports the application.

A.1.6 End-application of Interest

The end-application of interest will be selected from A.1.2 to fulfill the user series listed in A.1.4. An example would be the PDC application as it satisfies the "Tactical traffic management services" user service functional capability to "Provide pre-flight runway, taxi sequence, and movement restrictions" through the Tower Data Link System (TDLS) system in the Air Traffic Control Tower (ATCT).

A.1.7 Operational Domain

The application is used primarily in one or more of the following phases of flight and operational domains:

Pre-flight domain—activities which occur prior to aircraft movement.

Airport departure surface operations domain—activities that occur between commencement of aircraft movement and airborne departure from the end of the active runway used by the aircraft involved in the application.

Departure terminal domain—activities that occur between airborne departure from the end of the active runway and departure from terminal airspace.

En route/cruise—activities that occur between departure from terminal airspace at departure airport and entry into terminal airspace at arrival airport.

Arrival terminal domain—activities that occur between entry into terminal airspace at arrival airport and arrival at the threshold of the active runway to be used.

Airport arrival surface operations domain—activities that occur between airborne arrival at the threshold of the active runway and arrival at the position at which the aircraft will be parked and the flight terminated.

Post-flight domain—activities that occur after the aircraft has concluded the flight.

A.1.8 Targeted User Class

The targeted user class is the node of the end-to-end communications activity that applies. The nodes are:

Air traffic services provider—Any of the entities that provide control, direction, advice, or other ATC information to the pilot/aircrew/flight deck domain or the aircraft operator management domain.

Flight services provider—Any of the entities that provide advisory information to the pilot/aircrew/flight deck domain or the aircraft operator management domain.

Pilot/aircrew/flight deck—The entities that control the movement of an aircraft through airspace and manage aircraft on-board systems.

Aircraft operator management—The entities that plan aircraft movements, perform dispatch functions, and otherwise provide management of operations (but not physical control of the aircraft).

Thus, as an example of operational domain and targeted user class, the PDC application occurs during the pre-flight phase as an interaction between the air traffic services provider and the pilot/aircrew/flight deck.

A.1.9 User Need Met

User need met is the benefit each targeted user class derives from the application.

A.1.10 How the Application Works

This cell is satisfied by a short description of how the application performs the functionality desired.

A.1.11 Weather Involvement

Identifies any involvement with the collection, analysis, or distribution of weather data or products.

A.1.12 Satellite Communications

Identifies any involvement of satellite communications systems with the delivery of the application.

A.1.13 Status

The status of each application will be characterized as either:

Conceptual—the application has been defined, but development has not started. Details of the activities that led to the agreement to the application concept are included.

Development—the application is under development. Additional information should be included to indicate the stage of development, for example, engineering development, preliminary testing, product demonstration, etc.

Operational—the application is in service today. A degree of operational status may also be included; for example, TDLS is operational today at 57 airports in the U.S.

A.1.14 Schedule

For conceptual or developmental applications, a schedule of implementation is included if available. For operational applications, any available schedule of upgrades or improvements are listed. Future intentions, including application termination or replacement, will also be noted.

A.1.15 References

Identifies documentation/references referred to in completing the previous sections.

A.2 Controller to Pilot Data Link Communications (CPDLC)

A.2.1 CPDLC—ATC Separation Assurance Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Controller Pilot Data Link Communications (CPDLC)**
Objective of Application:	**Air Traffic Control (ATC) Separation Assurance Services.** Provide data link communications between pilots and controllers to assure separation between IFR aircraft, avoid potential hazards and collisions, maintain minimum distance from Special Use Airspace (SUA), monitor flight progress, and provide hand-offs between controllers, sectors, and facilities.
Data Links Used:	Very High Frequency Digital Link (VDL) Mode(M) 2 for CPDLC Build 1, 1A, and 2 VDL Mode 3 for CPDLC Build 3
Operational Domain:	En-route / cruise Build 1—Miami Air Route Traffic Control Center (ARTCC) Build 1A-3—Continental United States (CONUS)
Targeted User Class:	Air Traffic Service Providers Pilot / Aircrew / Flight Deck
User Need Met:	Accurate, reliable communication with reduced frequency congestion.
Weather Involvement:	N/A
Satellite Communications:	N/A
Status:	Development Build 1—Preliminary testing Build 1A, 2—Engineering development Build 3—Conceptual development
Schedule:	Build 1 Initial Operating Capability (IOC)—2002 Build 1A IOC—2004 Build 2 IOC—2006 Build 3 IOC—2010
References	National Airspace System Architecture, Version 4.0, FAA

A.2.2 CPDLC—ATC Advisory Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Controller Pilot Data Link Communications (CPDLC)**
Objective of Application:	**Air Traffic Control (ATC) Advisory Services** Provide data link communications between pilots and controllers including weather advisories, traffic advisories, and NAS status advisories.
Data Links Used:	Very High Frequency Digital Link (VDL) M 2 for CPDLC Build 1, 1A, and 2 VDL Mode 3 for CPDLC Build 3
Operational Domain:	En-route / cruise Build 1—Miami Air Route Traffic Control Center (ARTCC) only Build 1A-3—Continental United States (CONUS)
Targeted User Class:	Air Traffic Services (ATS) Providers Pilot / Aircrew / Flight Deck
User Need Met:	Accurate, reliable communication with reduced frequency congestion.
Weather Involvement:	N/A

CHARACTERISTIC	DESCRIPTION
Satellite Communications:	N/A
Status:	Development Build 1—Preliminary testing Build 1A, 2—Engineering development Build 3—Conceptual development
Schedule:	Build 1 Initial Operating Capability (IOC)—2002 Build 1A IOC—2004 Build 2 IOC—2006 Build 3 IOC—2010
References	National Airspace System Architecture, Version 4.0, FAA

A.2.3 CPDLC—Tactical Traffic Management Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Controller Pilot Data Link Communications (CPDLC)**
Objective of Application:	**Tactical Traffic Management Services.** Provide data link communications between pilots and controllers including sequencing spacing, and routing restrictions; projection of aircraft in-flight position and potential conflicts; and to communicate user preferences.
Data Links Used:	Very High Frequency Digital Link (VDL) Mode(M) 2 for CPDLC Build 1, 1A, and 2 VDL Mode 3 for CPDLC Build 3
Operational Domain:	En-route / cruise Build 1—Miami Air Route Traffic Control Center (ARTCC) only Build 1A-3—Continental United States (CONUS)
Targeted User Class:	Air Traffic Service (ATS) Providers Pilot / Aircrew / Flight Deck
User Need Met:	Accurate, reliable communication with reduced frequency congestion.
Weather Involvement:	N/A
Satellite Communications:	N/A
Status:	Development Build 1—Preliminary testing Build 1A, 2—Engineering development Build 3—Conceptual development
Schedule:	Build 1 Initial Operating Capability (IOC)—2002 Build 1A IOC—2004 Build 2 IOC—2006 Build 3 IOC—2010
References	National Airspace System Architecture, Version 4.0, FAA

A.3 Future Air Navigation System (FANS) 1/A

A.3.1 Future Air Navigation System (FANS) 1/A

CHARACTERISTIC	DESCRIPTION
Application Name:	**Future Air Navigation System (FANS)1/A**
Objective of Application:	**ATC Separation Assurance Services**
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS)
End Application of Interest	Air Traffic Control (ATC) Separation Assurance Services Separate Instrument Flight Rules (IFR) aircraft. Monitor flight progress.
Operational Domain:	En route/cruise
Targeted User Class:	Air traffic service provider Pilot/aircrew/flight deck
User Need Met:	Provides aircraft position reports and communications
How It Works:	Provides Automatic Dependent Surveillance (ADS) and controller-pilot data link communications (CPDLC) to aircraft in flight.
Weather Involvement	N/A

CHARACTERISTIC	DESCRIPTION
Satellite Communications	Primary oceanic connectivity for data link equipped aircraft is FANS1/A over Inmarsat.
Status:	Operational in the South Pacific for ADS and CPDLC and North Atlantic for ADS. Trial and test applications in other areas of the world.
Schedule:	Schedule for further implementation is tied to implementation of automation at oceanic Air Route Traffic Control Centers (ARTCC).
References	National Airspace System Architecture, Version 4.0, FAA

A.4 Aircraft Communications Addressing and Reporting System (ACARS)

A.4.1 ACARS Flight Plan Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Aircraft Communications Addressing and Reporting System (ACARS).**
Objective of Application:	**Flight Plan Services**—File flight plans and amendments. Process flight plans and amendments. Provide information for flight plans
Data Links Used:	ACARS
End-application of Interest:	Air Traffic Control Tower (ATCT)—Tower Data Link Services (TDLS) Aircraft—ACARS terminal, including man-machine interface
Operational Domain:	Pre-flight Domain. The aircraft must file and receive an approved flight plan to commence movement on the airport surface. A flight plan may be filed into the Flight Management System (FMS) and a pre-departure clearance (PDC) or oceanic clearance required to commence surface movement will be issued and may be sent to the aircraft via ACARS.
Targeted User Class:	Air traffic services provider: By delivering clearances over ACARS using PDC voice frequency congestion and departure delays have been reduced at major airports. Clearances are issued in a more timely and effective manner. Communications errors are reduced. This provides significant benefits in time and stress avoidance to air traffic controllers and provides for more efficient use of airspace capacity Pilot/flight crew: Receipt of flight plans over ACARS in the aircraft allows the crew to make use of valuable time during turnaround. Automatic entry of flight plan information into FMS eliminates errors that can occur during manual entry. Aircraft Operator Management: Benefits from the knowledge of flight plan approval and an aircraft's clearance to depart.
User Need Met:	File flight plan and delivery of clearance to operate aircraft.
How the Application Works:	A flight plan is filed via ACARS into FMS, which arrives at the host computer located in the Air Route Traffic Control Center (ARTCC). After approval the host computer transmits the flight plan to the appropriate ATCT for issuance of a departure clearance. The flight plan is received from the host on the TDLS terminal at the ATCT which routes it to Flight Data Input/Output (FDIO) which displays it on the TDLS terminal. The flight plan information is reviewed to insure that all entries are complete and that Notices To Airman (NOTAMS) are included and the PDC is approved and sent automatically from the ATCT, via TDLS, through the FAA National Area Data Interchange Network (NADIN) and ARINC Data Network Service (ADNS) to the aircraft operator's host computer. When the pilot depresses the "request clearance" button on his data link management unit an ACARS message is generated from the aircraft to the aircraft operator's host computer requesting the clearance. The aircraft operators host computer generates a response and sends an ACARS message which includes the PDC to the ACARS terminal in the aircraft.
Weather Involvement:	Weather information may be transmitted to the aircraft via ACARS.
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ARINC Data Network Service (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 BPS, respectively, may be used.
Status:	Operational: ACARS is provided to over 300+ North American Airports, including every major U.S. Airport via a network of Very High Frequency (VHF) ground stations and the Inmarsat satellite network.

CHARACTERISTIC	DESCRIPTION
Schedule:	To address projected frequency spectrum capacity limitations over the next decade many ACARS messages will be transitioned to ARINC Very High Frequency Digital Link Mode 2 (VDL Mode 2).
References:	Need for Change Current ACARS slides, 1998; Aeronautical Data Link slides, 1998; ACARS & VDL Mode 2 Program Status slides, 1998; ARINC ACARS description; ARINC Acronyms

A.4.2 ACARS—ATC Separation Assurance Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Aircraft Communications Addressing and Reporting System (ACARS).**
Objective of Application:	**ATC Separation Assurance Services**—En route position reports and Estimated Time Arrival (ETA) updates provided by the aircraft assist ATC separation in monitoring flight progress and separating Instrument Flight Rules (IFR) aircraft. Transmission of hazard reports to the aircraft assists the aircraft in avoiding potential hazards.
Data Links Used:	ACARS
End-application of Interest:	Air Traffic Control Tower: Tower Data Link Services (TDLS)—ATC Separation Assurance Services Aircraft—ACARS terminal, including man-machine interface
Operational Domain:	En route/cruise—Automatic position reports and ETA updates and/or changes are transmitted from the aircraft. Hazard reports are transmitted to the aircraft.
Targeted User Class:	Air Traffic Services Provider—The receipt of aircraft position reports and ETA updates assist in the provision, control, and direction of aircraft within the National Airspace System (NAS). The pilot/aircrew/flight deck benefit from the receipt of hazard reports and gate assignment information. The aircraft operator management—receives position reports, ETA updates/changes, engine parameters, maintenance reports, and provisioning information from the aircraft which assist in planning aircraft movements and management of aircraft operations.
User Need Met:	ETA information and automatic position reports are sent to ATC and are used to monitor flight progress, insure the maintenance of minimum distance from special use airspace (SUA), and maintain the separation of IFR aircraft.
How the Application Works:	Notice to Airman (NOTAM) changes and hazard reports, such as wind shear/microburst alerts, can be uplinked to the aircraft via an ACARS message without crew request where they can be viewed when pilots are not focused on other duties during high-workload time. ETA information and automatic position reports generated directly from the aircraft's navigation system are sent in an ACARS message to the appropriate ATCT via TDLS
Weather Involvement:	Weather information/updates which advise of adverse weather conditions may be sent to the aircraft via ACARS messages
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ARINC Data Network Services (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used.
Status:	Operational: ACARS is provided to over 300+ North American Airports, including every major U.S. Airport via a network of Very High Frequency (VHF) ground stations and the Inmarsat satellite network.
Schedule:	To address projected frequency spectrum capacity limitations over the next decade many ACARS messages will be transitioned to ARINC Very High Frequency Digital Link Mode 2 (VDL Mode 2).
References:	Need for Change Current ACARS slides, 1998; Aeronautical Data Link slides, 1998; ACARS & VDL Mode 2 Program Status slides, 1998; ARINC ACARS description; ARINC Acronyms

A.4.3 ACARS—ATC Advisory Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Aircraft Communications Addressing and Reporting System (ACARS).**
Objective of Application:	**ATC Advisory Services**; Provide in-flight or pre-flight weather advisories; Provide in-flight or pre-flight traffic advisories
Data Links Used:	ACARS
End-application of Interest:	Air Traffic Control Tower (ATCT): Tower Data Link Services (TDLS) Aircraft—ACARS terminal, including man-machine interface
Operational Domain:	Airport departure surface operations domain—pre-flight weather advisories and pre-flight traffic advisories are transmitted to the aircraft cockpit. En route/cruise—in-flight weather and traffic advisories are transmitted directly to the cockpit.
Targeted User Class:	The pilot/aircrew/flight deck benefit from the receipt of pre-flight and in flight weather and traffic advisories
User Need Met:	Delivery of weather and traffic advisories to the cockpit.
How the Application Works:	Pre-flight and in-flight weather information and pre-flight- and in-flight traffic advisories are input into TDLS which in the form of an ACARS message are transmitted directly to the ACARS man-machine interface in the cockpit
Weather Involvement:	Weather advisories are transmitted to the aircraft via ACARS.
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ARINC Data Network Service (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used.
Status:	Operational: ACARS is provided to over 300+ North American Airports, including every major U.S. Airport via a network of Very High frequency (VHF) ground stations and the Inmarsat satellite network.
Schedule:	To address projected frequency spectrum capacity limitations over the next decade many ACARS messages will be transitioned to ARINC Very High Frequency Digital Link Mode 2 (VDL Mode 2).
References:	Need for Change Current ACARS slides, 1998; Aeronautical Data Link slides, 1998; ACARS & VDL Mode 2 Program Status slides, 1998; ARINC ACARS description; ARINC Acronyms

A.4.4 ACARS—Tactical Traffic Management Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Aircraft Communications Addressing and Reporting System (ACARS).**
Objective of Application:	**Tactical Traffic Management Services**—Provide in-flight sequencing, spacing, and routing restrictions; Provide pre-flight runway, taxi sequence, and movement restrictions; Project aircraft in-flight position and potential conflicts; Process user preferences.
Data Links Used:	ACARS
End-application of Interest:	Air Traffic Control Tower (ATCT)—Tower Data Link Services (TDLS) & Flight Management System (FMS) Aircraft Operator Management Aircraft—ACARS terminal, including man-machine interface
Operational Domain:	Airport departure surface operations domain—ATCT provides pre-flight runway, taxi sequence, and movement restrictions to the aircraft. Aircraft provides Out/Off/On/In (OOOI) out event to the aircraft dispatcher. Departure terminal domain—ATCT provides in-flight sequencing, spacing, and routing restrictions to the aircraft; ATCT receives and processes user preferences from the aircraft;

CHARACTERISTIC	DESCRIPTION
	The aircraft provides destination Estimated Time of Arrival (ETA) and submits special requests to ATCT; Aircraft provides fuel remaining and OOOI off event to the dispatcher. En route/cruise—ATCT provides in-flight sequencing, spacing, and routing restrictions to the aircraft; Aircraft provides position reports and ETA updates to ATCT; Aircraft provides engine parameters and maintenance reports to the aircraft dispatcher. Arrival terminal domain—ATCT provides hazard reports to aircraft; Aircraft provides ETA changes to ATCT and OOOI on event to aircraft dispatcher. Airport arrival surface operations domain—Aircraft provides OOOI In event to dispatcher; Aircraft receives gate coordination from the dispatcher and provides final maintenance status and fuel verification to dispatcher.
Targeted User Class:	Air traffic services provider—Tactical Traffic Management Services—Provides in-flight sequencing, spacing, and routing restrictions and pre-flight runway, taxi sequence, and movement restrictions to the aircraft; Air traffic is able to project aircraft in-flight position potential conflicts and to process user preferences. Pilot/flight crew: The receipt of information from the aircraft dispatcher during pre-flight provides necessary information for aircraft movement; The provision of position reports and ETA updates to ATCT provides for efficient flight and arrival at the destination. Aircraft operator management—The receipt of OOOI events and other information from the aircraft provides information for efficient management of the flight crew and maintenance of the aircraft.
User Need Met:	The transmission and receipt of information by ATCT, the Aircraft, and Aircraft operator management provides the information necessary for the completion of tactical traffic management services by Air Traffic and the efficient management and scheduling of the aircraft by the aircraft operator management.
How the Application Works:	Information from ATCT is input into TDLS and is transmitted through the FAA National Airspace Data Interchange Network (NADIN) II Packet Switch Network (PSN), and ARINC Data Network Service (ADNS) into an FAA host computer at an Air route Traffic Control Center (ARTCC). The information is transmitted through ADNS to ACARS, which transmits the information directly to the aircraft. The aircraft operators input information into their host computer which generates an ACARS message that is transmitted to the aircraft. The pilot/flight crew input information into the ACARS man machine interface in the cockpit which is transmitted via ACARS to and through the aircraft operators host computer into the FAA's NADIN system and to the appropriate ATCT TDLS system.
Weather Involvement:	None
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ARINC Data Network Service (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used.
Status:	Operational: ACARS is provided to over 300+ North American Airports, including every major U.S. Airport via a network of Very High Frequency (VHF) ground stations and the Inmarsat satellite network.
Schedule:	To address projected frequency spectrum capacity limitations over the next decade many ACARS messages will be transitioned to ARINC Very High Frequency Digital Link Mode 2 (VDL Mode 2).
References:	Need for Change Current ACARS slides, 1998; Aeronautical Data Link slides, 1998; ACARS & VDL Mode 2 Program Status slides, 1998; ARINC ACARS description; ARINC Acronyms

A.4.5 ACARS—Strategic Traffic Management Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Aircraft Communications Addressing and Reporting System (ACARS).**
Objective of Application:	**Strategic Traffic Management Services**—Monitor National Air Space (NAS) traffic status and assess NAS traffic performance
Data Links Used:	ACARS
End-application of Interest:	Air Traffic Control Tower (ATCT): Tower Data Link Services (TDLS) & Flight Management System (FMS)
Operational Domain:	Departure terminal domain—ATCT provides in-flight sequencing, spacing, and routing restrictions to the aircraft; ATCT receives and processes user preferences from the aircraft; The pilot/crew provides destination Estimated Time Arrival (ETA) to ATCT. En route/cruise—ATCT provides in-flight sequencing, spacing, and routing restrictions to the aircraft; Aircraft provides position reports and ETA updates to ATCT.
Targeted User Class:	Air traffic services provider—The information is used by Strategic Traffic Management Services.
User Need Met:	Strategic Traffic Management Services uses the aircraft movement information to monitor NAS traffic status and assess NAS traffic performance.
How the Application Works:	Information is input into the man-machine interface in the aircraft cockpit by the pilot/crew and transmitted through the ACARS system where it is forwarded through ARINC Data Network Service (ADNS) to the FAA's National Area Data Interchange Network (NADIN) II Packet Switch Network (PSN) and routed to the appropriate Air Traffic Services Provider responsible for Strategic Traffic Management Services and to TDLS, when appropriate.
Weather Involvement:	None
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System (CPS), which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ADNS and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used.
Status:	Operational: ACARS is provided to over 300+ North American Airports, including every major U.S. Airport via a network of Very High Frequency (VHF) ground stations and the Inmarsat satellite network.
Schedule:	To address projected frequency spectrum capacity limitations over the next decade many ACARS messages will be transitioned to ARINC Very High Frequency Digital Link Mode 2 (VDL Mode 2).
References:	Need for Change Current ACARS slides, 1998; Aeronautical Data Link slides, 1998; ACARS & VDL Mode 2 Program Status slides, 1998; ARINC ACARS description; ARINC Acronyms

A.4.6 ACARS—Emergency and Alerting Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Aircraft Communications Addressing and Reporting System (ACARS).**
Objective of Application:	**Emergency and Alerting Services**—Provide emergency assistance and alerts
Data Links Used:	ACARS
End-application of Interest:	Air Traffic Control Tower (ATCT) Aircraft—ACARS terminal, including man-machine interface.
Operational Domain:	Departure terminal domain—ATCT provides the aircraft with hazard reports (alerts). En route/cruise—ATCT provides the aircraft with hazard reports (alerts). Arrival terminal domain—ATCT provides the aircraft with hazard reports (alerts).
Targeted User Class:	Air Traffic Services (ATS) Provider—Emergency and Alerting Services
User Need Met:	The Air Traffic Services Provider provides emergency and alerting services to the aircraft

CHARACTERISTIC	DESCRIPTION
How the Application Works:	Hazard reports and weather advisories are input into Tower Data Link Services (TDLS) which transmits the information to the FAA's host computer, through National Area Data Interchange Network (NADIN) II and ARINC Data Network Service (ADNS) which transmits the information to the ACARS man machine terminal in the aircraft cockpit.
Weather Involvement:	Weather advisories are transmitted to the aircraft via ACARS.
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ADNS and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used.
Status:	Operational: ACARS is provided to over 300+ North American Airports, including every major U.S. Airport via a network of Very High Frequency (VHF) ground stations and the Inmarsat satellite network.
Schedule:	To address projected frequency spectrum capacity limitations over the next decade many ACARS messages will be transitioned to ARINC Very High Frequency Digital Link Mode 2 (VDL Mode 2).
References:	Need for Change Current ACARS slides, 1998; Aeronautical Data Link slides, 1998; ACARS & VDL Mode 2 Program Status slides, 1998; ARINC ACARS description ARINC Acronyms

A.4.7 ACARS—Navigation Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Aircraft Communications Addressing and Reporting System (ACARS).**
Objective of Application:	**Navigation Services**—Provide airborne navigation guidance; Provide surface navigation guidance.
Data Links Used:	ACARS
End-application of Interest:	Air Traffic Control Tower (ATCT): Tower Data Link Services (TDLS) Aircraft—ACARS terminal, including man-machine interface
Operational Domain:	Airport departure surface operations domain—ATCT provides surface navigation guidance to the aircraft. Departure terminal domain—ATCT provides airborne navigation guidance to the aircraft. En route/cruise—ATCT provides airborne navigation guidance to the aircraft. Arrival terminal domain—ATCT provides airborne navigation guidance to the aircraft. Airport arrival surface operations domain—ATCT provides surface navigation guidance to the aircraft.
Targeted User Class:	Air traffic services provider: By providing airborne and surface navigation services with TDLS over ACARS voice frequency congestion has been reduced at major airports. Guidance is issued in a more timely and effective manner. Communications errors are reduced. This provides significant benefits in time and stress avoidance to air traffic controllers and provides for more efficient use of airspace capacity Pilot/flight crew: Receipt of airborne and surface navigation guidance over ACARS in the aircraft allows the crew to make use of valuable time during busy periods.
User Need Met:	Receipt of surface and airborne navigation guidance necessary to safely operate, land, and taxi the aircraft.
How the Application Works:	Airborne and surface navigation information are input into TDLS which sends the information to the FAA's host computer, through National Area Data Interchange Network (NADIN) II and ARINC Data Network Service (ADNS) which transmits the information to the ACARS man machine terminal in the aircraft's cockpit.
Weather Involvement:	None

CHARACTERISTIC	DESCRIPTION
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ADNS and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used.
Status:	Operational: ACARS is provided to over 300+ North American Airports, including every major U.S. Airport via a network of Very High Frequency (VHF) ground stations and the Inmarsat satellite network.
Schedule:	To address projected frequency spectrum capacity limitations over the next decade many ACARS messages will be transitioned to Very High Frequency Digital Link Mode 2 (VDL Mode 2).
References:	Need for Change Current ACARS slides, 1998; Aeronautical Data Link slides, 1998; ACARS & VDL Mode 2 Program Status slides, 1998; ARINC ACARS description; ARINC Acronyms.

A.4.8 ACARS—Surveillance Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Aircraft Communications Addressing and Reporting System (ACARS).**
Objective of Application:	**Surveillance Services**—Provide aircraft position/ID and provide aircraft intent, state, and performance
Data Links Used:	ACARS
End-application of Interest:	Air traffic services provider: Tower Data Link System (TDLS) Aircraft operator management Aircraft—ACARS terminal, including man-machine interface
Operational Domain:	Pre-flight domain—Crew information, fuel/verification, delay reports and Out/off/On/In (OOOI) events are provided to aircraft operator management. Weight and balance, runway analysis, dispatch release, and remote maintenance release are provided to the pilot/flight crew deck. Airport departure surface operations domain—OOOI events, destination Estimated Time of Arrival (ETA) and fuel remaining are provided to the aircraft operator management Departure terminal domain—Aircraft position ID and intent is provided to the Air Traffic Services Provider. Arrival terminal domain—ETA changes are provided to the Air Traffic Services Provider and OOOI event is provided to the aircraft operator management. En route/cruise domain—Aircraft position/ID and intent are provided to the Air Traffic Services Provider. Aircraft Operator Management provides gate assignment to aircraft. Post-flight domain—OOOI event, gate coordination, final maintenance status, and fuel verification are provided to the Aircraft Operator Management
Targeted User Class:	Air traffic services provider—Receipt of position ID, position reports, and ETA changes provides the information necessary for the provision of Tactical Traffic Management Services to the aircraft. Pilot/aircrew/flight deck—Information necessary for the safe and efficient flight is provided to the pilot/flight crew in the cockpit. Aircraft operator management—Information necessary to track current status of the aircraft, crew information, fuel information, and ETA information necessary for efficient flight management are provided to the aircraft dispatcher.
User Need Met:	Air traffic services receives the information necessary to manage and control the flight. Pilot/aircrew/flight deck—receive the information needed to efficiently and safely complete flight. Aircraft operator management—receives the information necessary to effectively manage the aircraft, crew, and flight operations.

CHARACTERISTIC	DESCRIPTION
How the Application Works:	Automatic position reports/position ID are generated by the aircraft's navigation system, and ETA information is input into the ACARS man-machine interface in the cockpit and all the information is transmitted via ACARS, through ARINC Data Network Services (ADNS), to the aircraft operators host computer and the FAA's host system in an Air Route Traffic Control Center (ARTCC), which routes the information to the appropriate Air Traffic Control Tower (ATCT) where the information is provided via TDLS. Information sent to the aircraft by the Aircraft operator management is input into the operator's host computer system that uses ACARS to send the information to the ACARS man-machine interface in the aircraft.
Weather Involvement:	None
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ADNS and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used.
Status:	Operational: ACARS is provided to over 300+ North American Airports, including every major U.S. Airport via a network of Very High Frequency (VHF) ground stations and the Inmarsat satellite network.
Schedule:	To address projected frequency spectrum capacity limitations over the next decade many ACARS messages will be transitioned to Very High Frequency Digital Link Mode 2 (VDL Mode 2).
References:	Need for Change Current ACARS slides, 1998; Aeronautical Data Link slides, 1998; ACARS & VDL Mode 2 Program Status slides, 1998; ARINC ACARS description; ARINC Acronyms

A.4.9 ACARS—On-board Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Aircraft Communications Addressing and Reporting System (ACARS).**
Objective of Application:	**On-board Services**—provide administrative flight information
Data Links Used:	ACARS
End-application of Interest:	Aircraft—ACARS terminal, including man-machine interface
Operational Domain:	Pre-flight domain—Administrative flight information is provided to the aircraft by aircraft operator management. Airport departure surface operations domain—Administrative flight information is provided to the aircraft by aircraft operator management. Departure terminal domain—Administrative flight information is provided to the aircraft by aircraft operator management. En route/cruise domain—Administrative flight information is provided to the aircraft by aircraft operator management. Arrival terminal domain—Administrative flight information is provided to the aircraft by aircraft operator management. Airport arrival surface operations domain—Administrative flight information is provided to the aircraft by aircraft operator management. Post-flight domain—Administrative flight information is provided to the aircraft by aircraft operator management.
Targeted User Class:	Pilot/flight crew: Receipt of administrative flight information over ACARS in the aircraft allows the crew to make efficient use of valuable time and provides for efficient flight operations.
User Need Met:	Pilot/aircrew/flight deck—receives administrative information necessary to efficiently complete flight (e.g., connecting gate information).
How the Application Works:	The aircraft operator management personnel inputs the information into their host computer system which routes the message via ARINC Data Network Services (ADNS) which sends the information to the ACARS man-machine interface in the aircraft.
Weather Involvement:	None

CHARACTERISTIC	DESCRIPTION
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ADNS and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used.
Status:	Operational: ACARS is provided to over 300+ North American Airports, including every major U.S. Airport via a network of Very High Frequency (VHF) ground stations and the Inmarsat satellite network.
Schedule:	To address projected frequency spectrum capacity limitations over the next decade many ACARS messages will be transitioned to ARINC Very High Frequency Digital Link Mode 2 (VDL Mode 2).
References:	Need for Change Current ACARS slides, 1998; Aeronautical Data Link slides, 1998; ACARS & VDL Mode 2 Program Status slides, 1998; ARINC ACARS description; ARINC Acronyms

A.5 Pre-Departure Clearance (PDC)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Pre-Departure Clearance (PDC)**. The FAA Clearance Delivery Specialist in the Air Traffic Control Tower (ATCT) uses this term. Pilots refer to Departure Clearance.
Objective of Application:	Flight Plan Services
Data Links Used:	Current—ACARS. Near-term—Very High Frequency Digital Link Mode 2 (VDL Mode 2)
End-application of Interest	Air Traffic Services Provider automated systems file and process flight plans for transmission to the aircraft over data link.
Operational Domain:	Pre-flight. The aircraft requires the clearance in order to commence movement on the airport surface.
Targeted User Class:	Air traffic services provider; Provides PDC Pilot/flight crew; Receives PDC
User Need Met	By delivering clearances over ACARS using PDC, voice frequency congestion and departure delays have been reduced at major airports. Clearances are issued in a more timely and effective manner. Communications errors are reduced. This provides significant benefits in time and productivity for air traffic controllers.
How the Application Works	The FAA sends approved flight plans to the appropriate ATCT for issuance of a departure clearance. The flight plan information is reviewed at the Tower Data Link Services (TDLS) workstation to insure that all entries are complete and include appropriate Notices To Airman (NOTAMS). The PDC is approved and sent via ACARS to the aircraft operator's host computer. When the pilot requests his clearance, an ACARS message is generated from the aircraft to the aircraft operator's host computer. The host computer generates an ACARS message sending the PDC directly to the aircraft.
Weather Involvement	None.
Satellite Communications	A few PDCs are delivered via GLOBALink satellite data link in areas where there is no Very High Frequency (VHF) coverage (business airports served by major airport clearance delivery but not Line Of Sight (LOS) to the ACARS VHF station.
Status:	Operational at 57 airports in the U.S. Delivers about 300,000 clearances to airlines.
Schedule:	No schedule for upgrade. No schedule for expansion of service to other airports in the U.S. Any expansion or upgrade would be tied to host platform (TDLS).
References	National Airspace System Architecture, Version 4.0, FAA

A.6 Data Link Delivery of Expected clearance (DDTC)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Data Link Delivery of Expected Taxi Clearances (DDTC)**
Objective of Application:	Tactical Traffic Management Services—Provide pre-flight runway, taxi sequence, and movement restrictions

CHARACTERISTIC	DESCRIPTION
	Navigation Services—Provide surface navigation guidance
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS).
End-application of Interest:	Airport Traffic Control Tower (ATCT) Aircraft operator management Aircraft—ACARS terminal, including man-machine interface
Operational Domain:	Pre-flight domain Airport arrival surface operations domain
Targeted User Class:	Air Traffic Services Provider—issues pre-taxi instructions prior to aircraft movement on the runway Pilot/flight crew—Pre taxi instructions when ready Aircraft Operator Management—Airline ramp controllers are able to automate routine ramp management.
User Need Met:	Pilot/flight crew—pre-taxi instructions are received when the pilot is ready not when the pilot can get on the frequency. This leaves ground frequencies for exceptions and emergencies.
How the Application Works:	The pilot/flight crew requests an expected taxi clearance. Based upon flight plan information and airport configuration, ground control frequency and expected taxi route information is automatically generated when taxi request is received from the pilot. The information can then be sent manually by the controller or the application can be configured to operate in the "auto" Mode which requires no controller intervention. The expected taxi clearance is sent to the ramp controller server where it is forwarded through ARINC Data Network Service (ADNS) to ACARS to the ACARS man-machine interface in the aircraft.
Weather Involvement:	None
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ADNS and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used.
Status:	Development—DDTC is currently under evaluation by the FAA and national deployment is expected.
Schedule:	DDTC is operational at Detroit. Other locations have not been scheduled
References:	ARINC Information sheet

A.7 TWDL

A.7.1 TWDL—ATC Separation Assurance Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Two-Way Data Link (TWDL)**
Objective of Application:	**Air Traffic Control (ATC) Separation Assurance Services**—En route position reports and ETA updates provided by the aircraft assist ATC in monitoring flight progress and separating IFR aircraft. Transmission of hazard reports to the aircraft assists the aircraft in avoiding potential hazards.
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS); VHF Digital Link (VDL) Mode 2 (VDL Mode 2); GLOBALink High Frequency (HF)
End-application of Interest:	Air Route Traffic Control Center (ARTCC): ATC Separation Assurance Services Pilot/flight crew—TWDL (Controller Pilot Data Link Communications—CPDLC) cockpit terminal.
Operational Domain:	En route/cruise—Automatic position reports and Estimated Time of Arrival (ETA) updates and/or changes is transmitted from the aircraft. Hazard reports are transmitted to the aircraft.
Targeted User Class:	Air Traffic Services Provider—The receipt of aircraft position reports and ETA updates assist in the provision, control, direction, of aircraft within the International Civil Aviation Organization (ICAO) assigned Oceanic Flight Information Region (FIR) The pilot/aircrew/flight deck benefit from the receipt of hazard reports and gate assignment information.

CHARACTERISTIC	DESCRIPTION
User Need Met:	ETA information and automatic position reports are sent to the ATC and are used to monitor flight progress, insure the maintenance of minimum distance from special use airspace (SUA), and maintain the separation of Instrument Flight Rules (IFR) aircraft.
How the Application Works:	TWDL/CPDLC adhere to Radio Technical Commission for Aeronautics (RTCA) Document # 219. Aircraft equipped with Future Air Navigation System (FANS) 1/A, are equipped to transmit and receive TWDL (CPDLC) formatted messages. This allows Notice to Airmen (NOTAM) changes and hazard reports, such as wind shear/microburst alerts, to be uplinked to the aircraft by an ARTCC oceanic controller where they can be viewed when pilots are not focused on other duties during high-workload time. ETA information and automatic position reports may be by the pilot/aircrew in a CPDLC messages directly to the ARTCC oceanic controller. Uplink and downlink messages may be transmitted via VHF or HF radio or satellite link.
Weather Involvement:	Weather information/updates which advise of adverse weather conditions may be sent to the aircraft via a TWDL/CPDLC message
Satellite Communications:	TWDL/CPDLC messages may be transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the ARTCC via ARINC Data Network Service (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with a FANS 1/A Flight Management System (FMS) terminal, which provides CPDLC/TWDL data link messaging capabilities.
Status:	Development—CPDLC is available in the South Pacific, Asian, and Far East Russian FIRS using satellite communications. Currently there are about 500 FANS-1/A equipped aircraft. Aeronautical Telecommunications Network (ATN) is in a developmental state and a backward compatibility problem exists between FANS-1/A and ATN. Work is progressing on ATN to address FANS –1/A applications. Currently the Boeing B747-400, B777, and B757 are certified for FANS1. The MD 90 is also certified for the Boeing FANS 1. The Airbus A320, 330, and 340 have the FANS A option although FANS-A is not yet operational.
Schedule:	Certification for the MD-11 for FANS 1 is expected to be completed by the end of 2000. Current FAA plans call for the integration of FANS1A, CPDLC/TWDL, and Oceanic Data Link (ODL) into the FAA systems in 2002-2003.
References:	RTCA DO 219; Two-Way Data Link End System prototype System Specification, ARINC, 1993; National Airspace System Architecture, Version 4.0, FAA; ATC Data Link News, Controller Pilot Data Link Communications, 1999; ATC Data link News, FANS-1/A Aircraft, May 19, 199

A.7.2 TWDL—ATC Advisory Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Two-Way Data Link (TWDL)**
Objective of Application:	**ATC Advisory Services** Provide in-flight weather advisories and in-flight traffic advisories
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS); VHF Digital Link Mode 2 (VDL Mode 2); GLOBALink High Frequency (HF)
End-application of Interest:	Air Route Traffic Control Center (ARTCC): ATC Advisory Services Aircraft –TWDL (Controller Pilot Data Link Communications—CPDLC) cockpit terminal.
Operational Domain:	En route/cruise—in-flight weather and traffic advisories are transmitted directly to the cockpit.
Targeted User Class:	The pilot/aircrew/flight deck benefit from the receipt of in flight weather and traffic advisories
User Need Met:	Delivery of weather and traffic advisories to the cockpit.
How the Application Works:	TWDL/CPDLC adhere to Radio Technical Commission for Aeronautics (RTCA) Document # 219. Aircraft equipped with Future Air Navigation System (FANS) 1/A, are equipped to transmit and receive TWDL (CPDLC) formatted messages. In-flight weather information and in-flight traffic advisories are input into a TWDL/CPDLC terminal, by the ARTCC oceanic controller, which transmits the message to the TWDL/CPDLC cockpit terminal. Uplink and downlink messages may be transmitted via VHF or HF radio or satellite link.
Weather Involvement:	Weather information/updates which advise of adverse weather conditions may be sent to the aircraft, by the ARTCC controller via a TWDL/CPDLC message

CHARACTERISTIC	DESCRIPTION
Satellite Communications:	TWDL/CPDLC messages may be transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the ARTCC via ARINC Data Network Service (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with a FANS 1/A Flight Management System (FMS) terminal, which provides CPDLC/TWDL data link messaging capabilities.
Status:	Development—CPDLC is available in the South Pacific, Asian, and Far East Russian FIRS using satellite communications. Currently there are about 500 FANS-1/A equipped aircraft. Aeronautical Telecommunications Network (ATN) is in a developmental state and a backward compatibility problem exists between FANS-1/A and ATN. Work is progressing on ATN to address FANS –1/A applications. Currently the Boeing B747-400, B777, and B757 are certified for FANS1. The MD 90 is also certified for the Boeing FANS 1. The Airbus A320, 330, and 340 have the FANS A option although FANS-A is not yet operational.
Schedule:	Certification for the MD-11 for FANS 1 is expected to be completed by the end of 2000. Current FAA plans call for the integration of FANS1A, CPDLC/TWDL, and Oceanic Data Link (ODL) into the FAA systems in 2002-2003.
References:	RTCA DO 219; Two-Way Data Link End System prototype System Specification, ARINC, 1993; National Airspace System Architecture, Version 4.0, FAA; ATC Data Link News, Controller Pilot Data Link Communications, 1999; ATC Data link News, FANS-1/A Aircraft, May 19, 199

A.7.3 TWDL—Tactical Traffic Management Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Two-Way Data Link (TWDL)**
Objective of Application:	**Tactical Traffic Management Services**—Provide in-flight sequencing, spacing, and routing restrictions; Project aircraft in-flight position and potential conflicts; Process user preferences.
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS); VHF Digital Link (VDL) Mode 2 (VDL Mode 2); GLOBALink High Frequency (HF)
End-application of Interest:	Air Route Traffic Control Center (ARTCC): Tactical Traffic Management Services Pilot/flight crew—TWDL (Controller Pilot Data Link Communications—CPDLC) cockpit terminal.
Operational Domain:	En route/cruise—ARTCC controller provides in-flight sequencing, spacing, and routing restrictions to the aircraft; Aircraft provides position reports and ETA updates to ARTCC controller
Targeted User Class:	Air traffic services provider—Tactical Traffic Management Services—Provides in-flight sequencing, spacing, and routing and movement restrictions to the aircraft; Air Traffic is able to project aircraft in-flight position, potential conflicts and to process user preferences. Pilot/flight crew: The provision of position reports and ETA updates to ATCT provides for efficient flight and arrival at the destination.
User Need Met:	The transmission and receipt of information by the ARTCC controller provides the information necessary for the completion of tactical traffic management services by Air Traffic
How the Application Works:	TWDL/CPDLC adhere to Radio Technical Commission for Aeronautics (RTCA) Document # 219. Aircraft equipped with Future Air Navigation System (FANS) 1/A, are equipped to transmit and receive TWDL (CPDLC) formatted messages. The ARTCC oceanic controller inputs information into a TWDL/CPDLC terminal which transmits the information via ACARS, directly to the aircraft cockpit. The pilot/flight crew input information into the FANS1 man machine interface in the cockpit which is transmitted via ACARS to the appropriate ARTCC oceanic controller. Uplink and downlink messages may be transmitted via VHF or HF radio or satellite link.
Weather Involvement:	None

CHARACTERISTIC	DESCRIPTION
Satellite Communications:	TWDL/CPDLC messages may be transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the ARTCC via ARINC Data Network Service (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU)interfaces with a FANS 1/A Flight Management System (FMS) terminal, which provides CPDLC/TWDL data link messaging capabilities
Status:	Development—CPDLC is available in the South Pacific, Asian, and Far East Russian FIRS using satellite communications. Currently there are about 500 FANS-1/A equipped aircraft. Aeronautical Telecommunications Network (ATN) is in a developmental state and a backward compatibility problem exists between FANS-1/A and ATN. Work is progressing on ATN to address FANS –1/A applications. Currently the Boeing B747-400, B777, and B757 are certified for FANS1. The MD 90 is also certified for the Boeing FANS 1. The Airbus A320, 330, and 340 have the FANS A option although FANS-A is not yet operational.
Schedule:	Certification for the MD-11 for FANS 1 is expected to be completed by the end of 2000. Current FAA plans call for the integration of FANS1A, CPDLC/TWDL, and Oceanic Data Link (ODL) into the FAA systems in 2002-2003.
References:	RTCA DO 219; Two-Way Data Link End System prototype System Specification, ARINC, 1993; National Airspace System Architecture, Version 4.0, FAA; ATC Data Link News, Controller Pilot Data Link Communications, 1999; ATC Data link News, FANS-1/A Aircraft, May 19, 199

A.7.4 TWDL—Strategic Traffic Management Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Two-Way Data Link (TWDL)**
Objective of Application:	**Strategic Traffic Management Services**; Monitor NAS traffic status and assess NAS traffic performance
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS); VHF Digital Link (VDL) Mode 2 (VDL Mode 2); GLOBALink High Frequency (HF)
End-application of Interest:	Air Route Traffic Control Center(ARTCC); Oceanic air traffic (AT) controller
Operational Domain:	En route/cruise—ARTCC oceanic AT controller provides in-flight sequencing, spacing, and routing restrictions to the aircraft; Aircraft provides position reports and ETA updates to ARTCC oceanic AT controller.
Targeted User Class:	Air traffic services provider—The information is used by Strategic Traffic Management Services.
User Need Met:	Strategic Traffic Management Services uses the aircraft movement information to monitor NAS traffic status and assess NAS traffic performance.
How the Application Works:	TWDL/CPDLC adhere to Radio Technical Commission for Aeronautics (RTCA) Document # 219. Aircraft equipped with Future Air Navigation System (FANS) 1/A, are equipped to transmit and receive TWDL (CPDLC) formatted messages. The Oceanic AT controller inputs a CPDLC/TWDL message, containing movement information or restrictions directly into a terminal and transmits the message to a FANS 1/A equipped aircraft. The pilot/flight crew input the aircraft position or ETA changes into a CPDLC/TWDL message terminal in the cockpit and transmit the message to the appropriate ARTCC oceanic AT controller. Uplink and downlink messages may be transmitted via VHF or HF radio or satellite link.
Weather Involvement:	None
Satellite Communications:	TWDL/CPDLC messages may be transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the ARTCC via ARINC Data Network Service (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with a FANS 1/A Flight Management System (FMS) terminal, which provides CPDLC/TWDL data link messaging capabilities.

CHARACTERISTIC	DESCRIPTION
Status:	Development—CPDLC is available in the South Pacific, Asian, and Far East Russian FIRS using satellite communications. Currently there are about 500 FANS-1/A equipped aircraft. Aeronautical Telecommunications Network (ATN) is in a developmental state and a backward compatibility problem exists between FANS-1/A and ATN. Work is progressing on ATN to address FANS -1/A applications. Currently the Boeing B747-400, B777, and B757 are certified for FANS1. The MD 90 is also certified for the Boeing FANS 1. The Airbus A320, 330, and 340 have the FANS A option although FANS-A is not yet operational.
Schedule:	Certification for the MD-11 for FANS 1 is expected to be completed by the end of 2000. Current FAA plans call for the integration of FANS1A, CPDLC/TWDL, and Oceanic Data Link (ODL) into the FAA systems in 2002-2003.
References:	RTCA DO 219; Two-Way Data Link End System prototype System Specification, ARINC, 1993; National Airspace System Architecture, Version 4.0, FAA; ATC Data Link News, Controller Pilot Data Link Communications, 1999; ATC Data link News, FANS-1/A Aircraft, May 19, 199

A.7.5 TWDL—Emergency and Alerting Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Two-Way Data Link (TWDL)**
Objective of Application:	**Emergency and Alerting Services** Provide emergency assistance and alerts
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS); VHF Digital Link (VDL) Mode 2 (VDL Mode 2); GLOBALink High Frequency (HF)
End-application of Interest:	Air Route Traffic Control Center (ARTCC) Oceanic Air Traffic Controller (ATC) Aircraft—CPDLC/TWDL cockpit terminal
Operational Domain:	En route/cruise—ARTCC Oceanic Air Traffic Controller provides the aircraft with hazard reports (alerts).
Targeted User Class:	Air Traffic Services Provider—Emergency and Alerting Services
User Need Met:	The Air Traffic Services Provider provides emergency and alerting services to the aircraft
How the Application Works:	TWDL/CPDLC adhere to Radio Technical Commission for Aeronautics (RTCA) Document # 219. Aircraft equipped with Future Air Navigation System (FANS) 1/A, are equipped to transmit and receive TWDL (CPDLC) formatted messages. The Oceanic ATC inputs hazard reports and weather advisories into an TWDL/CPDLC terminal and sends the information to the aircraft where it is received in the FANS1/A equipped cockpit. Uplink and downlink messages may be transmitted via VHF or HF radio or satellite link.
Weather Involvement:	None
Satellite Communications:	TWDL/CPDLC messages may be transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the ARTCC via ARINC Data Network Service (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with a FANS 1/A Flight Management System (FMS) terminal, which provides CPDLC/TWDL data link messaging capabilities.
Status:	Development—CPDLC is available in the South Pacific, Asian, and Far East Russian FIRS using satellite communications. Currently there are about 500 FANS-1/A equipped aircraft. Aeronautical Telecommunications Network (ATN) is in a developmental state and a backward compatibility problem exists between FANS-1/A and ATN. Work is progressing on ATN to address FANS -1/A applications. Currently the Boeing B747-400, B777, and B757 are certified for FANS1. The MD 90 is also certified for the Boeing FANS 1. The Airbus A320, 330, and 340 have the FANS A option although FANS-A is not yet operational.
Schedule:	Certification for the MD-11 for FANS 1 is expected to be completed by the end of 2000. Current FAA plans call for the integration of FANS1A, CPDLC/TWDL, and Oceanic Data Link (ODL) into the FAA systems in 2002-2003.

CHARACTERISTIC	DESCRIPTION
References:	RTCA DO 219; Two-Way Data Link End System prototype System Specification, ARINC, 1993; National Airspace System Architecture, Version 4.0, FAA; ATC Data Link News, Controller Pilot Data Link Communications, 1999; ATC Data link News, FANS-1/A Aircraft, May 19, 199

A.7.6 TWDL—Navigation Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Two-Way Data Link (TWDL)**
Objective of Application:	**Navigation Services**—Provide airborne navigation guidance
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS); VHF Digital Link (VDL) Mode 2 (VDL Mode 2); GLOBALink High Frequency (HF)
End-application of Interest:	Air Route Traffic Control Center (ARTCC) Oceanic Air Traffic Controller (ATC) Aircraft—CPDLC/TWDL cockpit terminal
Operational Domain:	En route/cruise—ARTCC provides airborne navigation guidance to the aircraft.
Targeted User Class:	Air traffic services provider: By providing airborne navigation services with TWDL/CPDLC voice frequency congestion is reduced. Guidance is issued in a more timely and effective manner. Communications errors are reduced. This provides significant benefits in time and stress avoidance to air traffic oceanic controllers and provides for more efficient use of airspace capacity Pilot/flight crew: Receipt of airborne and surface navigation guidance over TWDL/CPDLC in the aircraft allows the crew to make use of valuable time during busy periods.
User Need Met:	Receipt of airborne navigation guidance necessary to safely operate the aircraft.
How the Application Works:	TWDL/CPDLC adhere to Radio Technical Commission for Aeronautics (RTCA) Document # 219. Aircraft equipped with Future Air Navigation System (FANS) 1/A, are equipped to transmit and receive TWDL (CPDLC) formatted messages. The Oceanic ATC inputs hazard reports and weather advisories into an TWDL/CPDLC terminal and sends the information to the aircraft where it is received in the FANS1/A equipped cockpit. Uplink and downlink messages may be transmitted via VHF or HF radio or satellite link.
Weather Involvement:	Weather information/updates which advise of adverse weather conditions may be sent to the aircraft via a TWDL/CPDLC message.
Satellite Communications:	TWDL/CPDLC messages may be transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the ARTCC via ARINC Data Network Service (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with a FANS 1/A Flight Management System (FMS) terminal, which provides CPDLC/TWDL data link messaging capabilities.
Status:	Development—CPDLC is available in the South Pacific, Asian, and Far East Russian FIRS using satellite communications. Currently there are about 500 FANS-1/A equipped aircraft. Aeronautical Telecommunications Network (ATN) is in a developmental state and a backward compatibility problem exists between FANS-1/A and ATN. Work is progressing on ATN to address FANS –1/A applications. Currently the Boeing B747-400, B777, and B757 are certified for FANS1. The MD 90 is also certified for the Boeing FANS 1. The Airbus A320, 330, and 340 have the FANS A option although FANS-A is not yet operational.
Schedule:	Certification for the MD-11 for FANS 1 is expected to be completed by the end of 2000. Current FAA plans call for the integration of FANS1A, CPDLC/TWDL, and Oceanic Data Link (ODL) into the FAA systems in 2002-2003.
References:	RTCA DO 219; Two-Way Data Link End System prototype System Specification, ARINC, 1993; National Airspace System Architecture, Version 4.0, FAA; ATC Data Link News, Controller Pilot Data Link Communications, 1999; ATC Data link News, FANS-1/A Aircraft, May 19, 199

A.7.7 TWDL—Surveillance Services

CHARACTERISTIC	DESCRIPTION
Application Name:	**Two-Way Data Link (TWDL)**
Objective of Application:	**Surveillance Services**—Provide aircraft position/ID and provide aircraft intent, state, and performance
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS); VHF Digital Link (VDL) Mode 2 (VDL Mode 2); GLOBALink High Frequency (HF)
End-application of Interest:	Air traffic services provider: Air Route Traffic Control Center (ARTCC) Oceanic Air Traffic Controller (ATC) Aircraft—TWLD/CPDLC cockpit terminal
Operational Domain:	En route/cruise domain—Aircraft position/ID and intent are provided to the Air Traffic Services Provider.
Targeted User Class:	Air traffic services provider—Receipt of position ID, position reports, and ETA changes provides the information necessary for the provision of Tactical Traffic Management Services to the aircraft. Pilot/aircrew/flight deck—Information necessary for the safe and efficient flight is provided to the pilot/flight crew in the cockpit.
User Need Met:	Air traffic services receives the information necessary to manage and provide airborne navigation services. Pilot/aircrew/flight deck—receive the information needed to efficiently and safely complete flight.
How the Application Works:	TWDL/CPDLC adhere to Radio Technical Commission for Aeronautics (RTCA) Document # 219. Aircraft equipped with Future Air Navigation System (FANS) 1/A, are equipped to transmit and receive TWDL (CPDLC) formatted messages. A CPDLC/TWDL message, containing the position ID, position reports, and ETA changes is entered into the FANS – 1/AS TWDL/CPDLC cockpit terminal and sent to the appropriate ARTCC Oceanic controller. Uplink and downlink messages may be transmitted via VHF or HF radio or satellite link.
Weather Involvement:	None
Satellite Communications:	TWDL/CPDLC messages may be transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the ARTCC via ARINC Data Network Service (ADNS) and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with a FANS 1/A Flight Management System (FMS) terminal, which provides CPDLC/TWDL data link messaging capabilities.
Status:	Development—CPDLC is available in the South Pacific, Asian, and Far East Russian FIRS using satellite communications. Currently there are about 500 FANS-1/A equipped aircraft. Aeronautical Telecommunications Network (ATN) is in a developmental state and a backward compatibility problem exists between FANS-1/A and ATN. Work is progressing on ATN to address FANS –1/A applications. Currently the Boeing B747-400, B777, and B757 are certified for FANS1. The MD 90 is also certified for the Boeing FANS 1. The Airbus A320, 330, and 340 have the FANS A option although FANS-A is not yet operational.
Schedule:	Certification for the MD-11 for FANS 1 is expected to be completed by the end of 2000. Current FAA plans call for the integration of FANS1A, CPDLC/TWDL, and Oceanic Data Link (ODL) into the FAA systems in 2002-2003.
References:	RTCA DO 219; Two-Way Data Link End System prototype System Specification, ARINC, 1993; National Airspace System Architecture, Version 4.0, FAA; ATC Data Link News, Controller Pilot Data Link Communications, 1999; ATC Data link News, FANS-1/A Aircraft, May 19, 199

A.8 Digital Airport Terminal Information Service (D-ATIS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Digital Airport Terminal Information Service (D-ATIS).**
Objective of Application:	ATC Advisory Services.
Data Links Used:	ACARS

CHARACTERISTIC	DESCRIPTION
End-application of Interest	Provide in-flight or pre-flight weather advisories, and in-flight or pre-flight NAS status advisories from the TDLS workstation in the tower to the aircraft Management Unit (MU) Display
Operational Domain:	Pre-flight En route/cruise. Arrival terminal domain
Targeted User Class:	Air traffic services provider Pilot/flight crew
User Need Met	An aircraft entering controlled terminal airspace must have the latest airport weather and operations information. D-ATIS is a safety-enhancing alternative to the laborious task of shifting a radio to the ATIS frequency and manually copying the voice ATIS message information at a time in the flight regime when the crew is performing other critical tasks. Pilots may obtain D-ATIS well in advance of entry into the terminal domain in order to do advance planning.
How the Application Works	The Air Traffic Control Tower (ATCT) is required to issue a new ATIS message at least once per hour, and each time important weather or operations information contained in the message changes. Using the D-ATIS window on the Tower Data Link Services (TDLS) terminal, the tower controller selects the operations data desired based on pre-programmed airport operations data (active runways, type of operations, equipment not in operation, Notice to Airmen (NOTAM), etc. stored in the D-ATIS database in the TDLS. When the operator and supervisor are satisfied that the message is correct, the new message is issued by depressing the send key. The digital message is sent via FAA and ARINC ground networks to a national D-ATIS database maintained by ARINC. At the same time the TDLS system in the tower creates a synthesized voice message to be broadcast on the manual ATIS frequency. When a pilot wants the D-ATIS, he requests it for a specific airport via ACARS. D-ATIS can also be uplinked to the aircraft without crew request whenever changes occur.
Weather Involvement	Weather is a critical element of the D-ATIS message. Weather information from automated surface observing system (ASOS), automated weather observing system (AWOS), Systems Atlanta information Display System (SAIDS) or other weather source is automatically input to the message format.
Satellite Communications	The D-ATIS message is a standard ARINC message, and can be delivered by satellite
Status:	Operational at 58 airports in the U.S. (FAA-sponsored) and numerous airports internationally. About 150,000 updates are processed each month, and about 1 million D-ATIS messages are delivered to data link-equipped aircraft each month.
Schedule:	No schedule for upgrade. No FAA schedule for expansion of service to other airports in the U.S. Any expansion or upgrade would be tied to host platform (TDLS).

A.9 Automatic Dependent Surveillance—A (Addressed)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Automatic Dependent Surveillance—A (Addressed)**
Objective of Application:	Surveillance Services
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS).
End Application of Interest	Provide aircraft position/ID. Provide aircraft intent, state, and performance.
Operational Domain:	Enroute/cruise. Departure and Arrival Terminal
Targeted User Class:	Air Traffic Control (ATC) service provider. Aircraft operator management.
User Need Met:	ADS-A provides surveillance data to ATC service providers to assist separation of IFR aircraft. Also allows aircraft operator management to monitor flight progress.

CHARACTERISTIC	DESCRIPTION
How the Application Works:	Using addressable data link, the aircraft periodically originates a message containing position (usually lat/long), altitude, and other flight data obtained directly from the on board sensors and navigation equipment. This message is addressed to the Air Traffic Control (ATC) authority having control of the aircraft or to the aircraft operator management host system to be used by airline dispatch to monitor flight progress. No intervention on the part of the flight crew is required. In the Aeronautical Telecommunications Network (ATN) environment of the near future ADS-A will become ADS-C (Contract).
Weather Involvement:	Some carriers' ADS-A messages include meteorological data that is input to the Meteorological Data Collection and Reporting System (MDCRS) application.
Satellite Communications:	ADS-A messages in the oceanic environment are delivered over Inmarsat (Geo).
Status:	Operational for ATC in the North Atlantic and Pacific U.S. Flight Information Regions (FIR) over ACARS.
Schedule:	No schedule for implementation in the domestic airspace of the U.S.
References	National Airspace System Architecture, Version 4.0, FAA

A.10 Automatic Dependent Surveillance—Broadcast (ADS-B)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Automatic Dependent Surveillance—B (ADS-B) (Broadcast)**
Objective of Application:	ATC Separation Assurance Services
Data Links Used:	Undetermined
End Application of Interest	Separate Instrument Flight Rules aircraft. Avoid potential hazards and collisions.
Operational Domain:	Primary: En route/cruise. Departure Terminal and Arrival Terminal
Targeted User Class:	Pilot/aircrew/flight deck. ATC service provider.
User Need Met:	Augments the classic "see and avoid" by providing situational awareness of nearby aircraft and potential collisions.
How the Application Works:	Every aircraft equipped for ADS-B periodically transmits a 56-bit coded pulse ("squitter") containing aircraft ID, time, position and altitude. Other aircraft in the vicinity (up to 200 miles in the Ohio Valley trials) receive the squitters and display relative position information to the pilot. The ADS-B transmissions may also be intercepted by ground stations and provided to Air Traffic Control (ATC) as input to Traffic Information Service (TIS).
Weather Involvement:	None.
Satellite Communications:	None.
Status:	Development. The Ohio Valley trials declared a successful demonstration of ADS-B using Mode S, UAT and VDL Mode 4. The Capstone project in Alaska will also demonstrate ADS-B in the terminal domain at Bethel.
Schedule:	No firm schedule at this time. Development cannot continue much further until a data link is decided upon.
References	None

A.11 Traffic Information Service (TIS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Traffic Information Service (TIS)**
Objective of Application:	ATC Advisory Services
Data Links Used: (proposed)	Undetermined
End Application of Interest	Provide in-flight traffic advisories.
Operational Domain:	En route/cruise. Departure and Arrival Terminal domains.
Targeted User Class:	Pilot/aircrew/flight deck.
User Need Met:	Augments the classic "see and avoid" by providing situational awareness of nearby aircraft and potential collisions.

CHARACTERISTIC	DESCRIPTION
How the Application Works:	The Air Traffic Control (ATC) authority combines inputs from radar and intercepted ADS-B transmissions and fuses them into a tactical plot. This tactical picture is transmitted via data link to the aircraft where it is displayed in the cockpit. Also referred to as CDTI, or Cockpit Display of Traffic Information.
Weather Involvement:	None.
Satellite Communications:	None
Status:	Conceptual. Limited TIS has been demonstrated in the Western Maryland/Northern Virginia area. The Capstone project in Alaska intends to demonstrate TIS as well.
Schedule:	No firm schedule at this time.
References	None

A.12 Wide Area Augmentation System (WAAS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Wide Area Augmentation System. (WAAS)**
Objective of Application	Provides a primary means navigation capability for all phases of flight from en-route through non-precision approach. Broadcasts improve the integrity and availability of Global Positioning System (GPS) with 25 widely dispersed Wide-area reference stations (WRS) that constantly monitor the GPS broadcast signal. The WRS relays the GPS information to two Wide-area Master stations (WMS) where all WRS data is integrated and the integrity of GPS satellites is determined. The WMS sends timely data to four Ground Earth Stations (GES) which up-link the integrity data to two Geo-stationary Earth Orbit (GEO) satellites.
Data Links Used:	GPS. Two bands: 1215 to 1240 MHz, 1559 to1610 MHz. Civil only use 1575.42 MHz (L1). 1227.6 MHz (L2). 2.046 MHz (SPS), 20.46 MHz (Precise).
End-application of Interest	Navigation Services.
Operational Domain:	En-route/cruise domain
Targeted User Class:	Pilot/aircrew/flight deck
User Need Met	WAAS improves the accuracy of position information and provides integrity information for GPS
How the Application Works	The pilot/aircrew interrogates the GEO satellite broadcasts. The integrity data enables the users to determine when GPS satellites should not be used for specific phases of flight. With the addition of WAAS, the improved availability of GPS-like ranging signals provides navigation system users with more ranging sources than GPS alone. The WAAS provides differential corrections that are applicable over a wide geographic area. WAAS corrections enable the user avionics to determine a range correction for each satellite from any user location in the coverage area.
Weather Involvement	None.
Satellite Communications	GPS satellites
Status:	Thirty hardware systems installed in Phase 1 are complete. Operational software will be delivered after last hardware delivery. Acceptance from contractor is scheduled for April 25, 2000. Operational WAAS is scheduled for commissioning in September 2000.
Schedule:	One phase is operational but not commissioned. Quantities for Phase 2/3 hardware deliveries have not been defined.
References	National Airspace System Architecture, Version 4.0, FAA

A.13 Local Area Augmentation System (LAAS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Local Area Augmentation System (LAAS)**
Objective of Application:	Navigation Services
Data Links Used:	Very High Frequency (VHF) 108—118 MHz
End Application of Interest	Provide airborne and surface navigation guidance by providing corrections to GPS positioning information.
Operational Domain:	Airport departure surface operations En route/cruise Arrival terminal domain Airport arrival surface operations

CHARACTERISTIC	DESCRIPTION
Targeted User Class:	Pilot/flight deck Air traffic services provider
User Need Met:	LAAS will enable precision approaches to be executed (eventually up to CAT III) using a seamless navigation system. Controllers will also be able to provide improved surface navigation capability to aircraft equipped.
How the Application Works:	A ground station at a precisely surveyed location near the airport receives the same Global Positioning System (GPS) positioning information as aircraft in the vicinity, and transmits a differential correction to the position, enabling aircraft to know their position within one meter. One LAAS station can service more than one airport within a given area.
Weather Involvement:	None
Satellite Communications:	GPS satellite
Status:	Developmental. FAA signed agreements in April 1999 with both Honeywell and Raytheon consortiums that will develop certify and produce LAAS equipment. Both will produce CAT I equipment for test and evaluation that will supplement the WAAS
Schedule:	It is desired to have at least one public use CAT I LAAS by mid 2001, and a public use CAT III LAAS by late 2002.
References	National Airspace System Architecture, Version 4.0, FAA

A.14 Traffic Alert and Collision Avoidance System (TCAS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Traffic Alert and Collision Avoidance System (TCAS)**
Objective of Application:	ATC Separation Assurance Services
Data Links Used:	Mode S.
End Application of Interest	Avoid potential hazards and collisions.
Operational Domain:	Departure Terminal En route/cruise Arrival Terminal domains.
Targeted User Class:	Pilot/aircrew/flight deck.
User Need Met:	Augments the classic "see and avoid" by providing situational awareness of nearby aircraft and potential collisions, and situation resolution advisories.
How the Application Works:	Each TCAS-equipped aircraft periodically transmits interrogation pulses to Mode C and Mode S equipped aircraft. The responses are analyzed by collision avoidance logic and displayed in the cockpit. Aural and visual warnings are also given to the pilot, if the situation warrants.
Weather Involvement:	None.
Satellite Communications:	None.
Status:	In service. Installed on all aircraft in Part 121 service carrying more than 30 passengers. The current version of TCAS is Version 7, which is capable of ADS-B as well.
Schedule:	No plans for further upgrade or replacement.
References	National Airspace System Architecture, Version 4.0, FAA

A.15 Instrument Landing System (ILS) LF/MF

CHARACTERISTIC	DESCRIPTION
Application Name:	**Instrument Landing System (ILS)**. Categories I, II, III Approaches. Category I provides for an approach to Decision Height (DH) 200' and Runway Visual Range (RVR) 2400'; CAT II DH100' and RVR 1200'; CAT IIIa no DH or DH less than 100'and RVR not less than 700'; CAT IIIb no DH or DH below 50' and RVR less than 700' but more than 150' and CAT IIIc has no DH or RVR limitation.
Objective of Application:	The ILS is designed to provide an approach path for exact alignment and descent of an aircraft on final approach to a runway. The components of an ILS may include two highly directional transmitting systems and along the approach three or fewer marker beacons. The directional transmitters are known as the localizer and the glide slope. Compass locators located at the outer marker or middle marker may be substituted for marker beacons. DME, when specified in the procedure, may be substituted for the OM.
Data Links Used:	Compass Locator is L/MF spectrum for use of Automatic Direction Finder (ADF) equipped aircraft. Compass Locator operates in the 195-535 kHz range.
End-application of Interest	Navigation Services.

CHARACTERISTIC	DESCRIPTION
Operational Domain:	Arrival Terminal Domain.
Targeted User Class:	Aircraft operated under Instrument Flight Rules (IFR).
User Need Met	Precision approach to runway in periods of inclement weather or reduced visibility.
How the Application Works	The Compass Locator radiates an omnidirectional signal in the L/MF spectrum that is detected by an ADF in the aircraft, which provides directional information to the flight crew for positioning on the approach to the runway.
Weather Involvement	System normally used in periods of reduced visibility/ceiling.
Satellite Communications	None.
Status:	Presently in use with declining numbers in service. CAT I use will become obsolete with GPS systems in use (LAAS).
Schedule:	Not scheduled for new systems to be installed.
References	National Airspace System Architecture, Version 4.0, FAA

A.16 Instrument Landing System (ILS) Very High Frequency (VHF)

CHARACTERISTIC	DESCRIPTION
Application Name:	**ILS-Instrument Landing System**. Categories I, II, III Approaches. Category I provides for an approach to Decision Height (DH) 200' and Runway Visual Range (RVR) 2400'; CAT II DH100' and RVR 1200'; CAT IIIa no DH or DH less than 100'and RVR not less than 700'; CAT IIIb no DH or DH below 50' and RVR less than 700' but more than 150' and CAT IIIc has no DH or RVR limitation.
Objective of Application:	The ILS is designed to provide an approach path for exact alignment and descent of an aircraft on final approach to a runway. The components of an ILS may include two highly directional transmitting systems and along the approach three or fewer marker beacons. The directional transmitters are known as the localizer and the glide slope. Compass locators located at the outer marker or middle marker may be substituted for marker beacons. DME, when specified in the procedure, may be substituted for the OM.
Data Links Used:	Localizer and markers use VHF radio spectrum for dissemination of information. The localizer uses 108.10-111.95MHz while all markers operate on 75 MHz.
End-application of Interest	Navigation Services.
Operational Domain:	Arrival Terminal Domain.
Targeted User Class:	Aircraft being operated under instrument flight rules.
User Need Met	Precision approach provided to properly equipped aircraft.
How the Application Works	Markers project a vertically radiated signal, which provides information as to the location of the aircraft along the approach to the runway. The localizer projects a signal that depends upon the aircraft location for the indication of being on the proper azimuthal heading. A difference in depth of modulation is used to determine the precise location.
Weather Involvement	System is of primary benefit during reduced ceiling and visibility.
Satellite Communications	None
Status:	Primary precision approach system in use at this time. Used at airports with jet operations.
Schedule:	Will be phased out, as Global Positioning System (GPS) becomes available for Local Area Augmentation Systems (LAAS).
References	National Airspace System Architecture, Version 4.0, FAA

A.17 Instrument Landing System (ILS) Ultra High Frequency (UHF) and L-Band

CHARACTERISTIC	DESCRIPTION
Application Name:	**Instrument Landing System (ILS)**. Categories I, II, III Approaches. Category I provides for an approach to Decision Height (DH) 200' and Runway Visual Range (RVR) 2400'; CAT II DH100' and RVR 1200'; CAT IIIa no DH or DH less than 100'and RVR not less than 700'; CAT IIIb no DH or DH below 50' and RVR less than 700' but more than 150' and CAT IIIc has no DH or RVR limitation.
Objective of Application:	The ILS is designed to provide an approach path for exact alignment and descent of an aircraft on final approach to a runway. The components of an ILS may include two highly directional transmitting systems and along the approach three or fewer marker beacons. The directional transmitters are known as the localizer and the glide slope. Compass locators located at the outer marker or middle marker may be substituted for marker beacons. DME, when specified in the procedure, may be substituted for the OM.

CHARACTERISTIC	DESCRIPTION
Data Links Used:	Glide Slope and DME utilize UHF radio spectrum for information dissemination. GS operates in 329.15-335.00 MHz range while DME utilizes 962-1213 MHz range.
End-application of Interest	Navigation Services.
Operational Domain:	Arrival Terminal Domain.
Targeted User Class:	Aircraft being operated under instrument flight rules.
User Need Met	Precision approach provided to properly equipped aircraft.
How the Application Works	The aircraft interrogates the DME and measures time until the transmission is returned, subtracts the proper delay and converts this information into nautical miles readout. Glide slope functions as the localizer except the signal is vertically radiated and the aircraft position is translated into fly up or fly down.
Weather Involvement	System is of primary benefit during reduced ceiling and visibility.
Satellite Communications	None
Status:	Presently in use at all airports with jet service.
Schedule:	Will phase out, as Global Positioning System (GPS) becomes available. Present systems have a service life extension program to keep system going until GPS is adopted.
References	National Airspace System Architecture, Version 4.0, FAA

A.18 Tower Data Link Services (TDLS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Tower Data Link Services (TDLS)**
Objective of Application:	Predeparture Clearance (PDC) are sent to the aircraft over ACARS Digital-Automatic Terminal Information Service (D-ATIS) messages are sent to the aircraft via TDLS TDLS is also used for Flight Data Input/Output (FDIO) in Air Traffic Control Tower (ATCT).
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS)
End-application of Interest:	ATCT: PDC, D-ATIS & FDIO Aircraft—ACARS terminal, including man-machine interface
Operational Domain:	Pre-flight domain—TDLS used by ATCT to retrieve/enter flight plans into FDIO and to issue PDC which is transmitted to the pilot/flight crew in the aircraft cockpit via ACARS. Arrival terminal domain—The receipt of D-ATIS messages in the aircraft cockpit provides the information necessary to complete the flight.
Targeted User Class:	Air traffic services provider—Reduces stress for air traffic controllers and provides significant benefits. Provides a centralized source for tower specialists to generate ATIS messages and to use FDIO. Pilot/aircrew/flight deck—Receipt of ACARS messages in the cockpit eliminates the necessity of waiting in the dispatch office for paperwork (PDC). Receipt of D-ATIS messages while in flight avoids the necessity of copying long transmissions on crowded radio frequencies, eliminates the need for the pilot to monitor the ATIS voice frequency, reduces flight crew misunderstanding by providing printed test, and provide better flight crew planning with earlier receipt of ATIS messages. Aircraft operator management—Benefit with knowledge of an aircraft's clearance to depart and flight plan approval.
User Need Met:	Delivery of clearance to operate aircraft and delivery of terminal conditions/information necessary to complete the flight.
How the Application Works:	In the ATCT TDLS terminal is used to enter and retrieve flight plans. PDC are input into TDLS which uses ARINC Data Network Services (ADNS) and ACARS to transmit the PDC directly to the aircraft cockpit. D-ATIS messages are input into TDLS by each ATCT and transmitted to a central D-ATIS database via ADNS. The aircraft can request (label5D or B9) and receive (label A9) D-ATIS messages. Upon receipt of the request the D-ATIS server issues a D-ATIS message to the requestor and a D-ATIS message is sent via ACARS to the aircraft.
Weather Involvement:	See D-ATIS
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer and the FAA's host computer in the Air Route Traffic Control Center (ARTCC) via ADNS and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used

CHARACTERISTIC	DESCRIPTION
Status:	Operational: TDLC is available at 57 US airports.
Schedule:	There is currently no schedule for upgrade or change to TDLS
References:	Need for Change Current ACARS slides, 1998; Aeronautical Data Link slides, 1998; ACARS & VDL Mode 2 Program Status slides, 1998; ARINC ACARS description; ARINC Acronyms; Chapter 24, Tower and Airport Surface, National Airspace Architecture, Version 4.0, January 1999, FAA

A.19 Decision Support Services

A.19.1 Surface Movement Advisor (SMA)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Surface Movement Advisor (SMA)**
Objective of Application:	SMA is intended to monitor movement on the airport surface. SMA provides a collaborative decision making capability among ATC, airlines and airport operators to reduce delays in surface operations.
Data Links Used:	Local connectivity.
End-application of Interest	Tactical Traffic Management Services.
Operational Domain:	Airport arrival surface operations Airport departure surface operations domains.
Targeted User Class:	Air traffic services provider, pilot/aircrew/flight deck aircraft operator management.
User Need Met	More efficient use of the airport surface; thereby saving time and fuel.
How the Application Works	Detailed graphical airport layout has input from the local Automated Radar Terminal System (ARTS) with data blocks derived from this system depicting aircraft data blocks from the Airport Surveillance Radar (ASR) 2700-2900 MHz, and the Air Traffic Control Beacon Indicator (ATCBI) which operates in the 1030-1090 MHz range. The ATCBI generates the data blocks for transponder equipped aircraft.
Weather Involvement	System assists more when Air Traffic has obstructions to vision.
Satellite Communications	None.
Status:	R&D site at Atlanta Hartsfield airport, additional sites now at Philadelphia and Detroit. R&D site is under AAR 700. All other sites are under AOZ 100.
Schedule:	Dallas/Ft.Worth (DFW) and Chicago (ORD) are to be installed in 12/99. Product continues to be evaluated for added value by Air Traffic Operations (ATO).
References	National Airspace System Architecture, Version 4.0, FAA

A.19.2 Airport Movement Area Safety System (AMASS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Airport Movement Area Safety System (AMASS).**
Objective of Application:	AMASS is an enhancement to the ASDE 3 that provides automated alerts and warnings to potential runway incursions and other hazards. AMASS tracks all ground operations, compares each movement and automatically provides visual and audio alert of potential conflicts on the movement area.
Data Links Used:	Airport Surface Detection Equipment (ASDE 3) (15.7-16.2 GHz) is linked to AMASS via Terminal Automation Interface Unit (TAIU). Airport Surveillance Radar (ASR) 2700-2900MHz and Air Traffic Control Beacon Indicator (ATCBI) data blocks are an input from the Automated Radar Terminal System (ARTS). Data is displayed in Air Traffic Control Tower (ATCT)/Terminal Radar Approach Control (TRACON).
Operational Domain:	Airport departure surface operations domain and airport arrival surface operations.
Targeted User Class:	Tactical Traffic Management Services and Emergency and alerting services.

CHARACTERISTIC	DESCRIPTION
Status:	Forty systems are under contract. System certified Y2K compliant. Prototype installed in San Francisco, CA. Full Scale Development (FSD) sites at St. Louis, Detroit and Atlanta. System installed in Chicago 7/99.
Schedule:	Last Delivery of the system is scheduled 4/01/00. NTSB recommended Operational Readiness Demonstration (ORD) of all systems be completed by 8/99. Additional human factor requirements have been proposed by Air Traffic. This will impact schedule and cost. Issue is being worked by AND and AT.
References	National Airspace System Architecture, Version 4.0, FAA

A.19.3 Center Terminal Radar Approach Control (TRACON) Automation System (CTAS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Center TRACON Automation System (CTAS)**. System has been placed under umbrella of Free Flight Phase 1 (FFP1) and includes: passive Final Approach Spacing Tool (pFAST), User Request Evaluation Tool (URET), Traffic Management Advisor (TMA), Surface Movement Advisor (SMA) and is integrated with Controller –Pilot Data Link Communication (CPDLC) and Collaborative Decision Making (CDM).
Objective of Application:	CTAS aids the Enroute controller, terminal controller and traffic managers by maximizing use of airspace and runways through various tools embedded in the system.
Data Links Used:	Two way interface with Host in ARTCC. Input data from Host into CTAS collection of tools; output data to Host for display on controller displays.
End-application of Interest	ATC separation assurance services Tactical Traffic Management Services Strategic Traffic Management Services.
Operational Domain:	Departure Terminal Enroute/Cruise Arrival Terminal Domain.
Targeted User Class:	Air traffic services provider Flight services provider Pilot/aircrew/flight deck Aircraft operator management
User Need Met	Improves traffic throughput by increasing system capacity, reduce delays and make more efficient use of airspace and runway capacity.
How the Application Works	Application software is based in a Sun Sparc workstation with an Input Source Manager (ISM) for connectivity to Air Route Traffic Control Center (ARTCC) Host system.
Weather Involvement	Weather data is supplied from the National Meterologic Center from the National Oceanic and Atmospheric Administration (NOAA) Rapid Update Cycle known as "nowcast" and is updated every three hours. Weather affects the overall system capacity. Weather data comes into system from National Area Data Interchange Network (NADIN) I.
Satellite Communications	Output data is supplied to various sites as is needed. Satellite system used to get data to National Air Traffic Control Command Center.
Status:	All data links are not yet defined. Development site is Memphis (ZME). No Interface Requirements document exists for Leased Interfacility NAS Communications System (LINCS) and CTAS.
Schedule:	9/1999 –5/2003. CTAS has been placed on fast track. Prototype sites Build 1 has been delivered to: Miami (ZMA), Atlanta (ZTL), Denver (ZDV) and Los Angeles (ZLA). System certification issues remain.
References	National Airspace System Architecture, Version 4.0, FAA

A.19.4 Traffic Management Advisor (TMA)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Traffic Management Advisor (TMA)**. TMA is a subset of Center Terminal Radar Approach Control (TRACON) Automation System (CTAS) and included in Free Flight Phase 1 (FFP1).
Objective of Application:	TMA aids the Enroute controller and traffic managers in making efficient decision regarding the metering, sequencing and spacing of enroute arrival aircraft.
Data Links Used:	Two way interface with Host in Air Route Traffic Control Center (ARTCC). Input data from Host into CTAS collection of tools; output data to Host for display on controller displays.

End-application of Interest	Tactical Traffic Management Services.
Operational Domain:	Departure Terminal Enroute/Cruise Arrival Terminal Domain.
Targeted User Class:	Air traffic services provider Flight services provider Pilot/aircrew/flight deck Aircraft operator management
User Need Met	Improves traffic throughput by increasing system capacity, reduce delays and make more use of airspace and runway capacity.
How the Application Works	Application software is based in a Sun Sparc workstation with an Input Source Manager (ISM) for connectivity to ARTCC Host system.
Weather Involvement	Weather data is supplied from the National Meterologic Center from the National Oceanic and Atmospheric Administration (NOAA) Rapid Update Cycle known as nowcast and is updated every three hours. Weather affects the overall system capacity.
Satellite Communications	None directly. Output data is supplied to various sites as is needed. Satellite system used to get data to National Air Traffic Control Command Center.
Status:	All data links are operational. Development sites are in use at: Ft. Worth (ZFW), Denver (ZDV), Miami (ZMA), Atlanta (ZTL) and Los Angeles (ZLA).
Schedule:	1998—2002. TMA is now scheduled for Minneapolis (ZMP), Chicago (ZAU) and Oakland (ZOA).
References	National Airspace System Architecture, Version 4.0, FAA

A.20 Flight Information Service (FIS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Flight Information Service (FIS)**
Objective of Application:	ATC Advisory Services
Data Links Used:	ACARS
End Application of Interest	Provide in-flight weather advisories.
Operational Domain:	Terminal En route/cruise.
Targeted User Class:	Pilot/aircrew/flight deck.
User Need Met:	Provides situational awareness of weather conditions, including weather-related hazards.
How the Application Works:	All aircraft may obtain verbal weather advisories from Flight Service Stations (AFSS/FSS) via Very High Frequency (VHF) voice. Data link equipped aircraft receive graphic or text weather from a weather service provider via the data link. Weather to be delivered via an addressable data link requires a request-response transaction; weather to be delivered via a broadcast link does not.
Weather Involvement:	This is primarily weather service for pilots.
Satellite Communications:	The FIS services can be provided via satellite data link. Example: an Aircraft Communications Addressing and Reporting System (ACARS) equipped corporate aircraft on the ground at Fulton county airport, Georgia (not in Line Of Sight (LOS) with Hartsfield airport) will request and receive route weather via the GLOBALink satellite data service.
Status:	Voice FIS available today from FAA over Flight Watch channels from AFSS/FSS. Text weather and limited graphics are available today over ACARS.
Schedule:	No schedule to implement FAA FIS from AFSS/FSS. FAA has selected two service providers to provide FIS-B over Very High Frequency Digital Link (VDL). Contracts scheduled for fourth quarter of 1999. Operational demonstrations required in 2000. National implementation required within three years.
References	National Airspace System Architecture, Version 4.0, FAA

A.21 Direct User Access Terminal System (DUATS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Direct User Access Terminal System (DUATS)**
Objective of Application:	Flight Plan Services—File flight plans ATC Advisory Services—pre-flight weather advisories

CHARACTERISTIC	DESCRIPTION
Data Links Used:	NONE
End-application of Interest:	Not Applicable
Operational Domain:	Pre-flight—The General Aviation (GA) pilot must obtain a current weather briefing and file a flight plan prior to flight.
Targeted User Class:	Flight Plan Services—Receives filed flight plan ATC Advisory Services—Provides weather briefing
User Need Met:	Pilot/aircrew/flight deck—Files flight plan
How the Application Works:	The pilot uses a personal computer to dial in on the Public Switched Telephone Network (PSTN) to an FAA contracted vendor (GTE Federal Systems or Data Transformation Corporation) that maintains a connection with Flight Service Data Processing System (FSDPS), from which the vendor provides a current weather briefing that FSDPS receives from the FAA's Host Computer System (HCS). The pilot then files a flight plan which is input, by the contract vendor, into FSDPS which provides the flight plan to the appropriate Automated Flight Service Station (AFSS).
Weather Involvement:	Weather briefing received from the FAA's HCS/FSDPS is provided through the contract vendor to the pilot connected to the DUATS line
Satellite Communications:	N/A
Status:	Operational—DUATS service is operational throughout the United States and is provided by two FAA contracted vendors—GTE Federal Systems Division & Data Transformation Corporation.
Schedule:	DUATS service is currently scheduled to be incorporated into the FAA's Operational and Supportability Implementation System (OASIS) by 2002.
References:	Chapter 23, National Airspace System Architecture, Version 4.0, January 1999;Federal Aviation Regulations/Aeronautical Information Manual 98, Jeppesen, p. A-325

A.22 Graphic Weather Service (GWS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Graphic Weather Service (GWS)**
Objective of Application:	ATC Advisory Services
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS).
End Application of Interest	Provide in-flight weather advisories.
Operational Domain:	En route/cruise. Terminal
Targeted User Class:	Pilot/aircrew/flight deck.
User Need Met:	Provides graphical situational awareness of weather conditions, including weather-related hazards.
How the Application Works:	The weather service provider obtains weather graphics from commercial or Government sources, and modifies them to meet geographical, content or other distribution needs. Broadcast GWS distributes the graphics periodically via data link to the aircraft. A request-reply GWS service responds to a data link request from the aircraft. The GWS server compresses the graphic, using a compression algorithm such as Weather-Huffman, and sends the compressed message to the aircraft. A processor in the aircraft must receive, decompress and store the image, to be recalled by the pilot at his convenience.
Weather Involvement:	This is a weather service. The entire purpose is to provide graphic weather information to pilots for safety of flight.
Satellite Communications:	GWS services can be provided via satellite data link.
Status:	Commercial GWS under development for ACARS and VDL Mode 2 and VDL Mode 3.
Schedule:	The FAA FIS-B policy implementation requires the designated service providers to demonstrate a broadcast GWS within six months of designation, which should be in late 1999.
References	National Airspace System Architecture, Version 4.0, FAA

A.23 Terminal Weather Information for Pilots (TWIP)

CHARACTERISTIC	DESCRIPTION
Application Name:	**Terminal Weather Information for Pilots (TWIP)**
Objective of Application:	ATC Advisory Services—Provides terminal weather information to the pilot in the cockpit.
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS).

CHARACTERISTIC	DESCRIPTION
End-application of Interest:	Air Traffic Control Tower (ATCT)—TWIP Aircraft—ACARS terminal, including man-machine interface
Operational Domain:	En route/cruise—the aircraft requires a description and depiction of the airport weather (microburst alerts, wind shear alerts or significant precipitation), the present convective activity within 15 NM of the terminal area, and expected weather that will impact airport operations to insure aircraft safety upon entry into terminal airspace. Arrival terminal domain—the aircraft requires a description and depiction of the airport weather (microburst alerts, wind shear alerts or significant precipitation), the present convective activity within 15 NM of the terminal area, and expected weather that will impact airport operations to insure aircraft safety during landing operations.
Targeted User Class:	Air Traffic flight services provider –Able to provide Increased Capacity and Reduced Delays by alleviating requests for weather information from pilots that allows for more even distribution of the air traffic controllers' workload, especially during peak traffic conditions. With more efficient communications through TWIP over ACARS, controllers can provide more timely service to more aircraft. Pilot/aircrew/flight deck—Current pilot/controller voice radio communications frequently require multiple transmissions and read-backs to insure correct receipt of the intended information. With TWIP, flight crew misunderstandings are reduced because the message content can be verified during and after the data link transmission; With more timely and complete information concerning weather conditions, pilots can better anticipate, plan and request dynamic changes to the planned flight to optimize fuel burn and flight time; TWIP messages minimize weather induced risk by affording the Pilot/aircrew more time to prepare for changes to their planned flight. Receipt of TWIP messages over an ACARS terminal in the cockpit allows the crew to review the message at the least disruptive time. This allows the crew to better manage cockpit work flow; TWIP continually generates revised weather products which provide pilots with better "Nowcast" assessments and increase the opportunity for safe utility in flight planning and en route operations.
User Need Met:	Delivery of current terminal weather information to the aircraft.
How the Application Works:	The FAA's Terminal Doppler Weather Radar (TDWR) provides information to the TWIP data processor (TDP) that accepts messages and generates TWIP products which are stored in the form of messages in the ARINC Tandem database These messages are intended to enhance pilot situational awareness of terminal weather phenomena such as micro bursts, gust fronts and heavy precipitation. A pilot can initiate an ACARS request which results in the transmission of a TWIP message to the ACARS terminal in the aircraft cockpit. The TDP also has a predetermined criterion for forced messages; when this criterion is exceeded, a message is generated and sent to an airline host computer The aircraft operator can determines which aircraft should receive the message and transmits the TWIP message to the aircraft through ACARS.
Weather Involvement:	TWIP products include weather information about terminal weather conditions with descriptions/depictions of the present airport weather (micro burst alerts, wind shear alerts, or significant precipitation), the present convective activity within 15 Nautical Miles (NM) of the terminal area, and expected weather that will impact airport operations (micro bursts, wind shear, and significant precipitation). TWIP products are updated and stored in a database each minute.
Satellite Communications:	N/A
Status:	Operational at 45 airports equipped with TDWR.
Schedule:	The FAA has plans to deploy the Integrated Terminal Weather System (ITWS) with completion scheduled for 2002. TWIP functionality will be moved to ITWS. The FAA also plans to field Airport Surveillance Radar-Weather Systems Processor (ASR-WSP) by 2002 to support airports without TDWR that need improved windshear and microburst detection capability. ASR-WSP will have the capability to provide weather information to TWIP which will result in the expansion, beyond TWDR equipped airports, of the capability to provide TWIP messages.
References:	Information sheet, TWIP, FAA Data Link Program Office (AND310); FAA National Airspace System Architecture, Version 4.0, Section 26, January 1999

A.24 MDCRS

CHARACTERISTIC	DESCRIPTION
Application Name:	**Meteorological Data Collection and Reporting System (MDCRS)**
Objective of Application:	ATC Advisory Services—Information on atmospheric conditions is provided for inclusion with current weather information.
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS).
End-application of Interest:	ATC Advisory Services—Atmospheric weather conditions are sent to National Weather Service (NWS) for inclusion in current weather conditions for dissemination to the pilot/aircrew/flight.
Operational Domain:	Pre-flight domain—Weather including atmospheric conditions are required for flight planning. Departure terminal domain—Weather including atmospheric conditions are required for flight. En route/cruise—Weather including atmospheric conditions are required for flight. Arrival terminal domain—Weather including atmospheric conditions are required for flight.
Targeted User Class:	Flight services provider—Provides additional information to support forecasts of winds aloft and defines severe areas of weather. Pilot/aircrew— Receives a more accurate forecast which contributes to flight planning efficiency and enhances aviation safety.
User Need Met:	Accurate weather forecast required for efficient flight planning and for safe flight operations.
How the Application Works	Pilot reports (PIREPS), and aircraft sensors, provide position, time, altitude, temperature, wind direction, velocity, and turbulence reports which are downlinked from an aircraft via ACARS, to a MDCRS processor which forwards the information to a MDCRS database and, after the data is reformatted to World Meteorological Organization (WMO) specifications, to NWS where the information is incorporated into upper air forecasts provided to airlines flight planning computers and the FAA for distribution to pilot/aircrew.
Weather Involvement:	MDCRS information is provided to NWS where it is incorporated into weather information provided to airline flight planning computers. MDCRS information is also incorporated into the weather forecasts provided by NWS to the FAA. MDCRS processes weather observations from ground level to 43,000 feet at various time and altitude intervals. Observations are time-stamped and forwarded to NWS approximately every 5 minutes.
Satellite Communications:	Some ACARS messages are transmitted via an Inmarsat satellite. On the ground the messages are processed by an ARINC Digital Link Service Processor (DSP) in the ACARS Central Processing System, which connects to the aircraft operator's host computer via ARINC's ADNS and/or ARINC Packet Network (APN). In the aircraft a Satellite Data Unit (SDU) interfaces with an ACARS Management Unit (MU) via an ARINC 429 port. The satellite P, R and T channels which provide speeds of 600, 1200, and 10,500 bps, respectively, may be used.
Status:	Operational—Over 10,000 observations per day are provided to NWS and the U. K. Meteorological Office, Bracknell, England
Schedule:	When aircraft sensors include humidity and icing data these items may be included in MDCRS.
References:	ARINC MDCRS Information Sheet

A.25 Electronic Pilot Reports (E-PIREPS)

CHARACTERISTIC	DESCRIPTION
Application Name:	**E-PIREPS—Electronic Pilot Reports**
Objective of Application:	ATC Advisory Services – Downlink of current atmospheric conditions
Data Links Used:	Aircraft Communications Addressing and Reporting System (ACARS).
End-application of Interest	ATC Advisory Services Flight Plan Services Emergency and Alerting Services
Operational Domain:	En-route/cruise
Targeted User Class:	Pilot/aircrew/flight deck
User Need Met	Provides the aircraft localized and en route weather conditions.
How the Application Works	Similar to MDCRS. Equipped aircraft will transmit observed weather to national Weather Service (NWS) for inclusion in current weather conditions and distribution.

Weather Involvement	The E-PIREPS are designed to provide additional weather data on in-flight icing; turbulence; support to ground de-icing; forecasting and detection of thunderstorm cells containing turbulence, hail and wind shear, precipitation intensity, wind speed/direction, and ceiling and visibility. These reports enhance accuracy detection/prediction, and timely (0 to 6 hours) for flight planning; operations, and "free flight "initiatives.
Satellite Communications	Weather information can be disseminated via satellite link.
Status:	Testing is on going with a number of sensor equipped aircraft evaluating weather products during demonstration flights.
Schedule:	Developmental. Evaluation and testing is in progress; FAA is identifying and selecting service providers; RTCA is publishing aeronautical standards, and publishing operational guidance and training material.
References	National Airspace System Architecture, Version 4.0, FAA

B APPENDIX B—Relevant Data Link Programs

B.1 Characterize Current and Near-Term Communications System Architecture—Relevant Data Link Programs

B.1.1 Task Description

The purpose of this task is to survey, analyze and document the current NAS Communications System Architecture (NAS/CSA) relevant data link programs to a sufficient level of detail and thus use this as the baseline or commencement point for the 2007/2015 CSA development.

B.1.2 Data Link Programs of Interest Section

Free Flight Phase One	B.2
NEXCOM	B.3
CPDLC	B.4
Safe Flight 21	B.5
FISdl	B.6
CAA/Ohio Valley Experiment Program	B.7
Capstone	B.8
AGATE/Communications Work Package	B.9

B.1.3 Standard Description Template

Each application defined in this document will be characterized with the following template.

CHARACTERISTIC	DESCRIPTION
Program Name:	
Objective of Program:	Section B.1.4
Data Links Used:	Section B.1.5
Operational Domain:	Section B.1.6
Targeted User Class:	Section B.1.7
Status:	Section B.1.8
Schedule:	Section B.1.9

B.1.4 Objective of Data Link Program

The objective of the data link program will be characterized by determining the "best fit " to the accepted list of user services and functional capabilities delineated in the following table. The "best fit" may apply to multiple "user needs" and multiple "functional capabilities." Each "best fit" match will be the subject of a complete table entry. If the program is too broad to restrict to the objectives in the table, a concise program objective is stated from program documentation.

User Services	Functional Capabilities
Flight Plan Services	• File flight plans and amendments • Process flight plans and amendments • Provide information for flight plans
ATC Separation Assurance Services	• Separate IFR aircraft • Avoid potential hazards and collisions • Maintain minimum distance from special use airspace (SUA) • Monitor flight progress • Hand-off to controller—sector—facility

User Services	Functional Capabilities
ATC Advisory Services	• Provide in-flight or pre-flight weather advisories • Provide in-flight or pre-flight traffic advisories • Provide in-flight NAS status advisories
Tactical Traffic Management Services	• Provide in-flight sequencing, spacing, and routing restrictions • Provide pre-flight runway, taxi sequence, and movement restrictions • Project aircraft in-flight position and potential conflicts • Process user preferences
Strategic Traffic Management Services	• Provide future NAS traffic projections • Collaborate with users on NAS projections and user preferences • Monitor NAS traffic status • Assess NAS traffic performance
Emergency and Alerting Services	• Provide emergency assistance and alerts • Support search and rescue (SAR)
Navigation Services	• Provide airborne navigation guidance • Provide surface navigation guidance
Surveillance Services	• Provide aircraft position/ID • Provide aircraft intent, state, and performance
Airspace Management Services	• Manage design and use of NAS airspace • Manage use of SUA
NAS Support Services	• Monitor and maintain NAS infrastructure • Manage aviation spectrum for U.S. aviation community
On-board Services	• Provide administrative flight information • Provide in-flight entertainment • Provide public communications

B.1.5 Data Links Used

Each entry for each data link program will match the application to one of the data links in the following list. More information on the characteristics of each data link can be found in Appendix C.

ACARS
VDL Mode 2
VDL Mode 3
VDL Mode 4
VDL-B
Mode S
UAT
Satellite (LEO)
Satellite (GEO)
Little LEO (Packet; store & forward)
Narrowband Big LEOs, MEOs
Narrowband GEOs
Any wideband satellite systems

B.1.6 Operational Domain

The Operational Domain of interest is the phase of flight affected by the data link program. Each data link program will address more than one phase of flight. Each phase of flight domain is defined below and addressed separately in the following sections:

Pre-flight domain—activities which occur prior to aircraft movement.

Airport departure surface operations domain—activities which occur between commencement of aircraft movement and airborne departure from the end of the active runway used by the aircraft involved in the application.

Departure terminal domain—activities which occur between airborne departure from the end of the active runway and departure from terminal airspace.

En route/cruise—activities which occur between departure from terminal airspace at departure airport and entry into terminal airspace at arrival airport.

Arrival terminal domain—activities which occur between entry into terminal airspace and arrival at the threshold of the active runway to be used.

Airport arrival surface operations domain—activities which occur between airborne arrival at the threshold of the active runway and arrival at the position at which the aircraft will be parked and the flight terminated.

Post-flight domain—activities which occur after the aircraft has concluded the flight.

B.1.7 Targeted User Class

The targeted user class is the node of the end-to-end communications activity that applies. The nodes are:

Air traffic services provider—Any of the entities which provide control, direction, advice, or other ATC information to the pilot/aircrew/flight deck domain or the aircraft operator management domain.

Flight services provider—Any of the entities which provide advisory information to the pilot/aircrew/flight deck domain or the aircraft operator management domain.

Pilot/aircrew/flight deck—The entities which control the movement of an aircraft through airspace and manage aircraft on-board systems.

Aircraft operator management—The entities which plan aircraft movements and provide management of operations (but not physical control of the aircraft).

B.1.8 Status

The status of each data link program is characterized as:

Conceptual—the application has been defined, but development is not yet funded and has not started. Details of the activities which led to the agreement to the data link concept are included.

Development—the program is funded and under development. Additional information is included to indicate the stage of development, for example, engineering development, preliminary testing, product demonstration, etc.

Operational—the data link is in service today. None of the programs listed has an operational data link today.

B.1.9 Schedule

For conceptual or developmental programs, a schedule of roll-out is included if available. For operational data links, any available schedule of upgrades or improvements is listed. Future intentions, including application termination or replacement, are listed if available.

B.2 Free Flight Phase One (FFP1)

CHARACTERISTIC	DESCRIPTION
Program Name:	**Free Flight Phase One (FFP1)**
Objective of Program:	Begin the movement toward Free Flight; Implement the elements of free flight that are currently available.
Data Links Used:	Very High Frequency Digital Link Mode 2 (VDL Mode 2)
Operational Domain:	En Route/Cruise
Targeted User Class:	Pilot/Aircrew/Flight Deck. Air Traffic Services Provider. Aircraft Operation Management.
Status:	Development.
Schedule:	Phase 1 complete by 2002; Phase 2 not defined.

B.3 Next Generation Air/Ground Communications System (NEXCOM)

CHARACTERISTIC	DESCRIPTION
Program Name:	**Next Generation Air/Ground Communications System (NEXCOM)**
Objective of Program:	Replace current analog air-ground radios with digital radios. Implement Very High Frequency Digital Link Mode 3 (VDL Mode 3).
Data Links Used:	VDL Mode 3
End-application of Interest	ATC Separation Assurance Services: Air-ground voice Tactical Traffic Management Services: Air-ground voice Emergency and Alerting Services: Air-ground voice
Operational Domain:	Departure Terminal Domain En route/cruise Domain Arrival Terminal Domain
Targeted User Class:	Air traffic services provider. Pilot/aircrew/flight deck.
Status:	Request for Information (RFI) issued June 1999. Revised RFI expected in September 1999.
Schedule:	Request for Offer: May 2000 Operational Capabilities Demonstration: June 2000 Operational Capabilities Test: Nov 2000-April 2001 Segment One: 2003-2005 Segment Two: 2005-2010 Segment Three: 2010-2015

B.4 Controller Pilot Data Link Communications (CPDLC)

CHARACTERISTIC	DESCRIPTION
Program Name:	**Controller Pilot Data Link Communications (CPDLC)**
Objective of Program:	ATC Separation Assurance Services. Provide data link communications between pilots and controllers to assure separation between IFR aircraft, avoid potential hazards and collisions, maintain minimum distance from Special Use Area (SUA), monitor flight progress, and provide hand-offs between controllers, sectors, and facilities.
Data Links Used:	Very High Frequency Digital Link Mode 2 (VDL Mode 2) for CPDLC Build 1, 1A, and 2 VDL Mode 3 for CPDLC Build 3

CHARACTERISTIC	DESCRIPTION
Operational Domain:	En-route / cruise Build 1—Miami Air Route Traffic control Center (ARTCC) Build 1A, 2, 3—Continental United States (CONUS)
Targeted User Class:	Air Traffic Service Provider Pilot/Aircrew/Flight Deck
Status:	Development Build 1—Preliminary testing Build 1A, 2—Engineering development Build 3—Conceptual development
Schedule:	Build 1 Initial Operational Capability (IOC)– 2002 in Miami ARTCC Build 1A IOC—2003 at unspecified key site; National deployment by 2006 Build 2 IOC—2006 Build 3 IOC—2010+

B.5 Safe Flight 21

CHARACTERISTIC	DESCRIPTION
Program Name:	**Safe Flight 21**
Objective of Program:	ATC Separation Assurance Services; Avoid potential hazards and collisions; Maintain minimum distance from special use airspace (SUA); Monitor flight progress; Hand-off to controller sector/facility; ATC Advisory Services—Provide in-flight or pre-flight traffic advisories; Provide in-flight National Air Space (NAS) status advisories Emergency and Alerting Services—Support search and rescue (SAR) Surveillance Services Provide aircraft intent, state, and performance; Provide aircraft position/ID
Data Links Used:	VDL Mode 4 VDL-B Mode S UAT
Operational Domain:	Airport departure surface operations domain Departure terminal domain En route/cruise Arrival terminal domain Airport arrival surface operations domain
Targeted User Class:	The air traffic services provider The flight services provider The pilot/aircrew/flight deck
Status:	Development
Schedule:	See Figure B5-1 on the following page

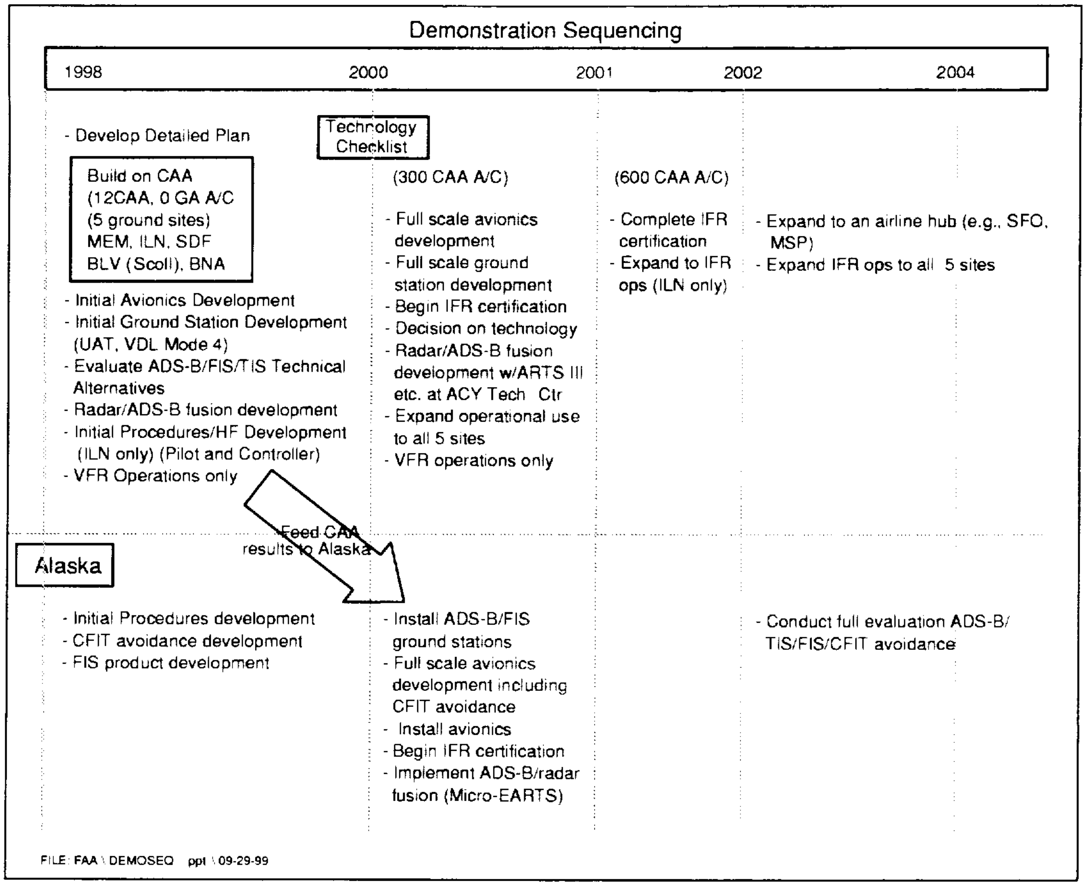


Figure B.5-1. Safe Flight 21 Schedule

B.6 Flight Information Service Data Link (FISDL)

CHARACTERISTIC	DESCRIPTION
Program Name:	FISDL
Objective of Program:	Avoid potential hazards and collisions; Provide current NAS weather, status and flow information to all classes of users
Data Links Used:	Very High Frequency Digital Link –B (VDL-B)
Operational Domain:	Pre-flight domain Airport departure surface operations domain En route/cruise
Targeted User Class:	The flight services provider The pilot/aircrew/flight deck
Status:	Development
Schedule	IOC—6 months after award (~ Feb 00), with first sites in Alaska National Deployment—1 year after award (~ Aug 00)

B.7 Cargo Airlines Association (CAA)/Ohio Valley Experiment Program

CHARACTERISTIC	DESCRIPTION
Program Name:	**Cargo Airlines Association (CAA)/Ohio Valley Experiment**
Objective of Program:	Demonstrate the effectiveness of ADS-B. This program is one of two comprising Safe Flight 21.
Data Links Used:	Mode S UAT VDL Mode 4
Operational Domain:	En Route/Cruise Terminal
Targeted User Class:	Pilot/aircrew/flight deck
Status:	Initial demonstration July 10 at Wilmington, Ohio. Additional demonstrations planned.
Schedule:	See Figure B.5.1

B.8 Capstone

CHARACTERISTIC	DESCRIPTION
Program Name:	**Capstone**
Objective of Program:	Demonstrate the effectiveness of ADS-B. Demonstrate usefulness of ADS data to controllers in a non-radar environment. This program is one of two comprising Safe Flight 21.
Data Links Used:	Mode S UAT VDL Mode 4
Operational Domain:	En Route/Cruise Terminal
Targeted User Class:	Pilot/aircrew/flight deck
Status:	Initial demonstration Spring 2000 at Bethel, Alaska. Additional demonstrations planned.
Schedule:	See Figure B.5.1

B.9 AGATE/Communications Work Package

CHARACTERISTIC	DESCRIPTION
Program Name:	**AGATE—Advanced General Aviation Transport Experiment.** The AGATE Consortium is a cost sharing industry-university-government partnership initiated by NASA to create the technological basis for revitalization of the U.S. general aviation industry. It was founded in 1994 to develop affordable new technology as well as the industry standards and certification methods for airframe, cockpit, flight training systems, and airspace infrastructure for next generation single pilot, 4-6 place, near all-weather light airplanes. The AGATE consortium has more than 70 members from industry, universities, the FAA, and other government agencies.
Objective of Program:	The AGATE Communications Work Package focuses on developing technologies to meet the needs for ATC/ATM Services, Navigation, and Flight Information Services.
Data Links Used:	VDL Mode 2, VDL-B
Operational Domain:	All
Targeted User Class:	Pilot/Aircrew/Flight Deck
Status:	Development. Some prototype systems will be fielded for evaluation. Follow-on activity may occur under the NASA Small Aircraft Transportation System (SATS) program.
Schedule:	The NASA program was started in 1994 and will complete in 2001.

C Appendix C—Communications/Datalink Technical Characterization

The purpose of this task is to provide the technical characteristics of current and near-term communications and datalink systems.

- Analog Voice
- DSB-AM
- High Frequency (HF) Voice
- Digital Voice
  - VDL Mode 3
  - Inmarsat-3
- Data Communication
  - Aircraft Communications Addressing and Reporting System (ACARS)
  - VHF Digital Link Mode 2 (VDL Mode 2)
  - VHF Digital Link Mode3 (VDL Mode 3)
  - Inmarsat-3
  - Inmarsat-4 (Horizons)
  - Other GEO Satellite Systems (e.g., Astrolink)
  - ICO Global (MEO system)
  - Iridium (LEO system)
  - ORBCOMM (LEO system)
  - High Frequency Data Link (HFDL)
  - Gate-Aircraft Terminal Environment Link (Gatelink)
- Ground-to-Air Broadcast Systems
  - VHF Digital Link Broadcast (VDL-B)
  - Satellite Digital Audio Radio Service (SDARS)
- Air-Air and Air-Ground Broadcast Systems
  - Mode-S
  - Universal Access Transceiver (UAT)
  - VHF Digital Link Mode 4 (VDL Mode 4)

C.1 Standard Description Template

Each link is characterized according to section 4.6.1 of the Task Order and organized using the following template.

CHARACTERISTIC	Segment	DESCRIPTION
System Name		Name
Communication type	R/F Ground	HF, VHF, L-Band, SATCOM ...
Frequency/Spectrum of Operations	R/F Ground	Frequency
System Bandwidth Requirement	R/F Ground	Bandwidth for channel and system
System and Channel Capacity	R/F	Number of channels and channel size

CHARACTERISTIC	Segment	DESCRIPTION
Direction of communications	R/F	Simplex, broadcast, duplex....
Method of information delivery	R/F Ground	Voice, data, compressed voice
Data/message priority capability	R/F Ground	High, medium, low
System and component redundancy	R/F Ground	
Physical channel characteristics	R/F	Line of sight (LOS), other
Electromagnetic interference	R/F	Text description
Phase of Flight Operations	Ground	Pre-flight, departure, terminal ....
Channel Data Rate	R/F Ground	Signaling rate
Robustness of channel and system	R/F	Resistance to interference, fading...
System Integrity	R/F Ground	Probability
Quality of service	R/F Ground	Bit error rate, voice quality
Range/coverage	R/F Ground	Oceanic, global, regional...
Link and channel availability	R/F Ground	Probability
Security/encryption capability	R/F Ground	Text description
Degree/level of host penetration	R/F	Percentage or class of users
Modulation scheme	R/F	AM, FM, D8PSK,....
Access scheme	R/F	CSMA, TDMA, ...
Timeliness/latency, delay requirements	R/F Ground	Delay
Avionics versatility	R/F	Application to other aircraft
Equipage requirements	R/F	Mandatory, optional
Architecture requirements	R/F Ground	Open System or proprietary
Source documents		References

Integrity is the ability of a system to deliver uncorrupted information and may include timely warnings that the information or system should not be used. Integrity is provided by the application, transport and network layers (rather than the link and physical layers) and is usually specified in terms of the probability of an undetected error. The integrity values in the following link descriptions thereby reflect service integrity requirements rather than "link integrity" requirements. The only meaningful measure of "link integrity" is a bit error rate, which is shown under quality of service.

Comm Link	System integrity (probability)
Voice DSB-AM	No integrity requirement for 2015 voice services
VDL Mode 2	CPCLC and DSSDL will be ATN compliant services and require that the end -to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message be less than or equal to 10E-8 per message
VDL Mode 3	No integrity requirement for 2015 voice services
VDL-B	Some FIS products may require that the end-to end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message be less than or equal to 10E-8 per message.
Mode-S	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has be supplied to the ADS-B system. ADS-B system integrity is 10E-6 or better on a per report basis. [Note: Due to constraints imposed by the Mode-S squitter message length, multiple messages must typically be received before all required data elements needed to generate a particular ADS-B report are available.]
UAT	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has be supplied to the ADS-B system. ADS-B system integrity is 10E-6 or better on a per report basis. Currently, the UAT worst-case overall undetected error probability for an ADS-B message is 3.7x10E-11, which exceeds the minimum requirement. [Note: For UAT, ADS-B messages map directly (one-to-one correspondence) to ADS-B reports; they are not segmented as they are in Mode-S ADS-B.]
Inmarsat-3	No integrity requirement for 2015 data services
GEO Satellite	Some FIS products may require that the end-to-end system probability of not detecting a mis-delivered, non-delivered, or corrupted 255-octet message be less than or equal to 10E-8 per message
MEO Satellite	No integrity requirement for 2015 data services
ICO Global Satellite	No integrity requirement for 2015 data services

Comm Link	System integrity (probability)
Iridium Satellite	No integrity requirement for 2015 voice services
HFDL	No integrity requirement for 2015 data services

C.2 Analog Voice

C.2.1 VHF DSB-AM

Most current ATC communication in the NAS is carried out using analog voice. Most of this communication uses double side-band amplitude modulation (DSB-AM) in the VHF Aeronautical Mobile (Route) Service band, using 25 KHz channels. Some military aircraft use UHF; controllers in oceanic sectors use a service provider for relaying HF messages to and from aircraft.

DSB-AM has been used since the 1940s, first in 100 kHz channels, then in 50 kHz channels. Recently, Europe has further reduced channel spacing to 8.33 kHz channels in some air space sectors due to their critical need for more channels. In the United States, the FAA provides simultaneous transmission over UHF channels for military aircraft. In the Oceanic domain beyond the range of VHF, aircraft use HF channels. Voice limits communications efficiency since the controller must provide all information verbally. Studies have shown that controller workload is directly correlated to the amount of voice communications required. Voice is subject to misinterpretation and human error and has been cited as having an error rate of 3% and higher. With the introduction of ACARS, AOC voice traffic dropped significantly although it is still used.

By 2015, most domestic sectors will have transitioned to digital voice using VDL Mode 3, which will be mandatory in many classes of airspace. Although spectrum congestion is currently a problem, channel loading will cease to be a limiting factor as the busiest sectors are converted to VDL Mode 3, which is more efficient than DSB-AM, and more pilot-controller communications will be conducted using data links instead of voice links.

Federal Air Regulations Part 91/JAR OPS 1.865 require two-way radio communications capability to operate an aircraft in class A, B, C or D airspace. Additionally, two-way radio communication is required to operate an aircraft on an Instrument Flight Plan in class E airspace. Two-way radio communication with ATC must be maintained continuously. ICAO has similar requirements.

Since many national authorities do not have current plans to implement VDL Mode 3 for voice, aircraft that fly in international airspace probably will continue to need to use radios that support the current DSB-AM modulation, as well as 8.33 KHz channelization for parts of Europe.

Voice is necessary for the foreseeable future and is likely to continue as primary means of communication. Any changes in voice technology are likely to occur only with digital voice; and the legacy analog voice probably will continue unchanged.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Analog voice/VHF double sideband (DSB)—amplitude modulated (AM)**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	Leased telephone channels
Frequency/ Spectrum of Operations	RF	117.975 MHz—137 MHz
System Bandwidth Requirement	RF	Nominal 3 kHz per channel with audio input 350 - 2,500 Hz 760 channels total in VHF band @ 25 kHz spacing/channel
	Ground	N/A

CHARACTERISTIC	SEGMENT	DESCRIPTION
System and Channel Capacity (number of channels and channel size)	RF	Nominal 3 kHz per channel with audio input 350 - 2,500 Hz 760 channels total in VHF band @ 25 kHz spacing/channel System is constrained by frequency allocation, not technical limits. Expansion to 112 MHz has been discussed if radionavigation systems are decommissioned.
	Ground	Telephone line per assigned radio frequency
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Simplex - Transmission or reception on a single frequency but not simultaneously.
	Ground	Voice telephone lines are duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Voice
	Ground	Voice
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	N/A
	Ground	N/A
System and component redundancy requirement (1/2, 1/3, etc):	RF	Airborne - One unit required for GA, two units for air carrier. Redundancy: GA typically equips with two units (1:1); air carrier equips with three units (1:2).
	Ground	1:1 plus some overlap of ground stations
Physical channel characteristics (LOS, OTH, etc.):	RF	Line of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics:	RF	RTCA DO-160C, Sections 15, 18, 19, 20, and 21.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	3 kHz
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Voice communications are error prone and highly variable. An error rate of 3% has been measured in high activity sectors.
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	VHF voice communications are generally considered poor due to system and background noise. (The human ear is VERY good at puling voice out of a noisy AM signal.) A standard voice quality metric has not been applied.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 250 nm at 30,000 feet 100 nm at 5,000 feet Coverage: United States including the Gulf of Mexico.
Link and channel availability	RF	Exceeds 99.7%
Security/ encryption capability	RF	N/A
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	All commercial, all military and most GA aircraft equipped. All aircraft participating in IFR airspace are required to equip. Approximately 20,000 GA aircraft use only unrestricted airspace and do not equip with a radio.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Double sideband—Amplitude Modulation (DS-AM)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	N/A

CHARACTERISTIC	SEGMENT	DESCRIPTION
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	System	Respond to 75% of calls within 10 seconds and 94% of calls within 60 seconds
	System	No measured data. Air Traffic Controllers determine access and priority based on traffic and situation.
Avionics versatility (applicability to other aircraft platforms)	Avionics	Any aircraft equipped with VHF transmitter and receiver.
Equipage requirements (mandatory for IFR, optional, primary, backup,	Avionics	Mandatory for IFR flight operations; not required in uncontrolled airspace.
	Ground	Ground stations required for coverage.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications, etc.)	RF/Avionics	Signal in space characteristics are set by National and International standards. Avionics are developed by vendors with proprietary designs. Some integration with navigation.
	Ground	Vendors provide ground communications using proprietary hardware/software designs and commercial telecommunications standards.
Source documents		Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; ARINC Quality Management Reports, Air/Ground Voice Performance

C.3 HF VOICE

HF voice communications are the oldest form of radio communications to aircraft. HF frequencies are prone to noise from solar and atmospheric sources. HF can provide coverage over large areas due to its propagation characteristics and has continued to be the major system in use for Oceanic areas. VHF communications eliminated the need for HF aeronautical voice in the domestic airspace. Due to the noise and range factors, voice communications are slow and communications are not always possible.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**HF Voice**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	High Frequency (HF)
	Ground	Leased telco circuits
Frequency/ Spectrum of Operations:	RF	2.8 MHz to 22 MHz
System Bandwidth Requirement:	RF	2.2 MHz of band used for Aeronautical. All frequencies can not be used simultaneously due to ionospheric propagation characteristics.
	Ground	3000 Hz analog per channel, single side band
System and Channel Capacity (number of channels and channel size):	RF	Frequencies assigned by International Civil Aviation Organization (ICAO) for each Flight Information Region (FIR). One voice channel per frequency, two frequencies per Sector. Frequencies change during the 24 hour period due to propagation.
	Ground	Telephone line per assigned radio frequency
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Simplex - Transmission or reception on a single frequency but not simultaneously.
	Ground	Full duplex with a separate channel for each transmit and receive path, however the communications equipment often blocks receive voice when the operator is transmitting resulting in a half-duplex operation.
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Voice
	Ground	Voice
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	N/A
	Ground	N/A
System and component redundancy requirement (1/2, 1/3, etc):	RF	1:1 Two units installed, one required.
	Ground	1:2 One spare unit for multiple operational units. Procedures and overlapping coverage also provide some redundancy.

CHARACTERISTIC	SEGMENT	DESCRIPTION
Physical channel characteristics (LOS, OTH, etc.):	RF	Sky wave and groundwave propagation Modes. Noise and ionospheric activity affect communications quality.
Electromagnetic interference (EMI) / compatibility characteristics:	RF	RTCA DO-160C, Sections 15, 18, 19, 20, and 21.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Primarily Oceanic. Technically, HF can operate in any domain and may be used for backup; but VHF voice is preferred whenever available.
Channel data rate (digital) and/or occupied bandwidth (analog) requirement:	RF	3 kHz
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Signals in the HF band are influenced by the characteristics inherent in transmitting through the ionosphere, which include various emissions from the sun interacting with the earth's magnetic field. The ionosphere continually changes due to yearly, seasonal, and diurnal effects of the earth's rotation on its axis around the sun and the 11-year sunspot cycle which affects frequency propagation. In addition HF is also affected by a number of unpredictable events including solar flares, solar mass emissions, and solar storms.
System integrity (probability)	System	99.72% based on 2 operational errors for CY1999. Radio operators repeat voice messages and receive confirmation to overcome weak signals and propagation noise.
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Considered very poor quality. No standard of measurement applied.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Oceanic. Includes the Pacific, Atlantic, and Caribbean Flight Information Region (FIR) assigned by ICAO.
Link and channel availability	RF	RF propagation during an eleven year solar cycle will range from.90 to.99. (Decreased availability during low-propagation periods is addressed through geographic diversity of equipment) Several HF frequencies are assigned to each FIR by ICAO and are available depending upon propagation conditions. Components: Air Ground System (AGS) workstations = 99.98; Data Paths from Comm centers to Air Route Traffic Control Center (ARTCC) = 99.95; HF radio hardware = 99.9885;
Security/ encryption capability	RF	N/A
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Required for all aircraft using Oceanic. Approximately 8,000 total commercial, G/A, and military aircraft are equipped. Most equipped G/A are executive jet aircraft. Data for North Atlantic traffic indicates 86% commercial transport, 10% GA, and 4% military.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Single Side Band—Amplitude Modulation (SSB-AM)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	N/A
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Normal signal propagation delay
	System	Delay is primarily caused by need to repeat voice messages until a successful confirmation is obtained. Air Traffic Control (ATC) clearances are delivered within a three-minute average while advisories and requests are delivered within a five-minute average. All communications (including AOC) are delivered in less than 30 minutes.
Avionics versatility (applicability to other aircraft platforms)	Avionics	Equipment can be used by all classes of aircraft although use by low-performance G/A aircraft is rare.

CHARACTERISTIC	SEGMENT	DESCRIPTION
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Avionics	Mandatory for aircraft travelling in Oceanic FIRs
	Ground	N/A
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.)	RF/Avionics	Signal in space characteristics are set by National and International standards. Avionics are developed by vendors with proprietary designs.
Level of integration with other aircraft avionics (independent data link, shares communications link with applications, etc.)	Ground	Vendors provide ground communications using proprietary hardware/software designs and commercial telecommunications standards. HF Voice equipment may be shared with other HF applications (i.e., Data Link via HF).
Source documents		Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO ARINC Quality Management Reports, Air/Ground Voice Performance

C.4 Digital Voice

The only planned terrestrial network for digital voice is VDL Mode 3. As specified in ICAO Annex 10, Chapter 6, "VHF Air-Ground Digital Link," VDL Mode 3 uses the same modulation techniques as VDL Mode 2 and uses the same physical layer protocols with a few exceptions.

The VDL Mode 3 system is required to support a transparent, simplex voice operation based on a "Listen Before Push to Talk" channel access.

The ICAO "Manual on VHF Digital Link (VDL) Mode 3 Technical Specifications" requires that the vocoder "incorporate and default to the Augmented Multiband Excitation (AMBE) vocoder algorithm, version AMBE-ATC-10, from Digital Voice Systems, Incorporated (DVSI) for speech compression unless commanded otherwise." A single specific algorithm is specified to achieve interoperability.

Technical characteristics for VDL Mode 3, which includes digital voice, are listed in the table below.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Very High Frequency Digital Link Mode 3 (VDL Mode 3)**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	Very High Frequency (VHF)
	Ground	Undetermined
Frequency/ Spectrum of Operations:	RF	118-137MHz
System Bandwidth Requirement:	RF	25KHz/channel; Radios are specified for 112-137 MHz tuning range.
	Ground	Undetermined
System and Channel Capacity (number of channels and channel size):	RF	As a system, VDL Mode 3 can be used for all frequencies in the VHF aeronautical band, pending frequency sharing criteria. VDL Mode 3 is planned as the replacement for all current ATC analog voice frequencies, approximately 500 channels. Each VDL Mode 3 frequency provides four subchannels per 25KHz channel.
	Ground	Fractional T-1 interfaces indicated in draft specification.
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Simplex - Transmission or reception on a single frequency but not simultaneously, within a subchannel. Subchannels can communicate independently with TDMA scheme.
	Ground	Undetermined
Method of information delivery (voice, voice recording, data, combination, etc.):	RF	Pulse code modulated voice or data in any given subchannel
	Ground	Data, ATN-compliant network protocols

CHARACTERISTIC	SEGMENT	DESCRIPTION
System and component redundancy requirement (1/2, 1/3, etc):	Ground	Undetermined, 1:1 is current practice.
	RF	Ground components: 1:1 is current practice Airborne: 1:2
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	VDL Mode 3 will begin deployment for voice function in approximately 2005 for En Route phase of flight. Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight will be added as the system expands.
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	10,500 symbols/sec (3 bits per symbol) 31.5 Kbps/channel 4.8 Kbps/subchannel, 4 subchannels/channel
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Digital = BER of 10^{-3} for minimum, uncorrected signal BER of 10^{-6} daily average
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Voice: The PCM voice will be encoded using an 8 kHz sampling rate at a resolution of 16 bits per sample.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 200 nm at 30,000 feet 80 nm at 5,000 feet Coverage: Implementation will begin in 2005 with U.S. En Route. Coverage will expand to all U.S. phases of flight.
Link and channel availability	RF	Radio availability =.99999
Security/ encryption capability	RF	No encryption at RF level. Should support ATN defined encryption and authentication at application level.
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	System is in implementation. Will be available to commercial, G/A, and military aircraft
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Time Division Multiple Access (TDMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	< 250 msec
	System	< 250 msec

CHARACTERISTIC	SEGMENT	DESCRIPTION
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Ground	Ground stations required for service/coverage.
	Avionics	NEXCOM will initially be deployed in analog voice Mode to allow fielding and aircraft equipage. When switched to digital voice Mode, approximately 2006, equipage will be mandatory for high En Route.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)		Signal in space and protocols are defined by National and International standards. Ground equipment will be provided by vendors using proprietary designs. VDL data can support numerous applications.
Source documents		Implementation aspects for VDL Mode 3 system (version 2.0), VDL Circuit Mode MASPS and MOPS, Aeronautical Mobile Communications Panel (AMCP); Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; RTCA /DO-224.

For satellite networks, which are operated by service providers rather than by national authorities, the SARPs specify vocoders selected by the service providers, subject to the AMCP validation process. Inmarsat uses several vocoders, depending on the specific service; the specifications are contained in Annex 10, Chapter 4. Specifications for vocoders for AMS(R)S using Next Generation Satellite Systems will be contained in technical manuals referenced by Annex 10, Chapter 12. No NGSS technical manuals have been approved yet.

At present, only Inmarsat provides satellite voice service satisfying the requirements of AMS(R)S. Iridium planned to provide AMS(R)S service for voice and data, but Iridium is no longer viable. Technical characteristics of the Inmarsat voice service are presented in the table below, along with data aspects of the Inmarsat-3 service.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Inmarsat-3**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	SATCOM – GEO satellite. Five satellites.
	Ground	Ground Earth Stations (GES)
Frequency/ Spectrum of Operations:		C Band ~ 4,000 to 8,000 MHz, and L Band ~1,000 to 2,000 MHz
System Bandwidth Requirement	RF	10 Mhz satellite 17.5 kHz for 21Kbps channel with A-QPSK modulation 10 kHz for 10.5 Kbps channel with A-QPSK 8.4 kHz for 8.4 Kbps channel with A-QPSK 5.0 kHz for 4.8 Kbps channel with A-QPSK 5.0 kHz for 2.4 Kbps channel with A-BPSK 5.0 kHz for 1.2 Kbps channel with A-BPSK 5.0 kHz for 0.6 Kbps channel with A-BPSK
	Ground	N/A
System and Channel Capacity (number of channels and channel size)	RF	Six channels per aircraft for Aero H (High) for current equipage Voice at either 9.6 kbps or 4.8 kbps Data at 10.5 - to 0.6 kbps Maximum voice capacity with additional aircraft equipment is 24 voice channels.
	Ground	N/A
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Complex - see Access scheme block
	Ground	Half Duplex

CHARACTERISTIC	SEGMENT	DESCRIPTION
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Digitally encoded voice & data services
	Ground	Digitally encoded voice & data services
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None - Pilot can seize voice channel if needed
	Ground	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	2 ground stations per region; one satellite per region; Some aircraft may have redundant avionics
	Ground	2 ground stations per region
Physical channel characteristics (LOS, OTH, etc.):	RF	Geosynchronous Satellite LOS, with ~ 1/3 earth footprint
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Primarily Oceanic. Currently InMarSat is not allowed to operate in domestic airspace.
Channel data rate (digital) and/or occupied band width (analog) requirement:		Voice: 10.5 Kbps/with 0.5 Forward Error Correction; Data: Aero-H: 9.6 Kbps; Aero-I: 4.8 Kbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Highly robust
System integrity (probability)	System	BER of 10^{-3} for voice, 10^{-5} for data
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Voice is toll quality. Call blocking probability less than 1 per 50 attempts in busy hour
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	1/3 Earth Regional: Indian Ocean, Pacific Ocean, East Atlantic and West Atlantic regions overlap and cover the entire earth within +/- 85 degrees latitude.
Link and channel availability	RF	98.8% (spot beam) Satellite operates within the 10 MHz band assigned to AMS (R) S for satellite service by ICAO.
Security/ encryption capability	RF	N/A
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Commercial aircraft approximately 1,000 equipped out of estimated 2,000 oceanic fleet.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Aeronautical-Quadrature Phase Shift Key (A-QPSK), Aeronautical variation of QPSK
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	P-Channel (Packet): Time Division Multiplexing (TDM) for signaling and user data (ground-to-air) R-Channel(Random): Slotted Aloha, aircraft-to-ground signaling T-Channel (Reservation): TDMA - used for reserving time slots C-Channel (Circuit-mode): Used for voice
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	8 seconds/95% for 380 octet user packet at 10.5 kbps 45 seconds/95% for 380 octet user packet at 600 bps
	System	End to end delay within acceptable limits for voice transmission
Avionics versatility (applicability to other aircraft platforms)		Size and weight of Avionics and antenna are prohibitive for small aircraft.

CHARACTERISTIC	SEGMENT	DESCRIPTION
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Optional
	Ground	Ground Earth Stations (GES) required for receipt of satellite signals
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary hardware and software
	Avionics	Independent data link
Source documents		Inmarsat SDM; Nera System Summary; Inmarsat fact sheets; Annex 10, Aeronautical Telecommunications, International Civil Aviation Association (ICAO); ARINC Market Survey for Aeronautical Data Link Services; INMARSAT Aeronautical System Definition Manual

C.5 Data Communication

The recommended architecture assumes that all two-way data communication is conducted using ATN compliant subnetworks. It is important to note that the Aeronautical Telecommunication Network is not a single network managed by one organization, but is similar to the Internet in that it uses a set of requirements to enable end-to-end communications over a collection of separate but interconnected networks.

Although it is technically feasible to use "Voice over IP" (or voice over CLNP in the case of the ATN), we know of no such standards to have been considered for aeronautical use. The protocols are specified by ITU Recommendation H.323, "Packet Based Multimedia Communication Systems." If packet Mode voice were used instead of circuit Mode, it would be necessary to amend the FAR and corresponding ICAO requirements that two-way communication be maintained continuously.

All ATN implementations must comply with Chapter 3 of Annex 10, Volume III, Part1 and the related "Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN)," ICAO DOC 9705/AN956, or subsequent revisions.

The ATN architecture makes it possible to use a broad variety of subnetworks, with interfaces already specified for VDL Mode 2 and VDL Mode 3. In addition, the Technical Manual specifies mappings of the ATN priority levels to the priority levels defined for, inter alia, VDL and Mode-S. Satellite service providers can support the ATN through the use of a subnetwork dependent convergence facility (SNDCF) using ISO/IEC 8208:1995: "Information Technology—Data Communications—X.25 Packet Layer Protocol for Data Terminal Equipment." Because other protocols may be more suitable for use with satellites, the ATN Panel has begun work on SNDCF for other protocols.

Arguably, it would be beneficial for the AATT 2015 architecture to have an SNDCF for the internet protocol (IP). Besides producing benefits of greater availability of implementations and likelihood of commercial investment in improving the protocols, research has begun on improvements for TCP/IP when using satellite communications. Existing protocols, including the OSI protocols on which ATN is based, do not fully address the satellite environment, which includes greater propagation delays, more noise, asymmetric channels for some implementations, and other characteristics.

The use of ATN routers makes it possible to use satellite or terrestrial links without the application being concerned about the link, as long as the link satisfies the requirements for Quality of Service (QoS) and policy based routing.

C.5.1 ACARS

ACARS is the dominant data link in current commercial aviation use. It was fielded in 1979 to provide a limited set of operational control messages: Out (left the gate), Off (the runway), On (the runway), In (at the gate) or OOOI messages. Airlines use the OOOI messages for management of their fleets based on the time-stamped messages received for each ACARS equipped flight. Once established, many additional uses for ACARS were conceived and fielded including weather, flight planning, air traffic and maintenance messages. In the last several years, ACARS traffic has increased 15-20% a year. The current low speed of ACARS, 2.4 Kbps, and its 1970's character oriented protocols, limit its ability to serve the ever-increasing traffic load. While users can select uplink message assurance, ACARS lacks an inherent positive message assurance capability and is limited in its ability to carry critical air traffic control messages. Although legacy ACARS equipment is expected to continue for many years, an improved data link, VDL Mode 2, is under development. Originally intended for the VHF frequency band, ACARS has been extended to HF and satellite L-band using supplementary protocols.

Most ACARS equipped aircraft are Class 3, commercial airline, users. A few Class 2, General Aviation business and corporate, are equipped and almost no Class 1, private General Aviation users, are equipped. ACARS stations are typically located at major airports with coverage at ground level at the terminal surface. En Route coverage is typically based on Class A Airspace, above 18,000 feet. The coverage approach is chosen to serve the primary users, Class 3.

ACARS is an open architecture with the standards and protocols set by ICAO but it is not an ATN subnetwork. It is, however, compatible with ATN subnetworks. Numerous manufacturers and vendors provide a variety of communications services via ACARS. ACARS transmits blocks of about 220 characters and any information can be transmitted as long as the formatting protocols are followed. Air carriers have developed numerous specialty products for their internal use.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Aircraft Communications Addressing and Reporting System (ACARS)**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	Very High Frequency (VHF) Radio
	Ground	ARINC Data Network System (ADNS) & ARINC Packet Network (APN)
Frequency/ Spectrum of Operations:		Currently 129.125, 130.025, 130.450, 131.125, 131.550, 136.800 MHz in U.S. Two more frequencies are planned.
System Bandwidth Requirement:	RF	25 KHz channel x 10 total frequencies. ACARS could be extended to more frequencies but 10 is the maximum planned. Future growth capacity will be provided by VDL Mode 2.
	Ground	Leased telco circuits.
System and Channel Capacity (number of channels and channel size):	RF	Currently running 7 channels (frequencies) at ORD. Channel assignments are regulatory; there is no system limitation on the number of channels.
	Ground	ADNS & APN X.25 packet switched services
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Simplex - Transmission or reception on a single frequency but not simultaneously.
	Ground	Simplex
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	None
	Ground	ACARS provides a limited 2-level message priority capability that enables Type A messages to be delivered ahead of Type B messages within the wide area network.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System and component redundancy requirement (1/2, 1/3, etc):	RF	Airborne: Typically no backup radio (not dispatch critical). In some avionics suites, the ACARS radio can be preempted for voice communication.
	Ground	Ground Stations: Normally multiple stations within range. Critical airports have four ground stations for high availability. 1:2 in Central Processing Equipment
Physical channel characteristics (LOS, OTH, etc.):	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	RTCA DO-160C, Sections 15, 18, 19, 20, and 21.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight and some Oceanic in Alaska.
Channel data rate (digital) and/or occupied bandwidth (analog) requirement:	RF	2400 bits per second RF data rate
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	The undetected error rate of ACARS is 10^{-6}. CRC and application level confirmations can increase end-to-end integrity to 10^{-10}
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	VHF ACARS end-to-end performance for 1999 was 99.9978 for critical airports. Message success rate varies from 97.63 to 99.71%. Message success is affected by undeliverable messages (aircraft may not be in service), lack of acknowledgement, message priority and message timeout requirements.
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	Range dependent on altitude: Maximum 200 nm at 30,000 feet 80 nm at 5,000 feet Coverage: VHF coverage is LOS from a ground station, so no oceanic coverage is available. Coverage is total within the continental US and extends to large portions of the globe.
Link and channel availability	RF	99.9991 (critical airports); Other locations 99.19
Security/ encryption capability	RF	None inherent to ACARS. End-system application encryption has been successfully tested.
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Approximately 6,200 total users. An estimated 1,500 are GA (business and executive aircraft). 230 are regional airlines and military are less than 10. Equipage by military, cargo, and regional users are increasing.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Amplitude Modulation Minimum Shift Keying (AM MSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Carrier Sense Multiple Access (CSMA)—non persistent
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	ARINC conducts regular flight checks to insure that radio frequency utilization does not exceed 40%.
	System	The measured mean plus one sigma transit delay of ACARS is approximately 5 seconds, end-to-end.
Avionics versatility (applicability to other aircraft platforms)	Avionics	ACARS can be installed on any aircraft type.
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Optional
	Ground	Ground stations necessary for coverage

CHARACTERISTIC	SEGMENT	DESCRIPTION
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Ground networks are proprietary designs with commercial communications interfaces.
	RF/Avionics	Signal in space characteristics are set by National and International standards. Avionics are developed by vendors with proprietary designs but are voluntarily certified in the ARINC AQP program. Can share VHF equipment with other applications (VHF voice).
Source documents		ARINC Specification 618; ARINC Specification 620; ARINC Specification 724B; Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; ARINC Quality Management Reports, Air/Ground Voice Performance; Aeronautical Data Link Services Market Survey Response

C.5.2 VDL Mode 2

VDL Mode 2 is a 1990s concept for aeronautical data link. It has been designed by the international aviation community as a replacement for ACARS. Many of the limitations of ACARS have been overcome in the VDL Mode 2 system. The best known improvement is the increase in channel data rate from the ACARS 2.4 Kbps rate to a 31.5 Kbps rate. The improved rate is expected to increase user data rates 10 to 15 times over the current ACARS. The variation is dependent upon user message sizes, channel loading assumptions, and service provider options. VDL Mode 2 can carry all message types carried by ACARS plus Air Traffic Service messages such as CPDLC which require performance levels of latency and message assurance not possible with ACARS.

VDL Mode 2 is a subnetwork in the Aeronautical Telecommunication Network, ATN, concept. ATN has been developed by ICAO to provide a global air/ground and ground/ground network for all aviation related traffic. ATN addresses both the communications aspects and the applications.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**VHF Digital Link Mode 2** (VDL Mode 2)
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	ARINC Data Network System (ADNS) & ARINC Packet Network (APN)
Frequency/ Spectrum of Operations		136.975MHz, 136.950MHz, 136.925MHz, 136.900MHz currently approved for VDL in international frequency plans. The 136.500 - 137.0 MHz band (20 channels) is potentially assignable to VDL Mode 2 in the U.S. Additional frequencies are based on availability and sharing critieria.
System Bandwidth Requirement	RF	25KHz
	Ground	Primary 56 Kbps , dial backup 64 Kbps ISDN
System and Channel Capacity (number of channels and channel size)	RF	Unlimited system growth - primarily dependent on regulatory frequency allocation. Ground stations are capable of four independent frequencies. Initial deployment will be based on aircraft equipage and will only require 1-2 frequencies.
	Ground	APN X.25 packet switched services and IP and ATN protocols
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Simplex - Transmission or reception on a single frequency but not simultaneously.
	Ground	Simplex
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	data
	Ground	data

CHARACTERISTIC	SEGMENT	DESCRIPTION
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
	Ground	The VDL Mode 2 ground network can prioritize messages over the wide area network and within the ground station in accordance with ATN priority schemes. Once presented to the radio for transmission, messages are not preempted.
Physical channel characteristics (LOS, OTH, etc.)	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	RTCA DO-160C, Sections 15, 18, 19, 20, and 21.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	First VDL Mode 2 usage expected in 2000 in En Route. Potentially applicable to all domestic phases of flight: Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	31.5 kbps/25KHz channel
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	VHF channels are susceptible to terrain multipath but relatively robust and inherently resistant to fading, atmospheric attenuation, and weather.
System integrity (probability)	System	Design availability for Initial Operating Capability (IOC) is .9999. Higher availability will be achieved with additional ground stations and supporting network components for critical airports and applications.
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Within the VDL Mode 2 subnetwork, the probability of a lost packet is less than 10^{-7}. The subnetwork uses logical acknowledgements for packet delivery assurance. An additional end-to-end message assurance is applied to assure message delivery (all packets for a message).
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Range dependent on altitude: Maximum 200 nm at 30,000 feet 80 nm at 5,000 feet Coverage: Implementation will begin in 2000 with U.S. En Route and high density airports (Airspace A and B). Coverage will expand as users equip.
Link and channel availability	RF	The availability of each ground station is 0.997. Ground station availability based on providing RF signal so radio and all components included. For typical applications, two ground stations will be available to achieve 0.9999 system availability.
Security/ encryption capability	RF	None at the RF level - VDL Mode 2 will support authentication and encryption of applications as planned by ATN.
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	None - system to be deployed in 2000. VDL Mode 2 is applicable to all user classes but is expected to be first implemented by air carriers and regional airlines operating in Class A airspace (above 18,000 feet) and associated Class B airspace airports.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Carrier Sense Multiple Access (CSMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	95% of messages delivered within 3.5 seconds within the VDL Mode 2 subnetwork. End-to-end delivery is estimated at 95% within 5 seconds.

CHARACTERISTIC	SEGMENT	DESCRIPTION
Avionics versatility (applicability to other aircraft platforms)	System	VDL Mode 2 can be used for all applications.
	Avionics	VDL Mode 2 can be used on any class aircraft.
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.)	Ground	Ground stations must be installed for coverage
	System	Signal in space characteristics are set by National and International standards. Avionics are developed by vendors with proprietary designs. Can share VHF equipment with other applications (VHF voice).
Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)		The digital radios used by VDL Mode 2 are capable of providing analog voice service and/or VDL Mode 3 service with appropriate software and hardware additions. Radio is dedicated to one Mode when installed.
Source documents		ARINC VDL Mode 2/ATN Briefing for FAA

C.5.3 VDL Mode 3

VDL Mode 3 also is an ATN subnetwork. VDL Mode 3 has been designed for Air Traffic controller-pilot communications for both voice and data. VDL Mode 3 uses time division multiplexing to split each 25 kHz channel into four subchannels, which can be any combination of voice or data. This approach allows VDL Mode 3 to provide a traditional voice service and a data link service over a single system. Each subchannel operates at 4.8 Kbps. For voice service, VDL Mode 3 includes a voice encoder/decoder (vocoder) that allows digital signals to be converted to voice. As a data channel, VDL Mode 3 can provide data service at 4.8 Kbps in each data subchannel.

VDL Mode 3 is under development by the FAA as the NEXCOM program. Initially, NEXCOM will provide voice service to replace the current 25 kHz, double side-band amplitude modulated (DSB-AM) voice service.

The technical characteristics of VDL Mode 3 are described in Section C.4 above.

C.5.4 InMarSat-3

Currently limited aviation communications is available via satellite. The InMarSat GEO satellite provides voice and low-speed data service to aircraft in the Oceanic domain. The data service has been used to supplement HF voice air traffic control. Satellite voice for air traffic has been limited to emergency voice. The satellite services are installed on aircraft for commercial passenger voice service and the air traffic control services are provided as a secondary consideration. In an emergency, the pilot has priority access to the communication channel. The large dish size used for GEO satellites is expensive and difficult to install on smaller aircraft such as GA. Cargo aircraft do not have the passenger voice communications support, and therefore, traditionally have not been equipped with satellite communications equipment.

The technical characteristics of Inmarsat-3 are described in Section C.4 above.

C.5.5 Inmarsat-4

The Inmarsat-4 (Horizons) satellites are proposed for 2001. Due to the crowded spectrum in L-band, Horizons may be deployed at S-band. Data rates of 144 Kbps with an Aero-I aircraft terminal and 384 Kbps with an Aero-H terminal are forecast. The Horizons satellites may have 150-200 spot beams and 15-20 wide area beams.

Characteristic	Segment	Description
System Name:		**Inmarsat 4 - Horizons**
Communications/link type (HF, VHF, L-Band, SATCOM, other):Ground	RF	SATCOM - GEO. Four satellites
	Ground	Ground Earth Stations
Frequency/ Spectrum of Operations:	RF	S Band under consideration, L-Band dependent on world allocation
System Bandwidth Requirement:	RF	18 Mhz estimated
	Ground	Unknown
System and Channel Capacity (number of channels and channel size):	RF	Estimated 1,000 circuits/satellite using 15-20 beams
	Ground	
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Duplex
	Ground	
Method of information delivery (voice, voice recording, data, combination, etc.):	RF	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	Unknown
	Ground	Unknown
System and component redundancy requirement (1/2, 1/3, etc):	RF	Unknown
	Ground	Unknown
Physical channel characteristics (LOS, OTH, etc.):	RF	Geosynchronous satellite, LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	Some S Band interference possible from existing ground station sources
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	Primarily Oceanic. Currently InMarSat is not allowed to operate in domestic airspace.
Channel data rate (digital) and/or occupied bandwidth (analog) requirement:	RF	144 kbps and 384 kbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Relatively robust. Terrain multipath
System integrity (probability)	System	Unknown, should be equal or greater than INMARSAT 3
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Unknown, should be equal or greater than INMARSAT 3
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	System	Geo-stationary worldwide
Link and channel availability	System	Unknown
Security/ encryption capability	System	Unknown
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Future system
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	System	Unknown

Characteristic	Segment	Description
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	System	Unknown
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	System	Unknown
Avionics versatility (applicability to other aircraft platforms)	System	Probable size and weight of avionics indicate that it will be difficult to equip small aircraft
Equipage requirements (mandatory for IFR, optional, primary, backup)	System	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Will require ICAO SARPs
Source documents		ARINC Market Survey for Aeronautical Data Link Services

C.5.6 Other GEO Satellite Systems

Other GEO satellites have been proposed that potentially are applicable to the aviation market. They include the AMSC/TMI satellites, Loral Skynet, CyberStar and Orion satellites, the ASC and AceS systems, and the proposed Celestri combination GEO/LEO satellite system. They are not discussed further in this report due to their limited service offering or due to their limited remaining satellite life expectency. Many details of proposed satellites are unavailable either because they are proprietary developments or the designs still are in development. A representative 2007 GEO system based on the LM/TRW Astrolink and Hughes Spaceway systems is presented below.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		LM/TRW Astrolink GEO, Hughes Spaceway GEO. (At least one of these or a similar system should be operational in 2007)
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	Ka-band
	Ground	Unknown
Frequency/ Spectrum of Operations:	RF	Ka-band, 20 GHz downlink from satellite, 30 GHz uplink to satellite
System Bandwidth Requirement:	RF	500 MHz or more, each direction, maybe split 4 or 7 ways for frequency reuse in each cell (spot beam)
	Ground	Unknown
System and Channel Capacity (number of channels and channel size):	RF	16kbps to 2Mbps standard channels, hundreds of channels available. Over 100Mbps gateway or hub channels.
	Ground	Unknown
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	duplex, may be asymmetric
	Ground	Duplex
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data

CHARACTERISTIC	SEGMENT	DESCRIPTION
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	Multiple priorities available
	Ground	Unknown
System and component redundancy requirement (1/2, 1/3, etc):	RF	Design life of 10 to 15 years, high system availability (0.9999 goal)
	Ground	Unknown, typically multiple ground stations in view
Physical channel characteristics (LOS, OTH, etc.):	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	possible interference from terrestrial Ka-band systems (LMDS, fiber alternatives systems), regulated through spectrum licensing
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	All
Channel data rate (digital) and/or occupied band width (analog) requirement:		FDM/TDMA burst (packet) channels, variable bit rates, 1 to 100+ Mbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	variable rate coding and variable data rates to mitigate deep rain fades, many frequencies available to avoid fixed interference
System integrity (probability)	System	0.9999 availability typical goal
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	10^{-9} or better typical
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	global possible, but most systems do not intend to cover oceans and polar regions, GEO systems point spot beams to land masses and high population areas in particular
Link and channel availability	RF	0.9999 availability typical goal
Security/ encryption capability	RF	terminal authentication during access encryption can be overlaid, but not a basic feature
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Fixed ground terminal service beginning in 2003
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	digital, QPSK, burst (packets), FEC variable rates 1/2 or higher
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	FDM/TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	latency: approx. 0.3 second for GEO
	System	
Avionics versatility (applicability to other aircraft platforms)		Not designed for fast moving terminals, can be achieved if business is identified and the developer designs capability.
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	optional
	Ground	

CHARACTERISTIC	SEGMENT	DESCRIPTION
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
	Avionics	Independent
Source documents		FCC and ITU spectrum license applications, conference publications

C.5.7 ICO Global

MEO satellite systems have been proposed for the Aeronautical Mobile Service. MEO systems have several advantages over the GEO and LEO approaches. The reduced transmission distance of MEO systems provides a higher link margin. Compared to LEO systems, the MEO satellites are in view to an individual aircraft longer and experience less frequent handoffs. Boeing, ICO-Global, Celestri, and Teledesic are possible MEO satellites for the 2007 time frame. The following table is based on the ICO-Global system.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**ICO Global**
Communications/link type (HF, VHF, L-Band, SATCOM, other):		SATCOM MEO satellites; 10 satellites in two planes of 5 each (plus 2 spares)
Frequency/ Spectrum of Operations:	Service Band, Uplink	2.170 – 2.200 GHz
	Service Band, Downlink	1.98 – 2.010 GHz
	Feeder Band, Uplink	6.725 – 7.025 GHz
	Feeder Band, Downlink	5 GHz (AMS(R)S)
	Crosslink Band	N/A
System Bandwidth Requirement:	System	Unknown
System and Channel Capacity (number of channels and channel size):	RF	24,000 circuits total/4.8 Kbps voice
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Duplex
Method of information delivery (voice, voice recording, data, combination, etc.):	RF	GSM Voice
Data/message priority capability / designation (high, intermediate, low, etc.):	System	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	10 satellites in two planes of 5 each (plus 2 spares)
Physical channel characteristics (LOS, OTH, etc.):	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	Service Link Margin 8.5 dB, DO-160D for avionics

CHARACTERISTIC	SEGMENT	DESCRIPTION
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	All
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	4.8 Kbps voice
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Moderate. Max one-satellite duration: 120 minutes Connectivity characteristics: Simultaneous fixed view required
System integrity (probability)	System	Not stated
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Unknown
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	System	Full earth coverage
Link and channel availability	RF	Not stated
Security/ encryption capability	System	Not stated
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	RF	None
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	QPSK
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	TDMA (implied that path diversity and combining will be used
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Latency: ~140ms path + sat switching + 100ms in 2 codecs
Avionics versatility (applicability to other aircraft platforms)	RF	No avionics available.
Equipage requirements (mandatory for IFR, optional, primary, backup)	RF	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
Source documents		ARINC Satellite Study

C.5.8 Iridium

The Iridium service is the only service other than Inmarsat that became operational and announced plans for an AMS(R)S service; the Iridium service now has been terminated. The Iridium system is shown in the following template to represent potential LEO systems, although Iridium has gone bankrupt and will not be available. The 66 satellite Iridium LEO system was designed for mobile voice and low-speed data and has been proposed for aeronautical mobile users. FCC filings have indicated future Iridium versions would provide higher speed data services. In addition to the low data rate, LEO systems must overcome the frequent handoff problem that occurs as a satellite transits the user location.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**Iridium**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	SATCOM; LEO satellites; 66 satellites in 6 planes of 11 each (plus 12 spares)
Frequency/ Spectrum of Operations	Service Band, Uplink	1.62135 – 1.62650 GHz (AMS(R)S)
	Service Band, Downlink	1.62135 – 1.62650 GHz (AMS(R)S)
	Feeder Band, Uplink	29 GHz
	Feeder Band, Downlink	19 GHz
	Crosslink Band	23 GHz
System Bandwidth Requirement	System	10.5 MHz
	Channel	31.5 kHz/50 kbps/12 users
System and Channel Capacity (number of channels and channel size)	RF	3840 circuits/sat; 56,000 circuits total
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	System	duplex
Method of information delivery (voice, voice recording, data, combination, etc.)	System	Voice and data
Data/message priority capability / designation (high, intermediate, low, etc.)	System	None
System and component redundancy requirement (1/2, 1/3, etc)	RF	66 satellites in 6 planes of 11 each (plus 12 spares)
	Ground	Satellite-satellite switching for high ground system availability
Physical channel characteristics (LOS, OTH, etc.)	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics	RF	Service link margin: 16.5 dB no combining min BER 10^{-2} DO 1600 for avionics
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	All
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	2.4 Kbps and 4.8 Kbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	High. Max one-satellite duration: 9 minutes Connectivity characteristics: Flex to any station at any location
System integrity (probability)	RF	1×10^{-6}

CHARACTERISTIC	SEGMENT	DESCRIPTION
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Compressed voice, toll quality
Range/ Coverage/ footprint (oceanic, global, regional / line-of-sight	System	Full earth coverage
Link and channel availability	RF	99.5%
Security/ encryption capability	System	Proprietary protocol
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	RF	No aviation usage
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	QPSK, FEC rate ¾,
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	FDMA/TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	12 ms path; 175 ms total
Avionics versatility (applicability to other aircraft platforms)	RF	No avionics available
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
Source documents		ARINC Satellite Study

C.5.9 ORBCOMM

Although the Orbcomm service does not operate in an AMS(R) band, it is used for provision of routine weather products to aircraft; the system is described below.

Characteristic	Segment	Description
System Name:		**ORBCOMM**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	SATCOM – LEO satellites. 35 satellites currently, an additional launch is planned for 2000 (enhancing coverage in the equatorial regions of the world).
	Ground	Ground Earth Station
Frequency/ Spectrum of Operations:	Downlinks	137 –138 MHz and 400 MHz
	Uplinks	148 – 150 MHz
System Bandwidth Requirement:	RF	50 kHz
	Ground	N/A

Characteristic	Segment	Description
System and Channel Capacity (number of channels and channel size):	RF	Unknown
	Ground	N/A
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Simplex
	Ground	Unknown
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	None
	Ground	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	GES redundancy. Satellites are overlapping in coverage.
	Ground	GES is redundant and has two steerable high-gain VHF antennas that track satellites.
Physical channel characteristics (LOS, OTH, etc.):	RF	Low Earth Orbit (LEO) satellites. LOS
Electromagnetic interference (EMI) / compatibility characteristics:	RF	N/A
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	Ground	All
Channel data rate (digital) and/or occupied bandwidth (analog) requirement:	RF	2400 bps uplink; 4800 bps downlink; 9600 bps downlink (future)
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Not stated
System integrity (probability)	System	Not stated
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Store and forward message assurance
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight	RF	Worldwide coverage
Link and channel availability	RF	Not stated
Security/ encryption capability	RF	Not stated
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	No avionics available.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Not stated
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Not stated
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Unknown
	System	Unknown
Avionics versatility (applicability to other aircraft platforms)	Avionics	Avidyne markets the Echo Flight system, which uses Orbcomm for delivery of weather products on a request-reply basis.

Characteristic	Segment	Description
Equipage requirements (mandatory for IFR, optional, primary, backup)	Avionics	Not approved
	Ground	GES required for receipt of satellite signals
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications)	System	Proprietary
	Avionics	N/A
Source documents		www.orbcomm.com

C.5.10 HFDL (GLOBALink/HF)

HF data link provides an alternative to oceanic satellite data and HF voice communications. The aircraft changes are small, consisting primarily of a radio upgrade and a new message display capability. HF antenna and aircraft wiring can remain the same. HFDL is cheaper to install and operate than satellite. For cargo aircraft that do not need the passenger voice service of satellite, HFDL provides a cost effective data link. HFDL is adaptive to radio propagation and interference. It seeks the ground station with the best signal and adjusts the data signaling rate to reduce errors caused by interference. HFDL service is faster, less error prone, and more available than traditional HF voice communications. HFDL has not yet been approved for carrying air traffic messages and aircraft equipage is just beginning.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		HIGH FREQUENCY DATA LINK (HFDL) (GLOBAlink/HF)
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	High Frequency (HF)
	Ground	ARINC Data Network System (ADNS) & ARINC Packet Network (APN)
Frequency/ Spectrum of Operations:		2.8 MHz to 22 MHz
System Bandwidth Requirement:	RF	3 kHz Single Side band, carrier frequency plus 1440 Hz. Each Station provides 2 channels
	Ground	N/A
System and Channel Capacity (number of channels and channel size):	RF	Two channels per ground station
	Ground	ADNS & APN X.25 packet switched services
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Half-duplex
	Ground	Full duplex with a separate channel for each transmit and receive path, however the communications equipment often blocks receive voice when the operator is transmitting resulting in a half-duplex operation.
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data

CHARACTERISTIC	SEGMENT	DESCRIPTION
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	N/A
	Ground	A ground based priority and preemption capability that enables Air Traffic Services (ATS) messages to be delivered ahead of Aeronautical Operational Control (AOC) messages. A higher priority single or multiblock ATS message will be serviced before lower priority multiblock messages. The transmission of lower priority multiblock messages will resume when the higher priority message is completed. Lower priority messages will be delivered in their entirety to the aircraft. Lower priority single-block messages are not preempted due to protocol and avionics implementation requirements. The immediate preemption by higher priority messages of lower priority multiblock messages is also supported.
System and Component Redundancy	RF	HFDL Ground Stations (HGS) are geographically located to provide a 1 / 2 equipment diversification with each site transmitting two frequencies to provide a 1 / 4 relationship for radio frequencies.
	Ground	ETE availability for HFDL through ADNS and APN provides redundancy with an availability of 1.00000. In the North Atlantic Region redundancy is also provided with an equipment availability of.99451 for the passport backbone Access Module. In the Pacific Region total redundancy is provided ETE.
Physical channel characteristics (LOS, OTH, etc.):	RF	Via ionosphere
Electromagnetic interference (EMI) / compatibility characteristics:	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	Adaptable to propagation conditions: 1800, 1200, 600, 300 bps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Signals in the HF band are influenced by the characteristics inherent in transmitting through the ionosphere, which include various emissions from the sun interacting with the earth's magnetic field, ionosphere changes, and the 11-year sunspot cycle which affects frequency propagation. HF is also affected by other unpredictable solar events. Frequency management techniques are used to mitigate these effects
System integrity (probability)	System	No integrity requirement for 2007 data services, Forward error detection
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	95% of uplink message blocks in 60 seconds (one-way); 95% of uplink message blocks in 75 seconds (round-trip); 99% of uplink message blocks in 180 seconds (round-trip
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	3,000 nm from each ground station. Ten stations deployed as of December 1999 with 3-4 more sites under consideration to complete Global coverage.
Link and channel availability	RF	≥99.8% End to End Operational Availability
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Commercial aircraft, 50-100 equipped. New service with potential 8,000 users

CHARACTERISTIC	SEGMENT	DESCRIPTION
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	M-Phase Shift Keying (M-PSK) 1800 (8-PSK); 1200(4-PSK); 600 (2-PSK); 300 (2-PSK)
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.) Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Slotted TDMA
Timeliness/latency delay requirements	RF	Uplink end-to-end: 2 minutes/95%, 6 minutes/99% of messages Downlinks end-to-end: 1 minute/95%, 3 minutes/99%
Avionics versatility (applicability to other aircraft platforms)	Avionics	Any aircraft equipped with HF transmit and receive equipment and the appropriate HFDL interface unit
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Avionics	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares communications link with applications, etc.)	System	Signal in space defined by national and international standards. HF Voice equipment may be shared with other HF applications (i.e., HF voice).
Source documents		Annex 10, AERONAUTICAL TELECOMMUNICATIONS, ICAO; ARINC Quality Management Reports, Air/Ground Voice Performance; ARINC specification 635-2 ARINC Aeronautical Data Link Proposal, 1997; HFDL Ground Station System Segment Specification

C.6 Gate-Aircraft Terminal Environment Link (Gatelink)

Gatelink is a potential short-range communication link for aircraft in the airport environment. It was intended to transfer large amounts of data to and from the aircraft when it is parked or potentially taxiing. Infrared (IR) links have been discussed as well as cable connections for parked aircraft. The characteristics below are based on a 2-Ghz prototype currently being tested. Gatelink is not considered viable for communications beyond the immediate airport ramp area.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Gate-Aircraft Terminal Environment Link (Gatelink)**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	S-Band,
	Ground	Ethernet
Frequency/ Spectrum of Operations:		2.4-2.485 GHz
System Bandwidth Requirement:	RF	Nominal 1 MHz.
	Ground	Nominal 1 MHz
System and Channel Capacity (number of channels and channel size):	RF	75 Channels in North America
	Ground	10 MBPS
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Half-duplex
	Ground	Half duplex

CHARACTERISTIC	SEGMENT	DESCRIPTION
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	data
	Ground	data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	None
	Ground	None
System and component redundancy requirement (1/2, 1/3, etc):	RF	NA
	Ground	NA
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS), short range
Electromagnetic interference (EMI) / compatibility characteristics:	RF	Recent tests at Dallas/Forth Worth disclosed the system encountered difficulties from equipment operating in the airport environment. For very short messages the success rate is high. Large files, as are envisioned for Gatelink, have difficulties. In an environment with many aircraft, the large amount of retries will reduce the effective data rate to the KHz level.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Preflight/post-flight at or near gate
Channel data rate (digital) and/or occupied bandwidth (analog) requirement:	RF	Unknown
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	Short range RF is resistant to fading, multi-path, atmospheric attenuation, and weather.
System integrity (probability)	System	Availability at Initial Operating Capability (IOC) was.9999
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	95% of messages delivered within 3.5 seconds
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Typical range is 100 yards or less
Link and channel availability	RF	99.9991 (critical airports); CPS availability 99.99
Security/ encryption capability	RF	Security of access scheme i.e. spread spectrum
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	None - not operational
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential Quaternary Phase Shift Keying (DQPSK) for 2 MBPS. Differential Binary Phase Shift Keying (DBPSK) for 1 MBPS.
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Spread spectrum. Direct sequence frequency hopping or pattern frequency hopping.
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	System	Unknown
Avionics versatility (applicability to other aircraft platforms)	Avionics	Avionics are not aircraft specific

CHARACTERISTIC	SEGMENT	DESCRIPTION
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Avionics	Equipment is non-mandatory. Used only for non-essential applications such as AOC, crew, passenger, maintenance, and cabin applications
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	System	Signal in space defined by AEEC.
Source documents		ARINC 763, IEEE 802.11

C.7 Effects of Modulation Schemes on Performance

The ICAO AMCP and RTCA Special Committee 172 for data link considered a number of modulation schemes. The ones considered in detail were Differential Eight-Phase Shift Keying (D8PSK), Eight-Level Frequency Modulation (8LFM), 4-ary Quadrature Amplitude Modulation (4QAM), and 16-ary QAM (16QAM). Key considerations were a desire to achieve the maximum bit rate within the existing 25 kHz channel spacing.

The resulting report showed that Working Group C examined four detailed proposals for the VDL Mode 2 modulation scheme (namely 4QAM, 16QAM, 8LFM, and D8PSK) after having been provided background information on these and many other digital modulations. Based on analysis, simulation and direct measurement, the following conclusions are presented:

4QAM has insufficient throughput and is eliminated from consideration as a primary modulation. It initially was to be the backup Mode for 16QAM where a link could not be established because of range or fading.

16QAM is the most complex scheme and is significantly more costly than the others. It has a less certain performance at longer ranges and under fading conditions.

8LFM with a nonlinear transmitter that can provide more RF power on the channel provides more margin than D8PSK. D8PSK has greatly superior ACI performance for digital modulation against digital modulation however.

D8PSK has been found to be the most efficient digital modulation scheme that can be implemented with currently available technology while meeting the spectral limitations of a 25 kHz channel. D8PSK provides a channel data rate of 31.5 K bits per second with a baud rate of 10.5 K baud and three bits per symbol.

The analysis indicated that 16QAM could yield a throughput of 37.8 kb/s for longer (1024 octet) messages. Potentially, weather services would use longer message sizes and could benefit from the greater throughput. The Adjacent Channel Interference (ACI) would be a significant factor however, if a weather service is proposed in the aeronautical VHF band. An additional consideration will be the expected availability of radios and experience with D8PSK due to their use for VDL Mode 2 and Mode 3.

C.8 ACARS Transition

Although ACARS currently is used for data communication, the existing ACARS networks are being transitioned to VDL Mode 2. ARINC's GLOBALink™ service is designed to be used as an ATN compliant subnetwork, but it includes provisions for supporting legacy ACARS applications. ACARS is expected to not only still be in existence in 2015 but also to be carrying almost twice its current traffic. Nevertheless, because of the superior performance of VDL Mode 2 with respect to the Mode A network, and the more stringent performance requirements of ATM communications vis-à-vis AOC, the legacy ACARS network is not considered part of the recommended AATT architecture for 2015.

C.9 Ground-to-Air Broadcast Communication Using Non-ATN Protocols

Ground-to-air broadcast services will not be used for safety, distress, or urgency communication, so they are not subject to the same stringent requirements as ATM communications. Since the intention of the architecture is to leverage available capacity on commercial satellites, the service provider is likely to determine the specifications for the protocols, although these often will be based on ITU recommendations or TCP/IP standards in preference to proprietary protocols.

Suitability of the service providers' protocols may need to be determined on a case-by-case basis. The ICAO AMCP has formalized a set of acceptability criteria for evaluating potential providers of Next Generation Satellite Services (NGSS). We recommend that acceptability criteria be developed for broadcast systems. In addition, it would be useful to develop upper layer protocols for interfacing to broadcast service providers so that a broadcast application would need to support only one interface regardless of the service provider.

C.9.1 VHF Digital Link—Broadcast (VDL-B)

VDL-B is a broadcast variation of VDL Mode 2. Currently intended for Flight Information Services, VDL-B provides weather information to suitably equipped aircraft. The broadcast approach can increase the throughput of data to the user since the protocol overhead of request/reply and confirmation is not required. Under the FAA's FIS Policy, two VHF band frequencies were provided to each of two vendors for implementation of a FIS-B service. As a condition of the frequency, each vendor is required to transmit a minimum set of weather products to be available at no cost to users. The vendor is allowed to charge fees for additional optional products such as weather graphics. The protocols for the FIS-B systems are partially proprietary and may be specified by the vendor. The vendors are expected to use the D8PSK physical layer, but the upper layers are not standardized.

VDL-B is not an ICAO SARPs-recognized version of VDL and the SARPs do not yet include a broadcast mode. The VDL-B term has been used to describe a data link intended primarily or solely for broadcast of data one-way to aircraft. Weather and traffic information are frequently recommended applications for broadcast functions. The description in this report is based on VDL Mode 2 and FIS, which is common usage of the term VDL-B. One of the two selected vendors for the FAA's FIS Policy has an interim VHF system using proprietary hardware and protocols. One of the two vendors has indicated an intention to use D8PSK for future implementation. Other variations of VDL-B are possible since it is not an official term or definition and the vendors may develop proprietary systems.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**VHF Data Link—Broadcast (VDL-B)**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Very High Frequency (VHF)
	Ground	Leased telco for current implementation. VDL Mode 2 network possible in the future. Other proprietary solutions possible.
Frequency/ Spectrum of Operations		118-137MHz
System Bandwidth Requirement	RF	25KHz
	Ground	N/A

CHARACTERISTIC	SEGMENT	DESCRIPTION
System and Channel Capacity (number of channels and channel size)	RF	Two frequencies per vendor, Total of four frequencies.
	Ground	Leased telco.
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Broadcast
	Ground	Duplex (return needed for ground station monitor and control)
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Data
	Ground	Data
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None
	Ground	VDL-B is a proposed broadcast service that provides advisory and weather information to all aircraft monitoring the channel. The information provided contributes to the safety of flight. This service is similar to Flight information services (FIS)
System and component redundancy requirement (1/2, 1/3, etc)	RF	Since FIS is an advisory service, high availability is not required and redundancy will probably not be used.
	Ground	None expected.
Physical channel characteristics (LOS, OTH, etc.)	RF	Line of sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics	RF	DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	The FIS-B information will be available in all phases of flight if the aircraft is within range of the ground station. En Route will have the most coverage while coverage on the ground will be limited. Pre-flight, departure surface operations, terminal, en route/cruise, landing, and post-flight
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	31.5 KBPS if D8PSK used 19.2 for GMSK Other data rates possible
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	RF is robust and resistant to interference, fading, multi-path, atmospheric attenuation, weather
System integrity (probability)	System	Based on non-critical service category, availability is estimated as 0.99
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Unknown
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	LOS (180 nautical miles for aircraft at 25,000 feet) 80 nm at 5,000 feet
Link and channel availability	RF	0.99
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	Intended for G/A market but available to all users.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Differential 8 Phase Shift Keying (D8PSK) or Gaussian Mean Shift Keying (GMSK)

CHARACTERISTIC	SEGMENT	DESCRIPTION
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Broadcast mode has not been defined
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Unkown
	System	> 5 seconds
	Avionics	Optional
	Ground	Required for message transmission
Avionics Versatility	Avionics	If D8PSK approach used, then the radio could be used for multiple applications.
Equipage Requirements	RF	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	Ground	Required for message transmission
	System	Proprietary hardware/software mix.
	Avionics	Can share VHF equipment with other applications
Source documents		None

C.9.2 Satellite Digital Audio Radio Service (SDARS)

The Satellite Digital Audio Radio Service (SDARS) was established to provide continuous nationwide radio programming with compact disc quality sound. It is intended to be able to offer niche programming that will serve listeners with special interests. In addition, SDARS has the technological potential to provide a wide range of audio programming options to rural and mountainous sections of the country that historically have been under-served by terrestrial radio.

Two companies, American Mobile Radio Corporation and CD Radio (now Sirius Satellite Radio), were awarded frequency authorizations by the FCC.

Although the intended purpose of the system is to provide audio entertainment for automobiles and remote areas, the 64 KHz channels could serve as media for data broadcasts (including graphics) as well. Both companies have established agreements with automobile manufacturers to install radios, which indicates that there are manufacturers for the receivers and antennas. If this technology were used for transmission of weather maps, the market for these products could extend beyond aviation, as many operators of truck fleets might be interested in acquiring broadcast weather services or other broadcast capabilities.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**Satellite Digital Audio Radio System (SDARS)**
Communications/link type (HF, VHF, L-Band, SATCOM, other)	RF	Satellite Broadcast, S-band
Frequency/ Spectrum of Operations		Sirius Satellite Radio has the license for 2320-2332.5 MHz; AMRC has the license for 2332.5-2345 MHz
System Bandwidth Requirement	RF	12.5 MHz
System and Channel Capacity (number of channels and channel size)	RF	Sirius offers fifty 64 KHz channels

CHARACTERISTIC	SEGMENT	DESCRIPTION
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Broadcast
Method of information delivery (voice, voice recording, data, combination, etc.)	Avionics	Digital Audio
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	Dedicated channels
System and component redundancy requirement (1/2, 1/3, etc)	RF	Two satellites
	Ground	Unknown
Physical channel characteristics (LOS, OTH, etc.)	RF	Line of sight
Electromagnetic interference (EMI) / compatibility characteristics	RF	Unknown
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Not intended for aeronautical applications
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	No published information
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	Unknown
System integrity (probability)	System	Unknown
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	High
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Regional - intended for U.S.
Link and channel availability	RF	Unknown
Security/ encryption capability	RF	Unknown - probable proprietary signal to deter theft
Avionics	RF	N/A
Equipage Requirements	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	N/A
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	XM
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Unknown

CHARACTERISTIC	SEGMENT	DESCRIPTION
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Unknown
	System	Unknown
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	System	Proprietary
Source documents		FCC and Sirius web sites

C.10 Air-Air and Air-Ground Broadcast Communications

C.10.1 Mode-S

Mode-S is an evolution of the traditional Secondary Surveillance Radar (SSR). For Mode-S, each aircraft has a unique 24-bit address, which allows transmission selectively addressed to a single aircraft instead of broadcast to all aircraft in an antenna beam. The Mode-S transponder has 56 bit registers that can be filled with airborne information such as aircraft speed, waypoint, meteorological information, and call sign. The information in the register can be sent either by an interrogation from the ground system or based on an event such as a turn. For ADS-B, equipped aircraft can exchange information without a master ground station. Although capable of sending weather and other information, the Mode-S communications capability is allocated to support its surveillance role and will consist of aircraft position and intent. ADS-B uses the Mode-S downlink frequency (i.e., 1090 MHz) and link protocols to squitter (i.e., spontaneously broadcast) onboard derived data characterizing the status (current and future) of own aircraft or surface vehicle via various ADS-B extended squitter message types (e.g., State Vector [position/velocity], Mode Status [identification/type category/current intent], and On-Condition [future intent/coordination data]).

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name		**Mode S**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	L-Band (also known as D-Band)
Frequency/ Spectrum of Operations:		1090 MHz, +/- 1MHz
System Bandwidth Requirement:	RF	2 MHz (based on the existing Mode-S downlink)
	Ground	Leased telecommunications
System and Channel Capacity (number of channels and channel size):	RF	Single 2 MHz channel
	Ground	Leased telecommunications
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Broadcast from aircraft
	Ground	Ground stations transmit at 1030 MHz and receive at 1090 MHz. For ADS-B service, receive only stations have been proposed.
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	Data
	Ground	Data

CHARACTERISTIC	SEGMENT	DESCRIPTION
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	Surveillance function has priority over communications function
	Ground	None. The probability of successful message reception and report update are specified (see Table 3-4 of RTCA DO-242 ADS-B MASPS) depending upon the specific operational applications being supported by the ADS-B system. In this broadcast system more critical data (as determine by the operation being supported) are broadcast more frequently to improve the probability of message reception and report update.
System and component redundancy requirement (1/2, 1/3, etc):	RF	This depends on the ADS-B equipage class, its hardware implementation, and the specific operational applications being supported. The system level minimum availability requirements for equipage classes A1 through A3, for example, is 0.999. This, coupled with the minimum system level continuity of service requirement for the probability of being unavailable during an operation of no more than 2 x 10 –4 per hour of flight along with the specific availability requirements for the operation being performed (e.g., parallel approach), will determine whether equipment redundancy is needed to satisfy the operational requirement. This is expected to be part of the certification process and will be based on the intended use of the ADS-B equipment and the operational approval(s) being sought.
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics:	RF	ADS-B equipment has broad EMI requirements: transmitting and/or receiving equipment shall not compromise the operation of any co-located communication or navigation equipment (i.e., GPS, VOR, DME, ADF, LORAN) or ATCRBS and/or Mode-S transponders. Likewise, the ADS-B antenna shall be mounted such that it does not compromise the operation of any other proximate antenna.
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Operational applications supported by ADS-B have been identified across all phases of flight, except possibly pre- and post-flight.
Channel data rate (digital) and/or occupied band width (analog) requirement:	RF	1 Mbps Mode-S provides data link capability as a secondary service to surveillance. Extended length message, ELM, format provides 80 user bits per 112 bit message. A typical rate is one ELM per four seconds (RTCA DO-181)
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	The L-Band frequency is subject to fading and multi-path; Mode-S uses a 24-bit parity field and forward error detection and correction (FEDC) to help address this.
System integrity (probability)	System	ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has been supplied to the ADS-B system. ADS-B system integrity is 10^{-6} or better on a per report basis. [Note: Due to constraints imposed by the Mode-S extended squitter message length, multiple messages must typically be received before all required data elements needed to generate a particular ADS-B report are available.]
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Mode-S system performance for undetected error rate is specified to be less than one error in 10^{-7} based on 112-bit transmissions.

CHARACTERISTIC	SEGMENT	DESCRIPTION
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Assuming LOS exists, range performance depends on traffic density and the 1090 MHz interference environment (i.e., ADS-B uses the same frequency as ATC transponder-based surveillance). In low-density environments (e.g., oceanic) range performance is typically 100+ nm, while in a high-traffic density and 1090 interference environments (e.g., LAX terminal area) the range performance is on the order of 50 to 60 nm with current receiver techniques (improved processing techniques have been identified that are expected to provide range performance to 90 nm in dense environments).
Link and channel availability	RF	100%, as ADS-B is a true broadcast system
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	TBD, since still being developed. However, a significant number of initial implementations are expected to occur in aircraft already equipped with TCASII/Mode-S transponders (commercial air transport and high-end business aircraft). This area of equipage (i.e., TCASII/Mode-S) is expected to increase as the ICAO mandate for TCASII Change 7 (called ACAS in the international community) starts to occur in 2003.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	Pulse Position Modulation (PPM) Each ADS-B message consists of a four pulse preamble (0.5 microsecond pulses, with the 2nd, 3rd, and 4th pulses spaced 1.0, 3.5, and 4.5 microseconds after the 1st) followed by a data block beginning 8 microseconds after 1st preamble pulse. The data block consists of 112 one-microsecond intervals with each interval corresponding to a bit (a binary "1" if a 0.5 pulse is in the first half of the interval or a "0" if the pulse is in the second half of the interval.
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Random access; squitter transmissions are randomly distributed about their mean value between some fixed high and low limits (e.g., "one-second" squitters have a one second mean value and are randomly transmitted every 0.8 to 1.2 seconds). This done to minimize collisions on the link. When collisions do occur, the receiver uses the next available message (which in a broadcast system like ADS-B will arrive shortly) to obtain the data.
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	
	ADS-B System	ADS-B uncompensated latency must be less than 1.2 ms or 0.4 ms depending upon the uncertainty of the position data (error [95% probable]) being used to support a particular operational application. The error is categorized according to navigation uncertainty categories (NUCs) from 1 to 9, with the higher NUCs indicating more accurate position data. The 1.2 ms requirement applies to NUCs less than 8 (0.05 to 10 nm position error), while the 0.4 ms must be met for NUCs 8 or 9 (3 to 10 m error).
Avionics versatility (applicability to other aircraft platforms)	Avionics	ADS-B as defined is intended to be applicable to all aircraft category types as well as surface vehicles operating in the aircraft movement area of an airport. A range of equipage classes have been defined to accommodate the various levels of user requirements from GA to air transport.
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	Avionics	No mandate of the ADS-B system is planned. However, if ADS-B equipment is used to perform a particular operation (e.g., IFR), a specific ADS-B equipage class, with certain minimum performance characteristics (e.g., transmitter power), will be required.

CHARACTERISTIC	SEGMENT	DESCRIPTION
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.)	Ground	No mandate of the ADS-B system is planned. However, if FAA were to use ADS-B to monitor ground vehicles on the airport movement areas, all such vehicles would have to be equipped with at least a minimum (i.e., broadcast-only) ADS-B system.
Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	System	ADS-B uses the Mode-S architecture which is a sub-network of the ATN and is based on an open system architecture.
	Avionics	The signal in space characteristics are defined by national and international forums.
Source documents		RTCA DO-242 ADS-B MASPS, RTCA DO-181 Mode-S MOPS, draft material for 1090 MHz ADS-B MOPS

C.10.2 Universal Access Transceiver (UAT)

The Universal Access Transceiver concept is intended for distribution of surveillance and weather data. It uses a unique hybrid access method of TDMA and random access. The TDMA portion is used to transmit the traffic and weather information, while the random access portion is used by aircraft to transmit their own location in conformance with the RTCA DO-242 broadcast approach. The system is experimental and currently operates on a UHF frequency of 966 MHz. The bandwidth of the system is 3 MHz and a suitable frequency assignment would be difficult. UAT has not been standardized and is not currently recognized by ICAO/ATN. The system is being evaluated in the Safe Flight 21 initiative and would become an open system architecture if developed. The UAT implementation of ADS-B functionality had as its genesis a Mitre IR&D effort to evaluate a multi-purpose broadcast data link architecture in a flight environment. Its use for ADS-B was seen as a capacity and performance driver of the link. The current evaluation system (no standard exists or is in process at this time) uses a single frequency (experimental frequency assigned), a binary FM waveform, and broadcasts with 50 W of power. The system provides for broadcast burst transmissions from ground stations and aircraft using a hybrid TDMA/random access scheme. The UAT message structure, net access scheme, and signal structure have been designed to support the RTCA DO-242 ADS-B MASPS (i.e., to transmit State Vector, Mode-Status, and On-Condition messages and provide the corresponding ADS-B reports for use by operational applications). The UAT also is investigating support for other situational awareness services (e.g., TIS-B & FIS-B) through sharing of the channel resources with ADS-B.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**UAT**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	UHF
Frequency/ Spectrum of Operations	System	The UAT evaluation system operates on an experimental frequency assignment of 966 MHz. [Note: This band was selected due to the availability of spectrum. However, the system is not frequency specific and could operate in any suitable spectrum.]
System Bandwidth Requirement	RF	3 MHz
	Ground	≥ 1 MHz
System and Channel Capacity (number of channels and channel size)	RF	One channel, 2 MHz
	Ground	Single 1 MB/s channel
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.)	RF	Two part: Ground broadcasts information to aircraft, aircraft transmit position information.
	Ground System	Telco
Data/message priority capability / designation (high, intermediate, low, etc.)	RF	None

CHARACTERISTIC	SEGMENT	DESCRIPTION
System and component redundancy requirement (1/2, 1/3, etc)	Ground	None, broadcast system. The probability of successful message reception/report update are specified (see Table 3-4 of RTCA DO-242 ADS-B MASPS) depending upon the specific operational applications being supported by the ADS-B system. The more critical data (as determine by the operation being supported) have minimum requirements that broadcast more frequently to improve the probability of message reception and report update. [Note: The ground station TDMA access protocol (see access scheme description below) may have some capability for message prioritization. However, this could not be determined from the documentation available.]
	RF	This is still to be determined. It depends on the ADS-B equipage class, its hardware implementation, and the specific operational applications being supported. The system level minimum availability requirements for equipage classes A1 through A3, for example, is 0.999. This, coupled with the minimum system level continuity of service requirement for the probability of being unavailable during an operation of no more than 2 x 10 –4 per hour of flight, along with the specific availability requirements for the operation being performed (e.g., parallel approach), will determine whether equipment redundancy is needed to satisfy the operational requirement. This is expected to be part of the certification process and will be based on the intended use of the ADS-B equipment and the operational approval(s) being sought.
Physical channel characteristics (LOS, OTH, etc.)	RF	LOS
Electromagnetic interference (EMI) / compatibility characteristics	RF	UAT is being designed for operation on a clear channel. Interference to or from off-channel systems can only be assessed once an operational frequency is identified. DO-160D
Phase of Flight Operations (Pre-flight, departure surface operations, terminal, en route/cruise, landing, post-flight, combination)	System	Primarily En Route but operational applications supported by ADS-B have been identified across all phases of flight, except possibly pre- and post-flight. UAT is being designed to support all ADS-B applications (as defined by DO-242)
Channel data rate (digital) and/or occupied band width (analog) requirement	RF	1 Mbps
Robustness of channel and system (resistance to interference, fading, multi-path, atmospheric attenuation, weather, etc.)	RF	In general, the UHF frequency is subject to fading and multipath; UAT uses a 48-bit Reed-Solomon forward error correction (FEC) code and a 24-bit cyclic redundancy code (CRC) (acts as a 24-bit parity code) to help address this.
System integrity (probability)	System	UAT will be judged according to ADS-B standards. ADS-B integrity is defined in terms of the probability of an undetected error in an ADS-B report received by an application, given that correct source data has been supplied to the ADS-B system. ADS-B system integrity is 10–6 or better on a per report basis. Currently, the UAT worst-case overall undetected error probability for an ADS-B message is 3.7x10-11, which exceeds the minimum requirement. [Note: For UAT ADS-B messages map directly (i.e., one-to-one correspondence) to ADS-B reports (i.e., they are not segmented as they are in Mode-S ADS-B).]
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Worst-case overall undetected error probability for an UAT ADS-B message is 3.7x10-11
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	LOS. Similar to VHF: 200 nm at 30,000 feet, 80 nm at 5,000 feet. The UAT proposal is to establish a series of ground stations to provide coverage over the U.S. at low (5,000 feet) altitude.

CHARACTERISTIC	SEGMENT	DESCRIPTION
Link and channel availability	RF	Estimated at 0.99 since it will be an advisory service.
Security/ encryption capability	RF	None
Degree / level of host penetration or utilization (transport only, G/A only, combination of hosts, % penetration, etc.)	System	None. This is a new system design that is not implemented. It currently has appeal and support from the GA community who perceive it to be a lower cost and possibly improved performance alternative to other ADS-B candidate systems (i.e., Mode-S and VDL Mode 4). However, frequency allocation, product development, and standardization/certification of a final design will have to occur before the validity of this perception can be determined.
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	UAT uses both TDMA and Binary Continuous Phase Frequency Shift Keying in its signal cycle. The TDMA signal is used by the ground station for broadcast uplink. The Binary portion is used by aircraft to report position.
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	TDMA
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	UAT uses multiple access techniques: time division multiple access (TDMA) in the first portion (e.g., 188 ms) of a one second "frame" (i.e., slots to separate ground station messages from the aircraft and surface vehicle messages) and random access in the second portion (e.g., 812 ms) of the frame for ADS-B messages from aircraft and surface vehicles.
Avionics versatility (applicability to other aircraft platforms)	RF	UAT is being designed to meet ADS-B requirements. ADS-B uncompensated latency must be less than 1.2 ms or 0.4 ms depending upon the uncertainty of the position data (error [95% probable]) being used to support a particular operational application. The error is categorized according to navigation uncertainty categories (NUCs) from 1 to 9, with the higher NUCs indicating more accurate position data. The 1.2 ms requirement applies to NUCs less than 8 (i.e., 0.05 to 10 nm position error), while the 0.4 ms must be met for NUCs 8 or 9 (i.e., 3 to 10 nm error).
Equipage requirements (mandatory for IFR, optional, primary, backup, etc.)	RF	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	Avionics	UAT is a new system design being developed from scratch to meet ADS-B requirements. Therefore, since ADS-B as defined is intended to be applicable to all aircraft category types as well as surface vehicles operating in the aircraft movement area of an airport, UAT should be expected to have the avionics versatility needed to address the set of ADS-B requirements. A range of ADS-B equipage classes have been defined to accommodate the various levels of user requirements from GA to air transport
	Ground	Design information available to all vendors
	System	UAT is a new system and currently does have any standards (e.g., RTCA MOPS or ICAO SARPS).
Source documents	UAT	UAT system information was obtained from various briefings to RTCA SC-186 Plenary meetings and private Mitre correspondence. The system description is largely for an evaluation system involved in the current Safe Flight 21 tests and can be expected to change.

C.10.3 VDL Mode 4

VDL Mode 4 is a combined communication and surveillance concept. VDL Mode 4 also is termed Self-Organizing TDMA in reference to the ability of the system to mediate access to the time slots without reliance on a master ground station. With STDMA, the users can vary their channel access (number of time slots used) based on their need and the current loading of the channel. This technique makes VDL Mode 4 highly flexible and adaptable but less consistent in performance for critical functions. ICAO currently is validating the surveillance application for VDL Mode 4. Both Gaussian Filtered Frequency Shift Keying (GFSK) at 19.2 Kbps and D8PSK at 31.5KBPS have been proposed for VDL Mode 4. Recently the D8PSK Mode was removed from consideration based on superior performance by the GFSK method.

CHARACTERISTIC	SEGMENT	DESCRIPTION
System Name:		**Very High Frequency Digital Link Mode 4 (VDL Mode 4)**
Communications/link type (HF, VHF, L-Band, SATCOM, other):	RF	VHF
	Ground	Undetermined
Frequency/ Spectrum of Operations:		118-137MHz
System Bandwidth Requirement:	RF	25KHz, Since all users need to exchange information on a common channel, VDL Mode 4 will use only one frequency/channel in an area.
	Ground	Undefined
System and Channel Capacity (number of channels and channel size):	RF	VDL Mode 4 is a developmental system. This information has not been defined.
	Ground	Undefined
Direction of Communications (simplex, broadcast, half-duplex, duplex, asymmetric, etc.):	RF	Simplex - Transmission or reception on a single frequency but not simultaneously. Channel is shared using TDMA.
	Ground	Half Duplex
Method of information delivery (voice, voice recording, data, combination, etc.):	Avionics	data
	Ground	data
Data/message priority capability / designation (high, intermediate, low, etc.):	RF	ATN subnetwork expected
	Ground	Undefined - none expected
System and component redundancy requirement (1/2, 1/3, etc):	RF	none required, optional redundancy defined
	Ground	Unknown
Physical channel characteristics (LOS, OTH, etc.):	RF	Line Of Sight (LOS)
Electromagnetic interference (EMI) / compatibility characteristics:	RF	N/A
Channel data rate (digital) and/or occupied bandwidth (analog) requirement:	RF	19.2KBPS using Gaussian Filtered Frequency Shift Keying (GFSK); 31.5KBPS using D8PSK
Robustness of channel and system (resistance to interference, fading, multipath, atmospheric attenuation, weather, etc.)	RF	Will meet or exceed the requirements for VDL Mode 2 where RF is robust and resistant to interference, fading, multi-path, atmospheric attenuation, weather
System integrity (probability)	System	Undetermined (should be in range of 10^{-6})
Quality of Service Performance (via BER for digital, voice/qualitative (synthetic, toll grade, etc.)	System	Undetermined
Range/ Coverage / footprint (oceanic, global, regional / line-of-sight, etc.)	RF	Line Of Sight (180 nautical miles for aircraft at 25,000 feet) 80 nautical miles at 5,000 feet
Link and channel availability	RF	Undefined , due to surveillance requirement should meet 0.99999
Security/ encryption capability	RF	none
Degree / level of host penetration or utilization (transport only, G/A only,	System	Available to commercial, G/A, and military aircraft (will also be available aircraft to aircraft) Current users estimated as 100 GA.

CHARACTERISTIC	SEGMENT	DESCRIPTION
combination of hosts, % penetration, etc.)		
Modulation scheme (analog/digital, AM, FM, PSK, etc.)	RF	GFSK = 19.2 KBPS D8PSK = 31.5 KBPS
Access Scheme (CSMA, TDMA, SCPC, FDMA, CDMA/spread spectrum, hybrid, etc.)	RF	Self-Organizing Time Division Multiple Access (S-TDMA)
Timeliness/latency, delay requirements (real-time, end-end delay, minimal acceptable time delivery envelope, etc.)	RF	Will meet or exceed VDL Mode 2 (< 250 msec)
Avionics versatility (applicability to other aircraft platforms)	System	Will meet or exceed VDL Mode 2 (< 5 seconds)
	Avionics	N/A
Equipage Requirements	Avionics	Optional
Architecture requirements (OSA/open system architecture, proprietary hardware/software, mix, etc.) Level of integration with other aircraft avionics (independent data link, shares comm link with applications, etc.)	Ground	Mandatory for receipt and transmission of messages
	System	proprietary, patented
	Avionics	VHF equipment could be shared with other applications
Source documents		VDL Mode 4 Standards and Recommended Practices (SARPS) Draft, Version 5.4, 21 March 1997; VDL Mode 4 Acceptance Presentation, Helios Technology VDL Mode 4 CNS/ATM applications; Delivering CNS/ATM applications with VDL Mode 4

C.11 Protocols for Passenger Communications

Protocols for providing communication services to passengers are not pertinent to the NAS architecture except to the extent that the protocols facilitate or preclude using the link for ATM or AWIN. Certification requirements already include specifications regarding harmful interference.

Digital television compression techniques (Digital Video Broadcasting [DVB] group standards), broadband Internet, corporate communications, and interactivity are pushing new developments in the space segment entirely dedicated to digital data transfer. Such services are Astrolink (Lockheed Martin), Skybridge (Alcatel), and Galenos (Eutelsat). Multicasting Internet data over satellite (addressing a number of selected end users) becomes a common service. MPEG 4 and Null Packet Optimization (NPO) increase the efficiencies of data transfer.

On the other hand, the satellite industry is affected by heavy competition from the optical fiber network and is pushed out from highly populated areas. Broadcasting and global access will remain the uncontested satellite business area.

C.12 Link Considerations

C.12.1 Ground based systems

All aviation communications systems based on ground stations have limitations of coverage and range. The majority of aviation communications systems are line of sight limited. The radio frequency power available permits operation at distances up to 200 nautical miles (nm).. The curvature of the earth however, blocks the signal to aircraft unless the aircraft is at high altitude. At low altitudes such as 5,000 feet, the line of sight range is reduced to 30 nm. Mountains also block signals and reduce potential coverage. Satellites are much less limited in coverage but do become constrained by available power. A geosynchronous satellite can cover one-third of the earth but the radio frequency power will be far less than for terrestrial systems. Traditionally satellite systems have used dish antennas to increase received power. Newer satellite concepts include low earth orbit (LEO) and medium earth orbit (MEO) systems that are closer to the earth, which improves the available power while reducing the coverage for each satellite.

C.12.2 Frequency band

The aviation industry traditionally has used frequency spectrum allocated specifically to aviation applications and protected by national and international law from interference. Under international agreement, the aviation communications frequencies are limited to ATC and AOC use. Services such as entertainment and passenger communications have been prohibited. All of the VHF systems, voice DSB-AM, ACARS, VDL Mode 2, Mode 3, and Mode 4 are designed to operate within the current 25 kHz channel spacing of the 118 - 137 MHz protected VHF band.

C.12.3 General Satellite Comments

Three major configurations of satellite systems were considered. GEO systems depend on satellites in geosynchronous orbit. Usually a single satellite provides wide area coverage that is essentially constant. Coverage is not possible at the poles. MEO satellites move relative to the earth and their coverage shifts. A number of satellites are needed and earth coverage is virtually complete. A failure of a single satellite causes a short-term outage. LEO satellites move quickly relative to the earth and require numerous satellites for full earth coverage; therefore, an outage of a single satellite is short-term.

Alternatives to existing systems likely will be provided by established service provides, such as Inmarsat and Boeing, which are aggressively pursuing multimedia to the passenger with asymmetrical return link. There will be a premium charge for this type of system relative to fixed ground terminals, particularly when outside of populated areas.

Boeing already has demonstrated direct video broadcast (DVB) standard communication to the aircraft. The emerging DVB-RCS (return channel satellite) standard probably will be capable of asymmetric communication with aircraft and be available in 2007.

By 2015, EHF (Q/V) band systems operating in the 37.5-40.5 gHz and 47.2-50.2 gHz range should be available in addition to Ka-band systems. The EHF systems will have similar capabilities to Ka systems, with greater bandwidth and higher data rates, but more severe rain fade. The following table lists system characteristics based on FCC filings. Most of these EHF systems never will be fielded. None of them are likely until the Ka-band systems are saturated. It is expected at least one EHF System will be available in 2015.

Table C.12.3.-1EHF Satellite FCC Filings

			Architecture	Communications System			
Company	System Name	Service Type	NGSO (No. of planes) GSO (No. of slots)	Phased Array Antenna	On-Board Processing	Cost ($B)	Data Rates (Mbps)
CAI Satcom	N/A	FSS	1 GSO (1)	No	No	0.3	38
Denali	Pentriad	FSS & BSS	9 HEO (3 at 63.4°)	Yes	No	1.9	10 - 3875
GE Americom	GE*StarPlus	FSS	11 GSO (9)	No	Yes	3.4	1.5-155
Globalstar	GS-40	FSS	80 LEO (10 at 52°)	Yes	No	N/A	2 - 52
Hughes	Expressway	FSS	14 GSO (10)	No	No	3.9	1.5 - 155
Hughes	SpaceCast	BSS	6 GSO (4)	No	No	1.7	0.4 - 155
Hughes	StarLynx	MSS	20 MEO (4 at 55°) 4 GSO (2)	Yes	Yes	2.9	<2 portable <8 vehicle
LEO One USA	Little LEO	MSS	48 LEO (8 at 50°)	No	Yes	0.3	0.032 - 0.256
Lockheed Martin	Q/V-Band System	FSS & BSS	9 GSO (9)	Yes	Yes	4.7	0.384 - 2488
Lockheed Martin	LM-MEO	FSS	32 MEO (4 at 50°)	Yes	Yes	6.82	10.4 - 113.8
Loral	CyberPath	FSS	4 GSO (4)	Yes	Yes	1.2	0.4 - 90
Motorola	M-Star	FSS	72 LEO (12 at 47°)	Yes	No	6.2	2 - 52
OSC	OrbLink	FSS	7 MEO (1 at 0°)	No	No	0.9	10 - 1250
PanAmSat	V-Stream	FSS	12 GSO (11)	No	No	3.5	1.5 - 155
Spectrum Astro	Aster	FSS	25 GSO (5)	No	No	2.4	2 - 622
Teledesic	V-Band Supplement	FSS & BSS	72 LEO (6 at 84.7°)	Yes	Yes	1.95	10 -100 up 1000 down
TRW	Global EHF Satellite Network	FSS	15 MEO (3 at 50°) 4 GSO (4)	Yes	Yes	3.4	1.5 - 1555

GSO = Geostationary Orbit, NGSO = Non- Geostationary Orbit, MEO = Medium Earth Orbit, LEO = Low Earth Orbit
BSS = Broadcast Service Satellite, FSS = Fixed Service Satellite, MSS = Mobile Service Satellite
Note that the Cost column numbers are generally artifacts of FCC financial rules, not actual system costs.

Ka and extremely high frequency (EHF) systems are intended for fixed or slowly moving terminals, not for aviation speed terminals (path delay variation, Doppler, frequent hand-off between spot beams). Coding and other link margin features may be used to compensate for fast motion when above atmospheric degradation (rain). The GEO and MEO systems avoid oceans by not pointing spot beams there (systems with phased array antennas will be capable of pointing at oceans) and LEO systems plan to power down the satellites while over the oceans or low population areas. These issues are not technological problems; they are design choices based on business cases. To insure capability for aeronautic use, economic opportunity needs to be communicated to the system developers (business cases supporting premium charges, particularly over unpopulated areas).

C.13 Overview of Data Links for 2007 and 2015

Tables C.13-1 and C.13-2 provide an overview of the data link choices for the time periods of 2007 and 2015. These tables were developed to support Tasks 5, 6 and 7 and are based upon the information gathered in Task 9. In order to create these tables, estimates and predictions were required especially for developing systems that are not currently deployed.

By 2007, the current aeronautical SATCOM systems are expected to be at the end of their satellite service life and will be replaced by a new generation with higher bandwidth. A future Ka is predicted and represents the potential for a number of proposed systems to succeed and reach implementation. By 2015, a new generation of satellites is expected that will offer vastly broader bandwidth. The next generation could be developed in any of several frequency bands. The purpose of the table is to indicate the satellite capability potentially available for aeronautical use, not to attempt to predict the specific system or frequency band.

The VHF systems will be growing or declining based on user demand. ACARS will still be in significant use in 2007 due to aircraft equipage and can be expected to be in decline in 2015 as new aircraft and legacy aircraft retrofits cause transition to VDL Mode 2. VDL Mode 2 will grow to support user demand. The number of channels for VDL Mode 2 is limited by frequency allocation, not by technical design. VDL Mode 3 is expected to replace existing analog voice channels, approximately 400-500 of the current 760 channels in the VHF band. It is important to note that the aircraft typically can only utilize one VHF data channel at a time per system. Numerous frequencies are used to provide full ATC coverage on a non-interference basis.

Table C.13-1 Overview of Data Capacity Provided by Data Links Available in 2007

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
	kbps	Channels	Channels	Aircraft	
HFDL	1.8	2	1	50	Intended for Oceanic
ACARS	2.4	10	1	25	Will transition to VDL Mode 2
VDL Mode 2	31.5	4	1	150	Can expand if frequencies available
VDL Mode 3	31.5	Voice Only in 2007	0	N/A	
VDL Mode 4	19.2	1-2	1	500	Intended for surveillance
VDL – B	31.5	2	1	Broadcast	Intended for FIS
Mode-S	1000*	1	1	500	Intended for surveillance
UAT	1000	1	1	500	Intended for surveillance/FIS
SATCOM	10.5	6	6	200	Satellites nearing end-of-life
Future SATCOM	384	15	1	~200	Planned future satellite
Future Ka Sat	2,000	~50	~50	~200	Estimated capability - assumes capacity split for satellite beams

* The Mode-S data link is limited to a secondary, non-interference basis with the surveillance function and has a capacity of 300 bps per aircraft in track per sensor (RTCA/DO-237).

Table C.13-2 Overview of Data Capacity Provided by Data Links Available in 2015

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
	kbps	Channels	Channels	Aircraft	
HFDL	1.8	2	1	50	Intended for Oceanic
ACARS	2.4	10	1	25	ACARS should be in decline as users transition to VDL Mode 2

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
VDL Mode 2	31.5	4+	1	150	System can expand indefinitely as user demand grows
VDL Mode 3	31.5*	~300	1	60	Assumes NEXCOM will deploy to all phases of flight
VDL Mode 4	19.2	1-2	1	500	Intended for surveillance
VDL – B	31.5	2	1	Broadcast	Intended for FIS
Mode-S	1000**	1	1	500	Intended for surveillance
UAT	1000	1	1	500	Intended for surveillance/FIS
SATCOM	-	-	-	-	Assumes satellites past service life
Future SATCOM	384	15	1	~200	Planned future satellite
Future Ka Satellite	2,000	~50	~50	~200	Estimated capability - assumes capacity split for satellite beams
Fourth Generation Satellite	>100,000	>100	>100	Unknown	Based on frequency license filings

* Channel split between voice and data.
** The Mode-S data link is limited to a secondary, non-interference basis with the surveillance function and has a capacity of 300 bps per aircraft in track per sensor (RTCA/DO-237).

D Appendix D—Networks, Standards, and Protocols

D.1 Characterize Current and Near-Term Communications System Architecture—Networks, Standards, and Protocols

D.2 Task Description

The purpose of this task is to identify networks, standards and protocols used by current and near term data links identified in Appendix C and to characterize the networks, standards and protocols.

D.3 The datalinks identified in Appendix C are:

ACARS
VDL Mode 2
VDL Mode 3
VDL Mode 4
VDL-B
Mode S
UAT
Satellite (LEO)
Satellite (GEO)
HFDL

D.4 The networks to be characterized in this task are:

	Section
ACARS	D.7
ATN	D.8
Relevant ARINC/SITA Proprietary Networks	
ADNS	D.9
APN	D.10
APIN	D.11
MDNS	D.12
AOCNet	D.13

D.5 The Standards and Protocols to be characterized in this task are:

ARINC 618	D.15
ARINC 622	D.16
ARINC 623	D.17
FANS 1/A	D.18
ICAO CNS/ATM-1	D.19
ATN	D.20
TCP/IP	D.21
Frame Relay	D.22
Asynchronous Transfer Mode (ATM)	D.23

D.6 Network Description Network Standard Description

Each network listed will be characterized using the following template.

CHARACTERISTIC	DESCRIPTION
Network Name:	
Data Links Used:	Section D.6.1
Operational Domain:	Section D.6.2
User Class Participants:	Section D.6.3
Status:	Section D.6.4
Schedule:	Section D.6.5
Network Purpose:	Section D.6.6

D.6.1 Data Links

The data links identified in Appendix C are listed in Section D.3. For each network, standard, and protocol, the relevant data links are identified. A summary table of data links and networks is shown in TableD.6-1. A summary table of data link to protocols and standards is shown in Table D.6-2.

D.6.2 Operational Domains

The Operational Domains of interest for each network are the phases of operations in which it is principally used. The phases of operations are:

Pre-flight domain—activities that occur prior to aircraft movement.

Airport departure surface operations domain—activities that occur between commencement of aircraft movement and airborne departure from the end of the active runway used by the aircraft involved in the application.

Departure terminal domain—activities that occur between airborne departure from the end of the active runway and departure from terminal airspace.

En route/cruise—activities that occur between departure from terminal airspace at departure airport and entry into terminal airspace at arrival airport.

Arrival terminal domain—activities that occur between entry into terminal airspace and arrival at the threshold of the active runway to be used.

Airport arrival surface operations domain—activities that occur between airborne arrival at the threshold of the active runway and arrival at the position at which the aircraft will be parked and the flight terminated.

Post-flight domain—activities that occur after the aircraft has concluded the flight.

Network characteristics are listed below.

Table D.6-1. Networks for Identified Data Links

	NETWORK						
Datalink	ACARS	ATN	ADNS	APN	APIN	MDNS	AOCNet
ACARS			X	X		X	
VDL Mode 2	X	X	X		X	X	X
VDL Mode 3		X					
VDL Mode 4							

Datalink	ACARS	ATN	ADNS	APN	APIN	MDNS	AOCNet
	NETWORK						
VDL-B							
Mode S							
UAT							
Satellite (LEO)							
Satellite (GEO)	X			X		X	
Other—HFDL	X	X	X	X			

Table D.6-2. Protocols and Standards for Identified Data Links

Datalink	618	622	623	FANS 1A	ICAO CNS/ATM-1	ATN	TCP/IP	Frame Relay	ATM
	PROTOCOLS & STANDARDS								
ACARS	X	X	X	X					
VDL Mode 2	X	X	X		X	X	X	X	X
VDL Mode 3					X	X			
VDL Mode 4									
VDL-B									
Mode S									
UAT									
Satellite (LEO)									
Satellite (GEO)	X	X	X	X	X	X			
Other—HFDL	X	X	X	X	X	X			

D.6.3 User Class Participants

The user class participants are the nodes of the end-to-end communications paths that ride the network. The nodes are:

Air traffic services provider—Any of the entities that provide control, direction, advice, or other ATC information to the pilot/aircrew/flight deck domain or the aircraft operator management domain.

Flight services provider—Any of the entities that provide advisory information to the pilot/aircrew/flight deck domain or the aircraft operator management domain.

Pilot/aircrew/flight deck—The entities that control the movement of an aircraft through airspace and manage aircraft on-board systems.

Aircraft operator management—The entities that plan aircraft movements and provide management of operations (but not physical control of the aircraft).

D.6.4 Status

The status of each network will be characterized as either:

Conceptual—the application has been defined, but development is not yet funded and has not started. Details of the activities that led to the agreement to the data link concept should be included.

Development—the program is funded and under development. Additional information should be included to indicate the stage of development, for example, engineering development, preliminary testing, product demonstration, etc.

Operational—the data link is in service today. None of the programs listed has an operational data link today.

D.6.5 Schedule

For conceptual or developmental networks, a schedule of rollout is included, if available. For operational data links, any available schedule of upgrades or improvements are listed. Future intentions, including application termination or replacement, are listed if available.

D.6.6 Network Purpose.

The network purpose will be characterized by determining the "best fit " to the accepted list of user services and functional capabilities delineated in the following table. The "best fit" may apply to multiple "user needs" and multiple "functional capabilities."

User Services	Functional Capabilities
Flight Plan Services	• File flight plans and amendments
	• Process flight plans and amendments
	• Provide information for flight plans
ATC Separation Assurance Services	• Separate IFR aircraft
	• Avoid potential hazards and collisions
	• Maintain minimum distance from special use airspace (SUA)
	• Monitor flight progress
	• Hand-off to controller—sector—facility
ATC Advisory Services	• Provide in-flight or pre-flight weather advisories
	• Provide in-flight or pre-flight traffic advisories
	• Provide in-flight NAS status advisories
Tactical Traffic Management Services	• Provide in-flight sequencing, spacing, and routing restrictions
	• Provide pre-flight runway, taxi sequence, and movement restrictions
	• Project aircraft in-flight position and potential conflicts
	• Process user preferences
Strategic Traffic Management Services	• Provide future NAS traffic projections
	• Collaborate with users on NAS projections and user preferences
	• Monitor NAS traffic status
	• Assess NAS traffic performance
Emergency and Alerting Services	• Provide emergency assistance and alerts
	• Support search and rescue (SAR)
Navigation Services	• Provide airborne navigation guidance
	• Provide surface navigation guidance
Surveillance Services	• Provide aircraft position/ID
	• Provide aircraft intent, state, and performance
Airspace Management Services	• Manage design and use of NAS airspace
	• Manage use of SUA
NAS Support Services	• Monitor and maintain NAS infrastructure
	• Manage aviation spectrum for U.S. aviation community
On-board Services	• Provide administrative flight information
	• Provide in-flight entertainment
	• Provide public communications

D.7 Aircraft Communications Addressing and Reporting System (ACARS)

CHARACTERISTIC	DESCRIPTION
Network Name:	**Aircraft Communications Addressing and Reporting System (ACARS)**
Data Links Used:	ACARS is described as both a data link and a network
Operational Domain:	Pre-flight domain Airport departure surface operations domain Departure terminal domain En route/cruise Arrival terminal domain Airport arrival surface operations domain Post-flight domain
User Class Participants:	air traffic services provider flight services provider domain pilot/aircrew/flight deck aircraft operator management
Status:	Operational
Schedule:	N/A
Network Purpose:	Flight Plan Services—Provide information for flight plans; ATC Separation Assurance Services—Avoid potential hazards and collisions; Monitor flight progress ATC Advisory Services—Provide in-flight or pre-flight weather advisories; Provide in-flight NAS status advisories Surveillance Services—Provide aircraft position/ID On-board Services—Provide administrative flight information

D.8 Aeronautical Telecommunication Network (ATN)

CHARACTERISTIC	DESCRIPTION
Network Name:	**Aeronautical Telecommunication Network (ATN)**
Data Links Used:	VDL Mode 2, VDL Mode 3, VDL Mode A
Operational Domain:	Pre-flight domain Airport departure surface operations domain – Departure terminal domain En route/cruise Arrival terminal domain – Airport arrival surface operations domain – Post-flight domain –
User Class Participants:	air traffic services provider flight services provider pilot/aircrew/flight deck aircraft operator management
Status:	Developmental
Schedule:	First implementation 2002 for Controller Pilot Data Link Communications (CPDLC)/VDL Mode 2

CHARACTERISTIC	DESCRIPTION
Network Purpose:	Flight Plan Services—File flight plans and amendments; Process flight plans and amendments; Provide information for flight plans ATC Separation Assurance Services—Separate IFR aircraft; Avoid potential hazards and collisions; Maintain minimum distance from special use airspace (SUA); Monitor flight progress; Hand-off to controller—sector—facility; ATC Advisory Services—Provide in-flight or pre-flight weather advisories; Provide in-flight or pre-flight traffic advisories; Provide in-flight NAS status advisories Tactical Traffic Management Services—Provide in-flight sequencing, spacing, and routing restrictions; Provide pre-flight runway, taxi sequence, and movement restrictions; Project aircraft in-flight position and potential conflicts; Process user preferences Strategic Traffic Management Services—Provide future NAS traffic projections; Collaborate with users on NAS projections and user preferences; Monitor NAS traffic status; Assess NAS traffic performance Emergency and Alerting Services—Provide emergency assistance and alerts; Support search and rescue (SAR) Navigation Services—Provide airborne navigation guidance; Provide surface navigation guidance Surveillance Services—Provide aircraft position/ID; Provide aircraft intent, state, and performance Airspace Management Services—Manage design and use of NAS airspace; Manage use of SUA NAS Support Services—Monitor and maintain NAS infrastructure; Manage aviation spectrum for U.S. aviation community On-board Services—Provide administrative flight information; Provide in-flight entertainment; Provide public communications

D.9 ARINC Data Network Service (ADNS)

CHARACTERISTIC	DESCRIPTION
Network Name:	**ARINC Data Network Service (ADNS)**
Data Links Used:	Aircraft Communications Addressing and Reporting Service (ACARS) and VDL Mode 2
Operational Domain:	Ground-Ground, message switching network
User Class Participants:	Primarily AOC traffic for airlines, some ATC—serves as a data transport network for ACARS. Functionally equivalent to FAA NADIN Message Switch Network
Status:	Mature, fully deployed
Schedule:	N/A
Network Purpose:	Flight Plan Services—File flight plans and amendments; Process flight plans and amendments; Provide information for flight plans

D.10 ARINC Packet Network (APN)

CHARACTERISTIC	DESCRIPTION
Network Name:	**ARINC Packet Network (APN)**
Data Links Used:	Aircraft Communications Addressing and Reporting Service (ACARS)
Operational Domain:	Ground-Ground, X.25 packet switching network
User Class Participants:	Primarily AOC traffic for airlines, some ATC—serves as a data transport network for ACARS and ADNS. Functionally equivalent to FAA's NADIN Packet Switch Network
Status:	Mature, fully deployed
Schedule:	N/A
Network Purpose:	Flight Plan Services—File flight plans and amendments; Process flight plans and amendments; Provide information for flight plans

D.11 ARINC Private IP Network (APIN)

CHARACTERISTIC	DESCRIPTION
Network Name:	**ARINC Private IP Network (APIN)**
Data Links Used:	VDL Mode 2
Operational Domain:	Ground-Ground, internet data network
User Class Participants:	Primarily Air Traffic Management information between airlines and FAA (see AOCNet)
Status:	Deployed, expanding
Schedule:	N/A
Network Purpose:	Flight Plan Services—File flight plans and amendments; Process flight plans and amendments; Provide information for flight plans

D.12 Managed Data Network Services (MDNS)

CHARACTERISTIC	DESCRIPTION
Network Name:	**Managed Data Network Services (MDNS)**
Data Links Used:	ACARS; VDL Mode 2
Operational Domain:	Ground-Ground, SITA refers to all of its services under the name MDNS, therefore it is functionally equivalent to ADNS, and APN.
User Class Participants:	Air traffic services provider Flight services provider Pilot/aircrew/flight deck Aircraft operator management
Status:	Deployed
Schedule:	N/A
Network Purpose:	Flight Plan Services—File flight plans and amendments; Process flight plans and amendments; Provide information for flight plans

D.13 Proprietary AOCNet

CHARACTERISTIC	DESCRIPTION
Network Name:	**Proprietary AOCNet**
Data Links Used:	VDL Mode 2
Operational Domain:	Pre-flight, airport departure surface operations, en route/cruise, airport arrival surface operations, post-flight domain. AOCNet is a private IP (internetwork protocol) implementation for exchange of collaborative decision making information between the airlines and FAA. Security features are provided through firewall implementations
User Class Participants:	Air traffic services provider Flight services provider Pilot/aircrew/flight deck Aircraft operator management
Status:	Operational
Schedule:	N/A

CHARACTERISTIC	DESCRIPTION
Network Purpose:	Flight Plan Services—File flight plans and amendments; Process flight plans and amendments; Provide information for flight plans ATC Separation Assurance Services—Monitor flight progress ATC Advisory Services—Provide in-flight or pre-flight weather advisories; Provide in-flight or pre-flight traffic advisories; Provide in-flight NAS status advisories Tactical Traffic Management Services—Provide pre-flight runway, taxi sequence, and movement restrictions; Process user preferences Strategic Traffic Management Services—Provide future NAS traffic projections; Collaborate with users on NAS projections and user preferences; Monitor NAS traffic status; Assess NAS traffic performance Airspace Management Services—Manage design and use of NAS airspace; Manage use of SUA NAS Support Services—Monitor and maintain NAS infrastructure; On-board Services—Provide administrative flight information

D.14 Characterization of Standards and Protocols

Standards and protocols will be characterized using the following template.

CHARACTERISTIC	DESCRIPTION
Standard/Protocol Name:	
Purpose:	Section D.14.1
Governing Bodies:	Section D.14.2
Operational Domain:	Section D.14.3
User Class Participants:	Section D.14.4
Status:	Section D.14.5
Schedule:	Section D.14.6

D.14.1 Standard/Protocol Purpose

Standards and protocols are industry or governmental specifications established to allow consistent implementation and compatibility. Standards may be applied to many aspects of system design and operation. The characterization in this section provides details on what aspects are standardized and under what conditions.

D.14.2 Governing Bodies

The governing bodies for a standard or protocol are those organizations having configuration management over the item, and those bodies through which changes are proposed, negotiated, and approved. The organizations which govern the standards and protocols include U.S. national organization, international organizations, and industry organizations.

D.14.3 Operational Domain

To characterize a standard/protocol, operational domain is the type of communications involved; air-to ground, ground-to-air, ground-to-ground; and the purpose of communications; operational ATC, operational FIS, administrative.

D.14.4 User Class Participants

The user class participants are the interests served by the networks using the protocols and standards are identified. They include airspace users and providers, such as pilots, controllers, and dispatchers, as well as network service providers.

D.14.5 Status

The discussion of the status of each standard or protocol should include degree of conformance within the aviation community, and proposed changes and their status.

D.14.6 Schedule

If there is any implementation of any network or system involved with the standard or protocol, such information should be included.

D.15 ARINC Specification 618, Air/Ground Character-Oriented Protocol Specification

CHARACTERISTIC	DESCRIPTION
Standard/Protocol Name:	**ARINC Specification 618, Air/Ground Character-Oriented Protocol Specification**
Purpose:	Provides the provisions for air to ground communications between aircraft and ground stations operating in an ACARS network. The protocol defines the message protocol including priorities and multiblock handling, message block formats, and character definitions.
Governing Bodies:	Airlines Electronic Engineering Committee (AEEC
Operational Domain:	Air-to-ground, ground-to-air, primarily AOC, some ATC applications
User Class Participants:	Pilots, dispatch controllers, ATC controllers
Status:	Mature
Schedule:	None, updates promulgated as needed

D.16 ARINC Specification 622, ATS Data Link Applications Over ACARS Air-Ground Network

CHARACTERISTIC	DESCRIPTION
Standard/Protocol Name:	**ARINC Specification 622, ATS Data Link Applications Over ACARS Air-Ground Network**
Purpose:	Defines the bit-oriented message formats and procedures for applications using ACARS as a transmission media. The protocol defines formatting and addressing, CRC integrity check, Bit-to Hex conversion, and the ATS Facilities Notification (AFN) process.
Governing Bodies:	Airlines Electronic Engineering Committee (AEEC)
Operational Domain:	Air-to-ground, ground-to-air, primarily Air Traffic Service (ATS) applications
User Class Participants:	Pilots, dispatch controllers, ATC controllers
Status:	Mature
Schedule:	None, updates promulgated as needed

D.17 ARINC Specification 623, Character-Oriented Air Traffic Service (ATS) Applications

CHARACTERISTIC	DESCRIPTION
Standard/Protocol Name:	**ARINC Specification 623, Character-Oriented Air Traffic Service (ATS) Applications**
Purpose:	Defines the application text formats for character-oriented Air Traffic Services messages to be transmitted over ACARS networks. Functions include CRC integrity check and addressing to ATS facilities.
Governing Bodies:	Airlines Electronic Engineering Committee (AEEC)
Operational Domain:	Air-to-ground, ground-to-air, primarily Air Traffic Service (ATS) applications
User Class Participants:	Pilots, dispatch controllers, ATC controllers
Status:	Mature
Schedule:	None, updates promulgated as needed

D.18 FANS 1/A (Future Air Navigation System 1/A)

CHARACTERISTIC	DESCRIPTION
Standard/Protocol Name:	**FANS 1/A (Future Air Navigation System 1/A)**
Purpose:	A specific collection of ATS applications provided via ACARS networks to support Oceanic air/ground communications. The applications are ATS Facilities Notification (AFN), Automatic Dependent Surveillance (ADS), and Controller-Pilot Data Link Communications (CPDLC). FANS 1/A can be used over VHF, Satellite or any other media.
Governing Bodies:	International Civil Aviation Organization (ICAO)
Operational Domain:	Oceanic air-to-ground ATC
User Class Participants:	Pilots, Controllers
Status:	Established for VHF and Satellite media; extension to HF media is being planned
Schedule:	Operational

D.19 ICAO CNS/ATM-1 (Communications, Navigation, and Surveillance/Air Traffic Management)

CHARACTERISTIC	DESCRIPTION
Standard/Protocol Name:	**ICAO CNS/ATM-1 (Communications, Navigation, and Surveillance/Air Traffic Management) (An informal term for the first implementation of ATN, not officially recognized.)**
Purpose:	Initial implementation for CPDCC, AFN, and ADS (see ATN).
Governing Bodies:	International Civil Aviation Organization (ICAO)
Operational Domain:	Pre-flight domain Airport departure surface operations domain – Departure terminal domain En route/cruise Arrival terminal domain – Airport arrival surface operations domain – Post-flight domain –
User Class Participants:	Air traffic controllers and pilots
Status:	Under development in both Europe and United States
Schedule:	Estimated as 2003 for CPDLC

D.20 Aeronautical Telecommunication Network (ATN)

CHARACTERISTIC	DESCRIPTION
Standard/Protocol Name:	**Aeronautical Telecommunication Network (ATN)**
Purpose:	To provide seamless, integrated air/ground and ground/ground communications services for ATC applications worldwide. Initial applications are AFN, ADS and CPDLC.
Governing Bodies:	International Civil Aviation Organization (ICAO)
Operational Domain:	Pre-flight domain Airport departure surface operations domain – Departure terminal domain En route/cruise Arrival terminal domain – Airport arrival surface operations domain – Post-flight domain –
User Class Participants:	Air traffic controllers and pilots
Status:	Under development in both Europe and United States
Schedule:	Estimated as 2003 for CPDLC

D.21 Transmission Control Protocol/Internet Protocol (TCP/IP)

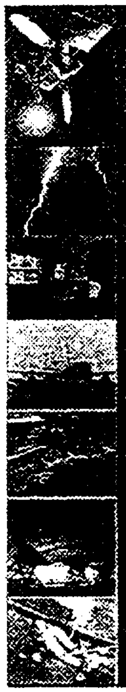
CHARACTERISTIC	DESCRIPTION
Standard/Protocol Name:	**Transmission Control Protocol/Internet Protocol (TCP/IP)**
Purpose:	TCP/IP provides ground-ground communications services. Its functions include routing, addressing, end-to-end data integrity, flow, and congestion control.
Governing Bodies:	TCP/IP is a de facto standard without formal government or standards organization support. The Internet Engineering Task Force is a member organization that provides user guidance.
Operational Domain:	Ground-ground networks, applicable to all information types
User Class Participants:	All; TCP/IP is a generic protocol that could support all user classes
Status:	A mature protocol widely deployed in commercial networks and currently being used by VDL Mode 2
Schedule:	N/A

D.22 Frame Relay

CHARACTERISTIC	DESCRIPTION
Standard/Protocol Name:	**Frame Relay**
Purpose:	High-speed data transmission of variable length data. Frame relay maximizes transmission efficiency by minimizing services. It does not provide protocol conversions, error checking, lost packet notification, or packet segmentation. Those functions are allocated to the higher-level protocol layers using the frame relay service. Latency of data can vary with loading. Commonly used with X.25 protocol.
Governing Bodies:	American National Standards Institute (ANSI) and International Telecommunications Union—Telecommunications (ITU-T)
Operational Domain:	Ground-ground networks
User Class Participants:	networks supporting non-real time applications with appropriate error correcting functionality
Status:	Commercially available, currently being implemented in aviation industry networks.
Schedule:	N/A

D.23 Asynchronous Transfer Mode (ATM)

CHARACTERISTIC	DESCRIPTION
Standard/Protocol Name:	**Asynchronous Transfer Mode (ATM)**
Purpose:	Very high-speed transmission protocol. ATM is closely related to Frame Relay. ATM achieves higher speed than Frame Relay by using fixed length (53 bit) cells. Data integrity is limited to header information to improve message delivery accuracy. Quality of Service (QOS) features are available to guarantee a constant bit rate in order to achieve latency and other performance requirements. ATM can carry any form of data, including voice, and is closely associated with Synchronous Optical Network (SONET) fiber optic networks.
Governing Bodies:	American National Standards Institute (ANSI) and International Telecommunication Union–Telecommunication (ITU-T)
Operational Domain:	Ground-ground communications.
User Class Participants:	All, ATM is expected to be a common backbone method that will carry all forms of data.
Status:	Emerging. Although in common use in commercial fiber optic networks, few aviation industry applications require the high bandwidth.
Schedule:	Not applicable



AATT TO 24

Communications System Architecture Development

for

Air Traffic Management and Aviation Weather Information Dissemination

May, 2000

AATT TO24
SAIC Team

Agenda

- →Task Overview
- →Requirements Collection
- →Candidate Architecture Concepts
- →Functional Architecture
- →Current/Near Term Link Definition
- →Communication Load Analysis
- →Architecture Alternatives
- →Transition Schedules
- →Gap Discussion
- →Summary

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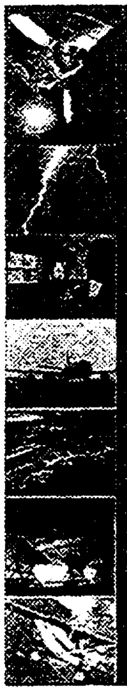
2



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NASA Ames
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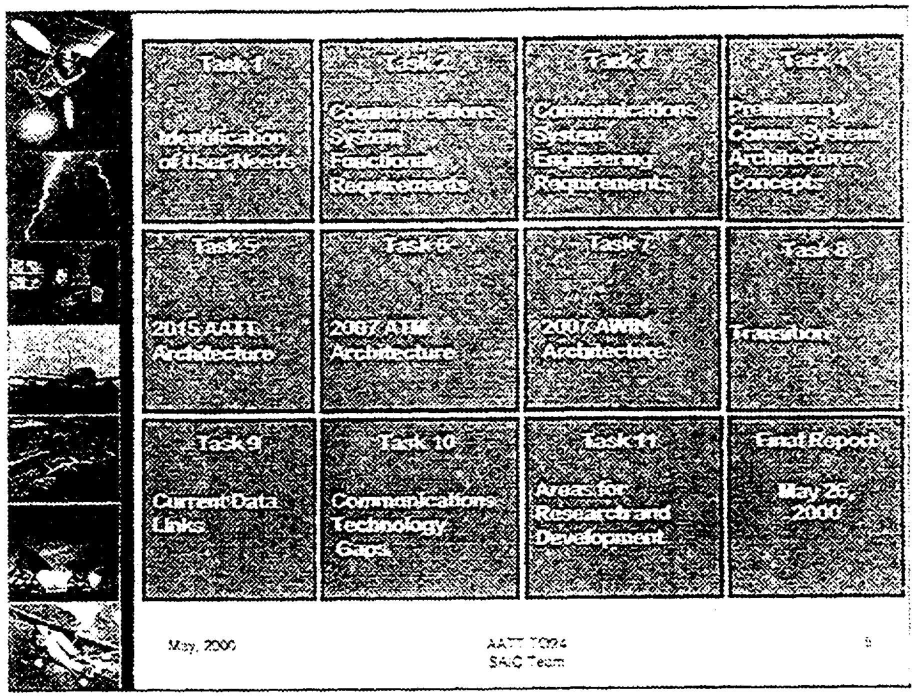
Task 1
Identification of User Needs
Task 2
Communications System Functional Requirements
Task 3
Communications System Engineering Requirements
Task 4
Preliminary Comm. System Architecture Concepts
Task 5
2015 AATT Architecture
Task 6
2007 ATM Architecture
Task 7
2007 AWIN Architecture
Task 8
Transition
Task 9
Current Data Links
Task 10
Communications Technology Gaps
Task 11
Areas for Research and Development
Final Report
May 26, 2000
May, 2000
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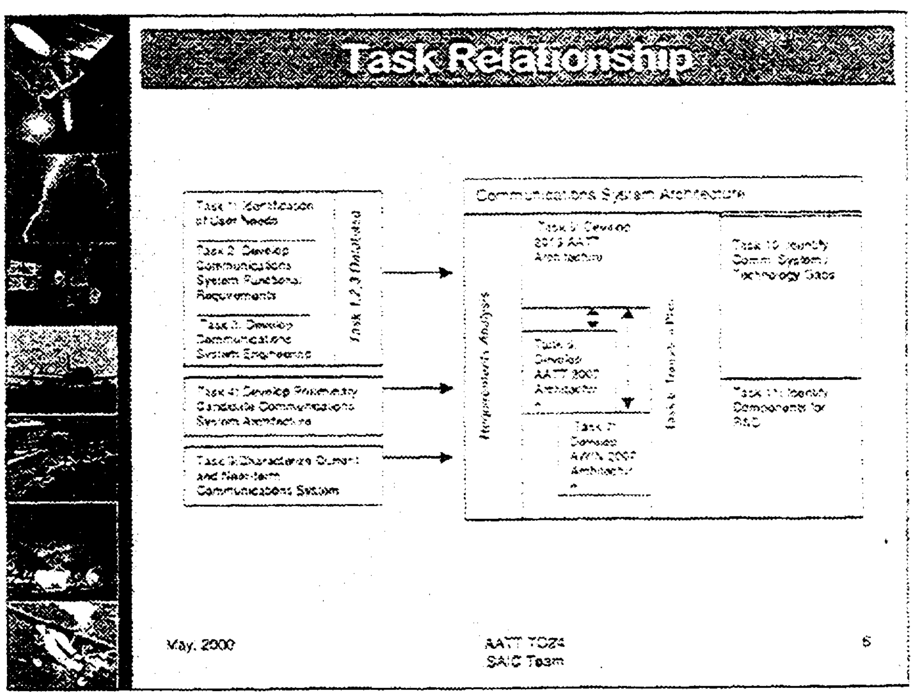
Task Relationship
Communications System Architecture
Task 2: Develop Communications System Functional Requirements
Task 1,2,3 Database
Requirements Analysis
Task 4: Develop Preliminary Candidate Communications System Architecture
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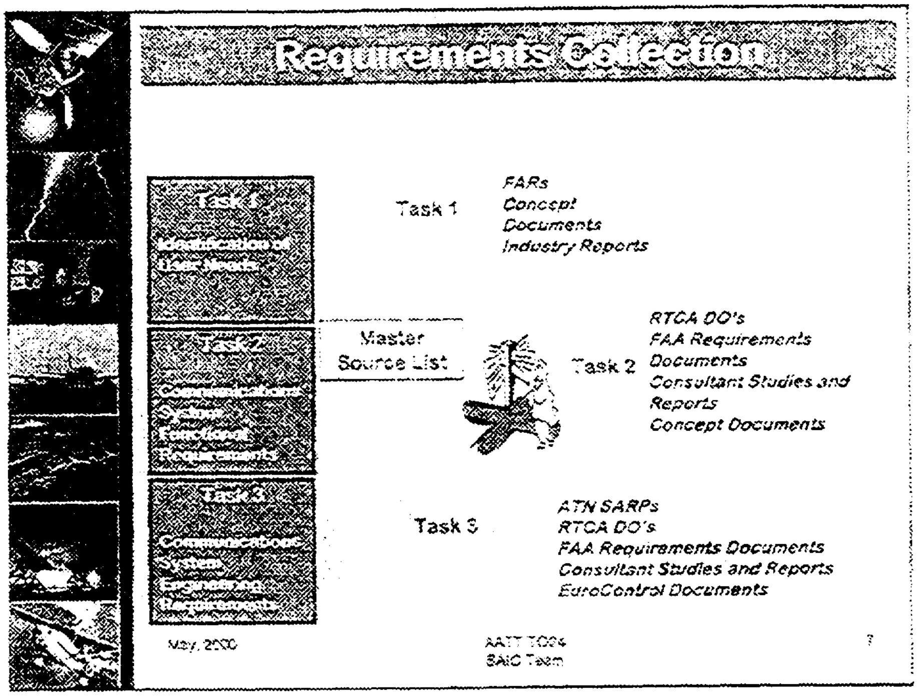
3


Requirements Collection
Task 1
Identification of User Needs
Task 2
Communications System Functional Requirements
Task 3
Communications System Engineering Requirements
Task 1
FARs
Concept Documents
Industry Reports
Master Source List
Task 2
RTCA DO's
FAA Requirements Documents
Consultant Studies and Reports
Concept Documents
Task 3
ATN SARPs
RTCA DO's
FAA Requirements Documents
Consultant Studies and Reports
EuroControl Documents
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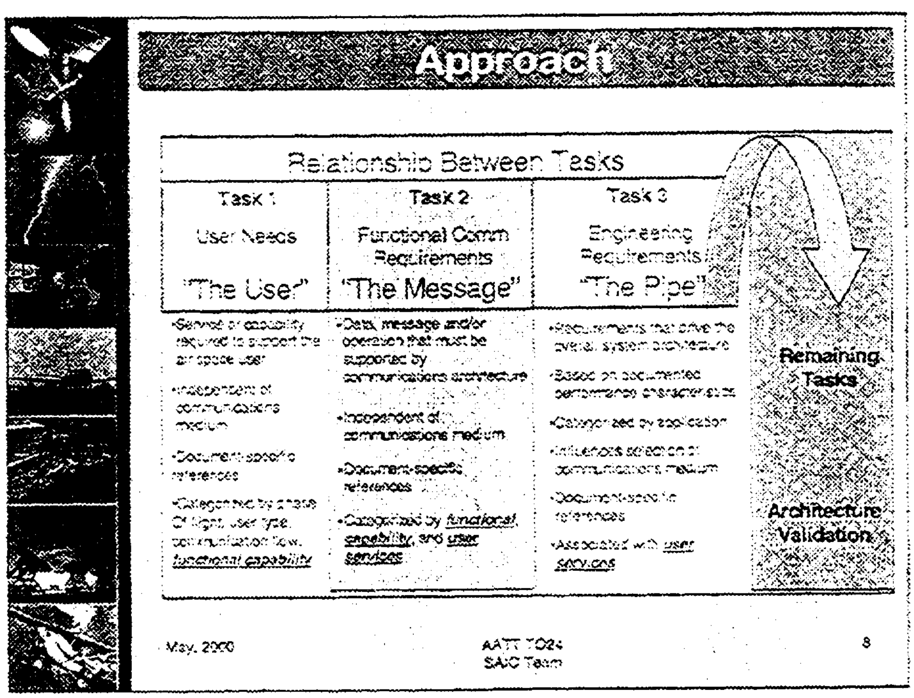
Approach
Relationship Between Tasks
Task 1
User Needs
"The User"
Task 2
Functional Comm Requirements
"The Message"
Task 3
Engineering Requirements
"The Pipe"
•Data, message and/or operation that must be supported by communications architecture
•Independent of communications medium
•Document-specific references
•Categorized by functional capability, and user services
•Categorized by application
•Associated with user services
Remaining Tasks
Architecture Validation
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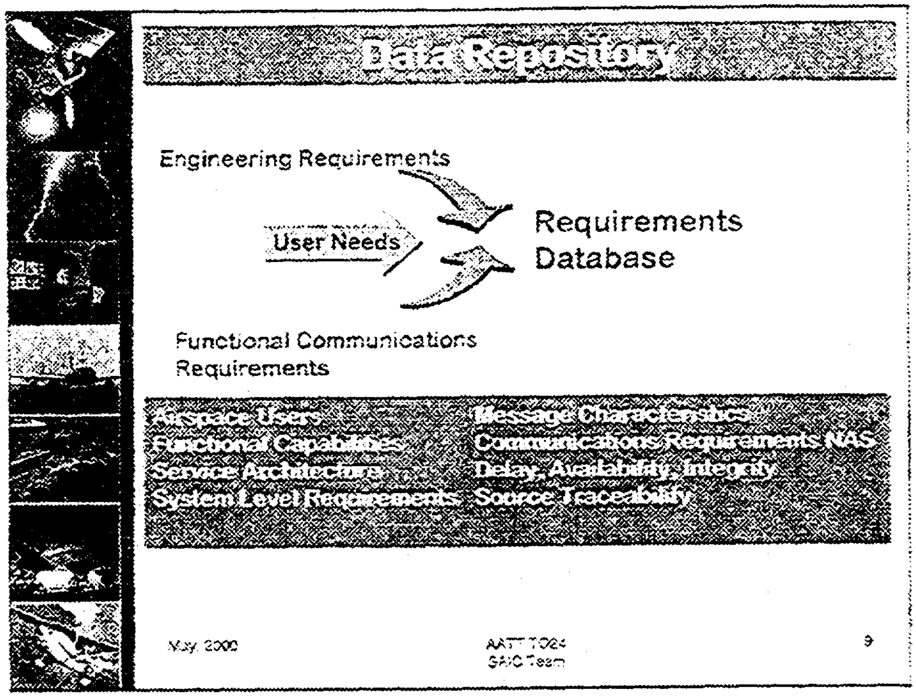

Data Repository
Engineering Requirements
User Needs
Requirements Database
Functional Communications Requirements
Airspace Users
Functional Capabilities
Service Architecture
System Level Requirements
Message Characteristics
Communications Requirements NAS
Delay, Availability, Integrity
Source Traceability
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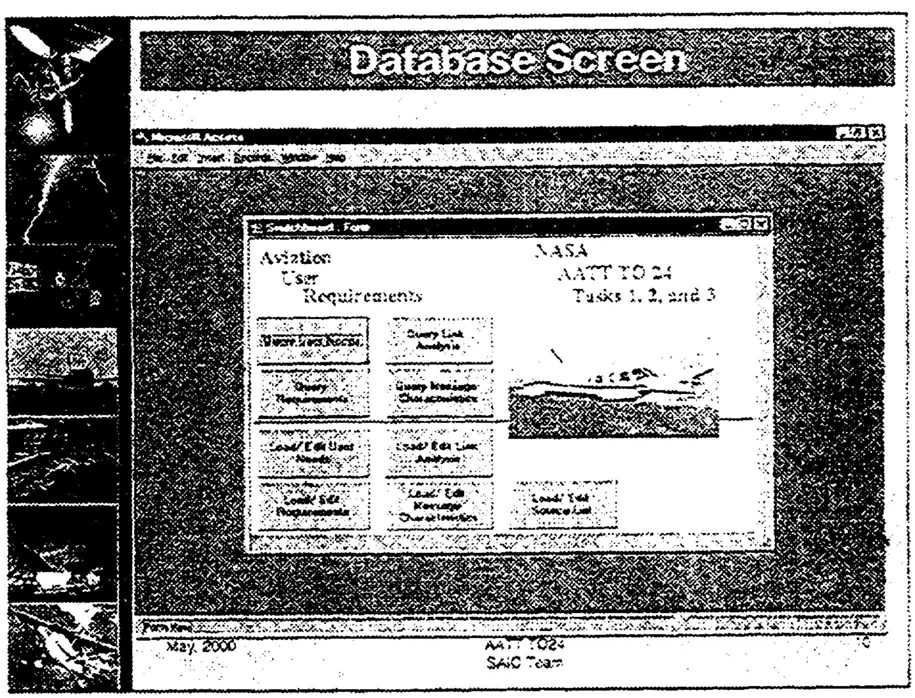

Database Screen
Aviation User Requirements
NASA AATT TO 24 Tasks 1, 2, and 3
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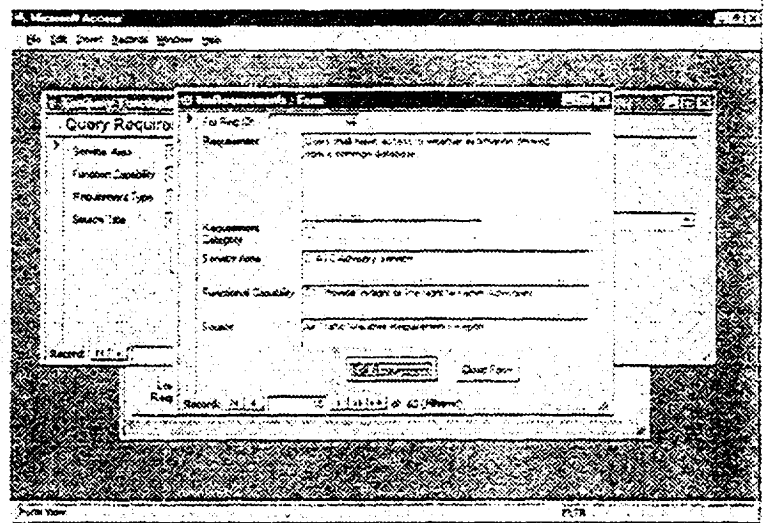
User Friendly Forms



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Task 4
Preliminary Candidate Comm. System Architecture Concepts

Task 4 developed a common base for architecture concepts.

Mature to Present (Top Down)
Benefits Driven (Based on Equipage)
Evolutionary Path
Architecture Selection Challenges

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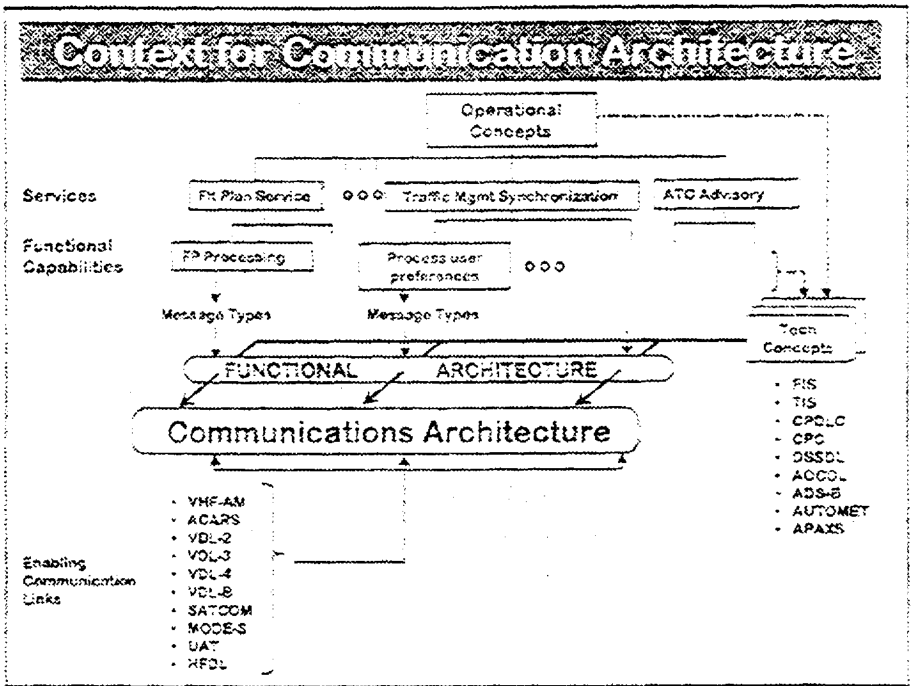
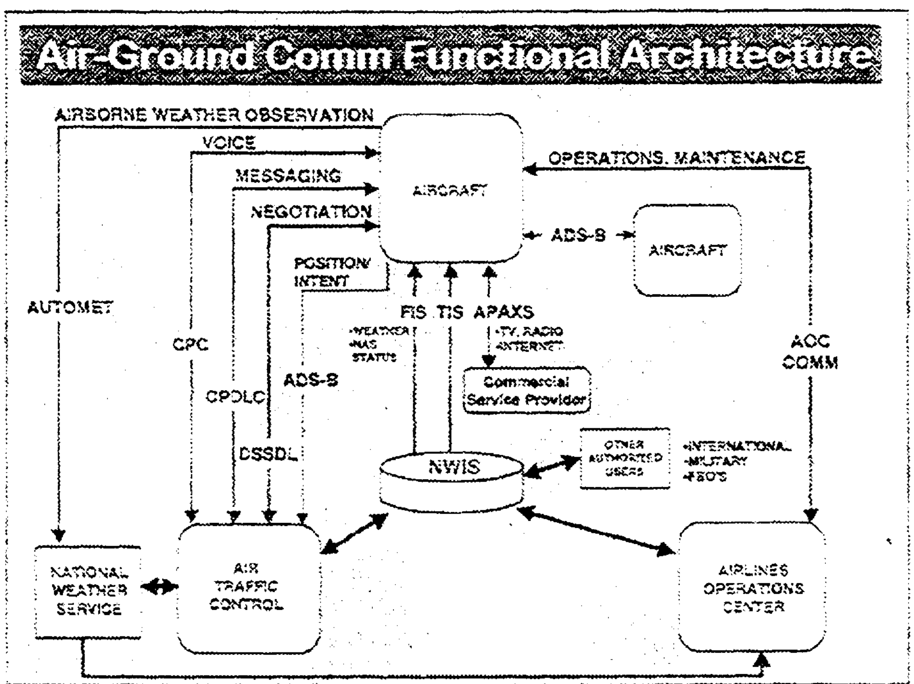
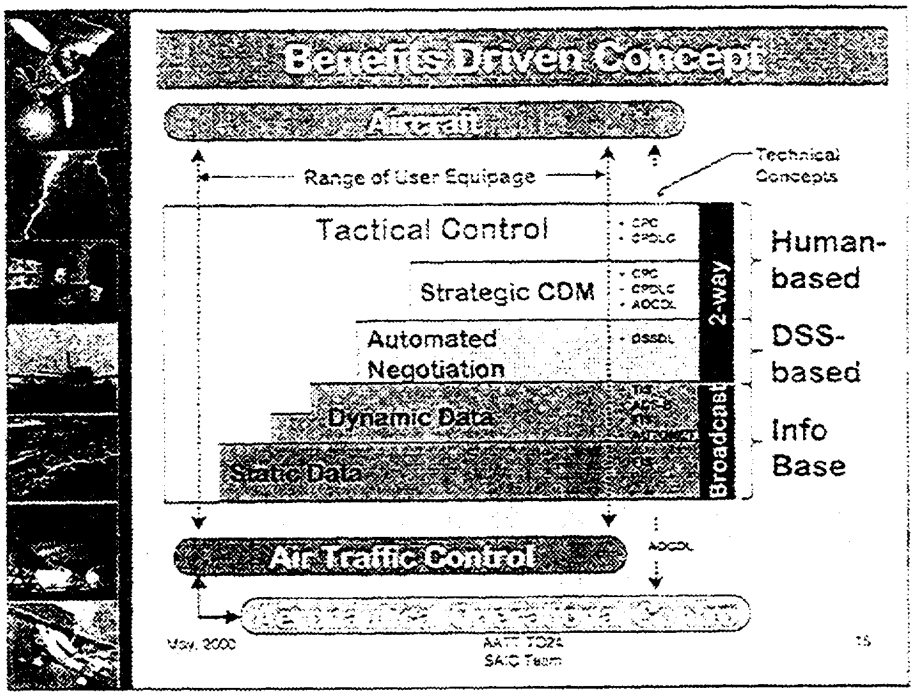
5


Context for Communication Architecture
Operational Concepts
Services
Flt Plan Service
Traffic Mgmt Synchronization
ATC Advisory
Functional Capabilities
FP Processing
Process user preferences
Message Types
Message Types
Tech Concepts
FUNCTIONAL ARCHITECTURE
Communications Architecture
FIS
TIS
CPDLC
CPC
DSSDL
AOCDL
ADS-B
AUTOMET
APAXS
Enabling Communication Links
VHF-AM
ACARS
VDL-2
VDL-3
VDL-4
VDL-B
SATCOM
MODE-S
UAT
HFDL


Air-Ground Comm Functional Architecture
AIRBORNE WEATHER OBSERVATION
VOICE
MESSAGING
NEGOTIATION
AIRCRAFT
OPERATIONS, MAINTENANCE
ADS-B
AIRCRAFT
POSITION/ INTENT
FIS TIS APAXS
AUTOMET
CPC
CPDLC
ADS-B
DSSDL
AOC COMM
Commercial Service Provider
NWIS
OTHER AUTHORIZED USERS
NATIONAL WEATHER SERVICE
AIR TRAFFIC CONTROL
AIRLINES OPERATIONS CENTER


Benefits Driven Concept
Aircraft
Range of User Equipage
Technical Concepts
Tactical Control
Strategic CDM
Automated Negotiation
Dynamic Data
Static Data
2-way
Broadcast
Human-based
DSS-based
Info Base
Air Traffic Control
AOCDL
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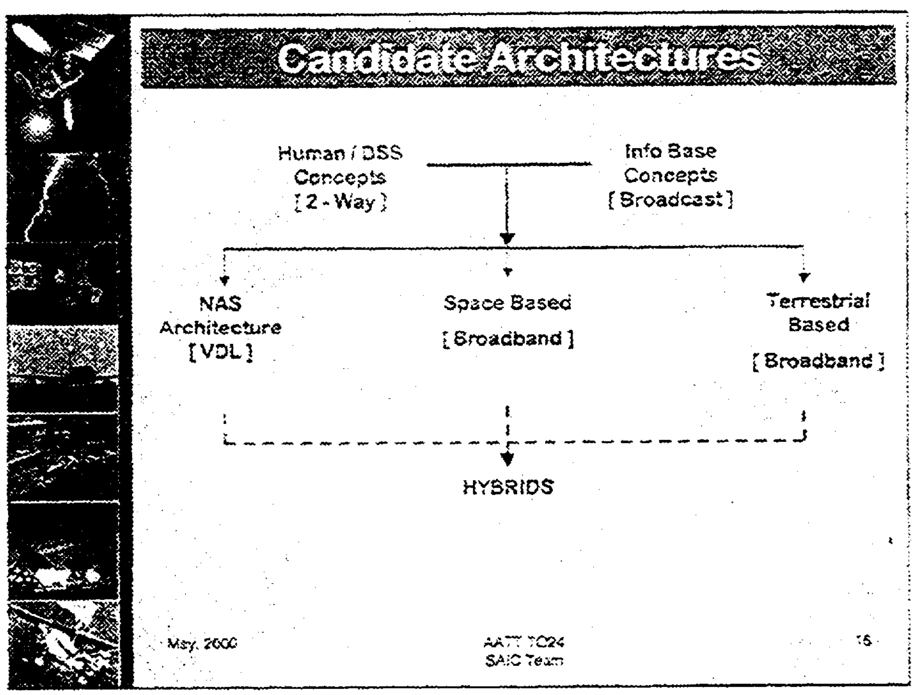
15


Candidate Architectures
Human / DSS Concepts [2 - Way]
Info Base Concepts [Broadcast]
NAS Architecture [VDL]
Space Based [Broadband]
Terrestrial Based [Broadband]
HYBRIDS
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8

Architecture Selection Drivers

- VDL - Planned Network
- Broadband
  - Space - Commercial Cabin Services
  - Terrestrial - ADS-B Link Decision
- Hybrid - Cost / Schedule / Performance Trades

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Architecture Selection Challenges

- Conflicting Report Data - contributes to load estimate uncertainty
  - Air Traffic forecasts
  - Message definition, size, and frequency
- Selection of Hybrid Architecture should be driven by Cost, Schedule, or Performance considerations
  - Cost not a consideration for this task
  - 2007 Schedule not a driver - given no cost constraints
  - Performance - function of a selected link - many unknowns
    - ADS-B link decision - can have major impact on architecture selection
    - SATCOM implementation - driven by commercial cabin services (could lead to class 1 Avionics cost/performance issues)
    - FIS-B implementation - commercial design implementation can drive overall architecture

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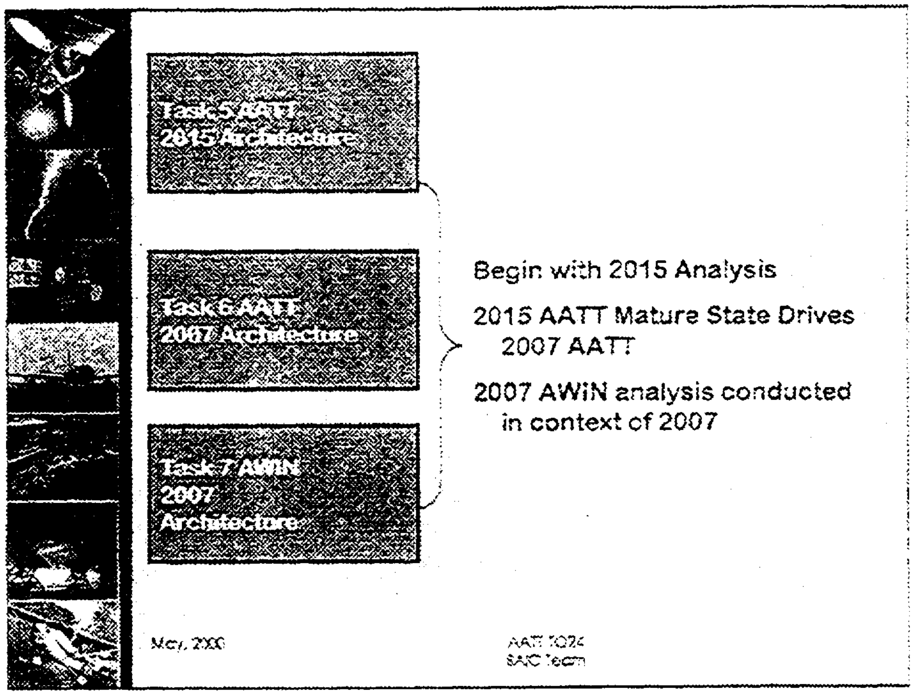
9


Task 5 AATT
2015 Architecture
Task 6 AATT
2007 Architecture
Task 7 AWIN
2007
Architecture
Begin with 2015 Analysis
2015 AATT Mature State Drives 2007 AATT
2007 AWIN analysis conducted in context of 2007
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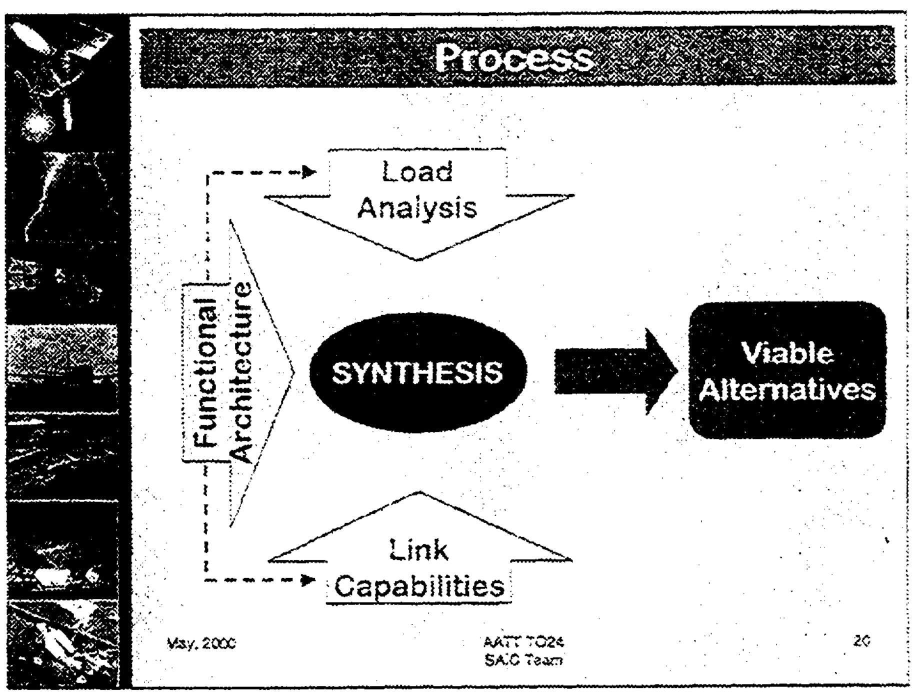
Process
Load Analysis
Functional Architecture
SYNTHESIS
Viable Alternatives
Link Capabilities
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10

Functional Analysis

- 9 Technical Concepts
- Defined Message categories and message types for each Technical Concept
- Concept Description
- Concept Diagram

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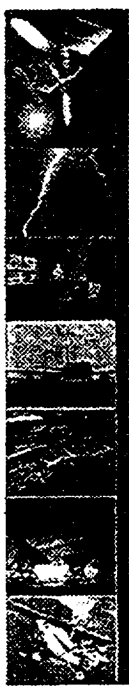

Operational Concept - Tech Concept

Operational Concept	Technical Concept
Aircraft continuously receive Flight Information to enable common situational awareness	Flight Information Services (FIS)
Aircraft continuously receive Traffic Information to enable common situational awareness	Traffic Information Services (TIS)
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	Controller-Pilot Data Link Communications (CPDLC)
Controller - Pilot voice communication	Controller Pilot Communications (CPC)
Aircraft exchange performance / preference data with ATC to optimize decision support	Decision Support System Data Link (DSSDL)
Aircraft continuously broadcast their position and intent to enable optimum maneuvering	Automated Dependent Surveillance Broadcast (ADS-B)
Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance	Airline Operational Control Data Link (AOCDL)
Aircraft report airborne weather to improve weather nowcasting/forecasting	Automated Meteorological Transmission (AUTOMET)
Passengers enjoy in-flight television, radio, internet, and entertainment service	Aeronautical Passenger Services (APAXS)

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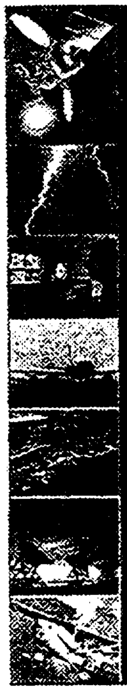

Message Categories

TECHNICAL CONCEPT	Msg Category #	MESSAGE CATEGORY	MESSAGE CONTENT
Flight Information Services (FIS)	1	Flight Information	Dynamic NAS status data and weather data
Traffic Information Services (TIS)	2	Traffic Information	Real time aircraft position data including trajectory information provided by ATC
Controller-Pilot Data Link Communications (CPDLC)	3	Controller ↔ Pilot Messaging	Clearances, Flight Plan Modifications, and Advisories
Controller-Pilot Communications (CPC)	4	Controller ↔ Pilot Voice	Clearances, Flight Plan Modifications, and Advisories
Decision Support System Data Link (DSSDL)	5	Aircraft ↔ ATC Messaging	Aircraft performance / preference
Airline Operational Control Data Link (AOCDL)	6	Aircraft↔AOC Messaging	Air carrier fleet management operations and maintenance
Automatic Dependent Surveillance-Broadcast (ADS-B)	7	ADS Reporting	Aircraft continuously broadcast their position and intent
Automated Meteorological Transmission (AUTOMET)	8	Aircraft Weather Reporting	Aircraft report airborne weather (wind velocity/magnitude, temperature, humidity)
Aeronautical Passenger Services (APAXS)	9	Passenger Services	In-flight television, radio, and entertainment services, including internet services

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Concept Description - Flight Information Service

- Aircraft continually receive dynamic Flight Information to enable common situational awareness
  - Weather Information
  - NAS Status
  - NAS Traffic Flow Status

Note: We assume that static data will be loaded on aircraft via portable storage media prior to flight.

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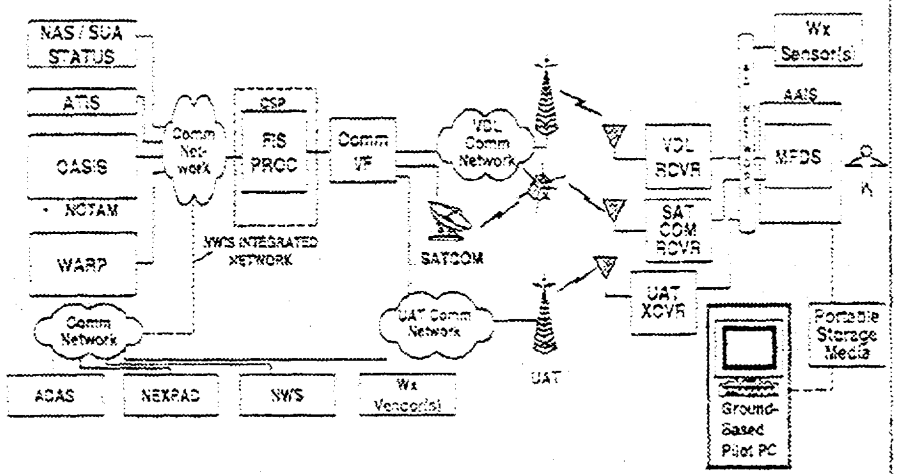
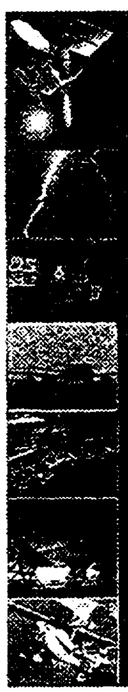
12

2015 Flight Information Service - FIS

Ground Systems Air / Ground Comm Aircraft





Concept Description - Traffic Information Service

- Aircraft continually receive dynamic Traffic Information data to enable common situational awareness (air, ground)
  - Traffic Information combined with air-air ADS-B data and displayed on CDTI
    - Tactical Maneuvering - close proximity traffic
    - Strategic Trajectory Planning
- Real time aircraft position data received by ATC from the ground-based surveillance sensor network.
  - ATC combines received aircraft position data with trajectory and intent data and then broadcasts to participating aircraft.

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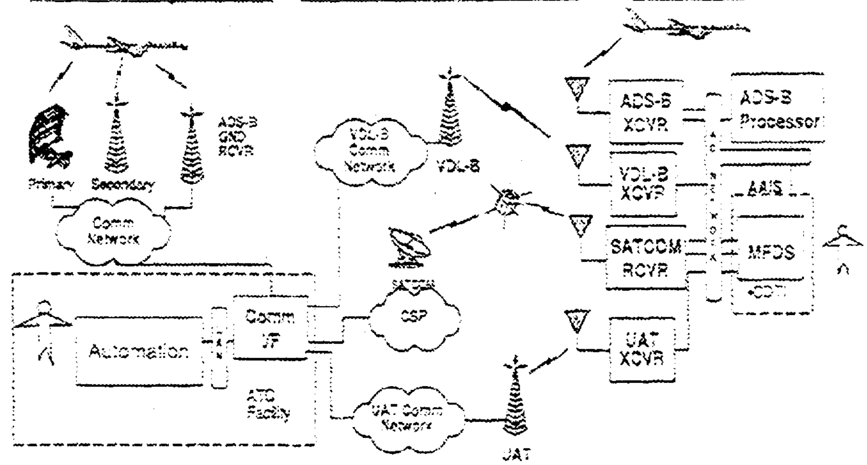
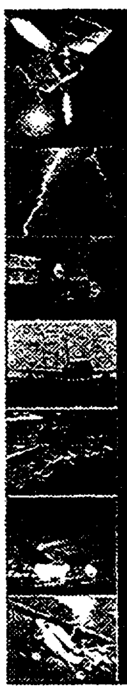
13

2015 TIS
Traffic Information Services

Ground Systems Air / Ground Comm Aircraft





Concept Description - Controller/Pilot Data Link Communication

- Controller - Pilot exchange data messages to reduce voice frequency congestion and provide a more precise and efficient means of communicating instructions and requests.
- Messages support efficient clearances, flight plan modifications, and advisories for tactical control and strategic CDM.
- CPDLC messages are ATN compliant, which accommodates message prioritization. Fixed or free-text messages are supported.

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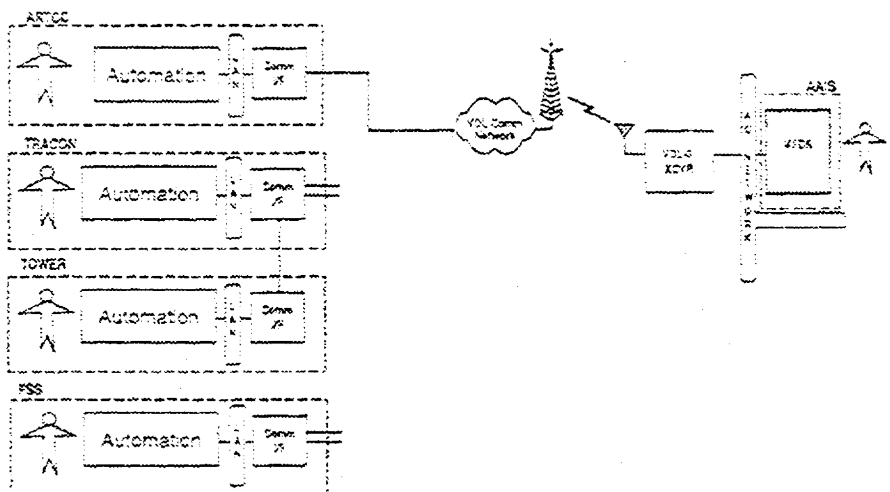
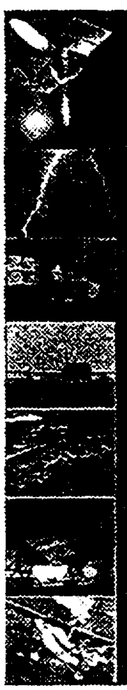
14

2015 CPDLC
Controller / Pilot Data Link Communications

Ground Systems   Air / Ground Comm   Aircraft





Concept Description - Controller/Pilot Voice Communication

- CPC supports tactical control and strategic CDM.
- CPC communication remains the foundation of air traffic control.
- It is critical to maintain a high quality, robust voice communication service.
- Digitized voice service can be combined with data service provided QOS is maintained

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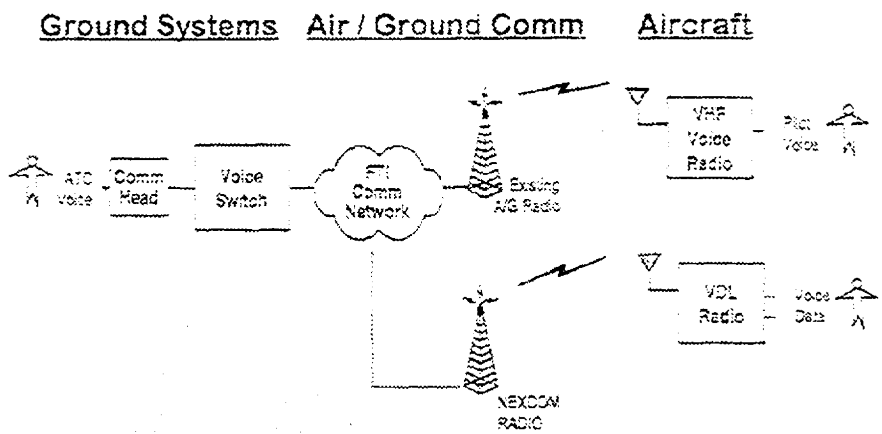
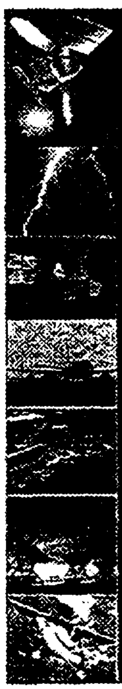
15

2015 - CPC Controller/Pilot Voice Communication





Concept Description - Decision Support System Data Link

- Aircraft exchange performance / preference data to optimize flight operation
  - with ATC
  - with other aircraft
- Supports calculations by ATC and Aircraft DSS algorithms that provide input to controllers and pilots
- Does not require human intervention or acknowledgement

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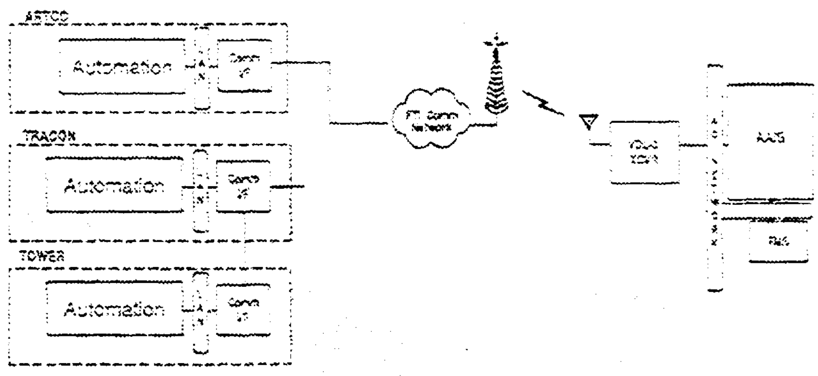
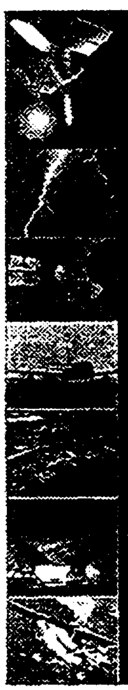
16

2015 DSSDL
Decision Support System Data Link

Ground Systems | Air / Ground Comm | Aircraft





Concept Description - Aeronautical Operation Center Data Link

- Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance.
- AOCDL allows the dispatcher to conduct individual flights (and the entire schedule) efficiently to enhance the business success and profitability of the airline.
- Most major airlines operate a centralized AOC function at an operations center that is responsible for worldwide operations.
- Supports data exchange for strategic CDM between pilot/aircraft and AOC

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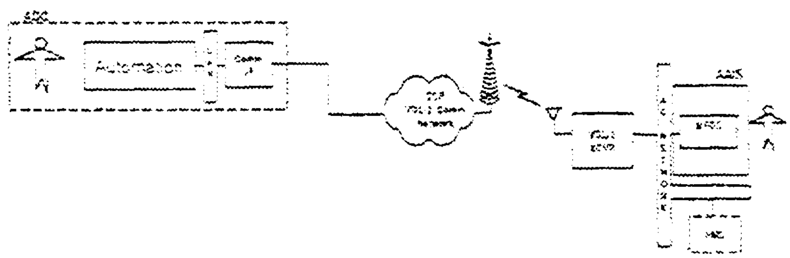
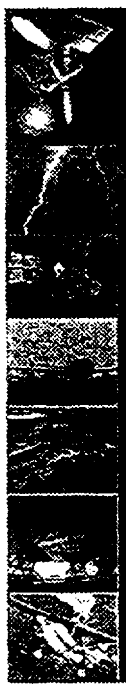
2015 AOCDL
Aeronautical Operational Control Data Link

Ground Systems | Air / Ground Comm | Aircraft





Concept Description – Automatic Dependent Surveillance – Broadcast

- Aircraft continuously broadcast dynamic traffic information data to enable optimum maneuvering
- Traffic information consists of position, velocity, and intent information using GPS as the primary source of navigation data to
  - aircraft
  - surface vehicles
- Supports
  - air-air pair-wise maneuvers
  - approach maneuvers
  - extended separation services
  - surface separation services

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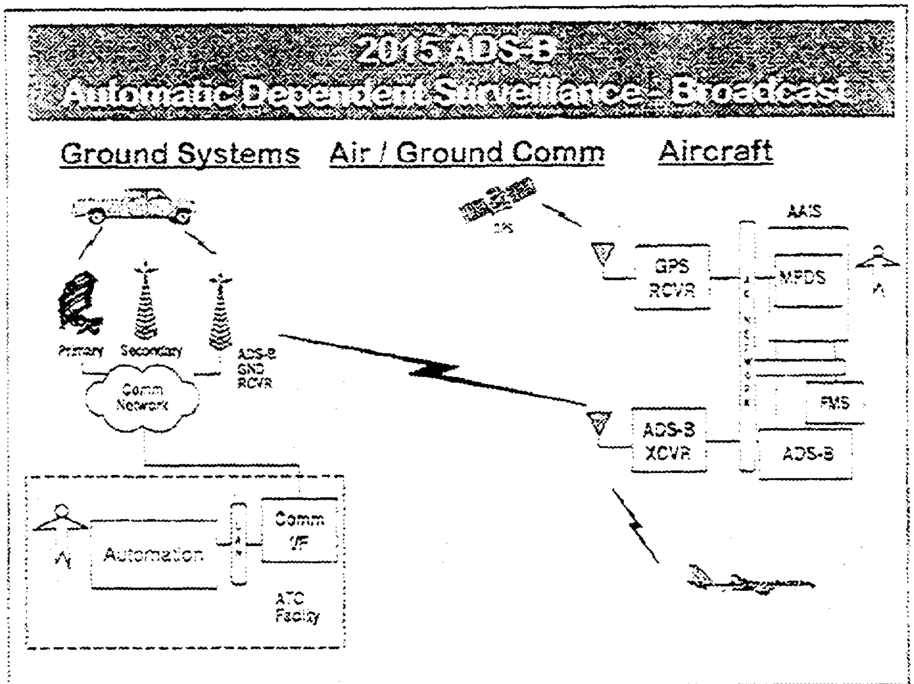
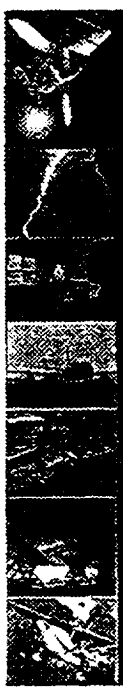
18





Concept Description - Aeronautical Passenger Services

- Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service.
- Assumed SATCOM only in en route domain

  This was included because of potential for infrastructure support to ATC service

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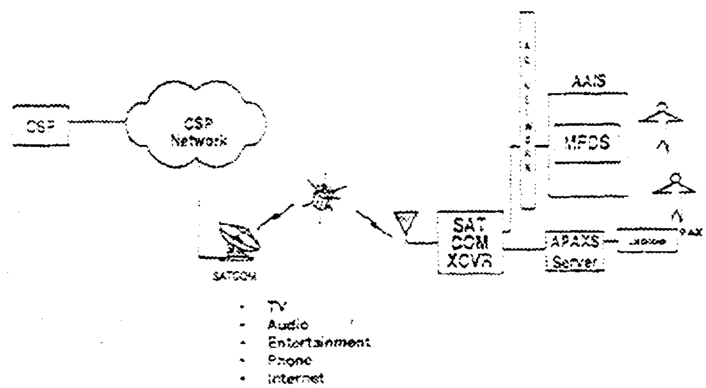
2015 APAXS
Aeronautical Passenger Services

Ground Systems   Air / Ground Comm   Aircraft



Concept Description - Automated Meteorological Transmission

→Aircraft report airborne weather data to improve weather nowcasting/forecasting.

Also know as...
- MDCRS, E-MDCRS [NOAA, NWS]
- ACARS [NOAA, FSL]
- EPIREPS [NASA]

→AUTOMET definition is currently under the auspices of the RTCA SC 195

→Minimum Interoperability Standards (MIS) for Automated Meteorological Transmission (RTCA DO-252)

→wind, temperature, water vapor and turbulence.

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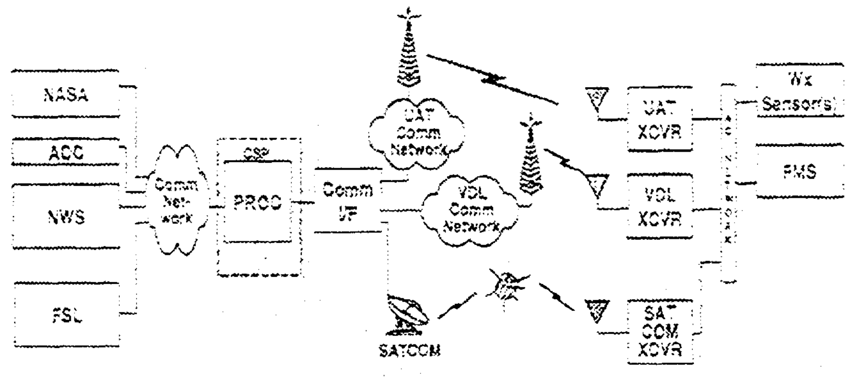
20

Automated Meteorological Transmission - AUTOMET



2015 Link Summary

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
	Kbps	Channels	Channels	Aircraft	
HFDL	1.8	2	1	50	Intended for Oceanic
ACARS	2.4	10	1	25	ACARS should be in decline as users transition to VDL Mode 2
VDL Mode 2	31.5	4+	1	150	System can expand indefinitely as user demand grows
VDL Mode 3	31.5*	~300	1	60	Assumes NEXCOM will deploy to all phases of flight
VDL Mode 4	19.2	1-2	[illegible]	500	Intended for surveillance
VDL - B	31.5	2	1	Broadcast	Intended for FIS
Mode S	1000**	1	1	500	Intended for surveillance
UAT	1000	1	1	500	Intended for surveillance/FIS
SATCOM	-	-	-	-	Assumes satellites past service life
Future SATCOM	64	15	1	~200	Planned future satellite
Future Ka Satellite	2,000	~50	~50	~200	Estimated capability - assumes capacity split for satellite beams
Fourth Generation Satellite	>100,000	>100	>100	Unknown	Based on frequency license filings

* Channel split between voice and data.
** The Mode-S data link is limited to a secondary, non-interference basis with the surveillance function and has a capacity of 300 bps per aircraft in track per sensor (RTCA/DO-237).

Load Analysis

- Established Data Set (Task 1,2,3 Msg. Characteristics, performance requirements)
- Defined User Classes
- Defined Equipage Forecast
- Defined Domains
- Defined Assumptions
- Method of Calculation
- Load Analysis Results

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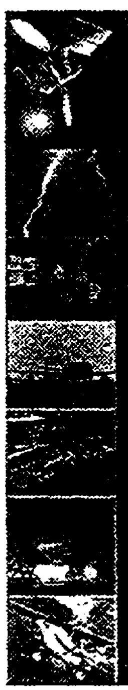
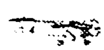
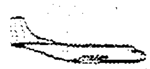


Load Analysis - User Classes

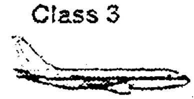
Class 1



Class 2



Class 3



Class of Aircraft	Definition and Comment
Class 1	Operators who are required to conform to FAR Part 91 only, such as low-end General Aviation (GA) operating normally up to 10,000 ft. This class includes operators of rotorcraft, gliders, and experimental craft and any other user desiring to operate in controlled airspace below 10,000 ft. The primary distinguishing factor of this class is that the aircraft are smaller and that the operators tend to make minimal avionics investments.
Class 2	Operators who are required to conform to FAR Parts 91 and 135, such as air taxis and commuter aircraft. It is likely that high-end GA and business jets and any other users desiring to operate in controlled airspace will invest in the necessary avionics to be able to achieve the additional benefits.
Class 3	Operators who are required to conform to FAR Parts 91 and 121, such as Commercial Transports. This class includes passenger and cargo aircraft and any other user desiring to operate in controlled airspace. These users will invest in the avionics necessary to achieve the additional benefits.

May, 2000 AATT TO24 SAIC Team 44

2

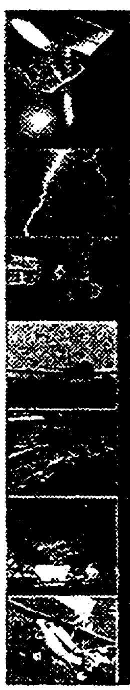
Load Analysis - Equipage Forecast (%)

	2015						
	CPC	CPDLC	DSSOL	ADS-B / TIS	FIS / AUTOMET	APAXS	AOCOL
Class 1	100	48	10	50	52	2	0
Class 2	100	74	34	68	74	3	8
Class 3	100	98	70	90	79	48	51

	2007 (30% of 2015 for CPDLC, DSSOL, ADS-B/TIS, APAXS and 70% of 2015 for FIS/AUTOMET, and 100% of AOCOL)						
	CPC	CPDLC	DSSOL	ADS-B / TIS	FIS / AUTOMET	APAXS	AOCOL
Class 1	100	14	3	15	16	1	0
Class 2	100	22	10	20	22	1	8
Class 3	100	29	21	27	24	14	51

Estimate based on 1999 FAA forecast

May, 2000 AATT TO24 SAIC Team 45



Domain Definitions

Domain	Definition and Comment
En route	Airspace in which en route air traffic control services are normally available. The average flight duration is 25 minutes per en route center.
Terminal	Airspace in which approach control services are normally available. The average flight duration is 10 minutes.
Airport	Airspace, including runways and other areas used for taxiing, takeoff, and landing, in which tower control services are normally available. The average flight duration is 10 minutes.
Oceanic	Airspace over the oceans of the world, considered international airspace, where oceanic separation and procedures per the International Civil Aviation Organization are applied. The average flight duration is 180 minutes.

May, 2000 AATT TO24 SAIC Team 46

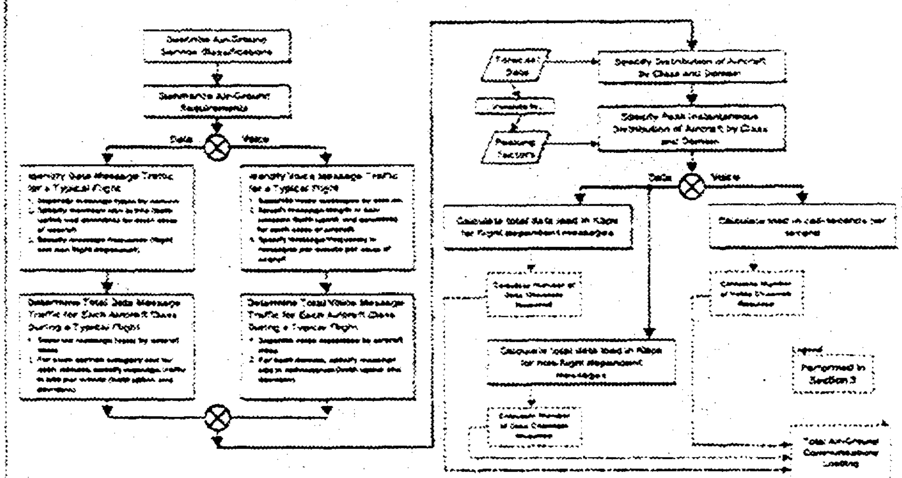
3

Load Analysis - Assumptions

- Use of CSP is acceptable for all services provided QOS can be satisfied
- Ground and Airborne processing and storage capacities are sufficient that they are not considered a factor
- 8 bits per character is used to convert messages size in characters to message size in bits.
- ATN protocol overheads are applied to all connection oriented messages, i.e., CPDLC, DSSDL, AOCDL, and AUTOMET messages, plus all flight dependent FIS messages.
- ATN protocol overhead varies according to message context and message size
- Non-flight dependent FIS messages and all TIS messages include an overhead of 10% for error detection and synchronization.
- Modulation efficiency for D8PSK is assumed to be 1.25 bps per Hertz
- All AUTOMET traffic is suppressed in the airport domain to reduce channel requirements
- Class 1 and Class 2 aircraft will not subscribe to APAXS
- SATCOM links provide CONUS coverage

May, 2000 | AATT TO24 SAIC Team | 47

Method of Calculation



FIS Products

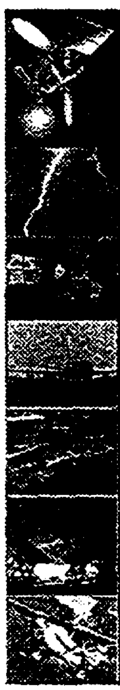
Primary Source: Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems (Phase I Report), Lockheed Martin Aeronautical Systems 1999.

Assumptions:

- Projected weather products are bit-mapped pictures in a multi-dimensional grid.
- Broadcast weather products represent computer generated, synthesized, integrated information.
- These products represent generic projections of products that will be available five to 10 years in the future.

Secondary Source: RTCA DO 237, Aeronautical Spectrum Planning, 1997

May, 2000 AATT TO24 SAIC Team 49



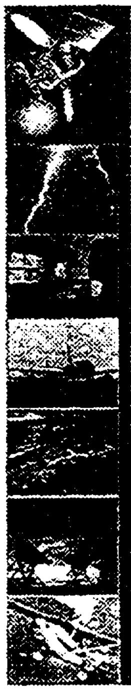
2015 FIS Message Set

Msg ID	Message Category	Definition/Comment	Source
[illegible]	Convection	Includes data regarding cloud tops, reactive area, lightning activity, projected decay, water content, etc.	[illegible]
[illegible]	Locations / ATIS	Automated Terminal Information Service, Airfield Defined	[illegible]
[illegible]	Destination Field Conditions	Combination of text, icons, and graphics accurately describing NOTAM information, [illegible] readings, [illegible] snow conditions, [illegible]	[illegible]
[illegible]	En Route Strategic General Imagery	Backup for synthesized weather products or for direct imagery requirements; examples include satellite images, lightning strike data, fixed screen surface analyses	[illegible]
[illegible]	[illegible] Planning / ATIS	Automated Terminal Information Service, Terminal Defined	[illegible]
[illegible]	FIS Planning Services	Includes real-time weather advisories and warnings	[illegible]
[illegible]	General Hazard	A general hazard product would likely include weather hazards in addition to other known hazards (traffic, terrain...)	[illegible]
[illegible]	Icing (Terminal Tactical)	May not be practical, difficult to implement. Would depend on automatic reports from in flight aircraft to a central ground location for constant polling, updating and reporting.	[illegible]
[illegible]	Icing Flight Conditions (En Route Far Term, Near Term Strategic, Tactical)	SLD and icing are included in this product aimed at GA.	[illegible]
[illegible]	Low Level Wind Shear (Terminal Tactical)	This product may identify [illegible] winds caused by microbursts, frontal passage, etc. Generated from ground-based sensors, fused with NEXRAD or TDWR data to create a near-ground level view.	[illegible]
[illegible]	Radar Mosaic	Real-time broadcasts of NEXRAD or TDWR-type RADAR pictures in the terminal area.	[illegible]
[illegible]	Surface Conditions (En Route Far Term Strategic)	This product will project surface conditions to enhance situational awareness and support contingency planning.	[illegible]
[illegible]	Turbulence (En Route Far Term and Near Term Strategic, En route Tactical)	Strategic turbulence information will become one of the most important future products. A true tactical product may not be feasible but future product may combine current sensed condition with predictive forecasts.	[illegible]
[illegible]	Winds/Temperature (En Route Far Term and Near Term Strategic)	This product contains information on en route winds and temperatures.	[illegible]

Note: (1) Source [illegible] is the Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems (Phase I Report), Lockheed Martin Aeronautical Systems 1999. Source [illegible] is RTCA DO 237, Aeronautical Spectrum Planning, 1997.

May, 2000 AATT TO24 SAIC Team 50

5



2015 FIS Load Analysis Results

2-way

→Worst case scenario: En Route airspace with high density Terminal area and four major Airports

	Airport	Terminal	En Route	Total
FIS - Domain	36.4	135	1092	
Region (x)	145.6 (4)	135 (1)	1092 (1)	1372.6

Note: (x) is domain multiplier (K-bits per second)

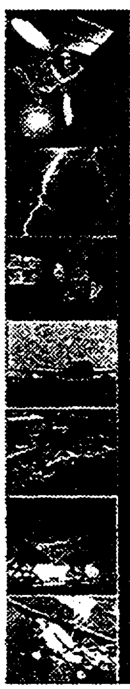
Broadcast

→Regional scenario: En Route airspace with 5 Terminal/Airport areas

	Airport	Terminal	En Route	Total
FIS - Domain	0.2	0.9	6.9	
FIS - Region	1.0 (5)	4.5 (5)	6.9 (1)	12.4
FIS - National				248 (20)

Note: (x) is domain multiplier (K-bits per second)

May, 2000 AATT TO24 SAIC Team 51



2015 FIS Viable Alternatives

→Broadcast is preferable for FIS

→VDL-B can support a regional broadcast of FIS data

- Allocation of only 2 frequencies per CSP poses coverage / interference problems for National implementation

→UAT, SATCOM can support Regional and National implementation

Operational Concept	Technical Concept	VHF-AM	VDL-2 ATN	VDL-3 ATN	VDL-4 ATN	VDL-B	Mode-S	UAT	SATCOM Broadcast	SATCOM 2way
Aircraft continuously receive flight information to enable common situational awareness	FIS					✓		✓	✓	

✓ Acceptable Alternative — NAS Architecture ★ Preferred Operation

May, 2000 AATT TO24 SAIC Team 52

6

2015 TIS Load Analysis Results

TIS Message

Message Type	Message Identifier	Message Category
2	MS	Air Traffic Information

- ID, Position, Intent

Broadcast

→Traffic Information by Domain (K-bits per second)

	Airport	Terminal	En Route	Total
TIS - Domain	23.7	7.0	20.5	
TIS - Regional	N/A	35.0 (5)	20.5	55.5
TIS - National	N/A	58.5 [1139] ²	170 (4140)	228.5

Note 1: Region defined as 1 En Route, 5 Terminal

Note 2: National Peak Total number of aircraft per domain

May, 2000 — AATT TO24 SAIC Team — 53

2015 TIS Viable Alternatives

→TIS is assumed broadcast
- ATN message overhead on VDL 2-way links makes them undesirable for TIS data

→VDL-B can support domain broadcast of TIS data
- Requires dedicated frequency for each domain so not viable until after NEXCOM implementation

→Mode-S is current NAS Architecture solution
- Cannot support broadcast load requirement for our concept of TIS (tactical and strategic)

→UAT, SATCOM can support Regional and National broadcast

Operational Concept	Technical Concept	VHF-AM	VDL-2/ATN	VDL-3/ATN	VDL-4/ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Traffic Information to enable common situational awareness	TIS					✓		✓	✓	

✓ Acceptable Alternative ☐ NAS Architecture ★ Restricted Operation

2015 CPDLC Load Analysis Results

CPDLC Messages

Msg ID	Message Type
V32	Pilot Controller Communications
V34	Pre-Departure Clearance
V41	System Management and Control

Result Summary:
Single VDL-3 sub-channel can conservatively support 4.8 kbps of data.

	Airport	Terminal	En Route
CPDLC- Domain	6.3	2.2	2.4
CPDLC – (Estimate per Sector)	1.6 (4)	0.3 (7)	0.1 (20)

May, 2000 AATT TO24 SAIC Team 55

2015 CPDLC Viable Alternatives

- VDL-3 is the NAS Architecture solution for CPDLC
  - Easily supports load requirements

Operational Concept	Technical Concept	VHF/AM	VDL-2/ATN	VDL-3/ATN	VDL-4/ATN	VDL-B	Mode-S	UAT	SATCOM-Proprietary	SATCOM-Other
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	CPDLC			✓						

✓ Acceptable Alternative   NAS Architecture   ★ Restricted Operation

May, 2000 AATT TO24 SAIC Team 56

2015 CPC Load Analysis Results

- In 2015 most routine messages are sent via CPDLC
  - Clearance Delivery
  - Transfer of Communication
  - Initial contact
  - Altimeter
- Our Analysis assumed an average of 1.5 call-seconds per minute per flight

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	2.7	1.3	0.7	0.7	2.0	0.5
2	0.9	0.4	0.3	0.3	0.2	0.1
3	1.2	0.5	0.0	0.0	0.2	0.0
Total	7.0		1.9		2.7	
Voice Channels Required (P=0.2)	8		3		4	

Call-seconds per second

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2015 CPC Viable Alternatives

- Our communication load analysis indicates that a single VDL-3 sub-channel is sufficient to support controller pilot communication under worst case loading conditions.

Operational Concept	Technical Concept	VHF-AM	VDL-2 ATN	VDL-3 ATN	VDL-4 ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Controller - Pilot voice communication	CPC	✓		✓						

✓ Acceptable Alternative   ▭ NAS Architecture   ★ Restricted Operation

May, 2000 AATT TO24 SAIC Team 58

9

2015 DSSDL Load Analysis Results

DSSDL Messages

Msg ID (M#)	Message Type
M3	Advanced ATM
M1[illegible]	Delivery of Route Deviation Warnings
V03	TFM Information

Result Summary:
Single VDL-3 sub-channel can conservatively support 4.8 kbps of data.

	Airport	Terminal	En Route
DSSDL – Domain	0.5	0.3	0.2
DSSDL – (Estimated by Sector)	0.1 (4)	0.1 (7)	0.1 (20)

May, 2000 AATT TO24 SAIC Team 59

2015 DSSDL Viable Alternatives

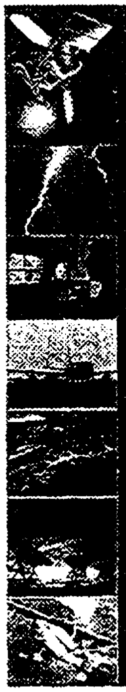
- VDL-3 is the NAS Architecture solution for DSSDL
  - Easily supports load requirements

Operational Concept	Technical Concept	VHF-AM	VDL-2/ATN	VDL-3/ATN	VDL-4/ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft exchange performance/preference data with ATC to optimize decision support	DSSDL			✓						

✓ Acceptable Alternative ▭ NAS Architecture ★ Restricted Operation

May, 2000 AATT TO24 SAIC Team 60

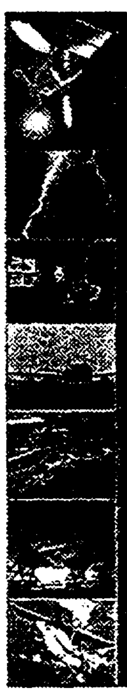
10



2015 AOCDL Message Set

Msg ID (Mx)	Message Type
M8	Airline Maintenance Support Electronic Database Updating
M9	Airline Maintenance Support In-Flight Emergency Support
M10	Airline Maintenance Support Non-Routine Maintenance/Information Reporting
M11	Airline Maintenance Support On-Board Trouble Shooting (non-routine)
M12	Airline Maintenance Support Maintenance Information Reporting
M13	Diagnostic Data
M23	Flight Data Recorder
M25	Gate Assignment
M30	Out/Off/On/In
M33	Position Reports

May, 2000 AATT TO24 SAIC Team 61



2015 AOCDL Load Analysis Results

→ Worst case scenario: En Route airspace with high density Terminal area and four major Airports

	Airport	Terminal	En Route	Total
AOCDL	8.8	9.1	3.7	
Worst Case	35.2 (4)	9.1 (1)	3.7 (1)	48

Note: (x) is domain multiplier (K-bits per second)

May, 2000 AATT TO24 SAIC Team 62

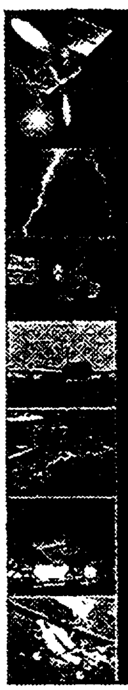
2015 AOCDL Viable Alternatives

- VDL-2 national network operated by CSP since 2001
- VDL-2 single frequency effective data rate is 19.2 kbps.
  - 4 frequencies used for AOCDL - 76.8 kbps
  - This is sufficient to support the projected demand
- UAT, SATCOM could support the load requirement
  - Unlikely use if existing network can support requirement

Operational Concept	Technical Concept	VHF AM	VDL-2 ATN	VDL-3 ATN	VDL-4 ATN	VDL-B	Mode-S	UAT	SATCOM [illegible]	SATCOM [illegible]
[illegible]	AOCDL		✓					✓		✓

✓ Acceptable Alternative — NAS Architecture

May, 2000 — AATT TO24 SAIC Team — 53



2015 ADS-B Load Analysis Results

- ADS-B messages containing identification, state vector, intent, status and other information are assembled by aircraft avionics.

	Airport	Terminal	En Route	Total
ADS-B	16.1	3.3	1.5	20.9

- Data transmitted
  - Airport - 192 transmitters, 1 message per 1.1s
  - Terminal - 137 transmitters, 1 message per 5.3s
  - En Route - 500 transmitters, 1 message per 12.1s

May, 2000 — AATT TO24 SAIC Team — 54

12

2015 ADS-B Viable Alternatives

- ADS-B link evaluation currently underway - decision in 2001
  - Mode-S, VDL-4, and UAT
  - SF-21 trials evaluating all links
- Mode-S is current NAS Architecture solution

Operational Concept	Technical Concept	VHF-AM	VDL-2 ATN	VDL-3 ATN	VDL-4 ATN	VDL-5	Mode-S	UAT	SATCOM Broadcast	SATCOM Data
[illegible]	ADS-B				✓		✓	✓		

✓ Acceptable Alternative — NAS Architecture — ▼ Restricted Operation

May, 2000 — AATT TO24 SAIC Team — 85

2015 AUTOMET Load Analysis Results

- AUTOMET message contains
  - Wind
  - Temperature
  - Humidity
  - Turbulence
- Message size and frequency based on 1999 RTCA MIS
- Assume no AUTOMET in Airport Domain
- Worst case scenario: En Route airspace with high density Terminal area

	Airport	Terminal	En Route	Total
AUTOMET	N/A	4.4	6.2	
Worst Case	N/A	4.4 (1)	6.2 (1)	10.6

Note: (x) is domain multiplier (K-bits per second)

May, 2000 — AATT TO24 SAIC Team — 86

13

2015 AUTOMET Viable Alternatives

- AUTOMET type data currently delivered via ACARS network
- Assume transition to VDL-2 network
- VDL-2 national network operated by CSP since 2001
- VDL-2 single frequency effective data rate is 19.2 kbps.
  - 4 frequencies used for AOCDL - 76.8 kbps
  - This is sufficient to support the projected demand
- UAT, SATCOM could support the load requirement
  - Unlikely use if existing network can support requirement

Operational Concept	Technical Concept	VHF-AM	VDL-2 ATN	VDL-3 ATN	VDL-4 ATN	VDL-B	Mode-S	UAT	SATCOM Broadcast	SATCOM Data
Aircraft report airborne weather to improve weather nowcasting/forecasting	AUTOMET		✓					✓		✓

✓ Acceptable Alternative — NAS Architecture

May, 2000 — AATT TO24 SAIC Team — 67

2015 APAXS Load Analysis Results

APAXS Messages

Msg ID (M#)	Message Type
M5	Airline Business Support: Electronic Database Updating
M7	Airline Business Support: Passenger Re-Accomodation
M31	Passenger Services: On Board Phone
M42	Miscellaneous "at-seat" services (TV, Internet, Radio)

- **Assume APAXS in En Route Domain only**

	En Route Uplink	En Route Downlink
APAXS - Domain	132	116
APAXS - CONUS	2,635	2,320

(K-bits per second)

May, 2000 — AATT TO24 SAIC Team — 68

14

2015 APAXS Viable Alternatives

- It is likely that commercial demand will drive broadband satellite service to the cabin by the 2007 time frame.
- The presence of APAXS may provide an opportunity to support air traffic services that would not be possible otherwise.
  - Note, there are no plans for this in the current NAS architecture.

Operational Concept	Technical Concept	VHF-AM	VDL-2 ATN	VDL-3 ATN	VDL-4 ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-Other
[illegible]	APAXS								✓	✓

✓ [illegible]   [illegible]   ★ [illegible]

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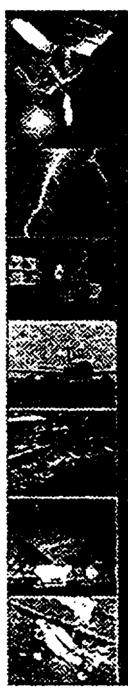

Combined Peak Data Message Traffic for All Aircraft Classes in 2007 - 2015

Data Message Traffic for All Classes of Aircraft (K-bits per second)

2015	Airport Uplink	Airport Downlink	Terminal Uplink	Terminal Downlink	En Route Uplink	En Route Downlink
FIS	0.0	2.6	0.9	0.0	3.9	0.0
TIS	20.?	0.0	7.6	0.0	26.5	0.0
CPDLC	3.4	2.6	1.0	0.9	[illegible]	1.0
DSSDL	0.2	3.3	[illegible]	0.2	[illegible]	[illegible]
ADC	0.4	6.4	0.6	8.5	0.2	3.5
ADS Reporting	0.0	18.1	3.9	0.0	0.0	1.2
AUTOMET	0.0	0.0	0.0	4.4	0.0	5.2
APAXS	0.0	0.0	0.0	0.0	131.7	118.5

Data Message Traffic for All Classes of Aircraft (K-bits per second)

2007	Airport Uplink	Airport Downlink	Terminal Uplink	Terminal Downlink	En Route Uplink	En Route Downlink
FIS	0.2	0.0	3.9	0.0	6.9	0.0
TIS	21.3	0.0	8.4	0.0	13.5	0.0
CPDLC	0.9	0.3	0.3	0.0	0.0	0.0
DSSDL	0.0	[illegible]	0.0	0.0	0.0	0.0
ADC	0.4	7.9	2.5	[illegible]	2.3	2.9
ADS Reporting	0.0	4.3	0.0	0.0	0.0	0.4
AUTOMET	0.0	0.0	0.0	1.2	0.0	1.7
APAXS	0.0	0.0	0.0	0.0	33.5	29.4

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2015 Architecture Alternatives Summary

Operational Concept	Technical Concept	VHF AM	VDL2 ATN	VDL3 ATN	VDL4 ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Flight information to enable common situational awareness	FIS					✓		✓	✓	
Aircraft continuously receive Traffic information to enable common situational awareness	TIS					✓		✓	✓	
Controller - Pilot Communication	CPC	✓		✓						
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	CPDLC			✓						
Aircraft exchange performance / preference data with ATC to optimize decision support	DSSDL			✓						
Aircraft continuously broadcast their position and intent to enable optimum maneuvering	ADS-B				✓		✓	✓		
Pilot - AOC data exchange supports efficient commercial transport operations and maintenance	AOCDL		✓					✓		✓
Aircraft report airborne weather to improve weather nowcasting/forecasting	AUTOMET		✓							
Passengers enjoy in-flight television, radio, telephone, and internet service	APAXS									

✓ Acceptable Alternative — NAS Architecture — AATT TO24 Recommendation

May, 2000 AATT TO24 SAIC Team 71

Top Down vs Bottom Up A...

- Top Down Architecture optimizes at the "system" level
  - May contain sub-optimal solutions for 1 or more sub-systems
  - For this task: Minimize the number of radio's aircraft and the ground infrastructure
- Bottom Up Architecture optimizes a... ...sub-system" level
  - Optimizes each sub-system without regard to tot... system
  - For this task: Select optimum radio

May, 2000 AATT TO24 SAIC Team 72

Top Down Observations

→ Human / DSS ATC interfaces satisfied by VDL-3 Link - NAS Architecture Baseline

- CPC
- CPDLC
- DSSDL

	Airport	Terminal	En Route
CPC	1 voice channel per sector		
CPDLC	4.3	2.2	2.4
DSSDL	0.5	0.3	0.2
Total	4.8	2.5	2.6

→ Human / AUTOMET AOC interfaces satisfied by VDL-2 Link - Consistent with current planning, Not in NAS Arch

- AOCDL
- AUTOMET

	Airport	Terminal	En Route
AOCDL	[illegible]	[illegible]	3.7
AUTOMET	N/A	[illegible]	3.2
Total	[illegible]	[illegible]	[illegible]

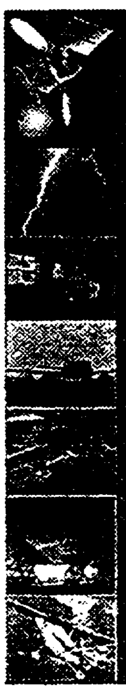
→ Dynamic Information Base satisfied with Broadband Link - No integrated plan for NAS Broadband data

- FIS
- TIS
- ADS-B

	Region
FIS	[illegible]
TIS	[illegible]
ADS-B	[illegible]

→ Broadband data solution can be Terrestrial or Space Based

May, 2000 AATT TO24 SAIC Team 73



Broadband Data Considerations

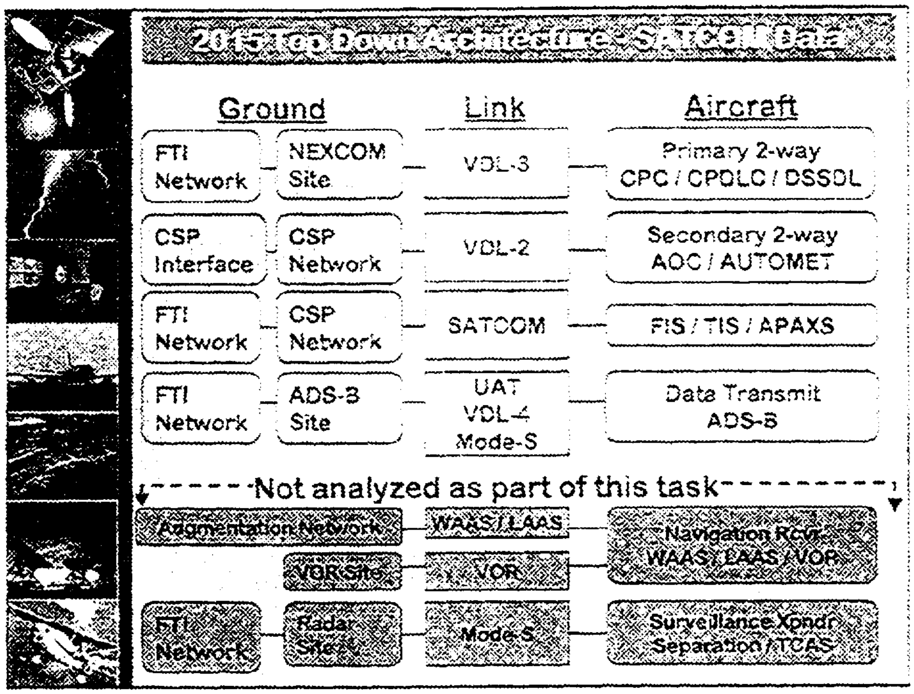
→ ADS-B link decision - can have major impact on Terrestrial vs Space based decision

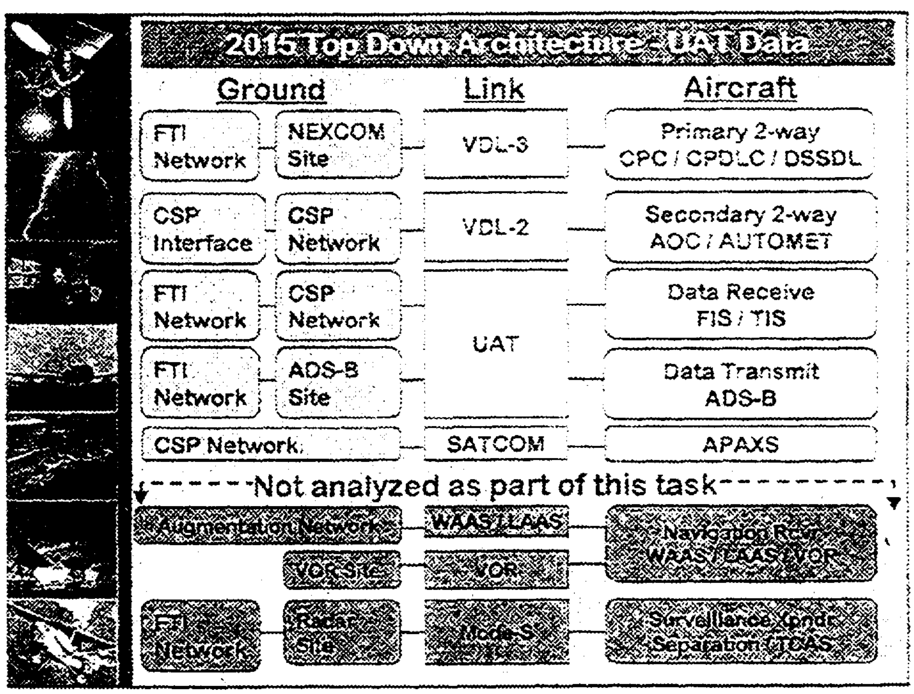
→ SATCOM implementation - driven by commercial cabin services (could lead to class 1 Avionics cost/performance issues)

	UAT	SATCOM
Base	• Terrestrial • FAA Radar, Navigation and/or Air-Ground Communication sites	• Space • Assume desirable CONUS coverage • Commercial service providers
Capacity	1Mbps	≥ 2Mbps
PRO's	– If selected as ADS-B link, all aircraft would eventually have UAT radio – Use of FAA sites – Avionics design complete – standards in development	• CONUS coverage without maintenance of terrestrial network • Higher data rates • Most likely will be available from commercial service providers
CON's	– Maintenance of terrestrial network – Additional radio required if not selected as part of ADS-B	• Immature avionics design - no standards – unproven for small GA aircraft • Additional radio required for non-APAXS equipped users

May, 2000 AATT TO24 SAIC Team 74

17


2015 Top Down Architecture - SATCOM Data
Ground
Link
Aircraft
FTI Network
NEXCOM Site
VDL-3
Primary 2-way CPC / CPDLC / DSSDL
CSP Interface
CSP Network
VDL-2
Secondary 2-way AOC / AUTOMET
FTI Network
CSP Network
SATCOM
FIS / TIS / APAXS
FTI Network
ADS-B Site
UAT VDL-4 Mode-S
Data Transmit ADS-B
Not analyzed as part of this task
Augmentation Network
WAAS / LAAS
Navigation Rcvr WAAS / LAAS / VOR
VOR Site
VOR
FTI Network
Radar Site
Mode-S
Surveillance Xpndr Separation / TCAS


2015 Top Down Architecture - UAT Data
Ground
Link
Aircraft
FTI Network
NEXCOM Site
VDL-3
Primary 2-way CPC / CPDLC / DSSDL
CSP Interface
CSP Network
VDL-2
Secondary 2-way AOC / AUTOMET
FTI Network
CSP Network
UAT
Data Receive FIS / TIS
FTI Network
ADS-B Site
Data Transmit ADS-B
CSP Network
SATCOM
APAXS
Not analyzed as part of this task
Augmentation Network
WAAS / LAAS
Navigation Rcvr WAAS / LAAS / VOR
VOR Site
VOR
FTI Network
Radar Site
Mode-S
Surveillance Xpndr Separation / TCAS

18

Interim Architecture Development

- →2007 AATT Architecture driven by 2015 AATT Architecture
  - Multiple Communication Solutions exist - pick solutions on the path to 2015 AATT
- →2007 AWIN Architecture part of the 2007 AATT Architecture
  - FIS
  - AUTOMET
  - CPC

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2007 AATT CSA

- →Human voice communications satisfied by VHF-AM
  - CPC: Transition to VDL-3
- →ATC data message interfaces satisfied by VDL-2 Link - NAS Architecture Baseline
  - CPDLC: Transition to VDL-3
  - DSSDL: Transition to VDL-3
- →Human / AUTOMET AOC interfaces satisfied by VDL-2 Link - No change from 2015, Not part of NAS Architecture
  - AOCDL
  - AUTOMET
- →Dynamic Information Base satisfied with Multiple Links - No integrated plan for NAS Broadband data
  - FIS: CSP supports VDL-B and Broadband solution
  - TIS: Broadband solution
  - ADS-B: Follow ADS-B link decision

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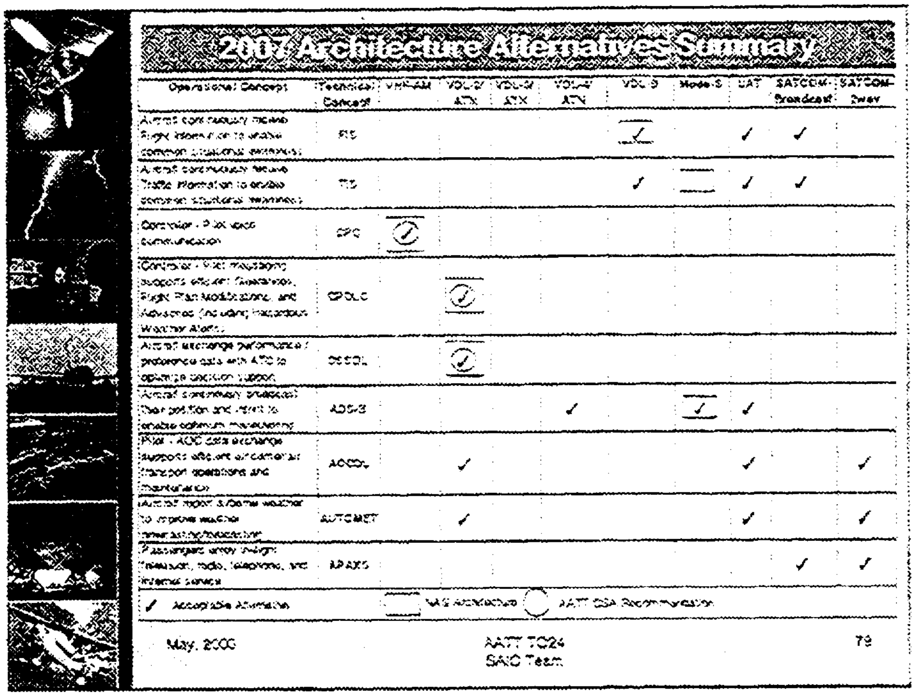

2007 Architecture Alternatives Summary

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Flight Information to enable common situational awareness	FIS					✓ (boxed)		✓	✓	
Aircraft continuously receive Traffic Information to enable common situational awareness	TIS					✓	(boxed)	✓	✓	
Controller - Pilot voice communication	CPC	✓ (boxed, circled)								
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	CPDLC		✓ (boxed, circled)							
Aircraft exchange performance / preference data with ATC to optimize decision support	DSSDL		✓ (boxed, circled)							
Aircraft continuously broadcast their position and intent to enable optimum maneuvering	ADS-B				✓		✓ (boxed)	✓		
Pilot - AOC data exchange supports efficient air commercial transport operations and maintenance	AOCDL		✓					✓		✓
Aircraft report airborne weather to improve weather forecasting/nowcasting	AUTOMET		✓					✓		✓
Passengers enjoy in-flight television, radio, telephone, and internet service	APAXS								✓	✓

✓ Acceptable Alternative   [box] NAS Architecture   (circle) AATT CSA Recommendation

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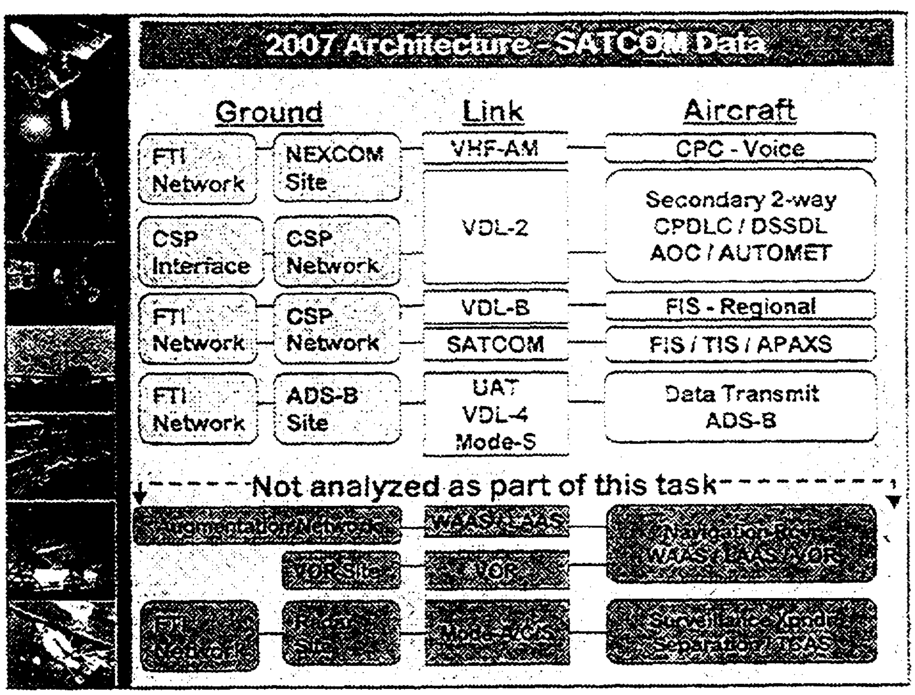
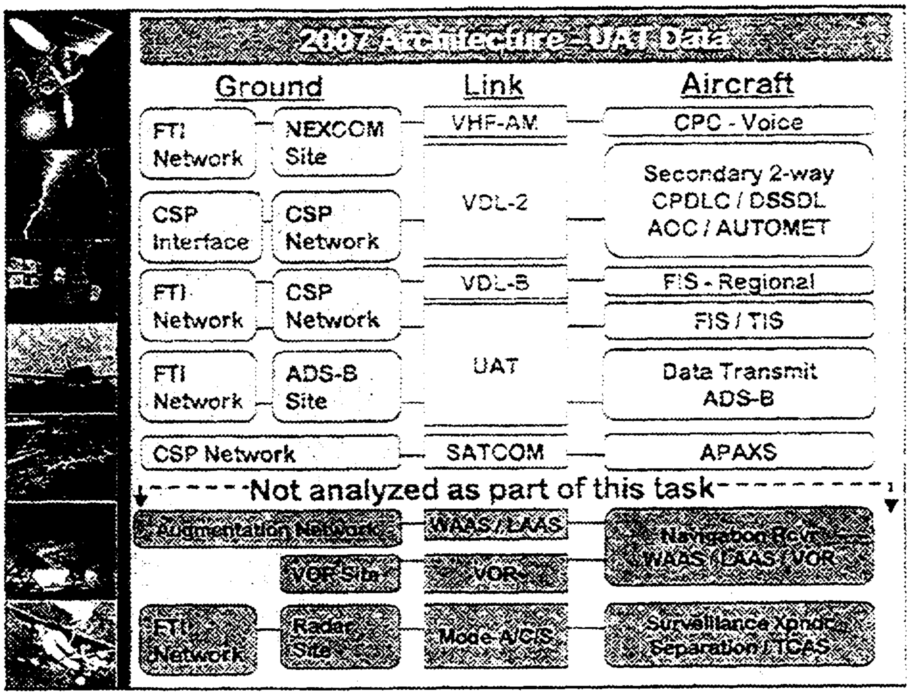
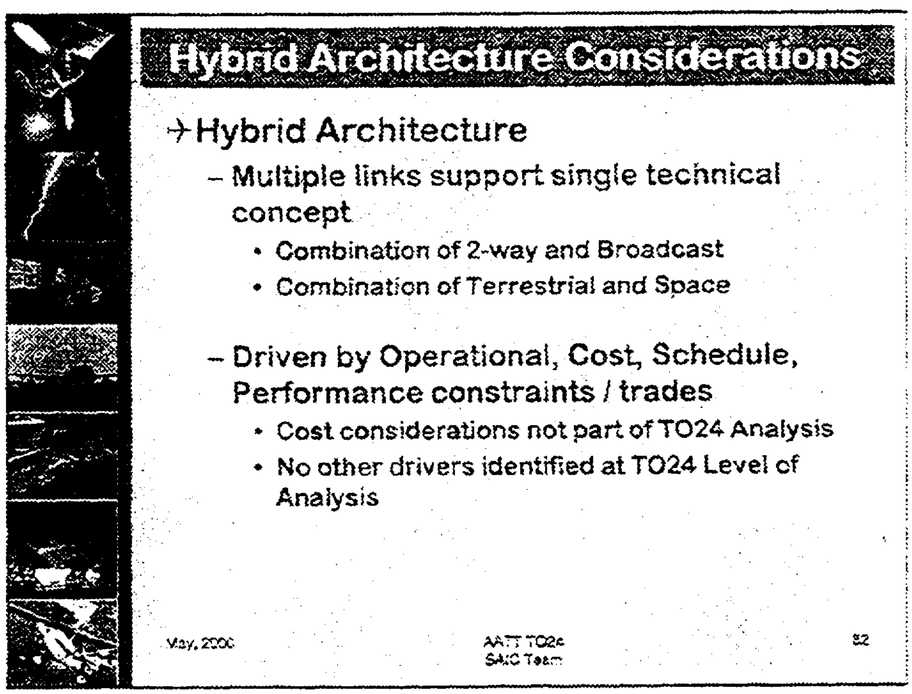


20


2007 Architecture - UAT Data
Ground
Link
Aircraft
FTI Network
NEXCOM Site
VHF-AM
CPC - Voice
CSP Interface
CSP Network
VDL-2
Secondary 2-way CPDLC / DSSDL AOC / AUTOMET
FTI Network
CSP Network
VDL-B
FIS - Regional
FIS / TIS
FTI Network
ADS-B Site
UAT
Data Transmit ADS-B
CSP Network
SATCOM
APAXS
Not analyzed as part of this task
Augmentation Network
WAAS / LAAS
Navigation Rcvr WAAS / LAAS / VOR
VOR Site
VOR
FTI Network
Radar Site
Mode A/C/S
Surveillance Xpndr Separation / TCAS


Hybrid Architecture Considerations
Hybrid Architecture
– Multiple links support single technical concept
• Combination of 2-way and Broadcast
• Combination of Terrestrial and Space
– Driven by Operational, Cost, Schedule, Performance constraints / trades
• Cost considerations not part of TO24 Analysis
• No other drivers identified at TO24 Level of Analysis
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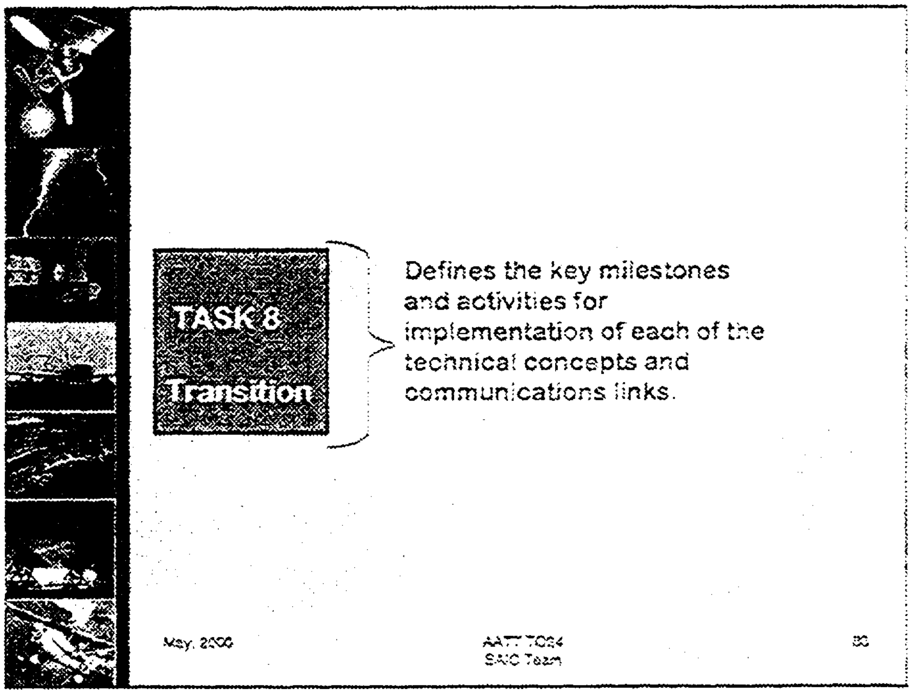
32

21


TASK 8
Transition
Defines the key milestones and activities for implementation of each of the technical concepts and communications links.
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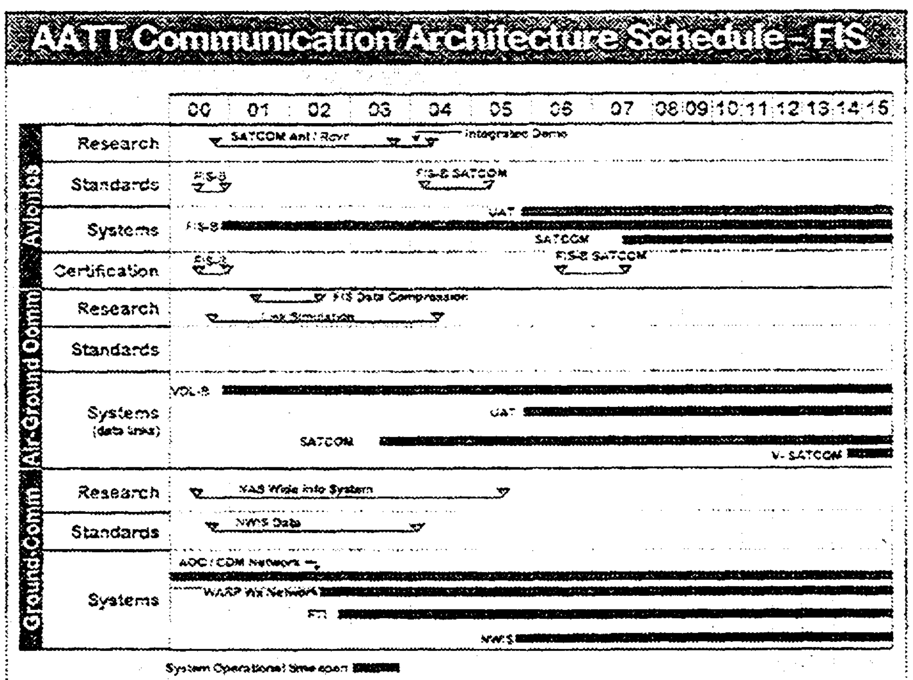
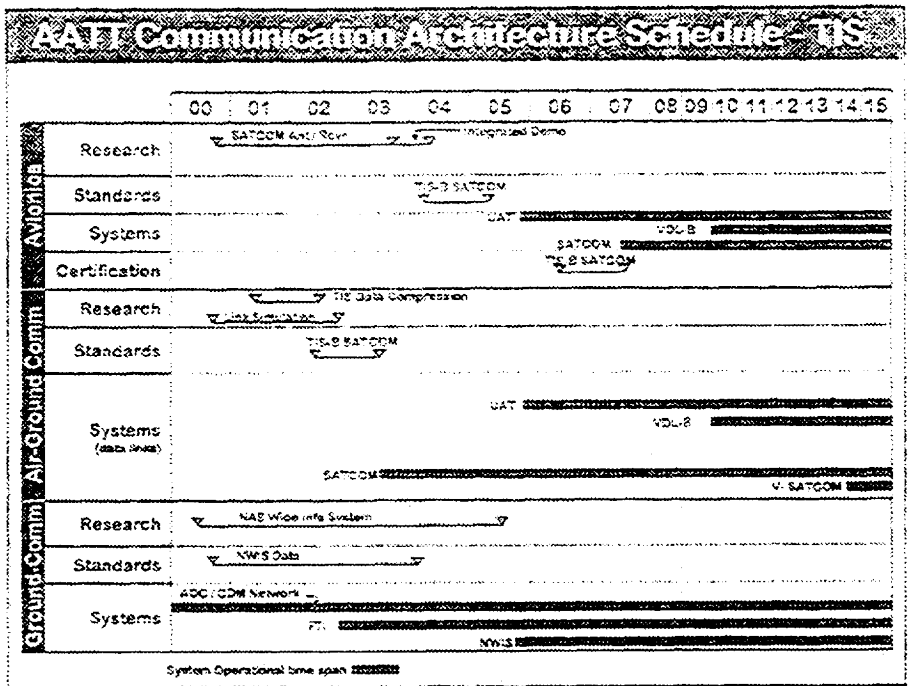
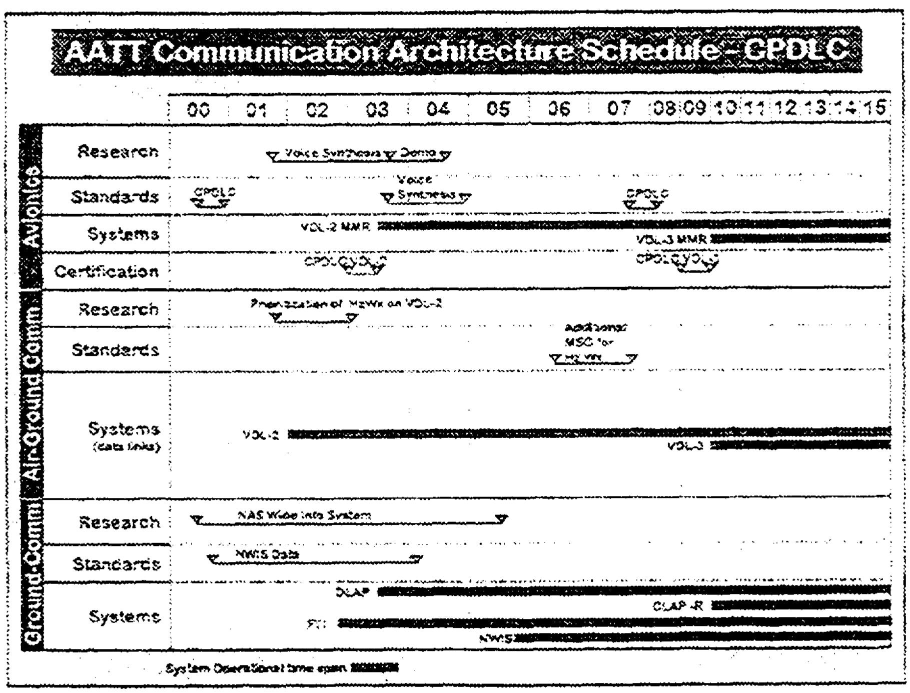
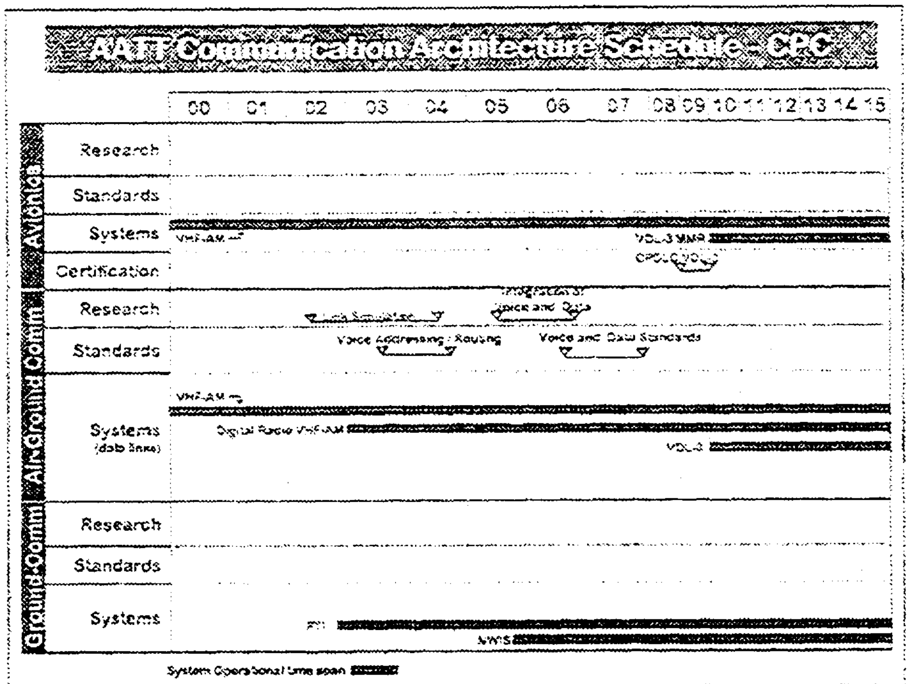
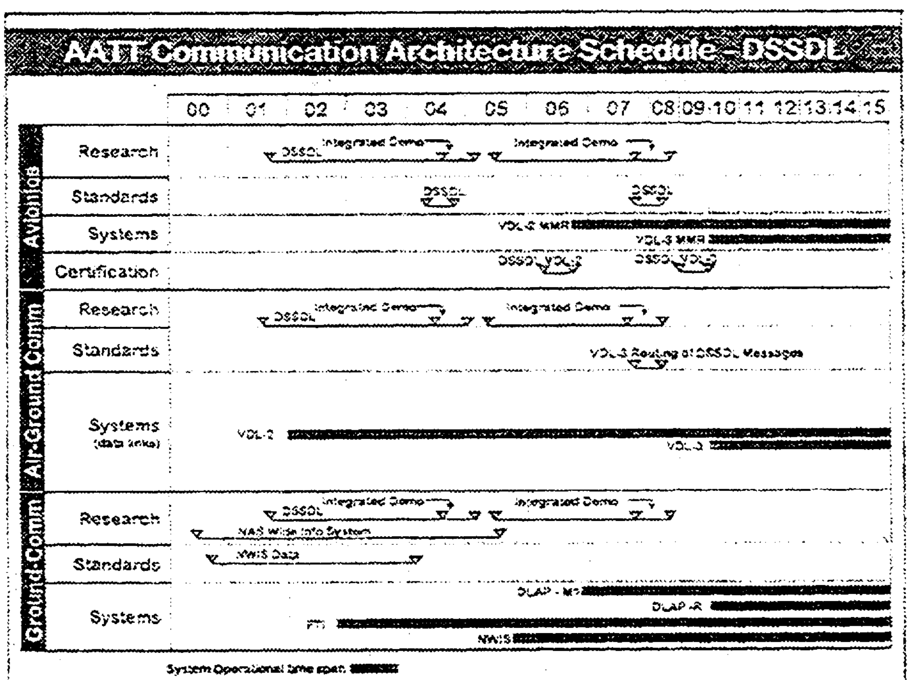

AATT Communication Architecture Schedule – FIS
00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
Avionics
Research
SATCOM Ant / Rcvr
Integrated Demo
Standards
FIS-B
FIS-B SATCOM
Systems
UAT
FIS-B
SATCOM
Certification
FIS-B
FIS-B SATCOM
Air-Ground Comm
Research
FIS Data Compression
Standards
Systems
(data links)
VDL-B
UAT
SATCOM
V-SATCOM
Ground Comm
Research
NAS Wide Info System
Standards
NWS Data
Systems
AOC / CDM Network
WARP Wx Network
NWS
System Operational time span


AATT Communication Architecture Schedule - TIS
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Avionics
Research
SATCOM Ant / Rcvr
Integrated Demo
Standards
TIS-B SATCOM
Systems
UAT
VDL-B
SATCOM
Certification
TIS-B SATCOM
Air-Ground Comm
Research
TIS Data Compression
Link Simulation
Standards
TIS-B SATCOM
Systems (data links)
UAT
VDL-B
SATCOM
V- SATCOM
Ground-Comm
Research
NAS Wide Info System
Standards
NWIS Data
Systems
ADC / CDM Network
FTI
NWIS
System Operational time span

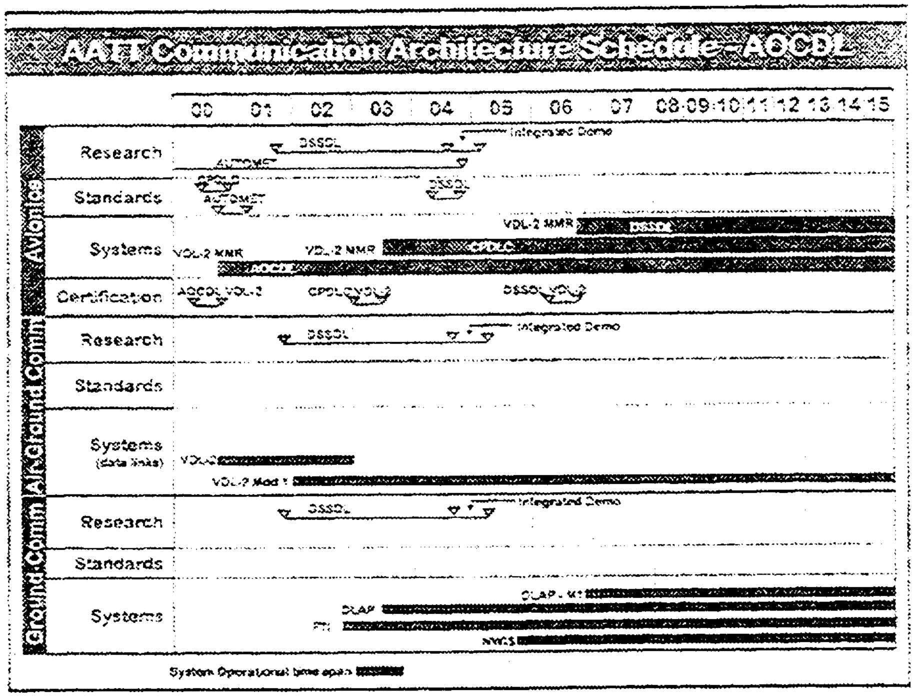

AATT Communication Architecture Schedule - CPDLC
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Avionics
Research
Voice Synthesis
Demo
Standards
CPDLC
Voice Synthesis
CPDLC
Systems
VDL-2 MMR
VDL-3 MMR
Certification
CPDLC/VDL-2
CPDLC/VDL-3
Air-Ground Comm
Research
Prioritization of HzWx on VDL-2
Standards
Additional MSC for HzWx
Systems (data links)
VDL-2
VDL-3
Ground-Comm
Research
NAS Wide Info System
Standards
NWIS Data
Systems
OLAP
OLAP -R
FTI
NWIS
System Operational time span

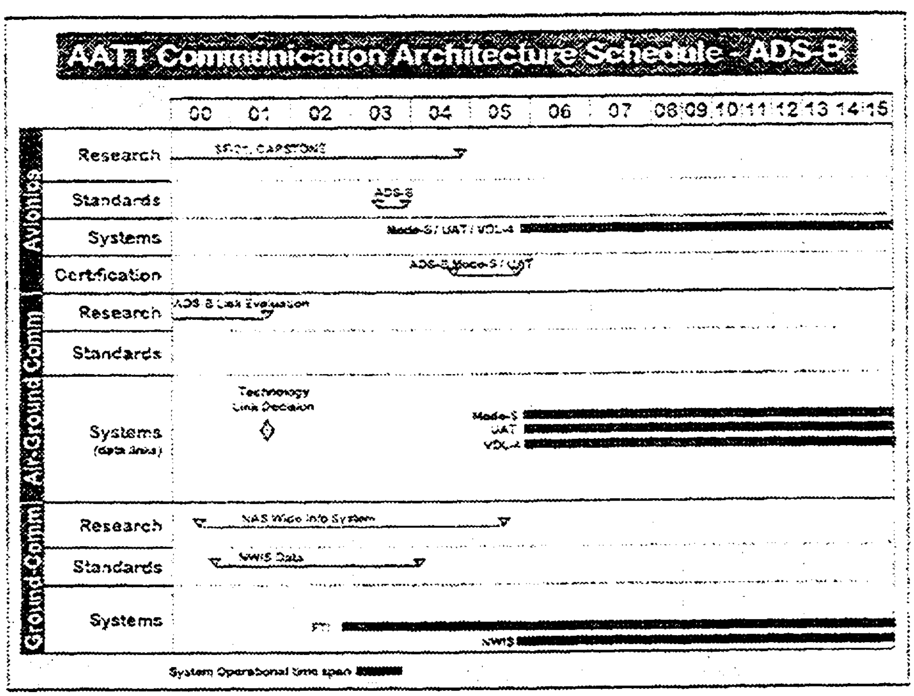
23


AATT Communication Architecture Schedule - CPC
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Avionics
Research
Standards
Systems
Certification
Air-Ground Comm
Research
Standards
Voice Addressing / Routing
Voice and Data Standards
Systems
(data links)
Ground-Ground Comm
Research
Standards
Systems
NWIS
System Operational time span

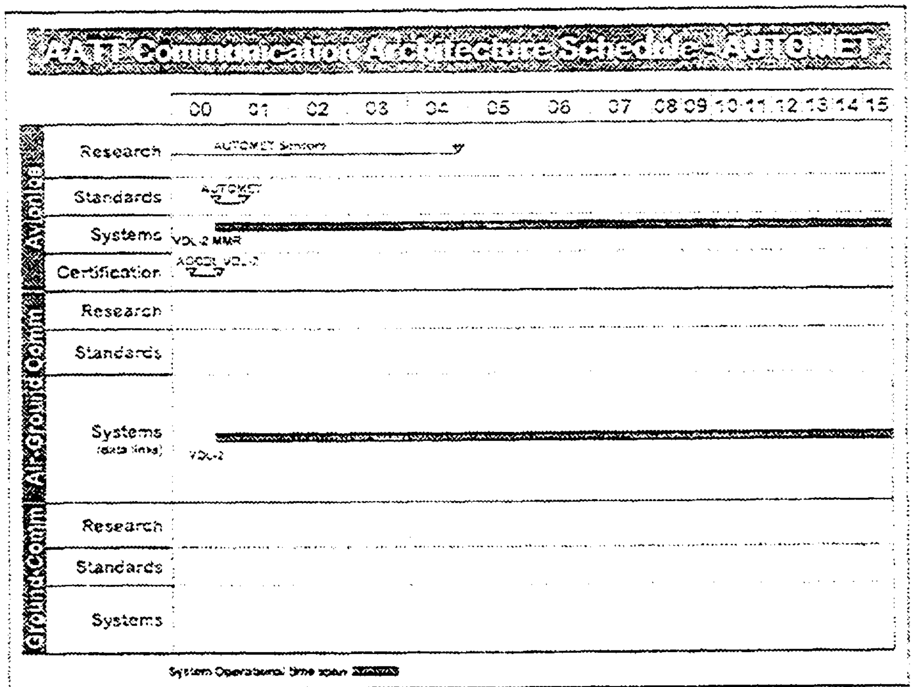

AATT Communication Architecture Schedule - DSSDL
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Avionics
Research
Integrated Demo
Standards
Systems
Certification
Air-Ground Comm
Research
Standards
Systems
(data links)
Ground-Ground Comm
Research
Standards
Systems
NWIS
System Operational time span

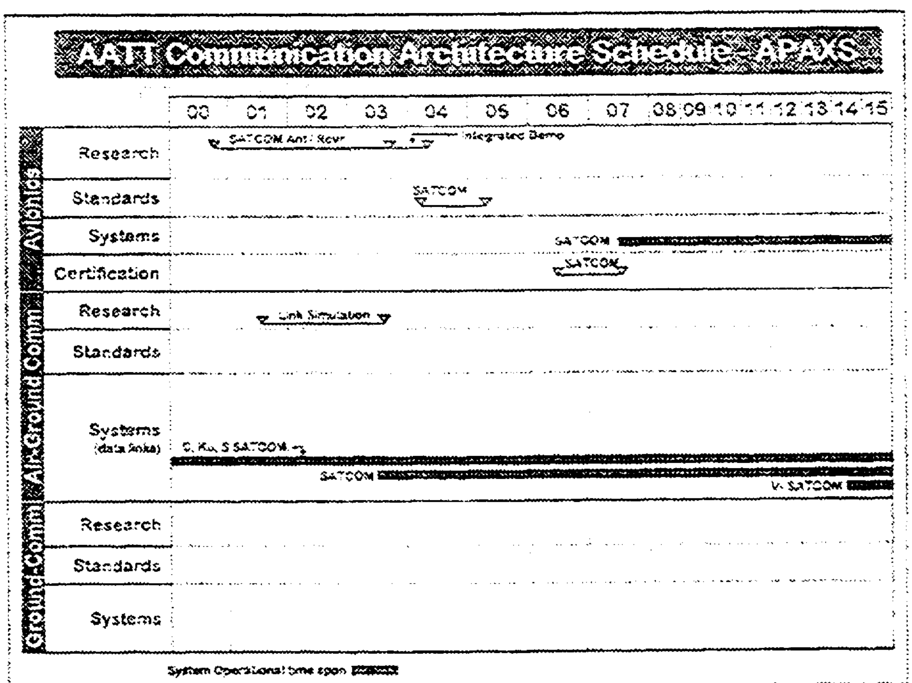
24


AATT Communication Architecture Schedule - AOCDL
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Avionics
Air-Ground Comm
Ground-Comm
Research
Standards
Systems
Certification
Research
Standards
Systems
(data links)
Research
Standards
Systems
Integrated Demo
DSSDL
VDL-2 MMR
CPDLC
AOCDL
NWIS
FTI
System Operational time span

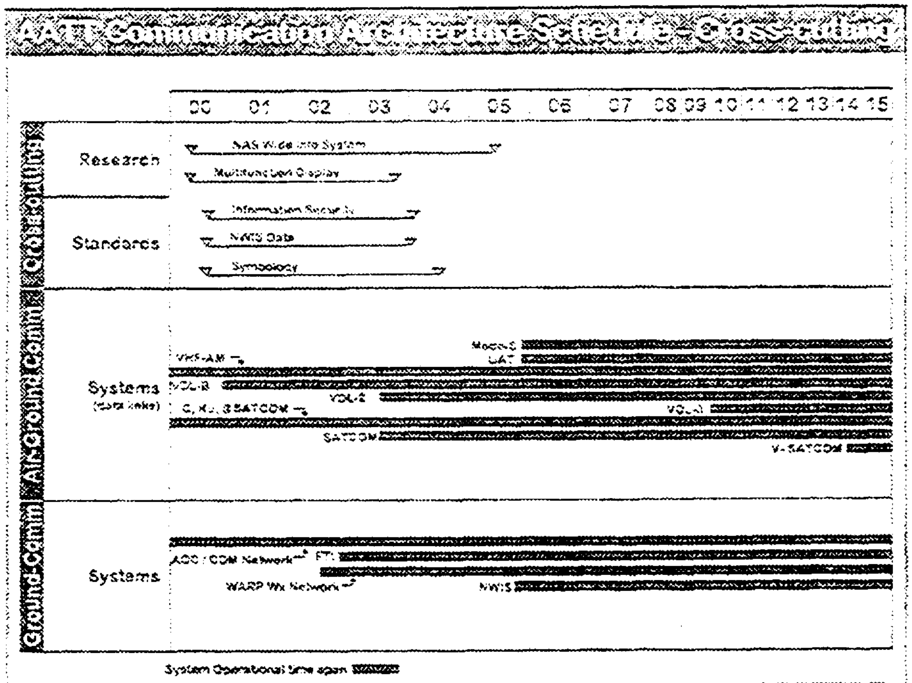

AATT Communication Architecture Schedule - ADS-B
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Avionics
Air-Ground Comm
Ground-Comm
Research
Standards
Systems
Certification
Research
Standards
Systems
(data links)
Research
Standards
Systems
ADS-B
Technology
Link Decision
Mode-S
UAT
VDL-4
NAS Wide Info System
NWIS Data
FTI
NWIS
System Operational time span

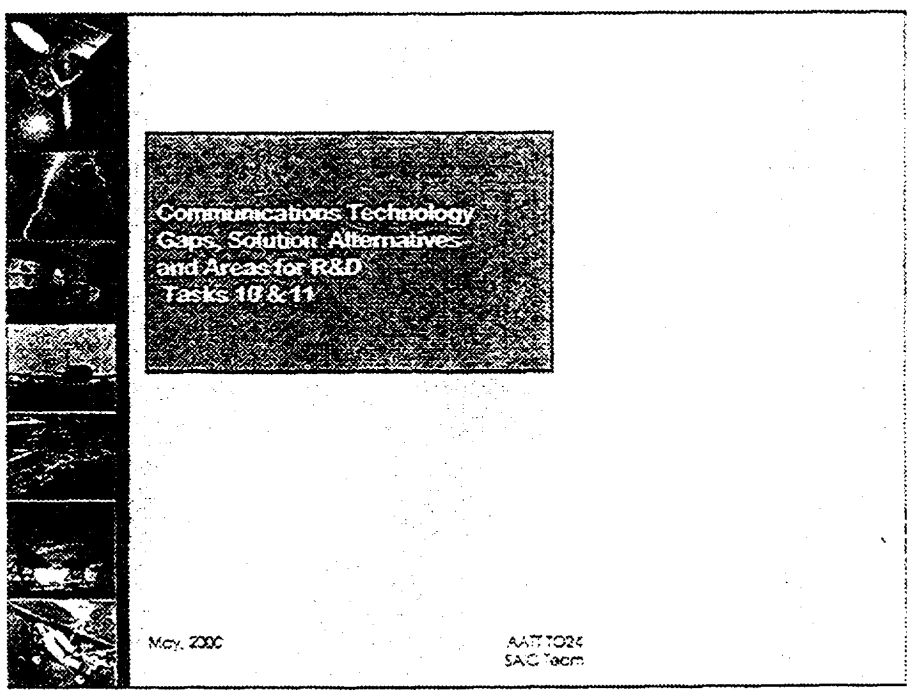
25


AATT Communication Architecture Schedule - AUTOMET
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Avionics
Air-Ground Comm.
Ground Comm.
Research
Standards
Systems
Certification
Systems (data links)
VDL-2 MMR
VDL-2
System Operational time span


AATT Communication Architecture Schedule - APAXS
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Avionics
Air-Ground Comm.
Ground Comm.
Research
Standards
Systems
Certification
Systems (data links)
SATCOM Ant / Rcvr
Integrated Demo
SATCOM
Link Simulation
C, Ku, S SATCOM
V- SATCOM
System Operational time span

26


AATT Communication Architecture Schedule - Cross-cutting
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Cross-cutting
Research
NAS Wide Info System
Multifunction Display
Standards
NWIS Data
Symbology
Air-Ground Comm
Systems
(data links)
Mode-S
VHF-AM
UAT
VDL-B
VDL-2
C, Ku, S SATCOM
VDL-3
SATCOM
V-SATCOM
Ground-Comm
Systems
ADC / COM Network
FTI
WARP Wx Network
NWIS
System Operational time span


Communications Technology
Gaps, Solution Alternatives
and Areas for R&D
Tasks 10 & 11
May, 2000
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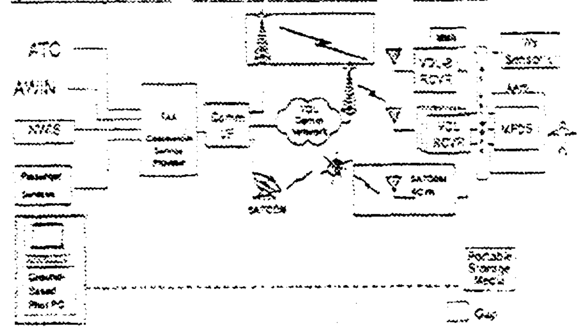
27

Communications Technology Gaps & Solution Alternatives



May, 2000 AATT TO24 SAIC Team 95

Communications Gaps & Solution Alternatives by Year/Segment

Architecture Requirement	Communications Technology Gap Areas	System or Component	Segment		
2007/2015			Ground	Air	Space
2007	Advanced Aircraft Information System	New System Required			
	High Speed Network (Flight Deck/Cabin)	Improved Component		x	
	Server	Improved Component		x	
	Multifunctional Displays	Improved Component		x	
	Intelligent Router	Improved Component		x	

May, 2000 AATT TO24 SAIC Team 96

2S

High Speed Aircraft LAN

- Distribution of data within the aircraft will require a high speed bus or local area network (LAN)
- Cockpit distribution of information
- Cabin services such as In-Flight Entertainment (IFE) and Internet applications
- Aircraft networks will have additional requirements beyond these of terrestrial LANs:
  - FAA certification including consideration of EMI, fire safety, redundancy, failure modes, security and maintenance.
  - Information security, quality of service provisions and a priority scheme.

May, 2000 AATT TO24 SAIC Team 97

Multifunction Display

Types of information for the pilot display are:

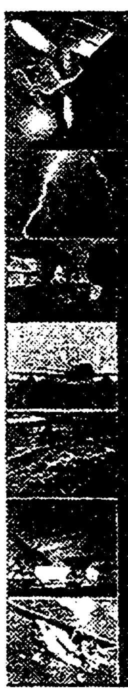
- Heads-up display symbology
- Fused display information about terrain, tower obstacles, and proximate aircraft
- Hazardous weather contours such as wind shear in terminal area, and icing, hail, turbulence and lightning areas
- Taxi instructions including active runways and airport layout

May, 2000 AATT TO24 SAIC Team 98

Communications Gaps & Solution Alternatives by Year/Segment (continued)

Architecture Requirement	Communications Technology Gap Areas	System or Component	Segment		
2007/2015			Ground	Air	Space
2015	Traffic Information System	New System Required			
	Com. interface to TIS				
	standard data set, access protocol, user verification	New System	x	x	

May, 2000 AATT TO24 SAIC Team 99

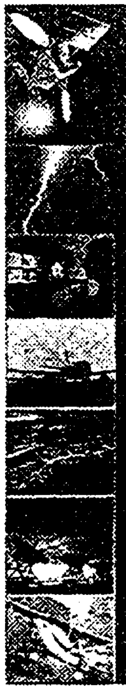


Communications Gaps & Solution Alternatives by Year/Segment (continued)

Architecture Requirement	Communications Technology Gap Areas	System or Component	Segment		
2007/2015			Ground	Air	Space
2007	SATCOM	New System, Component and Datalink Required			
	Multi-mode Radio with Ka Band interface	Improved Component		x	
	Development of efficient modulation techniques for Ka satellite bands	Improved Component		x	x
	Mobile Standards	Improved System			x
	Ka Band Receiver Improvements	Improved Component		x	
	Ka Band Antenna Improvements	Improved Component		x	

May, 2000 AATT TO24 SAIC Team 100

30



Communications Gaps & Solution Alternatives by Year Segment (continued)

Architecture Requirement	Communications Technology Gap Areas	System or Component	Segment		
2007/2015			Ground	Air	Space
2007	VHF Improvements				
	Directional VHF Antennas	Improved Component		x	
	Voice/Data Vocoders	Improved System	x	x	
	Modulation	Improved System	x		
	Virtual Network	Improved System	x		
	Compression	Improved Technology	x		
	Voice synthesis	Data Link	x		

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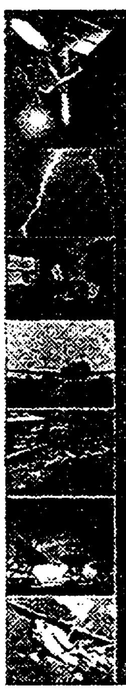

Cross Cutting Technology Gaps

Architecture Requirement 2007/2015	*Cross Cutting Technology Issues*	System or Component	Segment		
			Ground	Air	Space
2015	NAS-Wide Information System	New System Required			
	Com. Interface to Distributed NAS Wide Database (standard data set, access protocol, user verification)	New System	x	x	
2007	Information Security	Improved Datalink Required			
	Authentication	New System	x	x	
	Data Validation	Improved System	x	x	
	Protection from Interference	Improved System	x	x	x

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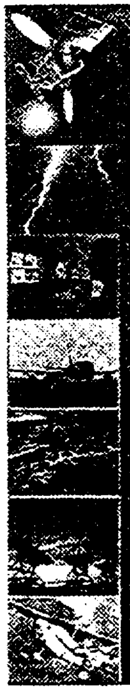

AATT TO 24 Challenges

- Evolving Standards, concepts, product definitions, communications technologies and services (AUTOMET, EPiRep, VDL-B, UAT, VDL -4)
- Variations and inconsistencies in documented message traffic and aircraft projections
- Pending link decisions that could impact recommendations (ADS-B)
- Concept definitions (NWIS, DAG)
- Market drivers (APAXS)

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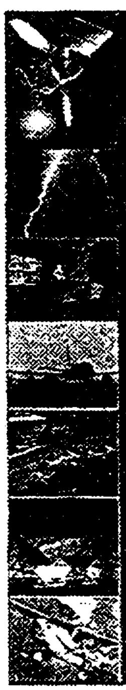

AATT TO24 Accomplishments

- Provided a framework for future decision making
- Provided a coherent structure for future research and analysis
- Collected, sorted and categorized input from multiple reports
- Provided traceability from user requirements to services and communications links through the use of functional capabilities and technical concepts
- Developed a repository for continued data collection
- Determined viable links for each service from a top down and bottom up perspective
- Identified key milestones for transition to 2015 AATT CSA
- Identified gap areas and solution candidates for further research

May, 2000 AATT TO24 SAIC Team 104

AATT TO 24 Status

Individual Task Reports Delivered:

July 99-May 00

AATT TO24 Team Presentations:

May, July, September, October, 1999

January, February, March, 2000

Final Presentation:

May 10-11, 2000

Final Report:

May 26, 2000

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A/A	Air to Air	CNS	Communications, Navigation and Surveillance
A/G	Air to Ground	CONOPS	concept of operations
AAC	Airlines administrative communications	CONUS	Continental United States
AAIS	Advanced Aircraft Information System	COTS	Commercial Off-The-Shelf
AATT	Advanced Air Transportation Technologies	CP	conflict probe
ACARS	aircraft communications addressing and reporting system	CPDLC	Controller-Pilot Data Link Communications System
ADAS	AWOS data acquisition system	CPU	central processing unit
ADS	Automatic Dependent Surveillance	CSA	communications system architecture
ADS-B	Automatic Dependent Surveillance - Broadcast	CSMA	Carrier Sense Multiple Access
AFSS	automated flight service station	CTAS	Center-TRACON Automation system
AIM	Aeronautical Information Manual	CWA	Center Weather Advisory
AIRMET	Airmen's information Manual	D8PSK	Differential Eight-Level Phase Shift Keying
AM	amplitude modulation	DA	descent advisor
AMS	acquisition management system	DAG-TM	Distributed Air/Ground Traffic Management
AMS(R)S	Aeronautical Mobile Satellite (Route) Service	DoD	Department of Defense
AMSRS	Aeronautical Mobile Satellite (Route) Service	DOT	Department of Transportation
AMSS	Aeronautical Mobile Satellite System	DOTS	dynamic ocean tracking system
AOC	airline operations center	DSR	Display System Replacement
ARINC	Aeronautical Radio Inc.	EMC	Electromagnetic Capability
ARTCC	Air route traffic control center	EMI	Electromagnetic Interference
ASIST	Aeronautics Safety Investment Strategy Team	FAA	Federal Aviation Administration
ASOS	automated surface observing system	FANS	Future Air Navigation System
ASR-9	airport surveillance radar-nine	FANS 1/A	future air navigation system
ASR-WSP	airport surveillance radar-weather system processor	FAR	Federal Air Regulations
ATC	Air Traffic Control	FAR	Federal Aviation Regulation
ATC DSS	Air Traffic Control Decision Support Systems	FBO	Fixed Base Operator
ATCSCC	Air traffic Control System Command Center	FBWTG	FAA bulk weather telecommunications gateway
ATCT	Air Traffic Control Tower	FCC	Federal Communications Commission
ATIS	Automatic Terminal Information Service	FDM	flight data management
ATM	air traffic management	FDP	flight data processor
ATN	Aeronautical Telecommunication Network	FEC	frame error check
ATS	air traffic services	FEDSIM	Federal Systems Integration and Management Center
ATSP	air traffic service provider	FFP1	Free Flight Phase 1
AvSP	Aviation Safety Program	FIS	Flight Information Service
AWIN	Aviation Weather Information Services	FL	flight level
AWIN	Aviation Weather Information	FMS	Flight Management System
AWOS	automated weather observing system	FOQA	Flight Operational Quality Assurance
BER	bit error rate	FP	flight plan
BER	Bit Error Rate	FSS	flight service station
CD	compact disk	FSS	Fixed Satellite Service
CDM	Collaborative Decision Making	G/G	Ground-to-Ground
CDMA	Code Division Multiple Access	G/T	Gain to System Noise Temperature Ratio
CDTI	Cockpit Display of Traffic Information	GA	General Aviation

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33

GEO	Geostationary Earth Orbit	PIREP	Pilot Report
GPS	Global Positioning System	PIREPS	pilot reports
HARS	high altitude route system	PSK	Phase Shift Keying
HF	high frequency	QAM	Quadrature Modulation
HF	High Frequency	QOS	Quality of Service
ICAO	International Civil Aviation Organization	RA	resolution advisory
IF	interface	RCP	Required Communications Performance
IFE	In-Flight Entertainment	RD	requirements document
IFR	instrument flight rules	RF	Radio Frequency
IFR	Instrument Flight Rules	RTCA	RTCA, Incorporated
IMC	instrument meteorological conditions	RTO	Research Task Order
IOC	initial operating capability	RVR	runway visual range
IP	Internet Protocol	SAIC	Science Applications International Corporation
ITWS	integrated terminal weather system	SAR	Search and Rescue
IWF	Integrated Weather Forecast	SARP	Standards and Recommended Practices
KBPS	Kilobits Per Second	SATCOM	Satellite Communications
LAN	Local Area Network	SIGMET	Significant Meteorological Information
LEO	Low Earth Orbit	SOW	Statement of Work
LLWAS	low-level wind shear alert system	SPECI	Special Weather Report
MBO	Military Base Operations	SSR	Secondary Surveillance Radar
MDCRS	Meteorological Data Collection and Reporting System	STC	supplemental type certificate
MEO	Medium Earth Orbit	SUA	Special Use Air Space
METAR	meteorological aviation report	TAF	Terminal Aerodrome Forecast
MFD	Multifunctional Display	TBD	to be determined
MOC	Mission Operational Control	TDWR	terminal Doppler weather radar
MOPS	minimum operational performance standards	TFM	traffic flow management
MSS	Mobile Satellite Service	TIS	Traffic Information Services
MTBF	Mean Time Between Failure	TM	traffic management
N/A	Not Applicable	TMS	traffic management system
NAS	National Airspace System	TRACON	Terminal Radar Approach Control Facility
NAS RD	NAS Requirements Document	TRM	Technical Reference Model
NASA	National Aeronautics and Space Administration	TWDL	Two-Way Data Link
NATCA	National Air Traffic Controllers Association	TWEB	Transcribed Weather Broadcast
NAWS	National Aeronautics and Space Administration	TWIP	terminal weather information for pilots
NESDIS	national environmental satellite, data, and information service	VDL	very high frequency digital link
NEXCOM	Next Generation A/G Communications System	VFR	visual flight rules
NEXRAD	next generation radar	VHF	very high frequency
NLDN	national lightning detection network	VOR	VHF-Omni Directional Range
NOTAM	Notice to Airmen	WAAS	Wide Area Augmentation System
NWS	National Weather Service	WAN	Wide Area Network
NWS/OSO	National Weather Service/Office of Systems Operations	WARP	weather and radar processor
OASIS	operational and supportability implementation system	WJHTC	William J. Hughes Technical Center
OAT	Office of Advanced Technology	WMSCR	weather message switching center replacement
ODAPS	oceanic display and planning system	WX	Weather
PFAST	passive final approach spacing tool	WXAP	weather accident prevention

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107

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This document is the NASA AATT Task Order 24 Final Report. NASA Research Task Order 24 calls for the development of eleven distinct task reports. Each task was a necessary exercise in the development of comprehensive communications systems architecture (CSA) for air traffic management and aviation weather information dissemination for 2015, the definition of the interim architecture for 2007, and the transition plan to achieve the desired End State. The eleven tasks are summarized below along with the associated Task Order reference. The output of each task was an individual task report. The task reports that make up the main body of this document include Task 5, Task 6, Task 7, Task 8, Task 10, and Task 11. The other tasks provide the supporting detail used in the development of the architecture. These reports are included in the appendices. The detailed user needs, functional communications requirements and engineering requirements associated with Tasks 1, 2, and 3 have been put into a relational database and are provided electronically.

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