Rey Juan Carlos University - Fuenlabrada Campus
April 24, 2013

ADS-B: An Air Navigation Revolution

Ernesto Atienza, Rami Falah, Santiago García, Lorena Gutiérrez, Miguel Ángel López Martínez, Óscar Robles

Abstract
The World is growing. Globalization is the order of the day. This implies the need of mankind to move worldwide. It is obvious that with the increase of the population, the air traffic increases on the same level, proportional to this growth. This is the spark that made us to think on how to make this viable in a short range, as well as in a long range.
This report has the objective to answer some questions related to air traffic management: would it be possible to automate the air traffic control? Would it increase this way the number of operations per hour?
Our work group is convinced it is, thanks to ADS-B. Next we will analyze if thanks to the ADS-B implementation we are able to achieve this objective, and also to increase air space capacity.

Contents

Introduction

The demand of the airspace will increase in the next 20 years. If we add the constant CO_2 emissions to the atmosphere and the imminent oil depletion, the system may collapse.
Due to these problems, two big organizations have been created; SESAR (in Europe) and NEXT-GEN (USA). These programs are dealing with the previous problems and with the actual limitations by using new methods which increase the safety and efficiency of the flights.
Could the use of ADS-B help to shorten out these purposes despite the actual limitations and problems?

In order to deal with these problems we have structured the paper into three parts: the first contains the main limitations the system is enclosed to, and the current methods, procedures and devices governing air navigation communication. Then we proceed with our selected system we think it could revolutionize the data and surveillance communication system: the so called Automatic Dependant Surveillance- Broadcast - ADS-B- which is completely implemented in the US, and in Europe is in a kind of beta mode. This is, it is starting to be implemented, but it's not used a primary system by itself.
In the third part we develop our contributions and support to the use of the ADS-B, this is, new areas in which the ADS-B could provide new solutions to problems that nowadays are not cover properly, and this way unify the communication, navigation and surveillance system.
As a curiosity, we've included a fourth section containing our visit to the World ATM Congress 2013.

1. Current navigation restrictions

1.1 Communication systems limitations

- VHF: Very High Frecuency

The transmission radio system VHF is one of the most used for the communication between the aircraft and tower.

It range depends basically on the existence of a line of sight between the transmitter and the receiver so that one of these problems is the need of the wave to have a free space to propagate. This is because these waves lack of the ability to perform ionosphere jumps.

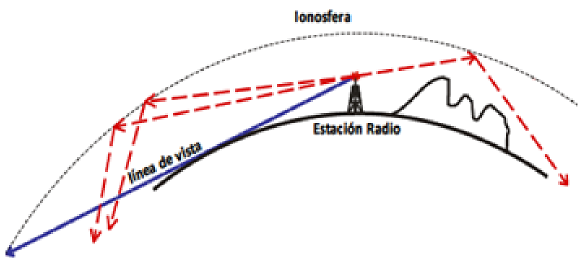

Figure 1. Ionosphere wave's reaction

We need to have in mind the attenuation and the dispersion of the waves. Another problem is the frequency or waves collapse, sometimes, produced by the FM radio stations. When the control tower is controlling several flights, the transmissions may collapse because of the use of the same frequency so they have to repeat the indications by wasting time.

- HF: High Frecuency

Nowadays it is also use the HF system. It is mainly used in oceanic flights because these waves do have the lack of ionosphere jumps so its range is high. The use of this kind of frequencies requires a decoder SELCAL which is so expensive and the transmission generates noise even if no message is being sent. One of the most important problems is the attenuation, so they can generate false responds.

- UHF: Ultra High Frequency

The main advantage of these waves is that the noise does not affect them and they can put up with a high density of communications. They are used mainly for military purposes.

If we observe the diffraction we can analyze the difference between these waves.

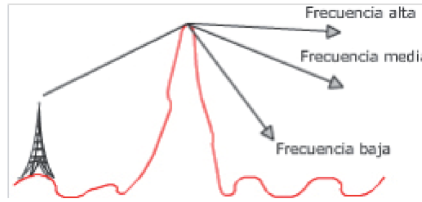

Figure 2. Wave diffraction

1.2 Data communication systems

- ACARS

Since the ACARS system uses telex formats that allowed us to cover a wide "range of possibilities" full of air and ground, and since in this final platform we can participate through an entire radio network transceivers that manages a central computer known: AFEPS (Arinc Front End System Processor), and could say that is receiving or transmitting the data link messages and routed to different airlines in the network.

The work of the joint air control unit (CDU) and avionics "ACARS Management Unit (MU)" in addition to the MU for VHF radios mentioned before becomes effective this support for pilots and participants of the performance of flight.

Considering his appearance in July 1978 with its main designers, Aeronautical Radio, Inc. (ARINC), and knowing their rejection due to ATN during the 20 years after the Internet Protocol, have sought objectives such as improving the Data integrity and reducing the workload of the crew.

Not to forget the three types of datalink messages that would be available to authorized personnel: Airline Administrative Control (AAC), Aeronautical Operational Control (AOC), Air Traffic Control (ATC), including ACC and AOC and were used to communicate between the aircraft and its base. The ATC message activity on his part complements previous communication between the aircraft and air traffic control (ATC).

- DATALINK

ADS allows the transmission of the derived parameters from the aircraft (position, identification...) via a data link "datalink".

Applications currently Surface to Air (T / A): Data Link Initiation Capability (DLIC), Controller Pilot Data

Link Communications (CPDLC), D-ATIS, DCL, D-Volmet.

Inside civil aviation, a system specific data link becomes use to send information between aircraft and air traffic controllers when an aircraft is too far from the ATC voice communication radio and radar observations possible.

In military aviation, a data link can also carry guided weapons information or information to help the earth fighter jets on aircraft carriers.

Knowing the two-way (full-duplex or half-duplex) will be responsible for sending the control signals and to receive telemetry within drones, ground vehicles, ships and spacecrafts.

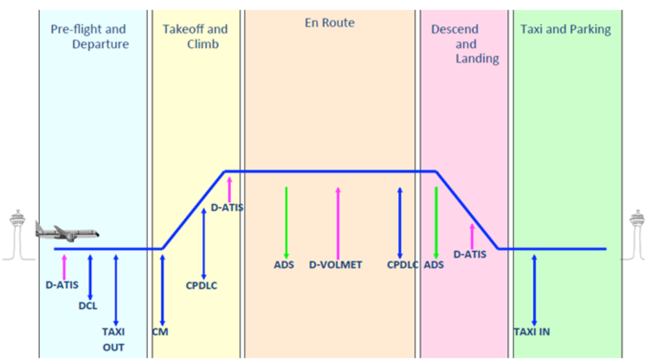

Figure 3. Data link applications during flight phases

Now it is shown a combination of the ACARS and Data-Link system in the aircraft communication and the different uses to make easier the pilot communication.

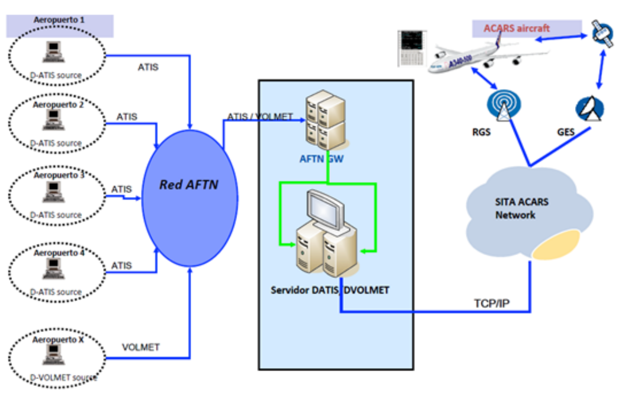

Figure 4. ACARS-DATALINK combination

1.3 Radars

- Primary radar

The route orientation of the studied radar antenna provides us the bearing of the aircraft from the ground station, this is, the direction, and the time needed for the pulse of the own radar to reach the target and return to the system provides a measure of the distance of the target from the ground station where is located. The bearing and distance of the target are converted to a ground position for being plot into a display to the Air Traffic Controller. the altitude is not taken into account by the ATC primary radars.

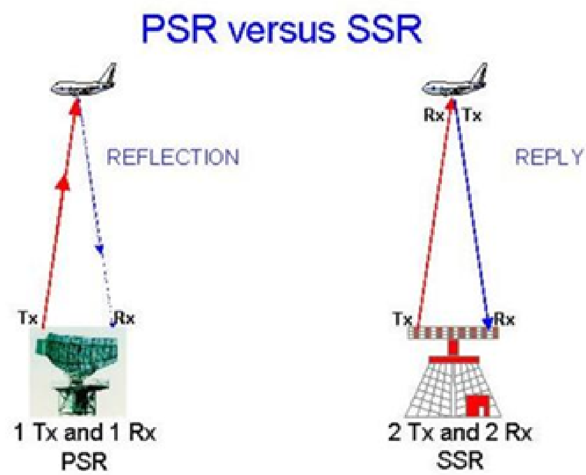

Figure 5. PSR vs. SSR

The advantage of Primary Surveillance Radar (PSR) is that it operates independently of the target aircraft, that is, no action from the aircraft is required for it to provide a radar return signal.

The disadvantages of PSR are that, firstly, enormous amounts of power must be exerted to ensure returns from the target.
This is especially true if long range is desired, which is most of the cases. Also, because of the small amount of energy returned at the receiver, the returns may cause a breakdown due to changes of target attitude or signal attenuation due to heavy rain or nay other meteorological condition.
This can cause the displayed target to fade. In addition, correlation of a particular radar return with a particular aircraft requires an identification process. When PSR was the only type of radar available, this was typically achieved by the Controller instructing an aircraft to turn and observing same on their display, or by correlating a DME distance report by the aircraft with the position of a particular return along a known track.

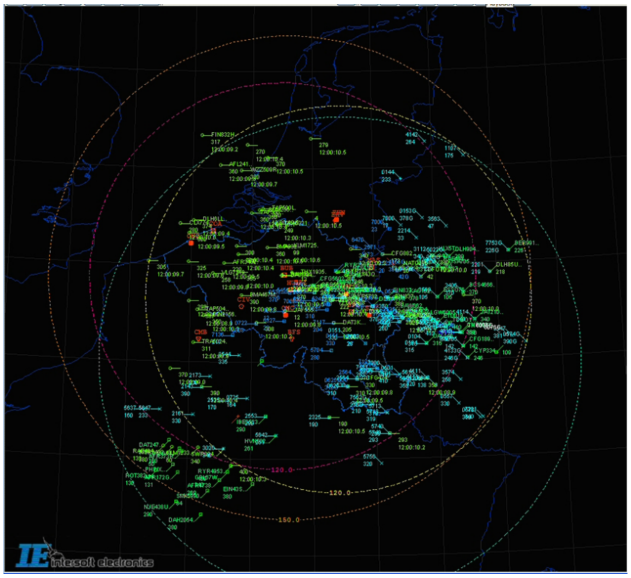

Figure 6. Radar display

- Secondary radar

The disadvantages of PSR outlined above led to the employment of another aspect of wartime radar development. This was the Identification Friend or Foe (IFF) system, which had been developed as a means of positively identifying friendly aircraft from enemy. The system which became known in civil use as Secondary Surveillance Radar (SSR), or in the USA as the Air Traffic Control Radar Beacon System, relies on a piece of equipment aboard the aircraft known as a 'transponder'.

The transponder is a radio receiver and transmitter operating on the radar frequency. The target aircraft's transponder responds to interrogation by the ground station by transmitting a coded reply signal. The great advantages of SSR are three: firstly, because the reply signal is transmitted from the aircraft it is much stronger when received at the ground station, thus giving the possibility of much greater range and reducing the problems of signal attenuation; similarly, the transmitting power required of the ground station for a given range is much reduced, thus providing considerable economy; and thirdly, because the signals in each direction are electronically coded the possibility is offered to transmit additional information between the two stations.

The disadvantage of SSR is that it requires a target aircraft to carry an operating transponder. Thus SSR is a 'dependant' surveillance system. For this reason, PSR will operate in conjunction with SSR in certain areas for the foreseeable future so that 'non-cooperating' targets, such as some light aircraft, can be detected.

Additional SSR Modes are used by military aircraft.

Incidentally, the sentences associated with the use of SSR link back to the early days of IFF when the equipment was code-named 'Parrot'. Thus an instruction to turn off the IFF equipment was to "strangle your parrot" and, conversely, to transmit the identification signal was to "squawk" - a phrase still in use today.

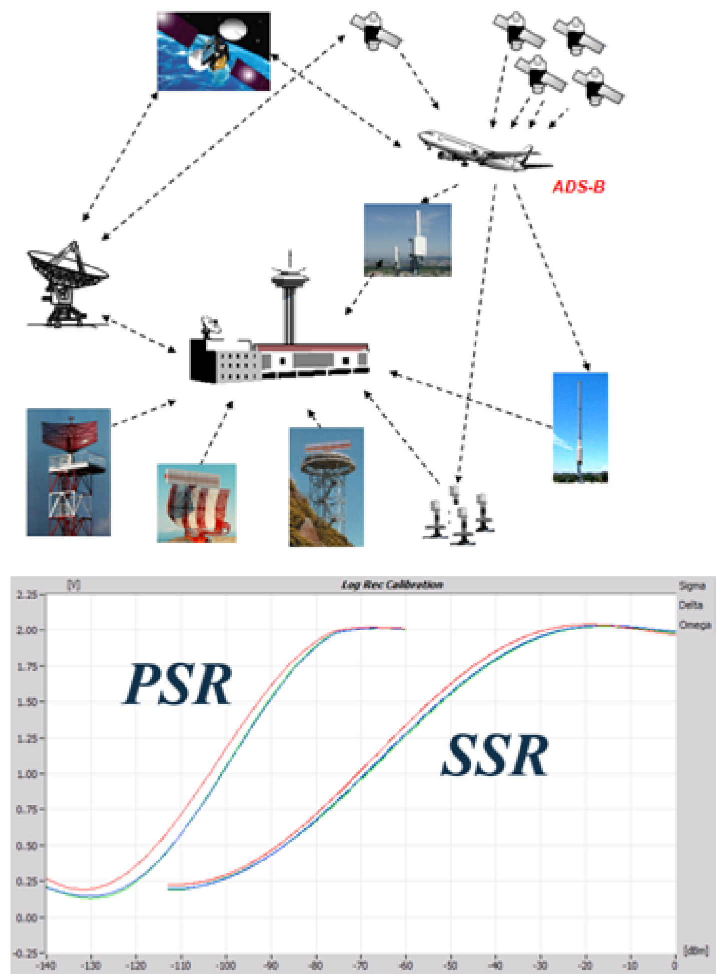

Figure 7. The use of ADS-B implemented with radar

2. Focus on the use of ADS-B

2.1 Main intro

The Automatic Dependent Surveillance-Broadcast (ADS-B) is a data link application that will transmit from aircraft and vehicles equipped to emit surveillance data (such as position and identification) by means of a broadcast-mode to users who can receive these data. That would provide for specific surveillance functions that would encourage co-operative air traffic management and collaborative decision-making among its users.

The main ADS-B benefits are extending the range and coverage of current ground-based secondary surveillance radar (especially around airport surfaces) to increasing air-to-air situational awareness. It also offers some innovative technology that could remove the delays attributed to reduced visibility, weather restrictions that would reduce departure operations. So the synthetic or virtual digital-imaging provided by the ADS-B will potentially increase safety.
Broadcast (ADS-B) application "Enhanced Air Traffic Services in Non-Radar Areas using ADS-B surveillance".

Improvement of the "gate-to-gate" concept, that is, accuracy surveillance in all phases.

Avionics devices that provide a cockpit display of traffic information (CDTI) enable pilots to acquire, verify, and maintain pre-defined spacing intervals from other ADS-B equipped aircraft. So the use of these displays influences pilot/controller operational communications.

The main goal of this system is to demonstrate a new air- and ground-based capability and to facilitate the controller task as well as in controlled tower, terminal radar and approach control. By this way the operational communications and workload will be diminished.

2.2 ATCO Communications efficiency

ADS-B could make a lot of improvements and advantages to the Air Traffic Controller, reducing their workload and making the things easier. It is also very useful to short out communication problems associated with misidentified aircraft, confusions, uncertainties, and operational concerns.
Communication problems were associated with the call sign procedure that was designed to distinguish between aircraft being talked to versus talked about. Fortunately, controllers and pilots detected and corrected these problems in mid-stream, and statistically, communication efficiency was not affected. In light of the findings and comments from the controllers and pilots, alternative call sign procedures will be constructed and evaluated for the departure spacing application.
A daily Pilot-Tower communication could be of the form:

- Pilot: *Alicante Tower, ECDGF good morning.*
- Tower: *ECDGF, Alicante Tower good morning go ahead,*
- Pilot: *Alicante Tower, ECDGF reaching Sierra to land in the field.*
  (Sierra is a point near the aerodrome to join to the circuit and approach to the field).
- Tower: *ECDGF proceed visual corridor report India, Sierra1.*
- Pilot: *proceed visual corridor report India, Sierra1, ECDGF.*

This communication if we introduce ADS-B system all previous communication is obtained by the Tower Controller and by this way the communications could be reduce to:

- Pilot: *Alicante Tower, ECDGF, good morning, reaching Sierra to land in the field.*
- Tower: *ECDGF, good morning, proceed visual corridor report India, Sierra1.*
- Pilot: *Proceed visual corridor report India, Sierra1, ECDGF.*

So by this way it is shown that some communications could be suppressed this means that when the air traffic controller support high work load, this reduction in communications helps a lot. Moreover it is not only the few communications suppressed, it is necessary to take into account that the frequency could be occupied by unnecessary communications, and an aircraft could need this communications to transmit something more important to the tower.

In ATC time is a very important factor that's mean that no time can be wasted, even less in frequency, because maybe the ATCO could need to use the frequency and an aircraft is using it in a useless way.

Furthermore in the Area Control Centers ADS-B advantages are much greater than in a Tower because its information display gives a lot of information like call sign, velocity, heading, accurate position, etc.

Once the Air Traffic Controller knows all this data, is able to arrange the airplanes routes and velocities on his mind is capable of organize the airspace in an efficient and quicker way, aiming by this way the less global delay and so saving fuel.

The most important point is that as shown before the operational communications are reduced so in this position where the Air Traffic Controller could aim very stressful traffic peaks where every second is needed, so once the aircraft make the first call the ATCO would have many information about this flight being the answer quicker better and more efficiency.

Here is shown some experimental data consisted of 15 hours of digitized voice communications.

It is obtained from an experiment carried out by the Federal Aviation Administration on Washington D.C.

Where a) N messages is the number of messages ,(b) TOF is the mean time on frequency per message, c) FOT is the total frequency occupancy time , (d) ROT is the runway ownership time and (e) TLC is the total time that the aircraft was under local control. [1] [2]

2.3 Use in non-radars Airspaces: ADS-B NRA

Because of the reduced cost of ADS-B GBTs compared with Primary Surveillance Radar (PSR) or Secondary Surveillance Radar (SSR) facilities, more GBTs could be installed instead of Radar station to cover the non-radar areas.[3]
During instrument conditions, airports without radar coverage switch to one-in, one-out procedures, limiting the arrival rate significantly. With ADS-B, controllers could maintain radar separation standards in areas with ADS-B GBTs and no radar. Benefits would include increased arrival rates at non-radar airports resulting in less holding prior to approach. Only operators who operate in non-radar environments under IFR would receive benefits.

Current radar surveillance cannot track aircraft beyond sight of land, requiring traffic over the ocean [4] to use inefficient and imprecise procedural techniques to provide separation. Therefore, the ADS-B is a powerful service to control the oceanic airspace, in this airspace management the controller wouldn't intervene. An aircraft send information (altitude, speed, heading, distance to the receptor aircraft...) to the close aircrafts and vice-versa.

With an ADS-B Cockpit Display of Traffic Information (CDTI), pilots are able to "see" other aircraft even low visibility conditions. Pilots can then maintain separation from these aircraft without instructions from Air Traffic Control (ATC).

Reduce the separation between aircrafts. This improves the efficiency and the safety in blocked airspaces like the North Atlantic region. Another application is to enable the Free Flight.

2.4 ADS-B for error avoidance, mitigation of errors and comparison with TCAS

ADS-B is characterized one more time by its capacity of avoid frequent errors taking into account its accuracy based on satellites systems.
This accuracy belongs to the fact that the system does not undergo any efficiency degradation due to meteorological conditions, ground or the distance. The pilot will have an accurate diagram about what is going on out of the airship.
Moreover the system can monitor the airspace in inhospitable or remote areas with no radar coverage. From this mechanism, the TCAS could benefit a lot from all this information given by ads-b, thus complementing the few external references have now the TCAS and increasing its performance.

From a comparative point of view of both systems, the benefits of ADS-B has on those currently in use (in this case) the TCAS (Traffic Collision Avoidance System) is that it manages to give the pilot safety, capacity and efficiency. The ADS-B leaves reliance on radar systems, which will allow the FAA to the expected growth in air traffic in the coming decades.

Furthermore, the project will be complemented by understanding failure indicators within it, which will provide more security into the route of the aircraft or just during the performance of the flight.

2.5 ADS-B: implementation of better separations

First of all it is necessary to distinguish between implementation in and implementation out.
Implementation of "ADS-B out" is planned in three steps:

- Deployment on the basis of an operational need in non-radar introducing surveillance based on minimum separation.

Table 1. Pilot-Managed Departures Executed with ADS-B/CDTI

Source	(a) N Messages	Time (in seconds) (b) TOF	(c) FOT	(d) ROT	(e) TLC	N Sets
Time of Day						
Day	6.38 (2.83)	2.47 (.64)	15.44 (7.06)*	135.81 (22.04)	201.00 (97.38)*	16
Night	5.13 (1.31)	2.19 (.53)	10.75 (2.02)	146.00 (12.26)	168.50 (45.24)	16
Spacing Interval						
Short Spacing	5.69 (1.70)	2.51 (.68)	14.12 (6.05)	128.81 (18.39)*	170.81 (80.46)	16
Long Spacing	5.81 (2.76)	2.15 (.44)	12.06 (5.17)	153.00 (6.43)	198.69 (72.14)	16

* statistically significant at $p \leq 05$

Table 2. Controller-Managed Departures Executed without ADS-B/CDTI

Source	(a) N Messages	Time (in seconds) (b) TOF	(c) FOT	(d) ROT	(e) TLC	N Sets
Time of Day						
Day	7.57 (1.72)	2.34 (.11)	17.71 (4.07)	60.14 (10.29)	213.29 (118.42)	7
Night	6.83 (1.72)	2.21 (.58)	14.67 (3.20)	77.17 (39.89)	184.00 (50.97)	6
Spacing Interval						
Short Spacing	8.67 (1.37)*	2.14 (.28)	18.67 (4.32)	58.17 (6.05)	224.50 (128.58)	6
Long Spacing	6.00 (0.58)	2.40 (.45)	14.29 (2.06)	76.43 (37.12)	178.57 (41.68)	7

* statistically significant at $p \leq 05$

7

Figure 8. Pilot-managed Departures executed with ADS-B

- Implementation at secondary airports in order to make more efficient the traffic.
- Replacing one part of radar coverage by ADS-B in order to reduce surveillance costs.

ADS-B out automatically transmits aircrafts parameters from the aircraft to the ATC on ground.
There is no need for the pilot's action and it conforms to EASA regulations on ADS-B out, for non-radar airspace operation.
Implementation of ADS-B IN: In this step, it is mainly discussed the option of introducing more complex applications in order the pilot to be able to space. As a consequence of that, the separation will pass from the controller to the pilot.
In conclusion, as the controller has the exact velocity and position desired at each moment by using ADS-B information, the controller can be more accurate when making separations.

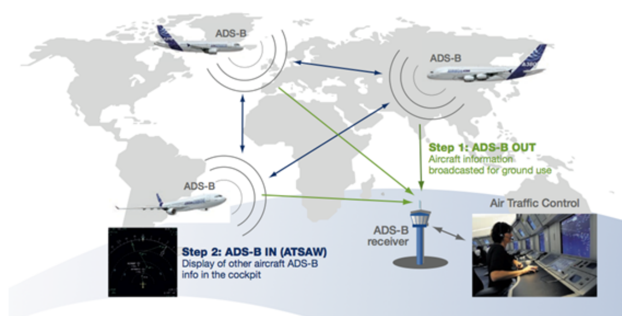

Figure 9. ADS-B interaction

The objective of the future step is to enable the flight crews to achieve and maintain the automatically a given spacing with designated aircraft. The operational benefits will be the enhanced traffic regularity, during the approach to airports with heavy traffic allowing increased airport capacity.

2.6 How to enclose ADS-B tasks with the controller intervention, and how does this imply in charge reduction volume

As well as air to air communication data link and ground to air services, the ADS-B, as a consequence of all the review seen before, is able to automate some of the controller and pilot duties.
The system design issue is this: given the technical capabilities we have been explaining for the ADS-B, which system functions should be automated and to what extent? These fundamental questions increasingly drive the design of many new systems, specially on our ADS-B solution. We will see later on in section three in which automation level we are moving, and how does this affect the matter we are handing.
For the automation purpose, we must rule over a predetermined tabulated algorithm that shows the different levels of automation of decision and action selection. Here we show the model for the types and levels of automation:

↪ High automation level

10.- The computer decides everything, acts autonomously, ignoring the human.

9.- Informs the human only if it, the computer, decides to.

8.- Informs the human only if asked.

7.- Executes automatically, then necessarily informs the human.

6.- Allows the human a restricted time to veto before automatic execution.

5.- Executes that suggestion if the human approves it.

4.- Suggests one alternative.

3.- Narrows the selection down to a few.

2.- The computer offers a complete set of decision/action alternatives.

1.- The computer offers no assistance: human must take all decisions and actions.

↪ Low automation level

[5]

As a consequence also, we are focusing on the reduction of charge volume, thanks to the accuracy of the ADS-B communication system and the positioning data provided thanks to the data capacity enhancements. The algorithm and the messaging is sent via MAC, which has more range and security encryption method, translated into more capacity to connect more devices with less systems, and because of its accurate positioning, we are also able to reduce the security volume space. [6] [7] [8]

2.7 Atmospheric feedback via ADS-B

Another application of the ADS-B is using the aircraft as "atmospheric sensors"that could increase and improve the input data that are supplied to tools devoted to monitoring and predicting the status of the atmosphere. From the information obtained of some aircraft, a scalar field estimate of the pressure can be obtained within an airspace volume. This application would be useful to increase the accuracy of the ISA model. Also, knowing more data, such as the wind velocity, the air temperature and the behavior of the atmosphere in general the concept of 4-D woud get better. [9]

3. New ideas for Air navigation improvement

An idea of the ADS-B application in current Air Traffic Control, where the Controllers have all the responsible of the aircrafts and it movements, is to use of it **to automate the Route Air Traffic Control**.

Once that the all aircraft data is obtained be means of the ADS-B and as explained before one of the uses of the ADS-B is to **compute the wind** so having all the wind of a zone and all aircraft data, the **Air Traffic Control could be automatized by the use of a computer** in which all data is introduced and the most economic, efficient and safest route is obtained.

By these means in the Route Control where currently the Controllers have all the responsible and have a high work load could be reduced by **using the automation levels according to Parasuraman in a factor level of 6** where the computer take all the decisions and the Controllers only keep an eye on it and they have an specified time to cancel the action done by the computer.

As well as we investigate about those ideas that we hope they will satisfy each condition and improve in a better way the needs for the future avionics field, we claim to develop this system in order to **enhance the communication in all the area**, not only between the pilot and the controller's infrastructure, also to focus a new type of service that gives each data of the position and other parameters to another aircraft which is flying, just to avoid any future collision.

In the case that the weather does not allow a fine summary of the data the ADS-B will provide to the pilot, as example we can estimate a huge storm at the cruise phase.

Focusing our efforts in effective and exact results for avoiding any disturbance, we can **implement a complementary subsystem that makes a feedback of the result obtained** in case that there are not weather troubles. [10]

All this improvement in the Air Traffic Control will reduce the workload and the number of Route Controllers. So the capacity of the Airspace will increase by this means increasing the number of operations per hour and the efficiency.

The use of the ADS-B to determine the wind in each area of the world complemented with the knowledge of the current position of the aircraft at each moment could change the concept of Air Navigation Control. Adding by this way a computer that analyze all those values being able to control by means of sequencing, merging and metering aircraft in an efficient, safety and fluent way.

Moreover to make it safer, **a radar could be introduced into the pilot cockpit with all the ADS-B data of all the near inbound aircrafts**. So all pilots could have the same information the Controllers have of the other aircrafts. By this way the pilot could also take his own decisions with a higher factor of safety. It is a way of mitigating errors that the computer or the human could have.

4. World ATM Congress 2013

As a data of interest, we attended the inaugural World ATM Congress in Madrid IFEMA.
Neglecting the political issues, which were inherent to the event, the Congress helped us to collect many information about the aviation world, and we had also the opportunity to ask about our issue: the ADS-B, so we could take a better perspective of what we are dealing with, even the chance to watch *insitu* how does a real ADS-B already impelemented works.

Aena, INDRA Sistemas, SESAR, Airbus ProSky, ATCA, The Boeing Company, Harris Corporation were some of the companies we took information from.

The most interesting and useful for us was COMSOFT, who had in their stand an operative ADS-B still in developing phase.
It was a ground transmitter device connected to a site monitor and a reference transponder with an interrogator. Their prototype, called Quadrant®, able to provide surveillance capability in regions of airspace where aircrafts are suitably equipped with a 1090 Mhz transmitter, which is nowadays the frequncy most used.
As we were told, this is becoming an important and cost-effective surveillance solution. We were lucky to see how does it work with a real flight simulation, and the output messages which were displayed with ASTERIX.[1]

To conlcude, it's been a really satisfying and interesting visit, where we had the chance to take an overview of what's going on at present in the aviation world, and what lies ahead.

Acknowledgments

Our team group is grateful to express our thank to the instructor Manuel Soler for his attention, briefing feedback and information provided along the semester every week without it we couldn't be able to develop such report.

References

[1] ADAN VELA, JOHN-PAUL CLARKE, ERIC FERON, NICOLAS DURAND, WILLIAN SINGHOSE, *Determinig the value of information for minimazing controller taskload: A Graph- Based Approach.*

[2] GARY W. LOHR, ROSA M. OSEGUERA-LOHR, TERENCE S. ABBOTT, *Flight Evaluation of a time-based airborne interarrival spacing tool* .

[3] A. LESTER AND R. JOHN HANSMAN, *Benefits and incentives for ADS-B equipage in the national airspace system*, 2007

[4] R. FRANCIS, *Air Traffic Surveillance in remote and oceanic airspace using orbital detection of Automatic Dependent Surveillance- Broadcast Signals* University of Western Ontario, Department of Electrical and Computer Engineering, 2007

[1] ASTERIX is the encryption code system that is considered to be used for the ADS-B implementation.

[5] Raja Parasuraman, Thomas B. Sheridan, Fellow, IEEE and Christopher D. Wickens, *A Model for Types and Levels of Human Interaction with Automation* IEEE Transactions of systems, man and cybernetics . *Part A: Systems and Humans. VOL. 30, NO.3*, 2000

[6] Dragoljub Patchevr, Aristotel Tentov, *New Concept of Automated Air Traffic Control System*, DOCTORAL CONSORTIUM ,2007

[7] O. Veronika Prinzo, *Automatic Dependent Surveillance- Broadcast / Cockpit Display of Traffic Information: Innovations in Pilot-Managed Departures*, Office of Aerospace Medicine, 2002

[8] Edward Valovage, *Enhanced ADS-B Research*, 25th Digital Avionics Systems Conference October 15, 2006

[9] JF Alonso Alarcón, FJ Sáez Nieto and J García-Heras Carretero, *Aircraft used as a sensor for atmospheric behaviour determination. Practical case: Pressure estimation using automatic dependent surveillance-broadcast*, Institution of Mechanical Engineers, Journal of AEROSPACE ENGINEERING, 2012

[10] Paul U. Lee, Connie Brasil, Jeffrey Homola, Angela Kessell, Matt Mainini, *Benefits and Feasibility of the Flexible Airspace Managment Concept*, Europe Air Traffic Management Research and Development Seminar 2011

[11] Damiano Taurino, Giuseppe Frau, Valentino Beato, Alessandro Tedeschi, *ADS-B Based Separation Support for General Aviation*.

[12] ENHANCED ADS-B RESEARCH Edward Valovage, PhD., Sensis Corporation, East Syracuse, NY