



**GUIDANCE ON THE IMPLEMENTATION OF AIR-GROUND DATA LINK APPLICATIONS
IN THE SAM REGION**

October 2013

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- AEEC 620 - *Datalink Ground System Standard and Interface Specification*
- AEEC 622 - *ATS Datalink Applications over ACARS Air-Ground Network*
- AEEC 623 – *Character-Oriented Air Traffic Service (ATS)*
- ICAO Annex 3 – *Meteorological Services for International Air Navigation*
- ICAO Annex 6 – *Aircraft Operations*
- ICAO Annex 10 – *Aeronautical Telecommunications – Volume 3 Communication Systems*
- ICAO Annex 11 – *Air Traffic Services*
- *Operational Concept and Technical Specifications for the Atlântico Area Control Centre (AO-ACC - Brazil)*
- ICAO Doc 9694 - *Manual of Air Traffic Services Data Link Applications*
- ICAO Doc 9776 – *Manual on VHF Digital Link (VDL) Mode 2*
- ICAO Doc 9869 - *Manual on Required Communication Performance*
- ICAO Doc 9896 – *Aeronautical Telecommunication Network (ATN) Manual for the ATN using IPS Standards and Protocols*
- *Technical Specifications for D-ATIS (Guarulhos and Galeão airports - Brazil)*
- *Technical Specifications for DCL (Guarulhos and Galeão airports - Brazil)*
- *Technical Specifications for the implementation of D-VOLMET (Brazil)*
- *GOLD – Global Operational Data Link Document*
- *Guidance for the Implementation of National Digital Networks using the IP Protocol*
- *Safety Guidance for the Implementation of IP Networks*
- *Caribbean and South America Regional Air Navigation Plan – FASID – Table CNS2A*
- *SAM Performance-based air navigation implementation plan (SAM PBIP)*
- *Global Air Navigation Plan for CNS/ATM Systems (Doc 9750) – Fourth Edition, “Aviation System Block Upgrades” (ASBU) initiative.*
- *SAM Routing Policy*

GLOSSARY OF ACRONYMS

• AAC	Aeronautical Administrative Communications
• ACC	Area Control Centre
• AEEC	Airlines Electronic Engineering Committee
• ACARS	Aircraft Communications Addressing and Reporting System
• ADS-C	Automatic Dependent Surveillance — Contract
• ADS-B	Automatic Dependent Surveillance – Broadcast
• AMHS	ATS Message Handling System
• ANRF	Air Navigation Report Form
• ANC	Air Navigation Commission
• ANSP	Air Navigation Service Provider
• AOA	ACARS <i>over</i> AVLC
• AOC	Aeronautical Operational Communication
• ARINC	Aeronautical Radio, Incorporated
• ASBU	Aviation System Block Upgrades
• ATC	Air Traffic Control
• ATIS	Automatic Terminal Information Service Note: D-ATIS: ATIS provided through data link
• ATM	Air Traffic Management
• ATN	Aeronautical Telecommunication Network
• ATS	Air Traffic Services
• AVLC	Aviation VHF Link Control
• BER	Bit Error Rate
• CAA	Civil Aviation Authority
• CLNS	Connectionless Network Service

- CPDLC Controller-Pilot Data Link Communications
- CSP Communication Service Provider
- DCL Departure Clearance
- DSP Data Link Service Provider
- DECEA *Departamento de Controle do Espaço Aéreo*
- FASID Facilities and Services Implementation Document
- FANS Future Air Navigation System
- FCI Future Communication Infrastructure
- FIR Flight Information Region
- FMS Flight Management System
- FOM FANS 1/A Operational Manual
- GOLD Global Operational Data Link Document
- GREPECAS Caribbean/South American Regional Planning and Implementation Group
- HFDL High Frequency Data Link
- IPS Internet Protocol Suite
- ISO International Organization for Standardization
- LAR Latin American Aeronautical Regulations
- LDACS L-Band Digital Aeronautical Communications System
- MAC Media Access Control
- MPLS Multiprotocol Label Switching
- ICAO International Civil Aviation Organization
- OCL Oceanic Clearance
- OSI Open System Interconnection
- PFF Performance Framework Form

- PIA Performance Improvement Area
- PIRG Planning and Implementation Regional Group
- QoS Quality of Service
- RAAC Meeting of Civil Aviation Authorities of the South American Region
- RCP Required Communication Performance
- REDDIG South American Digital Network
- RGS Remote Ground Station
- RSP Required Surveillance Performance
- RVSM Reduced Vertical Separation *Minima*
- SAM South American Region
- SAM/IG SAM Implementation Group
- SATCOM Satellite Communication
- SIGMET Significant Meteorological Information
- SITA *Société Internationale de Télécommunications Aéronautiques*
- SLA Service Level Agreement
- SRVSOP Regional Safety Oversight System
- TAF Terminal Aerodrome Forecasts
- TBO Trajectory-Based Operation
- TCP Transmission Control Protocol
- VDL VHF Data Link
- VDL Mode 0/A or VHF ACARS VHF Data Link Mode 0/A Subnetwork
- VDL Mode 2 VDL Data Link Mode 2 Subnetwork
- VGS VDL Ground Station
- VHF Very High Frequency (30 to 300 MHz)

- VOLMET Meteorological Information for Aircraft in Flight
Note: D-VOLMET: Data link VOLMET
- VPN Virtual Private Network
- WAN Wide Area Network

DEFINITIONS

For the purpose of this document, the following definitions apply:

Bandwidth: Maximum packet speed of a dedicated connection port expressed in kbit/s or Mbit/s.

ATN applications: Also known as ATN Baseline 1 or 2, are applications used in the ATN network, currently based on the ISO OSI model and, in the future, on the IPS model, for air-ground or ground-ground message exchange.

FANS1/A applications: Bit-oriented applications that follow the recommendations of AEEC 622 - *ATS Datalink Applications over ACARS Air-Ground Network*, for air-ground data link communications.

PRE-FANS applications: Character-oriented applications that follow the recommendations of AEEC 623 - *Character-Oriented Air Traffic Service (ATS)*, for air-ground data link communications.

Performance Improvement Area (PIA): Set of modules that provide the operational and performance objectives in the environment to which they apply, forming an executive vision of the intended evolution through ASBU implementation. It also facilitates comparison of ongoing programmes.

Automatic Dependent Surveillance – Broadcast: A means by which an aircraft, aerodrome vehicle, or other object transmits and/or receives data such as identification, position, and additional information, using a broadcast data link.

Automatic Dependent Surveillance – Contract (ADS-C): A means by which ADS-C messages will be exchanged through air-ground data link, specifying under what conditions ADS-C reports would be initiated, and what data would be contained in the reports.

Quality of Service (QoS): The term Quality of Service refers to a number of technologies that can identify the type of data contained in a packet and divide packets into traffic classes to prioritise delivery. The main advantages of a QoS-sensitive network are: traffic prioritisation for handling important flows before lower-priority flows, and a more reliable network, since the amount of bandwidth used by each application may be controlled and, thus, the competition among applications for the use of the bandwidth.

Physical layer (Level 1): The physical layer defines the technical characteristics of the electrical and optical (physical) devices of the system. It contains the cabling or other communication channels that communicate directly with the network interface controller. Consequently, it enables a simple and reliable communication, in most cases with basic error control:

Functions of the layer:

- Move bits (or bytes, depending on the unit of transmission) through a means of transmission;
- Define the electrical and mechanical characteristics of the means of transmission, the bit transfer rate, voltage, etc.
- Execute or control the amount and delivery rate of information on the network.

The physical layer is not responsible for addressing issues such as transmission errors, since other layers of the OSI model address those issues.

Network layer (Level 3): The network layer is responsible for packet (datagram) addressing on the network, linking logical addresses (IP) to physical addresses in such a way that network packets may reach their destination. This layer also determines the route that packets will follow to reach their destination, based on factors such as network traffic conditions and priorities.

This layer is used when the network has more than one segment and, therefore, data packets will have more than one path to follow from origin to destination.

Functions of the layer:

- Move packets from original source to destination through one or more links.
- Define how network devices discover each other and how packets are routed to their final destination.

Clearance. Authorisation for an aircraft to proceed under conditions specified by an air traffic control unit.

Availability: Parameter that measures performance, which consists of the percentage of time in which the PP/node (as applicable) is operational during a given period of service provision.

Router: Equipment capable of IP processing, tasked with determining the route to be used for sending packets.

Media Access Control (MAC): Term used in computer networks to designate part of the link layer (layer 2 according to the OSI model). It provides access to a communication channel and, by routing through that channel, makes it possible to connect several computers in a network.

METAR: Aviation routine weather report. It is used for fully describing weather conditions observed in regular on-hour periods of time.

Routing protocol: Those used between routers for the exchange of network topology information. They permit updating of the routing table, which is used by routers to select the best path to send a packet between network segments.

Aeronautical telecommunication network: An internetwork architecture that allows air-ground or ground-ground exchange of information for ATS purposes using ISO or IPS protocols.

REDDIG: South American Aeronautical Telecommunication Network (SAM ATN), which supports current voice and data aeronautical fixed requirements, the exchange of radar and flight plan data, as well as the new ATN ground-ground applications between SAM States/Territories planned to be implemented in the short and medium term. The REDDIG is in the phase of being modernised and will be called REDDIG II.

Delay (or latency): Parameter that measures service performance, which consists of the mean transit time of a 64-byte packet between two PPs of the contracting party.

SPECI: Special aviation weather report. It is used when one or more significant variations of weather conditions occur between regular one-hour time intervals.

SIGMET: Weather message that consists of a concise, clear, abbreviated description of the occurrence and/or forecast of en-route weather phenomena that could affect the safety of air operations in a given FIR.

TAF (terminal aerodrome forecasts): Weather forecast for a given aerodrome.

1. INTRODUCTION

1.1 Background

In 1983, the International Civil Aviation Organization (ICAO) established a special committee for developing what was called the *Future Air Navigation Systems* (FANS) with respect to new operational concepts to be applied in air traffic management (ATM). The FANS report was published in 1988, setting the foundations for the establishment of an ATM strategy by the industry, using digital technologies based on data link and satellite transmissions.

In the 1990's, Boeing and Airbus had already developed equipment and software for ATS applications, such as *Controller–Pilot Data Link Communications* (CPDLC) and *Automatic Dependent Surveillance* (ADS), mainly using satellite communications in oceanic areas.

The use of data link for air traffic services (ATS) was given momentum by the use of the *Aircraft Communications Addressing and Reporting System* (ACARS) platform, a system developed by *Aeronautical Radio, Incorporated* (ARINC) for exchanging small and simple messages between aircraft and airlines. The system was modified to be able to transmit messages of interest to air traffic control, also using very high frequency (VHF) and high frequency (HF) equipment.

Regarding ICAO documentation to support the implementation of data link infrastructure, a series of documents were developed for use in the Asia-Pacific (APAC) and European and North Atlantic (EUR-NAT) Regions, especially the Global Operational Data Link Document - GOLD. The second edition of the GOLD was approved in April 2013 with a view to extending the use of ground-air data link in a globally harmonised manner.

Another item worth highlighting is that the GOLD describes under what conditions the various technologies must be used, but must not be considered as a guide on how an ANSP can implement the communication infrastructure and the systems to support data link applications. In this regard, this document attempts to provide general guidelines to be followed by the ANSPs and/or aeronautical authorities of the SAM Region for the implementation of their data links.

Although a number of activities are already under way in the SAM Region for data link implementation, it should be noted that everything started with joint initiatives for the Caribbean and Central American (CAR) and SAM Regions.

Accordingly, note should be taken of effective action taken in recent years in a sequence of events that promote the implementation of data link at regional level.

In this regard, the first meeting of the former CNS/ATM Subgroup (CNS/ATM/SG/1) of the Caribbean and South American Regional Planning and Implementation Group (GREPECAS), held in Lima-Peru, on 15-19 March 2010, agreed to work under the programmes and projects management modality instead of using working groups, to ensure better coordination on ATM and CNS matters and develop performance-based CAR/SAM plans with a view to implementing the global air traffic management (ATM) system.

There were two projects under the Ground-Ground and Air-Ground Communications Infrastructure Programme, namely:

- a) CAR/SAM ATN architecture (D1); and
- b) ATN ground-ground and ground-air applications (D2).

The GREPECAS/16 meeting, held in Punta Cana, Dominican Republic, on 28 March-1 April 2011, agreed that projects should be developed independently by region, CAR or SAM. Accordingly, everything that was being done within the CAR/SAM CNS/ATM Subgroup was divided into CAR and SAM.

In order to conduct work under the new GREPECAS organisation, the Programmes and Projects Revision Committee (CRPP) was created to draft GREPECAS annual reports to be approved by the Group through the fast-track mechanism, which would then be submitted by the Secretariat to the Air Navigation Commission (ANC), and then to the Council, as applicable.

In practical terms, with regard to data link, the seventh meeting of the SAM Implementation Group (SAM/IG/7), held in Lima – Peru on 23-27 May 2011, created the ATN Ground-Ground and Ground-Air Applications Project (D2) for the SAM Region.

The tasks assigned to Project D2 include the drafting of a guide for the implementation of air-ground data link applications in the SAM Region, as foreseen within the framework of activities under Regional Project RLA/06/901 – Assistance for the implementation of a regional ATM system, taking into account the ATM operational concept and the corresponding communication, navigation and surveillance (CNS) technological support.

It should be noted that the guide also takes into account the experience of Brazil in data link implementation, as reflected in the table describing the tasks corresponding to Project D2. It especially describes the main requirements met through the implementation of character-oriented applications, such as digital meteorological information for aircraft in flight (D-VOLMET) via data link, departure clearance (DCL) via data link, and data link-automatic terminal information services (D-ATIS), in addition to the adoption of data link for communications in the Oceanic FIR, called Atlantico ACC (AO-ACC), using controller-pilot data link communications (CPDLC) and automatic dependent surveillance - contract (ADS-C).

Finally, it should be noted that this guide may be considered as a living document that shall be updated periodically, taking into account the many recurring global initiatives on this topic and the efforts made by SAM States and the ICAO Lima Regional Office for the adoption of the performance-based navigation implementation plan for the SAM Region (SAM PBIP), in accordance with the new Aviation System Block Upgrade (ASBU) concept presented and approved at the Twelfth Air Navigation Conference (AN-Conf/12), held in Montreal – Canada, on 19-30 November 2012.

1.2 Scope of the document

This guide is intended for national air navigation service providers (ANSPs), civil aviation authorities, and aircraft operators of the ICAO South American (SAM) Region that need introductory information on technical and operational concepts and considerations that should be borne in mind before planning and implementing ground-air data link in the Region.

This guide is not to be used by States for the implementation of air-ground data link for ADS-B purposes, as ATS surveillance sensor, or as on-board traffic monitoring system to improve the situational awareness of the crew. To that end, the guide on technical and operational considerations for the implementation of ADS-B in the SAM Region was developed and presented at the SAM/IG/10 meeting held on 1-5 October 2012, as part of the tasks of the project entitled Enhanced ATM situational awareness in the SAM Region, under the Automation and Situational Awareness Programme.

1.3 **Organisation of the document**

The first part of this document contains the references, glossary of acronyms, and definitions, which serve as a reference for the whole document given the amount of information it contains. To supplement this part, Section 1.1 of the Background of Chapter 1 lists all the activities carried out to further the use of data link in ICAO Regions, especially the SAM Region.

Chapter 2 contains basic considerations for the implementation of air-ground data link, especially the guidelines of the new Global Air Navigation Plan, 4th edition (GANP) (Doc 9750), the new ICAO Aviation System Block Upgrade (ASBU) methodology, as well as a revision of the SAM Performance-based air navigation implementation plan (SAM PBIP), as aligned to the ASBUs.

Chapter 2 also suggests basic telecommunication infrastructures for the delivery of information to air traffic control units (ATCs), mainly taking into account air-ground subnetworks that use satellite and ground technologies, the ground subnetwork between remote stations and ATC units, based on ICAO stringent availability, reliability, and integrity requirements.

Chapter 3 describes the experience of Brazil with respect to the implementation of CPDLC and ADS-C applications in the Atlantico area control centre (AO-ACC), which is responsible for operations in the oceanic flight information region (FIR) of the country.

Bearing in mind the importance of PRE FANS applications, Chapter 4 lists the basic characteristics of character-oriented applications D-VOLMET, D-ATIS, and *Departure clearance* (DCL). In all the cases described, the experience of Brazil in the implementation of the aforementioned services was taken into account.

Finally, Chapter 5 summarises the contents of the guide regarding factors that should be taken into account by States for data link implementation.

2. GENERAL CONSIDERATIONS FOR AIR-GROUND DATA LINK IMPLEMENTATION IN THE SAM REGION

2.1 Introduction

Figure 1 shows the importance of data link applications in all flight phases, from take-off to landing.

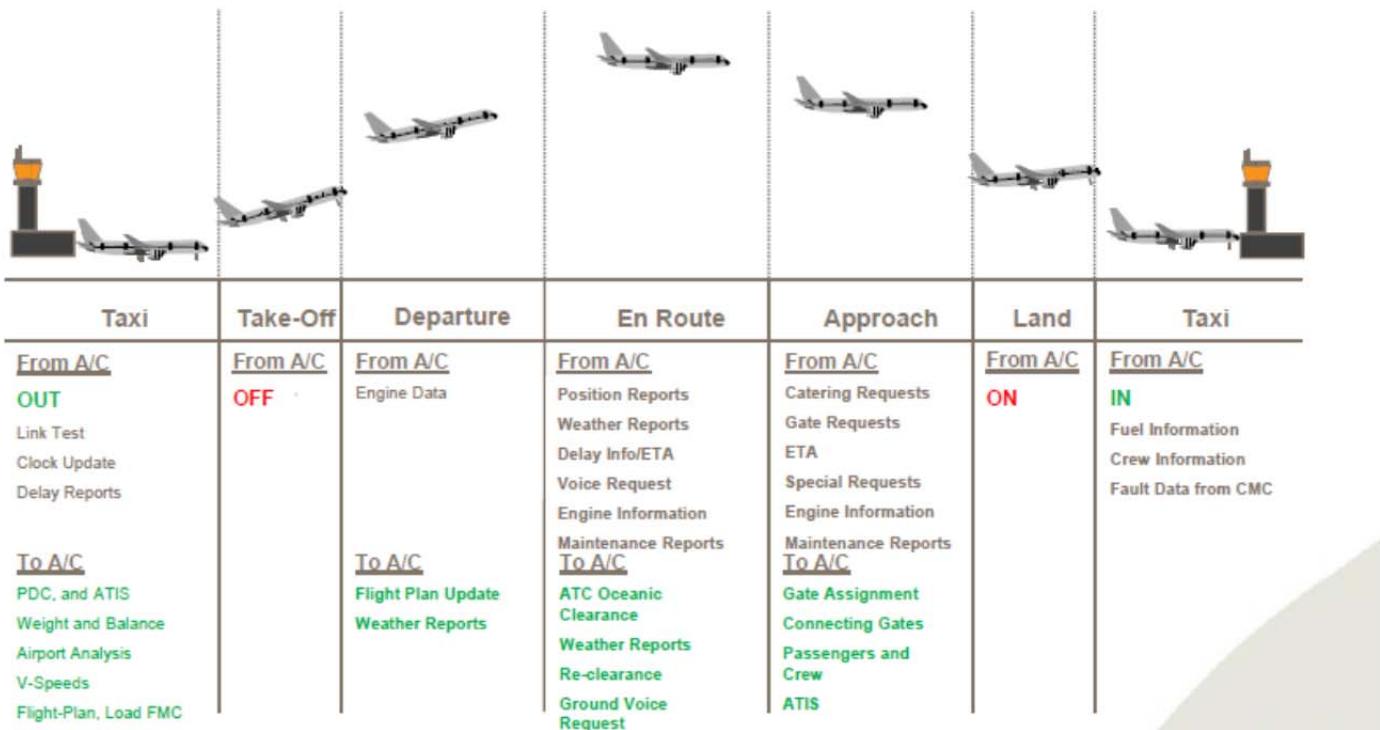


Figure 1: Ground-air data link applications

Air traffic activity has increased significantly in the South American (SAM) Region due to economic growth and tourism.

Consequently, civil authorities in the Region are making significant investments in air traffic control (ATC) supporting infrastructure in order to improve services to address traffic growth projections.

One infrastructure that must be modernised or implemented is the ground-air communications capability, through the adoption of the data link concept to replace traditional voice communications between pilots and air traffic controllers.

Data link services are aimed at supporting a more efficient air traffic management with a view to optimising airspace capacity, thus reducing longitudinal and lateral separation between aircraft.

The main application for pilot-controller communications is CPDLC, which has the advantage of reducing congestion in the traditional voice channels and enabling the use of automation resources. Furthermore, it minimises communication problems and controller and pilot workload.

The technological components of data link message handling are divided into: the air subnetwork consisting of airborne equipment (avionics), the air-ground means of communication, the ground communication subnetworks, and the users of the information (airlines, ATC units, etc.).

Platform selection involves operational, technical, financial, and strategic aspects of civil aviation authorities and/or national air navigation service providers (ANSPs).

The States and/or ANSPs need to develop a policy to make possible the required investment, starting with the development of a national ATM operational concept consisting of operational plans for the implementation of the ground infrastructure and incentives for operators to equip their aircraft.

As stated in the chapters below, satellite communication technology (SATCOM technology) and analog VHF radio (ACARS) are capable of transmitting many character- or bit-oriented data link applications in oceanic and/or remote continental areas. Likewise, high frequency data link (HFDL) can be used as foreseen in ICAO Annex 10 – Aeronautical telecommunications – Volume 3 Communication systems.

However, if CPDLC needs to be adopted in continental areas with significant air traffic density, the technologies mentioned in the previous paragraph cannot be used, and there is a need to apply the standard foreseen in ICAO Doc 9776 – Manual on VHF Digital Link (VDL) Mode 2, that is, VHF data-link radio Mode 2 (VDL Mode 2), and aeronautical telecommunication network (ATN) routers, which entails a significant investment by airlines and the ANSP.

A factor to be taken into account is regional data link implementation planning in the South American (SAM) Region, as detailed in the SAM Performance-based air navigation implementation plan (SAM PBIP) approved at the Twelfth Meeting of Civil Aviation Authorities of the South American Region (RAAC/12) held in Lima, Peru, on 3-6 October 2012.

To support the initiatives, the Twelfth Air Navigation Conference (AN-Conf/12) approved the new ICAO Aviation System Block Upgrades (ASBU) methodology, which will be part of the new Global Air Navigation Plan (GANP), 4th edition (Doc 9750), and through Recommendation 6/1 – Regional Performance Framework – Planning methodologies and tools, it agreed that States and regional planning groups (PIRGs) should finish harmonising regional plans with the GANP, focusing on the implementation of ASBU Block 0 modules.

In this regard, the ICAO Lima Regional Office reviewed the SAM PBIP in order to align it to the ASBU. The 18 modules of Block 0 were reviewed and it was felt that, initially, 15 modules would be applied in the SAM Region.

Upon analysing the content of the ASBU Block 0 modules under consideration, it was noted that practically all the elements contained therein were contemplated in the SAM PBIP, and relationships were established between regional performance objectives and the cited ASBU modules.

In this regard, **Appendix A** to this guide contains Module B0-TBO, which defines aspects for data link implementation in the SAM Region from 2013 to 2018 (Block 0) in support of Performance Improvement Area (PIA) 4, **Efficient flight paths, through trajectory-based operations**. The importance assigned to ADS-C in oceanic and remote continental areas and to CPDLC already being applied in continental areas is apparent.

Appendix B contains the Performance Framework Forms directly related to data link implementation in the SAM Region that were incorporated into the revised SAM PBIP. It should be noted that air-ground data link supports three PFFs (SAM ATM/06, SAM CNS/02, and SAM CNS/04).

As stated before, ASBU Block 0 includes Module B0-TBO – Trajectory-Based Operation. In order to monitor data link implementation in support of this module, ICAO has developed the Air Navigation Report Form (ANRF) shown in **Appendix C**.

It should be noted that all SAM data link implementation initiatives are aligned with the ASBU Communication Roadmap shown in **Appendix D**, a significant component of which is ACARS VHF, SATCOM (ACARS), and VDL Mode 2 data link, based on the Open System Interconnection (OSI) model of the International Organization for Standardization (ISO) – ATN/OSI network, at least until the end of the Block 2 cycle (2023-2028). From there on, massive use of L-band digital aeronautical communications system (LDACS) technology starts, which corresponds to the future communications infrastructure (FCI), based on the IP protocol suite (IPS) – ATN/IPS.

2.2 Basic data link characteristics

For ground-air transmission, a telecommunication structure must be used, which depends on the area being overflown by the aircraft: if flying over oceanic area, the most widely used technology is satellite link, but high frequency data link (HFDL) can also be used; if the aircraft is flying over continental area, satellite and ground technologies may be used, including HFDL, VHF ACARS, VDL Mode 2, and SATCOM. Taking into account the technologies most widely used at present, this guide will address the use of VDL and SATCOM.

Note: ICAO Annex 10 – Aeronautical telecommunications – Volume 3, Communication Systems, contemplates the possibility of using VDL Mode 3 (voice and data) and VDL Mode 4 for data. However, ANSPs and/or data link service providers (DSP) have not yet accepted the aforementioned equipment.

Figure 2 describes a basic telecommunication structure, already mentioned in Section 2.1 Introduction, for sending data from the aircraft to an ATC unit or airline address and *vice versa*.

It should be noted that if applications to be transmitted are character-oriented (PRE FANS) or bit-oriented (FANS 1/A), the architectures that can be used for the air-ground portion are: SATCOM, ACARS, HFDL, and VDL Mode 2. This could lead to the false conclusion that the technologies described above meet all data link performance requirements. But ACARS has a series of inherent limitations, as we will see later on in Section 2.5.3 and as listed in the FANS Operational Manual, which prevent its use in all cases of data link.

For example, for CPDLC in continental areas with high traffic density, VDL Mode 2 and layer 3 equipment (routers) must be used, thus establishing an ATN network.

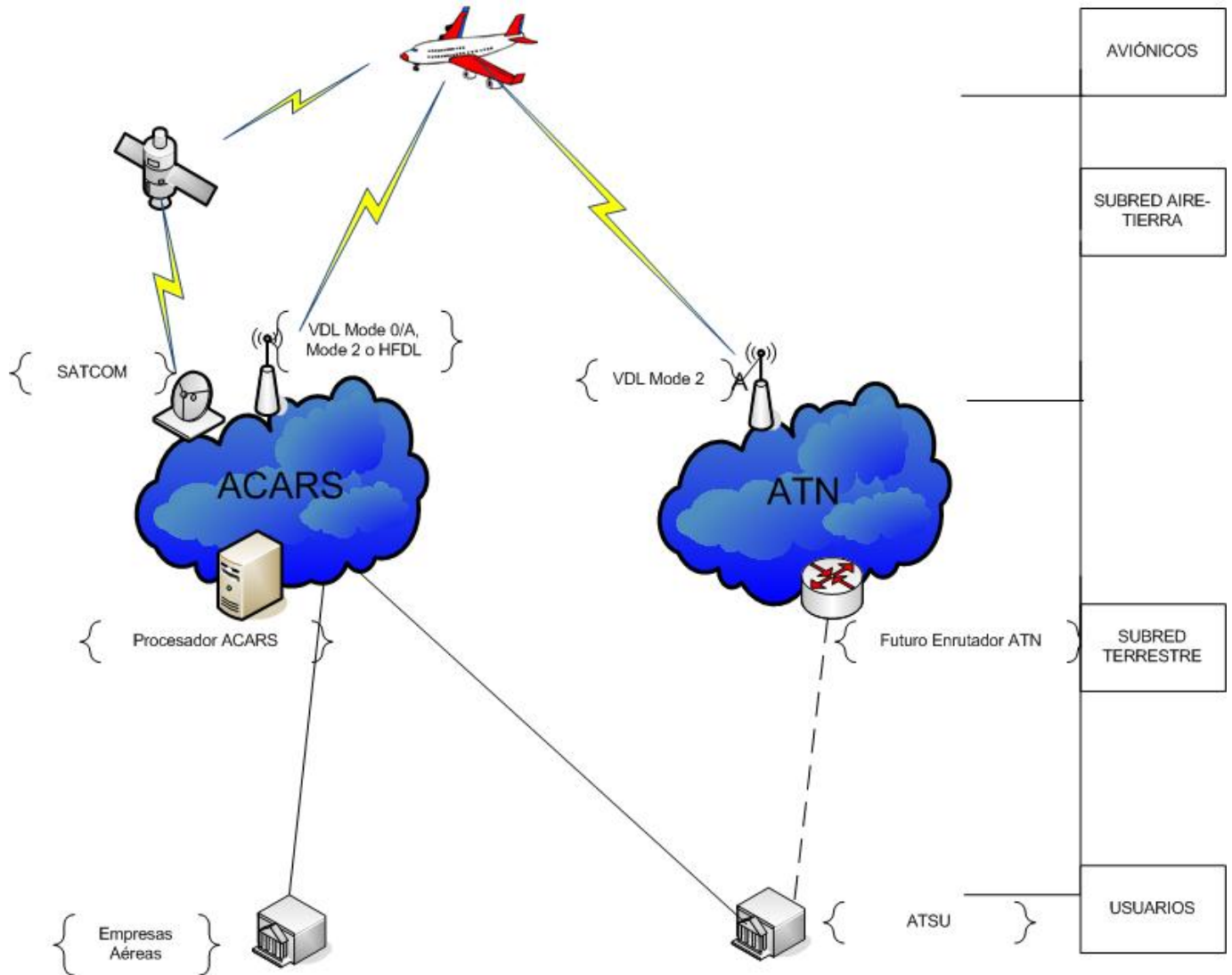


Figure 2 – Basic ground-air telecommunication infrastructure

Figure 2 shows that there are many systems and equipment between the aircraft and an ATC unit or AOC on the ground, and this affects end-to-end availability.

In this regard, it should be noted that in telecommunications and in the reliability theory, the term availability indicates the level of operability of a system or sub-system when required to operate. In simple terms, without getting into mathematical calculations, availability is the probability that, at any given time, the system is capable of “working”.

Since we are dealing with probability, it should be noted that equipment set up in parallel increases availability while equipment set up in series reduces availability. **Appendix E** presents some system availability concepts related to communication networks supporting the transmission of signals described in Figure 2.

All the aforementioned is of great importance, since when dealing with data communications, the technology used must be borne in mind in order to achieve the appropriate availability.

ICAO has some provisions that address this issue in detail. Doc 9694, Manual of Air Traffic Services “Data Link” Applications, contains important concepts on the adoption of data link for ATS services. It describes the main applications that use data link: CPDLC, ADS-C, ADS-B, *inter alia*. It also lists the main performance requirements in terms of availability, integrity, continuity, and reliability of each application.

However, a significant step forward was the adoption of Doc 9869, Manual on Required Communication Performance, which describes the Required Communication Performance (RCP) concept and relates applications to message handling times, availability, continuity, and integrity, with a view to defining ideal longitudinal and lateral separations in each airspace.

The RCP concept evaluates operational communications in terms of ATM functions, taking into account human factors, procedures, and environmental characteristics. Actually, RCP was developed in response to the need for operational criteria to assess the technologies available for controller-pilot communications.

By extension, types were adopted for RCP that define operational performance standards in terms of message handling times, continuity, availability, and integrity applicable to the most stringent ATM operational requirements. It should be noted that there are RCP types, like type 10, for which communication equipment and procedures are being developed to address the corresponding requirements.

Likewise, the GOLD document uses the concepts contained in Doc 9869, taking into account the technologies available for operations in oceanic or remote continental areas. Furthermore, it incorporates the Required Surveillance Performance (RSP) concepts, mainly for operations in oceanic areas.

Some comments are in order regarding the nomenclature used in the GOLD document for air-ground subnetwork equipment. In fact, there are a number of data link implementation initiatives in Europe and the United States that warrant a distinction amongst applications and technologies by using many terminologies. In South America, the rate of data link implementation is not so rapid, and a distinction between the various types of technologies and applications is not deemed necessary.

Thus, in terms of air-ground communication technologies the GOLD document refers to analog VHF as VDL Mode 0/A and this document will refer to it as ACARS VHF.

Regarding character-oriented applications, the GOLD document refers to these applications as ACARS ATS, the same nomenclature as that used in AEEC 623, Character-Oriented Air Traffic Service Applications. In this guide, these applications will be referred to as PRE-FANS to avoid possible confusion with ACARS VHF radio. Likewise, the implementation of an ATN network using VDL Mode 2 for CPDLC in continental areas with high traffic density is considered as ATN Baseline 1 (ATN B1) in the GOLD document. In this guide, it will be called ATN network.

Note: In Europe, ATN Baseline 1 is treated as Link 2000+ under the coordination of EUROCONTROL for the implementation of the Single European Sky ATM Research (SESAR).

It should be noted that there are nomenclatures in place, such as ATN Baseline 2 (ATN B2), that will enable the implementation of 4D path procedures, which cover longitude-, latitude-, altitude-, and time-based paths. Likewise, ATN Baseline 2 will support all the other applications that exist today, but technically improved. Nevertheless, the procedures involve new data link technologies, which are foreseen for ASBU Blocks 3 and 4.

2.3 On-board equipment

Appendix F to the GOLD document provides specific information about the equipment available for use on aircraft from the most varied manufacturers for data link support. Taking into account the updates that the reference document will require, this guide will not repeat information contained in the cited appendix.

The main on-board data link components are illustrated in Figure 3.

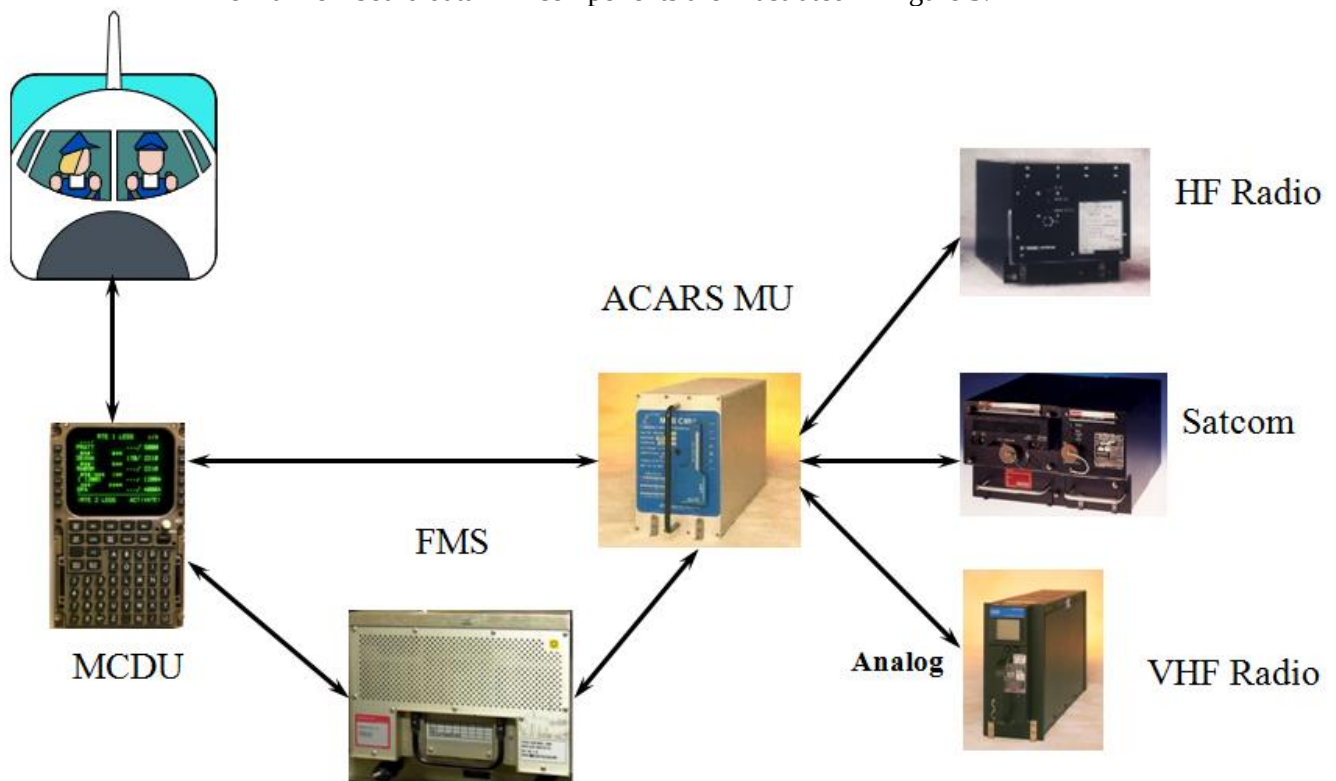


Figure 3: Data link on-board systems

In general, uplink and downlink messages are fed into the Multi-Function Control Display Unit (MCDU). Transceivers, as well as frequencies, are selected through the ACARS Management Unit (MU). It should be noted that the MU is also linked to the Flight Management System (FMS), which obtains aircraft position information. The system also includes antennae and printers.

Although Figure 3 is related to the ACARS system, when the ATN becomes available, there will be similar equipment in place with the addition of ATN routers and VDL Mode 2 digital radios.

2.4 Ground-air infrastructure

2.4.1 Introduction

When dealing with air-ground communications, it is important to identify the types of message flows that are transferred from the aircraft to an ATSU and *vice versa*:

- ACARS flows (AAC/AOC): data is transmitted between the aircraft and the airlines for the exchange of administrative and operational messages;
- ACARS flows (ATC): data is transmitted between the aircraft and an ATSU, and may be FANS or PRE-FANS messages; and
- ATN flows: data is transmitted from the aircraft to an ATSU, using VDL Mode 2 and ATN routers.

At present, there are three main types of air-ground networks:

- VHF, which uses the VHF signal between the aircraft and a ground station, and it may be ACARS VHF (VDL Mode 0/A) or VHF standardised by ICAO (VDL Mode 2);
- SATCOM ACARS: the signal goes from the aircraft to the satellite and is then transmitted to an earth station; and
- ACARS HF: which was subsequently introduced, and uses an HF signal between the aircraft and a ground HF station.

Most aircraft operating in South America are equipped with the Aircraft Communications Addressing and Reporting System (ACARS). In the future, it is intended that equipment shall be installed for controller/pilot communication using the Aeronautical Telecommunication Network (ATN), which is the standard foreseen by ICAO that enables CPDLC implementation in high-traffic continental areas.

As previously stated, ACARS messages use VHF analog links for transmitting character-oriented applications, based on the AEEC 623-2 specification, or bit-oriented applications using the character/bit conversion foreseen in the AEEC 622-3 specification.

Figure 2 shows the provider network (CSP), which may be considered as the network connecting the stations that receive data from the SATCOM, HFDL, and VHF (ACARS or VDL Mode 2) stations and send it to the airlines or an ATSU. The following sections will describe the main aspects of air-ground networks that use VHF and ground networks to support the exchange of data link messages between aircraft and users.

As reflected in the GOLD document, practically all aircraft are equipped for VHF data link, but not all of them are ready for SATCOM and/or HF communications. Furthermore, there are ANSPs that do not permit the use of means of communication such as SATCOM and/or HF.

2.4.2 (VHF) ground-air communication networks

2.4.2.1 General

As previously stated, this guide covers the installation of VHF equipment as part of the implementation of the air-ground subnetwork. In this regard, during the VHF implementation phase, the level of VHF coverage needs to be established for all the continental area in which a State operates.

As an example, when modernising its data link infrastructure, Brazil decided to give coverage to all its airspace, starting at flight level 245 (FL 245), which is the upper airspace limit. Figure 4 illustrates VHF coverage for data link to be implemented in Brazil by 2016, where red circles represent the existing coverage and blue circles show the future coverage to supplement existing coverage in FL 245.

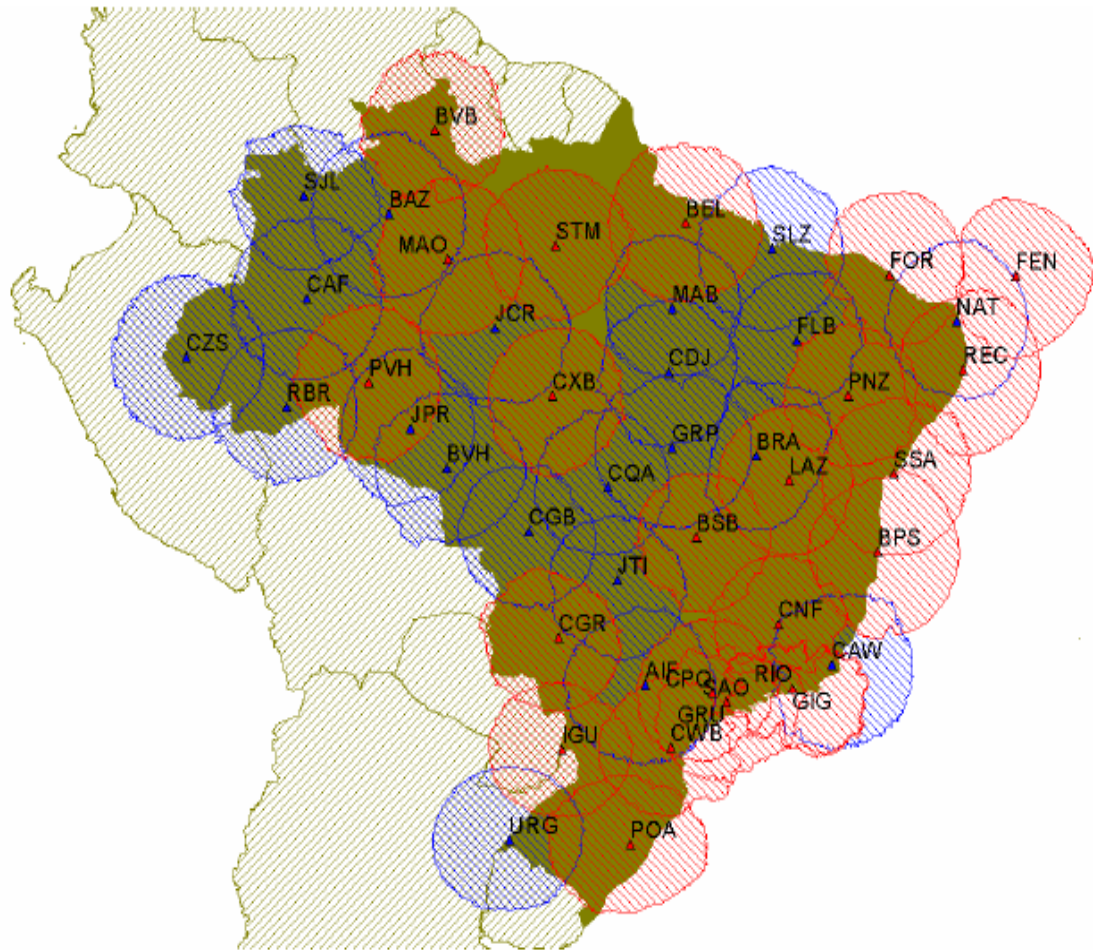


Figure 4: VHF coverage for data link in Brazil

Brazil has decided to install two types of VHF data link: analog (VDL Mode 0/A) for services related to PRE-FANS (character-oriented) and FANS 1A (CPDLC and ADS-C) applications in remote areas; VDL Mode 2 to support CPDLC in areas with more traffic density using ACARS, and for the future ATN.

In the oceanic area, Brazil is already using data link in the AO-ACC and aircraft may use the technology by logging on to said control centre for the exchange of CPDLC and ADS-C FANS (ACARS) messages using SATCOM. Chapter 3 (air-ground data link in the oceanic area) contains information on the main characteristics of AO-ACC functionalities.

It is important to mention that, even if it is possible to use VDL Mode 0/A (VHF ACARS) for the transmission of PRE FANS and FANS 1/A messages, it is not considered as a standard by ICAO. When consulting the existing documents, Annex 10 – Vol 3 and Doc 9776 (Manual on VHF Digital Link - VDL Mode 2) make no reference to the use of VDL Mode 0/A. However, the new GOLD document does admit the use of ACARS VHF.

When selecting the air-ground subnetwork platform, it is important to note that ACARS radios transmit at a rate of 2,4 kbit/s while VDL Mode 2 radios reach a transmission rate of 31,5 kbit/s, giving the possibility of transmitting more information in a given period of time.

Regarding avionics, whose basic structure is shown in Figure 3, the existing equipment can exchange messages using analog links (ACARS) or VDL Mode 2 radio link. Avionics manufacturers incorporated the capability of transmitting PRE FANS applications using VDL Mode 2 equipment. Thus, if an aircraft is overflying an area that has VDL Mode 2 and ACARS coverage, it is possible to select VDL Mode 2 to transmit PRE FANS (ACARS) applications, but then it will go back to transmitting through ACARS (VDL Mode 0/A) radios when outside of VDL Mode 2 coverage.

At present, most of the aircraft fleet is equipped for using ACARS data link, but it is foreseen that there will be a significant increase in the adoption of VDL Mode 2 equipment.

When talking about ATN, the discussion involves the implementation of CPDLC modules on the aircraft for transmission using ATN routers based on the Open System Interconnection (OSI) model of the International Organization for Standardization (ISO). In this sense, ISO standard 8473, Connectionless Network Protocol, is applied, which uses the VDL subnetwork protocol as reflected in ISO document 8208, Switched Virtual Circuit (SVC). Thus, the ATN CPDLC application only works while the aircraft has a VDL Mode 2 connection with the ground station linked to a ground ATN router.

CPDLC via the ATN is currently being used in Europe, where the implementation of the Single European Sky requires the adoption of CPDLC/ATN on all new aircraft in operation as of 2011. Regarding old aircraft (in operation before 2011), there are plans to retrofit all short-haul aircraft in operation in the European continent starting in 2015.

It should be noted that Eurocontrol does not require airlines to equip their aircraft with CPDLC/ATN, since the airworthiness certificate was obtained before 2014. This means that they may use CPDLC/ACARS throughout their service life in Europe.

On the other hand, Eurocontrol recognises that long-haul operations over oceanic areas require CPDLC and ADS-C using ACARS technology, and all South American aircraft flying to Europe and are certified up until 2014 shall be at least equipped with ACARS data link.

It is important to take note of the data link implementation policy of States and ANSPs with ACARS or VDL Mode 2 radio, since operators should have a clear idea of the timetable for the implementation of the ground architecture so that it may coincide with the installation of equipment on the fleet.

In principle, ICAO does not limit the way in which the VHF data link infrastructure must be implemented. For example, Doc 9776 (Manual on VHF Digital Link - VDL Mode 2) offers several possible scenarios:

- a) VDL Mode 2 and ATN network operated only by the civil aviation authority (CAA): VDL Mode 2 stations owned by the CAA are connected to ATN routers (also belonging to the CAA), providing at least ATS services;
- b) VDL Mode 2 and the ATN network operated only by the *Data Link Service Provider* (DSP): VDL Mode 2 stations owned by the DSP are connected to ATN routers (also owned by the DSP), supporting services of interest to airlines (AAC or AOC) and if required by the CAA, ATS services. In this case, the ATN router may be in another State;
- c) VDL Mode 2 and ATN network operated by the DSP and the CAA: VDL Mode 2 stations transmitting AAC, AOC messages to airlines through a DSP router (may be outside the State) and VDL Mode 2 stations (ATS messages for air traffic), linked to a router belonging to the CAA (inside the State);
- d) VDL Mode 2 and the ATN network operated by the DSP and the CAA: CAA VDL Mode 2 stations (ATS applications) and DSP VDL Mode 2 stations operating in the same area of coverage, each with its respective ATN routers.

Note: Although not mentioned in Doc 9776, the contents of the four options cited above may be adapted, so as to have ACARS VDL instead of VDL Mode 2. Likewise, for message routing, instead of ATN routers there would be ACARS processors.

Likewise, there is the possibility of considering the model currently being applied in Brazil, where services were given in concession through a bidding process. In this regard, the main features of the bidding process for the Basic Project are presented in **Appendix F** to this guide.

In this case, a bidding process was organised for the exploitation of the Aeronautical Mobile Service (AMS) in the data link category, and SITA was awarded the contract. The bidding process was carried out in accordance with a Concessions Law, which details the relationship between the Grantor and the Grantee during the life of the contract.

The concession system implemented in Brazil may be considered as a combination of the four options mentioned above, since the communication infrastructure, which includes remote stations, ACARS processor, and ATN router, is being implemented and operated by the Grantee under the supervision of the Grantor, which is the *Departamento de Controle do Espaço Aéreo* (DECEA).

2.4.2.2 **Data link solutions of the ground VHF subsystem**

The first aspect to be taken into account for data link implementation is the services that will be transmitted between the aircraft and the ATC units (ATSUs) and the private users. This is of vital importance, since it determines the technology to be used in VHF remote stations, which may be analog (ACARS) or VDL Mode 2.

The State must establish a data link implementation policy. This is critical since, as previously stated, the installation of equipment to support only FANS1/A messages requires a lower investment; while CPDLC implementation through the ATN requires a higher investment, not only for the ANSPs but also for airlines that will need to update on-board equipment.

In this sense, if the decision is made to install VHF ground station (VGS) equipment, it is important to note that it supports the two types of radio--VDL Mode 2 and ACARS--on the same rack. Consequently, the equipment is scalable, and the first step could be, for instance, the provision of ACARS and FANS 1/A applications, and if it is necessary to deploy CPDLC in continental areas with high traffic density, the station will already have a basic structure in place.

Normally, a VGS has two main components: a ground computer (VGC) and a VHF digital radio (VDR), which is generally a transceiver. Likewise, it is possible to install several radio sets in one same remote station, some supporting VDL Mode 2 and others supporting ACARS. In this case, the number of sets installed is directly related to the global availability of the system.

The VHF transceiver supports the Medium Access Control (MAC) sub-layer of layer 2 (link) and layer 1 (physical). The VGC computer is responsible for the protocols of all the layers located above the MAC, in addition to VDL Mode 2 and ACARS protocols.

Racks are normally used wherever several VHF radio units (which may operate simultaneously in ACARS mode and VDL Mode 2), Uninterruptible Power System (UPS), switches and/or routers can be installed. Figure 5 shows an example of a standard set.



Figure 5: Example of a VHF data link rack

2.4.2.3 **Main characteristics of the central processing subsystem**

The data link processor is considered to be the core of the system and handles the necessary functions for routing ACARS messages, in accordance with the specifications of AEEC 618 (Air/Ground Character-Oriented Protocol Specification) and AEEC 620 (“Data Link” Ground System and Interface Specification).

Message routing must support PRE FANS and FANS 1/A applications, maintaining consistency with the specifications of AEEC 623 (Character-Oriented Air Traffic Service (ATS) Applications) and AEEC 622 (ATS “Data Link” Applications Over ACARS Air-Ground Network), with all the functionalities.

Another critical issue is ensuring response and non-response times, system failures, management errors, and all other conditions that prevent proper operation. Furthermore, the system must be capable of generating notification messages for all errors, allowing for message retrieval within the required times, based on the level of safety applicable to ATS messages.

Likewise, the message processing system must convert ground-ground incoming messages into duly formatted uplink messages and switch them to the best remote station for closing the link with the aircraft.

The servers to be used for ATS applications are normally those related to PRE FANS applications, and which are considered that should be installed on the same location as the central processor. ATS servers must be enabled for data link communication with any aircraft overflying the airspace of a State. DCL, D-ATIS, and D-VOLMET systems are described in **Chapter 4** of this guide.

Note: It is very important for the processor to do the switching to the address of the ATS application servers of the ANSP and airline AOC/AAC. Specifically in the case of ATS messages, if the data link system does not belong to an ANSP, as is the case of the data link concession in Brazil, internetworking among the DSP data link systems is required.

2.4.2.4 **Main characteristics of the ATN routing subsystem**

As previously mentioned, Europe has already adopted the ATN network, which is called ATN Baseline 1. The decision to implement the ATN belongs to the State and the ANSP, taking into account demand aspects that may warrant such implementation.

South America has already started planning for the adoption of the ATN network for air-ground communications. There are some basic characteristics of ATN routers, one of which is that use must be made of any VDL Mode 2 station already installed.

Table 3 of Section 2.5.3 shows the availability for end-to-end applications, as described in Doc 9694, Manual of Air Traffic Services “Data Link” Applications. In this regard, routers shall have an availability of at least 99,996% to meet the requirements foreseen for ATN networks.

It should also be noted that routers must support the ATN CLNP protocol, which is the layer 3 protocol of the OSI model, since ATN network support is still based on ISO standards.

2.4.3 Future communications infrastructure (FCI)

In recent years, the Federal Aviation Administration (FAA), through its Next Generation Air Transportation System (NextGen) programme, and EUROCONTROL, through the Single European Sky ATM Research (SESAR), have established individual and common projects for the development of what is known as the Future Communications Infrastructure (FCI), covering technological evolution and foreseeing its implementation in ASBU Block 2 for all flight phases.

The tasks include the possibility of transmitting applications by concurrent means (multilink) to increase availability and maintain continuity. They also consider the adoption of Quality of Service (QoS), whereby the network is configured to treat each application differently, depending on criticality and need for real-time transmission.

It is interesting to note that multilink transmission and the use of QoS are very common in the IP protocol suite (IPS). However, they are not used for ATM purposes, because, to date, most applications have been developed based on the OSI protocol model, something that shall change in the short and medium term.

In terms of transmission technology, the L-Band Digital Aeronautical Communications System (LDACS) is foreseen as possible replacement of VDL Mode 2 for the implementation of air-ground data link. Several working papers on this matter have been submitted at recent meetings of the Aeronautical Communication Panel (ACP).

Trials conducted to date raise good expectations in terms of the transmission rate. However, the LDACS operates in the same frequency range (950 to 1215 MHz) as a series of aeronautical applications, such as: secondary radar (SSR), Universal Access Transceiver (UAT), and Distance Measuring Equipment (DME). Consequently, a large battery of tests is being conducted, analysing the impact between LDACS and other systems.

A SESAR project--P15.2.4 (Future Mobile Data Link System Definition)--is currently underway, which contemplates choosing between two possible future air-ground data link technologies: LDACS1 and LDACS2. Figure 7 illustrates the scope of the project, clearly showing that, with the FCI, VDL Mode will no longer exist as a platform to support air-ground communications.

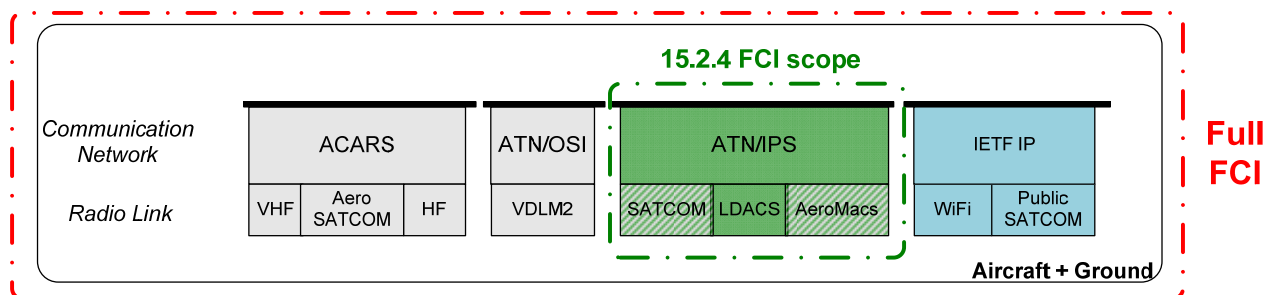


Figure 7: Scope of activities of P15.2.4

2.5 **Ground-ground communication subnetworks**

2.5.1 **Introduction**

The trends in the telecommunications market point to the use of converging networks, a concept used for telecommunication structures capable of transmitting any application, whether or not in real time. Thus, the same topology may be used for audio, data, video, and other applications, whether or not interactive.

For converging networks to operate satisfactorily, each application must be treated in a unique manner, in accordance with its intrinsic characteristics. For instance, telephony and videoconferencing are real-time applications and thus do not withstand significant delays, but do not need data integrity assurance. Whereas critical data applications may withstand a minor transmission delay, but do not admit information losses, thus requiring delivery confirmation at the destination.

Likewise, storage or electronic mail services allow for greater delays. To settle these differences, the Quality of Service (QoS) concept is applied in statistic networks, which allows for prioritisation of each application.

At present, radar and VHF applications run over deterministic channels leased from the CSP. This permits a strict control of the quality of the service provided, safety assurance, and security in terms of preventing access by other customers of the provider, because channelling resources are not compartmentalised.

The structure however is rigid, causing significant losses of telecommunication resources. On the other hand, statistic networks based on the Internet Protocol (IP) make resources available based on the demand from applications or from each customer, thus reducing implementation and maintenance costs.

For the implementation of the ground infrastructure to support air-ground data link, the ground subnetwork must ensure the availability required by ICAO provisions.

For IP-based networks, ICAO, through the Aeronautical Communications Panel (ACP), has developed Doc 9896 – Manual for the Aeronautical Telecommunication Network (ATN) using Standards and Protocols. The document addresses technical, safety, quality of service (QoS), and application issues. It should be noted that most ICAO provisions were developed based on the OSI Model and the trend over time has been to replace it with the IP Model.

In the SAM Region, a Guide for the Implementation of National Digital Networks using the IP Protocol was developed, containing elements to be considered by SAM States when implementing the network, including technical aspects related to equipment, systems, monitoring, and applications.

Likewise, a SAM Routing Policy was developed, reflecting the contents of Doc 9896 on intra-regional inter-domain routing techniques. The aforementioned techniques should be incorporated into the South American Digital Network (REDDIG) once the new infrastructure has been implemented (REDDIG II).

Taking into account the important and complex aspects involved in IP network security, a Security Guide for the Implementation of IP Networks was drafted containing good practices that might be taken into account by States when implementing their networks.

Section 2.5.2 will discuss an architecture compatible with availability requirements, based on the infrastructure that will be implemented for modernising the South American Digital Network (REDDIG) and which has also been adopted by several South American States. Section 2.5.3 will address the availability of such topology.

2.5.2 Architecture recommended for the ground subnetwork

2.5.2.1 General

In order to achieve the availability and reliability required for the ground subnetwork to support air-ground communications, it is recommended that two backbones be implemented: a satellite backbone and a ground MPLS backbone, as shown in Figure 8.

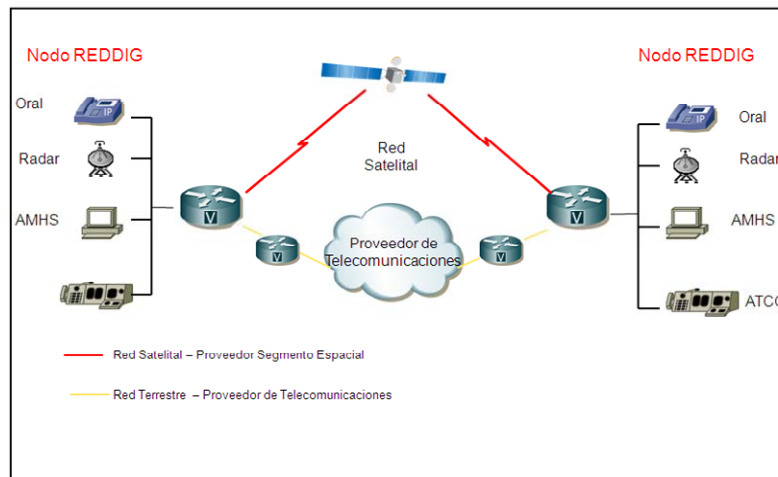


Figure 8: Basic topology of the ground subnetwork

2.5.2.2 Satellite structure

Satellite communications are the ideal solution for interconnecting geographically distant locations. Currently, the market offers many technological solutions for these communications with regard to equipment developed by different manufacturers for different applications.

It is important to stress that, in terms of satellite communications, the main problem are the monthly recurrent costs (OPEX). Accordingly, important issues are those related to coding, compression, modulation, and access technique, such as: time division multiple access (TDMA), frequency division multiple access (FDMA) or code division multiple access (CDMA).

Another very important issue is modulation. Modern modulation techniques for satellite transmission currently apply 8-PSK, which transmits 3 bits per symbol.

Since the transmission channel may cause information distortions and errors, an Error Correction Code is applied. Error correction techniques have evolved and modern techniques use Turbo-Coding 7/8, which introduces one redundancy bit for each seven bits of useful information.

Regarding the access technology that can be used, it is suggested that it should not be restricted to a specific access technology, modulation, error correction code, etc. The focus should be on services rather than on choosing a specific platform.

It should be noted that the satellite topology opens a series of implementation possibilities. For example, the ANSP may purchase the equipment and lease the space segment; it may lease services that contemplate equipment installation and the provision of the space segment; amongst other possibilities.

2.5.2.3 **Ground structure (IP/MPLS)**

At present, when ground networks are leased, CSPs offer almost invariably the IP/MPLS-based technology.

MPLS is a label-based packet routing technology whereby labels are added by certain network routers. MPLS is indifferent to the type of data transmitted, which may be IP (Internet protocol) traffic or other types of protocols at the backbone input and, from there on, all routing is based on the labels that are added as stated above.

Compared to IP routing, MPLS is more efficient, since it sends the routing table query to all network assets. Furthermore, it is flexible enough to permit the transmission of messages regardless of the protocols used in the upper layers.

MPLS permits the creation of Virtual Private Networks (VPN), ensuring full traffic isolation through the creation of label tables specific to each VPN. It is also possible to apply Quality of Service (QoS), assigning priority to critical applications and giving differential treatment to traffic in the various points of the VPN. The QoS creates the necessary conditions for better use of network resources, also enabling real-time transmission of voice and video and other continuous applications.

Figure 9 shows the transmission of packets in a traditional IP network. As may be noted, all routers query the routing table, which consumes processing resources and causes more delay in the transmission of information. This is because headers up to level 3 of the ISO OSI layer are removed in each router.

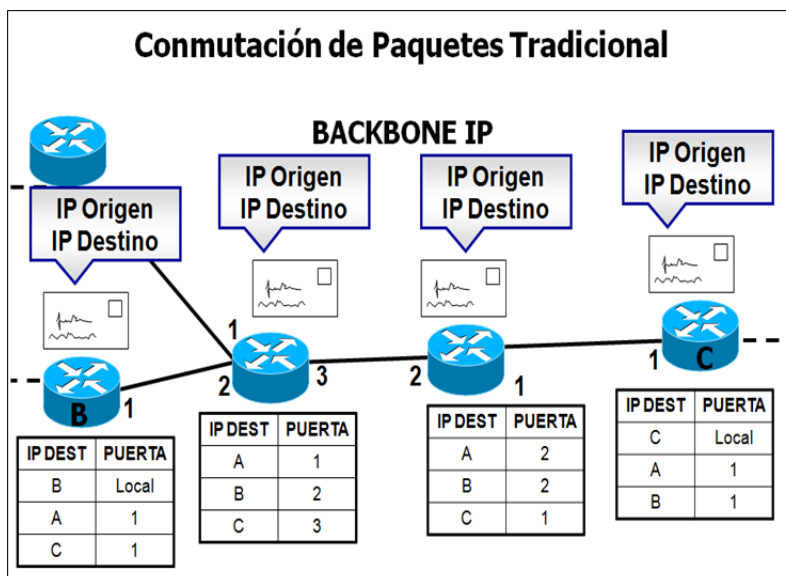


Figure 9 – IP switching

Figure 10 shows that packet routing using MPLS is done through a label table, and therefore it is not necessary to remove packet headers up to OSI level 3. MPLS operates on an intermediate layer with respect to the traditional definitions of layer 2 (link) and layer 3 (network), reason why it was called layer 2.5 protocol.

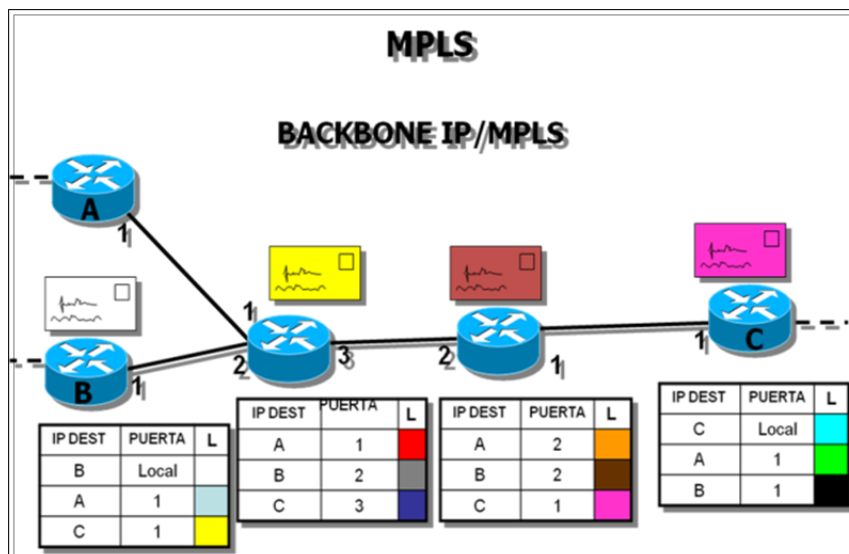


Figure 10: MPLS switching

In order to fully succeed with MPLS contracts, Service Level Agreements (SLA) must specify characteristics that ensure the creation of VPNs using MPLS, in accordance with RFC 2547 and RFC 3031, and enable the QoS configuration over MPLS/VPN, in accordance with RFC 3270 and RFC 2938.

In accordance with the required SLA priorities and levels, the various types of packets that will circulate over the network will be classified into at least five types of service, pursuant to RFC 2474 and 2475 (DiffServ), supplemented by RFC 2597 (Assured Forwarding PHB) and RFC 2598 (Expedited Forwarding).

An example of classification of QoS configurations is shown below:

- a) *Real time*: Delay- and jitter-sensitive applications that require packet prioritisation and band reservation;
- b) *Critical mission*: Interactive applications that are critical for the transfer of critical operational information that requires guaranteed delivery and priority treatment;
- c) *Management*: Network management applications using ICMP, SNMP, Telnet protocols, etc.;
- d) *Non-critical*: Applications with messages of different sizes that do not require immediate attention by users. Even if the content is important, these applications can wait until network resources are available; and
- e) *Standard*: All traffic not explicitly assigned to the aforementioned classes will be classified as standard, also known as *best effort*. This type of traffic can be delivered if resources are available in the network, but without having a negative impact on the other classes.

2.5.3 **Availability of communication subnetworks**

Figure 11 illustrates the main links between a VDL Mode 2 or SATCOM communication station and the ATC units. In this regard, availability considerations will be applied to subnetworks normally leased by ANSPs for the provision of services.

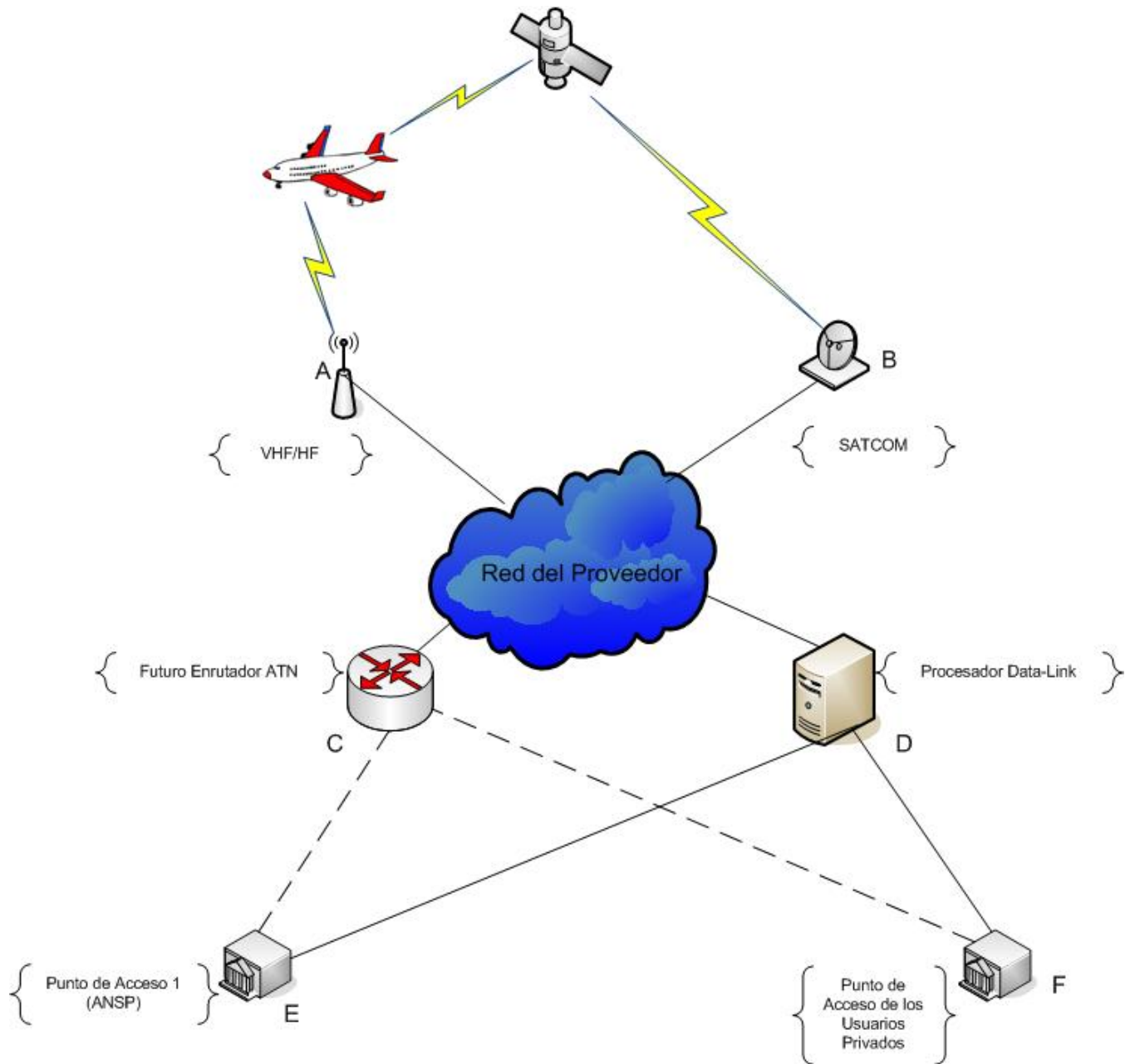


Figure 11: Basic ground-air telecommunications infrastructure

At present, FANS 1/A is used worldwide for data link implementation, with the possibility of using end-to-end equipment with ACARS technology for the applications described, *inter alia*, in the FANS 1/A Operational Manual (FOM), GOLD, AEEC 618, 620, 622, and 623 documents.

The FANS 1/A performance criteria contain a table with the main requirements, as described in the original English version below.

Criteria	Definition	Values
Performances	End-to-end round trip time for uplinks per delivery media (VHF, SATCOM, or HFDL). The timing is measured from sending of the uplink until reception of the MAS.	Round trip time of 2 minutes, 95% of the messages. Round trip time of 6 minutes, 99% of the messages.
	End-to-end one way time for downlinks per delivery media (VHF, SATCOM, or HFDL). The timing is measured by comparing the message sending time stamp and message receipt time stamp.	One way time of 1 minute, 95% of the messages. One way time of 3 minutes, 99% of the messages
	Uplink messages only: Undelivered messages will be determined by: • Message assurance failure is received. After trying both VHF and SATCOM. Depending on reason code received, the message might, in fact, have made it to the aircraft. • No message assurance or flight crew response is received by ATSU after 900 seconds	Less than 1% of all attempted messages undelivered
Availability	The ability of the network data link service to perform a required function under given conditions at a given time:	99.9%
	The maximum allowed time of continuous unavailability or downtime should be declared: it can be expressed in MTTR (Mean Time To Repair) *	TBD
Reliability	The ability of a data link application/system to perform a required function under given conditions for a given time interval: it can be expressed in MTBF (Mean Time Between Failure) *	TBD
Integrity	The probability of an undetected failure, event or occurrence within a given time interval.	10^{-6} /hour

* Availability = $MTBF \times 100 / (MTBF + MTTR)$

Table 1: FANS 1/A performance criteria

A simple look at Table 1 reveals that 99,9% availability is acceptable for completing any type of data link service. Furthermore, a delay of 1 minute for 95% of exchanged messages and of 3 minutes for 99% of total messages is acceptable, regardless of the means of communication used (SATCOM, VHF or HFDL).

<i>RCP type</i>	<i>Transaction time (sec)</i>	<i>Continuity (probability/flight hour)</i>	<i>Availability (probability/flight hour)</i>	<i>Integrity (acceptable rate/flight hour)</i>
RCP 10	10	0.999	0.99998	10^{-5}
RCP 60	60	0.999	0.9999	10^{-5}
RCP 120	120	0.999	0.9999	10^{-5}
RCP 240	240	0.999	0.999 0.9999 (efficiency) (See Note 3)	10^{-5}
RCP 400	400	0.999	0.999	10^{-5}

Table 2: Performance parameters by type of RCP

As previously stated, Doc 9869, Manual on Required Communication Performance, associates applications with message transaction times, availability, continuity, and integrity, in order to identify the ideal longitudinal and lateral separations for each airspace. In this regard, Table 2 shows the types of RCP for message delivery.

Comparing the requirements of Tables 1 and 2, it may be concluded that, in terms of transaction time and availability, it is possible to use FANS 1/A for RCP 240 and RCP 400 operational requirements. Nevertheless, note 3 of Table 2 indicates that availability values are based on the safety assessment, taking into account the environment as well as mitigation procedures in case of communication failure, and possible contingency actions. It also states that for RCP 240, the 99.99% availability parameter may be added, based on the operational impact of frequent service interruptions, and that the two values must be assessed by the State that implements the data link.

Accordingly, the GOLD document addresses the use of RCP 240 and 400, as well as the surveillance performance requirements (RSP 180 and RSP 400), since it mainly deals with operations in remote and oceanic areas, where it is perfectly feasible to adopt FANS 1/A for data link for 50 NM and 30 NM longitudinal separations and for 30 NM lateral separations. To support this, it describes that for continental areas where operational requirements are more stringent, such as RCP 150, VDL Mode 0/A equipment should not be used.

However, in terms of application availability, it is important to take into account the description in Table I3A1 of Doc 9694 Manual of Air Traffic Services “Data Link” Applications, which is reflected in Table 3 below:

<i>Application</i>	<i>Availability (%)</i>	<i>Integrity</i>	<i>Reliability (%)</i>	<i>Continuity (%)</i>
DLIC	99.9	10^{-6}	99.9	99.9
ADS	99.996	10^{-7}	99.996	99.996
CPDLC	99.99	10^{-7}	99.99	99.99
FIS	99.9	10^{-6}	99.9	99.9
AIDC	99.996	10^{-7}	99.9	99.9
ADS-B	99.996	10^{-7}	99.996	99.996

Table 3: Availability of data link applications

In summary, comparing Tables 3 and 1, it may be readily concluded that FANS 1/A cannot be used for transmitting most applications in the ATN environment, for which ATN routers and VDL Mode 2 radios shall be adopted.

Note should be taken of end-to-end service availability in the second column, which shows that telecommunication subnetworks used for delivering information must have a higher availability, since, as described in **Appendix E**, elements in series reduce global availability.

Thus, the following elements are identified in the end-to-end chain between an aircraft and an ATSU:

- a) Availability of on-board equipment: Flight Management System (FMS), printers, etc.;
- b) Air-ground subnetwork (SATCOM or VHF);
- c) Ground networks;
- d) Central processor or ATN router (if installed); and
- e) Availability of ATSU equipment.

To ensure maximum availability, the means of transmission of ground subnetworks must be redundant. Thus, with respect to ground subnetworks, Figure 11 illustrates the main elements between nodes A (VHF) B (SATCOM) and those located after applications are delivered by ground subnetworks (C - ATN router, and D – data link processor).

For air-ground means of transmission, redundant equipment is installed on the aircraft and in ground stations, permitting very high levels of availability. When SATCOM is used, availability is that described in the contract with the existing service provider (SITA and ARINC), which, in turn, subcontracts the space segment from market providers, which are normally INMARSAT and IRIDIUM. **Appendix G** shows some basic features of the SATCOM service provided by the major space segment providers.

Regarding VHF equipment, consideration should also be given to radio availability, the condition of the power supply infrastructure, the power generating system, and the possibility that the VHF may be out of service due to frequency interference.

The configuration shown in Figure 11 would be for continental areas, since the presence of VHF equipment necessarily implies the existence of remote stations installed in the territory of a State. Of course, for communications in oceanic areas, the adoption of satellite technology is the only possibility.

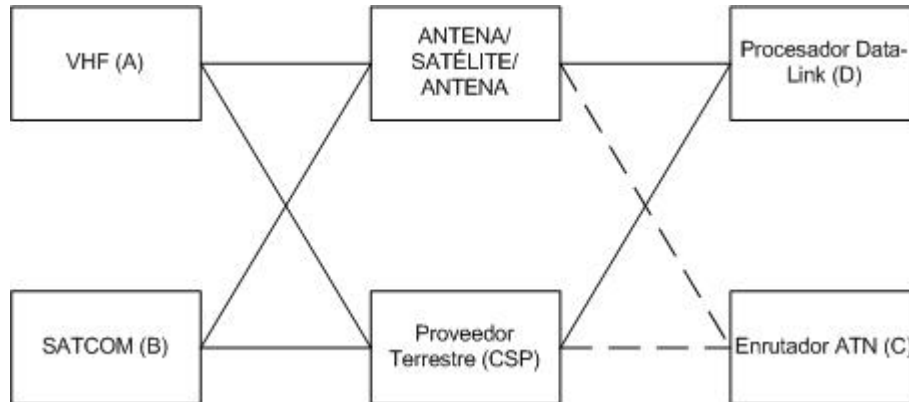


Figure 11: Diagram of communication networks

Considering that the availability of ground networks leased from the CSP is normally 99.5% and that the availability of satellite communication systems can easily reach 99.5%, it may be concluded that the resulting availability of media used in parallel is 99.998%, which is consistent with the values of Table 1 and with other elements that shall be installed in series, such as VHF or SATCOM, printers, etc.

Accordingly, the ANSP should design the ground subnetwork communication systems in such a way as to ensure adequate availability, so that when considering the remaining systems to be placed in series (avionics, ATSU equipment, etc.), the resulting availability will be consistent with the values contained in the tables of this section with respect to the operational characteristics selected by the ANSP in a given Flight Information Region (FIR).

3. AIR-GROUND DATA LINK IN OCEANIC AREAS

3.1 Data link in oceanic areas in general

As already stated, data link improves communications, surveillance, and navigation system performance. Accordingly, it is possible to meet RCP 240 and RSP 180 requirements through the use of FANS 1/A on aircraft and ATSUs. In practical terms, a 30 NM lateral separation and a 50 or 30 NM longitudinal separation can be guaranteed.

The main air-ground applications--CPDLC and ADS-C, which are bit-oriented applications--are enabled to this end. The following sections will refer to the way in which systems may be implemented to accommodate air-ground applications in oceanic areas, based on the successful experience of Brazil, which could serve as a starting point for those States planning to implement data link.

3.2 Data link in oceanic areas – AO-ACC Brazil

3.2.1 General

Before describing the functionalities of the Atlântico (AO) ACC of Brazil, Figure 12 shows the distribution of FIRs in Brazil.



Figure 12: Flight information regions of Brazil

As shown in Figure 12, the air traffic area managed by the ANSP of Brazil (*Departamento de Controle do Espaço Aéreo - DECEA*) is quite large, covering approximately 22.000.000 km². The AO ACC in the oceanic area covers more than 11.000.000 km².

3.2.2 Previous situation

Regarding the Aeronautical Mobile Service (AMS), bilateral communications between ATS units and aircraft overflying the oceanic portion of Brazil was done exclusively by voice using high frequency (HF) equipment.

As is well known, HF communications have long-distance coverage and, thus, can cover extensive areas through the implementation of a single ground station. However, HF communications are affected by events caused by the sun, the magnetic field of the earth, changes in atmospheric conditions affecting the ionosphere, which is the means of propagation of HF communications and, thus, how they are broadcast. These effects include:

- a) Longer ionosphere storms;
- b) Short sudden ionospheric disturbances (SID);
- c) Short Wave Fade (SWF), caused by X-rays from the sun;
- d) Wind and waves occurring in neutral atmosphere and affecting ion distribution and, therefore, ionosphere refractive properties;
- e) Acoustic Gravity Waves (AGW) with various scales associated to day-to-night transition periods and storms.

HF frequencies available worldwide for air traffic control, are defined by ICAO, a small group of which are for regional use. Consequently, there are some limitations in the selection of AMS channels, which is offset by the use of high-gain, high-power antennae. However, these resources do not ensure adequate availability of the system, resulting in periods of precarious communication.

Likewise, with respect to air navigation and surveillance, limitations inherent to the oceanic area make it unfeasible to implement radio aids and radar equipment on the surface. Consequently, because of safety considerations, larger aircraft separations are used, thus reducing airspace capacity and preventing demand being met in some portions of the oceanic region.

3.2.3 Current situation

The Atlântico ACC was created as a result of the convergence of oceanic airspace under the jurisdiction of Brazil into a single flight information region (Atlântico FIR), with a significant impact on the Brazilian ATM. Thus, the transition to the new seamless airspace concept was started.

Therefore, the creation of the AO-ACC favoured the implementation of CNS/ATM functionalities through satellite and digital communication technologies that encouraged the implementation of Reduced Vertical Separation Minima (RVSM), Automatic Dependent Surveillance-Contract (ADS-C) and Controller-Pilot Data Link Communications (CPDLC).

As is known, SATCOM is used for data communications in oceanic areas. In this regard, airlines sign a contract with the service provider (SITA or ARINC), which, in turn, have contracts with the space segment provider (INMARSAT or IRIDIUM). **Appendix G** gives more details about SATCOM operation. Figure 13 describes the path followed by data link messages between the AO-ACC and the aircraft.

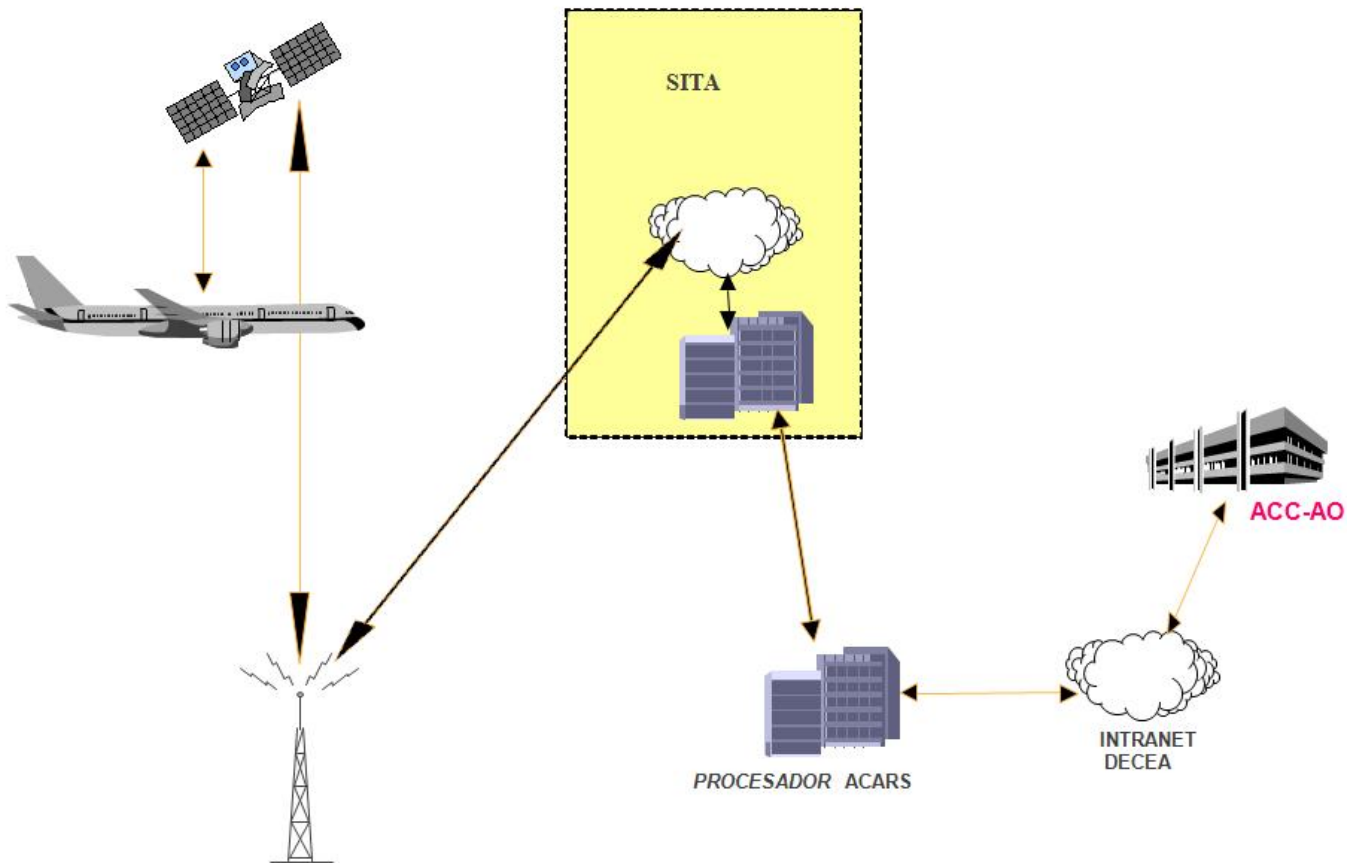


Figure 13: Ground-air data link message routing in the AO-ACC

Regarding start-up dates, ADS-C was implemented first, on 23 October 2008. A direct benefit of ADS-C was that equipped aircraft that logged on to the AO-ACC no longer needed to report their position at the fixes that had been mandatory until then. CPDLC started operating on 30 July 2009 in combination with ADS-C.

The use of new CNS media, together with ATM evolution, allowed users and, especially, airlines to use more economical and flexible routes, which by far offset the investment in avionics, in addition to reducing the workload of pilots and controllers. On the other hand, non-equipped aircraft continued to establish communications via HF.

Figure 14 illustrates the way in which the fleet that uses the services of the AO-ACC operates following the implementation of data link applications. The figure shows that aircraft using data link can fly at higher levels compared to those that continue communicating with the AO-ACC via HF alone.

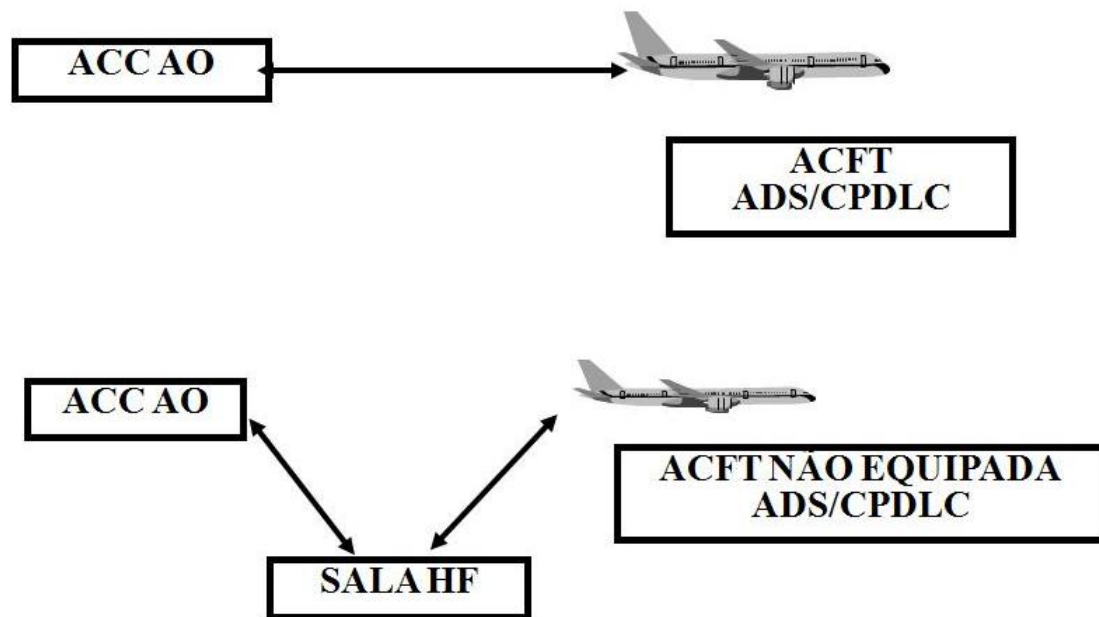


Figure 14: AO-ACC operational model using data link

The adoption of CPDLC and ADS-C functionalities enabled the achievement of a number of ATM objectives in oceanic airspace, such as:

- a) Increased airspace capacity, by reducing aircraft separation minima in all dimensions (vertical, lateral, and longitudinal);
- b) Increased capacity of ATC units;
- c) Use of optimum flight performance profiles;
- d) Adoption of a random and direct route system; and
- e) Air traffic demand was met, especially in the EUR/SAM corridor.

Likewise, the implementation of the aforementioned applications furthered the transition from air traffic control techniques based on pilot-controller voice communications to data link techniques, taking into account human factors, which received significant training in order to be able to fulfil their functions with the new technologies.

Clearly, HF communications deserved special attention, since they are used not only as an alternate means for aircraft equipped with data link, but also as the main means of communication for non-equipped aircraft. In more technical terms, the AO-ACC received more modern and powerful HF equipment to supplement the one already installed. The current HF system is capable of a global availability of 98%, taking into account the control fixes of the Atlântico FIR in the calculation.

In operational terms, the AO-ACC has consoles capable of displaying and handling flight plans, monitoring flight progress, predicting conflicts in fixed and random paths, automatically handling FPL messages, issuing short- and medium-term conflict alerts, and automatically exchanging messages with adjacent continental centres of Brazil.

ADS-C data display is available in all operation consoles, fed with information from surveillance radars. In case ADS-C and radar are unavailable, display is derived by extrapolation (flown track). The data handling system and ACC services provided by the Atlantico ACC have a high level of reliability, availability, and integrity. The possibility of significant failure or degradation that may result in partial or complete system interruption falls within internationally accepted tolerance parameters.

CPDLC has a set of authorisation/information/request message elements that is consistent with the phraseology used in radiotelephony and that meets ICAO requirements. The system permits communications on requests for flight level (FL), crossings, lateral deviation, route clearances, speed, frequency, *inter alia*.

3.2.4 **Aircraft approval for data link**

An important aspect in the operation of CPDLC and ADS-C is the process whereby aircraft are granted approval to use the aforementioned data link services.

As stated in Section 7.1 of ICAO Annex 6, Operation of Aircraft, in airspace where RCP-based operations are foreseen, aircraft shall be authorised by the State of the operator to conduct such operations in the cited airspace. Accordingly, when referring to CPDLC and ADS-C, applications are closely related to the performance requirements defined in Doc 9869.

Likewise, Latin American Regulation (LAR) 121 Chapter H, Instruments and equipment, was issued, defining a point of special interest for availability assurance, and specifying that equipment shall be installed in such a way that failure of any unit required for communication will not result in failure of any other required unit.

Regarding approval of operations, the authority of the State of registry will determine if the aircraft meets CPDLC and ADS-C (airworthiness certification) requirements, and approve the maintenance programme, configuration control, etc. Compliance with airworthiness requirements will not constitute operational approval.

Furthermore, the authority of the State of the operator is responsible for granting operational approval and issuing the authorisation for an operator to conduct CPDLC/ADS-C operations.

Approval issuance requires a close relationship between the CAA and the operators to ensure compliance with all requirements. In this sense, the Operations Inspector Manual (MIO) of the Regional Safety Oversight System (SRVSOP) defines five phases to be considered by the CAA and the operators:

- a) Phase 1 (Pre-application): may be initiated by the CAA or by the operator. In this phase, the operator will make the respective inquiries or request information to the CAA on the approval process, and the CAA invites the operator to a meeting to discuss all the issues involved in the CPDLC/ADS-C approval;
- b) Phase 2 (formal application): the formal application is submitted, accompanied by a series of documents defined in the MIO. The CAA may or may not accept the formal application for CPDLC/ADS-C, depending on the format, content, and all the documentation required, after reviewing all the documents submitted by the operator;
- c) Phase 3 (Document assessment): In this phase, the CAA team conducts a detailed analysis of all the documentation submitted with the formal application;

- d) Phase 4 (Inspection and demonstration): Depending on the requirements of each State, this phase involves validation tests/flights in accordance with the plan submitted; and
- e) Phase 5 (Approval): Once the operator has met the airworthiness, continuing airworthiness, and operational requirements, the CAA grants the CPDLC/ADS-C approval.

4. PRE FANS APPLICATIONS

4.1 General information

The basic reference document that defines ACARS air-ground data link characteristics is AEEC 618 Air-Ground Character-Oriented Protocol. This document defines the text format of the character-oriented application that may be transmitted in an ACARS data link. As previously stated, there are several data link means of transmission: SATCOM, VHF, and HF.

There are several ATS applications that use ACARS for air-ground data link, but this guide will explore the main concepts that may help States in the implementation of DCL, D-ATIS, and D-VOLMET, which are systems being implemented in Brazil. However, the basic components of the solutions are the same, whatever the application.

As already stated in other sections of this document, data link components are divided into the on-board subsystem, the ground subnetwork, and the air-ground data link *per se*. Of course, the on-board equipment belongs to the airline, which may also own the ground subnetwork or may lease the services from a CSP. Regarding VHF remote stations, they normally belong to a Data Link Service Provider (DSP) or to the domestic air navigation service provider (ANSP). The same occurs for servers used for PRE FANS applications.

Consequently, this chapter will basically deal with equipment connected to the ground subnetwork and that offers the possibility of data links. Regardless of who the owner of the servers is, what always matters is service reliability based on their availability.

The implementation of the solutions may vary in terms of ownership of the servers involved, since they may belong to the ANSP/State or be part of the services leased from a DSP. The text reflects the experience of Brazil in the implementation of DCL, D-VOLMET, and D-ATIS, which could serve as a reference for other States.

4.2 ATIS and D-ATIS (Data-Link Automatic Terminal Information Service)

4.2.1 Introduction

ATIS is a service mainly for broadcasting information using voice, aimed at alleviating the workload of the air traffic controller and the congestion in control frequencies, providing information of interest to aircraft operating in the terminal area by broadcasting in VHF frequency.

The pilot receives the ATIS information on a frequency that is specific for a given terminal area broadcast. The pilot listens to the recorded message until all relevant data has been understood. Following reception, the pilot copies the information.

ATIS messages include operational and meteorological information, which is updated periodically or whenever there are major modifications. Pilots must listen to the ATIS frequency before take-off and when executing approach procedures.

Normally, the procedure for recording new ATIS information implies contact with meteorological and operational information, recording in a digital storage medium, verification of the recorded information, and broadcast of the new information.

Although of vital importance for air traffic operations, the traditional service provided by ATIS poses some inconveniences:

- a) Constant changes in atmospheric conditions result in a significant increase in controller workload;
- b) Voice communications may not be well understood by the pilot;
- c) Information is only available in the VHF coverage area.

Another problem is that with ATIS, the pilot has to listen to all the information before it can be repeated. Consequently, ICAO Annex 11 (Air Traffic Services) recommends that ATIS messages should not exceed 30 seconds, without impairing comprehension of message contents.

Figure 15 illustrates the general architecture of a traditional ATIS system.

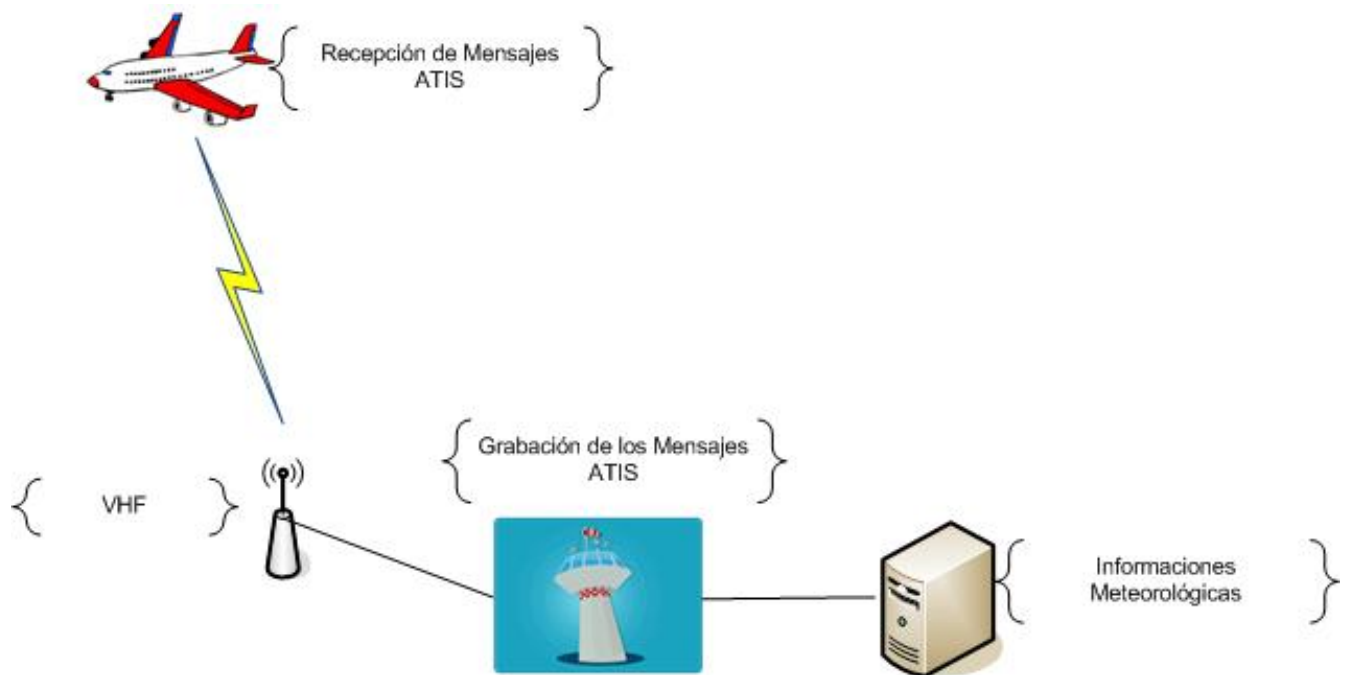


Figure 15: ATIS general architecture

4.2.2 Data link ATIS (D-ATIS)

The D-ATIS service provides terminal area information, updated using commands at the air traffic units where the service-related equipment is installed. Information is entered into the system through the computer keyboards.

The simpler solution may be adopted by an ANSP when the number of airports does not warrant the installation of D-ATIS. The installation of D-ATIS consists of dual servers--to ensure availability--at airport facilities that are fed by meteorological information sources (METAR, SPECI or TAF), as applicable.

D-ATIS has the advantage that the server can also provide the ATIS via voice broadcast, using locally recorded information. Likewise, D-ATIS information may be sent through the ground subnetwork to the ACARS central processor, which may route the message to the aircraft through an ACARS VHF or SATCOM. Figure 16 illustrates the basic architecture in general terms.

It should be noted that the ground subnetwork is represented only by two clouds for ease of understanding, since, in practical terms, normally only one communication network is leased from a CSP.

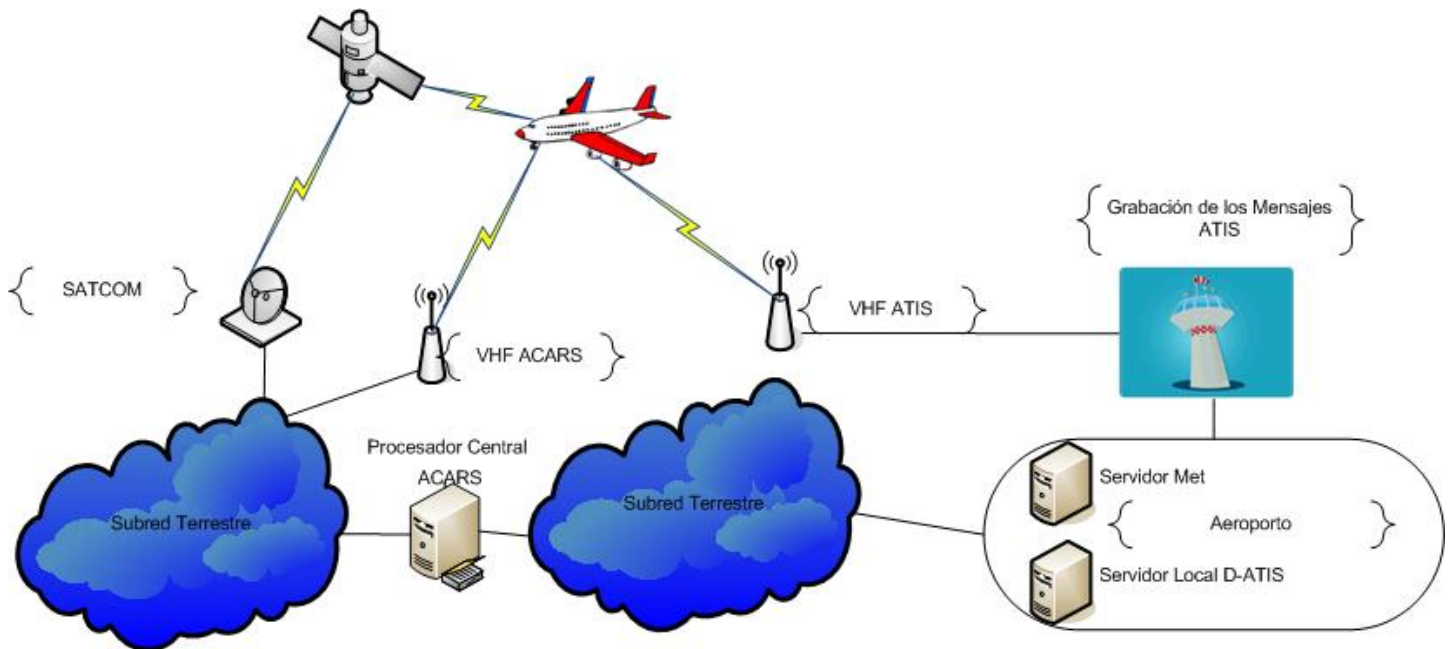


Figure 16: General architecture of D-ATIS for an aerodrome

When D-ATIS is installed in a State, it can start with the topology shown in Figure 16. For the implementation of D-ATIS in multiple airports, there are solutions that offer financial advantages. The most widely used technique consists of installing a central server, in dual configuration, which may receive information from various remote airports. Figure 17 describes that configuration.

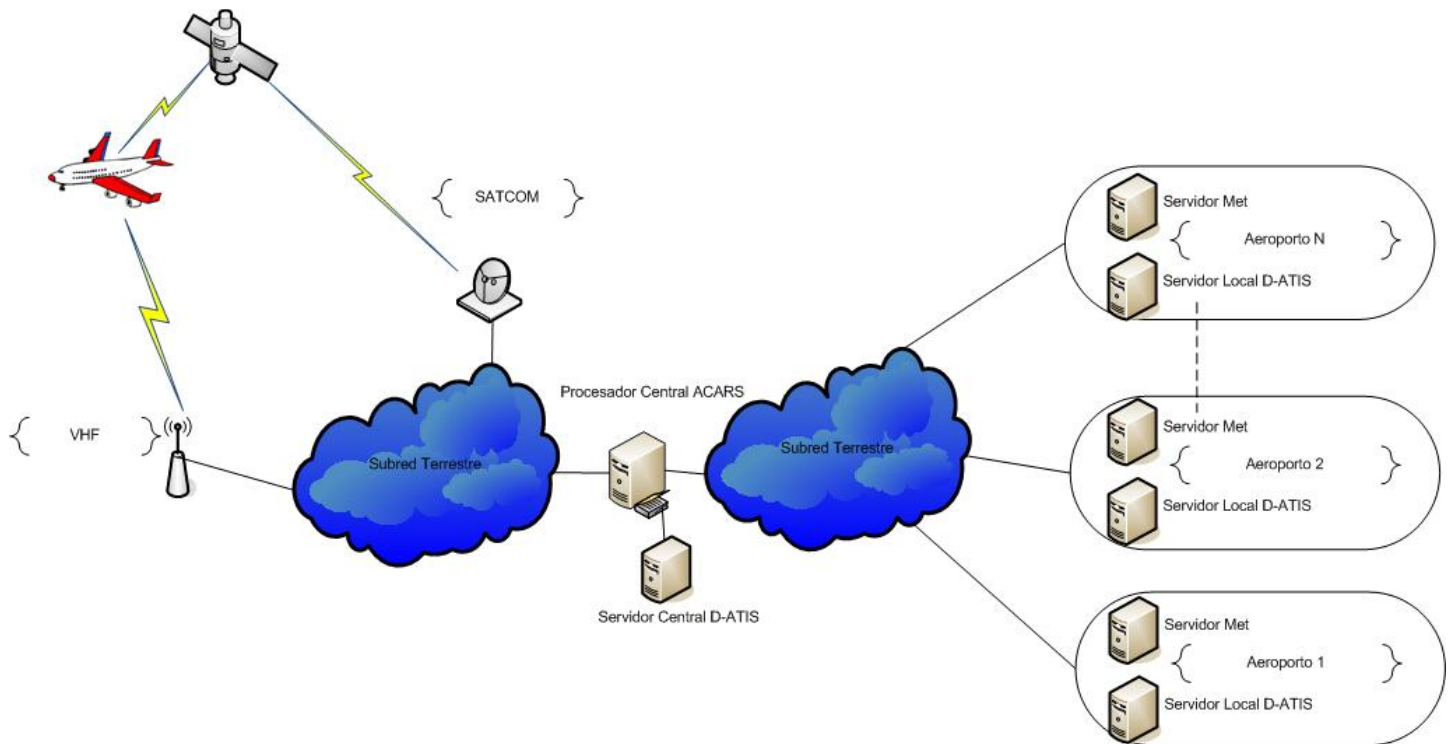


Figure 17: D-ATIS architecture with central processor

Mention should be made of the importance of installing the central server at a location offering high availability, not only of the server but also of the infrastructure (power supply, air conditioning), which could be, for instance, the ANSP main data centre. If the model adopted by a State consists of the data link service and ATS applications, it is suggested that the ACARS central processor be located at the same facilities as the D-ATIS central processor.

4.3 VOLMET and D-VOLMET

4.3.1 Introduction

According to ICAO Annex 3, the meteorological information service for aircraft in flight (VOLMET) provides aircraft in flight with current METAR, SPECI, TAF, and SIGMET information through continuous and repetitive voice broadcasts.

Crews need a constant provision of meteorological data related to departure, arrival, and alternate aerodromes, as well as to the intended route, for proper flight planning.

The meteorological information for aircraft in flight used by the operator for planning purposes will be provided upon request, as agreed upon between the meteorological authority and the operator interested in using VHF or HF. Thus, the crew must pay special attention to understanding the text and the transcription, since information is subject to interpretation errors and reception difficulties due to possible signal interference.

In order to have an idea of the effort involved in the provision of the VOLMET service, Figure 18 shows the VHF coverage in Brazilian territory for FL 300.



Figure 18: VOLMET VHF coverage in Brazil

In summary, almost 100 VHF units have been installed throughout the Brazilian territory to provide coverage consistent with continental FIRs only for the VOLMET service. In addition to maintenance and logistic issues, it should be noted that the ACCs of Brazil provide the service through consoles operated by meteorologists who take turns in the operational position.

4.3.2 Data link VOLMET (D-VOLMET)

D-VOLMET increases the reliability of conventional VOLMET, since use of written data messages facilitates reception and interpretation of the content, in addition to reducing the workload of pilots and air traffic controllers.

In the case of Brazil, there was a possibility of replacing the conventional service with data link. Consequently, D-VOLMET is in operation in Brazil since October 2012.

With D-VOLMET, meteorological data is sent through the ACARS data link network when requested by the crew using the MCDU on-board equipment. The meteorological information will be displayed and may be printed at any time. This represents a significant improvement in the efficiency and safety of flight activities, since it minimises the workload of the pilot and eliminates possible message interpretation errors. Figure 19 describes the crew interface for entering MCDU requests.

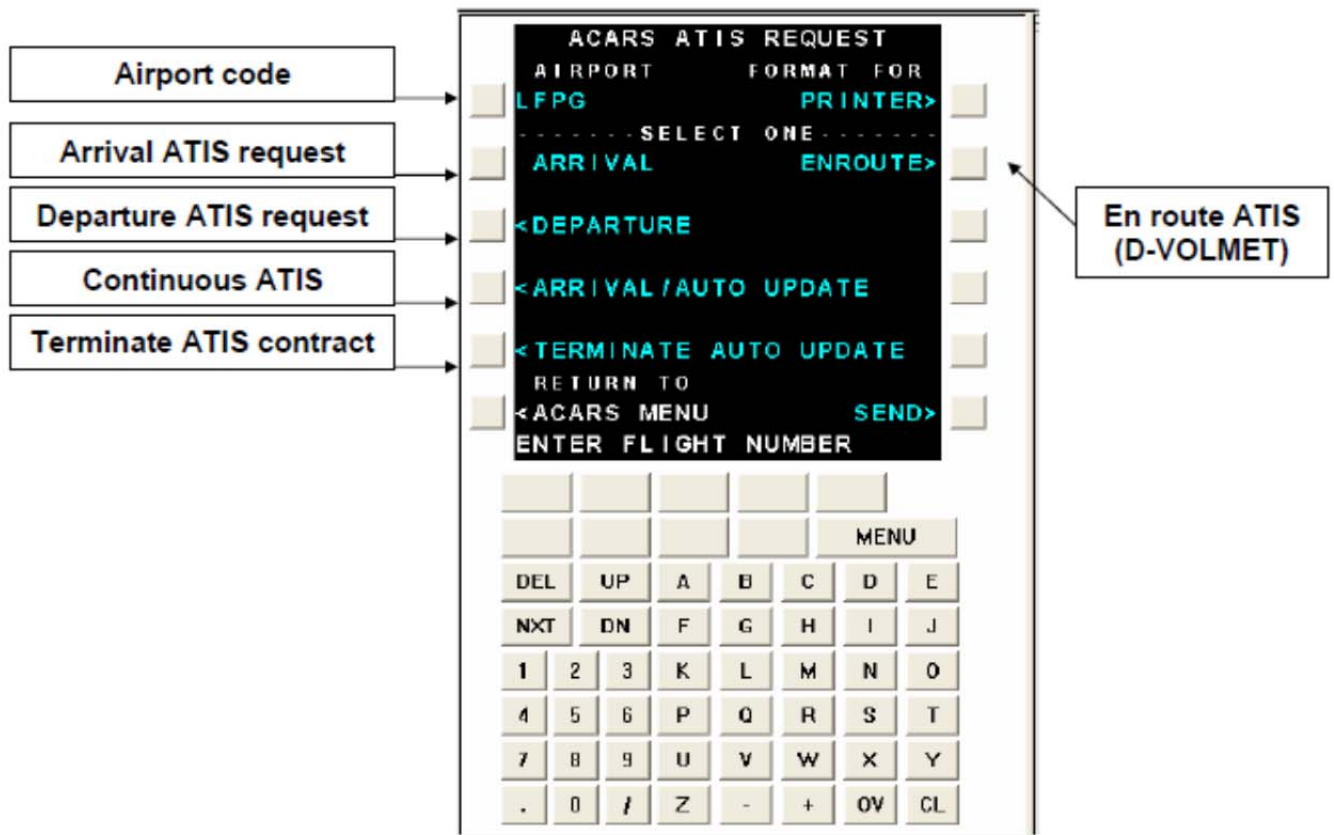


Figure 19: MCDU equipment for entering ACARS message requests

As described in Figure 19, the MCDU equipment allows the pilot to select the option corresponding to D-VOLMET and enter the location code of the airport or FIR of interest for the flight.

Upon inserting an FIR location indicator, the D-VOLMET information service provides the respective SIGMET messages in force for the respective FIR, which are then shown on the screen. If there are no messages available, a NIL SIGMET message will appear.

When an aerodrome location indicator is entered, the D-VOLMET service provides the METAR/SPECI or TAF messages.

In terms of server infrastructure for D-VOLMET implementation, the information will be stored in a meteorological data bank server, which in Brazil is called the OPMET bank, fed through the Internet or the intranet of the *Departamento de Controle do Espaço Aéreo* (DECEA) from airport data sources.

Figure 20 summarises the topology. In the figure, the requests sent by the crew are switched by the central processor and arrive at the central meteorological server. From there on, queries are made to the meteorological data bank, which can also be done through a ground communications subnetwork.

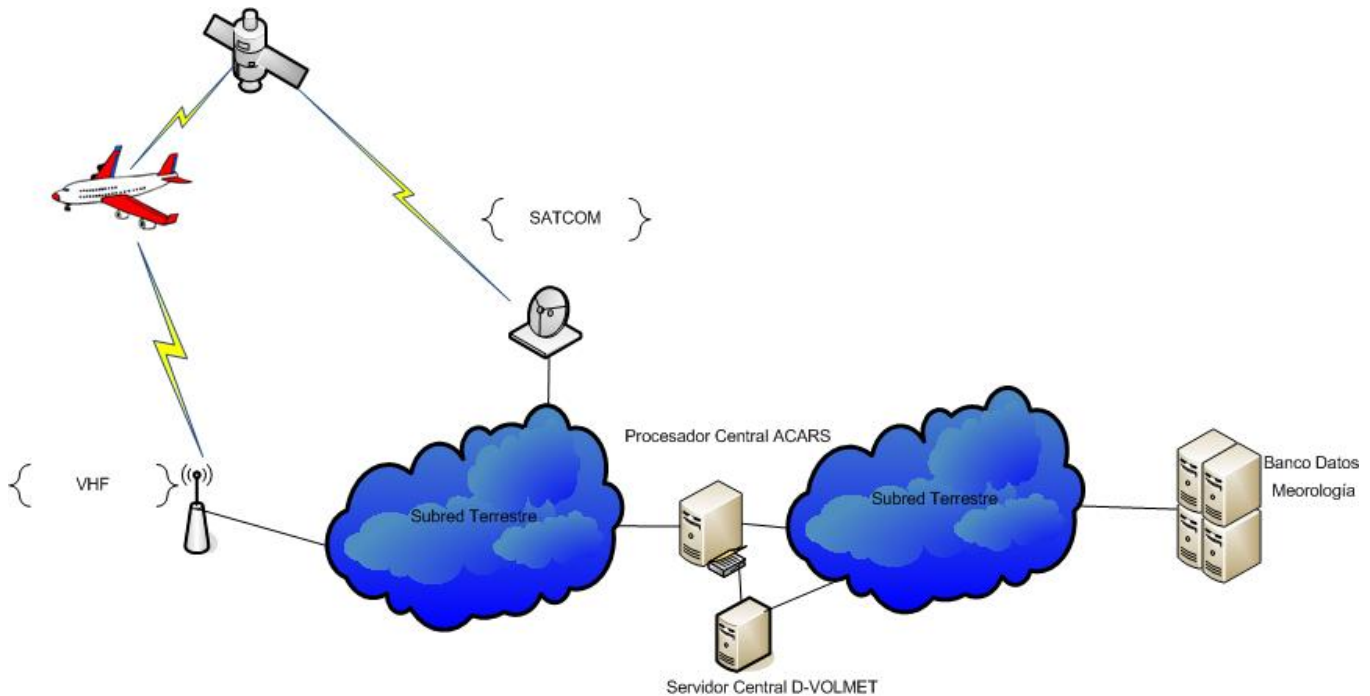


Figure 20: Basic architecture of the D-VOLMET system

4.4 Departure Clearance (DCL)

In conventional clearance operations, the pilot submits the flight plan, and after completing the pre-flight check, calls the respective position in the control tower over a VHF frequency to request information on possible approval of the flight plan.

In turn, the air traffic controller acknowledges the call and checks flight plan conditions on his/her screen. Then, the controller calls the pilot and reads the clearance information. If cleared, the pilot calls the respective position to request authorisation to start engines.

The whole process represents too much workload, especially during peak hours, loss of time of the crew and controllers, in addition to possible errors in the interpretation of the information.

As with other data link applications, use of DCL represents a significant improvement in efficiency and safety of flight activities, since it minimises the workload of the pilot and eliminates possible message interpretation errors.

Figure 21 presents a possible DCL architecture. As a practical example from Brazil, where DCL is being gradually implemented, clearance times dropped from several minutes to less than 1 minute in those airports that already have the service operational.

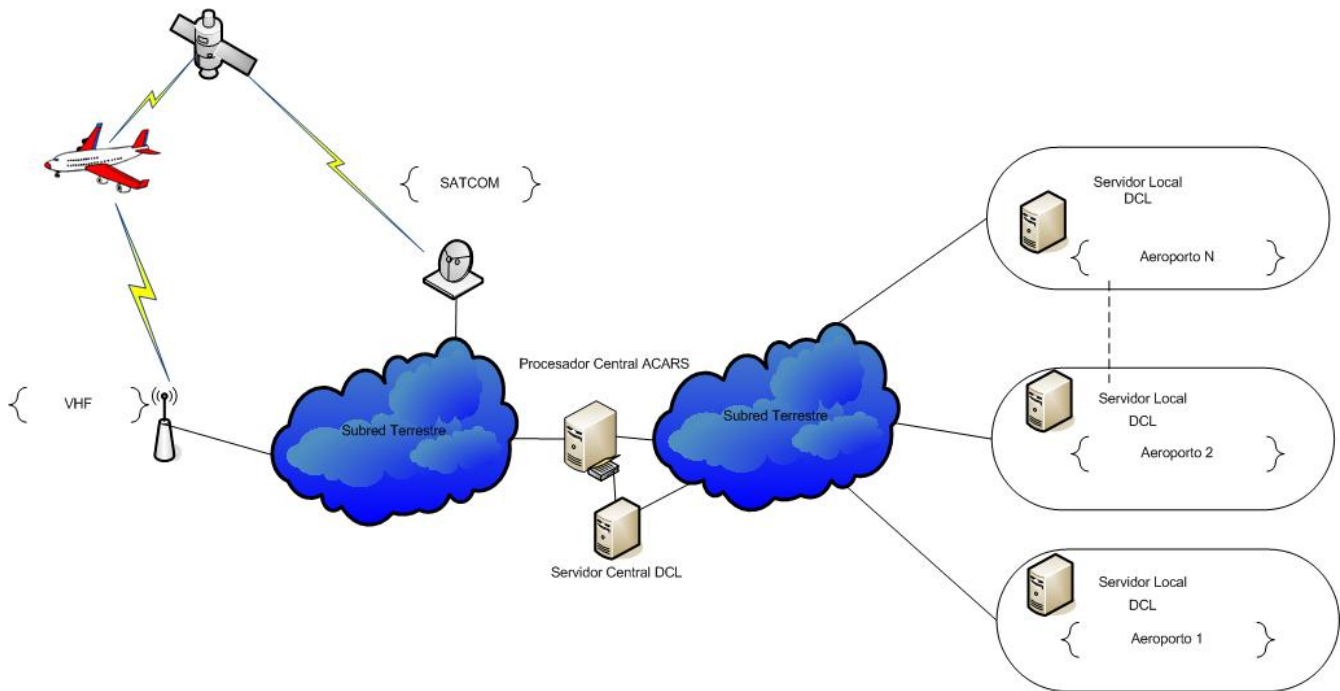


Figure 21: Basic DCL architecture

An important observation that may save investment costs is that the D-ATIS, D-VOLMET, and DCL central server may be the same piece of equipment. Of course, to ensure the availability required in Doc 9694, it is suggested that dual servers be installed in the corresponding data centre.

5. STATE CONSIDERATIONS FOR DATA LINK IMPLEMENTATION

5.1 General considerations for decision-making

The decision to implement data link in SAM States involves a series of key factors that will be presented in this chapter. It is important to note that the decision does not only take into account technical and operational aspects, but also political and strategic aspects of the State in relation to the implementation of its data link support infrastructure and the corresponding applications.

5.1.1 Operational concept

As stated in **Section 2.1 (Introduction)**, the establishment of an ATM operational concept in a State is the starting point for data link implementation. The States are not isolated and in the seamless airspace concept, regional and global initiatives (in that order) must be considered. Ideally, the SAM Performance-Based Navigation Implementation Plan (SAM PBIP) and the Fourth Edition of the Global Air Navigation Plan (GANP) (Doc 9750) should be taken into account from the beginning.

The institutions related to air traffic management (CAA, ANSP) should develop an evolutionary strategy aimed at providing benefits to the ATM community, through an orderly, safe, and cost-efficient implementation. It should be noted that the evolutionary implementation of the concept is related to the installed capacity on board aircraft, as described in **Section 2.3 (On-board equipment)**.

5.1.2 Implementation of the air-ground subnetwork

Section 2.4 (Ground-air infrastructure) deals with the possibility of implementing the air-ground architecture, whereby VHF equipment may belong to the CAA or the DSP service provider. It also addresses the decision of Brazil of modernising the data link platform through the concession of services, the main aspects of which are shown in **Appendix F**.

Regarding technical aspects, the decision regarding the flight level (FL) to be covered throughout a State's territory is crucial, since it determines the number of remote stations to be installed. The example of Brazil is cited, where the decision was made to have coverage in FL 245. **Section 2.4 (Ground-air infrastructure)** also addresses the technical aspects that could be considered by States for the implementation of VHF equipment (ACARS, VDL Mode 2).

Throughout the text, especially in **Sections 2.4 (Ground-air infrastructure)** and **3.2 (Data link in oceanic area – AO ACC Brazil)**, mention was made that in oceanic areas it is only possible to use SATCOM and HFDL. Consequently, this is a key issue in deciding on the model for VHF implementation in continental area (ACARS and/or VDL Mode 2) especially given the financial implications of investing in remote stations and on-board equipment. If a CAA decides to implement remote stations in its country, it is important that operators understand the advantages (financial, technical, and operational) of using the platform instead of SATCOM, for instance.

As with all telecommunication equipment, the technology evolves and the States and CAAs should take into account ICAO activities and the individual programmes of the States and Regions regarding new architectures, as detailed in **Section 2.4.3 (Future Communication Infrastructure)**.

5.1.3 **Implementation of the ground-ground subnetwork**

Section 2.5 (Ground-ground communication subnetworks) lists important aspects to be taken into account to ensure the availability of the ground subnetwork as part of the end-to-end chain between aircraft and ATC units.

Likewise, considering that ground-ground subnetworks are based on IP, it cites the main documents that should be taken into account by the Region and the States when implementing networks, such as: ICAO Doc 9896 – Manual for the Aeronautical Telecommunication Network (ATN), Guidance for the Implementation of National Digital Networks using the IP Protocol, SAM Routing Policy, and the Safety Guidance for the Implementation of IP Networks.

5.2 **Specific considerations for the implementation of CPDLC and ADS-C**

In **Section 3.2 (Data link in oceanic areas – AO ACC Brazil)** it is noted that, for the implementation of CPDLC and ADS-C, the systems to be taken into account by States with oceanic FIRs should be capable of displaying and monitoring flight plans, monitoring flight progress, predicting conflicts in fixed and random paths, automatically handling FPL messages, issuing short- and medium-term conflict alerts, and automatically exchanging messages with adjacent continental centres.

As to ADS-C data display, it should be available in all operation consoles, fed with surveillance radar information.

Also considering the possibility of having non-equipped aircraft capable of data link for CPDLC and ADS-C applications, HF equipment that can provide maximum availability should be available, taking into account the aforementioned propagation problems.

It should be noted that, pending ATN network implementation, CPDLC and ADS-C using ACARS could be used by States in remote continental routes, based on the operational concept established in each State, in accordance with the action to be taken by operators to install the corresponding avionics and systems in the ATC units involved.

Finally, Section 3.2 deals with the responsibility of CAAs and operators to implement CPDLC and ADS-C services and the action required for the approval of procedures, in accordance with ICAO Annex 6, Latin American Regulation (LAR) 121 Chapter H: Instruments and Equipment, and the SRVSOP Operations Inspector Manual (MIO).

5.3 **Specific considerations for the implementation of PRE FANS applications**

Chapter 4, PRE FANS Applications, addresses the basic requirements for the implementation of character-oriented applications and their advantages compared to traditional services.

The main applications that should be considered by CAAs are D-VOLMET, D-ATIS, and DCL. Service implementation involves the installation of servers that may be owned by a CAA, ANSP or DSP.

The decision to implement servers must take into account economic, technical, and operational aspects. It should be noted that as long as only few airports have data link functionalities, local servers for D-ATIS and DCL could be used. If the number of airports is significant, consideration should be given to the implementation of central servers to receive information from remote units and send it to remote stations through the central processor.

Regarding D-VOLMET, it is felt advisable to install a central data bank, like the OPMET bank of Brazil, to receive information from airports and send it, upon request, to aircraft, through the central processor.

APPENDIX A

DATA LINK IN THE SAM PERFORMANCE-BASED NAVIGATION IMPLEMENTATION PLAN (SAM PBIP)

1. **B0-40 TBO: Improved safety and efficiency through the initial application of data link en-route**

Introduction

1.1 Air-ground data exchange has been the subject of research and standardisation for decades, and is an essential ingredient of future operational concepts, since it permits a reliable and more complete transfer of information compared to radio. There are many technologies that have been extensively installed on aircraft, frequently also for purposes of aeronautical operational control (AOC) and airline administrative communications (AAC). Several applications have started to be seen in ATM in recent years, but they have not been fully implemented. Furthermore, the Operational Data Link Panel (OPLINKP) is working, on a priority basis, to ensure that applications are interoperable with different aircraft systems. This module addresses what is available and can be used more extensively.

1.2 One element of the module is the delivery of aircraft position information, constituting the automatic dependent surveillance contract (ADS-C), mainly for oceanic and remote areas where radar cannot be installed due to physical or financial reasons.

1.3 A second element are controller-pilot data link communications (CPDLC), which include a first set of data link applications allowing pilots and controllers to exchange ATC messages on communication handling, ATC clearances, and stuck microphones. CPDLC communications reduce misunderstandings and controller workload and enhance safety and efficiency, while improving ATM system capacity.

Baseline

1.4 Before this module, air-ground communications were conducted by radio (VHF or HF, depending on the airspace), with limitations in terms of quality, bandwidth, and security. There are also large portions of the world that lack radar surveillance. ATC instructions, position reports and other information must be transmitted by HF radio, with very deficient voice quality most of the time, resulting in a significant increase of controller and pilot workload (including HF radio operators), a deficient situational awareness of traffic outside of radar coverage, large separation minima, and misunderstandings. In high-density airspace, controllers currently spend 50% of their time talking to pilots over VHF voice channels, where frequencies are a scarce resource; this also means significant work for pilots and controllers and a source of misunderstandings.

Changes brought by the module

1.5 In this module, a first set of data link applications is implemented to cover ADS-C, CPDLC and other ATC applications, significantly improving ATS provision, as described in the following section.

1.6 An important objective of the ATM operational concept in terms of data link is regional implementation harmonisation and agreeing on a common technical and operational definition, applicable to all flight regions worldwide. This is to be achieved through the changes foreseen in Block 1. For the time being, the use of data link is based on different standards, technologies, and operational procedures, although there are many similarities.

Element 1: ADS-C in oceanic and remote areas

1.7 ADS-C provides automatic dependent surveillance in oceanic and remote areas, using position messages sent automatically by aircraft over data link at specified time intervals. This enhanced situational awareness (combined with the appropriate PBN levels) is enhancing safety in general, and permits a reduction of aircraft separation and a gradual departure from purely procedural means of control.

Element 2: Continental CPDLC

1.8 This application allows pilots and controllers to exchange messages, with a better quality of transmission. It particularly offers a way of alerting the pilot when the microphone is stuck, and a supplementary means of communication. CPDLC is used as a supplementary means of communication. The primary means continues to be voice communications.

1.9 In dense continental airspace, they can significantly reduce the volume of communications, thus allowing controllers to better organise their tasks, especially since they do not have to be interrupted to respond immediately to a radio communication. They are a more reliable means for transmitting and understanding changes in frequency, flight level, flight information, etc., thus improving safety and reducing the number of misunderstandings and repetitions.

Foreseen operational improvements

1.10 The Manual on Global Performance of the Air Navigation System (Doc 9883) proposes parameters to measure module success.

Element 1: ADS-C in oceanic and remote areas

Capacity

1.11 Better traffic location and reduced separation, thus increasing the offered capacity.

Efficiency

1.12 Routes/tracks, and flights may have reduced separation minima, allowing for flexible routes and vertical profiles that are closer to those preferred by users.

Flexibility

1.13 ADS-C facilitates route changes.

Safety

1.14 Enhanced situational awareness; safety nets based on ADS-C, such as level and route clearance compliance monitoring, danger area incursion warning; better support to search and rescue.

Cost/benefit analysis

1.15 The economic study was positive based on flight efficiency advantages (better routes and vertical profiles; better tactical resolution of conflicts). It should be noted that ground and on-board equipment must be synchronised to make sure that services are provided once aircraft are equipped, and that a minimum percentage of flights in the airspace under consideration is duly equipped.

Element 2: Continental CPDLC**Capacity**

1.16 Reduced communications and better organisation of controller's work, thus increasing sector capacity.

Safety

1.17 Enhanced situational awareness; less misunderstandings; resolution of stuck microphone situations.

Cost/benefit analysis

1.18 Must take into account:

- a) advantages for flights in terms of flight efficiency (better routes and vertical profiles; better tactical resolution of conflicts); and
- b) less controller workload and more capacity.

Required procedures (air and ground)

1.19 Procedures were defined and included in ICAO Doc 9694, Manual of Air Traffic Services Data Link Applications, and in the Global Operational Data Link Document (GOLD). Currently, the operational guidelines of GOLD and LINK2000+ have been merged in a GOLD update that contemplates applicability worldwide, regardless of airspace and technology.

System capacity required**Avionics**

1.20 Standards for this technology are already available in ICAO documents and in industry standards. At present, data link applications are based on two sets of ATS data link services: FANS 1/A and ATN B1, which will continue to exist. FANS1/A is used in oceanic and remote areas, while ATN B1 is being implemented in Europe in accordance with European Commission regulations (EC Reg. No. 29/2009) on data link implementation.

1.21 These two packages are different in terms of operation, safety, and performance, and do not share the same technology, but there are many similarities and may be integrated after solving some operational and technical issues through interim solutions, such as the acceptance of on-board FANS 1/A systems at ATN B1 ground facilities, and dual installation (FANS 1/A and ATN B1) on board the aircraft.

Ground systems

1.22 The technology required in ground systems includes the capability of managing ADS-C contracts, and processing and displaying ADS-C position messages. CPDLC messages must be processed and displayed to the relevant ATC unit. Surveillance--enhanced with the merging of data from all sensors--facilitates transition to/from the radar environment.

Human factor considerations

1.23 ADS-C is a means for displaying traffic status directly to the air traffic controller and reducing the work of controllers or radio operators in collecting position reports. In addition to establishing another communication channel, data link applications allow controllers to better organise their tactical work. Both pilots and controllers benefit from a lower risk of misunderstanding, compared to voice communications.

1.24 Data communications reduce congestion in speech channels, improve understanding, and allow for a more flexible air-ground exchange of information. This involves an evolution in the dialogue between pilots and controllers, who must receive training in the use of data link to replace radio communications. Both the pilot and the controller require automation support. In general, their respective responsibilities will not change.

1.25 Human factors were taken into account when developing the processes and procedures of this module. When planning for automation, the human-machine interface was taken into account from the functional and ergonomic viewpoint. However, there is still the possibility of latent failures, and attention must be paid throughout the implementation phase. In this regard, it is requested that any problem related to human factors that is identified during implementation be reported to the international community, through ICAO, as part of any safety reporting initiative.

Training and competence requirements

1.26 Pilots and controllers will require automated support. Accordingly, they will need to receive training in order to be able to work in the new environment and to identify aircraft and facilities that can accommodate data link services in a mixed environment.

1.27 This module requires training in the standards and operational procedures listed in the documents cited in the section entitled “Reference documents and guidelines” of this module. Likewise, competence requirements are identified in the regulatory requirements listed in paragraphs 15.28 to 15.30.

Regulation/standardisation requirements and approval plan (air and ground)

1.28 Regulation/standardisation: Use current published requirements, which include those mentioned in Section 8.4. It should also be noted that ICAO is developing the new OPLINK OPS guidelines.

1.29 Approval plans: Must be consistent with application requirements.

1.30 The *ad hoc* GOLD working group is updating the GOLD-Ed 1 within the context of the harmonisation of procedures, regardless of airspace and technology.

Reference documents and guidelines

- ICAO Doc 9694, Manual of Air Traffic Services Data Link Applications.
- Global Operational Data Link Document (GOLD) Ed 2 (under preparation)
- Commission Regulation (EC) No. 29/2009 of 16 January 2009, laying down requirements on data link services for the Single European Sky.
- EUROCAE ED-100A/RTCA DO-258A, Interoperability Requirements for ATS Applications using ARINC 622 Data Communications.
- EUROCAE ED-110B/RTCA DO-280B, Interoperability Requirements Standard for Aeronautical Telecommunication Network Baseline 1 (Interop ATN B1).
- EUROCAE ED-120/RTCA DO-290, Safety and Performance Requirements Standard for Initial Air Traffic Data Link Services in Continental Airspace (SPR IC).
- EUROCAE ED-122/RTCA DO-306, Safety and Performance Standard for Air Traffic Data Link Services in Oceanic and Remote Airspace (Oceanic SPR Standard).
- EUROCAE ED-154A/RTCA DO-305A, Future Air Navigation System 1/A – Aeronautical Telecommunication Network Interoperability Standard (FANS 1/A – ATN B1 Interop Standard).

Summary of the module

Title of the module:					
B0-40 TBO: Improved safety and efficiency through the initial application of data link en-route					
<u>Elements:</u> 1. ADS-C over oceanic and remote areas 2. Continental CPDLC		<u>Equipment/Air</u> - FANS 1/A; ATN B1		<u>Equipment/Ground</u> - ADS-C - VDL Mode 2/ continental CPDLC	
Implementation monitoring and impact on performance					
<u>Progress in implementation</u> 1. Indicator: <i>Percentage of CPDLCs implemented in FIRs with oceanic and remote areas</i>	Qualitative performance benefits only associated to five mains KPAs				
	<u>KPA-access/equity</u> Not applicable	<u>KPA-capacity</u> Better traffic location and smaller separation permit increased capacity. Reduced communication workload and better organisation of controller's tasks, thus increasing sector capacity	<u>KPA-efficiency</u> Route/track, and flight separation minima may be reduced, permitting flexible routings and vertical profiles that are closer to those preferred by users	<u>KPA-environment</u> Less emissions as a result of lower fuel consumption	<u>KPA-safety</u> Safety nets based on ADS-C support monitoring compliance with cleared levels and routes, danger area intrusion warnings, and better search and rescue. Less misunderstandings; resolution of stuck microphone situations

APPENDIX B

PERFORMANCE OBJECTIVE FORMATS (DATA LINK)

REGIONAL PERFORMANCE OBJECTIVE: <u>SAM ATM/06</u> IMPROVE ATM SITUATIONAL AWARENESS				
Benefits				
Safety	• The availability of electronic terrain and obstacle data in the cockpit permits a reduction in the number of CFIT accidents • Enhanced situational awareness provides data that facilitates the adoption of operational decisions, thus improving safety			
Environmental protection and sustainable development of air transport	• Enhanced air traffic surveillance reduces aircraft separation, improving air traffic flow and increasing ATC capacity • Improved collaboration between the flight crew and the ATM system • Improved collaborative decision-making (CDM) through aeronautical data sharing • Reduced pilot and controller workload			
Metrics				
• Reduction in the number of CFIT accidents • Reduction in the number of operational errors, including LHDs				
Strategy 2012 – 2018				
ATM OC COMPO-NENTS	TASKS	PERIOD START-END	RESPONSIBLE PARTY	STATUS
ATM-SDM AO CM	a) Develop an action plan to improve situational awareness of pilots and controllers	(*) - 2012	Regional Project	Valid
	b) Implement flight plan data processing systems (new FPL format) and ACC-to-ACC data communication tools	(*) – 2014	States	Valid
	c) Implement ATS surveillance technologies and their applications, as required	2012 – 2018+	States	Valid
	d) Implement air-ground data link communication systems (ADS-C/CPDLC in oceanic airspace, ADS-B, D-ATIS, DCL, D-VOLMET, etc.)	(*) – 2018+	States	Valid
	e) Implement advanced automation tools to support aeronautical information sharing	2015 – 2018+	States	Valid
	f) Monitor implementation	(*) – 2018+	GREPECAS	Valid
Link with GPIs	GPI/1: flexible use of airspace; GPI/6: air traffic flow management; and GPI/7: dynamic and flexible ATS route management; GPI/9: situational awareness; GPI/13: aerodrome design and management; GPI/14: runway operations; and GPI/16: decision support systems and alerting systems; GPI/17: implementation of data link applications; GPI/18: aeronautical information; GPI/19: meteorological systems, GPI/22: communication infrastructure.			

(*) Indicates that the task has been started before the target date.

REGIONAL PERFORMANCE OBJECTIVE: <u>SAM CNS/02</u> AERONAUTICAL MOBILE SERVICE IN THE SAM REGION				
Benefits				
Safety	• Reduction of operational coordination errors between adjacent ACCs, thus making ATS coordination more efficient; and • Reduction of pilot and controller workload			
Environmental protection and sustainable development of air transport	• Assurance of communication coverage and quality in ATS; • Increased availability of communications for ATS; • Support to AIM/MET service; and • Assurance of the radio frequency spectrum assigned to aviation for communication services			
Metrics				
• Percentage of compliance with FASID Table 2-A; • Number of CPDLC systems implemented; • Number of DCL systems implemented; • Number of D-ATIS systems implemented; and • Number of VOLMET systems implemented				
Strategy 2012 - 2018				
ATM OC COMPO-NENTS	TASKS	PERIOD START-END	RESPONSIBLE PARTY	STATUS
AOM ATM-SDM DCB CM	a) Complete implementation of services required in Table CNS 2-A “Aeronautical Mobile Service - AMSS”	(*) - 2014	States	Valid
	b) In continental routes: Complete VHF communications coverage in lower airspace, where so required by operations	2012- 2015	States	Valid
	c) Implement CPDLC in oceanic areas, maintaining HF service as backup	(*) - 2018	States	Valid
	d) Implement CPDLC in selected continental areas	2012- 2018	States	Valid
	e) Terminal area: Implementation of different VHF channels for control tower and APP services at all airports where a single channel is used for APP and control tower services	(*) - 2015	States	Valid
	f) Implementation of DCL services in selected aerodromes	2016-2018	States	Valid
	g) Implementation of D-ATIS services in selected aerodromes	2012-2017	States	Valid
	h) Implementation of VOLMET services (voice and data)	(*) - 2018	States	Valid
	i) Ensure protection of the radio frequency spectrum for current and foreseen communication services	(*) -2018	States ICAO	Valid
	j) Monitor implementation	2012-2018	GREPECAS	Valid
Link with GPIs	GPI/6: ATFM, GPI/9: situational awareness, GPI/17: data link applications, GPI/19: meteorological systems, GPI/22: communication infrastructure, GPI 23: aeronautical radio spectrum			

(*) Indicates that the task has been started before the target date.

REGIONAL PERFORMANCE OBJECTIVE: <u>SAM CNS/04</u> ATS SURVEILLANCE SERVICE IN THE SAM REGION				
Benefits				
Safety	- Improved ATM situational awareness; - Improved ATS coordination, reducing operational coordination errors between adjacent ACCs; and - Reduced pilot and controller workload			
Environmental protection and sustainable development of air transport	- Facilitates the provision of ATS; - Increased airspace capacity; - Supports PBN and random route implementation; and - Optimisation of resources as a result of information sharing			
Metrics				
- Number of ADS-C systems implemented in oceanic FIRs; - Number of adjacent ACCs that exchange ATS surveillance data; - Percentage of en-route airspace for upper levels with ADS-B coverage; and - Number of A-SMGCS systems implemented				
Strategy 2012 – 2018				
ATM OC COMPO- NENTS	TASKS	PERIOD START-END	RESPONSIBLE PARTY	STATUS
AOM AO TS CM ATM-SDM	a) Implement ADS-B and/or MLAT systems in en-route areas	2012-2018 +	States	Valid
	b) Implement advanced surface movement guidance and control systems (A-SMGCS) at airports that so require, according to a prior study	2013- 2018 +	States	Valid
	c) Implement the ADS-C service in all States that are responsible for an oceanic FIR	(*) - 2018	States	Valid
	d) Implement ATS surveillance data exchange between adjacent ACCs	(*)- 2018+	States	Valid
	e) Ensure protection of the radio frequency spectrum for current and foreseen communication services	(*) -2018	States ICAO	Valid
	f) Monitor implementation	2012-2018	GREPECAS	Valid
Link with GPIs	GPI/5: RNAV and RNP; GPI/6: ATFM; GPI/9: situational awareness; GPI/10: terminal area design and management; GPI/11: RNP and RNAV SIDs and STARs; GPI/12: functional integration of ground and on-board systems; GPI/13: aerodrome design and management; GPI/14: runway operations; GPI/17: data link applications, GPI/22: communication infrastructure, GPI/23: aeronautical radio spectrum			

(*) Indicates that the task has been started before the target date.

APPENDIX C

AIR NAVIGATION REPORTING FORMAT (ANRF) – B0-TBO

REGIONAL/NATIONAL PERFORMANCE OBJECTIVE – B0-40: Improved safety and efficiency through initial application of data link en-route					
Efficiency improvement Area 4: Efficient flight paths through trajectory-based operations					
ASBU B0-40: Impact on the main Key Performance Areas (KPAs)					
	Access and equity	Capacity	Efficiency	Environment	Safety
Applicable	N	Y	Y	Y	Y

ASBU B0-40: Progress in implementation	
Elements	Status of implementation (ground and air)
1. ADS-C over oceanic and remote areas	June 2018 Service provider
2. Continental CPDLC	June 2018 Service provider

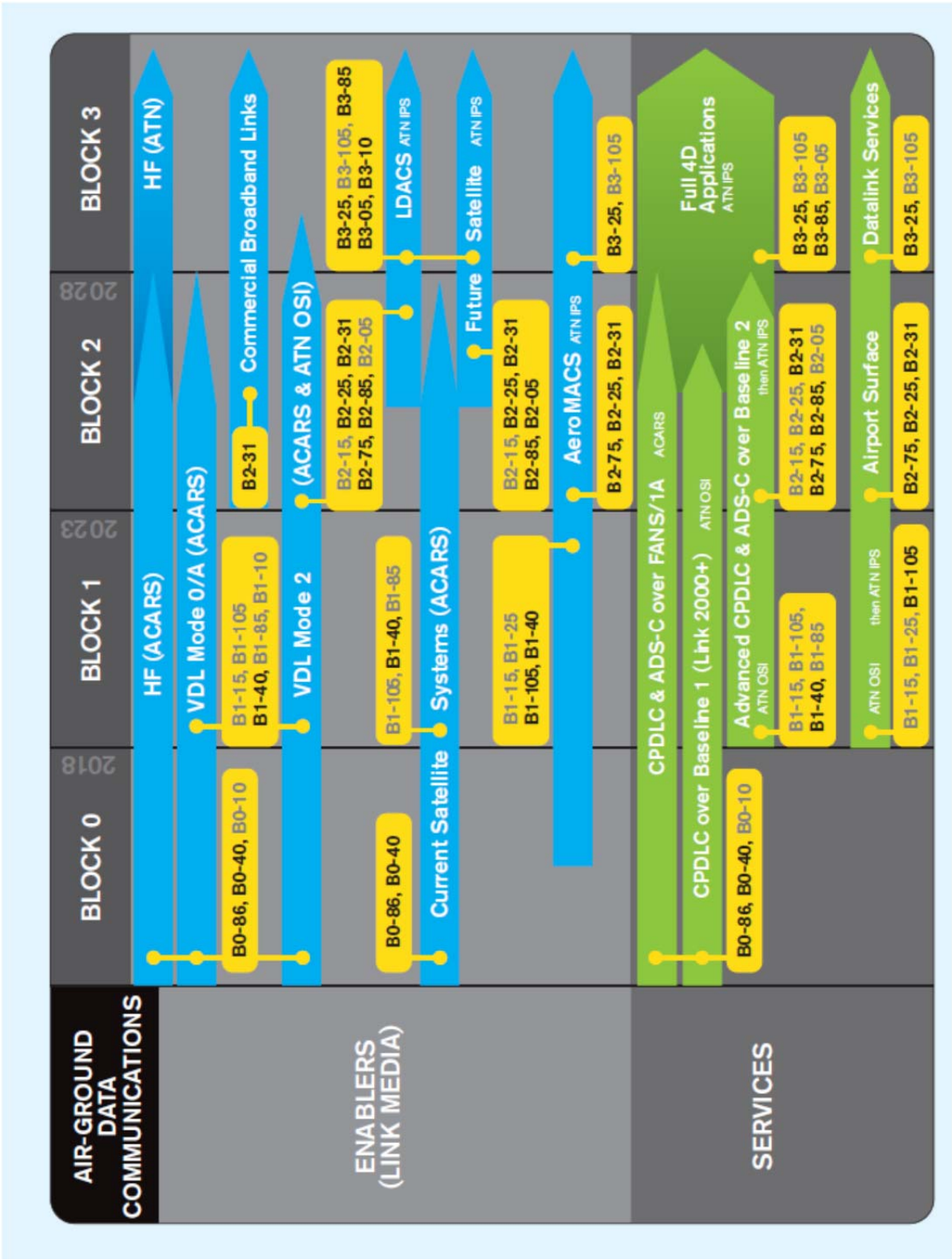
ASBU B0-40: Implementation obstacles/issues				
Elements	Area of implementation			
	Implementation of ground systems	Implementation of avionics	Availability of procedures	Operational approvals
1. ADS-C over oceanic and remote areas	NIL	ADS for general aviation is pending implementation	GOLD procedures are pending implementation	Lack of inspectors duly trained for approval of operations
2. Continental CPDLC	NIL	CPDLC for general aviation is pending implementation	GOLD procedures are pending implementation	Lack of inspectors duly trained for approval of operations

ASBU B0-40: Performance monitoring and measurement (Implementation)	
Elements	Performance indicators /Support metrics
1. ADS-C over oceanic and remote areas	Indicators: Percentage of FIRs in which ADS C has been implemented Support metrics: Number of ADS C procedures over oceanic and remote areas approved
2. Continental CPDLC	Indicators: Percentage of CPDLC systems implemented in FIRs with oceanic and remote areas Support metrics: Number of CPDLC procedures over oceanic and remote areas approved

ASBU B0-40: Performance monitoring and measurement (Benefits)	
Key performance areas	Benefits
Access and equity	NA
Capacity	A better location of traffic and smaller separations increase capacity. Less communication workload and better organisation of controller's tasks increase sector capacity.
Efficiency	Route/track and flight separation minima may be reduced, permitting flexible routings and vertical profiles closer to those preferred by users
Environment	Less emissions as a result of less fuel consumption
Safety	Safety nets based on ADS-C support monitoring compliance with cleared levels and routes, danger area intrusion warnings, and a better search and rescue. Less misunderstandings; solution of stuck microphone situations

APPENDIX D

ASBU COMMUNICATIONS ROADMAP



APPENDIX E

SYSTEM AVAILABILITY CALCULATION

E1- INTRODUCTION

Probabilities are numbers associated to events that indicate how likely it is for an event to occur during an experiment. A probability law is a function that associates a number to an event. Being E a random experiment and S the sample airspace, a probability law for experiment E is a rule that associates each event to a number $P(a)$ called probability of A .

The availability of a system is defined based on mathematical modelling, interconnecting all the components (links) of said system in series and in parallel. In order to define if two elements must be combined in series or in parallel, operating in pairs, the following rules apply:

- Elements are considered to be operating in series if the lack of any of them results in non-availability of the combination;
- On the other hand, elements are considered to be operating in parallel when the combination of the two links is rendered inoperative only if both fail.

E2- AVAILABILITY OF A COMBINATION IN SERIES

Figure E-1 represents two elements linked in series. It should be noted that it is just an example of a circuit that may have many coupled links configured in series.



Figure E1: Combination of two elements in series

The introduction indicates that a system with elements in series is considered to fail if one of the elements fails. Considering $P(A) = d_A$ as the probability of operation of element A , and $P(B) = d_B$ as the probability of element B , and $P(eq) = d(eq)$ as the equivalent result of the system, then:

$$P(eq) = P(A) * P(B) = d_A * d_B \quad (E-1)$$

E3- AVAILABILITY OF A COMBINATION IN PARALLEL

Figure E-2 represents two elements linked in parallel.

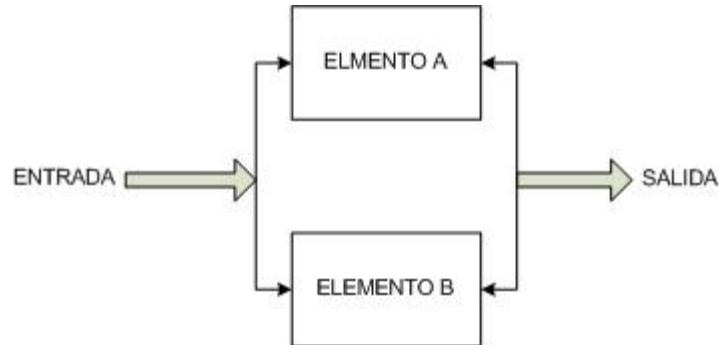


Figure E2: Combination of two elements in parallel

The rule presented in the introduction to this appendix states that the system is operational if at least one of the two elements is operating normally.

For the parallel configuration, the following probability corollary applies:

$$P(A \cup B) = P(A) + P(B) - P(A \cap B) \quad \forall \quad (E-2)$$

Considering $P(A)=dA$ as the probability of operation of element A, and $P(B)=dB$ as the probability of element B, and $P(eq)$ as the equivalent result of the system, and taking into account E-2, the following applies:

$$d_{eq} = d_a + d_b - d_a * d_b \quad (E-3)$$

APPENDIX F**HIGHLIGHTS OF THE PROJECT FOR THE CONCESSION OF THE DATA LINK NETWORK
IN BRAZIL****1. Purpose**

1.1 To GRANT the right to provide a public service--including the implementation of infrastructure--in the category of the aeronautical mobile service, enabling the exchange of messages between aircraft and users on the ground in the airspace under Brazilian jurisdiction. This capacity (called “data link” service) may be offered by the GRANTEE to airlines (called “private users”) for the exchange of messages between aircraft and their operators.

2. Fundamentals

2.1 The operation of the concession, based on the installed infrastructure, is for a period of 20 years, extendable for the same period.

2.2 To ensure the exchange of ATS messages, the Grantee must do *internetworking* with other possible data link service providers with international coverage.

Note: This is an important paragraph because there is no *internetworking* between providers for AOC and AAC messages.

2.3 The Grantee must give the Grantor the capability of exchanging messages via data link through ACARS, AOA, and ATN/VDL Mode 2 in continental areas, and SATCOM in oceanic areas.

Note: For SATCOM purposes, airlines pay the Grantee for all services, regardless of the type of message (AAC, AOC, and ATS), since the Grantee must pay the Space Segment Provider (INMARSAT).

2.4 The essential components of the infrastructure to be implemented, operated, and maintained by the GRANTEE are:

- Remote radio communication stations providing the coverage foreseen in the Basic Project.
- A message routing system called data link processor (and/or ATN router, if implemented), installed in Brazil, and interconnections between this system and the remote radio communication stations.
- Interconnections between the data link processor and other systems of data link service providers, for ATS purposes.
- Interconnections between the data link processor and automated systems of private users and of the GRANTOR.

Notes:

(i) *Remote radio communication stations must have the following frequency configuration:*

- f_{acars} - ACARS (ACARS link)
- f_{vdl-2} - ACARS Over AVLK - AOA (VDL-2 link)
ATN (where implemented)

(ii) *The communication capability in oceanic areas, even if not the subject matter of the contract must be provided by the GRANTEE to supplement the coverage of remote radio communication stations with SATCOM coverage subcontracted by the GRANTEE, in such a way that it will not be necessary to implement a SATCOM ground station to provide this capability in Brazil.*

- (iii) *The data link processor or the future ATN router shall be available at least 99,996% of the time on a monthly basis, taking into account even the availability of power supply. Likewise, it shall be fully independent from any other external message routing system, including that of the GRANTEE; that is, the system shall be fully autonomous in functional terms.*

2.5 The implementation of the data link communication infrastructure (remote radio communication stations and message routing system) shall support the traffic of messages of interest to DECEA for the provision of ATS services, and the traffic of messages of interest to aircraft operators that hire the message exchange service from the infrastructure operator, with duly equipped aircraft, within the radio communication coverage of the system.

2.6 “UPLINK” and “DOWNLINK” traffic of ATS messages processed by the “DATA LINK” service of the GRANTEE and the routing of ATS messages to the operational units in Brazilian territory shall not be charged by the GRANTEE.

2.7 “UPLINK” and “DOWNLINK” traffic of ATS messages to/from operational units in Brazilian territory shall be available to all private users, at no charge, within the aeronautical jurisdiction of Brazil.

3. Basic architecture

3.1 The architecture of the DATA LINK system, with the specified interfaces, is shown in Figure E1.

Notes:

- (i) *The DATA LINK system has the following components:*
- *Remote radio communication stations offering the coverage foreseen in the Basic Project.*
 - *A message routing system (called data link processor) and interconnections between this system and the remote radio communication stations.*
 - *Interconnections between the data link processor and foreign message routing systems for ATS purposes.*
 - *Interconnections between the data link processor and user systems of the GRANTOR, through an IP network;*
 - *Access points from the GRANTOR’s network (in Rio de Janeiro and Brasilia) to the GRANTEE’s network and to the associated traffic and safety management structure.*
- (ii) *System interfaces are:*
- *Those labelled “A”, “B”, “C”, and “D” in the figure.*
 - *Interconnections with foreign message routing systems for ATS purposes.*
 - *Interconnections with automated systems of PRIVATE USERS.*
- (iii) *The frequencies of remote stations to be used for ACARS communications must be connected to the data link processor (“B” interfaces).*
- (iv) *The frequencies to be used for ATN communications must be available at the access points of Brasília and Rio de Janeiro (“D” interfaces) for the future ATN router (“B” interface).*
- (v) *Messages to/from aircraft in oceanic areas must be sent to the SATCOM provider through the interconnection between the data link processor of the GRANTEE and other message routing systems.*
- (vi) *The DATA LINK system shall be implemented using COTS-type products, except when proven technically unfeasible.*

- (vii) *Interconnections between remote stations and the data link processor, and between stations and the access points of Brasília and Rio de Janeiro are part of the DATA LINK system and must be made available by the GRANTEE through an IP network.*

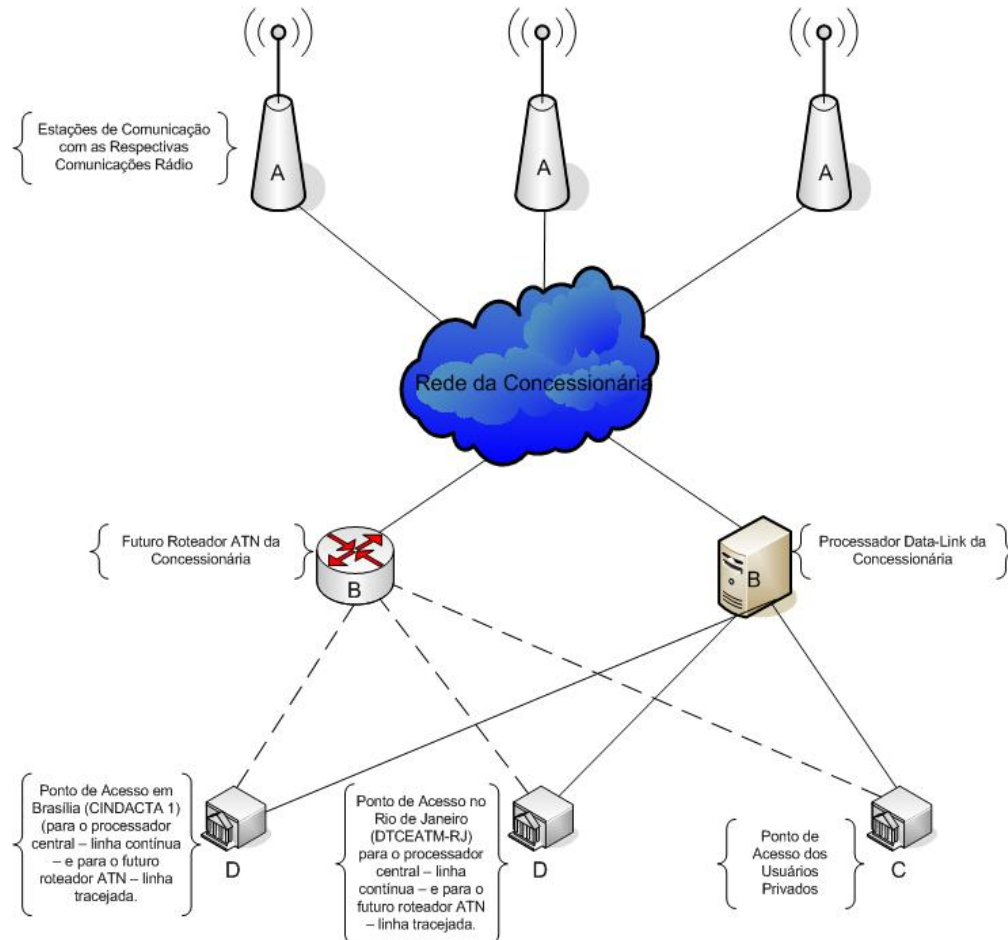


Figure E1: Basic concession architecture

Note: Due to operational reasons, the access point of Brasília was changed to Recife, where the AO ACC has been implemented, and which currently provides CPDLC and ADS-C functionalities in oceanic area.

APPENDIX G

SATCOM

G1- INTRODUCTION

For air-ground data delivery in oceanic or remote continental areas, satellite communication technology can be used, and the main satellite constellations that can be used by SAM States are those of INMARSAT and IRIDIUM.

The common name given to this type of communication is SATCOM. The next sections of this appendix will describe the basic characteristics of provider systems.

It should be noted that the States/ANSPs do not hire the space segment directly from INMARSAT and IRIDIUM; this is done by service providers (DSP), the main being SITA and ARINC. In conclusion, the States hire the services of the DSP, which, in turn, hires the space segment from INMARSAT and IRIDIUM.

G2 – IRIDIUM

The IRIDIUM satellite communication system was first conceived to have 77 satellites, which corresponds to the atomic number of the element iridium. However, it was launched in 1998 and the constellation consists of a set of 66 low earth orbit (LEO) satellites. The system was designed to be used for mobile telephony communications, but consideration was given to the possibility of using the constellation for air-ground data and voice communications between aircraft, air traffic control centres, and airlines.

The system also contemplates a ground network so that information received on ground may be routed anywhere on earth.

The IRIDIUM constellation, illustrated in Figure G1, is distributed throughout six orbital planes, each containing eleven LEO satellites. Global coverage is foreseen, including the poles, its efficiency improving as the number of satellites increases. The system ensures that each region on Earth is covered at least by one satellite at any time.

In addition to the operational satellites, there are some satellites in orbit that can be manoeuvred to take the position of any satellite that has experienced a failure. Satellites are orbiting at an approximate altitude of 420 NM, and complete an orbit around the globe every 100 minutes approximately, at a speed of 14.630 NM/h.

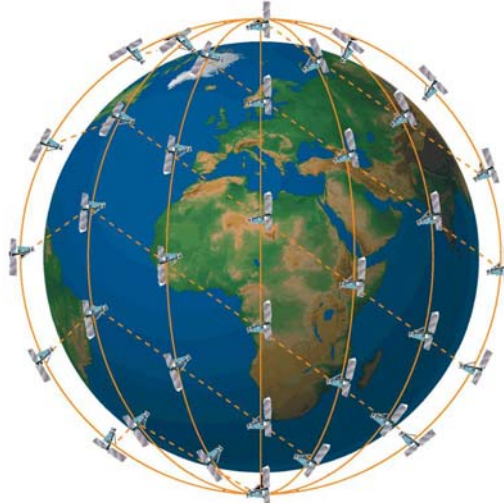


Figure G1- Illustration of the IRIDIUM constellation

Use of the IRIDIUM constellation for air-ground communications becomes very important in remote locations or where it is not feasible to install VHF equipment.

Avionics include a Satellite Data Unit (SDU), which is linked to the ACARS MU, and a small low-gain antenna installed in the aircraft fuselage. Thus, aircraft operators enjoy the advantage of having light equipment on-board that offers the assurance of global communications for transmitting AAC, AOC messages and voice communication services.

In terms of ATS applications, ICAO, after a thorough assessment of all technical characteristics, incorporated the use of IRIDIUM in the provisions related to the Aeronautical Mobile Satellite (Route) Service – AMS(R)S for FANS 1A applications, using the ACARS platform.

G3 – INMARSAT

The INMARSAT system is based on a constellation of geostationary satellites (GEO). There are three classes of satellites in use:

- a) Inmarsat-2: only provides global focus in the L band and is generally used for legacy services;
- b) Inmarsat-3: provides global and regional focus in some specific areas of the globe and consists of five satellites;
- c) Inmarsat-4: provides global, regional, and narrow focus, permitting use on the Broadband Global Area Network (BGAN).

Inmarsat-3 provides services for a capability called “Classic Aero”, involving a set of satellites certified for use in ATS/ACARS applications with circuit and packet switching.

At the last meetings of the ACP, note was taken of new concepts that ensure compliance with the stringent availability requirements foreseen in the GOLD for RSP and RCP to meet foreseen separations.

Since 2007, INMARSAT has a service called SwiftBroadband that shall replace the Classic Aero in the next few years. The high data delivery capacity may even serve as the basis for the use of the ATN by satellite.

In order to meet the most stringent availability requirements defined in the GOLD, the Swiftbroadband uses Inmarsat-4 satellites and the Inmarsat's Broadband Global Area Network (BGAN). Figure G2 illustrates the SwiftBroadband, clearly showing satellite redundancy to ensure service reliability.

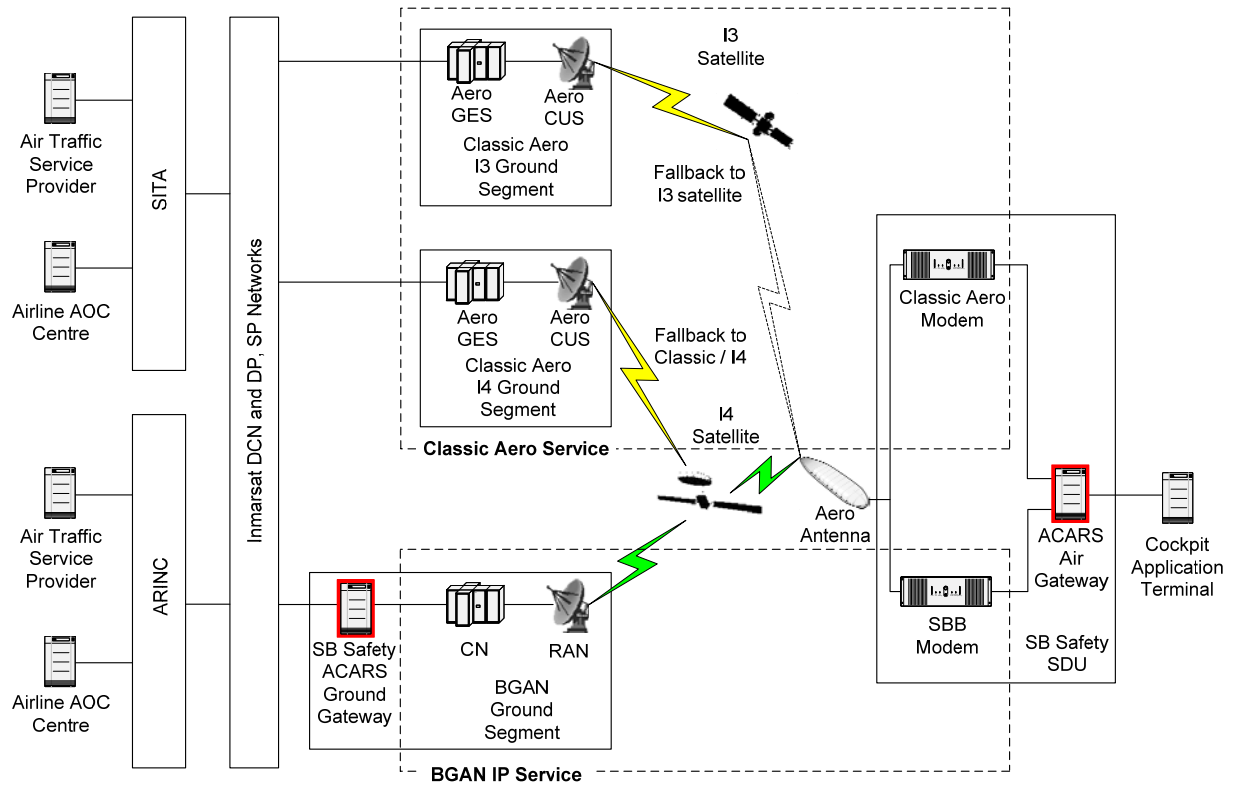


Figure G2: Basic architecture of the SwiftBroadband