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**Integration of Embraer 195 in Air Europa's datalink and development of new applications.**

# ENAC

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# ABSTRACT

This project is an End-of-Studies thesis of an ENAC student performed in the Spanish airline Air Europa in Palma de Mallorca. It deals with the integration in terms of datalink of a new aircraft type in airline's fleet, the Embraer 195, and with the development of new applications that make use of this new technology.

The project starts with a brief introduction to aviation communication and datalink in particular, focusing in Air Europa's trajectory until present situation. This complex domain is undergoing severe changes in recent years so all involved parties are detail introduced for a smooth understanding of following chapters. Likewise, a short presentation of Embraer's modular avionics is presented.

It follows the description of the steps taken and the problems encountered that led to have all Embraer messages correctly managed from its initial situation where only four messages where processed. Once familiar with the aircraft avionics, ground systems and datalink environment, three cases of datalink data integration are presented, highlighting the difficulties that arose in the process. The intermediate conclusions drawn in this part –some functions are missing in Embraer's datalink- led to the customization of Embraer's onboard datalink application, a complex process that benefitted from the fact that changing onboard's datalink was inevitable given the circumstances. Finally, a short mention of AIRE test flights is included as it is the most innovative application of datalink.

Key words: datalink, data integration, software customization, Air Europa, Embraer 195, AirCom Server

# RÉSUMÉ

Ce projet a été rédigé lors du stage de fin d'études d'un élève ENAC au sien de la compagnie aérienne espagnole Air Europa à Palma de Mallorca. Il traite de l'intégration d'un nouveau modèle d'avion, l'Embraer 195, dans l'architecture datalink de la compagnie et du postérieur développement des nouvelles applications qui utilisèrent ce système.

Le projet démarre avec une brève introduction à la communication aérienne et au datalink en particulier, en prêtant une spéciale attention à la trajectoire d'Air Europa. Ce domaine traverse une période d'évolution importante et de grands changements et c'est pourquoi il devient indispensable de bien définir le contexte pour une facile compréhension des chapitres suivants. Également, une courte présentation de l'avionique modulaire de l'Embraer est présentée.

Ensuite on trouve la description des mesures prises et les problèmes trouvées qui ont permis d'avoir tous les messages de l'Embraer gérées correctement a partir d'une situation initiale où il avait que quatre messages en fonctionnement. Une fois on est familiarisé avec l'avionique de l'avion, les systèmes au sol et le milieu datalink, trois cas d'intégration des donnés datalink dans autres systèmes sont exposés, en sourlignant les soucis qui ont surgit durant le procès. Les conclusions intermédiaires après cette partie –qu'il manquait de fonctionnalité au datalink d'Embraer- ont permis la personnalisation du logiciel datalink à bord l'Embraer, un processus complexe qui a bénéficié le fait que le changement était inévitable dans les circonstances où il s'est produit. Finalement, une brève mention des vols d'essais AIRE sont inclus, car il s'agit d'une des applications plus modernes du datalink.

Mots-clés : datalink, intégration de données, personnalisation du logiciel, Air Europa, Embraer 195, AirCom Server

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# 1.    INTRODUCTION

## 1.1.   SUMMARY

Air Europa is a Sky Team alliance associate member born 23 years ago as a charter company. Switching over time to a regular network carrier its fleet is composed by 30 B737, 6 A330, 2 B767 and 4 Embraer 195 (July 2009), 8 more to arrive in the following 2 years. This project takes place within Maintenance-Engineering department as part of the extra work created after the arrival of a new aircraft type.

## 1.2.   COMPANY OVERVIEW

Air Europa, as is now known, was the commercial name of the company founded in 1986 as Air España S.A as part of the British ILG-Air Europe Group. Originally it had the same livery as Air Europe but with its own titles, aircraft were registered in Spain and flew holiday charters from Mediterranean resorts and European cities using a Boeing 737-300.



**Figure 1-1 – Air Europa's corporate logo**

Juan José Hidalgo owned Halcón Viajes and Travelplan at that time, a travel agency and a tour operator founded by himself 20 years before. When in 1991 ILG and Air Europe ceased operations, Juan José Hidalgo leaded an investors group and acquired the extinct Air Europe, whose fleet was of just 9 leased aircraft. The commercial name remained and Air Europa became the first private airline in Spain offering scheduled services. In following years tourism sector sky-rocketed in Spain as a result of the 1992 Barcelona Olympic Games and the 1992 World Exposition in Seville and the fame Spain gained afterwards as tourism destination. At the same time a very famous TV advertisement (which is still remembered up to date) boosted the business figures of both travel agencies, opening hundreds of new offices every year for nearly a decade. As a result, Air Europa's activity increased up to 750 weekly scheduled flights, including flights to London, New York, La Habana and Salvador de Bahía. Within Spain, Air Europa offered the first alternative to government's airline monopolistic Iberia (later privatized) and the highly profitable Puente Aéreo service between Madrid and Barcelona.

In 1997 Globalia (full name: Globalia Corporación Empresarial) was created as the parent company for all Hidalgo's companies and became the basis for future expansion. Headquarters

were moved to Palma de Mallorca in 1999. In year 2000 the Oasis Hotels branch was created within the group (now with nearly 40 hotels in Spain and the Caribbean) and 2 years later the Pepe brand family was established. Pepe is the low cost division of Globalia, offering low cost rent a car, travel agency and mobile telephone services (PepeCar, PepeWorld and PepePhone).



**Figure 1-2 – Globalia corporate logo**

Finally in 2005 both Groundforce and Globalia Mantenimiento were created. Groundforce is now the biggest handling agent in Spain, with presence also in Portugal, Mexico and Morocco. Globalia Mantimiento offers aircraft maintenance in its hangar in Palma de Mallorca airport. Many smaller or support companies were also created, as Globalia Sistemas, offering IT services for the whole corporation. Globalia is currently formed by nearly 50 brands and employs more than 20.000 people.

Despite being all individual companies dependant of the same parent company, they enjoy a relatively high level of independence. There is no need for Halcón Viajes tour operator to sell Oasis hotels and Air Europa tickets or Air Europa aircraft to perform maintenance in Globalia Mantenimiento exclusively. In fact any deal between two Globalia companies is also compared to public market offers. If a better trade can be obtained elsewhere the fact of not being of Globalia will not stop the operation. Conversely, having the back up of Globalia will guarantee a minimum turnover for each company. It is important to note that no two companies inside Globalia compete directly between them but they rather transfer the business from one to another.

It is unavoidable that Air Europa's evolution is strongly linked to Globalia group. Starting as a company offering only charter and holiday flights at Travelplan requests, scheduled operations were progressively added to Air Europa's network reaching nowadays about 95% of all flights. In 1994 Air Europa entered the Puente Aéreo market and a year later already offered flights to London and New York. At the same time they specialized in Balearic and Canary islands flights, whose insular nature granted a steady demand as well as an important traffic peak during summer months. There are currently up to 70 flights a day to each archipelago.

Fleet homogenization became a priority by the beginning of the current decade. The mix of B733, B734, B738, B757 and B767 (not atypical in charter airlines) developed into a simpler and more efficient combination of B738 for shorthaul and A330 for longhaul (2 B767 remained though).  Operations were gradually shifted to a central hub in Madrid, were all A330 and B767 are based, with focus cities in Barcelona, Palma de Mallorca, Las Palmas and Tenerife. Codeshare agreements were signed with Alitalia, Air France and Continental, in year 2000 and company's frequent flyer program Fidelitas reached 100.000 customers by 2003.

Year 2007 marked an important milestone for Air Europa when it became an associate member of the Skyteam alliance and adopted Air France's and KLM's Flying Blue fidelity program. A year later an order for 12 Embraer 195 was signed, with aircraft joining the 30 B738, 6 A330 and 2 B767 strong fleet during 2009 and 2010. Air Europa was also the launch customer of the new Airbus A350, due to arrive in 2011, but as a result of the delays in the program the order was transferred to Boeing for eight B787 aircraft.

In the short future Air Europa will face very tough times, although in a very good position. Spanish air market is abruptly transforming: Vueling and Clickair, the only two Spanish low cost carriers, merged in July 2009 becoming the second biggest airline in Spain and fourth low cost in Europe. Spanair, similar in size to Air Europa, changed management and investors, moved its central hub to Barcelona and threats with a massive expansion in domestic routes, backed up by its Star Alliance companion Lufthansa. And Iberia, with no doubt the biggest Spanish airline with a vast Europe-Latin American hub in Madrid, is in talks with British Airways for merging, which would create one of the biggest airlines worldwide.

Aircraft maintenance is an important part of Globalia's business plan and an indispensable need for Air Europa. Air Europa is an approved EASA part M Continuing Airworthiness Management Organization, EASA part 145 Approved Aeronautical Repair Station for line maintenance and EASA 147 approved Training Organization. Globalia Mantenimiento (GMA), in turn, is an approved part 145 Repair Station for Base maintenance so, in general, line maintenance is performed by Air Europa and base maintenance by GMA. All daily inspections and most A-checks are performed by Air Europa's own engineers in the station where the aircraft is located. For all bigger engineering works (B and C-Checks) the aircraft is flown to Globalia's Mantenimiento Hangar, in Palma de Mallorca airport, and the work is carried out on a customer-provider relationship. Additionally, GMA also offers services to third-parties and Air Europa also performs C-checks in other stations than GMA.

Air Europa's headquarters are located in Llucmajor, 15Km from Palma de Mallorca city. However for practical reasons Air Europa's Maintenance department is situated in GMA's hangar. The hangar, built in 2007, has a surface of 9000 m$^2$ and capacity for three narrow-body aircraft or one narrow-body and one A330 aircraft. A 10 million euro investment is due to start in 2010 for doubling its current capacity after GMA obtained approval for base maintenance for A320 aircraft. (1)

**Figure 1-3 – Globalia Mantenimiento's hangar in Palma de Mallorca airport.**

Air Europa's maintenance department is formed by nearly 150 people in Mallorca in office positions and 220 engineers spread across Spanish stations, with an important presence in Madrid, given the amount of flights handled. It is further subdivided into five functional areas:

- Training: in charge of training new staff and offering continuous training for existing personnel.

- Logistics: in charge of purchasing and distributing supply material for the warehouses in Madrid, Barcelona, Tenerife, Las Palmas and Palma de Mallorca.

- Stations: in charge of daily inspections and small reparations in airport with Air Europa's presence.

- Maintrol: manages and coordinates all repair actions, logistics and staff 24/24 in all Air Europa's stations.

- Engineering: provides preventive maintenance, service bulletins implementation, liaison with manufacturers, suppliers and aviation authorities, development of new programs and preserves all technical records.

This project takes places within Air Europa's Maintenance-Engineering department. As work is highly specialized the department is organized in working groups:

- Systems: Formed by 8 people dealing with the maintenance of the onboard systems (avionics, landing gear, structure...)
- Engines: 4 people dedicated to engines, separated by engine type.
- Technical records: a team of 10 people for keeping a database of all technical documentation of Air Europa's fleet and performs statistical and reliability analysis.
- Planning: 8 people to coordinate all maintenance tasks between them and with the operational schedule of the aircraft.

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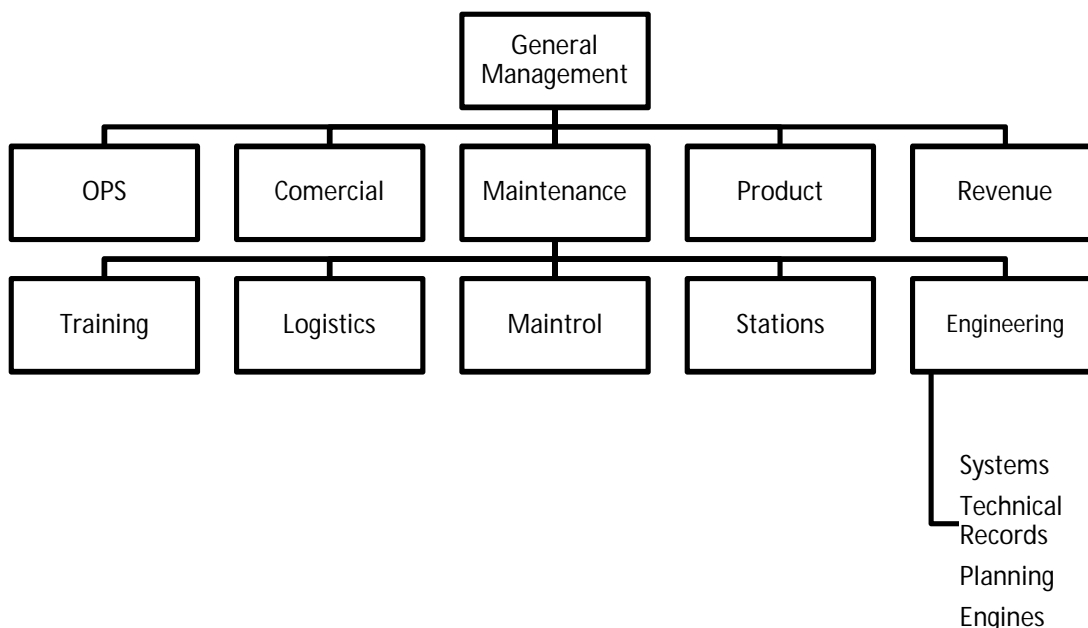
**Figure 1-4 – Air Europa's organization chart**

The project offered to me by Air Europa within the Systems group of Maintenance-Engineering and accepted as End of Studies project by ENAC was the natural consequence of the introduction of a new aircraft type in the fleet, the Embraer 195. The introduction of a new model always increases the work load: new systems, new procedures, new documentation... In this particular case another factor played his role as Embraer was a new manufacturer in Air Europa's fleet.

With the arrival of the Embraer aircraft the already existing and working infrastructure of Air Europa datalink systems had to adapt as much as possible to these new aircraft. On-ground datalink applications offer a decent degree of flexibility in order to adapt to different aircraft model or versions, but have to be configured. This was the first task committed and is presented in chapter 2. However, before being able to configure the datalink communication of the Embraer 195 much study and familiarization with the aircraft and the systems was needed. In parallel to these tasks a reference handbook was composed in order to assist crews with the use of the on-board menus and displays of Embraer's datalink.

Chapter 3 describes the integration of the received data by datalink into different systems of the company. Many applicable situations were envisaged, but also many of them required much more time than available for this project. The three integration cases performed are here presented, and were chosen for not exceeding the agreed stage length whilst showing the complexity of data integration between different departments.

Chapter 4 presents the process of modifying the onboard characteristics of the datalink application in the E195. Initially it was not expected to perform such changes but it turned out to be the logical step given the circumstances.

Chapter 2 and 3 were the original break-up of the project at its beginning as agreed between the company, the student and ENAC. As the time went by, an additional chapter was included. The required data and information for a smooth reading is generally presented along the principal part of this project. If more detailed information is available and is part of this project, the relevant annex will be mentioned.

## 1.3.    BRIEF INTRODUCTION TO DATALINK

### 1.3.1.  SUMMARY

Air space is a limited resource and aviation should take advantage of all possible technological innovation to maximize its usage. In this line new technologies are deployed in many areas as part of a long term global projects: SESAR in Europe, NextGen in USA. Amongst many other changes affecting navigation and surveillance, air/ground communication will greatly transform. It must adapt for new important applications, such as CPDLC, based on data transmission (datalink) instead than voice communications. Nowadays we are in the transition point between the old and the new technology; from ACARS to VDL2 datalink. Eurocontrol's program Link 2000+ coordinates and gives incentives to airlines for this transition to occur.

### 1.3.2.  HISTORIC EVOLUTION

In 1836, Samuel Morse demonstrated the ability of a telegraph system to transmit information over wires when the information was sent as a series of electrical signals. With the advent of radio communications, an international version of Morse code became widely used being the most well known usage of Morse code is for sending the SOS distress signal: ... - - - ...
The telegraph may be considered the precursor of the modern datalink. Datalink is the generic term designating the connection for data transmission between two end-systems. In aviation these end systems are normally on board an aircraft and on ground. It is a generic term in that datalink does not imply one particular technique for the information to be transmitted: depending of several circumstances the message can be sent via VHF, HF or SATCOM but the choice of the media used is transparent both for the crew and the end user on ground.



**Figure 1-5 - Datalink schematic overview**

As early as 1978, airlines realized the potential of datalink by introducing the Aircraft Communications Addressing and Reporting System (ACARS) addressable application to exchange company messages between their aircraft and their respective home bases. Using Very High Frequency (VHF) band, ACARS became the first VHF datalink (VDL).

Prior to its introduction, all communication between the aircraft (i.e., the flight crew) and personnel on the ground was performed using voice communication. This communication used either VHF or HF voice radios, which was further augmented with SATCOM in the early 1990s.

ACARS was originally developed by ARINC (Aeronautical Radio, Inc) in response to a requirement from Piedmont Airlines to find a better way to measure flight crew duty times. The initial application was called "OOOI" and it offered Airline's Operational Control (AOC) communications. OOOI gave actual times when aircraft left the gate (Out), took off (Off), landed (On) and arrived at gate at destination (In). As the system matured, airlines found that other time-sensitive information could be transmitted and received through the system and ACARS expansion was underway as a result. During the late 1980s and early 1990s, a datalink interface between the ACARS system and Flight management systems (FMS) was introduced. This interface enabled flight plans and weather information to be sent from the ground to the ACARS Management Unit, which would then be forwarded to the Flight Management Systems (FMS). This feature gave the airline the capability to update FMS data while in flight, and allowed the flight crew to evaluate new weather conditions or alternate flight plans. Maintenance services also found an important asset in the downlink of real-time aircraft parameters. The aircraft was no longer isolated from ground when in flight.

The original message service system has evolved over the past two decades to the generic Aircraft Communications and Reporting System (ACARS, but the word *Addressing* was dropped). Today, over 6,000 aircraft are using ACARS worldwide on a daily basis, with more than 20 million messages exchanged per month.

In late 80's, in some busy American airports departure clearances were delivered over ACARS, saving precious time at the saturated voice frequency. This marked the beginning of ATC communications or ATC services (ATS) over datalink opening a new bunch of possibilities for this digital link between the aircraft and ground systems.
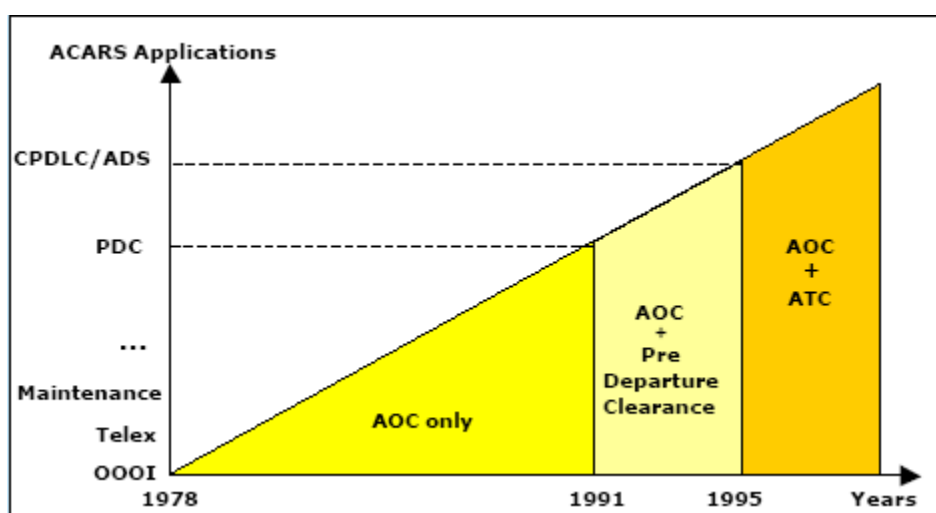


**Figure 1-6 - Evolution of datalink messages**

During the following 15 years, growing worldwide fleets and more bandwidth demanding messages made the already 20 years old transmission protocols and ground infrastructure reach its limit capacity. Further network expansion by installing more ground antennas was not

long term viable. Datalink service providers (DSP) resolved the saturation by implementing a new transmission protocol, called VHF datalink mode 2 (VDL2 uses D8PSK modulation as compared to MSK-AM), offering a nearly 15 fold increase in data throughput compared to the ageing ACARS system. Not only could airlines' operations benefit from this upgrade but new ATS applications were also projected as a result of increased datalink capacity, offering better safety levels and an important enhance on air traffic capacity. Eurocontrol launched a number of programs for encouraging fleet upgrading in the navigation and communication field after several studies demonstrated important benefits from an early VDL2 installation onboard both for the airlines and for air navigation service providers.

## 1.3.3. COMMUNICATION MEDIAS

The information may be sent by multiple channels and this choice is transparent to the crew and ground operators. Alternatively, the user may choose one particular media if requested. Datalink Service Providers (DSPs) use a variety of different air-to-ground communication media: VHF, HF and satellite. Each of them has its corresponding receptors and all of them are connected to a terrestrial datalink network to provide the end-to-end delivery of the information.

a) VHF datalinks (VDLs) are the most commonly used civil aviation datalink. VHF datalinks are economical to implement and provide excellent operational performance (e.g., fast response times: 2 to 8 seconds), but are limited to line of sight coverage. This means a nominal range of about 240 NM at 30,000 feet and this range limit will apply to any VHF-based datalink. For this reason, datalink service providers have installed countless antennas covering all continental terrain. Oceanic areas however, remain out of VHF coverage. Under this category are included both ACARS protocols based on classic VHF and VDL2 datalink.

b) Existing satellite datalinks can provide nearly global coverage. They offer datalink service in oceanic areas out of VHF range, but the current implementation provides no coverage in the Polar Regions (above and below 80 degrees of latitude) where, until recently, there were little economic reasons to deploy SATCOM coverage. Satellite datalinks are more expensive per message transmitted and also slower than VHF in response time (12 to 25 seconds).

c) HF datalink (HFDL), as implemented, provides near global coverage including over the northern Polar Regions. HFDL is an economic alternative to satellite datalinks for wide area coverage, but its message transit time (80 seconds) is slower than satellite's.

## 1.3.4. FUTURE AIR NAVIGATION SYSTEMS (FANS)

Parallel to ACARS use and development the ICAO created in 1983 its special committee on Future Air Navigation Systems (FANS) to make recommendations to upgrade the communications, navigation and surveillance systems so as to cope with the evolution of the worldwide air traffic. In 1989, based on the previous work, a second committee was created for the implementation of the CNS/ATM (Communication, Navigation, Surveillance / Air Traffic Management) concept. This concept was endorsed by the 10th ICAO's Air Navigation Conference in 1991. It bases future technologies on satellite systems and digital communications to obtain an increase in air space capacity, enhancing the operational flexibility and enhancing global air traffic safety. Worth noting that the *Future* Air Navigation Systems (FANS) name remains in use, despite being this future relative to 1989 and some of the applications and technologies are already in use. In this project there will be made a special emphasis on the communication facet of FANS.

### 1.3.4.1. NAVIGATION

To fully benefit from the CNS/ATM concept aircraft will need to attain a certain level of navigation performance in terms of accuracy, availability, integrity and service continuity. Required Navigation Performance (RNP) is a navigation concept defining the level of accuracy of on board systems in relation to position and speed estimation. The requirements are on the final output (4D position) rather than on technical installed equipment; each manufacturer may select how to fulfil the legal requirements.

This leads to a whole new concept in air navigation. Modern navigation involves the development of instrument procedures that are not based on conventional radio navaids. This type of navigation is called Area Navigation or RNAV. It can be used en-route, in association with the RNP concept, but also for terminal area navigation and instrument approach procedures[1].

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[1] For example, RNP-10 means aircraft will be within 10NM of their intended position 95% of time.
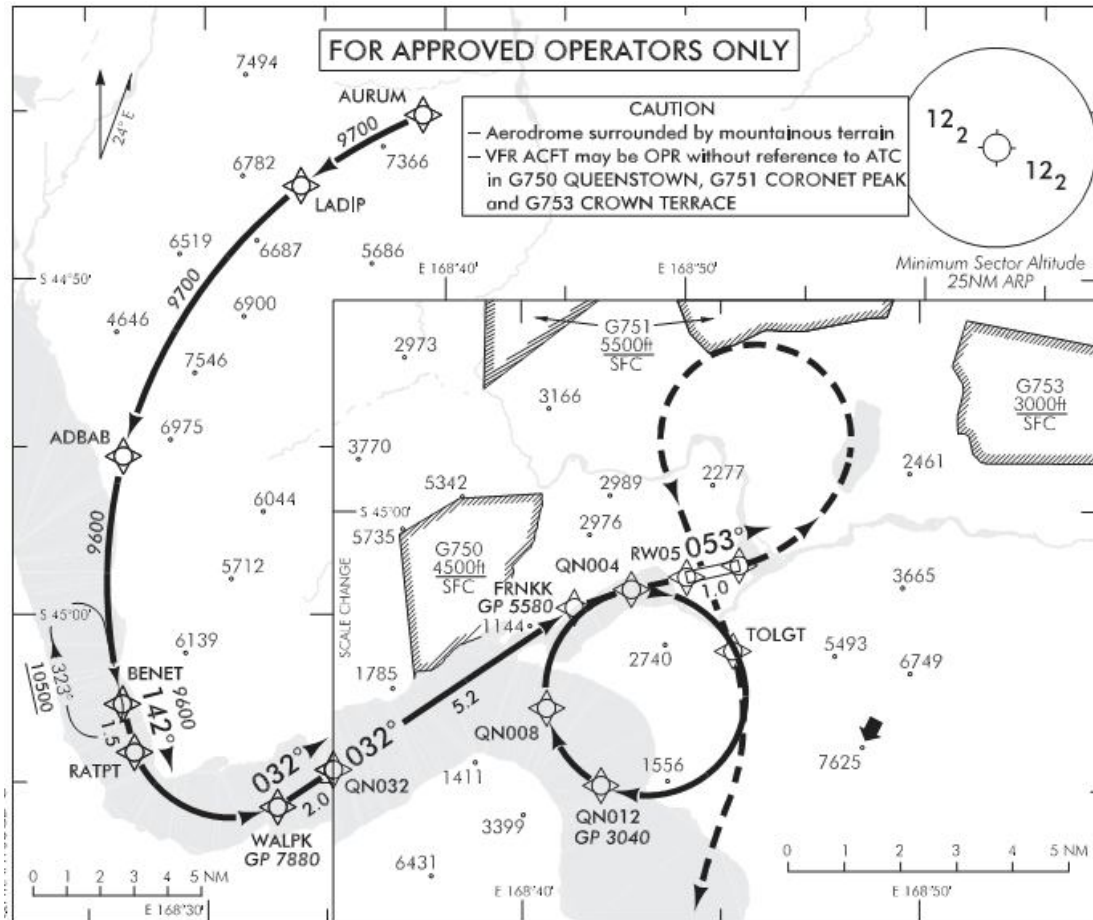
**Figure 1-7 - RNP approach in Queenstown (NZQN) (2)**

In the approach chart shown in figure 1-7 approved operators can perform this approach procedure where the aircraft is flown into a curved valley, turned 360° to lose altitude before coming to land. In the orography of this example ground navigation emitters (VOR or ILS) cannot be installed and approached were performed only if Visual Meteorological Condition (VMC) prevailed. By having accurate navigation avionics aircraft can descent much lower before having visual contact with ground, thus decreasing the amount of diversions caused by bad weather/visibility.

## 1.3.4.2. SURVEILLANCE

Air traffic surveillance was based mainly on primary and secondary radars and both showed economical and/or capacity limitations with existing long term traffic forecast. Wherever radar coverage is possible, Secondary Surveillance Radars (SSR) modes A and C are still used. Even it is called radar the principle behind SSR's is that a ground station interrogates the on board transponder of all close-by aircraft, receiving the requested data in the reply of all of them. Mode S is used in such areas where traffic densities are high enough that a selection of the aircraft being interrogated is needed.

In oceanic and remote airspaces, traffic was forecasted to continue increasing so new means of traffic surveillance were developed. Procedurally controlled surveillance (that is, reporting points along the route) is progressively replaced by Automatic Dependent Surveillance, which allows the aircraft to automatically send position data and flight plan intents to up to four different ATC centres, generally via SATCOM. It is expected that there will be no need for HF voice reporting any longer. With the possibilities offered to the controllers to select the rate and mode of reporting (at specified time intervals or on the occurrence of a special event such as a heading or attitude change), ADS[2] is expected to allow for reduced lateral and longitudinal separation.

## 1.3.4.3. COMMUNICATIONS

A major change provided by FANS is in the communications field. The information flow was observed to be inefficient because there are many different protocols and many different subnetworks forming the aeronautical global network. Many conversions from one specification to another are needed, decreasing overall performance. At the same time voice communication between crew and ATC is nearly saturated in some areas. For understanding the current datalink situation (and its forthcoming evolution) it is indispensable to get to the roots of the communications as specified in FANS – CNS/ATM.

### 1.3.4.3.1. ATN

ATN (Aeronautical Telecommunications Network) is a new global telecommunications network endorsed by CNS/ATM concept that will be used for transmitting aviation related data in substitution of current ACARS network and including the ground segment, too. Compared to ACARS, ATN is a global standard, which provides high data rate, high integrity, more reliable, and robust means for implementing current and future intensive datalink applications. ATN uses well-defined protocols and equipment, specifically designed to provide a reliable end-to-end communications service over dissimilar networks, in support of ATS. It is intended to provide the means, via a common Internet working protocol, for a worldwide datalink between ground and airborne host computers within the aeronautical community, both for ATC and AOC applications.

Figure 1-8 show a schematic overview of ATN. Datalink, as part of the global network, forms part of ATN. In order to overcome compatibility, standardization and other problems, and following the recommendation of the original FANS committee, ICAO has chosen to implement datalink using the ATN technology.

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[2] ADS, Automatic Dependant Surveillance is further subdivided in ADS-Contract and ADS-Broadcast. The former transits data using datalink to an ATC centre; the later radiates in all directions for other aircraft to receive this data. (12)
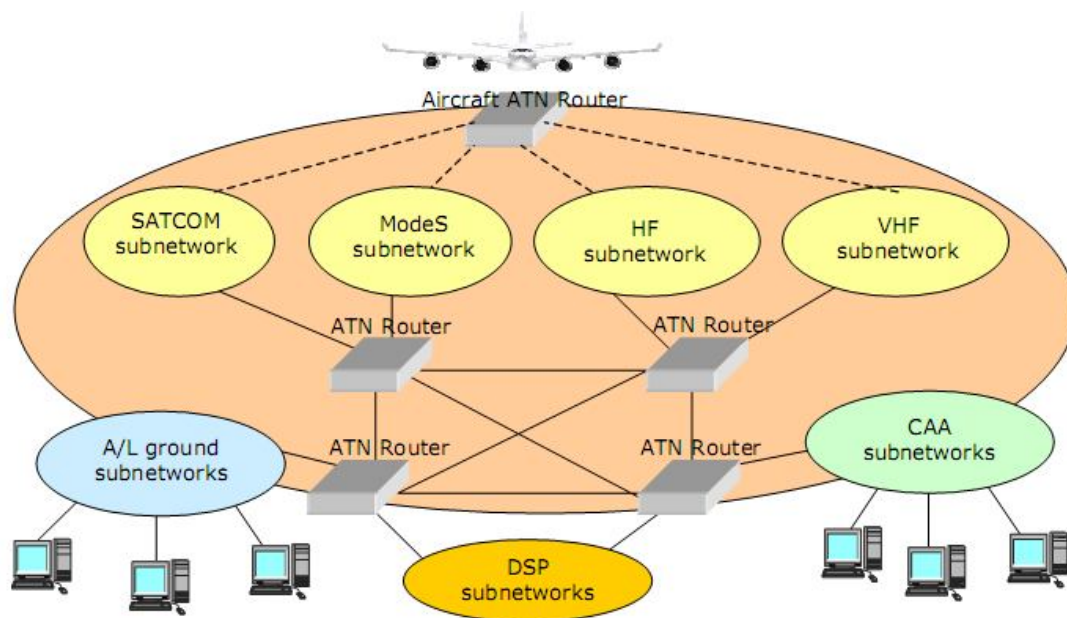
**Figure 1-8 - Schematic overview of ATN**

Since datalink applications will be used for directing aircraft movements and/or for providing data to the aircrew so that they can make safe decisions, the integrity of the messages must be sufficiently robust to make the possibility for an erroneous or misaddressed message remote. To meet this requirement the ATN protocols have error-checking functions, a feature missing in current ACARS.

ATN is a very ambitious plan and its development will be established in phases. At each phase new applications will be introduced. At this stage the most important ones are Controller-Pilot Datalink Communications (CPDLC) and Airborne Dependant Surveillance (ADS).

### 1.3.4.3.2.    CONTROLLER-PILOT DATA LINK COMMUNICATION (CPDLC)

Nowadays, the standard method of communication between an air traffic controller and a pilot is voice radio, using either VHF or HF bands in remote areas. One of the major problems with voice radio communications used in this manner is that all pilots being handled by a particular controller are tuned to the same frequency. As the number of flights air traffic controllers must handle is steadily increasing the number of pilots tuned to a particular station also increases. This increases the chances that one pilot will accidentally override another, thus requiring the transmission to be repeated. In addition, each exchange between a controller and pilot requires a certain amount of time to complete; eventually, as the number of flights being controlled reaches a saturation point, the controller will not be able to handle any further aircraft.

Traditionally, this problem has been countered by dividing a saturated Air Traffic Control sector into two smaller sectors, each with its own controller and each using a different voice communications channel. However, this strategy suffers from two problems:

- Each sector division increases the amount of "handover traffic". That is the overhead involved in transferring a flight between sectors, which requires a voice exchange between the pilot and both controllers, plus co-ordination between the controllers.
- The number of available voice channels is finite, and, in high density airspace, such as central Europe or the Eastern Seaboard of the USA, there may not be a new channel available. In some cases it may not be possible or feasible to further divide down a section.

A new strategy is needed to cope with increased demands on Air Traffic Control, and data link based communications offers a possible strategy by increasing the effective capacity of the communications channel. Controller-Pilot Data Link Communications (CPDLC) is a powerful tool to sustain data link communications between a pilot and the controller of the relevant flight region. It is particularly adapted to such areas where voice communications are difficult (e.g. HF voice over oceans or remote part of the world), and became very convenient to alleviate congested VHF of some dense continental airspaces when utilised for routine dialogue (e.g. frequency transfer).

CPDLC allows flight crew and controllers to communicate via data link thanks to written messages composed of one or several elements chosen in a set of internationally agreed preformatted elements. Those elements are in line with the existing ICAO voice phraseology and can be used for clearances, requests, reports, negotiations and other kinds of dialog with ATC (e.g. emergency messages, ATC transfer, frequency changes...).
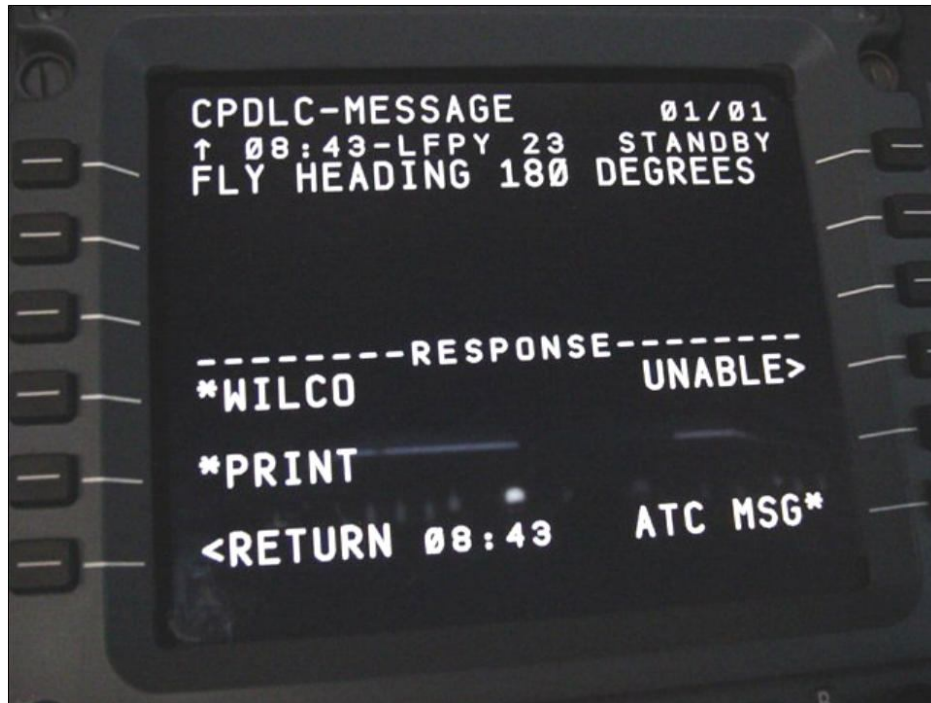
**Figure 1-9 - CPDLC message in Air Europa aircraft**

Advantages and drawbacks of CPDLC, compared to voice communications, have been discussed at length for some years. Among the main ones, CPDLC is a remedy to shortcomings of the existing systems:

- Significant reduction of the transmission time.
- Suppression of the errors or misunderstandings pertaining to poor voice quality, fading or language skills.
- Suppression of mistakenly actions on ATC messages intended for another flight.
- Suppression of the tiring listening watch of the radio traffic
- Possibility for an immediate access to previously recorded messages
- Automatic loading within the FMS of route or flight plan clearances, thus avoiding transcription errors, long and fastidious manual keystrokes.

The following points however must be well understood and will have to be underlined in training for an optimum use of CPDLC:
- Handling of CPDLC messages requires time:
    - Reading and interpreting a written clearance was found to be less immediate than hearing the same one.
    - Preparing and sending a request through the combination of the MCDU and DCDU is longer than directly using the microphone.
- The party line is lost (the pilot can no longer listen to the surrounding transmissions).

The business case was already performed by Eurocontrol and results are positive. CPDLC will reduce the controller's and the pilot's workload through a decrease in radiotelephony activity.

It is estimated that sector capacity will increase 11% if 75% of flights are data-link equipped. (3). Whenever it is possible to defer the creation of a new sector, there is a cost avoidance equivalent to the cost of operating the sector. It may be summarised as follows: datalink enables a reduction in the radio telephony workload, this procedures a reduction in the overall workload of the controller, this, in turn, leads to a sector capacity increase, enabling the opening of new sectors to be deferred, permitting the avoidance of additional controller costs and associated support costs.

Safety will also benefit from CPDLC. The availability of a second communication channel will reduce communication errors, aircrew fatigue, and controller fatigue and will thus contribute to higher safety levels. Radio communications have a number of drawbacks in today's busy traffic environment. Pilots have to listen to each controller-initiated communication while approximately only one in twenty communications is addressed to the flight in question. This leads to aircrew fatigue. Blocking of frequencies by simultaneous transmissions and stuck microphone buttons are a common occurrence. A reduction of the pilot's communication workload will allow him to concentrate on other tasks and thus contribute to higher safety levels.

The biggest factor that avoids CPDLC to be widely used now is datalink capacity. Current communications protocols (ACARS) have a very limited capacity, not enough to support CPDLC. For a full ATN implementation, a better datalink technology has to be put in practice which is under way with VDL2.

### 1.3.4.3.3.    VHF DATALINK MODE 2 (VDL2)

Due to its intrinsic limitations and scarce frequency, VHF ACARS would not be able to face for a long time the general growth of the data communications traffic. Therefore, new VHF datalink systems were developed and standardized to enable high-speed VHF communications over the next few years. ICAO decided to use the name "VHF Digital Link" (VDL) for these high-speed VHF data link systems. VDL defines the protocols needed to exchange bit-oriented data across an air/ground VHF data link in an ATN compliant environment.

Different forms of VHF data link have been defined depending on the signal modulation and the network access protocols:

- Mode 1: CSMA (Carrier Sense Multiple Access) with MSK-AM (Minimum Shift Kwying-Amplitud Modulation) modulation at 2.4 kbits/s (similar to ACARS);
- Mode 2: CSMA with D8PSK (8-Differential Phase Shift Keying) modulation at 31.5 kbits/s;
- Mode 3: TDMA (Time Division Multiple Access) with D8PSK modulation at 31.5 kbits/s providing integrated voice and data services;

- Mode 4: current candidate technology for ADS-B, VDL Mode 4 is STDMA-based (Self-Organized Time Division Multiple Access) and provides data only services with GFSK (Gaussian Frequency Shift Keying) or D8PSK modulation but there are patent issues linked to the use of VDL mode 4.

Currently only VDL mode 2 (known as VDL2) is deployed by the Datalink Service Providers (DSP) as an expansion to their ACARS network, which was already saturated in busier areas. By deploying it should be understood installing new antennas that work at different frequencies as compared to ACARS, able to send and receive signals using VDL2's modulation. So on-top of the classic ACARS network of antennas, new VDL2 antennas are being added.



**Figure 1-10 - SITA's VHF coverage in Europe (4)**

**Figure 1-11 - SITA's VDL2 coverage in Europe (4)**

As the data link traffic over ACARS network continues to increase, congestion of the current ground networks is expected soon. VDL2 was found the best way to improve the performance of data link applications in a fast and efficient way, increasing the capacity of ACARS network. This new technology increases the rate of data transmission from 2.4Kbits per second to 31.5Kbits per second and this 15-fold increase allows for implementing CPDLC. Given that VDL2 was already being deployed, ICAO selected this protocol for the air part of the future aviation network but before its eventual implementation in ATN environments, the VDL2 standard happened to be a good interim solution in ACARS environments.

However the situation became then a catch-22: avionics manufacturers would not develop VLD2 capable systems if there were no application that required this technology; aeronautical service providers would not develop high capacity applications if few aircraft would be able to use them by having VDL2 installed; airlines would not invest in VDL2 equipment if no benefit could be obtained by investing. Long term gains were evident for all parts, but no one was interested in being the first in investing in VDL2.

Eventually, under commercial and financial pressures, airlines have asked for FANS benefits without waiting for complete availability of all the appropriate tools. The Aeronautical Telecommunication Network (ATN) is not yet finished and many new applications were based on ATN protocols. An interim solution was adopted, ACARS over AVLC (AOA), which uses ancient ACARS protocols over ATN technology and financial incentives were given to pioneer airlines in installing VDL2 in their aircraft. Only this way it was possible to unblock the situation

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the industry was in. This is the reason why FANS operations have already started using the existing communications messages (ACARS) which are of less performance than the ATN. However ICAO backed this interim solution as a valuable step towards an early introduction of ATM applications.

### 1.3.4.3.4.    ACARS OVER AVLC (AOA)

The long term trend is to shift all data communication to ATN network. A transition technology, AOA (ACARS over AVLC; full name: Aircraft Control and Reporting System over Aviation Very High Frequency Link Control) allows transmission of current ACARS messages using the structure of the ATN network. Instead of ACARS messages being sent using classic VHF link, ACARS messages will be sent using AVLC protocol, which is a part of the ATN network). (5)

ACARS protocols remain still unchanged simply because there is no replacement yet. That is, there is still only one definition so as to how to send one particular message and this specification belongs to the older ACARS. What is indeed changed is the communication media used for sending those messages but regardless of the media used (standard VHF or VDL2) the message sent remains unchanged for the user, only changes the way it goes from air to ground. VDL2 was already been deployed as it is the technology chosen for the future ATN network and the technology chosen by major Datalink Service Providers for expanding their network. So the interim solution found was to use a higher throughput signal modulation of VDL2, (VDL2 offers almost 15 more data speed/ throughput than plain ACARS) to send the same ACARS messages. Although it is not the final solution it gives a logical intermediate step between ACARS and ATN.

At current stage, there and still many antennas and many aircraft not suited for VDL2. The higher throughput of VDL2 allows the datalink service providers to reduce the number of frequencies used to cope with the data traffic. Accordingly, VDL2 antennas are installed in areas with high density of datalink traffic; new airliners already come with VDL2 capabilities.

Figure 1-12 summarizes the different possibilities of datalink. From left to right, when ATN will be fully developed data will be relied using VHF ground stations (VGS) directly to ATN network. Now, AOA employs VDL2 (as marked by the AVLC link title)[3] but on ground message is transferred to ACARS network infrastructure. In areas with no VDL2 coverage or for aircraft not yet equipped with this technology, the protocol is ACARS, and can use either a VHF ground station (VGS) or a Remote Ground Station (which may include HF receptors) and the same final destination is reached as in AOA.

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[3] VDL2 only applies to the air segment of the transmission.
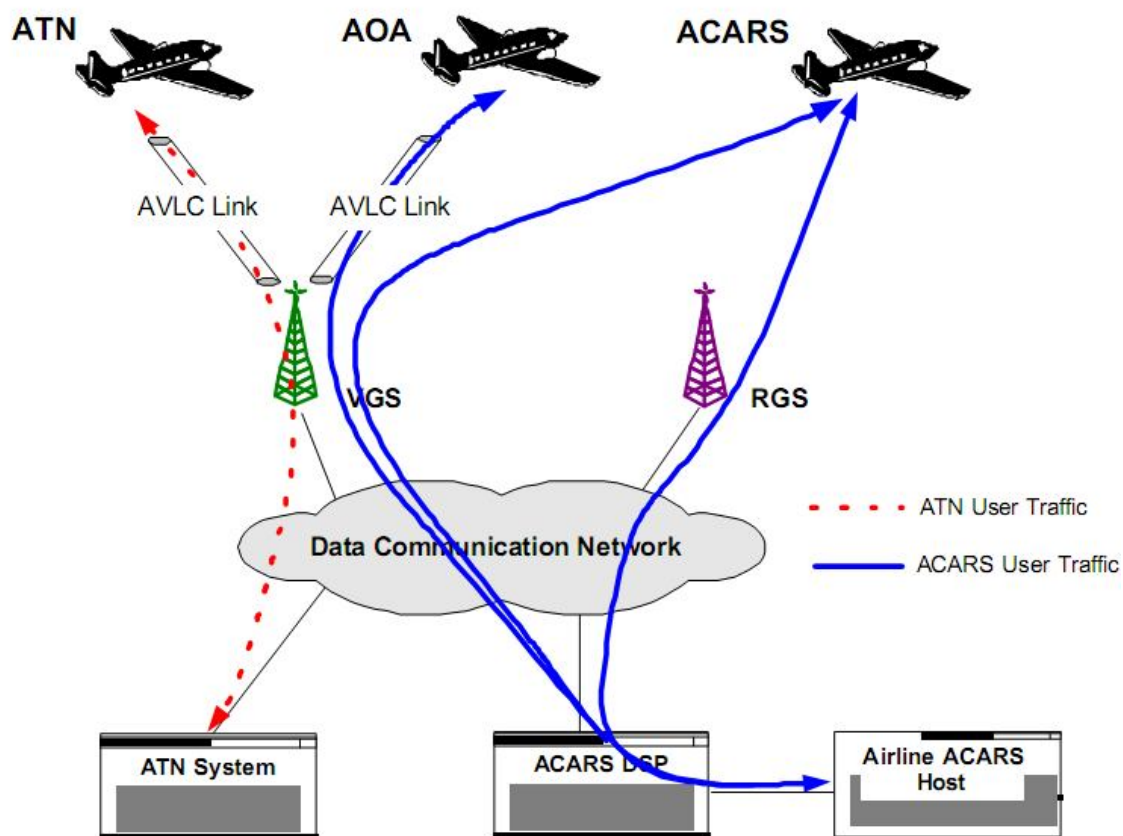
**Figure 1-12 - ATN, AOA and ACARS datalink overview**

The existence of AOA, a temporary solution, was not enough for airlines to invest in VDL2. At the same time, some real world test period was necessary in order to improve protocols and procedures before wide use of VDL2 (and CPDLC) take place. It is worth recalling that VDL2 is not a goal in itself; VDL2 will allow new datalink technologies to exist and these are the final goals. If a mandate would dictate a compulsory installation of VDL2 without a transition period a situation would be created where a major change (affecting safety amongst others) would be put into practice without even being tested on a limited number of aircraft. Eurocontrol considered necessary a transition period where a limited number of aircraft would use VDL2 and its associated services before forcing all remaining airlines to use it too. With this aim the Link2000+ program was launched.

### 1.3.4.3.5.    LINK 2000+ PROGRAM

Link 2000+ is a Eurocontrol's program, part of the global SESAR[4] program, packaging a first set of en-route controller-pilot data-link-communication (CPDLC) services for implementation in

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[4] SESAR (Single European Sky ATM Research) is a European project aiming to increase technological innovation and eliminate airspace fragmentation in order to cope with the predicted increase of air traffic in Europe at long term.

the European Airspace using the ATN and VDL Mode 2. Its objective is to coordinate the European implementation of CPDLC over VDL2 which will be in fact, mandatory for all aircraft and air navigation service providers between year 2011 and 2015 depending on some parameters, as will be shown.

Given the abrupt change it will introduce and in order to ensure a smooth transition, a three-step approach has been adopted.
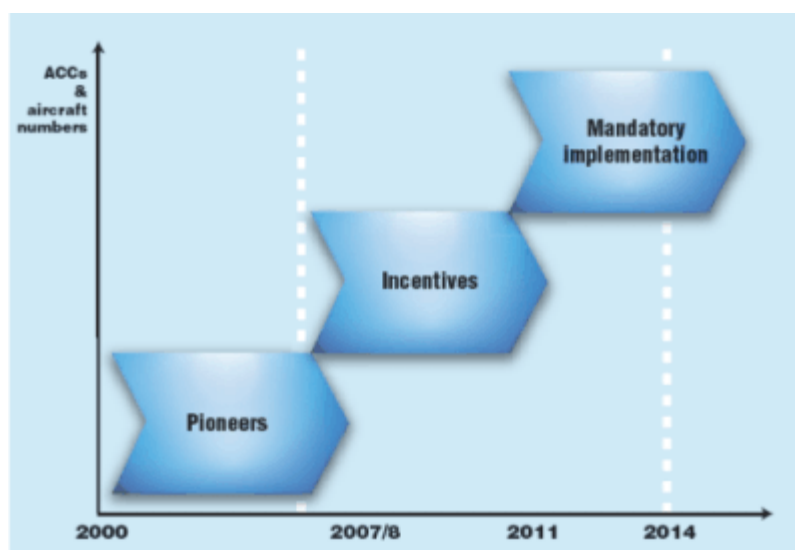


**Figure 1-13 – Link 2000+ program breakdown**

**Pioneers Support**

During this phase, started in year 2000, airlines have been offered financial support to join the programme early. The target of 100 aircraft VLD2 equipped has been exceeded, with 350 aircraft from 15 airlines installing the needed avionics. Air Europa is amongst the pioneer airlines.

The technical risk of joining early is partially removed, since all avionics are pre-tested by the LINK 2000+ Test Facility at the Eurocontrol Experimental Center in Brétigny and by flight trials on an experimental aircraft. Nevertheless operational uncertainty and the additional workload related to these test remain. Certified compliant avionics were available from all avionics providers implementing the same standards as specified in the Link Pioneer Baseline.

## Incentives

First studies shown that data link benefits would be maximised if early equipage of aircraft could be achieved. A study performed by Eurocontrol in January 2008 concluded that, from an ATC point of view, benefits can be obtained whatever proportion of aircraft were equipped with CPDLC and however low was always better than none. (6). So in this second phase the economic incentive plans made possible a continuous increase of equipped aircraft. In fact,

these incentives were, and still are, not only a way to accelerate CPDLC implementation, but also a way to pressure the ground sector to install and implement all needed equipment and procedures as soon as possible. Air Navigation Service Providers (ANSP) will obtain a higher benefit the more aircraft are equipped.


**Single European Sky Implementing Rule Mandate**
Incentives will be withdrawn two years before there is a legal obligation to equip. The instrument to introduce mandatory implementation is a Single European Sky implementing rule (IR). IATA has published a position statement supporting this mandatory carriage for air ground data link under certain conditions, namely timelines. Eurocontrol developed this implementing rule for datalink services and the results show a wide acceptance in most of the areas. Once agreed, the IR will be legally binding and will apply to ground implementation by air navigation service providers and to aircraft operators.

Eventually, on 30th September 2008, the Single Sky Committee expressed a positive opinion on the proposed legislation. The rule relies upon the ATN/VDL2 technology to ensure the level of interoperability required but is also open to other technologies such as datalink over VDL2, which is already being implemented. The key element of the deliberation was the date proposed for the introduction of the IR. This lengthy process achieved a delicate balance marking the conclusion of more than 3 year's deliberation on this subject. The publication of the European Comission regulation (EC) 29/2009 of 16th January 2009 laid down officially the requirements and timelines for datalink services for the Single European Sky.

The airspace of applicability is above FL285, and the geographical scope and key dates are illustrated in figure 1-14. New delivered aircraft from year 2011 onwards will be equipped with VDL2 and able to benefit from CPDLC; the retrofit campaign will last until year 2015. For Air Navigation Service Providers (ANSP) the deadline is either 2013 or 2015, depending on country.
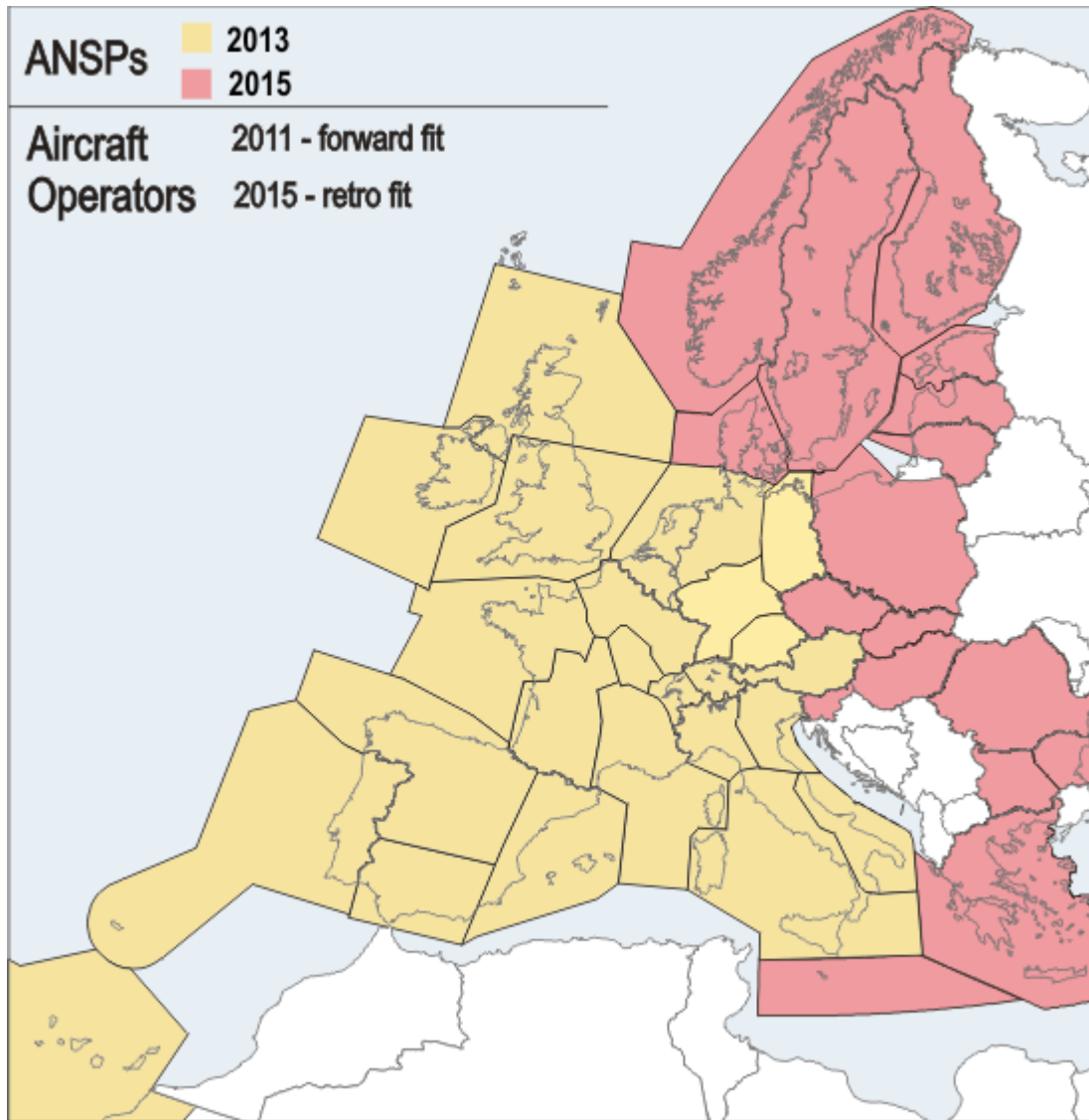
**Figure 1-14 - Time and geographic appliability of datalink IR**

Out of all future CPDLC's utilities LINK 2000+ implements only three basic services, which today represent routine tasks that fill up to 50% of controllers' time and will provide an 11% capacity increase when 75% of flights are equipped:

- ATC communications management - ACM: to handle repetitive frequency changes.
- ATC clearances: to provide standard clearances - ACL (e.g. "Climb to level 350")
- ATC microphone check - AMC: to enable communication in case of blocked frequencies

These services do not replace voice as a primary means of communication - both media will always be available, thus providing mutual back-up, a definite safety improvement. In case of non-standard communications of emergency, "revert to voice" is the procedure.

## 1.3.4.4. AIR TRAFFIC MANAGEMENT

ATM (in CSN/ATM) groups a large set of methods to improve the management of all the parts of the air traffic, e.g. traffic flow management, strategic (long term) and tactical (short term) control or air traffic services. New methods are developed and progressively implemented to provide greater airspace capacity to cope with the large increase of air traffic demand. A close co-operation of ATC, crews and airline operational centres is expected to be reached through data communications, and automated sharing of real-time information. CPDLC, ADS and AOC/ATC inter-facility link are some of the tools used to support new ATM methods such as Collaborative Decision Making (CDM). The aim of CDM is to enable the corresponding actors (crews, controllers and airline operations) involved in ATM system, to improve mutual knowledge of the forecast/current situations, of each other constraints, preferences and capabilities, so as to resolve potential problems in a combined way. Datalink is also an important player in CDM applications by transmitting real time data to ground (for example, updated estimated time of arrival).

## 1.4. HOW DATALINK COMMUNICATION WORKS

### 1.4.1. SUMMARY

Current datalink, ACARS, is based on the inter-connexion of several subnetworks, each with its own specifications made by a private company, ARINC, in late 70's. The basic unit transmitted is a character, forming messages. Each message is pre-defined in the specifications, with a particular field (the free text field) where each avionics manufacturer may create its own data format. This technology is reaching its limit capacity; Aeronautical Telecommunication Network (ATN) is expected to replace ACARS in short term, with a clean and open network structure offering better overall performance.

### 1.4.2. ACARS

The first datalink, ACARS, was a project from a private company, ARINC. ARINC developed first antennas and first specifications upon request of Piedmont Airlines for an automatic means of reporting OOOI timing, thus the name Aircraft Communication Addressing and Reporting System. ACARS technical specifications were developed by a private company for a particular IT solution and, as such, belong to this private company. These specification are publicly available but only for a fee (in the range of 200$ per document) (7).

The success of ACARS in first users made it a desired feature on many other airline and aircraft. Over time other IT enterprises, namely SITA, started offering ACARS technology by creating its own network and antennas. However, the technical specifications still belonged to ARINC. On the other hand, the fact of everybody using ARINC's specification made possible full integration of all users in that no two similar standards were used at the same time: what works for ARINC's customers works for SITA's, too. Even SITA and ARINC being competitors they collaborate frequently in, for example, transferring messages form one network to the other if no coverage is found with the preferred one.

Datalink communication is based on countless specifications, all from ARINC. Each specification defines how data must be transferred between systems and inside each system. Much data is not 'created' in the datalink hardware itself: estimated time of arrival, for example, is calculated by the FMS. This value has to be transferred to the ACARS management unit and then send downlink. Once in ARINC's network, message has to be forwarded to the end-user using IATA's standards, thus a conversion is required (also standardised). Figure 1-15 summarizes all relevant ARINC specification that must be followed in datalink/avionics environment.
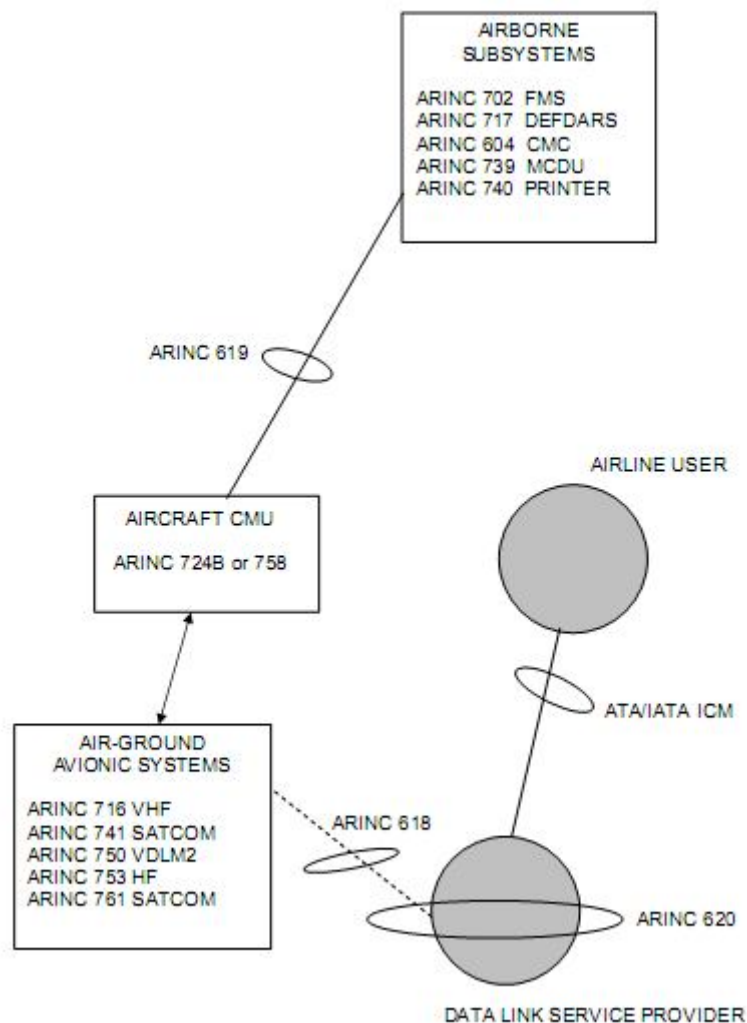
**Figure 1-15 - Applicable ARINC specification in ACARS environment**

ACARS network, as most data transmission networks, can be modeled using the Open System Interconnection (OSI) layer model proposed by the International Standard Organization ISO. In this model, each layer, numbered from 1 (the lowest) to 7, is in charge of conceptually similar functions, providing services to the layer above it and receives services from the layer below it. It is not necessary that all layer exists, although it is commonly the case. The services provided by each layer are:

Layer 1: Physical layer
Provides electrical and physical specification for devices. This layer defines the relationship between a device and a physical medium, that is, how to transmit the desired data (put it in the medium). In particular, it specifies the modulation of the signal.

Layer 2: Data link layer
Provides functional and procedural means to transfer data between network devices and to detect (and sometimes correct) errors occurred in the physical layer. To make clear the

difference with previous layer, layer 1 defines how one device sends data (regardless if someone will receive it); layer 2 defines how two (or more) devices communicate between them.

Layer 3: Network Layer
Provides procedures for transferring variable length data sequences and between devices and assuring the desired quality of service. In other words, how to fragment and transmit (route) a long message is such way that no fragment is lost on the way.

Layer 4: Transport Layer
Provides transparent data transfer between end users, providing reliable data transfers to the upper layers. This layer keeps track of those segments that failed transmission in below layers and retransmits them to arrive the desired end user.

The three remaining layers (not here included because they are not applicable) and further description of the here presented can be found in a very good summary in the Wikipedia article.

In datalink context ARINC 618 specifies all above layers for air/ground transmission of data. What is particular to datalink communication is that the end user of the ARINC 618-specified part is the datalink service provider; that is, the ground antenna. However, the message must arrive to the airline, the real end user of the message sent from the aircraft (in most cases). The conversion of the 'air' message to a 'ground' message is based in ARINC 620 specification. All this collection of standards will be simplified when ATN will enter into practice.

1.4.2.1. ARINC 618

ARINC 618 specification defines the air/ground segment of datalink transmission. However, it does not strictly follow the layers model proposed by the ISO. Firstly because it is a character oriented network (not a bit oriented one), it commutes messages, not packets, and does not have each of the layers clearly defined. The reason is quite simple: ACARS was defined in late 70's and the OSI model was proposed in 1977. Nevertheless keeping the layer model in mind will help to understand the function of ACARS.

ACARS is a half duplex protocol, that is, does not allow communications in both direction at the same time.

### 1.4.2.1.1.   LAYER 1
The message transmission is based on a 2400 bits per second Minimum Shift Keying modulation, coding data on the air/ground path by modulating the amplitude of VHF signal.

The encoding scheme demands that phase coherence be maintained through the transmission media for successful decoding to be possible. The establishment of correct phase relationships

should be performed by the ground and airborne decoding hardware during the Pre-key period of preamble transmissions.

The presence of 1200 Hz indicates a bit change from the previous bit, the presence of a 2400 Hz tone indicates that there is no bit change. The phases of the two tones should be chosen such that the minimum phase discontinuity occurs at the interface with the preceding bit. The phase is further defined such that the amplitude of each tone is zero at the bit transition. The slope of the waveforms at the end of a bit cell should be positive for a binary "one" and negative for a binary "zero." A diagram illustrating this encoding scheme is shown in figure 1-16 of this document. The tolerance on the tone frequencies is ±0.02 percent.

| Bit Order | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Message | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| Waveform | | | | | | | | | | | |
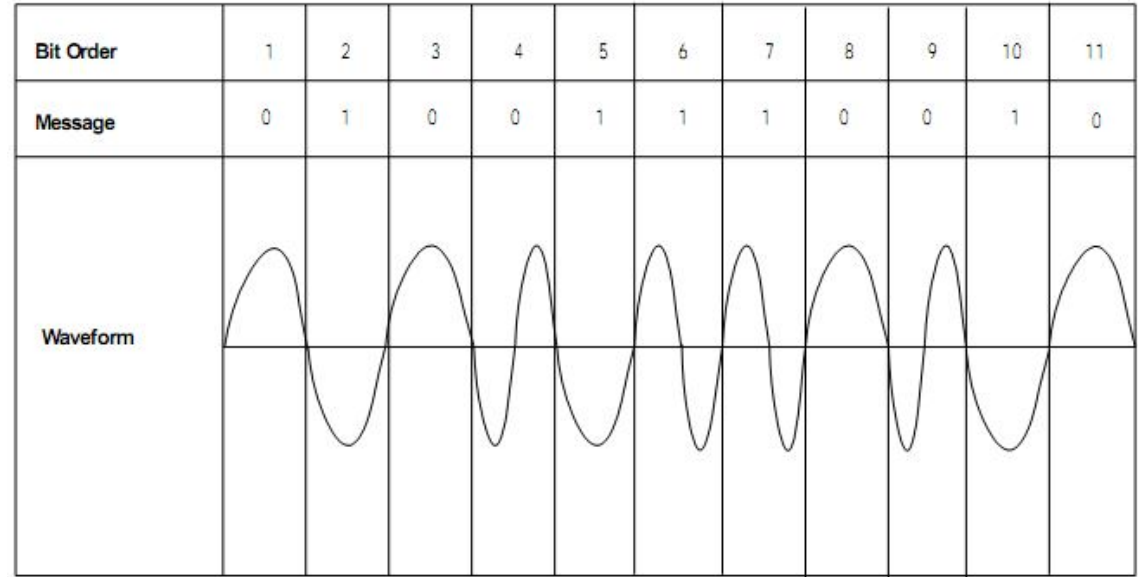
**Figure 1-16 - Sample data modulation**

### 1.4.2.1.2.    LAYER 2-3

Layers 2 and 3 are mixed together in ARINC 618 specification. Each end user must have a valid and unique address. For a transmission to happen the address must be known and it cannot be obtained in any automatic way (by broadcasting a request in MAC level or using DHCP servers as in internet environments can be done). For this reason ACARS air/ground transmission cannot be considered a network with a full layer 3.

ARINC 618 specifies a non-persistent Carrier Sense Multiple Access (CSMA) medium access. If the channel is sensed idle, the message is transmitted. If the channel is busy, a random time between 30ms and 300ms is waited. At this point, the process repeats until the channel is sensed idle and the frame is transmitted.

The general format of the message is shown in figure 1-17. Fields will be described shortly. It is worth noting that no destination address is included in the message: the destination address is assumed from the aircraft registration number (4th field). The message is handled to the airline owner of the aircraft sending the message. For this reason aircraft must be registered and unregistered at the Datalink Service Provider.

| Name | SOH | Mode | Aircraft Registration Number | T A K | Label | DBI | STX | MSN | Flight ID |
|------|-----|------|-----|-----|-----|-----|-----|-----|-----|
| Size | 1 | 1 | 7 | 1 | 2 | 1 | 1 | 4 | 6 |
| Example | \<SOH> | 2 | .N123XX | | 5Z | 2 | \<STX> | M01A | XX0000 |

| Application Text |
|---|
| 0-210 |

| Suffix | BCS | BCS Suffix |
|--------|-----|------------|
| 1 | 2 | 1 |
| \<ETX> | | \<DEL> |
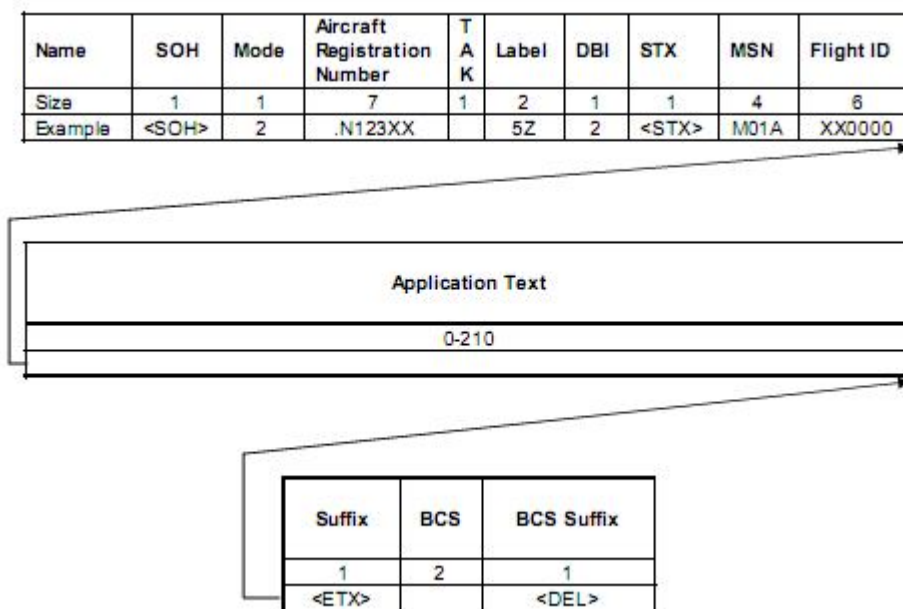
**Figure 1-17 - General format of Air/Ground downlink message**

Layer 2 of ARINC 618 specification adds the header and suffix shown in figure 1-17 used to transmit and identify the message.

Layer 3 of ARINC 618 specification adds three fields to the above message (figure 1-18):

- Pre-key: a synchronism message for automatic gain control and for transmitter power to stabilize.
- Bit ambiguity: two characters to enable bit ambiguity resolution are sent (+*). By sending this the receiver may check if character recognition is properly working.
- Character synchronization: two \<SYN> characters are transmitted to established character synchronization.

If application text is longer than 210 chars, the message is split in blocks, which is a function of the third layer.
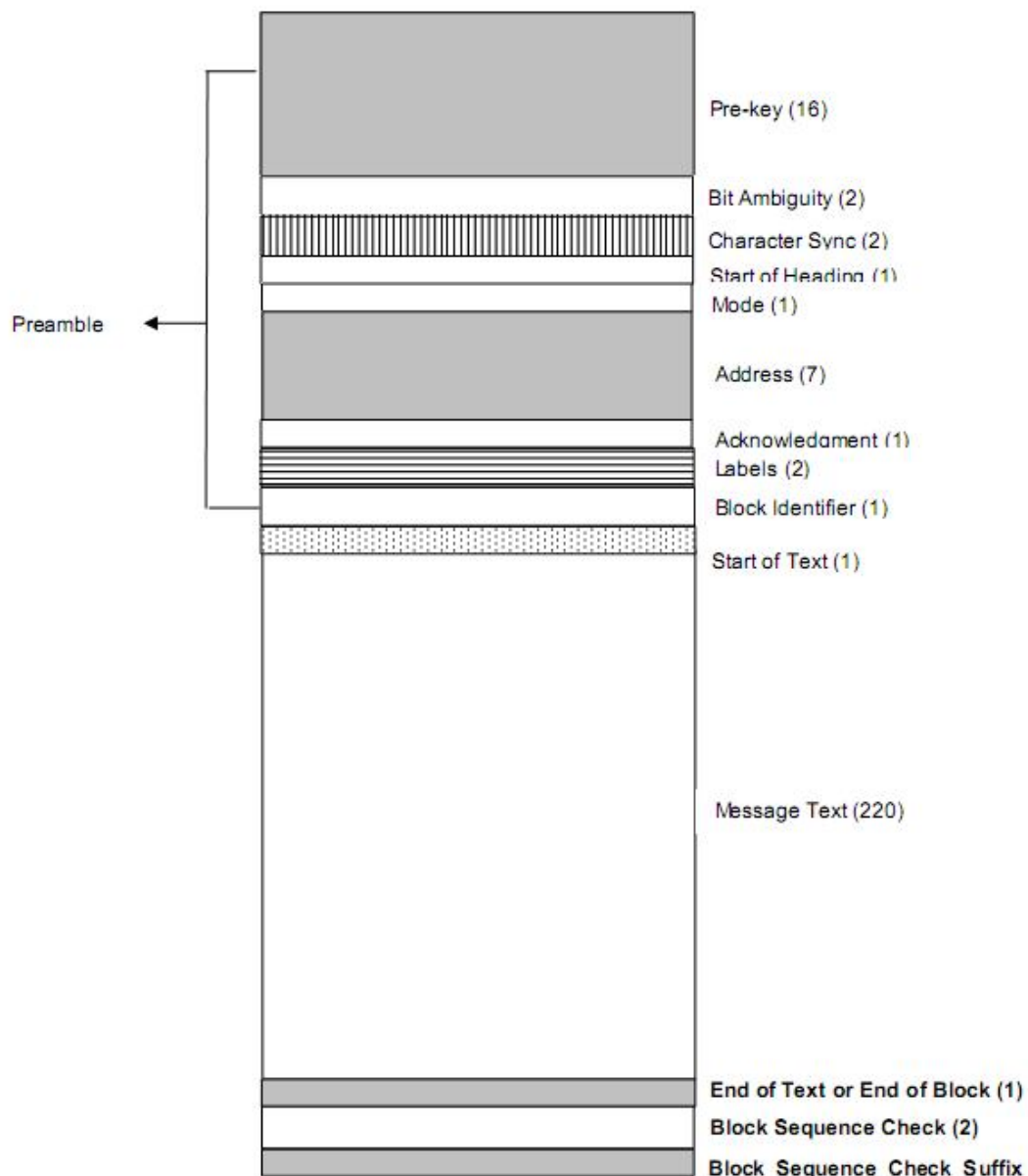
**Figure 1-18 - ACARS message structure**

## 1.4.2.2. THE MESSAGE

### 1.4.2.2.1.    Generic downlink message

As messages are sent in accordance to ARINC 618 specification they are character oriented, that is, the minimum transmittable unit is a char. The message user wants to transmit is formed by characters. As seen in figures 1-17 and 1-18 additional fields have to be added for transmitting the desired data. Some of them may be changed by the user, but they are mostly defined by the specification.

As shown in figure 1-15 ARINC 618 message are transformed to IATA Interline Communication Manual (ICM) standard messaging. This process is also standardized in ARINC 620 specification. So what is eventually received by the company is an ICM compliant ARINC 618 message transformed in accordance with ARINC 620 specification. For an average user all this specifications and transformation are transparent. However, they become important when advance applications are planned or, in the case of this project, new datalink software is designed.

The general format of a downlink message received by the company (already ARINC 620 converted) is:

| Line | Content | Example |
|------|---------|---------|
| 1 | Priority / Destination address | QU PMIARUX |
| 2 | Origin signature / Timestamp | .QXSXMXS 181605 |
| 3 | Standard message identifier (SMI) | M11 |
| 4 | Text elements | FI UX5035/AN EC-KRJ |
| 5 | Communication service line | DT DSP RGS 121212 M01A |
| 6 – n | Free text | – MESSAGE |

Line 1

Specifies the priority of the message (2 chars) inside the DSP network and the destination address (7 chars). In case it existed more than one destination end user (16 maximum), the subsequent addresses should be separated by empty spaces. The line ends with a carriage return and line feed combination[5].

Line 2

The origin signature starts with an point [.] followed by the address of the sender. It follows a timestamp in the format ddhhmm (day/hour/minute). The line ends with a carriage return and line feed combination. However, the initial sender is an aircraft, but this converted message is sent by the DSP that is contracted by the company after the ARINC 620 conversion. For this reason the sender appears to be a DSP instead of an aircraft. The format followed is DSPXXXX, where DSP is the datalink service provider that handled the message according to table 1-1 and XXXX are internal characters:

---

[5] In informatics <cr/lf> represents the combination of two control codes: CR (carriage return) and LF (line feed). The name comes from old typewriters when for creating a new line two movement were needed. Currently those actions can be perfomed simultaneously with the 'enter' or 'return' key.

| DSP | Identificador ICAO |
|---|---|
| SITA Aircom | QXS |
| ARINC | DDL |
| Brasil | DPV |
| Brasil / SITA Internetworking | QXB |
| ADCC China | BJS |
| SITA / Avicom | QXJ |
| Avicom Japan | JDL |

**Table 1-1 - DSP abreviations**

Line 3

The standard message identifier (SMI) is a three alphanumeric digits code that univocally identifies the message type. The approved SMI's list is included in ARINC 620 specification, along with its equivalent in the air segment (a two letter code, called label, for ARINC 618 compliant messages). SMI's and labels do not match thus the need for a conversion. The line ends with a carriage return and line feed combination.

Line 4

This line is called text element line because it has text elements (TE). Each TE is a data field comprised of three parts:

- TE identifier: 2 chars followed by a space
- Data: variable length according to TE
- TE terminator: [/] if another TE follows, <CR/LF> otherwise.

There are many TE defined in ARINC 620, but two of them are mandatory as a result of the ARINC 620 conversion.
- FI XX0000: Flight identifier: it is the current flight number at the moment message was sent, with IATA code and 4 numeric chars.
- AN XXXXXXX: Aircraft number: it is the aircraft's registration (which is a number in US), left justified. In case there are less than 7 chars, the remaining gap is filled with dots [.] by ARINC and with empty spaces by SITA.

Line 5

This line offers information about the communication service. It has four fields, starting with the "DT" label:
- DSP identifier: same as in line 2.
- Code of the station that first received the message: 3 chars followed by a space. With this information a vague approximation of aircraft position may be obtained.
- Time at which message was received; format ddhhmm (day/hours/minutes)
- Sequence number of received messages of the station is the second field.

Line 6-n

This last line corresponds to free text and it does not form part of the structured message defined in ARINC's specifications. What is enclosed in this field is defined by the avionics manufacturer. It always starts with a particular text element identifiers: a dash [-] followed by a space. A second space follows as do after any TE.

It does not fully correspond to free text that crews may add to some messages; it is free text in the sense than no standard applies for this part and is the manufacturer that may chose what to include.

## 1.4.2.2.2. Generic uplink message

An uplink message follows an equivalent format to downlink messages.

## 1.4.2.3. EXAMPLE OF COMMUNICATION

The example presented in this paragraph corresponds to the communication of a Boeing 737 with Honeywell avionics, from the moment message is sent until is received in company's servers. This aircraft have been chosen for the simplicity of the messages.

## 1.4.2.3.1. Message triggering

An Air Europa 737-800 aircraft, registration EC-JKZ, operating flight UX2154 from Barcelona (BCN/LEBL) to Madrid (MAD/LEMD) touches down in Madrid. Accordingly, the ON message is triggered (after main landing gear is compressed, meaning touchdown) and systems sends a downlink message called ON report.

## 1.4.2.3.2. Air segment message

According to ARINC 618 specifications message label is set to QR, address of the aircraft is .EC-JKZ. The ARINC 618 message is:

`<SOH>2.EC-JKZ<NAK>QR1<STX>M04AUX2154LEBLLEMD1525<ETX>23<DEL>`

which should be read as:

`<SOH>`: Start of header. Control bit indicating the start of the header of the message.

`2`: Mode. The number 2 means that no particular DSP is addressed. All DSP's will receive this message but only the one having this aircraft registered will further process the message.

`.EC-JKZ`: aircraft's 7-char long registration.

`<NAK>`: Acknowledge bit: in this case no ACK is requested.

`QR`: Message label. Indicates what fields will the message have and how should they be interpreted.

`1`: Block ID. Identifies the fragments of a long message.

`<STX>`: Start of text bit, marking the beginning of the text field and the end of the header.

`M04A`: Sequence code.

`UX2154`: Flight ID

`LEBL`: Origin airport.

`LEMD`: Destination airport.

`1525`: Touchdown time (ON event)

[Free text if existed]

`<ETX>` End of text control bit

`23`: Error check field. This number is obtained with a mathematical calculation of all preceding fields and is included by the onboard avionics. If on ground, doing the same calculation, another number is obtaing, it indicates that a error occurred and message is disregarded.

`<DEL>`: End of message bit, indicating it may be deleted from the server.


On ground this message is received by both ARINC's and SITA's antennas, but only SITA, who has a contract with Air Europa for the B737 fleet will take further action.


### 1.4.2.3.3.    Message conversion

SITA, based on the agreement signed with Air Europa for managing the B737 fleet, converts the message in accordance to ARINC 620 specification into a message with ARR SMI.

```
QU PMIARUX
.QXSXMXS 191220
_ARR
FI UX4008/AN EC-JKZ/DA LEBL/DS LEMD/ON 1525
DT QXS MAD1 191526 M15A
  -
```

The conversion specification is scrupulously followed. Now the message has to be sent to hte airlines so the new sender is SITA (QXS) and the original sender (aircraft and flight identifier) is situated in the text element line. As in the original message the free text line is empty, in the converted message so is still (only a dash appears)

### 1.4.2.3.4.        Reception of the message

Message is sent to the company address and received by its server. In the case of Air Europa it is called Air Com Server and details of its functionality are presented in annex A4.

### 1.4.2.3.5.        Remarks

The format of ON messages is very brief so if more data is desired (such as fuel on board data) it must be included in the free text part. If the same data is preferred in different format or if much more data is to be added a different message should be used instead. This is the case for B737 with Rockwell Collins avionics, A330 with Rockwell Collins ATSU and E195 with Honeywell systems. For these cases where the whole message is defined by the avionics manufacturer ARINC 618 specification has reserved message labels in the A80 and and M10 series and then no conversion is made as no predefined conversion exists.

### 1.4.3.  AERONAUTICAL TELECOMMUNICATION NETWORK (ATN)

ATN is a global aviation standard telecommunication network, intended to provide seamless ground-ground and air-ground communications services. As it was developed much later than ACARS it follows the OSI layer scheme. Its standard does not belong to a particular enterprise; it is backed by ICAO and was planned as a global network from the beginning and it is considered the backbone for future aviation communication.

ATN consists of ATN internet (or WAN, Wide Area Network), ATN subnetworks and ATN applications. ATN internet is global part of the network, routing messages between continents and large distances. It is a collection of Intermediate Systems (IS or routers, layer 3), using the IP protocol. They are in charge of distributing the messages to their destination; message content is not interpreted. End Systems (ES) are user computers were ATN applications are running (CPDLC for example) and normally belong to a subnetwork. More than one computer may exist in a given subnetwork and almost any data communication infrastructure may be an ATN subnetwork (Ethernet, X.25, Frame relay...). Each End System accesses the ATN internet via an ATN router, thus the ATN router is also the gateway to the ATN internet. (similar to a home router and home WIFI). Figure CCCC shows this description in a schematic way.
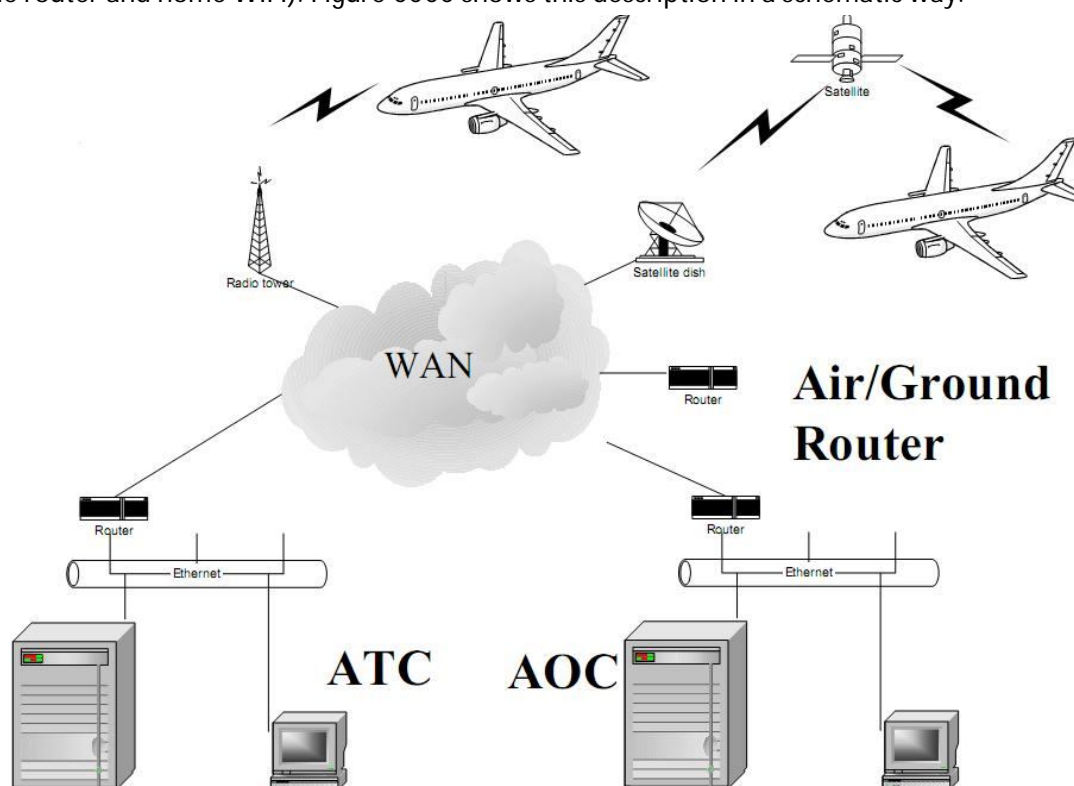


**Figure 1-19 - ATN network schematic view**

ATN applications communicate between them. For example, an aircraft sends a CPDLC message to an ATC centre; the communication is made between these two applications. But step by step there are many transmissions in between. The CPDLC application on board the aircraft gives the message to the onboard datalink system, which is in fact a router. This router hands the message to the VHF radio which, in turn, gives the message to the medium air with a particular modulation. In reception the process is reversed; the medium air gives the message to an antenna, then to a router that interprets the destination of the message. If the message is for the router's subnetwork, the message is forwarded to that particular end systems. Otherwise the message is reinjected in the network bound for the final destination. It is up to network's protocols and logic to direct through the network to the ATC computer. In the end system the message is accepted and presented in the relevant application, in this example, the

CPDLC. It is evident that the message transits through multiple en-route routers but this process is transparent to the end used. There are some details, such as session and presentation, that have been omitted for clarity. A simple scheme of the data routing is presented in Fig.1-20.



**Figure 1-20 - ATN routing**

## 1.5.  DATALINK IN AIR EUROPA

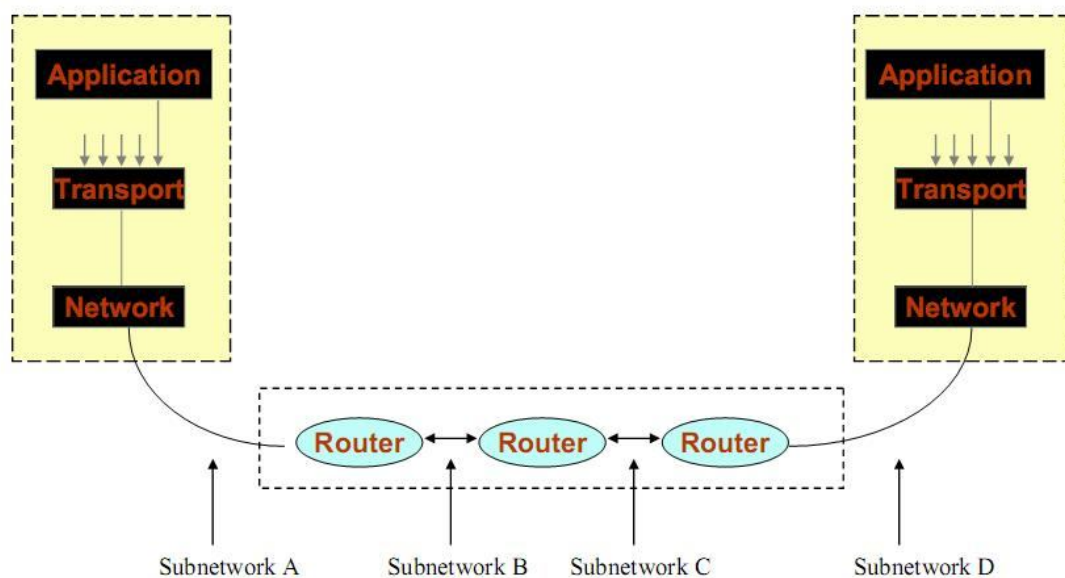Air Europa took advantage of Eurocontrol's program Link 2000+ in 2004 which financially encouraged airlines to install datalink under VDL mode 2. VDL2 will be a mandatory feature to be installed on all aircraft from year 2015 onwards and compulsory for all newly built aircraft as soon as year 2011. When joining the program Air Europa's fleet had no datalink at all, whilst many competitors operated the well established ACARS network. As a consequence, Link 2000+ was not only a way to be at the level of the competitor but also to outperform them.

The program was seen as a worth investment and 21$^{st}$ September 2004 the first B737-800 had datalink under VDL2 installed. Under the terms of the contract of Link 2000+ Air Europa agreed to have 20 aircraft ready for VDL2 communications. Air Europa's fleet was progressively being upgraded during the following months. At the same time, some pioneer applications of VDL2 were put in practice. Controller-Pilot Datalink Communication (CPDLC) is a new technique in ATC communication where voice messages are replaced by written predefined messages.

The first operational use in Air Europa of CPDLC took place over Maastricht ACC, during the course of a Warsaw-Madrid flight the 4$^{th}$ November 2005 becoming the second company in Europe to accomplish this type of communication in operational flights only after SAS. (8) Canary Islands ACC, belonging to AENA (Spanish Airport and Air Navigation Authority) declared that would be the second European sector CPDLC capable after Maastricht ACC. (9). Given the amount of Air Europa's flights (up to 65 daily in summer) bound for the Canary Islands, the announce was seen with optimism.

In parallel to ATC application, some Airline Operational Control (AOC) applications were gradually introduced. As is commonly the case in datalink communications the first application was the transmission of OOOI events in order to feed without human intervention the company's operational systems. SITA's AirComServer was chosen as the ground processing system becoming the key link in the datalink application. Some messages sent from aircraft were identified, reformatted and retransmitted to the appropriate users or applications, creating the baseline for the growing use of datalink communications.

During the following years there was a hard work for of homogenization of the fleet, presentation of the system, their applications and potential benefits, both inside and outside the company. The use of datalink radically changes the way in which the work should be organized: much information may be available in real time as there is no longer need to wait until the aircraft lands for obtaining it and many repetitive or with little added-value tasks are no longer justified. This change should not be forced by a directive but each potential datalink end-user must see the benefits of taking advantage of the system. It is considered that it takes up to two or three years for an airline to become a mature user of datalink.

However, no experts were hired from outside Air Europa to develop datalink applications and the utilities linked to its use; individual training and effort, assistance to numerous working

groups, meetings and seminars were the base for the growing know-how. Yet nobody was full-time committed to develop and upgrade the system and its applications: datalink was a shared part-time duty between three individuals from Maintenance-Engineering, Operations and a Pilot.

By year 2008, 22 out of 32 B738 and all six A330 were capable of sending and receiving datalink messages. The leases for the 10 no-datalink-equipped 737 units are due to finish in the following two/three years so the investment was seen not worth for these aircraft. The two only remaining B767, whose lease is also close to its end, are used for charter flights, as backup planes or for high demand periods; the investment was neither justified for this subfleet. AENA's plans for developing CPDLC applications in the Canary Islands ACC were eventually withdrew, slowing down the development of the system as no close-by ATC sector to Air Europa's flights would invest in the technology.

Both A330 and B738 fleets had some basic applications in use. Many messages were constantly sent from the aircrafts but only some of them were processed on ground. Basic AOC applications were in use: operations department received in real time OOOI events and some in-flight created reports, loadsheet was uplinked via datalink, free text messages could be sent uplink and downlink and some maintenance related messages were processed. However, many other messages were identified but not processed, i.e. it was known what the purpose of the message was and what information it contained, but the message was forwarded to nobody on ground and consequently no action was taken upon its arrival. The opposite was also true: some messages were received and identified, but it was unclear what could be the benefit of further processing that message. Much important or potentially useful information was disregarded this way. There was still nobody fully committed to develop additional datalink applications and take further advantage of a system already established.

By January 2009, the first Embraer 195 joined Air Europa's fleet. 10 more are due to arrive in 2009 and 2010, 4 during the course of this stage. The Embraer 195 became the third aircraft type capable of sending and receiving datalink messages in Air Europa's fleet.

The arrival of the Embraer 195 forced to take up again the datalink integration subject. When the A330 joined the fleet in March 2006, many messages followed exactly the same format as the already existing B738, simply because the onboard datalink unit was exactly the same model from the same manufacturer for both aircraft, thus sending exactly the same messages. With very little work, or with no work at all in many cases, most datalink messages were correctly processed and correctly forwarded to the right end-users. Datalink-wise, the A330 joined the fleet nearly as another B738 would do. It has to be also said that the A330 offered a new range of messages in comparison to the B738 that were progressively introduced into practice. Airbus and the A330 were a mature manufacturer and aircraft and many applications were already widely available and well tested by many existing customers.

The introduction of the Embraer 195 was radically different. Both the manufacturer and the aircraft are relatively young and many problems related to this fact quickly arose. The

philosophy of the onboard avionics is totally different in comparison to an A330 or B737 and the manufacturer of the onboard datalink unit is different and so are the messages sent - nothing could be reused.

The project offered to me fitted naturally in the future development of Air Europa's datalink, particularly for the Embraer 195. Shortly speaking, the aim of this project is the integration of the Embraer 195 with the rest of the fleet, in terms of datalink and, if possible, development of new functionalities and applications.

Such a global project cannot be accomplished if not divided into smaller pieces. The project was envisaged as a succession of steps, each of bigger complexity than the preceding, centred initially on the Embraer 195 datalink. Each step was defined with large-scale goals, knowing that it is not easy to predict in advance what problems will come up on daily work. Nevertheless, three clear objectives where initially specified:

- Integration of Embraer 195 subfleet into the company's datalink.
- Development of a user manual for the onboard HMI of Embraer's datalink.
- Once familiar with the aircraft and its datalink, development of some functionalities beyond the basic ones.

However, in this third goal it became unavoidable the inclusion of the A330 and B738 datalink applications. The effort for creating a new application for the Embraer 195 is just marginally increased if the A330 and B738 fleets are included. Most of the work is independent of the aircraft involved: the message –datalink- is just the medium. What is important is to have the available data and to process the information once it arrives. Conversely, once understood the principles and the details of the Embraer datalink, the A330 and B738 datalinks are just a small step further. For this reason, new applications were developed, where applicable, for all three fleets at the same time, maximizing fleet homogenization.  As initially presented, this last point led to an additional part to specifying the details of a new onboard datalink application for the Embraer fleet.

## 1.6.    THE EMBRAER 195

Air Europa placed an order for 11 Embraer 195 to expand its fleet and to replace some older B737 with a smaller aircraft. The first unit joined the fleet the first week of 2009.



**Figure 1-21 - Embraer 195 registration EC-KYP in Air Europa livery**

The Embraer 195 has 122 seats in Air Europa's configuration and is structurally and performance-wise similar to a B737 but in smaller scale. Given its lower weight (50790 Kg at MTOM compared to 71500Kg-79000Kg of the B737) it offers about a 20% less fuel burn, which makes this aircraft very suitable for thinner routes where a 186 seats big B738 is not economically viable. But there is much more different than similar.

The Embraer 195 avionics differs extensively in comparison with the B737 or A330. A modular avionics solution has been adopted by Honeywell, called PRIMUS EPIC system. The EPIC system is a distributive, multi-tasking architecture where functions that were performed by separate Line Replaceable Units (LRU) in earlier aircraft are now performed by modules in an electronic card rack called Modular Avionics unit (MAU). The modules located in the three MAU's on the aircraft perform most of the distributed functions. Many modules perform more than one task by multi-tasking and, at the same time, some complex tasks are performed in more than one module.

Multi-tasking consists in that each microprocessor in the EPIC system is designed to perform a multitude of functions. To the operator it appears that the microprocessor is performing all of these tasks simultaneously while in fact each microprocessor can only perform one at a time, although it performs them in order and at a high rate of speed. The microprocessor only allots a limited amount of time to a particular job. When the time has expired the microprocessor puts away the operating instructions for that task and calls for the operating instructions for the next one. It repeats this procedure endlessly. Although it is only performing a limited amount of the steps required for a particular task at any given moment, the microprocessor is able to work at a very high rate of speed and perform each complete duty very quickly.

In this architecture, one particular task is performed by several modules and one module performs more than one task. For example, there is no one single box (LRU), cloned for redundancy, that manages the flight (like the Flight Management, Guidance and Envelope Computer in the A330 fleet) where if the principal controller fails, the secondary (the redundant, inactive until that moment) take the control. No, in modular avionics the flight management is split between two modules in two different MAU's and, if one of the MAU's fails, the remaining rearrange the repartition of tasks previously active for managing the flight and take the control of most (or sometimes even all) functions. It is virtually impossible to know what task is each module performing at a given moment as it performs many different tasks in the same second (read flight plan, check attitude, monitor air speed...) and conversely, it is not possible to say that any task is performed at one module as it is done a little time in one module, then in another one and so on. The required safety levels are achieved in this configuration by global redundancy instead of redundancy of each LRU individually.

The distribution of the functions between all the MAU's provides a level of redundancy for the overall system, instead of redundancy for each subsystem or function. Each MAU is provided power from at least two different electrical power sources and the design insures that most of the avionics functions and capabilities will still be available to the crew in the event of single or multiple power failures.

As a consequence, the heart of the Primus EPIC System is the Modular Avionics Unit (MAU). This cabinet houses most of the processors, memory, input-output circuits, and software programs that allow the EPIC system to function. Each of the three Modular Avionics Units (MAU's) is a hardware cabinet that serves as a Modular Card Rack, each of them having a given number of slots. All slots/modules of the MAU are internally interconnected, and all three MAU's are interconnected between them and with the radios (there are three radios in the E195) and display panels using a data bus called Aircraft Standard Communication Bus (ASCB) (see figure 1-23).

Each MAU hosts about a dozen modules, mainly identical (similar in aspect to PC cards) and are interconnected inside each MAU. All three MAU's share information using a data bus and it is from this bus where the remaining systems take data from.

**Figure 1-22 - Sample MAU modules**
**Left, Flight Control Module, right, Enhanced Ground Proximity Warning Module**

Such solution offers an important weight and volume reduction by limiting secondary hardware waiting the principal to fail (inactive most of time) as most hardware is working constantly. However, with modular avionics the general philosophy –and the associated problems- are shifted to a software level out of a hardware approach. Much wiring has disappeared as data is shared continuously over an Aircraft Standard Communication bus (ASCB) and is stored in a database module situated in MAU-2 for safety. Figure 1-23 show the scheme for the overall data sharing in the modular avionics of the Embraer 195.

**Figure 1-23 - Embraer Primus Epic system block diagram**

44
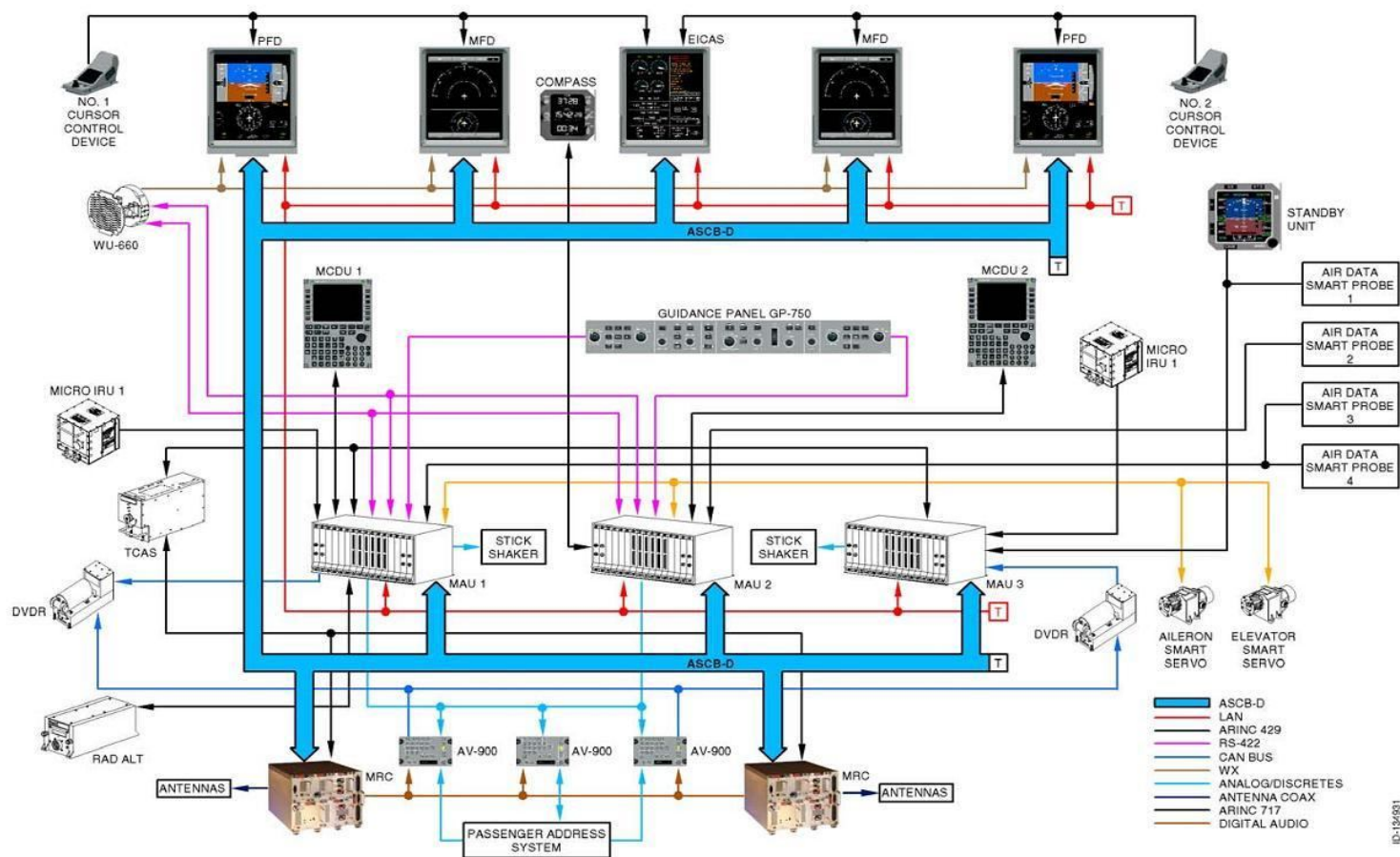
Each module of each MAU can perform different tasks at different moments, provided a software change takes place. Consequently, most functional upgrades consist of a software update, easily done by connecting a laptop to the LAN of the aircraft. As in a home PC would happen when installing new and more powerful software major software modifications may require a change of the hardware (in particular the processor) of each module.

Each software version is called EPIC Load and comes in a CD. Each Load affects all systems as, shortly said, everything is shared and inter-connected. By June 2009 EPIC Load 21.4 is the latest version. Future EPIC Load updates will include new functionalities such as Automatic Dependant Surveillance - Broadcast (ADS-B) (Load 23) or CPDLC (Load 25).

Communication Management Function (CMF) is one of the presented modules and is in charge of the datalink communication. It receives messages from various onboard systems and sends them via the appropriate medium (VHF, HF or SATCOM) downlink or, conversely, routes the received uplink messages to the right end-system. The CMF itself can also be a possible end-system. The Multipurpose Common Display Unit (MCDU) is the human-machine interface of the CMF. The Central Maintenance Computer (CMC), despite its name, it is a module –not a computer- located in MAU-1. The CMC module collects the maintenance data, stores it, and permits retrieval of the information through the flight deck display system, through a PC via LAN or using datalink. Flight Management System (FMS) can also send and receive information through datalink. A schematic overview of data transmission is presented in Figure 1-24
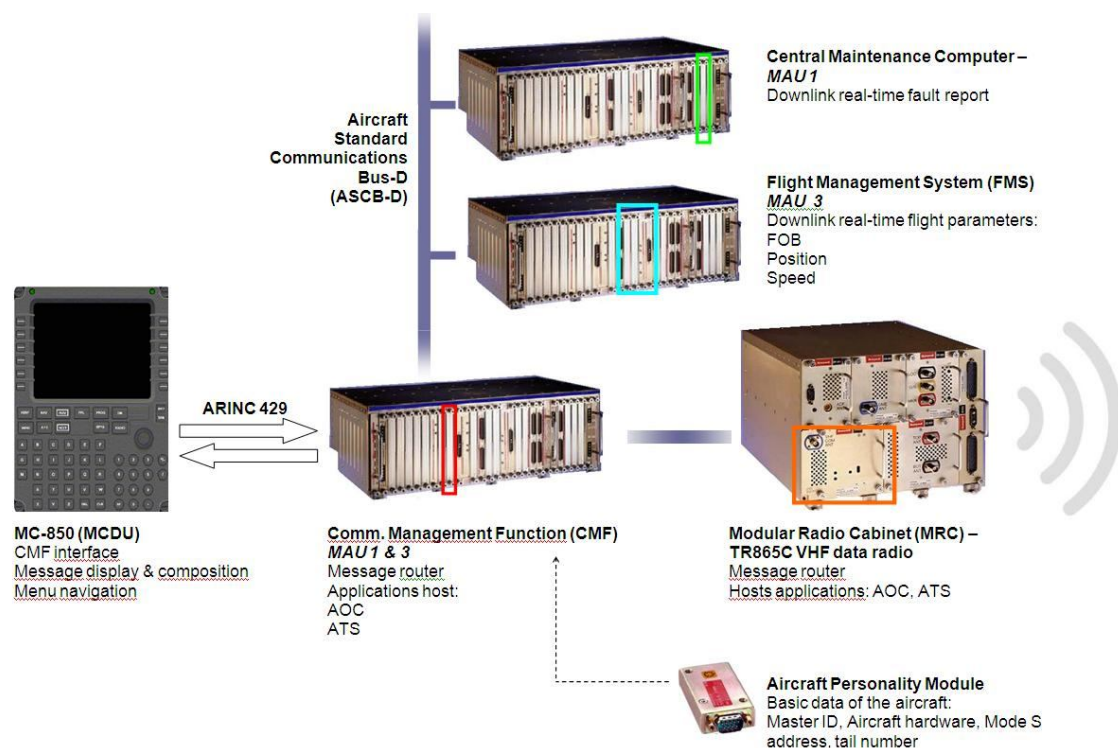


**Figure 1-24 - Datalink Communication in E-195**

## 1.7.  DATALINK APPLICATIONS IN AIR EUROPA

In order to be able to accommodate the Embraer 195 in Air Europa's fleet, it is indispensable to get knowledge of the existing situation and the particularities of the Embraer 195 itself.

The entire datalink concept in Air Europa revolves around a ground-based software application called AirCom Server. It is the centre of the datalink network inside the airline as all messages transit through it, either going from ground-based user to an aircraft (uplink) or from an aircraft to a ground user (downlink).

All messages are composed of a header, the initial part of a message whose format is based on international standards (ARINC 618 and 620) offering basic information (who sent the message) and a free text field. This free text field is where each avionics manufacturer –not the airlines- can create their own data templates for being sent downlink or uplink. In order to understand the content of a message it is usually necessary a decoding template. The reason is that the information that any character represents inside a message is based on what is the message processed and what position it occupies within the message. These decoding tools and a list of all possible messages can be obtained from the manufacturer's manual. Airlines have very limited margin for changing the format of the messages; in most cases the format in fixed. The only way to customize menus and messages is by purchasing a manufacturer's tool that allows such changes or acquiring modified software.

```
QU PMIARUX
.DDLXCXA XS/191029
_CFD
FI UX885/AN EC-KOM
DT DDL MAD 191029 C00A
-    .1/WRN/DBNAEA/WN0903191029    344100506NAV  PRED W/S
DET FAULT
```

**Figure 1-25 - In-flight warning raw message**

On passing through AirCom Server, messages are identified based on a three alphanumeric code called Standard Message Identifier (SMI) and, in some cases, a sub code (Sub-SMI). The identification is made automatically once introduced the SMI's and sub-SMI's manually in AirCom Server database by the system administrator. If a message arrives and the SMI was not previously introduced, the message cannot be identified and is presented with 'default' title. All messages are presented for users in a message log.

**Figure 1-26 - AirCom Server message log**

In AirCom Server's message log basic information is shown for each message: time at which the message arrived to AirCom Server, if it is an uplink or downlink message, the aircraft that sent or will receive the message and also the title, as defined by the administrator, given to that message. Normally all messages transiting through AirComServer have at least a valid title that offers some indication about what information does the message contain.

Once the message is identified, it may be redistributed to some user that will take profit from the information sent. Possible types of users are personal email addresses, database files, text files, SMS messages or other software application. There are up to 13 different types of users, although not all of them are currently employed. The problem arises in that for understanding the messages as they arrive (previous figure 1-25) it is generally needed to know how they were coded. This can be done for some messages that are rather intuitive, but is unfeasible for all messages of all possible aircraft by all users: there are more than 100 messages and some codifications are hard.

The transcription from the codified message to a plain text message (and vice versa) in AirCom Server is done by means of templates, that extract the information from the raw data, and models, the definition of message that will be forwarded. Each template and its associated models are created by the Air Com Server administrator user. As part of this project I was granted administrator user rights. The most common technique to define a data field in the

template is to specify the expected length of the field and its starting point using an offset from a known position[6]. The template definition becomes more complex when the message has variable length, as is usually the case with error reports.

Once the data is extracted from the raw message it may be forwarded to any user in a more comprehensible way. For instance, the message in figure 1-25 is forwarded as:

```
MENSAJE IN-FLIGHT WARNING

A/C:                    EC-KOM
FLIGHT:                 UX0885/19
ROUTE:                  MAD-RAK

RELATED ATA:            34-41
WARNING TIME:           10:29
WARNING MESSAGE:        NAV PRED W/S DET FAULT
FLIGHT PHASE:           CRUISE
```

**Figure 1-27 - In-flight warning message formatted**

When messages are forwarded to another software application, the format has to match the one expected by the destination system. In Air Europa's environment STAR is the application that most uses datalink. STAR is the operational control department's system that shows company's daily flights program (aircraft assigned, origin, destination, duration...) in a graphic way, allowing with a quick glimpse to know the situation of all flights, aircraft and crew. In order to be truthful, actual departure and arrival times have to be inserted, updating the scheduled timing, offering an accurate representation of the daily flights. It can be done manually, but it is one of the first time-consuming little added-value tasks to be taken by datalink.

---

[6] Many messages have one or several known strings in a particular fixed position of the message that help identifying and locating data fields.
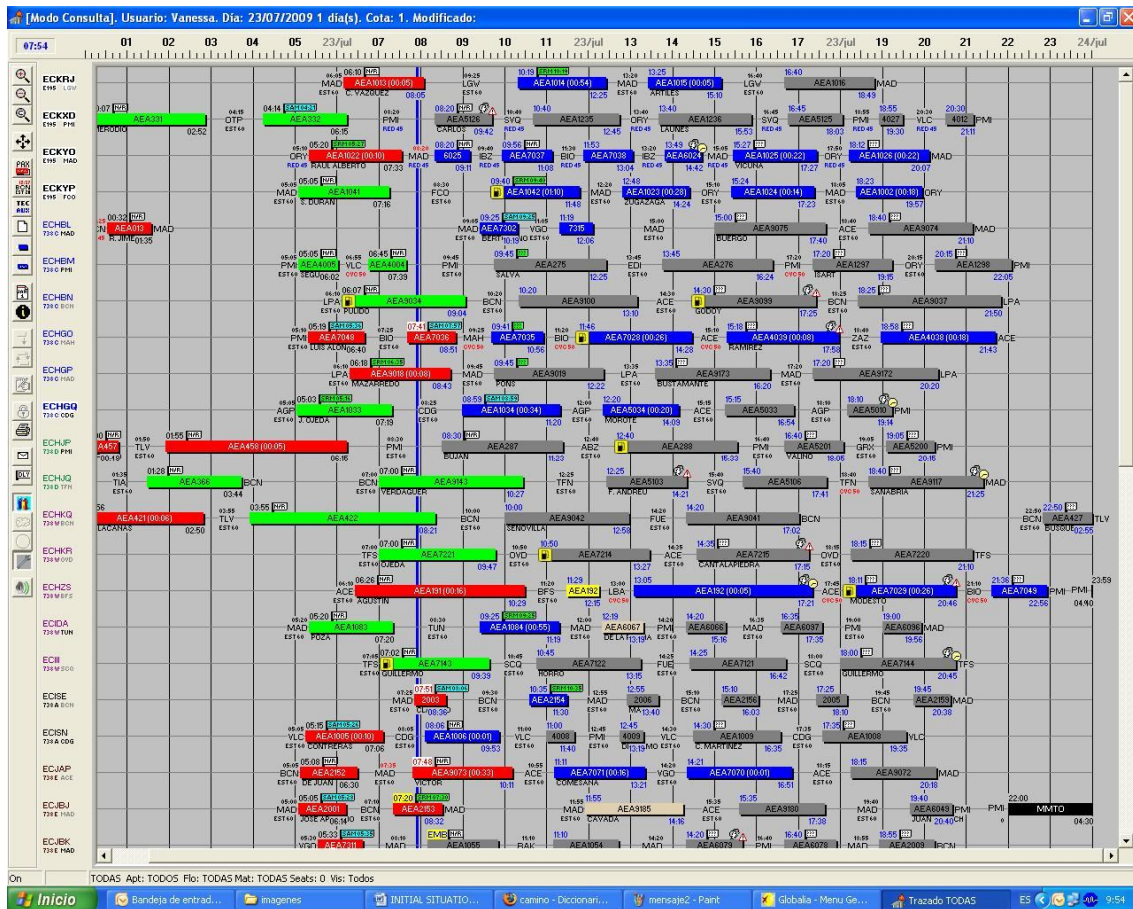
**Figure 1-28 - STAR screenshot**

One of the key points of AirComServer (and any other ground processing tool) is that is relatively easy to create the desired format by inserting fields and characters using user-friendly menus. What is more, the same message may be forwarded to several users or applications with a specific format for each of them. Again, the message in fig 1-25 is also forwarded to a file for keeping a database as:

WRN 19/03/09 10:29 ECKOM UX0885 MAD RAK CRUISE 34 NAV PRED W/S DET FAULT – 3441

**Figure 1-29 - In-flight warning message formatted differently than in Fig 1-25**

For more information regarding the template creation and administration, see annex A4 – AirCom Server Handbook.

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# 2.  INTEGRATION OF E-195 IN AIR EUROPA DATALINK

## 2.1.  INTRODUCTION

Ground applications were not processing Embraer's messages because they were not defined in AirCom Server. As first task of this project I configured the ground tools for accepting and forwarding E-195 messages.

## 2.2.  GENERAL OVERVIEW

Integrating the E-195 in Air Europa datalink basically means configuring the ground applications for being able to properly receive, identify and process (which generally means to forward) Embraer's messages. As explained in precedent chapter, the means for identifying and processing messages in AirCom Server is the template. A template must be defined before the arrival of a message in order to AirCom Server to identify it and process it as requested. If a message arrives and fits no template, message is classified as unknown: message is a valid one, belongs to Air Europa fleet and is correctly received but if nothing was previously configured, the system does not know what to further do with it. The first essential step is to create the templates for all messages being identified and processed and that was the first task of the project: gather all message definitions from manufacturer's manuals and configure the templates in AirCom Server for correctly detect and forward all messages.

The Embraer 195 has actually a limited collection of messages. The variety of messages that the onboard Communication Managment Fuction (CMF) may send is limited to approximately 10 different types of messages in an average day whilst 10 additional messages are sent sporadically. All these messages are included in a configuration file called Airline Modifiable Information (AMI) that will come back mainly in chapter 4.

The first AOC messages processed by almost any operator are the OOOI reports. OOOI reports represent the four principal events of a flight: when it leaves the gate (OUT), takes off (OFF), lands (ON) and when arrives at destination gate (IN). By having these four messages in real time operations department may have a precisely updated status of company's fleet: if the aircraft has left the gate, if it is already airborne...  When the project started these were the only messages that were correctly processed for the, at that time, only Embraer 195. In fact, this was the only thing done in regards to Embraer and datalink. Within this project not only all messages were eventually correctly processed but also some data was automatically loaded in several company applications and the onboard datalink software was customized for the E-195 fleet. These steps will be described in oncoming chapters.

## 2.3. CONFIGURATION OF FIRST MESSAGES FOR E-195

One of the most important messages for the company is the AUTO INIT, the automatic initialization of flight data. At the beginning of each flight, there is some data that the pilot has to introduce into the Flight Management System (FMS) that will be used for all the duration of the flight. It slightly depends of the aircraft but common data fields are flight number, origin, destination, departure time, captain ID... The introduction of this information is via the keyboard of the Multipurpose Common Display Unit (MCDU). It is frequent that human mistakes are made or not the right format is followed. For example, Air Europa's flight 0965 may be introduced using the IATA code (UX) or the ICAO code (AEA) or with or without the initial zero (0965 or 965). As many messages are automatically processed for retransmission it is crucial that the right format is followed. If no flight number or a wrong one is introduced the default value UX0000 is assigned, and information later sent during the flight will not be automatically loaded, for example, in operational control software STAR since flight UX0000 does not represent a real flight.

At the same time this task is very repetitive for crews, so datalink offers an alternate method for filling these fields. Figure 2-1 show a schematic view of Embraer's MCDU screen where dashes (-) represent fields to be manually introduced. Alternatively, if an automatic data initialization is preferred, 6R button may be pressed (AUTO INIT*) and all fields will be automatically filled.



**Figure 2-1- Autoinit display in Embraer fleet**

The process behind this automatic initialization is quite intuitive. After selecting AUTO INIT*, a downlink message is sent. This message, called AUTO INIT REQ(uest) is received by AirCom Server and is further forwarded to STAR with the adequate format. In this message flight number and registration of the aircraft requiring data are included. The request is processed and all information is gathered from operational control servers and replied uplink to the aircraft, using a message called AUTO INIT REPLY, reversing the path. The format of the message for each aircraft type may vary, so AirCom Server has to adapt the uplink message design to the specific aircraft type. This is done by the administrator. Upon reception onboard, the Communications Management Function (CMF) reads and interprets the received message and forwards this information to the FMS. If the format sent uplink do not exactly match what was expected by the system, the message is rejected and manual data introduction must be performed.

| Jul-23 2009 10:02:17 | 4054783 | ✓ | In Down | INIT Message-E195 | .EC-KYO | UX0000 |
| Jul-23 2009 10:02:17 | 4054783 | → | Out Down | INIT Message-E195 -- To STAR | .EC-KYO | UX0000 |
| Jul-23 2009 10:02:27 | 4054784 | ✓ | In Up | INIT Response | .EC-KYO | UX7037 |
| Jul-23 2009 10:02:27 | 4054784 | ↗ | Out Up | INIT Response -- Insert Uplink I | .EC-KYO | UX7037 |

**Figure 2-2 - Autoinit messages**

In figure 2-2 the sequence of these messages may be observed in a screenshot of the AirCom Server message log. At 10:02:17 the request from the aircraft registered EC-KYO arrives. Message is marked as an *In Down* message (*in* for incoming, *down* for downlink) and is instantly forwarded to STAR, the operational control software. Ten seconds later an incoming uplink message is received and identified as *INIT Response* and the associated task to this message is to forward it uplink to the relevant aircraft. The last column shows the associated flight for each registration. Until the INIT Response was received, flight number was the default one (UX0000) and only after the reply the right one is taken.

This essential communication was commonly used in the A330 and B738 fleets, but it was not yet put into operation for the E195 fleet. Crews requested an automatic initialization of data but the uplink message was systematically rejected without further information given by the CMF about the possible reason. The first task of this project consisted in making this messaging work.

The first analysis I made showed that some formatting errors were made. But after correction, the uplink message was rejected anyway. The format of each message and the displays of the onboard screen are provided by the manufacturer, Honeywell in the case of E-195. I made some extra minor "what if" changes, sometimes even deviating from manufacturer's manual just in case of, but the fact of having only one aircraft in operation limited the amount of downlink requests performed per day as the message was only sent once every 3 or 4 hours: at the beginning of each flight. An additional obstacle came from the fact that crews were already

used to introduce data manually so happened that there was only one AUTO INIT REQ(uest) sent a day or none.

After four days of unsuccessful tests I passed the question to Honeywell. Surprisingly, Honeywell admitted that the datalink manual given to airlines contained several mistakes, but no manual's revision was publicly available. One of the errors of the manual was right in the AUTO INIT REPLY message. Even with the manufacturer's correction -a missing slash [/]- the reply was still not accepted by the aircraft and no further assistance was offered.

As no solution was close to be obtained I stepped back and tried to understand the whole process of datalink communication in detail, seeking an answer in some overlooked little nuance. It had to be small as no similar problem was reported when configuring the B738 and A330 fleet in the past. ACARS datalink is based in ARINC 618 and ARINC 620 communication specification so I made an in-depth study of both documents. At the same time it was useful for a deeper understanding of how datalink communication works, not only for solving this hurdle. The answer was eventually found in that Honeywell's specification demanded the intro or return key [↵] not to be used on message construction at the end of a line, but instead the two control characters Carriage Return <CR> and Line Feed <LF> should be introduced individually as ASCII characters. Interestingly, in informatics, both control characters were taken from the old typewriters where for creating a new line of text two manual movements needed to be done: moving the cylinder on which the paper was held (carriage) back to the left side of the paper (return) and then manually move up the paper (feed) one line. Just to note that other manufacturers accept the intro / return key without problem and a key labelled "carriage return" or "return" was already able to perform both actions simultaneously in old electric typewriters since 1960. All along ARINC 618 and ARINC 620 the two characters were explicitly mentioned, whereas in all previous messages (B737 and A330, both form Rockwell Collins datalink systems) the intro key was used and created no formatting problem. Both CR and LF characters were always explicitly mentioned in ARINC's specification so there had to be a reason. This was the little overlooked nuance: what worked for Rockwell Collins' messages did not in Honeywell's ones.

Once the AUTO INIT reply was correctly uplinked to the aircraft the remaining communication with the Embraer 195 started being reliable. No human-introduced data was used for identifying flight number or crew ID. With the experience gained in the decoding of the AUTO INIT REQ message, the remaining messages were much easier to decode. By decoding should be understood creating the right template in AirCom Server that will automatically identify the message, extract data from it and forward with the right format where applicable.

Most Embraer messages already existed or had an equivalent in either the B737 or A330 fleet so the same use given to the message in other fleets was given to the E-195's ones. For example, if a diversion report message (sent when an aircraft diverts from its original intended destination) was forwarded to a given people from operations, the same individuals will now receive the Embraer's diversion messages, too. Embraer's datalink capabilities were the least developed of all three fleets, so did not happen that a message only existed in Embraer and not in Airbus or Boeing.

By mid-March 2009 all messages sent by the E-195 fleet were correctly identified and forwarded. From most of them data was also extracted and forwarded to the relevant end user but some messages were left with no further processing, which was particularly the case with the warning/failure report messages. These messages are transmitted in real time when a fault or failure occurs in flight and inform about the systems that failed and the time at which it failed. In Airbus aircraft these messages are nearly in plain text and are easily understandable; in Embraer aircraft they are codified. These messages, called *current leg report* in Embraer nomenclature, require an additional web-based application for its decoding, AHEAD (Aircraft Health Analysis & Diagnosis). The airline configures so that AHEAD receives the failure messages via ACARS network. All messages from all airlines are centrally processed by Embraer and airlines have the right, provided AHEAD licence is purchased from Embraer, to retrieve its maintenance information using a web based interface. The initial small size of the Embraer fleet in Air Europa (2 units until June 2009) made of no economic interest the purchase of an AHEAD licence. However this vision changed when two more Embraer 195 joined the fleet in June 2009. At the moment of writing this project the agreement for purchase an AHEAD license was eventually signed, estimating an entry into daily service in September 2009.

Maintenance messages are not included in Honeywell CMF manual as they do not belong to AOC messaging, thus not included in the AMI file. These messages are generated by the Central Maintenance Computer (CMC). Aside of the abovementioned Current Leg Reports, there are some other maintenance messages that I could create a template for called Engine Trend Report. There are two: take off report and cruise report which are transmitted right after take off and at the beginning of cruise phase. Both are automatic and transmit nearly 100 parameters of the state of the engine. I had to refer to the Service Newsletter SNL 109-71-0004 for a decoding template of these messages. As the SNL states, these messages not only are sent to the airline but also straight to engines' manufacturer, in this case, General Electrics.
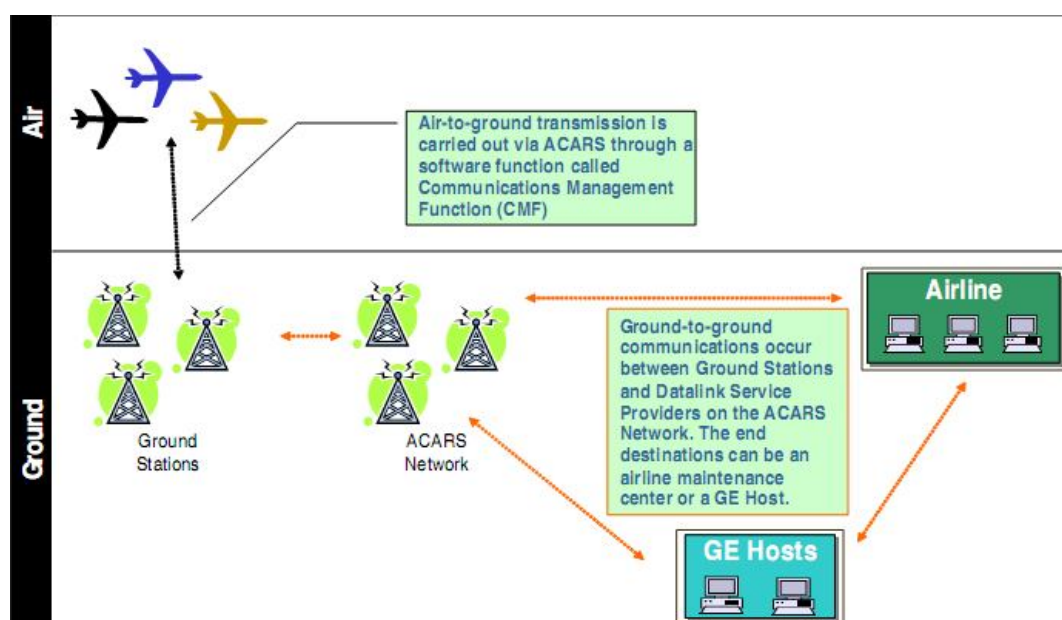


**Figure 2-3 - Engine Trend Reports are automatically sent to General Electric's servers**

In June 2009 I had to repeat this process of identifying messages. Detailed description is presented in chapter 4 but, summing up, new datalink software had to be installed in all E-195 aircraft and all messages changed. In fact Honeywell did not offer the possibility of keeping the same formats as before. Field delimiters changed from dashes to commas, new fields and messages were added and some existing ones were dropped. The consequence was that all templates had to be checked or modified which is essentially the same process as creating a new one.

First part of the project concluded satisfactory: all required templates in AirCom Server were created, allowing Embraer crews to make full use of all capabilities of the datalink system. The problems encountered along this part forced me to study and understand datalink in deeper detail than the "operatively necessary" but this knowledge was in fact very useful for the second and third part of the project. Once data was already received from all aircraft the question posed was if there was some way to process data on ground more efficiently than was already done. And a very simple principle was found. For example: departure and take off time of all flights were transmitted via datalink and already used. If all this times were put in a database, calculated the difference (take off minus departure time) and filtered by departure station, the average taxi-out time of an airport could be obtained[7]. This simple example show that if data received via datalink is considered jointly rather than each message individually, new useful information may arise. If datalinked data is sent to a database or another application, new uses may be found.

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[7] Taxi time value is not sent in any message. This value is important as fuel necessary for taxi must be loaded in the aircraft. If loaded in excess, flight will take off with an excess of fuel, which is uneconomical. If loaded too little, safety could be jeopardized. This is just an example; taxi times were calculated from the operational control application in Air Europa.

# 3.    DATALINKED DATA INTEGRATION

## 3.1.    INTRODUCTION

Integrating datalink data consists in loading automatically information received via datalink as soon as it arrives in another software application without human intervention in between. It saves time and offers real time data availability. In this project I managed the data integration in three cases which showed the two main families of complications that may be encountered: technical aspects and staff reluctance. Each data integration process consisted of a series of meetings where a balance between efficiency and technical simplicity should be found between maintenance-engineering (as datalink administrators) and the relevant ground department.

## 3.2.    GENERAL OVERVIEW OF DATA INTEGRATION

Datalink offers the possibility of having much data in real time, as opposed to the previous technologies and procedures, where data was collected at a fixed moment of time and its processing was comparatively slow. Additionally, data offered by datalink systems is already computerized which is not always the case when no datalink systems are used.

The basic example which perfectly describes this situation is the OOOI message processing. Before datalink broad use these times were reported in the technical log book (TLB)[8]. Pages of the TLB were sent via comail to the relevant department (in Air Europa it's called Technical Records) where they are read and introduced in a software application by hand. The shipment takes up to 5 days, depending on several circumstances. After this long process data is ready for consultation. However the same information travels though a different path. For operational control department it is crucial to have these timing as soon as possible. SITA's telexes were used for this mission. When aircraft left the gate or took off (or when it landed and parked at destination) the information was relied to the person in charge of the ground communication who sent the telex to the specified addresses. The problem came from the fact that in bigger airports at least two people were needed, one for sending the message, another one for informing the state of the aircraft. Take off runways and parking positions are sometimes out of sight from the office or staff can get busy with a different task while waiting to the aircraft to leave or depart. Additionally, when the message arrived to operational control department it was printed in paper –in older times- or received in a sort of inbox –in recent times-. Then it had to be manually copied to the relevant application. This process it was not only long, time consuming and staff consuming; it was also very prone to imprecision, mistakes or even purpose made "errors".

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[8] They still are reported in the TLB as some aircraft in the fleet do not have datalink installed.

OOOI via datalink is based in a series of sensors installed in the aircraft that detect changes of its state. These changes are interpreted and the resulting information is sent via datalink with a time stamp indicating at what moment it happened. For example, when parking brake is release with all passenger and cargo doors closed it is considered that aircraft is about to move, that is, it is about to leave the parking. This event is considered as the departure time and a message is automatically sent without human intervention via datalink to the airline operational centre with the time at which it happened. Time is taken from the onboard clock, which is synchronized with the GPS global clock. When this message arrives to the operational control department it is automatically loaded into relevant application. Not only it is faster (transmission time is less than 10 seconds in most cases) and automatic; there is much less probable to occur a mistake. Unfortunately there are still ways to fool the system, although much more elaborated that in the manual process.

When datalink installation was competed across Air Europa's fleet, the company reported an average reduction in flight and block times in the order of one minute and a half per flight. This was probably the result of the well known trend of making flight time longer that it actually was for salary and activity reasons. With about 200 daily flights, this little per flight difference equals to 110.000 extra minutes approximately at the end of the year across whole fleet, which represents 76 extra days in yearly activity, approximately two days per aircraft. The integrity of datalinked data and its real time availability can offer, as shown, huge benefits for the airline at long term. These two fictitious days per year do not only have crew salary implications but also maintenance costs as several maintenance activities depend on the aggregated flying hours of the aircraft.

Second part of this project searched for possible areas inside the company for integrating data already received via datalink. By doing so, time consuming activities with little added value performed for very simple tasks could possibly be eradicated.

The integration of data has consequences in two different aspects. Firstly, there must be designed a software interface between the relevant applications for the data flow to start. From the AirCom Server side it is relatively easy to create a new outbound message based on arrival data and send it to a selected application and I could do it myself. However, it is on the end side of the transmission where most changes should occur and these technical requirements are closely related, even subordinated sometimes, to human and organizational facets. Even if technical requirements are minimal the lack of willingness in using datalinked data may prevent the department from benefiting from this data.

So the second aspect to take in mind in order to make full use of datalinked data is that it is unavoidable that some changes must take place in the area or department where this information will be used. And changes sometimes imply problems. Using integrated datalinked data mainly represents a change in the way work is organized, a change in some of the existing processes. However the consequences of these changes may be far more important than expected: some working positions may no longer make sense, higher workload may be shifted into different positions or even a necessity of a new post may arise. In general terms,

introducing real time data from datalink sources reduces the amount of work for the end-user as compared to previous state. This initial benefit potentially creates an excess of staff in the department, unless the personnel is recycled into a more productive position.

In Air Europa's organization three target areas were selected, which are later described in further detail:

- Ground Handling: already users of OOOI data fed into their system their interest grew when new messages were presented, offering potential benefits in the form of precise estimated times of arrival and information about services requested by the aircraft upon arrival.

- Technical records: a high percentage of the work of this maintenance sub department consists in introducing data into a software application which is received in paper support. The manager of the department was very interested in the possibility of datalink easing this tedious work.

- Maintrol (Maintenance control): this 24h department coordinate all maintenance activities across all Air Europa daily operations. Although long time averse to making use of datalink Maintrol slowly accepted its use when evidence showed the potential benefits of receiving real time failures and warnings from in-flight aircraft.

Integrating data between software applications where several departments are involved is always a hard task. Doing so only for data coming from the Embraer fleet would not represent a wise approach when many messages and fields are shared between all aircraft models and the workload would only increase marginally if other aircraft would be included. Even though the project started with a clear emphasis on the Embraer 195 aircraft it became unavoidable at this stage the inclusion of Boeing and Airbus aircraft.

The avionics philosophy for Airbus and Boeing aircraft is similar between them and will not be described here as was already seen in detail in ENAC. The important characteristic is that both fleets share the same datalink system, the CMU-900 datalink by Rockwell Collins. All messages and formats are nearly identical as a consequence. In this chapter messages and fields that belong to Airbus A330 or Boeing 737 aircraft will be described or mentioned as they are part of the integrated data.

## 3.3. SISTEMA MANTENIMIENTO AERONAUTICO (SMA)

### 3.3.1. DATA SOURCES

Technical records department keeps an archive of technical data related to Air Europa fleet. In order to assist them in their task the SMA (Sistema de Mantenimiento de Aeronaves) application was developed by Globalia Sistemas.

Some of this stored data is mandatory by the civil aviation authority; some other data is used for in-house statistical analysis. Information is mainly obtained from technical log pages, filled by the crew and technicians. Each technical log page (TLP) is numbered and contains information of one flight: OOOI times, fuel data, failures occurred and the reparation made and many more. Crews fill these TLP's after each flight.

A technical log page arrives between 2 and 5 days after being filled to Technical Records office. Once arrived, it is manually processed and most data is manually entered into the SMA system. The SMA window used is shown below:



**Figure 3-1 - SMA screenshot**

The upper part of the window contains general data of the flight. From left to right, in the first line there is the flight number, date of flight, origin, destination, diversion airport and reason - if applicable-, aircraft registration and TLP number. Following in the second line, flight type (regular, charter, ferry flight...), if rejected take off occurred, if reduced thrust was used, if CAT-II/III landing was performed, if it was an ETOPS flight, if de-icing was needed and the captain.

Below, on the left side, there is data of oil and hydraulic fluid refilling and fuel data (consumption and uplift). On the right side, OOOI times, freight transported, takeoff weight (these two parameters are used for statistical purposes) and pilot flying information.

As may be imagined, manually processing all these fields is time consuming. Since many data is sent downlink from aircraft each day, it is theoretically possible to use some of it to feed SMA system automatically. Datalink could ease the work of technical records department, even if it was not planned for.

Before proposing technical records department the possibility of integrating datalinked data I performed an interim check of what data could be affected by this measure. First step was to identify the fields that can be potentially fed automatically. Fields, such as *freight*, that a well known source is available, in this case the load message (LDM). The LDM message, shown below, is sent uplink for each flight after completing the load sheet (also sent via datalink).

```
QK PMIARUX
.IBZAPUX 231014 GAT
□LDM
UX6054/23.ECKCG.12/168.2/4
-BCN.83/68/7/1.T2010.1/878.4/1132.PAX/1/157
SI BCN.B1882.C128.ENIL.MNIL.NBR.BAG128
SI 01 UM /// 01 WCHR /// 128 KGS CGO ( HUM )
```

**Figure 3-2 - Sample LDM message**

LDM message is used by crews to verify that the actual loading of the aircraft made by the loading staff is consistent with the information contained in the load sheet. Advantage can be taken from the fact that this message is sent via datalink to *intercept* it, extract the desired data and send to SMA. A similar process was done with 8 more fields, with sources varying from load sheet, flight plan, automatic messages and manual messages (all described shortly).

Once the identification was done my tutor and I presented technical records manager our vision of what data is available and where is it taken from. He agreed and pointed out the visual layout preferred in the systems after modification, as will be his department who will mostly use the application on a daily basis. Once we agreed what fields to use and how to display this data a meeting was held with the informatics and operations departments. The planned changes must be transmitted to the informatics department as they are in charge of the technical integration between different applications of the company. On the other hand, flight crews, belonging to operations department, are the ones that use datalink on board. As

some fields entered to the on board systems will be automatically loaded, it was found sensible to ask them to take part of the discussion. It is worth noting that Air Europa's crews are very enthusiastic about the use and expansion of datalink, so these changes were very well welcomed. Despite the automation of the data loading in SMA, the paper technical logbook will still be used, as there are still 10 aircraft without datalink installed. It was agreed, however, that on the long term the use of paper technical logbook will probably be abandoned.

When I started analyzing what data could be automatically sent to SMA, I realized that not only datalink could contribute with its data but also other applications had figures that could be sent to SMA, namely STAR (operational control application) and Graflight (SITA's flight planning application used by Air Europa). So what initially started as an individual meeting for integrating datalink's modest contribution to SMA, eventually developed into a multidepartmental succession of meetings and emails with Ground Operations, Flight Operations, IT Support, Maintenance-Engineering, Maintenance-Technical Records and Flight Crew planning departments present at different stages. As this project triggered the integration of datalinked data to SMA it was accepted that I continue with the broader data integration into SMA. So I not only took data from datalinked messages, but also from flight planning application and the operational control software.

Making a long story short, I included each applications's contribution in a document (Annex A2) which was the basis for the exposition of Air Europa's requests to Globalia Sistemas. I took into account the level of simplicity for each new data to integrate: some information required just an extra field in an already existing message; some other required opening a new interface between two independent applications. Data integrity and precision was also a key factor: automatic data was preferred over data introduced by hand; if precision was not high, data was disregarded. After several meetings the last specification passed to Globalia Sistemas required the integration of the following eight fields plus Airbus' Post Flight Report.

- ETOPS. The information whether a particular flight is ETOPS or not can be found in the flight plan, which is stored in the flight plan application. ETOPS flight plans include a known string at the beginning which is used for identifying ETOPS flights.
- Fuel at arrival: the amount of fuel at arrival can be obtained from an automatically sent message in the A330 fleet called servicing report. This report offers information about the state of the aircraft for maintenance purposes and, amongst other data, it was found that it contains the amount of fuel left in the tanks. This message was disregarded upon reception until that moment. For the B738 and Embraer fleet the IN event message, sent automatically when the parking brake is set upon arrival, also contains information about the remaining fuel on board but its inclusion remains doubtful unless the precision with which data is sent is increased[9].

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[9] The IN event report also exists on the A330 fleet but the precision of the data is higher in the servicing report: in the IN event, fuel data is rounded to the nearest hundredth, whereas in the servicing report it is done to the nearest tenth.

- Diversion code: when a diversion occurs the reason that caused it (maintenance, weather, operational...) is stored for analysis. It was agreed that the free text field of the diversion message will be displayed for consultation and decision of the code only in ground. The workload in cockpit during a diversion is already high so it was seen safer not to add extra work.
- CAT II/III: the category of the instrumental approach is sent in a special message at the end of the flight.
- TOW: The take off weight of a given flight was easily taken from the loadsheet. It is used for fuel burn statistics.
- Freight: Same as previous.
- Pilot landing/taking off: for crew planning department this information crossed with the CAT II/III landings is important for recent experience requirements about these instrumental approaches.
- Uplift: the information of the amount of fuel loaded at beginning of each flight had a dedicated field in an already processed message. Strangely nobody made use of this field so it was only necessary to promote its use.

The Post Flight Report (PFR) is an error report in the A330 fleet created by the onboard Central Maintenance System (CMS), sent automatically 10 minutes after engine shut-down (as per Air Europa configuration) including all failures and warnings that had occurred during flight. It can also be retrieved from the cockpit and it is a valuable report for maintenance and troubleshooting. The length of a particular PFR is unknown and combined with its overall size it was left for a second stage of data integration in SMA which eventually did not fit into this project deadline. Nevertheless it will be done whenever possible.

The overall problem encountered when presenting the requested modification to remaining departments were those values that appear very sporadically when infrequent conditions occur. For example, normally there is only one refueling for flight, so only one uplift field exists in the datalink menus. However, sometimes happen that a second or even third refueling has to be done. When reporting so in the paper technical logbook there is no problem as it is possible to fit this extra information in the field. But this cannot be done when reported via datalink. Another example is the pilot landing/taking off field in Embraer aircraft. Embraer's datalink only had one field labeled *pilot landing*. Boeing and Airbus aircraft, on the contrary, had two fields: pilot take off and pilot landing. The problem appeared on how to report in Embraer aircraft or, conversely, how to interpret Embraer messages. The same pilot who took off normally lands the flight, too. But this is not a must and it happens that the first officer can take off and, for any reason, captain takes the control for landing. In these cases, what information has to be put in the pilot landing field?

These type of questions appeared for almost every field that was due to be integrated; sometimes occurred that there were problems only with one of datalink systems (Rockwell Collins' or Howeywell's), depending on the specific message format. These questions could only be answered by reaching an agreement of all parties involved. Every part was very cooperative and prone to use datalink to ease work so agreements were promptly reached. However, as time was passing by in these meetings, the feeling that existing datalink messages

did not fully suits company's needs was increasing. This was particularly so in the case of the Embraer, whose datalink was the least complete of all three fleets. Emrbaer had also an extra drawback: Boeing and Airbus shared the same datalink system from Rockwell Collins; Embraer was 'the different one'. Was in these meetings where the idea of modifying the Embraer's onboard datalink software took place.

## 3.3.2. DATA PRESENTATION

The presentation was chosen to be as practical as possible, thus the preloaded data is inserted in the applicable field straight from the opening of the flight record. Additionally, a button close-by that pops-up a window showing where the information is taken from was added in some fields.

The pop-up window was included for allowing human supervision or confirmation on those cases were there could be a discrepancy between what is written in the paper technical logbook page and what the system has received automatically. By showing the original source of the automatically loaded data (the message or document where the information is extracted from) user may validate the source of data and decide appropriately whether to keep it or to insert the information contained in the technical log book page. Having data loaded automatically is also expected to decrease the amount of fields left blank as a result of a missing field in the paper technical logbook by mistake.

Figure 3-3 shows a comparison between the new and the older version. The change is very subtle and cannot be fully illustrated with static images. When a new query is launched for retrieving data of one particular flight, ETOPS, Freight and TOW fields are already preloaded with the value found in the applicable source. Those fields have a red background in its title. This means than a pop-up window is available showing where data has been taken from. Data preloading may fail for a diversity of reasons: no message is found, message with different format, numeric value out of logical range... In these cases, the pop up window shows whatever is available and is up to a human user to decide with the information there presented what is the right value to store. If this backup procedure also fails (no message was sent for example), there is always a paper technical log book page to check for data.  In case of discrepancy between datalinked data and written in TLP one, prevails the hand written one. Figures 3-4 and 3-5 show sample pop-up windows for ETOPS and FREIGHT fields.

**Figure 3-3 - Screenshot of new version of SMA (left) and old one (right)**



**Figure 3-4 - ETOPS pop-up window (red arrow added for illustration)**
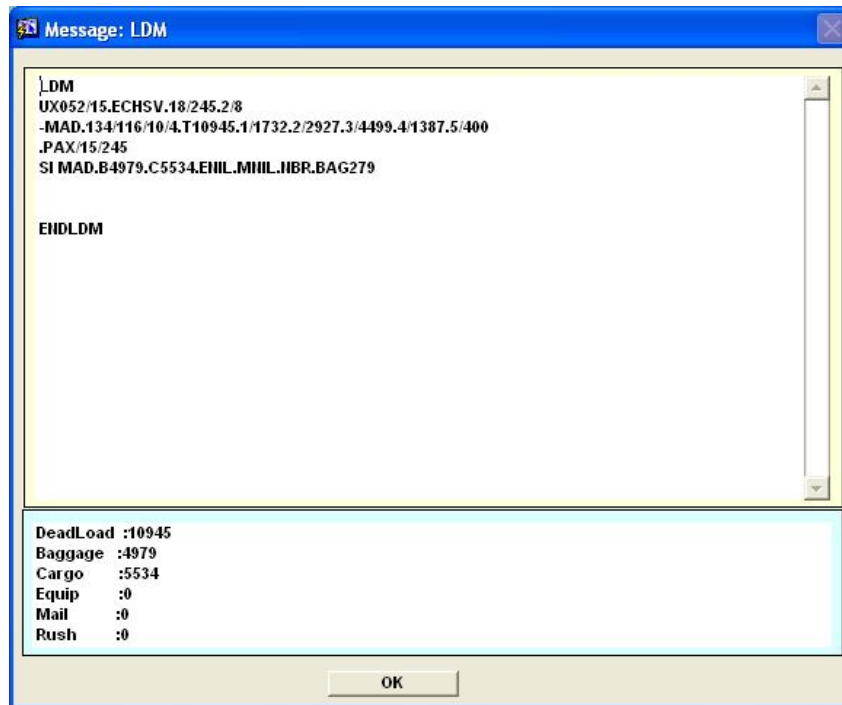
**Figure 3-5 - LDM pop-up window.**
**Upper part shows the raw LDM message; lower part the data extracted from the above message**

It is also important to note that despite these improvements the paper technical log book will continue to be used for some time in Air Europa. Firstly because there are 10 aircraft that do not have datalink installed and will not have it as they leave the fleet in the coming 2-3 years; secondly because the paper technical log book has fields that cannot be replaced by datalink messages and, last but not least, the technical log book is still an official document. However it is widely agreed that the trend will be to remove paperwork from cockpit taking advantage of IT systems. In this line several solutions for reduce the amount of physical documents in the flight deck are already in place, as the Electronic Flight Bags or the Tablet PC's used by some companies.

### 3.3.3. SUMMARY AND REMARKS

An important overall aspect of integrating datalink data (and other's application too) to SMA is that it required an in-depth analysis of all three datalink systems (Airbus', Boeing's and Embraer's); not only comparing them between them but also studying how they suit company's needs if datalinked data were to be integrated in bigger scale. Thanks to this study many deficiencies in all three systems were identified along with several improvement proposals for a future version of the onboard datalink application. Not surprisingly, Embraer's datalink was found with most missing features and potential improvements. It is not surprising because Embraer is the least mature of all three manufactures and it had the default version of datalink.

The integration of data in SMA (and to a lesser extent to Ground Handling –next chapter-) finished with a wishful thinking that the onboard datalink application of the E-195 should be upgraded. Some very useful messages in Rockwell's Collins datalink (the one installed in A330 and B737 fleet) were missing, some minor improvements could be done in several messages and some new features could be added if ever the change of onboard datalink was envisaged. However, there was no clear error, mistake or requirement that could justify the investment in new software at this point of time: the current datalink (as of May 2009) was not ideal but was neither so bad, there was always a way to circumvent Embraer's datalink shortages. All ideas for improvements were written down and stored, waiting for a trigger event that could justify modifying the onboard datalink of the E-195. Fortunately this trigger event arrived and is described in chapter 4.

At the same time the European Trading Scheme[10] (ETS) requires airlines to monitor fuel consumption and passenger and cargo loads. This method of using datalinked data to feed databases was found very interesting for this project, too. Firstly because data can be obtained instantly and secondly the ETS monitor scheme requires just picking up some data already integrated in this part, so no new staff or database is required. The ETS topic will come back again in chapter 4.

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[10] The European Trading Sheme (ETS) is a European trading program where large emitters (aviation is included) must monitor and report $CO_2$ emissions and emit no more that was allowed in advanced. Some of these allowances are obtained freely; some others are not.

## 3.4. MAINTENANCE CONTROL

Maintenance control department, frequently abbreviated as *Maintrol*, is the H24 division organizing all daily maintenance activities across all Air Europa stations. It is a very dynamic department in the sense that Maintrol looks for solutions for unexpected problems most of time: if an aircraft is grounded (AOG)[11] reparation must be carried as soon as practicable; some aircraft may need to stay overnight in a particular station and end up in a different station for operational reasons; some in flight problems may arise and crew may necessitate to consult maintenance.

It would be logical to think that a department that works so much in real time is an advanced user of datalink, as it offers real time interaction between ground and aircraft. However this was not the case. Maintrol refused the use of datalink: no maintenance reports were read and no free text message were sent to aircraft from Maintrol. When an aircraft in flight had to consult with maintenance the datalink message was sent to operations and then telephonically relied to Maintrol; Maintrol replied also telephonically to operations and they, in turn, replied to the initial datalink message. This procedure could be understandable if no direct link between in aircraft and Maintrol existed, but it is not the case. Crews were already used to not receive reply from Maintrol so they opted for this indirect link rather than sending the message directly to them.

During the curse of this project efforts were made for Maintrol to start using datalink, mainly consisting in raising awareness of its benefits to the company and explaining in detail its use. As a particular action warning and failures messages of A330 fleet were forwarded to Maintrol and Madrid Maintenance (Madrid Maintenance were very keen in using datalink but Maintrol also opposed to this).

Warning and failure message are real time messages transmitted via datalink by the Central Maintenance Computer (CMC) informing about the warning conditions and system failures occurred in flight with additional information that help on ground its reparation. This additional information consists of time at which the waning or failure occurred, the ATA[12] classification of the occurrence, the warning/failure text as presented to crew and the flight phase when it happened.

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[11] AOG stands for Aircraft On Ground which means that aircraft cannot fly in present conditions therefore staying on ground. Normally an aircraft goes AOG if a failure occurs that prevent the next flight to be dispatchable under applicable MEL (Minimum Equipment List). It can fly again when the failure is fixed.

[12] ATA stands for Air Transport Association and, in this context, means a numerical technical classification developed by this organization of all the systems and sub systems on an aircraft which is universally used in aircraft engineering and aircraft maintenance. (11)

```
MENSAJE IN-FLIGHT WARNING

A/C:                    EC-KOM
FLIGHT:                 UX0885/19
ROUTE:                  MAD-RAK

RELATED ATA:            34-41
WARNING TIME:           10:29
WARNING MESSAGE:        NAV PRED W/S DET FAULT
FLIGHT PHASE:           CRUISE
```

**Figure 3-6 - In flight warning message**

These messages became known by the general public after the accident of Air France flight 447 as being the only technical information that could offer some answers regarding the cause of the crash. The fact that these messages were not previously received by Maintrol does not imply any reduction in safety: these messages are received by plenty of other people and departments in Air Europa and, in fact, many aircraft (all B737 in Air Europa and countless in other companies) do not even have this feature installed.

The benefit of having and processing these messages is difficult to measure but is evident. All company's transatlantic flights depart and arrive to Madrid. Maintenance for the 6 Airbus A330 is normally performed in Madrid, unless it is required elsewhere for dispatching the flight. Ground time between flights may be short, especially in busy periods as summer, so knowing before the aircraft lands what will need to be repaired may save a precious time that can allow next flight to leave on time. For this reason Madrid's Maintenance were very keen in having these messages because they could wait the arrival of the aircraft with all tools and spare parts (if needed) ready for the reparation as soon as the aircraft arrived. It was seen beneficial as work could be done in less hurry than before. Otherwise captain indicated if anything had to be repaired about 30 min prior to landing using VHF communication. 30 minutes is not very much advance (failure has to be identified, the action to perform decide and spare part found and taken to the aircraft, if needed) and captain's description may not be as precise as the Central Maintenance Computer's.

The benefits of the introduction of warning and failure messages retransmissions to Maintrol and Madrid Maintenance were unfortunately not quantified, but qualitative feedback indicates that an improvement has been obtained by reducing maintenance time required after a transatlantic flight. The reduction, worth noting, is not obtained by requiring less time to perform a given action but by knowing in advance what will have to be done and a receiving the aircraft better prepared, the logistic was improved. Productivity was increased by doing maintenance tasks when the aircraft was still in flight instead of having all of them concentrated in a short turnaround time.

The technical difficulty of this integration of datalink messages is indeed limited. Messages are retransmitted as emails, only with a change of layout for easier reading. However the

interesting side of this data integration is the human reaction to a change, even if technically minimal and objectively beneficial. The negative to receive and use datalinked information was presented as dogmatic: many explanations were given but all of them on same basis for justifying the same stand. The explanation for this refusal has to be searched in that Maintrol is a small group of people (approximately 10), with a very particular job (which creates strong links between workmates), with personal profiles of all individuals fairly similar. It is out of the scope of this project study why a given group of people refuse adopting an apparently beneficial change. Psychology and mass behaviour theories should be consulted. However, this simple example show that in any technical field the best solution is not always blissfully accepted. Human reactions are unpredictable and what apparently is a very straightforward step may end up being a source of problems or even a bottleneck. In datalink dataintegration in particular, so important is the technical characteristics as are the human acceptance of the changes.

## 3.5. GROUND HANDLING

Ground handling is one of the many domains in which datalink may turn to be considerably helpful. Although flight times are generally standardized for commercial purposes, there use to be slight variations as a result of changing routes or different meteorological conditions. Likewise, not all passengers are the same: some may need special assistance or may continue onwards after arrival.

The handling agent of flight's origin base sends all relevant information after departure to the destination airport: departure time, estimated time of arrival, passengers' special needs... All messages that must be sent, generally standardized across airline industry, are defined in company's ground handling manual. At destination the turnaround is organized based on the information received via this ground-ground communications. All efforts are made for a high accuracy of the data transmitted but mistakes will always remain and some simple faults may lead to important knock on effects.

On the other hand once the aircraft is airborne it is virtually disconnected from ground handling operators. That is, even the aircraft in flight plays the main role in aviation, in general, in ground handling in particular, it stays disconnected from ground for most of the flight[13].

The procedure of sending information from origin to destination is widely used worldwide but it is not free of potential improvements. A significant concern is that data is static, that is, once sent it use not to be updated (unless for evident corrections). This is particularly true for the flight time.

In bigger airports where hundreds of flights are handled each day many shortcuts exist to ease the work. One of them is to standardize flying times for a given route instead of using real time for each flight. Thus a Madrid-Barcelona flying is considered to last always 1 hour, regardless of the route used and the prevailing winds. When sending the passenger information mistakes can be also made.

As introduced, these apparently unimportant mistakes may cause severe disruptions at destination and in airline network, ranging from customer service level to operational concerns. Let's consider the simple fact that the information of a passenger's assistance (i.e. wheelchair) has not been sent to destination and ground staff gets knowledge of it just after the aircraft opened the door. It may take some time, particularly in busy moments, to arrange this assistance. The simple fact of not receiving the assistance upon arrival will surely be considered a bad customer service from passenger's point of view. If the assistance is indispensable, it prevents the turnaround from continuing: no cleaning, refuelling or catering changing can be done if there are still passengers on board. Let's further imagine that this particular flight had arrived slightly late due to some thunderstorms found on route and that

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[13] After departure or before arrival voice VHF communication is sometimes used although it is time consuming and its range is limited.

the departure flight is ATC restricted in such way that a quick turnaround would be needed in order to comply with the restriction[14]. In the case of this example it would not be possible; the missing assistance has not yet arrived. If ATC slot is missed, there is no guarantee so as to when will the flight be able to leave. Considering an extra delay of 30min (which is not very pessimistic, especially in bad weather days), it may well happen that some onwards connections are also missed or, conversely, that the connecting flight will be delayed waiting for the connecting passengers.

This example may sound improbable but aspects such as technical failures, crew sickness, crews' duty time, airport curfews or additional staff mistakes has been left aside in this illustration. For these knock on effect not continuing forever airline operations managers tend to leave buffer time at each turnaround and for the flying time. Nevertheless, such situations – and worse- are not impossible and indeed happen.

It seems sensible to think that if crew could warn destination ground handling of the estimated arrival time and what would they need upon arrival, some of these problems could be avoided or, at least, reduced. With the intention of promoting the use of datalink messages in ground handling procedures, a series of meeting were held with ground handling/services department.

The intention was to integrate some of the already existing messages into company's ground handling application, called SmartHand. Two messages, formerly disregarded or little used, were found that could offer significant benefits for ground handling planning: progress report and ramp service request. The progress report message in particular was one of those messages that were given a name in AirCom Server but nothing else was done with them afterwards. The explanation is that no one wondered in detail what triggered these messages and what possible benefits could be obtained. I thought there must be a reason for having more that 100 progress reports each day and if no beneficial use was found, it would be sensible to switch if off somehow on board as each transmission costs money. Ramp service request, on the other hand, was already known but a new way of using it was developed in this part.

The overall plan for integrating data in ground handling application was essentially equal to the one followed with SMA data. Before meeting with ground handling department I checked all possible data that can be integrated in their application and what would be the necessary steps to follow. The slight difference in this case, however, was that my tutor could not attend the arranged meeting with ground handling so I had to present and defend our stand by myself.

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[14] Normally ATC restrictions imply a delay but, if flight is already delayed, the calculated take off time (CTOT) by the ATC may impose a very short turnaround.

### 3.5.1. PROGRESS REPORT

#### 3.5.1.1. General description

Progress report message (SMI: FML – ID. PRG) is a downlink message sent shortly before arrival (between 10min and 1h) with the estimated time of arrival, the estimated runway for landing and the estimated fuel remaining on board. It is sent by the A330 and B737 fleets and is meant to be used as a warning message for the handling agent that the flight is about to arrive. Figure 3-7 shows a sample progress report message.

```
QU PMIARUX
.QXSXMXS 271147
_FML
FI UX9083/AN EC-JBK
DT QXS BCN7 271147 F02A
-   PRG/FNAEA9083/DTLEBL,25R,77,115712,299E5B
```

**Figure 3-7 - Progress report message**

If correctly implemented, it would allow for a better ground staff and equipment management, reducing the uncertainty at what time the expected aircraft arrives. It should more profitable in the A330 fleet as, after a long transatlantic flight, the arrival may change as a consequence of a different winds found on route either delaying the flight or bringing it forward. Initially all progress report messages where disregarded upon arrival as no profitable application was found for them, partially explained as a result of the different implementation in Boeing and Airbus fleets and that no ground handling procedure existed for taking advantage of the information contained in the message. Before I started studying this message it was being sent for a couple of years by B737 and A330 aircraft and no use was found for this message, although it was partially known what information it contained.

The first issue I wanted to observe, way before proposing this message to ground handling for integration, was if there is indeed any substantial uncertainty in the flight duration, otherwise there was no point in further processing the progress report message. The following data could also be obtained from operational control software, but in fact I gathered from all messages sent via datalink from each aircraft after each flight. The positive aspect of this method is that data can be exported to an Excel file, where any imaginable calculations can be done without the restrictions of an already set program. Table 3-1 shows real data of transatlantic A330 flights originating in Madrid.

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| Destination | Number of flights | Avrg flight time | Stand. deviation | Longest flt | Shortest flt |
|---|---|---|---|---|---|
| CCS | 69 | 9:02 | 0:15 | 9:41 | 8:26 |
| CUN | 25 | 10:20 | 0:13 | 10:44 | 9:43 |
| EZE | 70 | 12:43 | 0:16 | 13:27 | 12:10 |
| HAV | 73 | 9:35 | 0:17 | 10:13 | 9:00 |
| SDQ | 67 | 8:31 | 0:15 | 9:06 | 8:00 |

Table 3-1 - Atlantic flights statistics[15]

Air Europa also operates frequent flights to the Canary Islands with the B738 fleet, reaching over 65 a day during summer season. The duration of these flights is also very prone to be affected by wind changes, alizé wind trade in the case of the Canary Islands, blowing from mainland Europe to the islands. In table 3-2 some empirical values from Madrid to Canary Islands flights can be observed:

| Destination | Number of flights | Avrg flight time | Stand. deviation | Longest flt | Shortest flt |
|---|---|---|---|---|---|
| ACE | 66 | 2:16 | 0:08 | 2:39 | 1:59 |
| FUE | 53 | 2:18 | 0:06 | 2:30 | 2:06 |
| LPA | 63 | 2:27 | 0:07 | 2:54 | 2:13 |
| TFN | 162 | 2:27 | 0:08 | 2:49 | 2:11 |
| TFS | 21 | 2:36 | 0:08 | 3:01 | 2:25 |

Table 3-2 - Canary Islands flights statistics[16]

It is evident from the above data that there is substantial variation in flight times. Values for Madrid bound flights are essentially similar. The uncertainty is diminished in each particular day as the variation is mainly caused by wind patterns and in the day of operation of the flight it is already known what wind components will be encountered. Flight plans are calculated accordingly. Nevertheless it always remains some degree of unknown related to the real flight time, particularly so the longer the flight is. In this scenario seems profitable trying to process and take advantage of the existence of the progress report.

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[15] CCS: Caracas Simon Bolivar airport, Venezuela; CUN: Cancun airport, Mexico; EZE: Ezeiza-Ministro Pistarini airport, Buenos Aires, Argentina; HAV: José Martí airport, Havana, Cuba; SDQ: Las    Américas airport, Santo Domingo, Dominican Republic.

[16] ACE: Arrecife airport, in Lanzarote island; FUE: Fuerteventura airport, Fuerteventura island; LPA: Las Palmas de Gran Canaria airport, Gran Canaria island: TFN: Tenerife Norte – Los Rodeos airport, Tenerife island; TFS: Tenerife Sur- Reina Sofía airport, Tenerife island.

Next step was to understand what the logic for this message to be transmitted is. I found progress report message to be sent with no apparent logic overall. Out of 101 A330 flights in 9 days of observation, only 26 messages were sent in the A330 fleet but up to 973 messages for 790 datalink equipped B738 flights during the same period. Strangely, some flights added up to 13 messages. For this reason, the messages was identified in AirCom Server but forwarded to no station, so no use at all was made of the information sent.

There were clearly two different policies for sending these messages and different reasons were sought for each fleet independently: one for Airbus aircraft, another one for Boeing ones.

### 3.5.1.2. Progress report in Airbus fleet

For the Airbus fleet, as I found in the A330 Aircraft Maintenance Manual Part I – 22-70-00-PB 001 – Conf 2 – D – 2 – e – 2 the message cannot be sent manually in that the is no prompt in any onboard system to select the transmission of a Progress Report. (Fig CCC)

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Progress (PRG) report

The PRG downlink message allows the transmission of a progress report to the ground. Generally, a progress report contains data relative to the A/C arrival time and EFOB at the destination. This message is sent in response to a ground request for progress report or automatically upon crossing a designated trigger. Specific trigger values can be customized by the airline in the AMI file. The PRG downlink message cannot be sent manually in a direct manner (via a dedicated prompt). However, the message can result from a pilot action (changing the destination). Progress reports are only sent relative to the active flight plan.

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So the only conclusion I could draw is that it must be sent automatically triggered by some event on board. According to the Airline Modifiable Information (AMI) Form provided for the configuration of Thales FMS, the message should not be sent automatically under any trigger condition, (3-8) what represented a disconcerting conclusion.

## 4.4. AOC DATA-LINK

| AMI OPTION | DEFAULT VALUE | CUSTOMIZED VALUE | CHOICE |
|---|---|---|---|
| AOC_FUNCTION | DISABLE | ENABLE (1) | ENABLE |
| AOC_FLIGHT_PLAN_INITIALIZATION | DISABLE | ENABLE | ENABLE |
| AOC_PERFORMANCE_INITIALIZATION | DISABLE | ENABLE | ENABLE |
| AOC_TAKE-OFF_INITIALIZATION | DISABLE | ENABLE | ENABLE |
| AOC_WIND_INITIALIZATION | DISABLE | ENABLE | ENABLE |
| AOC_MANUAL_POSITION_REPORT | DISABLE | ENABLE | ENABLE |
| AOC_MANUAL_FLIGHT_PLAN_REPORT | DISABLE | ENABLE | ENABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_ETA_CHANGE | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_TIME_TO_TD_#1 | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_TIME_TO_TD_#1 | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_TIME_TO_TD_#1 | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_TIME_TO_TD_#1 | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_TIME_TO_TD_#1 | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_TIME_TO_DEST_#1 | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_TIME_TO_DEST_#2 | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_TIME_TO_DEST_#3 | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_TIME_TO_DEST_#4 | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_AUTOMATIC_PROGRESS_REPORT_ON_TIME_TO_DEST_#5 | DISABLE | 1 to 59 mn (steps 1 mn) | DISABLE |
| AOC_DOWNLINK_MESSAGE_FLIGHT_NUMBER | DISABLE | ENABLE | DISABLE |
| AOC_DOWNLINK_MESSAGE_GROUND_ADDRESS | DISABLE | ENABLE (2) | DISABLE |
| AOC_DOWNLINK_MESSAGE_COMPANY_ADDRESS | DISABLE | ENABLE (2) | DISABLE |
| AOC_DOWNLINK_MESSAGE_TIME_STAMP | DISABLE | ENABLE | DISABLE |
| AOC_DOWNLINK_MESSAGE_SCRATCHPAD | DISABLE | ENABLE | DISABLE |
| AOC_DOWNLINK_MESSAGE_REJECTION_MESSAGE | DISABLE | ENABLE | DISABLE |
| AOC_DOWNLINK_MESSAGE_RESPONSE_MESSAGE | DISABLE | ENABLE | DISABLE |
| AOC_CUSTOMIZED_REPORT | DISABLE | ENABLE (3) | DISABLE |

**Figure 3-8 - Airline Modifiable Information for the A330 FMS**

So the question still remained so as to what triggered the transmission of the progress report message.

The question was passed to Airbus and some answers were offered. Regardless of the AMI specification, two trigger events cannot be override: change of runway at destination and change of airport at destination. That would indicate that in about 75% of the flights (the cases where no Progress report was sent in A330 fleet) no runway change is introduced in the FMS after the initial flight plan load (the amount of flights going to an alternate airport is negligible). This aspect was confirmed by a company's A330 captain I requested for that matter. After an observation period Airbus' answer seemed consistent with the factual observation. It was therefore accepted that no Progress Report is sent in the A330 fleet unless a runway or airport change occur. In this scenario, the progress report message in the A330 fleet becomes useless as no guarantee can be offer whatsoever that the message will be transmitted at all. The A330 case was left aside since the solution was clear: changing the AMI specifications and configuring the progress report message as desired. Unfortunately, there is an economic cost involved in these changes and are difficult to justify if only changes to progress reports' triggers are to be introduced.

### 3.5.1.3. Progress report in Boeing fleet

On B737 fleet seemed to happen right the opposite. Any change in any of the three parameters of the message triggered a new transmission with the updated fields. This was not useful either, as for some flights up to 15 messages were received. Contrary to the A330 case, no AMI file was found for the configuration of B737 fleet FMS since all values were left to default.

For the B737 fleet, I passed the question to Boeing. They confirmed that the current configuration triggers a new message transmission after change of any of the parameters of the message and that each message has a code that refers to what trigger condition forced each particular message to be sent. The possible causes for a message to be sent are described below, as received in the answer email:

```
25=Progress_Page_5R prompt
29=Time_to_Destination_1
2E=ETA_Change
2F=Dest_Airport_Change
30=Dest_Runway_Change
```

This new information opened the door for a new approach for processing the B737's progress report. By filtering progress report messages by trigger code, those with code number 29 would correspond to messages sent *x* minutes before arrival (exactly *Time_to_Destination_1* minutes before arrival, but this value was unknown).

I gathered progress report messages for 42 days by automatically configuring a retransmission of the message to a text file I created in my folder and these are the results of the analysis.

For the period ranging from 1/04/2009 until 12/05/2009, 5837 progress report messages were sent for the B737 fleet, 2378 of which with trigger code 29 (that is, sent because the aircraft was at *x* minutes before arrival). For each message the time at which it was sent is known. By comparing this time with the time estimated to arrive included in the message the following plot may be created.
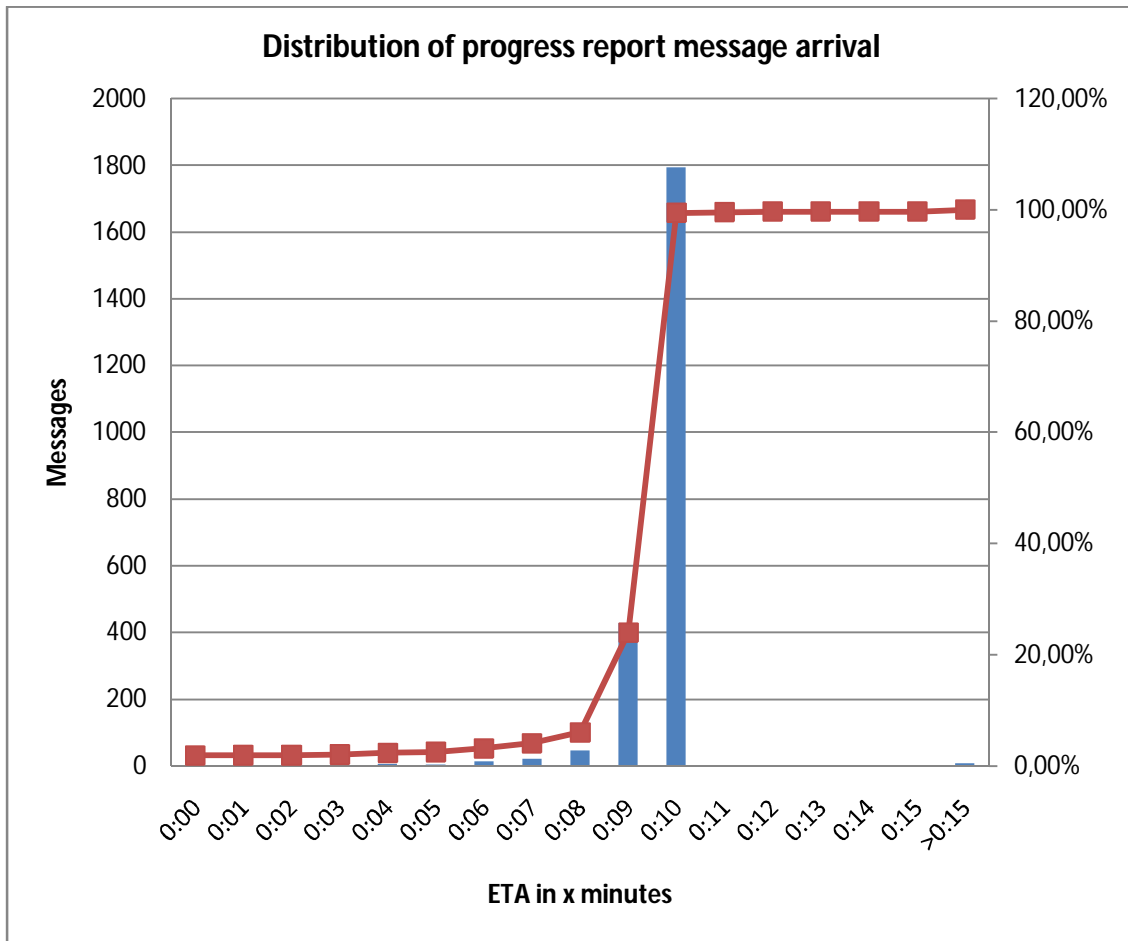
**Figure 3-9 - Distribution of progress report message arrival**

The graphic based on the following data:

| Time bef. arrival | Qty of messages | Cumulative prob. | Prob. for each class |
|---|---|---|---|
| 0:00 | 44 | 1,85% | 1,85% |
| 0:01 | 1 | 1,89% | 0,04% |
| 0:02 | 0 | 1,89% | 0,00% |
| 0:03 | 3 | 2,02% | 0,13% |
| 0:04 | 6 | 2,27% | 0,25% |
| 0:05 | 5 | 2,48% | 0,21% |
| 0:06 | 14 | 3,07% | 0,59% |
| 0:07 | 22 | 3,99% | 0,93% |
| 0:08 | 47 | 5,97% | 1,98% |
| 0:09 | 428 | 23,97% | 18,00% |
| 0:10 | 1795 | 99,45% | 75,48% |
| 0:11 | 3 | 99,58% | 0,13% |

| | | | |
|---|---|---|---|
| 0:12 | 1 | 99,62% | 0,04% |
| 0:13 | 0 | 99,62% | 0,00% |
| 0:14 | 0 | 99,62% | 0,00% |
| 0:15 | 1 | 99,66% | 0,04% |
| >0:15 | 8 | 100,00% | 0,34% |

**Table 3-3 - Distribution of progress report message arrivals**

Where *Qty of messages* is the amount of messages received (*Time bef. arrival*) minutes before arrival.

It may be said that the FMS aims to send the message 10 minutes prior to landing, as 93.48% of messages arrival estimate landing time between 9 and 10 minutes later. The deviation may come from the fact that a delay may arise if another message is being sent at that moment from the aircraft (there is a queue for downlink transmission) or from the delay of the network itself, considered very low, but not completely negligible.

Additionally it has been observed that if for some reason the first ETA is unable to be achieved (go around, longer route at last minute...), a second progress report message is sent with the corrected ETA. This explains the relatively high value of messages estimating arrival in less than 1 minute.

In the second part of the study I contrast the ETA included in the progress report message with the actual landing time. It is not sufficient to know that the FMS estimates landing in 10 minutes; it is also important to evaluate its accuracy. By comparing the ETA in the progress report with the corresponding time of the ON event message the following conclusions may be drawn based on 2064 observations:
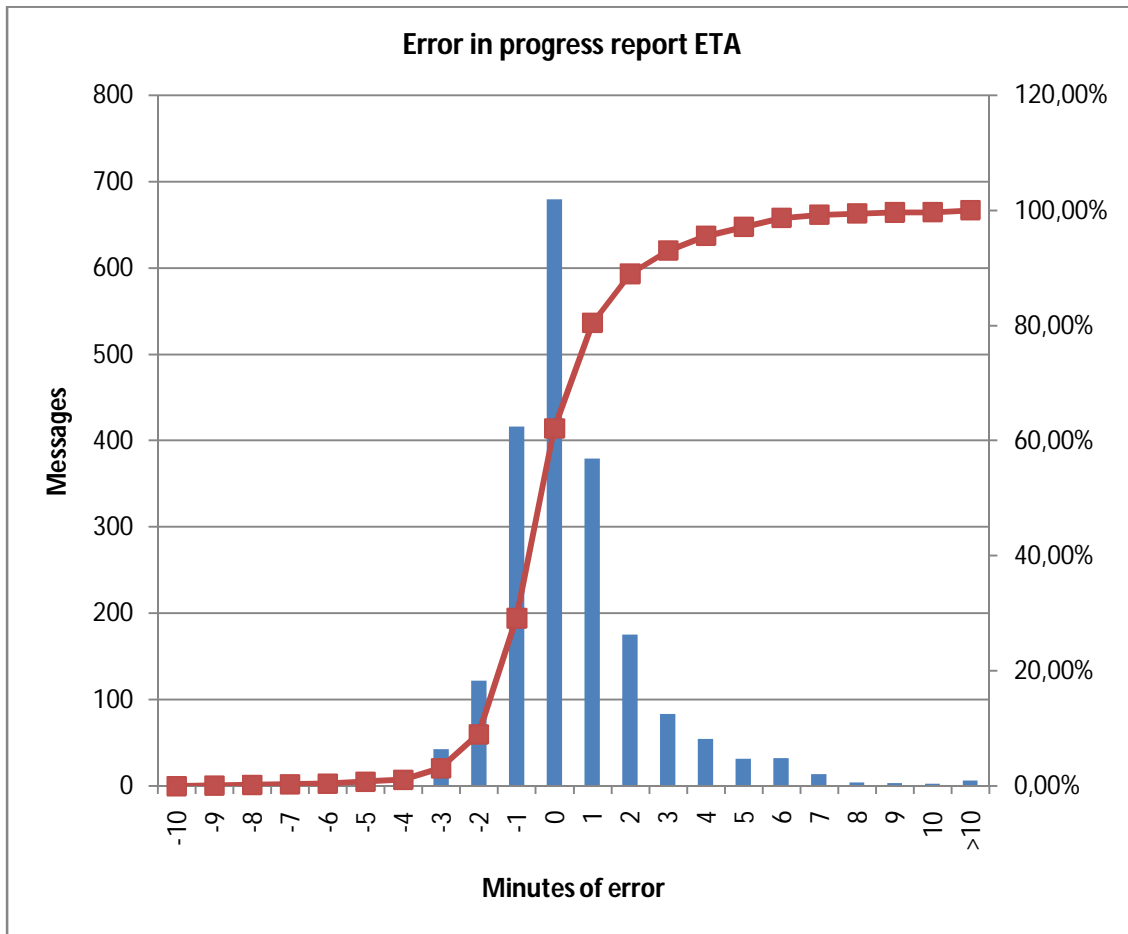
**Figure 3-10 - Error in progress' report ETA**
Negative values indicate arrival before ETA.

This second chart is based on the following data:

| Minutes of error | Qty of messages | Cumulative prob. | Prob. for each class |
|---|---|---|---|
| -10 | 0 | 0,00% | 0,00% |
| -9 | 2 | 0,10% | 0,10% |
| -8 | 2 | 0,19% | 0,10% |
| -7 | 2 | 0,29% | 0,10% |
| -6 | 3 | 0,44% | 0,15% |
| -5 | 6 | 0,73% | 0,29% |
| -4 | 7 | 1,07% | 0,34% |
| -3 | 42 | 3,10% | 2,03% |
| -2 | 122 | 9,01% | 5,91% |
| -1 | 416 | 29,17% | 20,16% |
| 0 | 680 | 62,11% | 32,95% |
| 1 | 379 | 80,47% | 18,36% |
| 2 | 175 | 88,95% | 8,48% |
| 3 | 83 | 92,97% | 4,02% |
| 4 | 54 | 95,59% | 2,62% |

| | | | |
|---|---|---|---|
| 5 | 31 | 97,09% | 1,50% |
| 6 | 32 | 98,64% | 1,55% |
| 7 | 13 | 99,27% | 0,63% |
| 8 | 4 | 99,47% | 0,19% |
| 9 | 3 | 99,61% | 0,15% |
| 10 | 2 | 99,71% | 0,10% |
| >10 | 6 | 100,00% | 0,29% |

**Table 3-4 - Error in progress' report ETA**

As shown, most flights (~71%) land within one minute of the ETA previously transmitted. More importantly, only 9% of flights arrive more that 1 minute before it was estimated, reducing the probability of getting ground handling caught absent as a result of an unexpected early arrival. Once the accuracy of the progress report has been confirmed it could be possible sending this information to ground handling's application (SmartHand).

With this aim a meeting was held between ground handling, flight operations and maintenance-engineering, where I was the representative of my department. I presented the findings of the progress report message itself and its accuracy and proposed to integrate it as a warning signal of the aircraft about to land. I ruled out integrating A330 messages as there was no clear pattern regarding its transmission: only B737's progress reports would be taken. For filtering the code 29 progress report from the remaining ones I created a new template for these ones and only these ones would be forwarded to ground handling application. I proposed to use the same technique I found it has been in place in other messages: creating and storing a text file (.txt) in a particular folder of a Globalia's ftp server. Each message constitutes one text file whose name is just a 6 digits sequential number. If the maximum number of text files is reached (1 million) the naming of the files start over again overwriting existing messages but this situation is expected to occur in more than a decade.

Once the file is stored in the ftp server SmartHand accesses this text file and read its content. The ftp server warns SmartHand that a new file has been created. As may be supposed the format of the data written must be agreed between both departments in order to know what to write and how to interpret the text file. In figure 3-11 a bunch of progress reports may be seen.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jul-29 2009 09:53:20 | 4090616 | → | Out Down | Progress Report B737 | .EC-JNF | UX1011 | | CDG7 | FILECNX | d:\ftp_root\acars\007291.txt |
| Jul-29 2009 09:53:20 | 4090616 | ✓ | In Down | Progress Report B737 | .EC-JNF | UX1011 | FML | CDG7 | RELAY | QXSXMXS |
| Jul-29 2009 09:25:29 | 4090458 | → | Out Down | Progress Report B737 | .EC-JHK | UX7221 | | OVD7 | FILECNX | d:\ftp_root\acars\007284.txt |
| Jul-29 2009 09:25:28 | 4090458 | ✓ | In Down | Progress Report B737 | .EC-JHK | UX7221 | FML | OVD7 | RELAY | QXSXMXS |
| Jul-29 2009 09:14:13 | 4090407 | → | Out Down | Progress Report B737 | .EC-JHL | UX9068 | | TFS7 | FILECNX | d:\ftp_root\acars\007281.txt |
| Jul-29 2009 09:14:13 | 4090407 | ✓ | In Down | Progress Report B737 | .EC-JHL | UX9068 | FML | TFS7 | RELAY | QXSXMXS |
| Jul-29 2009 09:08:24 | 4090384 | → | Out Down | Progress Report B737 | .EC-KCG | UX0342 | | PMI7 | FILECNX | d:\ftp_root\acars\007280.txt |
| Jul-29 2009 09:08:24 | 4090384 | ✓ | In Down | Progress Report B737 | .EC-KCG | UX0342 | FML | PMI7 | RELAY | QXSXMXS |
| Jul-29 2009 08:48:19 | 4090279 | → | Out Down | Progress Report B737 | .EC-JBJ | UX5141 | | SVQ7 | FILECNX | d:\ftp_root\acars\007276.txt |
| Jul-29 2009 08:48:19 | 4090279 | ✓ | In Down | Progress Report B737 | .EC-JBJ | UX5141 | FML | SVQ7 | RELAY | QXSXMXS |
| Jul-29 2009 08:40:46 | 4090243 | → | Out Down | Progress Report B737 | .EC-KEO | UX9018 | | MAD7 | FILECNX | d:\ftp_root\acars\007274.txt |
| Jul-29 2009 08:40:46 | 4090243 | ✓ | In Down | Progress Report B737 | .EC-KEO | UX9018 | FML | MAD7 | RELAY | QXSXMXS |

**Figure 3-11 - Progress report forwarded to an ftp server**

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There is no reply to this message. With this data ground handling is now able to warn its staff than a given Air Europa aircraft is 10 minutes from landing. It may not seem a lot of time but is sufficient to prepare ground equipment and staff and not getting caught absent when the aircraft arrives.

Unfortunately the efficiency of this new measure cannot be quantified as no data is available regarding these aspects.

## 3.5.2. RAMP SERVICE REQUEST

Ramp service request is a downlink message initially sent by the A330 and B737 fleets informing what services will the flight need upon arrival. No such message existed for the E195. It requires manual input from the crew, both for filing the fields and for launching its transmission. As a consequence, the moment at which it is sent (if sent at all) and the correctness of the data in it contained depends on human factors. AirCom Server reformats the message into a more legible layout (fig 3-12 and 3-13) and it is then forwarded to the relevant handling agent via ground communications.

```
QU PMIARUX  ZRHEEXH
.DDLXCXA XS/271042
_A80
FI UX41/AN  EC-KOM
DT DDL MVD 271042 M31A
-   3D01 RMPSRV 0041/26 LEMD/SAEZ  .EC-KOM
/LAV Y/CAB Y/MEDA N/SEC Y/WCHR 02/UMNR    /MAAS N
```

**Figure 3-12 - Raw Ramp services request message**

```
"RAMP SERVICES REQUEST" DATA LINK MESSAGE
FROM A/C EC-KOM TO EZE HANDLING

Flight ID: 0041
Route: MAD-EZE
Date/Time: 27/07/09 10:42

Lavatory Service required (Y/N)? Y
Cabin Service required (Y/N)? Y
Medical Service required (Y/N)? N
Security Service required (Y/N)? Y
Meet/Assist required (Y/N)? N
Number of WHEEL CHAIRS required: 02
Number of UM's on board:

Free Text:



Attn. EZE Handling:
Please, ACK this notification to the A/C by data
link message.
```

**Figure 3-13 - Reformatted Ramp services request message**

If the message is indeed sent (it is encouraged the message to be sent on all flights), it offers valuable information for turnaround planning. It is usually replied with a short ACK message, with no predefined format or procedure so each ground user sends it as considered appropriate.

It is a fact that many passengers on transatlantic flights continue their journey onwards once arrived to Madrid's hub. For that reason on the A330 fleet ground handling replies with the boarding gate for all connecting passengers on board. The datalink system on the Airbus fleet (ATSU) is not connected with the In-Flight Entertainment (IFE) system so the information has to be announced over PA instead of being displayed using the available screens. In addition to that, ground handling agents have to manually type all connecting gate information prior to its transmission. As a result, it was only broadly used on A330 arrivals, rarely on B737. After reception it was the user who copied the data received in the message into the window menu existing for this purpose:

**Figure 3-14 - Special services window**

This is feasible when there is no more than 1 transatlantic arrival per aircraft per day in MAD, giving a maximum of 6 daily messages (there are 6 A330 in the fleer) but becomes impractical when adding the nearly 50 daily B737 arrivals to MAD.

Another purpose of the meeting previously described with ground handling representatives was to agree on a solution for reducing human intervention in the process of reading and replaying to these messages. One reason for this goal was that it was desirable to expand the use of this message to the B737 fleet. The fact that from Maintenance-Engineering we suggest using a given message is because other departments are not normally updated of what messages exists. Experience showed positive reaction to the use of Ramp Service Request on the A330 fleet both from crew and ground handling agents but adopting its use for the B737 fleet without any technical improvement could imply a too high workload as the process was still mainly manual.

Ground handling was extremely cooperative and we quickly come to an agreement that it would be beneficial to integrate the ramp service request message. It was left to know the technical aspect of this integration. The problematic point with this message was with the associated reply to it called ramp service reply.

From the downlink side of the issue, it was agreed to integrate the Ramp Service Request message to SmartHand system by automatically loading the required assistance fields in it contained. At the same time flight status will change into *final*, which indicates that the flight is close to arrival and as such will be shown to users. This part alone would already reduce significantly the workload on ground; no manual processing of incoming messages would be further needed. The format of the message is known, it was only a matter of creating a routine that reads and extracts data from the ramp service request message when it arrives to the handling software.

The willingness to integrate data from handling representatives made possible that further improvements took place. Until that point the reply that was sent back to the aircraft is shown in Fig 3-15. It basically contained information intended for connecting passengers, such as flight number, destination, number of passengers in each connection and the assigned

boarding gate.  The message is copy-pasted for each flight on ground from another application and then the values are changed accordingly.

```
FLT------DEST---PAX---GATE
UX7304----VGO----10----E75
UX2004----BCN----11----E82
UX9185----ACE----03----E71
UX6067----PMI----02----E81
UX1023----ORY----09----E73
UX1043----FCO----26----E80
UX2006----BCN----11----E77
UX1015----LGW----30----B25
UX7306----VGO----01----E75
UX9172----LPA----10----E72
SLDS/GLORIA
```

**Figure 3-15 - Initial ramp service reply**

Before applying the changes shortly described, the reply was sent by ground handling as an email to AirCom Server who adapted the format and forwarded it uplink to the appropriate aircraft. The biggest inconveniences of this method were that email is not frequently used in ground handling. Most messages are sent using SITA's telex from embedded menus in the SmartHan application. Sending an email requires a second application to be installed/opened and it becomes a deviation from the common procedures. Additionally, the email has to be written following a particular format in order to AirCom Server accept it and forward it correctly, and no preformatted structure is presented to the user. Data is not preloaded either; data finding remains manual and, consequently, time consuming.

In these circumstances it was not infrequent that to reply was sent or that it contained formatting mistakes that prevented AirCom Server from forwarding the message. At crew's eyes, the final result in both cases was as no reply was sent. If this task was to be performed more than 50 times a day (with all daily B737 and A330 arrivals to MAD) it seemed logical to make it as much automatic as possible. A new procedure for sending the reply message had to be created and, taking advantage of the changes, some extra fields were introduced in the uplink message. Figure 3-16 show the agreed uplink message.

```
ACK RMPSVR (051010)
UX1012/10
-PKG T10
-BELT 18
-TTOS
 FLT        DEST   PAX    GATE
.UX1010    PMI     3     E10
.UX2345    MAD    19     E78
.AF9988    ORY    17     123
-SLOT UX1013/10
.SAM 1015
.OPS/GRF MAD (STAFF 23456)
SI NIL
```

**Figure 3-16 - Modified ramp service reply**

The first major change is that this new message is embedded in SmartHand application - requires no second application- which represents a major improvement for reducing ground handling workload, especially when many more messages are to be used on daily basis. After reception from the crew of a Ramp Service Request message -already integrated in SmartHand application- the user may reply using the right click of the mouse. A new window pops-up with the message structure and some data preloaded. The informatics aspect of this integration was left to Globalia Sistemas, as they are the only ones who have access to the source code of the Smarthand application, but the requested changes were specified in the meeting and in subsequent emails.

A second important improvement in the uplink message is the amount of data sent to the aircraft. On top of the boarding gate information for connecting passengers, new information has been added.

- Parking number: either a remote stand or an air-bridge stand, crew will be aware well before arrival of the estimated parking position, making it easier for planning the deboarding.
- Belt number: the belt number at which baggage will be delivered. This information may be useful for those passenger less used to the airport environment.
- Slot information: important information if the following flight is ATC restricted. By sending this information crew will be able to better manage the turnaround time, avoiding last minutes hurries or, at worst, missing a slot.

As with all datalink messages, the origin application, in this case SmartHand, sends the message to AirComServer. For this reason, and once the fields to be introduced were agreed, I defined the format of the message is such way that the transit through AirCom Server is as smooth as possible. In other words: the same information may be sent with different formats

and some of them are easier to process than others. Once the message arrived to AirCom Server, the right format is applied for an uplink transmission, selecting either the printer or the MCDU as the destination application. In this case, the message is sent to the screen and is then up to crew's decision printing it or not.

Another point of this meeting was to hear ground handling's opinion about datalink and what further improvements could be made. We quickly agreed that Embraer's datalink should be upgraded. Ramp service request message should be also included in the Embraer fleet, which was not at that moment, as it was a very useful message for ground handling.

Last week of July this semi-automatic message reply entered into daily operation. No problems or errors were reported. A possible measure the effectiveness of this new message reply is whether it would increase the amount of ramp service requests messages as a result of this improved reply. It would be desirable to have more ramp service request messages per flight than before the changes; that would indicate that crews want to have the information contained in the reply and, in order to obtain it, send the ramp service request message.

This analysis was performed 29$^{th}$ of July. At this moment the new reply was only in operation since 22$^{nd}$ of July, so a 7 full day period was taken as the basis for the study. For each period from 2$^{nd}$ to 8$^{th}$ (indexed with the number 1) ; from 12$^{th}$ to 18$^{th}$ (indexed with number 2) and from 22$^{nd}$ to 28$^{th}$ (indexed with number 3) of each month the amount of ramp service request messages sent from all aircraft is compared to the amount of flights able to send messages in that period. First data is obtained by filtering in AirCom Server historic log; the amount of flights is obtained from company's flight schedule in the intranet. In normal conditions each flight should send only 1 message per flight. The results are shown in table 3-5.

| PERIOD | # OF MESSAGES | # OF FLIGHTS | RATIO MESSAGES/FLIGHT |
|---|---|---|---|
| *July3* | 662 | 867,62 | 0,76 |
| July2 | 629 | 869,75 | 0,72 |
| July1 | 537 | 852,71 | 0,63 |
| June3 | 554 | 797,33 | 0,69 |
| June2 | 521 | 778,16 | 0,67 |
| June1 | 564 | 750,47 | 0,75 |
| May3' | 531 | 783,13 | 0,68 |
| May2' | 535 | 726,33 | 0,74 |
| May1' | 530 | 776,03 | 0,68 |
| April3 | 519 | 725,62 | 0,72 |
| April2 | 513 | 776,74 | 0,66 |
| April1 | 573 | 746,21 | 0,77 |
| March3 | 402 | 697,22 | 0,58 |

| | | | |
|---|---|---|---|
| March2 | 362 | 705,03 | 0,51 |
| March1 | 152 | 736,27 | 0,21 |
| February3 | 39 | 746,92 | 0,05 |

**Table 3-5 - Ramp request message sent evolution**

Some comments on these results are necessary. The low number of messages sent in February and March are the result of being the first months of operation of the ramp service request. That is, during the course of this project the ramp service message, despite belonging to the A330 and B737 fleets, was started being forwarded to ground stations so a transition period for everybody familiarizing with the new message was necessary. From April 2009 onwards the amount of ramp service request messages is stable at nearly 1 message every 2 flights. July3 is the only period with the new reply in operation. It is the second higher ratio of the series but due to the low number of observations available it cannot be concluded based on this data that the new reply has produced an increase in ramp service requests transmissions. Figure 3-17 presents the same information in a graphical way with a 3 periods moving average superposed:
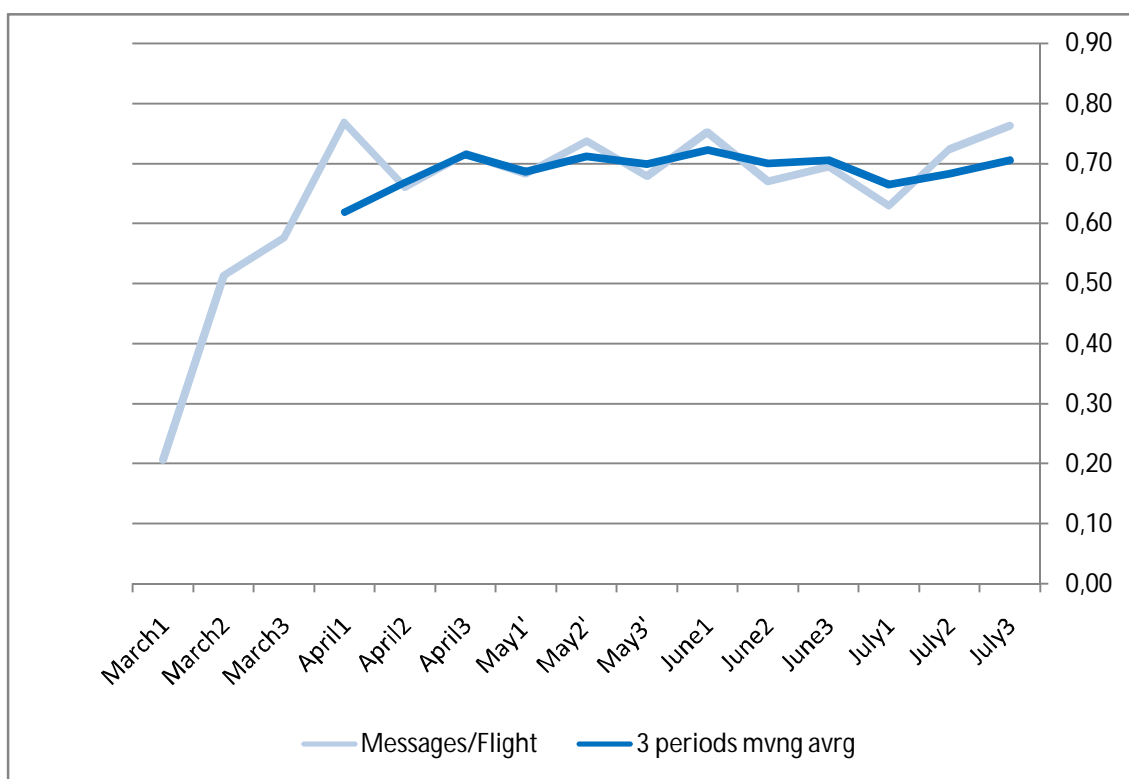


**Figure 3-17 - Evolution of Ramp Service Request transmissions**

Despite the statistics not being mathematically conclusive whether there has been a significant increase in request messages an encouraging trend can be observed in the month of July where the number of messages increased for two consecutive periods for the first time in the stable section. This increase in ramp service request transmission will probably affect positively the ground handling overall performance: it may be expected a decrease of

passengers requiring unexpectedly assistance at aircraft arrival or a better time management of machinery and staff. However these are long term effects that unfortunately will not fit into this project's deadline.

It has to be noted that a ratio of 100% of flights sending ramp service request is not achievable. There are charter and military transportation flights to airports out of Air Europa standard network where the message will not be understood by their ground applications. An increase of 10-15 percentage points until the 80-85% level could be considered a good result. It would indicate that there is added value on the new reply which forced to break the fairly stable trend of the last 4 months.

### 3.5.3. SUMMARY AND REMARKS

Ground handling representatives were very keen on new datalink data to be sent to them. Meeting was very fluent as were all subsequent emails for defining the technical aspects of the messages and formats. These new message forwarded to ground handling will probably make more predictable the time at which Air Europa's aircraft arrive and what will they need upon arrival. This shared information fits within Collaborative Decision Making policies promoted by airport authorities and air navigation service providers. By sharing available information by all involved parties in commercial aviation, an overall increase of capacity and on-time flights performance can be achieved. The remaining part of these policies is to share the same information with the airport authority, AENA in Spain, for a more predictable time of arrival of the aircraft.

On a technical note, again, as in the case of integrating data for SMA application, several possible improvements were noted along the meetings, particularly in the Embraer datalink although some minor improvements for the A330 and B737 were also found. The amount of changes for Embraer started to be quite respectable and it began to be sensible to think about modifying the on board software. Air Europa, however, never had modified any datalink software before so there was this unknown of how long it takes and how much will it cost to have the desired datalink. In any case, there was still no fundamental reason for changing as no substantial mistake was found.

# 4.   DEFINITION OF A NEW DATALINK SOFTWARE

## 4.1.   INTRODUCTION

As a result of a forced software change of the onboard characteristics of the datalink application in the E-195 fleet a new customized software was developed because the two standard alternatives were not satisfying. I wrote the specifications for this new software, based on the missing functionalities found in previous chapters and by comparison with other aircraft. After loading the new software in the aircraft, I reconfigured AirCom Server for processing these new messages and monitored the new aircraft. A new handbook was also written.

## 4.2.   NEW DATALINK SOFTWARE

In June 2009 decision was eventually taken that new datalink software will be ordered for the Embraer fleet. Reasons for this change are both practical and technical: technical in that Honeywell datalink product philosophy forced a change in the software loaded on board the Embraer; practical in that as the change was inevitable, it was made including those fields and messages that were subjectively missing.

Communication Management Function (CMF) is the part of the integrated avionics software dealing with the *datalink* communication. The configuration file for this function is called Airline Modifiable Information (AMI) database. In this database everything in relation with the datalink is defined: on board screen displays, available messages, format of these messages, frequencies to use... Generally, airlines do not have access to modify this database.

Upon introduction of a new subfleet a Datalink Service Provider (DSP) is usually chosen. In Europe it is either SITA or ARINC, both offering a very dense network throughout Europe. These networks operate at slightly different frequencies and have each their own ground antennas. Messages can be sent with any available network, but at significantly higher cost than if an exclusivity contract would be signed with any of the two companies, thus the reason for any major airline to have one DSP in exclusivity. In that case, unused frequencies have to be blocked. In May 2009 an agreement has been signed selecting SITA as unique DSP for the Embraer fleet.

Each new E-195 that joins the fleet comes with a default AMI database. It is fully functional without any restriction but the only particularity is that messages are sent using both SITA's and ARINC's networks, depending on availability. It is frequent that DSP contracts are not signed the first day of operation of a given aircraft (contractual restrictions from previous agreements, negotiation periods...) but datalink is used since the very first revenue flight or, as was here the case, datalink is also used during delivery flights. By being able to send messages

via both networks the availability of datalink communication is guaranteed from delivery and, at the same time, the same software suites both SITA's and ARINC's operators.

The typical next action by the airline after delivery flight is to block onboard the aircraft the frequencies associated with the DSP not chosen. In Air Europa's Embraer case that would mean inhibiting ARINC's frequencies in order to leave only SITA's ones active. This is a straightforward procedure both in Airbus and Boeing aircraft requiring no important change in the software. However, this step is different for the Embraer units.

For achieving the same effect in Embraer aircraft the full AMI database has to be changed, because part of the AMI database is the information of the DSP that the company has chosen, that is, what frequencies should be use for transmitting the messages. A new AMI database has to be ordered from Honeywell, the manufacturer of the Embraer avionics, and installed onboard the aircraft with all messages unchanged but with different frequency usage policies. At first sight that would imply a similar task compared to the Airbus/Boeing example, but there is an important difference between them.

When blocking frequencies onboard Airbus or Boeing, the only change introduced is the frequencies that will be used, leaving all other specifications aside. Changing the frequencies to use does not necessarily imply changing anything else. However, when loading a new AMI database in Embraer, everything is overwritten, including all menus, messages and formats, with the only difference of what frequencies are to be used. If new menus, messages and formats written are the same that were before, no changes will be noticed. But this apparently simple option is no longer provided by Honeywell: the choice of overwriting with the same menus, messages and formats (that is, the same AMI database just changing frequencies) is not supported by Honeywell. The reason alleged by Honeywell is that de default AMI (the one still included in each aircraft at delivery) is an ancient version based on and old standard and is no longer supported because they are now basing all their datalink applications in a renewed standard. Changing from the default AMI to any other, costs money; modifying the default AMI database for being only SITA, also costs money.

So, if an airline wants to block some frequencies in order to use only one DSP, everything has to be changed. If any airline wishes to block either SITA's or ARINC's frequencies from the default AMI database in Embraer because airline has signed an exclusivity contract with one particular DSP, all menus, formats and messages will probably change, too, unless the not-longer-supported default AMI is customized at extra cost.

Strangely enough, messages and displays in the new AMI database offered by Honeywell are the same for either SITA-only or ARINC-only version. While they offer some improvements as compared to be default version, there are also some important downsides. One of the most important messages was missing with no apparent reason in this new version and other important message lost some of their fields.

In particular, the AutoInit reply message disappeared in this new version. Oddly the Auto Init Request still remained: that is, crew could ask for an automatic initialization of flight data in the FMS via datalink, but the answer would never arrive as no reply message existed. Even if ground application would reply when seeing the request (ground applications are fully independent of the onboard systems), the onboard CMF would reject the message as being unknown. An explanation to this apparent mistake was offered by Honeywell, but it was not convincing at all. Without the Auto Init Reply message, crews are forced to introduce all data manually. It is worth noting that configuring the auto init reply was precisely the first task at the beginning of the project: setting AirCom Server so that the Auto Init Request and Replay are correctly processed for avoiding manual introduction of data by crew.

On the positive side some new messages were included which were missing in the default version although, globally, both versions were equivalent: what was missing in one version was included in the other one and vice versa. Bottom line was that neither version was satisfactory; ordering any of them cost money (too much for something that was not ideal) and ordering neither -and keeping the default AMI- also cost money because higher rates per message would be charged when using both SITA and ARINC.

In this scenario in which regardless of the step taken an economic cost was unavoidable an option long time abandoned –because of its cost- turn out to be the right solution: creating a fully customized AMI database with displays, messages and formats specified by Air Europa. After 4 months dealing with datalink issues since the project started in February 2009 and 2 months of datalink-related meetings with other departments the experience was judged sufficient to entrust me with a proposal of the specifications of a new AMI database for the Embraer 195 fleet.

Defining the goal was rather simple: conceiving the best possible AMI database for the Embraer 195. There were two auto-imposed restrictions:

- The new specification must be adequate to Embraer's missions. That is, there is no sense in including, for example, features commonly used on transatlantic flights as chances that Air Europa's Embraers will perform oceanic flights are extremely low.
- Embraer's datalink should be as close as possible to Boeing's and Airbus' ones. That implies reusing message formats whenever possible and keeping a similar architecture.

Honeywell, as other manufacturers do, offers two possibilities for modifying the AMI database: changes can be either ordered to Honeywell and done by their engineers or Honeywell can offer a tool and its associate training to airline staff and then changes performed in-house. The second option is generally worth when many changes are expected either now or in the future; for a sporadic modification or when no further development is expected it is better to commit these changes to Honeywell. Taking into account that no further development is foreseen, the currently available staff for training and costs involved in both options, it was decided to let Honeywell perform the desired changes as per Air Europa's specifications.

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For the sake of this description the names *default AMI* and *SITA-only AMI* will be used referring to the initial default AMI and the one that should be installed for having only SITA's frequencies available.

First issue I had was to define the baseline over which changes would be performed. The cost charged by Honeywell for the modifications is based on the amount of work involved. Starting from either the default version or the SITA-only version a good final datalink application could be obtained. Changes needed in either version were obviously different but the final product would be very similar.

Since both AMI versions could be partially reused and needed a similar workload before achieving the desired final version, the choice could not be centered on price. A first draft of the desired changes was passed to Honeywell and, as expected, price was not an issue for this selection so the AMI version which would host the desired changes was chosen to be the SITA-only one. The deciding factor supporting this decision was the previously stated fact that this version was the preferred one by Honeywell for future datalink development. If the default AMI would have been chosen as the base for introducing changes would have left Air Europa with a datalink in the Embraer fleet based on a version that even its manufacturer does not fully trust in.

Once the basic framework where changes would be applied was selected I could start a detailed study of required specifications. In short, it consisted in gathering together all missing functionalities of the SITA-only version as compared to the default AMI, adding all improvements envisaged during meetings described in chapter 3 and incorporating those messages present in either Boeing or Airbus datalinks missing in the Embraer one. The last version of the request and specification are included in annex A3.

In a summarized way, the changes requested are the following:

1. To make the AUTO INIT request message work again as it did in the default AMI version.
2. To add some extra fields were added to the already existing post flight report message; a message sent after flight which is used as a summary of the whole flight. In particular fuel burn fields were added as they will be used for feeding SMA system in a short future (when the A330 and B737 also have those fields transmittable).
3. To add the ETA time in the OFF report message, in line with the rest of the fleet.
4. To create a page called Fuel Load Info which should be filled before the flight with similar data as in the technical log book that, as 2. will feed SMA application.
5. To add the Ramp Service request as already exists in Rockwell Collins software. The format must match exactly the Rockwell's one for fitting in all existing templates.
6. To create a Main Menu, which was dropped in this AMI version and the initial page depended upon flight phase.
7. To scale the fuel on board (FOB) figure to be rounded to nearest tenth instead of nearest hundredth. This aspect, that seems so minimal, is very important for the European Emissions Trading Scheme (ETS) where a certain degree of accuracy must be

met. Bear in mind that if taxi fuel, for example is in the order of 100-250 Kg, having an accuracy of 100Kg is useless. By increasing this accuracy 10-fold new fuel statistics will be possible.

8. To revert Weather Request message to its initial version as in default AMI.

However, before this last variant was achieved two intermediate versions were created by Honeywell and loaded into the aircraft. In each new version I added those mistakes or errors found in the preceding and the feedback received from the pilots.

The first new AMI database designed by Honeywell's engineers was ready in three weeks time. During this time frequent consultation and refinement of the software took place and eventually on 30th June an engineering version was received. An engineering version is a non final version of the software, used for testing and evaluation in real environment before the final version is released. It is worth noting that the new AMI database is just comprised of three files of 300Kb combined.

Two days after reception it was installed in one single Embraer (EC-KRJ) for evaluation. As expected most messages had a different format so I had to create many templates for these new messages (same process as in chapter 2 of this project). This time, having done this task very frequently during this project, it took me just one full day compared to the couple of weeks it took at the beginning, when the destination user of each message, the AirCom Server application, the aircraft itself and the overall datalink system were unfamiliar. However the new software recently loaded was removed from the aircraft 4 days after its introduction when a potentially dangerous problem was observed: the fuel on board (FOB) information presented to the crew through datalink in the MCDU (datalink's HMI) did not match the FOB data presented from the FMS via the Primary Display; it didn't even match between different pages of the datalink menus. Even though datalink pages should not be used for checking fuel quantity on board, the fact of having incongruent information of such vital parameter on different displays in the flight deck made is safer to revert to the well tested default AMI version than keeping the evaluation version of the new AMI file. Figures 4-1 and 4-2 show this phenomenon. Both photos were taken with only 10 seconds of difference.

**Figure 4-1 - Fuel on board (FOB) field with figure and units in kilograms**



**Figure 4-2 - FOB field with figure in pounds and unit as KGS**

Honeywell was informed of the observed irregularity and began working in a solution. As changes were to be introduced to the apparently faulty new AMI version, I took advantage to incorporate further changes and making some minor corrections after receiving feedback from flight crews regarding possible improvements. A second engineering version was received by mid-July and tested again in one single airframe, this time EC-KXD. The requested improvements were introduced but the problem with the fuel on board figure continued.

A third version, this time with the FOB value toggling corrected, was received and loaded first week of August and there are no apparent failures or mistakes in this one so the formal final version of the product will be released by Honeywell, estimating first week of September.

Between each version of the software I crossed numerous emails with Honeywell for explaining the improvements we wanted and to describe the faults we observed.

When the modifications of the on board datalink application of the Embraer fleet were decided the most significant improvements were planned to be also introduced in the A330 and B737 fleets, namely those that implied new data fields to be loaded in SMA and the increase in fuel values accuracy, very useful for the ETS program. The process and available options were essentially the same: Rockwell Collins, the manufacturer of the A330 and B737 datalink, offers the possibility of modifying themselves the software or giving training for the airline staff in order to be the company who eventually make the changes. As in Embraer-Honeywell case it was decided to be Rockwell Collins who will perform the changes. Required modifications were passed for quotation and the reply was rather surprising: modifying Rockwell Collins' software was much more expensive (a 10-fold increase) and it would take much longer (6 months) as compared to Honeywell's software customization. With such cost and lead time the modification of A330 and B737 datalink was left aside for evaluation as in 6 months time there were further modifications of datalink planned. At the same time, A330's and B737's datalink was already very good and the modification requested consisted of just some minor aspects.

## 4.3.   SUMMARY AND REMARKS

Modifying the characteristics of the onboard datalink software, embedded in the CMF in the E-195, was the natural consequence of the missing fields and messages found in chapter 3. The analysis performed in that chapter was not intended to be used as the basis for modifying the software -the decision of customizing it came later- but turn out to be extremely helpful.

Writing the specification was a detailed task: once the final version is released, no more changes are allowed and this software will be used daily for the coming years so should not happen that, shortly after entry into service, someone realizes than any particular field is missing or is wrong. This is the reason I include so many fuel related fields, as the ETS program is not yet know exactly what figures will need at long term. It was felt better to be safe that to sorry later.

The final version of the request sent to Honeywell is the sixth one: it was quite demanding balancing everybody's opinion. In general terms, ground staff requested more changes to have the most data possible via datalink; on the other hand, flight crew preferred to keep the software as close as possible to the previous one. The cost of the modification would be the same (within limits) regardless the changes included so I introduced the maximum possible to maximize the investment. However I had to bear in mind that all fields created will have to be filled manually by the crew and, as Embraer-195 performs short-haul flights, there is no excessive spare time to be used in sending many datalink messages.

It is generally agreed within the company that the long term trend is probably the use of datalink even more. For this reason I tended to include more fields (satisfying ground sector) than requesting too little, in which case the whole modification would not make much sense. In this line some critics were received by flight crew about the new software as being less

intuitive than the preceding which is probably due to the fact of having more options and menus and, simply put, for being a new software at all. So now training and a familiarization period is required: on my tutor and my own side, whenever we went to an aircraft for seeing how the software was going all crews' questions were answered and explained the logic behind the changes. The overall feeling is that when explained, crews tend to accept better the change.

# 5.   USER HANDBOOK

One of the first steps was to create the user manual of the onboard menus of Embraer's datalink function. Based on Honeywell's manual for the Baseline AMI a first version was completed by the end of February. It contained the displayed pages on board and a description of each field of each page.  Every single display of the handbook was contrasted with the real display on board the aircraft. Even though the manufacturer's manual should be fully accurate, it was considered a sensible double check. Some minor changes were introduced in the handbook as a result.

However, this handbook never came to light because at the point it should, April 2009 approximately, as it was already known that in not longer than 2 months most onboard displays and options would change as a result of an onboard software update. It was seen more practical to wait and have the definitive version of the onboard software and the applicable handbook than introducing this one and modifying it some weeks later.

When the new version of datalink was loaded, a draft was already prepared for aiding crew members to navigate through the new datalink menus and pages. Again, it was based on the documentation received from the manufacturer. But the initially loaded version in June 2009 was an engineering version of a customized software, installed for testing. As such, there was no guarantee that no further changes would modify the software and therefore no official handbook was even planned. What was indeed produced is a draft, not double checked as the first handbook, given to crews as a basic aid. At the same time it was requested the crew to mark any mistakes or inaccuracies that could be present in this second handbook and also their feed-back after using this new in-test version of datalink.

Afterwards, a second engineering version was loaded in July 2009, after the problems reported in the first engineering version of the new AMI file and the feed-back received. A second draft was prepared and given to crew in a purely 'best effort' policy. This second engineering version was neither sure to receive no further changes. It was also requested to crews to point out possible mistakes as no documentation was received from Honeywell for this second engineering version.

By 13 August the third engineering version of the customized AMI software seem to be the definitive one. As in previous cases a draft to navigate through the menus and displays was produced but his one seems to be the last one. As the first handbook all displays depicted in it have been confronted with the real datalink software onboard the aircraft and supervised by my tutor. It will be then supervised by the deputy operation manager and finally accepted by the operations manager. The pages I wrote will be included as a new chapter in company's datalink handbook.

In annex A5 the last version of the handbook may be seen (only in Spanish).

## 6.    *AIRE* DEMONSTRATION FLIGHTS

Datalink offers capabilities that are not imagined at first sight. AIRE (Atlantic Interoperability Initiative to Reduce Emissions) is part of the FAA NextGen program –equivalent to European's SESAR- aiming to optimize oceanic flights. As such, the Embraer 195 is not directly affected as these flights are performed by the A330 fleet. However, these flights are the state of the art in datalink applications and are very illustrative of what are datalink possibilities and it was considered very instructive its inclusion in this project.

Only four selected airlines were invited by the FAA to participate in this year's flights (Air France, Lufthansa, American Airlines and Air Europa), based on the good relationship and previous experience with datalink use. FAA representatives, including the AIRE Program Manager, visited Air Europa premises for arranging this year's operations and, since this End of Studies project is strongly related to datalink, I was invited to assist to this meeting with my tutor.



**Figure 6-1 - Meeting with FAA representatives in Air Europa's premises**

The objective of these flights is to measure the level of fuel and emissions reduction as a result of a new optimized flight planning method. This optimization of the flight is based on the Oceanic Trajectory Based Operations (OTBO) and integrates trajectory planning, management and execution, from strategic planning to tactical decision making by allowing each flight to follow its optimal route, thus burning less fuel and emitting less pollutants. The difference with any existing flight optimization is that in this case, routes can be changed at any moment during the oceanic part of the flight. Normally, flight crews may request ATC a change in flight level after suggestion from the FMS if it is expected that fuel burn will be less in the new flight

profile. But additionally to these changes in these flights lateral profile can also be changed from flight operations perspective, not only from crew's one. In this scenario if flight dispatch, based on meteorological forecasts, estimates that a new route would offer any saving in fuel burn -even if the reason for the deviation is thousand miles ahead- this change can be performed, no matter how long or how deviate the new route is (traffic permitting). In summer 2008 prove of concept flights were performed as a first approach to determine if such procedures are feasible. Air Europa also participated in those flights and the results were very promising, offering fuel saving in the order of 1%-2%. In June and July 2009, the same test flights were conducted but the main goal of this year's test is to accurately quantify the savings offered by this new procedure in order to evaluate potential global benefits and general implementation procedures. Unlike last year's test, after this monitoring period this route changing will be possible to keep using them as standard procedure which grants that the investment for these trials will be recovered.

The concept lying underneath these de-routings is the refresh rate and the accuracy of meteorological forecasts used for flight planning. Weather models are updated two or three times a day with real data (depending on provider) and with this new data, forecasts are refreshed. This imply that from the moment at which flight plan has been calculated until the moment at which the aircraft overflies one particular point of that route may be a difference of up to 15 hours (assuming flight plan is calculated 3 hours before departure and flight time is 13h, as is the Madrid-Buenos Aires for example). The weather forecast, and in particular wind forecast, 15 hours ahead is probably less accurate that the latest available report, let's say, only 3 hours old. AIRE project was launched in order to undo the current suboptimal situation in which better data available by flight dispatch cannot be applied for having a better flight plan.

The protocol for obtaining a better route is fairly intuitive. Once the aircraft enters the oceanic segment airline operational control (AOC) monitors the pre-optimized flight path and weather reports. This protocol is only valid in Santa Maria Oceanic and New York Oceanic. These two centers cover most of the North Atlantic while keeping the number of centers involved low. If AOC finds a new user preferred trajectory, based on updated weather data, it sends a new flight plan starting from a intermediate point of the route (inside this Oceanic space) via datalink to the aircraft. It is done is such way that the proposed flight plan is automatically loaded in the inactive/secondary flight plan of the FMS. Flight crew determines if the proposed new route is acceptable and sends an acceptance or rejection message back to AOC. If route is accepted, sends the request to ATC for changing the actual route by the route that is still in the inactive/secondary flight plan. ATC receives this new trajectory request, performs all necessary checks and replies to the aircraft whether the new route is accepted or rejected. If new route is accepted by ATC, an acceptance message is sent to the aircraft and the flight plan is loaded as primary flight plan replacing the pre-optimized one and followed for the remaining of the flight. Otherwise, if the requested route cannot be accepted (conflict with other traffic is the most frequent cause for rejection), ATC evaluates any possible alternate trajectories and sends a proposal with the alternate route suggested to the aircraft. This new route will be followed or rejected after crew's inspection. If accepted, a WILCO message is sent to ATC; otherwise, a rejection message is sent and the process starts over again. AOC may reinitiate the process as

many times as required as long as in oceanic air space is initiated. It is also possible to alter a route already modified. The changed route may imply than after leaving oceanic air space a different route is followed, that is, there is no need that the exit point of the oceanic air space is kept fixed (for the moment only the entry point must be the same as the initial flight plan).

All this "conversation" between AOC, aircraft and ATC is held by datalink using satellite coverage, as it occurs far from any land area. The following image is taken from year 2008 trials from a Madrid-La Habana flight performed by Air Europa; this year's trials are essentially equal.



**Figure 6-2 - Planned and actual fligh path of flight UX0051**

Blue line represents the initially calculated flight plan route; red line the route eventually flown. A more southerly route was taken in the last part of the flight after a strong headwind was observed in the pre-optimized route. It is worth noting that the pre-optimized route is the optimal route at the moment of calculating the flight plan before departure; it becomes suboptimal only when weather changes if it changes at all. In this case, by the time aircraft would arrive to the place when wind changed adversely, flight plan (wind forecast in particular) would be 11 hours old (MAD-HAV flight time is roughly 9 hours; flight plans are presented 3 hours before flight). During this interval there has been sufficient time for wind to change. The new route in this example was started 1700NM approximately from destination.

These deroutings are not possible if seen only from flight deck perspective; there is no onboard system able to predict wind components at such distance. This is the reason for using ground based flight planning system with frequent weather updates. This year's better route optimization allowed for a fuel savings of 1700Kg (4.8%) of the total fuel burn in the oceanic

segment. This huge saving could be achieved because the derouting was found and accepted very early in flight and weather changed significantly so that a new best route was found.

It must be said that result seem only marginally positive. Although final results has not been published yet at the time of writing the project, Air Europa's interim results show that out of 24 flights programmed for June 2009 for monitoring, only in 8 cases a better route was found and accepted. It is important to note that not all flights are eligible for being de-routed: if weather forecasts do not change substantially, calculated flight plans are very close to optimal. In those cases were change is beneficial (one third of flights), an average saving of 400Kg was obtained in the oceanic section, which represent a saving of the order of 1.5% of the oceanic fuel burn. In any case it should be waited until the final results are published by the FAA taking into consideration the outcome of the test of all four companies involved (AirFrance, American, Lufthansa and Air Europa).

Further fuel burn reductions are expected in the approach phase. In Miami Airport there are Tailored Arrival (TA) procedures in practice after the oceanic segment as part of these trial flights. Unfortunately, the only TA arrival existing require aircraft to arrive from the north; the one weekly Air Europa flight to Miami approaches Miami from the south but here are plans to make the route longer only to be able to test this innovative procedure in September 2009.

A Tailored Arrival is a descent and approach procedure arranged between ATC and aircraft to follow a particular 4D trajectory calculated with the particular weather, weight and performance conditions of the flight by the ATC, aiming for a maximum fuel saving during descent. Ideally the descent is done with engines at idle. In this procedure it is the ATC who takes the initiative at crew's request.

When flight first contacts approach ATC it requests to perform a Tailored Arrival, reporting the selected descent speed to ATC. ATC replies, traffic permitting, with a 4D clearance via CPDLC; that is, a clearance for a particular lateral route, crossing altitudes and time restrictions based on existing traffic, weather and aircraft confitions. The requested time of arrival (RTA) concept was coined meaning that aircraft must be at a given point at a given moment (with precision of seconds). This point is usually close to the runway.   If FMS consider aircraft is able to follow this 4D route, an acceptance message is sent. In order to decide whether is possible or not to accept the 4D flight plan, current winds over the airport (winds aloft, direction and intensity of winds in airport vicinity) are loaded to the FMS via datalink. The descent is then performed at minimum engine thrust. Miami's TA require ATC to reclear the descent at different altitudes; other TA in less congested airports can clear all the way from cruising altitudes to right before landing. FMS and autopilot adjust descent speed to meet the agreed 4D trajectory and, if no unexpected event forces to interrupt the TA, aircraft is cleared to intercept ILS and land. This innovative procedure avoids leveling off at different altitudes which is the part where that most increases fuel burn during descent.
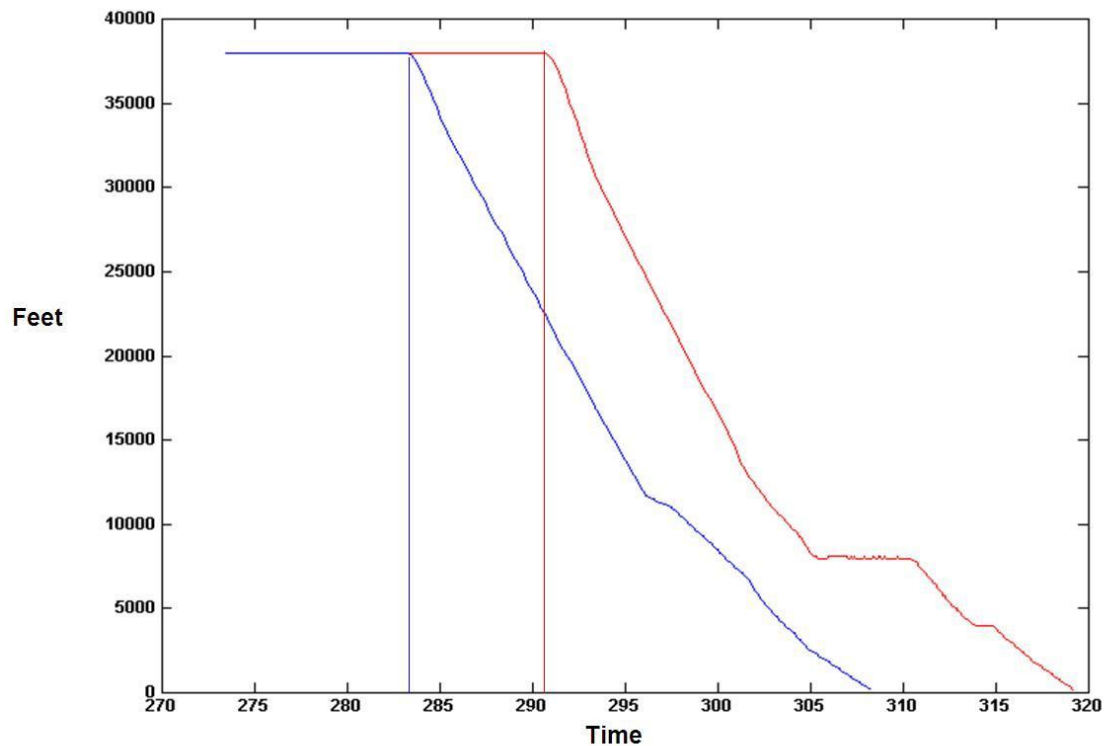
**Figure 6-3 - Tailored arrival vs classic descent profile**

Figure 6-3 shows the descent profile of a test Tailored Arrival after a Honolulu-San Francisco flight performed by a United Airlines B777 (blue, left) as compared to an everyday arrival on the same route (red, right). *Time* indicates flying time since departure. The duration in time of the descent is significantly shorter in a tailored arrival, 24 minutes as compared with 30 minutes in the 'classic' descent. But bigger fuel saving can be obtained by avoiding leveling off: in this comparison the non TA descent have leveled off for 5 minutes at 8000ft and then for 1 minute at 4000ft.

The results in TA approaches are very positive. Tests performed by the FAA in San Francisco by different companies and by Qantas in Sydney airport estimate fuel savings in the order of 30%-40% of the descent fuel. Qantas estimates fuel savings of 10Kg per descent in a B737, 30Kg per descent in a B767 and 100Kg in a 747 (10). Although may seem a small figure it may represent hundreds of tones yearly. Only considering Air Europa's B737 fleet if all arrivals to Madrid were to be performed using this technique (30 daily) it would represent an annual saving of more than 100.000 Kg of fuel and 315.000Kg of $CO_2$. An additional benefit of these arrivals is that less noise is emitted close to ground as a result of less thrust used and aircraft flying longer in higher altitudes. One of the most important aspects of Tailored Arrival is that they require very little investment for the airline. A last generation FMS and datalink communication is required, and these systems are already installed in virtually any major airliner. Crew familiarization is also quite simple: a TA is performed in a very similar manner as any other automatic approach, with the advantage of having good visibility.

Tailored arrival is the latest innovation for fuel saving. In this example they are done after a transatlantic flight, but they are feasible for every flight. For the moment these in-tests

procedure is carried out only in selected airports at off-peak time for minimizing traffic interruptions. Los Angeles (LAX) and San Francisco (SFO) have a decent experience with these flights. In Europe, Amsterdam has tested this procedure with positive results in low congestion and there will be high congestion trials in this year.

A suboptimal procedure, halfway between a classic approach and a TA, are Continuous Descent Approaches (CDA). It is not a customized (tailored) descent and approach in the sense that is static (no communication is needed); it is published along with other approaches in the AIP and it is the same for all aircraft and weather conditions.  It differs however from the classic approaches in that most (if not all) leveling off have been removed, thus allowing a continuous descent (at fixed angle) from a starting point. The starting point is usually at the end of the STAR, sometimes lower, but it is not as high as cruise level; it tend to be located in the 6000ft-12000ft range. Fuel burn and noise emission are reduced; not as much as in a TA but CDA's have the advantage that are easily implemented and are operational even in high congestion airports (see London Heathrow as an example).  As a previous step to wide TA use Eurocontrol have signed an agreement with airport and air navigation associations for implementing hundreds of CDA's across Europe.

# 7. AIRCOM SERVER HANDBOOK

As initially explained, datalink was a part time task shared between operations and maintenance. Changes to AirCom Server were introduced according to the needs but as nobody was fully committed to this task there was no document that captured all progress made in AirCom Server configuration. When I was learning how to operate AirCom Server many characteristics were found to be implicit, known by former users of the system, but needed for new users and nowhere specified. For example, some engine report messages are directly forwarded by SITA or ARINC (depending of the fleet) straight to the engine manufacturer but there is no indication of that transmission in AirCom Server or anywhere else.

In this project I made extensive use of AirCom Server as a system administrator. I created many templates and new users and some unused ones were deleted. Many other changes were introduced. For example, I made a complete restructuration of the organization tree of all templates: I found templates had to particular arrangement and they were stored on the go as they were created. I reorganized them be two big groups: messages concerning a request and messages reporting some information. Within each groups subgroups were created, mainly consisting on the addressee of the message: OPS, maintenance, ground handling...

After the project will be finished it may be difficult to know what caused one particular change to be put in place if its author –the student- is no longer linked to AirCom Server. It was therefore considered sensible to create an AirCom Server Administrator Handbook. This document does not aim to substitute the AirCom Server Administrator Guide offered by SITA, which is fairly useful and intuitive. Basic user skills are assumed for the full comprehension of the handbook whose purpose is to reflect the existent configuration; the grounds on which it is based and some unobservable details that may help in the future or for new users of the application. It also includes a short introduction of ARINC 618 and 620 protocols, the ones that govern datalink communications. The in-depth knowledge of both protocols is not necessary for daily datalink tasks but may be welcomed for advanced features or for those wanting to understand more than the basics. A step by step tutorial on how to create a template, along with the most common mistakes (the ones I made at the beginning), is also present. Finally, more and more messages are processed and forwarded on daily basis, and it becomes increasingly hard to remember the particularities of each of them, especially if no trace is left in the system. As it was shown in this project, many messages have a long story before they are first sent in daily operation: test messages, changes in format, spiteful details... In order not to repeat the laborious process of investigating the origin and details of each message all this elements are included in the AirCom Server Administrator Handbook.

It should help new datalink users to understand the basic functions of datalink and advanced users to see some infrequent details of some messages in particular that, very probably, nobody would remember in a couple of years should they not be included in this handbook.

Chapter A4 of the Annex show the first pages of this Handbook, only in Spanish, as it is meant only as a reference book used in punctual situations. After the foreword, a short global overview of datalink is presented, along with a detailed description of the process of reception of a message and the application of ARINC's 618 and 620 standards. These parts are already translated into English and included in the introductory part of the project. I opted to include these technical parts because ARINC's specifications (ARINC's 618 and 620 in particular) are rather dense and long –nearly 300 pages each- and I considered valuable offering the summary of the information there contained. Afterwards the step by step tutorial with screenshots of how to create a template is presented. From page 34 to page 137 (not included in the annex for being of very little practical information) all existing messages of all fleets (A330, B737 and E195) are described in detail highlighting those particularities that make each message special.

# 8.    CONCLUSION

This project was triggered by the arrival of the Embraer 195 to Air Europa's fleet and the increase of workload that resulted as a consequence. I was committed with the integration of the Embraer 195 and development of datalink applications with particular focus on the new aircraft. After a 6 months stage the key goals of the project as defined at its beginning have been satisfactory achieved and additional tasks also performed.

Embraer aircraft could use datalink without problems after the first month of the stage. The task of configuring ground applications had to be shared with intensive learning: datalink is an evolving technology in a domain halfway between aviation and telecommunications. Understanding the current situation and the daily details required going back nearly 30 years and rebuilding the evolution from ACARS to current technologies. This is also the only way to genuinely understand current and foreseen applications based on datalink. At the same time, datalink spreads its influences from ground handling to operational control so it greatly helps previous working experience in other departments, such as flight dispatching or airline operational control.

What was not initially planned was to modify the onboard characteristics of the Embraer 195. It turned out that requesting this modification was the most sensible step to take after the situation in which we were left. It was indeed previously envisaged the possibility of customizing the software, more a desire that a real need, but never seemed to be a reason to justify the investment. Defining the specifications for this new software was an ambitious final task for this project: everything learned all previous months would eventually materialise in a software used hundreds of times each day. When modifying the software current and forthcoming needs must be taken into account at equal level. At long term it is quite sure that the airline itself will perform these changes but this first time, in light of the troubles encountered with the new software, it was a prudent decision to let Honeywell perform them. Moreover, documenting changes is a must: many small details change very frequently, easily remembered for a week but undoubtedly forgotten after some months. Changes introduced in AirCom Server, the data integration in SMA and the datalink software of the Embraer, all comprised within this project, are meticulously documented. These documents along with this project could be well reused as an introductory guide to datalink for new comers as most tiresome technical details were left aside for the sake of a clear description.

After 6 months of work many things has been done but there are still plenty to do. The new Embraer datalink, for example, reports its position and estimated time of arrival every 15 minutes: this regular update may be very welcomed by ground handling agents or by the airport authority in the framework of Collaborative Decision Making (CDM) policies. Digital signature, a process in which crew sign and accept some documents such as loadsheet using datalink, is an ambitious long term datalink development already considered by the airline. In any case improvements are never enough; so Embraer's datalink can be further modified and

so can be Boeing's and Airbus'. It is agreed in the company that the long term trend will be datalink taking a major role in the information flow of the company. The initial investment – the onboard hardware- is already done; now it time to make profit from it.

In some sense this project summarises the process of introduction of datalink in any airline. First make sure aircraft are able to transmit data and learn what message format is followed; sign a contract with any datalink service provider; distribute the information received to the desired end-users and, if required, customize the software so that suits your needs even better. All these steps have been here presented although it would take more than 6 months if the company is a genuine new user of datalink. It is considered that it requires 2 or 3 years to become a mature user of datalink.

Aside of the main goals of the project I also performed many minor tasks related to Embraer and communications: investigation of failures, not only in datalink communication, but also in SATCOM and ADS; I also collaborated in the preparation of the documentation required for datalink project being subsidised as an R&D project; and I made the tutorial for decoding Embraer Fault History DataBase (a database of failures which can be downloaded), amongst others.

It is a fact that Air Europa's datalink has evolved considerably during this 6-months stage. However, this progress cannot be explained if not taking into account that most departments and individual workmates faced so positively the datalink issue. In some cases it was even them who approached me for more datalinked data. It was just needed that someone worked on it. In this line, I can do nothing but warmly thank my tutor for this project and the overall treatment received. She trusted in me since the very first day giving me a high degree of freedom in my work while being attentive at all times. All my doubts were promptly answered and new work was measured up for having always something to do but not too much. Aside of datalink matters I also attended to a B737 C-check, I participated in the ADS-B out certification of an A330, I processed Service Bulletins and was present in numerous interdepartmental meetings, including the AIRE test flights one and with Embraer representatives.  A great proportion of my satisfaction in Air Europa is directly attributable to her.

Part of the success of Air Europa, and the reason I am so satisfied of having done my project in this company, is that despite being a rather small airline -at least compared to Air France, Lufthansa or American Airlines, the other participants of the AIRE test flights- the ambitious and innovating mentality of each layer of the management make that there is little hesitation in participating in new technological programs or applying new procedures. At long term it yields very positives results and Air Europa is already seeing reward of previous efforts: this datalink adventure is now officially considered by the Spanish Ministry of Industry as a Research & Development project. As part of this R&D commitment Air Europa will participate in a two-years-long initiative to include environmental aspects in the Cost Index calculation in partnership with the University of Westminster, the Polytechnic University of Madrid and the Innaxis Foundation and I am very proud to be Air Europa's coordinator in this project.

# 9. GLOSSARY

| | |
|---|---|
| ACARS | Aircraft Communication and Reporting System |
| ADS | Automatic Dependant Surveillance |
| AEA | Air Europa (ICAO code) |
| AHEAD | Aircraft Health Analysis & Diagnosis |
| AIRE | Atlantic Interoperability Initiative to Reduce Emissions |
| AN | Aircraft Number |
| ANSP | Air Navigation Service Provider |
| AOA | ACARS over AVLC |
| AOC | Airline Operational Control |
| AOG | Aircraft On Ground |
| ARINC | Aeronautic Radio, Inc |
| ATC | Air Traffic Control |
| ATM | Air Traffic Management |
| ATN | Aeronautical Telecommunication Network |
| ATS | ATC Services |
| AVLC | Aviation VHF Link Control |
| CDA | Continiuos Descent Approach |
| CMC | Central Maintenance Computer |
| CMF | Communication Management Function |
| CMU | Communication Management Unit |
| CNS/ATM | Communication, Navigation, Surveillance / Air Traffic Management |
| CPDLC | Controller-Pilot DataLink Communication |
| CR/LF | Carriage Return / Line Feed |
| DCDU | Datalink Control and Display Unit |
| DSP | Datalink Service Provider |
| E-195 | Embraer 195 |
| EASA | European Aviation and Safety Agency |
| ENAC | Ecole National Aviation Civile |
| ETA | Estimated Time of Arrival |
| ETOPS | Extended Twin Operations |
| ETS | European Trading Scheme |
| FAA | Federal Aviation Administration |
| FANS | Future Air Naviation Systems |
| FI | Flight Identifier |
| FMS | Flight Management System |
| FOB | Fuel on Board |
| GMA | Globalia Mantenimiento |
| HF | High Frequency |
| HFDL | HF DataLink |
| HMI | Human Machine Interface |
| ICAO | International Civil Aviation Organization |
| LDM | Load Message |
| LRU | Line Replaceable Unit |
| MAU | Modular Avionics Unit |

| | |
|---|---|
| MCDU | Multi-Purpose Common Display Unit |
| MTOM | Maximum Take Off Mass |
| NextGen | Next Generation (an FAA program) |
| OOOI | Jointly Out, Off, On, In events message report |
| OPS | Operations |
| PFR | Post Flight Report |
| RGS | Remote Ground Station |
| RNP | Required Naviation Performance |
| SATCOM | Sattelite Communication |
| SESAR | Single European Sky ATM Research (an Eurocontrol program) |
| SITA | Societé International des Telecommunication Aériennes |
| SMA | Sistema Mantenimiento Aeronautico (Air Europa's software; Aeronautical Maintenance System) |
| SMI | Standard Message Identifier |
| SOS | Save Our Souls |
| SSR | Secondary Surveillance Radar |
| TA | Tailored Arrival |
| TE | Text Element |
| TLB | Technical Log Book |
| TLP | Technical Log book Page |
| UX | Air Europa (IATA code) |
| VDL2 | VHF DataLink mode 2 |
| VGS | VHF Ground Station |
| VHF | Very High Frequency |

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