MSc Program

Engineering Management

ANALYSIS OF HUMAN FACTORS IN THE MODERNISING AIR TRAFFIC INDUSTRY: THE AIR TRAFFIC CONTROLLER.

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supervised by

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PREFACE.

In this Master Thesis assignment, I will try to do a deep study of all different human factors in Air Traffic Control (ATC) operation, specifically those human factors that affect Air Traffic Controllers' actions, but not those related to the development of systems or other factors related to this industry. This comprehensive study will allow us to analyse the work environment of air traffic controllers (ATCO) and what their job involves. With a good knowledge of the different issues that affect human performance in ATC I will be able to understand how the human factors operate and hope to be able to propose new ideas and actions that could be taken to improve the operation of human factors in ATC, bearing in mind that change may be necessary in order to keep up with changes and advances in the ATC industry as a whole.

The Air Traffic industry is one that has always amazed me and in which I have been always very involved due to my family. Some of my very close relatives have worked or currently work for different companies involved in the world of aircraft and flights. From the most directly related type of job, such as pilots, flight assistants or controllers, to the engineering side in manufacturing companies that develop the different systems which ensure the safe journey and a good end to every flight.

For such a broad topic as Air Traffic Control (ATC), the literature is enormous and it would be very hard to give a good global vision in an assignment such as this one. Therefore, and in order to make the most of this task, I have decided to focus on what I think is a very important part of this industry, which is the human factors, especially applied to ATCOs. I thought of this subject mainly as it is my personal interest, but also it can be related to some of the many topics studied throughout this MSc in Engineering Management, for instance, human resource or managing people.
In order to achieve this goal an intensive research of material is needed. As literature about ATC is so large, the search for interesting material about human factors can be quite tough. The main ways I have chosen to carry out a thorough research include: firstly to look deep into the internet in search of all types of related documents, either by universities, companies related to the industry or even those from the schools of ATCOs. Secondly, with this initial search on the internet, interesting books have

shown up, so these books also need to be well studied to obtain the most information possible. A third step, which can be carried out parallel to the others, is the direct contact with controllers. These talks would be useful in order to solve some of the questions that may appear while conducting the whole research and when recording pieces of information found, together with personal ideas or solutions to the problems presented.

In order to be concise I will not differentiate between men and woman in this text. Instead of using ‘man and woman’ or ‘his and hers’, which can be cumbersome in a text of this length, I will always use the male word as conceptually and linguistically ‘man’ embraces both man and woman. Other terms, such as pilot, flight assistant, controller or others, also refer to both men and women. So in general, no distinction between man and woman is intended throughout this text.

I would like to thank to all those people that have help me achieve the goal of writing this master thesis and obtain the degree of MSc in Engineering Management. Especially I want to thank my girlfriend Frances for her great help at the beginning of this adventure for being patience and listen to me, helping me develop the subject I wanted to work on and also during this whole long process of transforming the study and research into a written work. For her support with the English language which sometimes did not let me express exactly what I wanted and whose help has let me improve my use of the language at the same time as writing a good thesis.

I would also like to thank my supervisor Professor Günter Schmidt for his help, giving me directions when I had not yet found my way but also for supporting me and giving me enough freedom to create my own work.

Besides these two main people who have helped me enormously, also thanks to all my colleagues from class, with whom I have had many conversations about the thesis and from each one some new ideas came up that I could add to the text. To Barbara Holloway whose experience in such works was of great help at the beginning and to my brothers who also helped me by giving me their two very different points of view.

Last, I want to dedicate this work also to my parents who were far away during all this procedure but have support and encourage me to do it.

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ABSTRACT.

In order to provide an overview of the chosen topic for the Thesis, I will say that the main focus is the Analysis of human factors within the profession of the ATCO and furthermore how these factors are affected by the modernization of the industry. On a broader scale the thesis will deal with questions such as, how the human factors affect the tasks carried out by the controllers, the training they need to receive, the selection process every controller has to get through even before receiving this training, and the abilities an ATCO needs in order to be successful in all these different stages of selection, training and working placement. All these factors are what make the ATCO profession one of the more demanding careers and a difficult one to succeed in.

Along with the study of human factors, I will be looking at how the changes and new developments in airspace capacity and technologies affect the way this job is carried out and the role played by the different human factors to support and facilitate these changes that are taking place.

Nowadays, there is an unstoppable growth in the air industry. With the new open sky laws, and the continuous start up of new low cost airlines, the way airspace is currently and has been managed for the last decades will no longer work. Now, a whole new method is required to increase the capacity of airspace.

Technology is fundamental in this industry. Controllers cannot see the aircraft under their control during most of the flight, only as the aeroplanes approach the airports, so they must rely on information given by radars and radio communication with the aircraft or with other controllers. Therefore, ATCOs need to rely heavily on the technology, although they can never be replaced by technology, or at least in the past and up to the current day the human component has been considered vital in Air Traffic Management (ATM).

0. PROBLEM FORMULATION.

The worldwide economic growth experienced in the past years has driven tremendous changes in the frequency and pattern of air travel, especially within Europe and North America. Citizens all over the world have become more mobile, and the number of people travelling by air for business and leisure is continuing to increase.

This new travel phenomenon is leading to an expansion of the air route networks and increased traffic flows, particularly between the regional and major hub airports situated near main cities and main tourist destinations, and airlines adapt to competition from other modes of transport.

Aviation has been playing a major role in economic growth, employment and trade. It is also a pre-requisite for mass tourism, one of the most important factors in stimulating economies.

Although it is assumed that the increase in economic development will slow over the following years in developed countries, the air traffic is forecasted to grow steadily over the next 15 years. It is expected in Europe to result in a doubling of aircraft movements by 2020[1] and to triple the demand of air transportation in North America by 2025[2]. Nevertheless, aviation growth is subject to cycles and sensitive to specific events. While specific events, such those of September 11th 2001 in the US, may have impact on passenger confidence and traffic growth in the short-term, empirical evidence is that underlying growth trends soon regain their previous levels.

Therefore, with an expected steady growth in number of flights, especially in commercial and business activity and recreational flying because during recent years there has been a marked reduction in the total number of military aircraft and in military aviation activity, an according increase of the capacity is needed. Substantial increases in capacity have been and are being delivered, thanks to national and international measures and the efforts made by all stakeholders, in particular by ATCOs. Despite this, capacity is lagging a few years behind traffic demand and the installed capacity can not be fully exploited, in particular due to controller shortage.

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[1] EUROCONTROL Air Traffic Management Strategy for the years 2000+.
[2] GAO United States Government Accountability Office.

Capacity is a complex mix of access to airports, airspace and services predictability of schedules, flexibility of operations, flight or mission efficiency, delay, timely availability of volumes of airspace and network effects, but airspace capacity related aspects also include as key issue controller workload as well as weather conditions, availability of communications, navigation and surveillance system. When capacity does not accomplish requirements, the most visible symptom is the delays.
However the increase of capacity must come together with an increase of safety levels and also caring about environmental issues, all these in a cost-effective way.

People will play a major role, as all ATM systems are expected to remain human-centred for the foreseeable future. It will be these people who will play the important role in achieving system safety and capacity enhancements. People are therefore an essential element in the ability to deliver ATM services, and their co-operation and involvement (qualitative and quantitative) in developing and effecting changes is essential.
Within all the important roles played by people, probably the most important one is the ATCO. Traditional ATC processes rely heavily on the cognitive skills of the ATCO, who acquires and processes data and makes decisions in real-time. These processes are based on innovations introduced in the past to manage the levels of traffic then experienced, and are now testing the limits of the people involved in their operation, as levels do not remain still.

These changing levels and processes make training of the ATCO a basic step in his career but furthermore, the selection process of the optimal candidates should be even more important, preventing the expenditure of great amounts of money and time in training people that do not accomplish some of the requirements to become ATCOs. Although, probably, they will be able to cope with everyday traffic, they might not be capable of acting when extraordinary events occur. Due to the intense level of traffic that many airports and airspace is nowadays suffering, ATCOs require formation and training that will give them high capability to fulfil their responsibilities. In order to assure the expected ATM performance, people with the right skills, knowledge, attitude and motivation are needed. This requires an exceptional level of human resource management which ensures the enhancement of human capabilities, such as flexibility, motivation, and commitment, and guarantees that a career in ATM is sufficiently rewarding and therefore attracts and retains a high quality staff.

In order to make humans able to cope with the increase in traffic and the ever changing environment, there is an increase in new technologies in ATM. Technologies that will consist basically in the automation of as many procedures as possible, so controllers are not overloaded with routine tasks and can focus on the most variable and most risky stages of a flight.

These new technologies will bring a number of benefits, helping the human element with automated tools will allow improvements in efficiency. However, they may result in an increased complexity of the procedural as well as technical and legal arrangements, making the job of the ATCO sometimes much more complicated and also raising questions about adequate human control over automated systems. Technology must build on human strengths and compensate for human vulnerabilities, minimizing both mistrust of automation and complacency about its abilities. The air traffic control system, the airspace system, and the future automation alternatives have to be studied from a human factors perspective, allowing us to see how these human factors are affected by the coming changes in automation and how they should be adapted to achieve better results.

Therefore human factors in ATC need to have a comprehensive study to help improve the selection and training processes as well as better facilitate the ATCOs in their daily tasks. Such a study should take into consideration all kinds of limitations and capabilities of each person and the individual differences between human beings, and relate these to the different roles played and positions held in the jobs associated with air traffic control.

On the other hand, to help humans develop their functions in the best possible way new trends and modernization of the industry is needed, but this has to be in accordance with human capabilities, as they are developed to help not to substitute humans.

1. INTRODUCTION.

1.1. Motivation.

The main reason that led me to choose this topic as the subject of my Master Thesis for this MSc programme was that ATC is a topic that has always interested me and has attracted my attention especially since becoming a Telecommunication Engineer. The Air Traffic industry uses the latest technologies in different fields and puts them all together in order to achieve the best performance. Especially regarding communications, ATCOs work with state of the art equipment for both air-ground and ground-ground communications. Although this will not be the main issue of the thesis, it is something that fascinates me and has made me develop a great interest in the Air Traffic industry as a whole. It was through my bachelor degree in Telecommunications, where I studied the different links between planes and ground, the ways data is transmitted and some of the equipment needs it in this field, when I have really become passionate about this topic and would like to eventually work in something related to Air Traffic.

Other reasons why I am currently so enthusiastic about this area and that encourage me to study it in depth, is that it is an industry that has been growing for the past years and is forecasted to keep growing steadily over the following years. This kind of steady growths leads to a continuously evolving industry, always trying to change in time to keep up with capacity demands. Such a rapidly changing industry makes for a good topic to study as there is much uncertainty, demand for innovation and room for improvement.

It is an industry that, with this expected growth, will take an even more important role in society than what it has today. Air traffic makes the world smaller and the different countries much closer, bringing, if it is well used, economic growth to all different parts of all five continents. Aviation has taken on a major role in the new globalization era, facilitating the transport of people and goods between places from every corner of the planet.

Furthermore, the motivation to delve deeply into this topic, and to focus especially on the human side, is because human factors are a key issue in such a technologically advanced industry and will remain like this for the foreseeable future. Humans are and will remain the main part of the system: their aptitudes and capabilities are fundamental in determining a good performance in air traffic.
Also, another very interesting topic for me will be how to manage such a team of highly skilled people, as this will be one of the areas of study most related to some of the lectures given in this programme.

1.2. Definition of the problem.

In order to discuss in depth the human factors in ATC, it is necessary to consider how human factors in ATC are managed and controlled today and why they are managed and controlled in such a way. This background analysis will form a large part of each chapter of my thesis as I will try to provide the reader with an explanation of each of the human factors and an insight into how it currently operates in ATC.

The main purpose of ATC is to guarantee the safe, orderly and expeditious flow of air traffic. ATC achieves its objectives by keeping aircraft apart, ensuring a safe separation of aircraft both in the air and on the ground, while maintaining the most efficient operational and economic conditions. Its efficiency can be measured by its success in keeping aircraft separated with minimal disruption.

An air traffic control system is a complex man-machine system, continuously in operation. As air traffic continues to increase, ATC must evolve to handle the growing demand, often by introducing innovative technology. The role and functions of the ATCO may change accordingly. The capabilities of the controller and the technology must be harnessed to accomplish their shared objectives. Therefore, not only by increasing or modernizing the technology available or the equipment in use, can the requirements of the air traffic be met with certainty, but accordingly a simultaneous development and improvement of the human force and its characteristics is essential.

From all of the three guarantees offered by ATC, the most important one is safety. Safety requires knowledge of certain minimum data, for instance height, speed and direction of an aircraft. Using this knowledge safety requirements impose a number of restrictions on air traffic, for instance, safe distances between aircraft. These safety standards exist to ensure that the air traffic flows in a coordinated and controlled manner. When the traffic is regularly and efficiently controlled, with the restrictions imposed for safety matters, these restrictions can be applied with out disruption to the air traffic flow. However, when the air traffic demand cannot be satisfied due to the mentioned restrictions, then the regularity and efficiency are affected. If the increase in the number of flights is to be accommodated, the establishment of appropriately safe conditions must precede the achievement of greater capacity.

The natural way to maintain or increase the security and safety levels with an increasing amount of air traffic, is by knowing more about the air traffic: having greater access to data about aircraft in the air and the guarantee that the data is precise and reliable, and also knowing more about the human characteristics. Knowing more about both themselves and the type and quantity of traffic controllers have to deal with, will enable them to see better their capabilities and limitations.
Traditional ATC processes rely heavily on the cognitive skills of the ATCO, who acquires and processes data and makes decisions in real-time. Furthermore, when the amount of data and its characteristics, such as low precision and reliability, requires great demand from the controller, the need of automation emerges.

1.3. Aim.

Through the study of human factors in ATC, we will get to know some of the issues that condition an ATCO’s decisions. By learning the stages they have gone through before reaching their current position and the steps they needed to take, we will have a better understanding of the profession and its environment. From this point we will be able to suggest ways to improve the performance of ATCOs and therefore improve the way air traffic works today. Further, by having a deeper knowledge of the industry, we will be able to predict how it will develop over the next years and to provide it with the capacity to cope with the future air traffic situation.

Within the study of different human factors involved in the air industry, to be more precise related to controllers and their performance, great emphasis will be placed on both the current state of the ATC industry and, even more so, on predictions for the future state of the ATC industry. The main aim is to see how human factors need to adapt to face the expected changes and new challenges like the increasing air traffic and the consequent need of greater capacity, modernization of facilities and new procedures and standards that may be introduced.

Today's processes are based on innovations introduced in the past to manage the levels of traffic then experienced, and are now testing the limits of the people involved in this job. From this perspective today's ATCOs have to start performing as if the current airspace were as full and busy as is expected in the near future. Therefore, training of ATCOs and execution of the ATCOs' work must be done with a view to future needs and not only thinking of the present situation.

1.4. Structure.

I aim to structure this thesis in an orderly and understandable way for all readers, including non-experts in the topic of ATC. With this purpose I will first introduce the reader to the world of controlling aircraft. An overview of the industry and some definitions related to air traffic and associated topics will be provided. Also, some ideas about how the industry operates as a whole, why it is important and jobs related to this field with special attention to the job of an ATCO.

Focussing on the thesis title, in the main part I will analyse different human factors and how they affect a controller's performance. Furthermore, I will study how they can be changed or improved in order to achieve a better result in the controller's everyday activity. In order to get the most out of these proposed changes or improvements, I will relate each factor to the new trends in capacity and automation. Automation issues will feature often in this thesis as automation may be part of the solution to dealing with increased air traffic capacity. However, as I mentioned before, the human factor is vital in ATC and humans cannot be replaced by machines in this type of industry. Therefore, it is interesting to see how machinery and humans work together in ATC. In each chapter I will discuss one human factor and aim to show the reader the complete picture of the development of this human factor within ATC, from its recent past situation, to how it is today and what it is expected to be in the future.

For each of the human factors to be studied, I will first define it and then apply it to ATC industry to see what role it plays. I will discuss how its role within ATC has evolved over the last years, reasons why the role and importance of this human factor may have changed, perhaps due to a great failure such as an aircraft accident or maybe as new requirements were made of the industry.
Finally, for each of these factors, I will try to see how it could be affected by the changing ATC world, having also a look at some of the predictions that have been made regarding automation and increased air traffic and greater demand for capacity.

In the last parts, I will draw conclusions from this study and summarise the main ideas of the thesis. The conclusions will be mainly concerned with the future of human factors in ATC and contain the results and proposals obtained from all the previous analysis of the situation as well as actions that should be taken at this point in time to improve the current situation in the management of the airspace.

2. FUNDAMENTALS.

When we fly, most people do not think about who designs the flight plan, who gets them where they are going to or how they do it, who makes sure the planes do not accidentally intersect each other ways or even collide, who makes sure the planes fly at the proper altitude, who guides the planes at the airport if there are any complications during take off and landing, who puts the planes in order before landing or take off. The answer to all of these questions is Air Traffic Control (ATC), and the people that do all these jobs, with the help of pilots, are called Air Traffic Controllers (ATCOs) (Stress and Air Traffic Controllers).

2.1. Mission of ATC.

ATCOs have the task of ensuring safe operations of commercial and private aircraft. They must coordinate the movements of thousands of aircraft, keep them at safe distances from each other, direct them during takeoff and landing from airports, direct them around bad weather and ensure the traffic flows smoothly and with minimal delays.

It was around 80 years ago when airplanes first started carrying passengers. By the end of the 1920s, people in the USA could take a plane to most Americans cities, but only during daylight hours, when pilots could see where they were. Then radio was introduced to the industry. Once pilots could talk to people on the ground and communication was available, it was possible to track the airplane's positions as it moved across the country.

In the 30s and 40s there was more and more air traffic but not much in the way of controlling it. Airplanes flew pretty much where pilots wanted to take them. But it was after the collision of two planes over the Grand Canyon in June 1956 when things changed.

Now, instead of flying the most direct route, airplanes had to fly from one radar beacon to another, in a zigzag pattern, that was less efficient but safer (Inside Air Traffic Control).

The goal of the global ATC system is to satisfy and balance the two critical goals of safety and efficiency. To accomplish with this, flights are controlled by controllers from the time it pushes off the gate to the time it reaches its destination and parks at the gate and the doors are opened. The great amount of aircraft in the air traffic system at a same time brings the need for separation and control of them.

The controller establishes minimum vertical separation of 1000 feet (approximately 300 meters) and minimum horizontal separation of between 2.5 and 6 nautical miles (i.e. 4.6 to 11.1 kilometres) between the aircraft involved[3], depending on which flight level (FL) is the plane flying at and the type of aircraft. If, however, pilots fly under visual flight rules (VFR), they are responsible for maintaining separation from other aircraft themselves. Their flight is not controlled by ATC and they may only use certain defined airspaces. The different needed separations between aircraft are shown in Fig. 1.

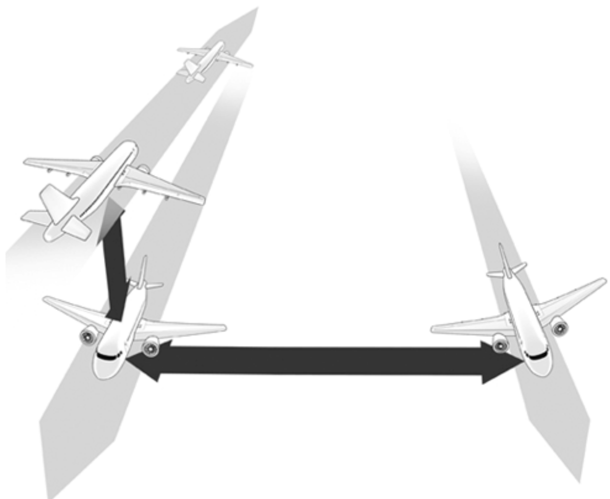

Fig. 1. Graphic of different separations between planes (Source: AustroControl).

2.2. Stages of a flight.

The typical profile of every other commercial flight has the following seven stages, which are then represented in Fig. 2.

[3] DFS – Deutsche Flugsicherung GmbH

1. Pre-flight: This portion of the flight starts on the ground and includes flight checks, push-back from the gate and taxi to runway.
2. Takeoff: The pilot powers up the aircraft and speeds down the runway.
3. Departure: The plane lifts off the ground and climbs to a cruising altitude.
4. En route: The aircraft travels through one or more centre airspaces and nears the destination airport.
5. Descent: the pilot descends and manoeuvres the aircraft to the destination airport.
6. Approach: The pilot aligns the aircraft with the designated landing runway.
7. Landing: The aircraft lands on the designated runway, taxis to the destination gate and parks at the terminal.

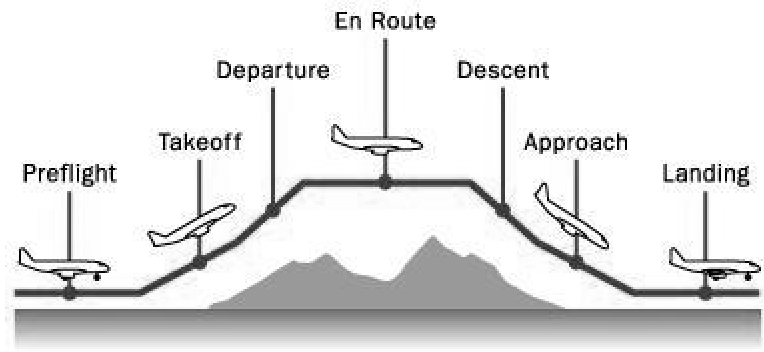

Fig. 2. Stages of a typical commercial flight.

Every different phase of the journey is controlled by a different controller. These controllers can be either in the same location or in facilities miles away.

2.3. Flight rules.

Flights are divided into two different groups, according to the rules the flight is conducted in accordance with. These applying rules depend on the characteristics of the airplane and the weather:

- *Visual Flight Rules* (VFR), are the regulations under which a pilot may operate an aircraft in weather conditions sufficient to allow the pilot, by visual reference to the environment outside the cockpit, to control the aircraft's attitude (orientation of the aircraft with respect to the horizon), navigate and maintain safe separation from obstacles such as terrain, buildings and other aircraft. This technique is therefore based on direct observation of external references. To avoid other aircraft, pilots fly at specified altitudes reserved for their general direction of flight, and pilots simply keep a constant lookout for other aircraft.

The procedure followed by pilots is first to plan the route to follow over a chart that displays terrain features, establishing a number of reference points which coincide with their flight path. These should be easy to identify landmarks, for instance, rivers, roads, buildings, etc. Then, during the flight, the pilot uses these existing references on the ground to know its position and to guide the aircraft to the points marked on the route.

This is a very elementary navigation method, whose effectiveness depends considerably on the pilot's expertise and skills and also presents many limitations, from having to fly close to the ground, to the dependency on weather and visibility conditions. VFR flights are permitted when Visual Meteorological Conditions (VCM) are met, otherwise conditions are considered Instrument Meteorological Conditions (IMC) and a flight may only operate under IFR. VFR works well where visibility is good, aircraft speeds are fairly low, and air traffic is sparse. VFR pilots must remain clear of clouds and have a range of visibility of at least 5 km.

In general, VFR flights are not assigned routes or altitudes by ATC. Aircraft that use this type of rules are, for example, those that provide sight seeing flights, aerial photography, lift services for parachuting and many others small privately owned aircraft.

- *Instrumental Flight Rules* (IFR), are the regulations and procedures for flying whereby navigation and obstacle clearance is maintained with reference to aircraft instruments, while separation from other aircraft is provided by ATC. An IFR flight can be piloted even when nothing can be seen out of the cockpit. Therefore, one of the benefits of this type of flights is the ability to fly through clouds, which otherwise is not allowed.

IFR is a more complex set of rules and pilots need to have a certificate to fly under IFR. These instruments include altimeter, airspeed indicator, attitude indicator and others, and are designed to work under any weather conditions, day or night, and give the pilot enough information to be able to guide the aircraft.
The majority of commercial flights operate under IFR for safety reasons, even when visibility is good so this will be the main kind of flying process I will be referring to.

2.4. Facilities in ATC and roles of ATCOs.

There are basically three types of ATC facilities, each with its respective roles for the controllers.

1. Airport Traffic Control Tower (ATCT).
2. Terminal Radar Approach CONtrol (TRACON).
3. Air Control Centre (ACC) or Air Route Traffic Control Centre (ARTCC).

Not every airport or every country has all these same three facilities. Each different scenario needs certain facilities to accommodate the air traffic around but as traffic is not always the same, neither are the facilities and they usually vary broadly from one airport to another. Anyhow, these are the most widely used and typical facilities in ATC.

2.4.1. ATCT.

The tower controller, located in a glass structure "on top of the tower", controls aircraft on the ground, just after takeoff, and just before landing. Tower control tasks are usually divided between the ground controller and the local area controller.
The key responsibilities of tower controllers are:

1. Issue clearances for the aircraft to push back from the gate and then to leave the ground. These clearances generally involve confirmation of schedules of flight plans that were filed previously through Flight Services and by airline dispatchers. For takeoffs and landings, they involve prior assurance of safe separation from other traffic.
2. Manage ground traffic to and from the gate. This involves lining aircraft up in a sequence for takeoff and coordinating the traffic on the runways so

that it does not conflict with other ground traffic (aircraft or vehicles) or with aircraft that are taking off or landing.

3. Hand off the departing aircraft to and accept the arriving aircraft from the TRACON controller residing in the radar room.

The ground functions of taxi management are handled by the ground controller, and the takeoffs and landings are handled by a local controller. At smaller facilities, or at times of very low traffic density, the two functions may be carried out by a single individual (National Research Council, 1997).

2.4.2. TRACON.

The TRACON controller, located in a windowless radar room either below the tower cab or somewhere else in the area, controls aircraft in the wider region of space around the airport.

The tasks of the terminal radar or TRACON controller are:

1. To manage the safe and expeditious flow of a departing aircraft from the moment it has been accepted from the tower to the handoff to the en route controller, a job usually handled by the departure controller.
2. To manage the arriving aircraft from a handoff from the en route controller to a handoff to the tower controller on a final approach for landing, a job usually handled by the approach controller.

A key component, as well as of the tower controller, is sequencing or "lining up" the aircraft in an orderly inbound or outbound flow, at regular spacing, so to maintain the safe separation between aircraft, which is the most important rule. For the TRACON controller this is even more challenging because separation is now a three-dimensional problem as aircraft are constantly climbing and descending, in addition to their lateral movement.

2.4.3. ACC.

In control centres or en route centres, controllers primarily use radar information to provide guidance to aircraft flying over their territory and to ensure that a safe distance is maintained between aircraft. However, there are certain areas for which there is no radar coverage; for these areas, non-radar procedures are used. The implications of this are that the minimum spacing between aircraft must be quite large, sometimes causing a loss of efficiency in traffic flow. Two major non-radar areas are the oceanic areas of Atlantic and the Pacific oceans. Oceanic controllers rely on aircraft position and intent data provided by pilots.

However, normally flights are guided along what is a generally orderly series of linear routes across the sky at different flight levels. The linear paths are defined by navigational aids called VORs (VHF Omnidirectional Range) each with a given name.

En route controllers also provide weather advisory and traffic information to aircraft under their control.

There are different numbers of air route traffic control centres depending on the size of the country or airspace under control. For example, in the USA there are 21, but in both Spain and Germany there are four, and in Austria only three.

These three basic types of facilities can be combined depending on the needs of the airspace to provide a much wider number of facilities. In the next table (Table 1) some examples are shown.

Table 1. Air Traffic Control Facilities (Source FAA).

Name	Description
Tower without Radar	An airport traffic control terminal that provides service using direct observation primarily to aircraft operating under VFR. These terminals are located at airports where the principal user category is low performance aircraft.
Terminal Radar Approach Control (TRACON)	An air traffic control terminal that provides radar-control service to aircraft arriving or departing the primary airport and adjacent airports, and to aircraft transiting the terminal's airspace.
Combination Radar Approach Control and Tower with Radar	An air traffic control terminal that provides radar control services to aircraft arriving or departing the primary airport and adjacent airports, and to aircraft transiting the terminal's airspace. This terminal is divided into two functional areas: radar approach control positions and tower positions. These two areas are located within the same facility, or in close proximity to one another, and controllers rotate between both areas.
Combination Non-Radar Approach control and Tower without Radar.	An air traffic control terminal that provides air traffic control services for the airport at which the tower is located and without the use of radar, approach and departure control services to aircraft operating under IFR to and from one or more adjacent airports.
Combined Control Facility	An air traffic control facility that provides approach

	control services for one or more airports as well as en route air traffic control (centre control) for a large area of airspace. Some may provide tower services along with approach control and en route services.
Tower with Radar	An airport traffic control terminal that provides traffic advisories, spacing, sequencing and separation services to VFR and IFR aircraft operating within the vicinity of the airport using a combination of radar and direct observations.
Air Route Traffic Control Centre (ARTCC)	An air traffic control facility that provides air traffic control service to aircraft operating on IFR flight plans within controlled airspace and principally during the en route phase of flight. When equipment capabilities and controller workload permit, certain advisory/assistance services may be provided to VFR aircraft.

Throughout the flight, pilots contact with a great number of different controllers located in different regions or countries. The normal procedure of a flight across the airspace from one airport to another is as follows:

First controller teams in airport towers and radar approach control facilities watch over all planes travelling through the "terminal" airspace, which is the whole airspace surrounding the airport. Relying on visual observation and radar, they closely monitor each plane to ensure a safe distance between all aircraft and to guide pilots on the ground during take off and landing. In addition, controllers keep pilots informed about changes in weather conditions.

The world of controlling aircraft is a very complex one. Simply clearing each flight, for example, from the gate to the runway may involve several steps.

The ATCO, after a pilot has called for clearance, will give such clearance from departure to destination. The plane will then push off the gate and talk to the ground controller who will take him to the appropriate runway and put him where he needs to be before the start of the procedure to take off or in line for his sequence if there is weather or any other factors affecting that flight.

The local controller will then take the aircraft and he is the one that actually issues the take off clearance to the aircraft to get him airborne.

After the flight takes off, the tower controller tells the pilot to contact departure control, a part of the TRACON. Once airborne, the plane quickly departs the terminal airspace surrounding the airport. TRACON has typically handled both departures and approaches for IFR within a designated area which usually includes both large and small airports. As each flight moves beyond the terminal radar control area, it is passed on to a regional air route traffic control centre, who will next take charge in the vast airspace between airports and where the flight is carefully directed to its destination.

Each en route centre is assigned a block of airspace, which contains many defined routes. Airplanes fly along these designated routes to reach their destination.

As the aircraft nears its destination, en route controllers pass the aircraft over to the terminal environment, where terminal controllers guide the aircraft to a safe landing.

The en route airspace is further divided into smaller, more manageable blocks of airspace called sectors. A sector is operated by a sector team, consisting of one to three controllers depending on traffic (This is Air Traffic Control).

In the Fig. 3 the relation between the different controllers and the stages of the flight is shown.

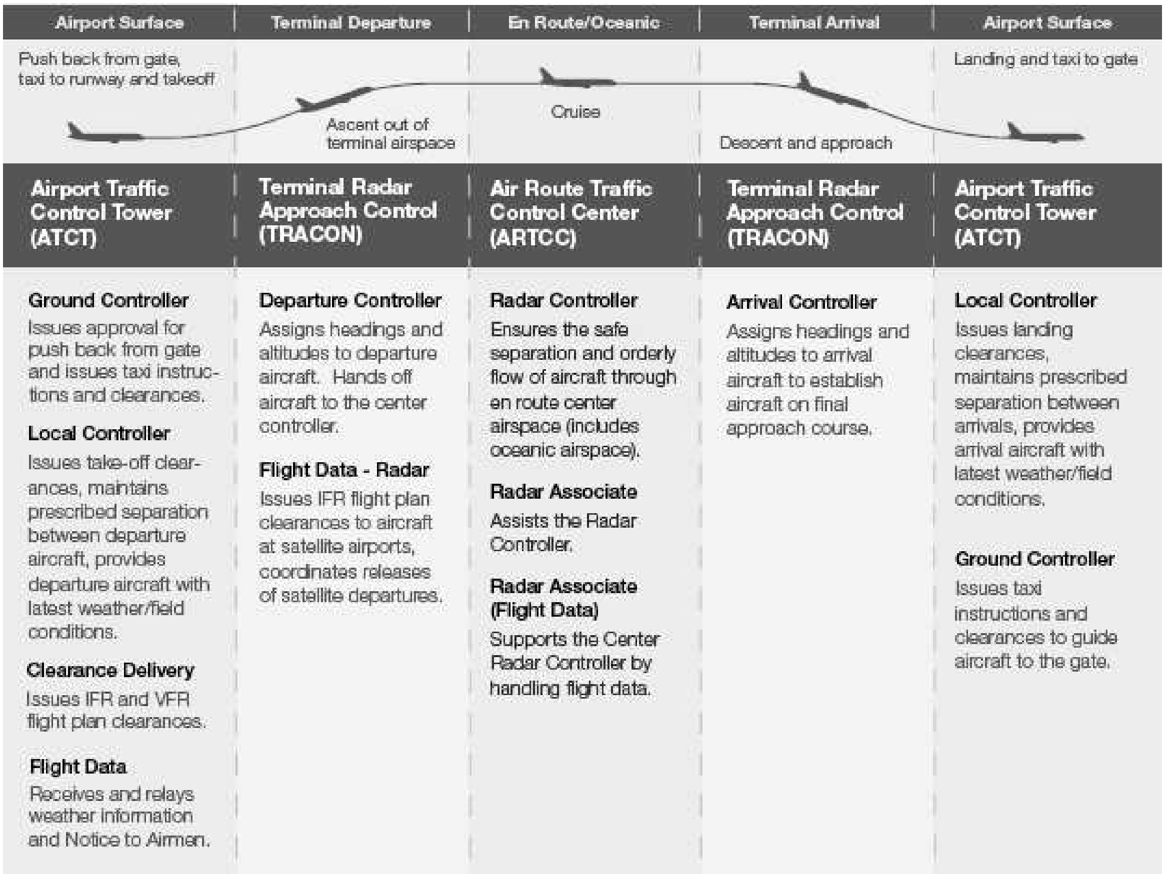

Fig. 3. Air Traffic Controllers' roles at flight stages and facilities.

2.5. Data between controllers and pilots.

2.5.1. Flight Plan and Flight Progress Strip.

According to the definition give by ICAO (International Civil Aviation Organization), a flight plan is “specified information provided to air traffic services units relative to an intended flight or portion of a flight of an aircraft”.

The flight plan is the basic source of information to know the intentions of the pilots. The air traffic control is based on this information. Every instruction that controllers transmit to the pilots and the requests that pilots make, are noted down on the flight progress strip, data that is transferred from the flight plan.

Flight plans generally include information such as aircraft identification, aircraft type and special equipment, true airspeed, departure and arrival points, route of flight, estimated time en route, cruising altitude, alternate airport in case of bad weather, type of flight (whether IFR or VFR), pilot's name and number of people on board.

A flight progress strip is a small strip of paper used to track a flight. It is still used because is a quick way to annotate a flight, keep record of the instructions that were issued, to allow others to see instantly what is happening and to pass this information to other controllers who go on to control the flight.

Although in some countries these flight progress strips have been replaced by computers systems, the term “hand off” which is used today to denote the computerized transfer of control of an aircraft from one sector to another, comes from the old technique of physically handing off the flight progress strip to the next controller to denote the transfer of responsibility.

2.5.2. Time.

In order to achieve a good running of the ATC services, the utilization of a common time reference, both on board the airplanes and on the ground in any part of the planet, is essential. This reference is the GMT (Greenwich Mean Time), also known for some years as UTC (Universal Time Coordinated).

Therefore, for ATC geographical time differences are irrelevant, on board every aircraft and in every ATC facility all over the world the time is exactly the same. Time is synchronised with great accuracy to ensure good and precise coordination between the various ATCOs at different stages of the flight and between controllers and pilots.

3. MAIN PART.

3.1 Human Factors.

3.1.1. What is human factors?

Human behaviour and performance are cited as causal factors in the majority of aircraft accidents. If the accident rate is to be decreased, human factors must be better understood and the knowledge more broadly applied. The expansion of human factors awareness presents the international aviation community with the single most significant opportunity to make aviation both safer and more efficient.

Human Factors as a term has to be clearly defined because when these words are used in everyday language they are often applied to any factor related to humans. The human element is the most flexible, adaptable and valuable part of the aviation system, but it is also the most vulnerable to influences which can adversely affect its performance. Throughout the years, some three out of four accidents have resulted from less than optimum human performance.

There are several differing definitions of human factors depending on the author but all of them lead us to similar ideas.
Human factors is the term used to describe the many aspects of human performance which interact with the environment to influence the outcome of events. These may be physiological or psychological (Skybrary).
According to the words of Professor Elwyn Edward, “human factors is concerned to optimize the relationship between people and their activities, by the systematic application of human sciences, integrated within the framework of systems engineering”.

Another definition of human factors is optimization of the interaction between people and machines, equipment, procedures, and environment to reduce the potential of injury and error[4].

As well, and applying the concept to the air industry, human factors in aviation are involved with the study of the human's capabilities, limitations, and behaviours and the integration of that knowledge into the systems we design for them with the goals of enhancing safety, performance, and the general well-being of the operators of the systems (Koonce, 1979)

The role of human factors in aviation has its roots in the earliest days of aviation. The pioneers of aviation had their concerns for the welfare of those who flew their aircraft (particularly themselves), and as the capabilities of the vehicles were expanded, the aircraft rapidly exceeded human capability of directly sensing and responding to the vehicle and the environment to effectively exert sufficient control to ensure the optimum outcome, safety of flight.

A further influence came from the performance of the human tasks that resulted from technological innovations in equipment, especially within large systems. The main impetus originated during the Second World War, particularly with radar displays and vigilance tasks, when human rather than equipment limitations seemed to determine what was achievable.

Human Factors, like most coherent activities, is multidisciplinary in nature. For example, conclusions are drawn from psychology to understand how people process information and make decisions. From psychology and physiology comes an understanding of sensory processes as the means of detecting and transmitting information about the world around us. The measures and movements of the body – essential in optimizing the design and layout of controls, and other workplace characteristics of the flight deck and cabin – call upon anthropometry and biomechanics. Biology and its increasingly important sub-discipline, chronobiology, are needed to understand the nature of the body's rhythms and sleep, and their effects

[4] Adapted from remarks published by H. Holbrook, 1995-96 President, Human Factors and Ergonomics Society.

in night flying and time-zone changes. Finally, no proper analysis or presentation of data from surveys or studies is possible without some basic understanding of statistics.

Human Factors is about people in their living and working situations; about their relationship with machines, with procedures and with the environment about them; and also about their relationships with other people. In aviation, Human Factors involves a set of personal, medical and biological considerations for optimal aircraft and air traffic control operations.

3.1.2. Human Error.

One major obstacle remains to make aviation's safety record all but perfect: human error. Human error is a safety obstacle not just in the cockpit but in every process surrounding flight operations. The objective today remains unchanged from 1986, when the ICAO Assembly proposed that Contracting States engage in far-reaching cooperation on safety problems related to the influence of human factors, and directed ICAO to develop and introduce material on various aspects of this issue. The goal now, as then, is to further improve safety in aviation by making States and the industry more aware of, and responsive to, the importance of human factors in civil aviation operations. This is accomplished through the provision of practical human factors material and measures developed on the basis of experience. The full understanding of human error holds the key to continued success in providing people everywhere with the safest means of transportation ever created (Dr. Assad Kotaite, ICAO Council President, 1999).

Throughout the last years, a significant evolution in the number of accidents due to human failure and technical failure has taken place. The relative number of human failures has increased respectively compared to the technical ones that have been drastically reduced. In the 70s an optimum level of security was reached, and since then the level has remained stable with only insignificant variations.

The next figure (Fig. 4) shows the tendency experienced in the last decades.

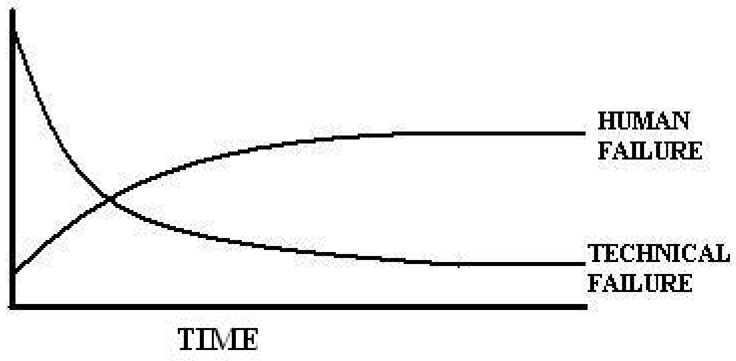

Fig. 4. Relative development of human and technical failures.

The analysis of this evolution is easy to explain regarding the number of accidents due to technical failure. The great development of new technologies applied to aviation in aircraft (new designs, new engines, avionic, etc) and to airports and navigation infrastructure (air traffic control, new airports, runways, etc), give us the reason for the enormous decrease in this type of accidents, without need for further explanation.

It is not so easy to explain the relatively increasing number of accidents caused by human failure, which represent, according to different authors, between 65% and 80% of the total number of accidents in aviation.

3.1.3. A model of human factors.

One practical diagram to illustrate a conceptual model of human factors uses blocks to represent the different components of human factors. This model is called SHEL, and was first developed by Edwards in 1972, with a modified diagram to illustrate the model developed by Hawkins in 1975. The name SHEL is derived from the initial letters of its components, Software (rules, manuals and regulations), Hardware (equipment), Environment (physical factors) and Liveware.

Software represents any components such as polices, rules, computational codes and practices that define the way in which the different components of the system interact with each other and with the external environment.

Hardware represents any physical and non-human component of the system, such as equipment, vehicles, tools, manuals and signs.
Environment represents the socio-political and economic environment in which the different components interact.
Liveware represents the operational personnel themselves in the centre and focuses on their relational and communicational aspects.

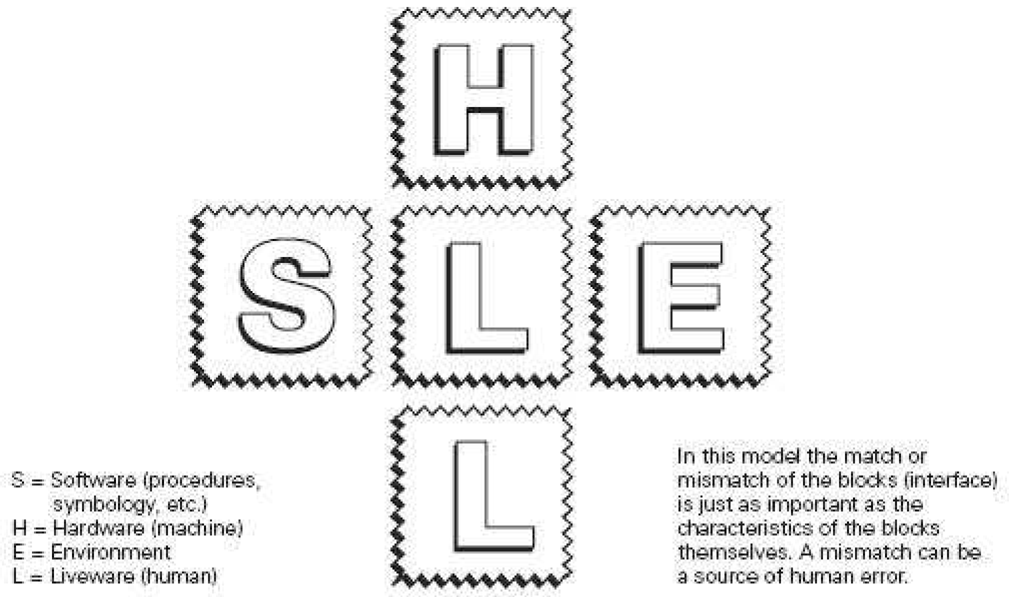

Fig. 5. The SHEL model as modified by Hawkins.

In the centre of the model is the liveware, a person, the most critical as well as the most flexible component in the system. Yet people are subject to considerable variations in performance and suffer many limitations, most of which are now predictable in general terms.
The edges of these blocks are not simple and straight, so the other components of the system must be carefully matched to them if stress in the system and eventual breakdown are to be avoided.

The Liveware is the hub of the SHEL model of human factors. The remaining components must be adapted and matched to this central component.
Liveware-Hardware. This interface is the one most commonly considered when speaking of human-machine systems: design of seats to fit the sitting characteristics of the human body, of displays to match the sensory and information processing

characteristics of the user, of controls with proper movement, coding and location. The user may never be aware of an L-H deficiency, even when it finally leads to disaster, because the natural human characteristic of adapting to L-H mismatches will mask such a deficiency, but will not remove its existence. This remains a potential hazard to which designers should be alert.

Liveware-Software. This encompasses humans and the non-physical aspects of the system such as procedures, manual and checklist layout, symbology and computer programmes. The problems are often less tangible in this interface and are consequently more difficult to resolve (for example, misinterpretation of checklists or symbology).

Liveware-Environment. The human-environment interface was one of the earliest recognized in air traffic industry. Initially, the measures taken all aimed at adapting the human to the environment. Later, the trend was to reverse this process by adapting the environment to match human requirements. Today, new challenges have arisen, problems associated with disturbed biological rhythms and related sleep disturbance and deprivation as a consequence of the different shifts.

The aviation system operates within the context of broad political and economical constraints, and those aspects of the environment will interact in this interface. Although the possibility of modifying these influences is beyond human factors practitioners, their incidence is central and should be properly considered and addressed by those in management with the possibility to do so.

Liveware-Liveware. This is the interface between people. Aircrew and controllers training and proficiency testing have traditionally been done on an individual basis. If each individual member was proficient, then it was assumed that the team consisting of these individuals would also be proficient and effective. This is not always the case, however, and for many years attention has increasingly turned to the breakdown of teamwork. In this interface, we are concerned with leadership, co-operation, teamwork and personality interactions (Civil Aviation Authority, 2002).

Some other further representations of this model show the environment as a global issue that affects all the other three parts. Such a model can be seen in Fig. 6:

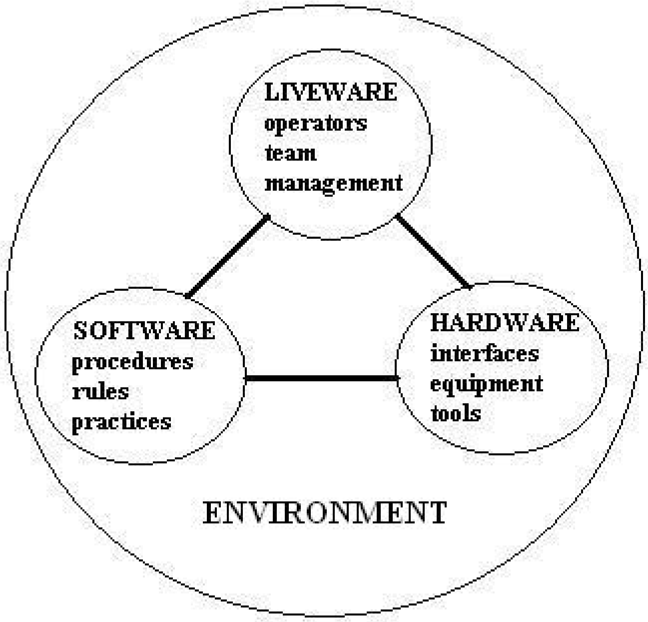

Fig. 6. SHEL model.

In the following chapters I will be focusing in different factors related to the division given by this model and how they affect controllers' performance. However I do focus more in a model such as the one modified by Hawkins, as it gives more emphasis to the liveware, to the person as the centre and main part of the scene. As the controller (human) is the most sensitive part of the model it must be analysed in depth to achieve its best performance.

The relationships between liveware and the rest of the components of the SHEL model are the origin to the factors that contribute to the risk of incidents and accidents. Therefore, because of individual causes or due to interaction between the human being with the other elements, incidents and accidents happen in three different circumstances which we will be referring to in further expositions. These are:

- Solving emergencies.
- Under stressful situations different than those of emergencies.
- Without apparent cause.

3.2. Human Capabilities and Limitations.

In order to get the most out of the ATCOs' performance, the first step is to know the common capabilities and limitations of human beings. We intend to use as a starting point the liveware block of the SHEL model, to gain an understanding of the characteristics of this central component, which is essential for the study of all the other human factors.

First of all, people have physical needs; they require food, water, oxygen, rest, and these limit their range of action. For example, working in circumstances where there is a lack of oxygen or without having an appropriate amount of sleep.

Humans are provided with a sensory system for collecting information from the world around them, so they can respond to external events and can carry out the required tasks. But before a person can react to information, it must first be sensed; there is a potential for error here, because the sensory systems function only within a narrow range. Once information is sensed, it makes its way to the brain, where it is processed, and a conclusion is drawn about the nature and meaning of the message received. This is the perception stage and is a breeding ground for errors. After these conclusions have been formed, decision-making and afterwards actions follow. Many factors can lead to errors in both stages. There is a mix of physiology, biology and psychology issues that affect error, all related to each other.

Capabilities and limitations of the human as part of the whole ATC system, will give us some of the conditions for the successful matching of the human with other system components.

3.2.1. Vision and Hearing.

Much of the information needed for ATC purposes cannot be sensed by man at all. With the exception of spoken messages between controllers and pilots and between controllers, information about the aircraft under control is sensed automatically, for example by radar, and needs to be converted into some suitable medium for humans. Limitations in human sensory capabilities restrict the modalities within which information can be presented to the man. It is important, that before seeking any other source of failure, we make sure that information is in fact present in a form which can be sensed by ATCOs.

In practise, the perception of useful ATC information is confined to the two sense modalities of sight and hearing. Data from other senses, such as touch, taste, smell, heat, cold and so on, are more likely to be distractive than informative. Most ATC information is visual; a trend likely to be accentuated, at least until more direct voice input or automated speech synthesis is adopted.

A busy controller may use both visual and auditory information continuously. Knowledge about sensory limits and how the information is perceived must be applied in the design of the displays and equipment that controllers use to acquire such information. Such factors cannot be treated as constants or absolutes, but must be set in their operational and physical environment.

Some important characteristics that differentiate the visual and auditory stimuli received by controllers during their work are that while auditory stimuli are essentially temporal in that their presentation occupies time, visual stimuli are characteristically spatial, its presentation needs space. Therefore, two or more visual stimuli can be presented sequentially or simultaneously, but auditory ones must usually be sequential. Also, visual stimuli can usually be stored on the display and presented continuously but auditory are transient as they cannot be kept continuously in front of the observer, though they can be repeated periodically. Higher rates of information transmission both to and from humans can usually be achieved with visual than with auditory data, because the rate of transmission of speech is limited to the speaking rate, whereas visual presentation of information can be much faster.

A key characteristic is that visual stimuli depend on direction of viewing and this can affect greatly their capability to command attention, whereas auditory stimuli tend to be more demanding of attention, potentially more disruptive and are less dependent on their direction of origin. For this reason, operator has to be looking in the right direction to perceive the visual stimulus but can be doing anything else and he will still perceive the auditory one.

Hearing resists subjective fatigue better than vision, and the reaction times to simple auditory stimuli can be slightly faster than those to simple visual ones.

Both types of stimuli can be blot out if the conditions are not appropriate. Noise can do so with the auditory information, as well as glare, reflections or inappropriate lighting with visual information.

Therefore, controllers should be always alerted of any new notification or change, also with some audible message, as it will call his attention faster than just a simple note on the screen. Messages should be displayed, because much more information can be gathered from a glance that by having a whole conversation with the pilot, and this information displayed should last long enough and in familiar forms so the controller needs to attend to each item for as short a time as possible, it is kept in the controllers' memory and he can interpret it immediately. For this finality, and to call more attention from controllers, important and new information should be coded differently from than past information. The most appropriate ways generally involve movement or changes, although, it can become distracting and irritating if it lingers after attention has been attracted. Information should be also presented at the optimum levels of detail, so the controller neither has to pay attention to irrelevant pieces of information nor lacks relevant information. Therefore, when designing equipment, these stimuli characteristics need to be taken care of and also human limitations, although according to selection procedure, only those with standard auditory and visual capacities will be suitable for the job.

By taking these actions, sensorial problems and visual or auditory illusions associated with the environment as well as perception errors, should be eradicated. These are circumstances of what we call "under stressful situations different than those of emergencies" incidents or accidents.

3.2.2. Memory.

ATCOs rely heavily on their memory to interpret what is displayed or available for display and to control the air traffic. Most of the tests on controllers are memory tests. Therefore, there is great importance on knowledge about the memory in order to know its limitations and decrease the number of failures. Because human memory is fallible, tasks and procedures are devised so that as far as possible safety does not depend solely on the memory of one man, but as well practical means sustain and support the memory giving guidance and direction by providing reminders.

There are different types of memory according to how the data sensed is processed by the human brain. First, sensory organs are hit with stimuli, sight, hearing, touch, smell, etc and are "registered" for a very short period of time. The Short Term Sensory Store (STSS) can hold comprehensive and relatively unstructured information on what is being sensed for up to about half a second. This is what is happening at the moment, constitutes the present and should be distinguished from true memory. A massive amount of sensory information without much recoding is stored; the information is recorded in the same way as it came in the system in terms of spatial location and form.

The prints left by sensible objects in this SSTS need to be translated to nerve stimuli so that they can be stored in memory. Only selected information will be passed onto the memory for further processing.

Translated nerve stimuli are initially stored during a short period of time of a maximum of 30 seconds in the Short Term Memory (STM), sometimes also called working memory. 90% of the information stored in STM, can disappear in approximately half minute. As well, the capacity of this memory is very limited, and it can only handle from about three or four elements to about nine, capacity commonly cited is 7±2 elements (letters, words, numbers, etc). STM is called working memory when referring to active task performance, therefore working memory represents the "workbench" at which most of the conscious cognitive activity takes places (Baddeley, 1986). Working memory can be divided into verbal or spatial. Controllers use the verbal working memory when receiving a request or read-back from the pilot (Morrow, et al., 1993) and the spatial one to replicate somehow the radar display, having a representation of the airspace but also incorporating three dimensional forms which are not represented in radar displays.

Finally, information that the controller has paid attention to with the intention of withholding it through different techniques like association, repletion and so on, is transferred to Long Term Memory (LTM) where it will not disappear under normal conditions. But as LTM is subject to fading in the natural forgetting process, several recalls or retrievals of memory may be needed for long term memories to last for years. This type of memory concerns all memory longer than a few minutes, and refers to our knowledge of the world from our experience, understanding, and acquisition of information. In case of controllers, knowledge of the airspace such as geography, terrain, routes, equipment and its characteristics, aircraft performance, etc

Memory is a fundamental part in the process of interaction between man and environment. Therefore, humans play an active role combining perception and memory, continuously influencing each other throughout every individual's life. In ATC the controller relies heavily on long term memory for his general knowledge of the principles, methods and techniques of ATC and for his specific knowledge about the way those principles are translated into practice in a particular airspace under his control. As well, the traffic at any given instant is changing within a timescale which refers to short term rather than long term memory. In other words, we can say that controllers draw a picture in their minds of the whole space under their control, with all its limitations and characteristics from the LTM and then apply the current traffic, also with its particular characteristics, from the STM to this picture.

Some of the errors in memory come from the stage of perception or more in detail, attention, which is when the person deliberately dedicates part of its resources to detect and select stimuli. Problems in memorizing may appear when attention is paid only to certain stimuli and not to others that could be relevant, also when the human is distracted for external stimulus, as well as when the person is saturated by having to respond to an excessive number of stimuli in a determined period of time. Another problem may come when the subject is exposed to some certain stimulus continuously leading to a loss of perception of such stimulus or when a stimulus causes such fascination that although attention is being paid, no response is performed.

Also, working memory is very susceptible to interference leading to error, both from other items competing for the same processes and from other information- processing activities. For example, speaking will disrupt verbal working memory, and visual scanning and search will disrupt spatial working memory (Liu and Wickens, 1992).

LTM may also have vulnerabilities; these can manifest themselves in different ways. For example one way is when controllers fail to recall developing aspects of the current situation of which they were at one time aware. Activities initiated by another agent, either human or computer, are more likely to lead to these situations.
Also, when not enough time is given to acquire the necessary knowledge, as when transferring a controller from one region to another or from one facility to another. As well, and related to the amount of time given to adapt, when new operation procedures or equipment is introduced, as old habits may interfere with the new procedures.

Some practical steps are needed to compensate for the fallibility of human memory. In ATC some routine steps are already taken, such as widespread redundancy in procedures and communications. Another is to repeat, check and read back information rather than to rely on memory. By designing redundant communication channels that will back up auditory communications with a visual "echo" of the spoken message, to be referred to if necessary can also help to solve some of the working memory problems.
Some procedures that support memory can be those such as reappraisal of traffic, whenever a decision is taken or new information is added, or the standard requirements for positive actions and acknowledgements. Other methods to help with memorizing include, writing down information that controller will not intend to transfer to LTM; the use of mnemonic resources to store information and recall it; receiving the data, if possible, through different ways; try to avoid emotional aspects in the storage of data and clarifying the data very clearly before memorizing it. For strengthening of the memory, working with specific types of information, helps the memory to be more capable of handling that type of information. And moreover, use the knowledge to do summaries and make sketches or diagrams in order to organize the information.

Some things, such as unusual circumstances that pose no danger or require no immediate action, are easier to forget than others. Even in low workload conditions, distractions can clobber working memory. Controllers should get a situation back to

normal while still thinking about it, otherwise they might forget about it or think they already did something they only planned on doing.
Because human memory is unreliable and every person and their memory are different, it needs all the help it can get. For this purpose, an ATCO must observe memory-joggers used by other controllers and use whatever cues work for him, because not every controllers uses same tricks to remember things.

3.2.3. Motivation.

Motivation is a key word in ATC. For most ATCOs, being a controller is important to them, they identify closely with their profession and with their place of work which they believe to be the best of its kind (Hopkin, V.D., 1995). Basically, they are proud of their job and, at least, at the beginning of their careers controllers are very self motivated workers. Motivation reflects the differences between what a person can do and actually will do, and is what drives or induces a person to behave in a particular fashion. Clearly, people are different and driven by different motivational forces.
The level of effort applied on doing something, is determined by the need of effort to achieve something. There is a relationship between expectancy and reward as motivators. But the effort must be accompanied by the proper abilities and skills.

Modifying behaviour and performance through rewards is called positive reinforcement, discouraging undesirable behaviour by use of penalties or punishment is called negative reinforcement. Even though positive reinforcement can be more effective in improving performance, both must be available to management. Different responses are to be expected from different individuals in relation to positive and negative reinforces, therefore care should be taken not to generate an effect which is opposite from that which is intended.

Controllers try hard to perform their tasks well. The demonstration of outstanding professional competence increases self-esteem and the esteem of colleagues in so far as it is directly observable by them or deductible from their handling of the air traffic. The combination of high motivation and team identification means that controllers will normally support colleagues in difficulty as well as they can, to sustain the high reputation of the ATC service at their place of work. Controllers are highly motivated to attain or exceed high professional standards at all times and a main driving force lies in the standards expected of each controller by his own colleagues, and ultimately imposed by them if necessary (Hopkin, V.D., 1995).

There are some facts that can make controllers lose their motivation or interest in their tasks. A loss in motivation can be caused by boredom at the workplace or because he has already achieved a level of satisfaction and is no longer encouraged to improve in his performance. As in any other job, there is a need for reward, as it is important for high performers to see that they are in a better position than poor performers to achieve a reward encouraging them to improve further, otherwise motivation may decrease.
Controllers often believe that their skills are insufficiently rewarded, that their management fails to appreciate their achievements and that they deserve more modern equipment. So it is in these areas, where further work is needed in order to maintain or increase motivation of the workforce, but in this case they should be targeted as a whole and not individually. Not just by increasing salaries motivation is ensured, also issues like time off, career development and the use of state of the art technologies are facts appreciated by current ATCOs.

Although effects on motivation will not be a major issue in the future plans of ATC and automation, some of the consequences for controllers and their interest in relevant tasks should be taken care of, otherwise the effects could be particularly serious especially if they are unintended and unidentified prior to the development of equipment. Consequences of an under motivated workforce can lead to incidents or accidents without apparent cause.

3.2.4. Body rhythm disturbances: Fatigue and Sleep.

Most living organisms are influenced by several rhythms associated principally with the earth’s spin and rotation around the Sun. The harmony of these rhythms is the

sine-qua-non condition for its good operation. Any variation in the biological rhythms has consequences in mental processes.
The most commonly recognized of the body's rhythms is the circadian or 24-hour rhythm, but some others repeat every 7 or even 30 days. This cycle is maintained by several agents: the most powerful are light and darkness, but meals and physical and social activities also have an influence on the body's systems. Any change in the light and dark periods or in the deprivation of any stage of sleep produces an immediate effect increasing fatigue. ATCOs with frequently changing shift schedules can suffer from reduced performance produced by circadian dysrhythmia (Elizalde, Oscar, 1991).

Fatigue may be considered to be a condition reflecting inadequate rest, as well as a collection of symptoms associated with displaced or disturbed biological rhythms. There are different types of fatigue: Acute fatigue is induced by long duty periods or by a string of particularly demanding tasks performed in a short term. Chronic fatigue is induced by the cumulative effects of fatigue over the longer term. Mental fatigue may result from emotional stress, even with normal physical rest. Like the disturbance of body rhythms, fatigue may lead to potentially unsafe situations and decrease in efficiency.

Sleep has a restorative function, and is essential for optimum mental performance. To ignore sleep for several days is an impossible task, which if intentionally forced, causes primarily psychic disorders and, relatively soon, death. Optimal performance is impossible without adequate sleep. Sleep is necessary for both our physical and psychological well-being. Not getting enough sleep affects memory and the abilities to perform complex tasks
While sleeping, our bodies go through different stages, each one with a particular function in the global restoration of the body. For example, if someone is deprived of the REM (Rapid Eye Movement) stage of sleep, it causes loss of concentration, aggressiveness and obsessions.
Insomnia defines a condition where a person has difficulty sleeping. When occurring under normal conditions and in harmony with the body rhythms, it is called clinical insomnia. Situational insomnia refers to difficulty in sleeping in particular situations

where biological rhythms are disturbed; such can be the case of changing shifts in controllers and night duty (Elizalde, Oscar, 1993).

The use of drugs or tranquilizers to induce sleep is usually inappropriate, as they have an adverse effect on performance for a certain period after ingestion. Alcohol is a depressant of the nervous system. It has a soporific effect, but it disturbs normal sleep patterns, and the effects persist after it has disappeared from the blood. Caffeine in coffee, tea and various soft drinks increases alertness and normally reduces reaction times, but it is also likely to disturb sleep. Amphetamines, when used to maintain the level of performance during sleep deprivation, only postpone the effects of sleep loss. Some loss of efficiency is to be expected. Therefore all these substances are to be avoided by the ATCOs in times around shifts.

The resolution of the problem of sleep disturbance or deprivation helps greatly to solve as well the problems of body rhythm disturbance and fatigue. Some techniques that can be apply in order to solve these problems are,

- Exercise and if possible in the open air,
- A balanced diet, taking into consideration the importance of meal times.
- Measures adopted in relation to light/darkness, rest/activity schedules and social interaction.
- Recognition of the adverse long-term effects of drugs (including caffeine and alcohol).
- Learning relaxation techniques.
- Scheduling shifts with the consideration of body rhythms, especially circadian.

3.3. Selection and Training.

The selection and training processes are two crucial stages in the life of an ATCO. Training and especially selection have varied throughout the years. Staffing needs change because ATCO workload and traffic volume are dynamic, so recruitment has to adapt to the needs of the job.

Having a good and accurate selection process will lead us to form the right group of people and will save time and money in the training stage as there will be no need to deal with less suitable candidates.

So far, no need for special recruitment has shown up. However, the profession of ATCOs is usually advertised as a challenging yet satisfying job which will bring the candidate success (DFS, www.dfs.de). Furthermore, ATC organizations such as NATS encourage candidates by literally asking "do you have what it takes to be one of our ATCOs?" (NATS, http://natscareers.co.uk). The well known characteristics of the job, conditions and salary of ATCOs make recruitment of a big enough group of candidates for a later selection process quite easy.

3.3.1. Selection.

There are many characteristics desired by ATC organizations for a candidate to have. Some of the most general ones are the ability to detect movement and recognize patterns, ability to prioritize between tasks, ability to filter verbally and visually, also ability to code and decode in a reasonably short time, possess inductive and deductive reasoning, have a great STM and LTM and be good at mathematical and probabilistic reasoning.

More capabilities have seemed advantageous, such as spatial ability, abstract reasoning, verbal reasoning and linguistic fluency. Psychomotor capabilities of relevance include manual dexterity, coordination, speed, accuracy and consistency in the performance of routine tasks, and effective usage of input devices.

Common requirements in all countries are good oral and written command of English, the international language of aviation, either European citizenship for all those countries in the European Union such as Austria, Germany, Spain and so fore, or US citizenship in the case of USA. Regarding the good grasp of English, this includes understanding speech under stress by someone whose native language is not English, who mispronounces words, and who is using noisy or distorting channels of speech communication.

Furthermore, every organization in every country has its own requirements and candidates have to go through different paths prior to training. Here I will show some of the differences between our closest and most developed countries in this subject.
One big difference that varies greatly depending on the country of application is the age at the moment of application, while in Spain it is only said that preferably between 21 and 28 years of age and also non-exclusive and in Austria is suggested to be between 18 and 25, in Germany the DFS requires a maximum age of 24 years and EUROCONTROL a maximum of 25. In the USA, and due to their special situation after the 1981 strike, the maximum age of application is set for most cases in 31 years.
Besides the difference in age, in most places candidates have to pass a medical examination where perfect hearing and colour vision is required and although the use of glasses or contact lenses is allowed, the eye correction may not exceed a very strict and low limit. In countries such us USA and UK, also security clearance must be given.
General intelligence is very important, for this purpose in most countries educational qualifications is requested from all applicants. But also here there are some differences, while in Spain and in the USA it is required to have gone and passed several years of university, in Germany, Austria or for EUROCONTROL only with a successfully finished secondary education at an advanced level is enough.

The general selection procedure for training is different depending on the country. In USA for example there is now the Air Traffic Collegiate Training Initiative Program (AT-CTI), where FAA has implemented partnership agreements with selected colleges to prepare students for potential hiring of ATCOs. These colleges will serve as one of the primary hiring sources for FAA, although candidates can directly apply for selection. In Spain, applicants must take several exams during the selection process. Exams where they are required to answer basic questions about aviation,

such as law, physics, meteorology, equipment and some others, and non-aviation specific contents are tested, as well as psychological tests in order to prove some of the capabilities and limitations of candidates. In places such as Germany or for the European control in Maastricht candidates are only given psychological tests.
This selection process of candidates for further training differs also in the time it takes. In the case of Spain, to complete the whole procedure and all the different stages, may take about half a year, and the application process is opened every two or three years for an average of 150 places. In places such as Austria, Germany or for EUROCONTROL, the application process is always open for candidates and the selection done straight away, although training only starts when a desired number of selected applicants is achieved.

As we have seen, psychological aspects are important in the selection process, these involve personality and attitude. The validity of personality measures in the selection of ATCOs is less certain than that of cognitive or behavioural ones. Apparently desirable attributes for which personality measures might be helpful include high motivation, tolerance of stress, tolerance of workload extremes, acceptance of boredom, emotional stability and possibly mild obsessionalism. Candidates should match the image of someone calm, confident, unflappable, decisive, mature in judgement and able to cope with excessive task demands.
Personality traits and attitudes influence the way we conduct our lives at home and at work. Personality traits are innate or acquired at early stages of life. They are deep rooted characteristics which define a person, and they are very stable and resistant to change. Attitudes are learned and enduring tendencies or predispositions, more or less predictable, to respond favourably or unfavourably to people, organizations, decisions, etc. An attitude is a predisposition to respond in a certain way; the response is the behaviour itself.
Attitudes and behaviour play an important role in safety; therefore an effective assessment of personality during selection is of great importance. On one hand, it is unrealistic to expect a change in personality through training, the selection process is the place and time to take the action and select only those whose personality matches the profile required. On the other hand, attitudes are more susceptible to change through training.

With everyday increasing dependency on computers and with the continuous development of new technologies and increasing automation in ATC industry, it may be desirable to include in selection procedures a test of ability to work with certain types of computers and information needed and given by them. Any of those tests should measure potential rather than actual ability so it will not favour just those familiar to computers but identify those with a bigger potential and talent to use these machines. The use of computer and automation also affects the process of selection itself, as now the tested population of candidates can be much bigger and broader because tests are easier to manage and correct with the help of these machines.

The more knowledge that is required during the selection process, the less teaching material that will be needed to teach during training and less time will be required in such training. For this purpose, there is now the case in some countries where additional knowledge is required prior to selection and in order to reach the training stage. This need to learn some basics before getting to the ATC school, has made the proliferation of more and more private academies with this objective. But these academies bring a problem as candidates now can be divided into two different groups, those that have been coached and those who have not. As nowadays, people can obtain and prepare psychological tests for ATC, academies can make a big difference in the selection process in favour of the ones being coached, without having yet results about if those students perform better the job than those who were not coached. Many times, the main reason why some applicants have the coaching and some others do not, is basically economical. It is also true, that those that visited these academies are frequently more focused and more highly motivated to go through the selection process and become ATCOs than others that prepare the process by themselves.

In case in some years, it is proved that those that were coached do finally perform better that those who were not, organizations should change their actual selection process and add a first stage were lessons and coaching are given to all candidates.

3.3.2. Training.

After selection, the training stage takes place. In contrast with the selection, the training process is much more harmonized in contents in the different countries and big differences cannot be noticed between them because many of the standards of air traffic control are agreed internationally. However, there are still some differences, especially regarding time length of the training.
The overall procedure to become and ATCO is the same in all of the studied countries, basically consisting of a period of theoretical course, learning of the job in simulators and on-the-job training.

In this whole teaching of the profession process, education and training can be seen as two different aspects. Education encompasses a broad-based set of knowledge, values, attitudes and skills required as a background upon which more specific job abilities can be acquired later. Training is a process aimed at developing specific skills, knowledge or attitudes for a job or a task. Proper and effective training cannot take place unless the foundations for the development of those skills, knowledge or attitudes have been laid by previous education.

The first stage of the training is more related to education and theoretical learning of the job and what it involves, where general knowledge about ATC is introduced as well as functioning of computers, radar and other equipment. Also the right use of the English language applied to aviation and ATC is taught and how to deal with emergencies, moments of great traffic and any other exceptional procedure from a theoretical viewpoint. The assurance of a perfect understanding of Aeronautical English is vital for the good running of the air traffic, so although during the selection process great emphasise should be put on this, further teaching during the training is to be done in order to achieve the required proficiency, consistent with safety, in the aeronautical phraseology. Beside the English as international aviation language, also in the different countries the especial terms use in aviation must be learnt in the country's own language as communication with local pilots are usually held in the local language, for example Spanish in Spain and German in Germany and Austria.

This first step takes more or less time depending on the place. While for example in Spain it is quite short as previous test of this knowledge is taken during the selection, in Austria it takes around six months and in places like UK, Germany or EUROCONTROL is held simultaneously with other stages and carried throughout the whole training so it is harder to calculate the time needed.

The second step in the training is the simulation part, where students apply their theoretical knowledge to control aircraft in a simulated environment. At this step, differences between the countries appear, as in some places such as USA and UK the student decides at this moment what type of controller he wants to be, either tower, control centre or approach, while in others as the case of Spain, students learn all three jobs and decide later on in the process of training, letting them move from one type of facility to another when developing their career as ATCO.

Here, after the student has learned what to do and how to do it, he must learn how well it has to be done to attain professional standards of proficiency, which is achieved through practical work using simulations or demonstrations rather than by classroom methods. By working with simulations, the future ATCO acquires skills and dexterity in using all the devices, the continuous planning of future work while doing current tasks, the fluency in speech and the required teamwork. Naturally, some of the concepts to be applied in simulator are strengthened through teaching material in classroom.

After the student has successfully completed the training in simulation under his chosen facility or under all different circumstances, depending on the country, he obtains a “student” license that allows him to control air traffic in any of the different airports or control centres under supervision of an instructor.

The third and last basic step in training, which will lead to the obtaining of the final ATCO license, is the on-the-job training. The facility where this stage takes place is chosen by the student as his first destination, where he will start developing his career. Here, everything that has been taught is put into practice, initially under close supervision, and the students learn that problems are not always like the simulated ones as well as get a real impression of responsibilities and stress of the controller. The already licensed to control student becomes familiar here with the environment

and characteristics surrounding the facility such as relief, obstacles and special weather conditions like fog or heavy rains.
This part normally takes between three and six months, but could be extended up to a year as the contractual relationship is a type of work placement.
At this stage, some of the important things in ATC, which makes the profession special, are learned. Such things are the relation with colleagues, pilots and personnel at the facility, the loyalty to the profession and willingness to defend it if it is challenged, and to become part of an integrated working team by trusting and respecting colleagues. A similar, but usually shorter, training is taken by controllers every time they move job or location, as the controller needs to get used to the new surroundings and special characteristics of the new job.

The whole process is said to last in the UK a minimum of six months to become an aerodrome controller or upwards of 12 months to become an area controller. In the case of Spain, the first two stages taken between 15 or 18 months, depending on the calendar plus an average of an extra three months to get the final license. In EUROCONTROL the theoretical and simulator lessons plus intensive on-the-job and simulator training in the facility takes two and a half years. And very similar is the case of AustroControl in Austria, where the approximate duration is about three years to become a fully capacitated controller. In the USA they have reduced the whole process from three or four years, as it used to take some years ago depending on the facility, to less than two years in most cases (FAA, 2008).

When talking about training, there is always a dilemma between what the companies in charge of the training of candidates want and what the ATC organizations require from their controllers to provide the air traffic service. While one of the main targets of training institutions is to reduce time and costs, ATC organizations obviously need assurance of quality in the preparation of their workforce.
One measure that some of the training schools in different countries are taking in order to reduce time in the college or academy and therefore cut down costs, is to make a stronger selection process by including tests on different topics and subjects that in the past were taught during the first phase of the training. Naturally, this allows the school not to waste more time explaining or teaching these basic concepts,

but this could lead in the worst of the cases to a good controller in performance that does not really understand the theory behind his actions.

The second main way to reduce time is to focus the candidates' training on only one type of facility, previously chosen by the student. This will save time as there is no need for further explanation of the different characteristics of the other jobs involved in ATC and will develop a much more focussed ATCO. This measure helps to shorten the training time by up to a half in the best cases (when focussed on aerodrome control). On the other hand, such a focussed controller may fail to understand the whole picture of ATC and the actions of his colleague in a different facility as well as to trust and respect them, because of the ignorance about what their job involves.

Also, another disadvantage of being focussed on only one type of job appears when wanting to move to another ATC job. Either the controller should not be allowed to move for example from tower to control centre, as the job is very different, or a whole new on-the-job and on simulator training is needed. This will require a complete retraining of the controller to adapt his capabilities to the new job and its new environment. Causing this the expenditure of the time and cost that was saved before, and sometimes due to age of the controller, personal conditions, more complicated location, etc. this training may not be successfully finished.

Regarding costs and quality, an optimum balance is also needed. On-the-job training allows the student to face having the permanent responsibility for the safety of aircraft and passenger and get a real feeling of what the profession is about. Although this training would be the most adequate one, due to several reasons the whole process cannot be based on this type of training; first because this type is comparatively expensive and second because of the obvious risk for aircraft.

Risk affects two factors in the learning process as well. If a student makes a mistake, the supervisor or instructor may have to intervene and correct it by taking control from the student without warning for safety reasons, and this will first, in some cases, not allow the student to realize what he has done wrong, and second, will not let the student learn all the consequences of his mistakes, as simulation can do, although sometimes these simulators could be seen just as a videogames.

In order to achieve the best training process, an adequate standardization of its different parts throughout the world would be required. With a global standardization ATCOs would be ready to work anywhere in the world, adapting themselves to the new area of free skies and a more global world, where planes and their pilots come from and go to every place.
The length of this course should be the same everywhere so as to not give advantage or preference to controllers in some countries where the whole selection and training process takes shorter. A standardized two years will accomplish all requirements, giving the students the basic knowledge and procedures, applying them in simulation and also in real ATC facilities.
The use of training packages which the student loads into a computer and works through independently will help instructors to be released from some repetitive tasks while the students can practise skills and acquire experience at their own pace in accordance with their own needs. This will also help to the standardization of the training process, allowing all students work from the same course material.
Students need to be trained under the conditions that are expected for the forthcoming years, with greater capacity and a more automated workplace where the use of computer assistance is essential, but never forgetting that controllers must be always able to control the air traffic without any computer assistance.

With the correct training, some types of incidents and accidents could be reduced or completely removed. Such cases include those incidents occurred when solving emergencies due to the lack of ability to handle the situation and prioritize tasks; as well as those caused due to the lack of knowledge resulting in what is classified as incident under stressful situations different than those of emergencies; and lastly, incidents caused without apparent cause such as deliberate deviation from the standard procedures, rules, etc. or those caused by lack of discipline and vigilance.

3.4. Workload, Responsibility and Stress.

3.4.1. Workload.

Workload is probably one of the best known human factors in ATC. Workload does not mean just the tasks the ATCO has to do because of his job. The full set of controller activities that are required to perform all the tasks in order to achieve the objective are known as the task demands. Workload depends also on who performs the work, in other words, the controller that takes care of the situation. If the same traffic scenario is presented to two controllers with different levels and types of experience, the task demands are the same but the workload may not be.

Workload is influenced by factors such as knowledge, experience, skill, understanding, professionalism, motivation and other personal factors and attitudes that will conduce the controller to find the work easy or difficult, familiar or unfamiliar, stressful or not and so on.

A certain event can vary in four ways that influence the resources the controller needs to deal with it. The first two dimensions which can vary are the frequency of occurrence in time and the extent to which the event is complex. Both, a high event rate and high complexity of the event, may increase the workload of the controller. The third and fourth dimensions can decrease or mitigate the workload, and include the extent to which the event is expected and to which the event is familiar or routine. A greater experience with high-workload situations or in handling a particular type of complex event reduces the resources required to deal with the event. Even in the absence of such familiarity, if events are anticipated, then advance preparation can reduce the demands on resources if the events actually occur.

High levels of workload may lead the controller to forget to check on the status of certain aircraft. Such a case was partially responsible for the collision between two aircraft on the runway of the Los Angeles International Airport in 1991. High workload can be a problem, not only because it can affect the controller's performance or safety, but also because it can set an upper limit to traffic capacity.

The aim in the last decade has been to decrease workload in ATC. This is because high workload has always been seen as something bad and harmful that must be reduced as much as possible. With this purpose, because there is evidence that human operators who experience high levels of workload can be susceptible to errors or performance breakdown, great effort has been put into the creation of different forms of computer assistance and automation. However, high workload also brings benefits to the controller in job satisfaction and interest, in the maintenance of skills through opportunities to use them, absence of boredom and in impressions that time does not drag during working hours.

Overload results only when each task competes for the same resources or the same input and output channels and when the total resource demand exceeds the controller's capacity. So controllers can check the radar or the flight progress strip while talking to a pilot, but cannot for example talk to a pilot while listening to other controllers, and also cannot check a big number of strips while building up the traffic picture with all of them and their associated data (flight level, speed, type of aircraft, etc.).

Also a too low workload can be dangerous for safety as it may result in boredom and reduced alertness, with consequent implications for handling emergencies. But low workload does not just mean low traffic, because it has been shown that maintaining vigilance under low task load requires considerable workload, especially mental workload.

Being conservative it can be said that operational performance in ATC can be compromised by both very high and very low task load (overload and underload), therefore the objective should not be to completely remove all kinds of workload but to achieve the good amount of workload that will ensure the controller feels satisfied and motivated and more importantly, keep safety levels high.

In order to be successful, controllers must use adaptive strategies to manage their performance. Controllers should attempt to manage the task demands at a reasonably constant level of effort, by accordingly decreasing the amount of time they spend processing each aircraft when an unexpected increase in traffic load appears. Also, controllers usually do other related but less important tasks, that in situations of work overload, can be taken over by a colleague so that the controller can focus on the control part.

Some measures such as decreasing sector size or increasing the number of controllers, does not necessarily solve the problem of overload, and many times increases it because of the consequent increase in intersector and intercontroller coordination and communication. Moreover, decreasing sector size reduces the amount of time spent with each aircraft, so the controller has less time to build up the picture of the traffic and be able to reorganize it according to the needs by giving instructions to pilots.

Regarding automation, it can help greatly in reducing workload as some of the more routine tasks can be reduced, but automation of a task must not be mixed with removal of a task, because often this automated task needs some sort of supervision or monitoring becoming sometimes an even more resource demanding or slower task than when it was being done by the controller, due to the complexity of the system or the way information is displayed. Automation usually reduces rather than increases workload; such is the case of advanced notification of conflict a decision aiding tool. However, this may increase boredom because it leaves the controller with little to do. Therefore, there is a need for balance between automation, workload and efficiency. More generally, automation changes the pattern of the controller's workload, normally decreasing it but could increase workload specifically related to vigilance or monitoring of tasks.

A very important fact is that ATCOs are proud of their job. Therefore when introducing automation to the everyday job, engineers and system developers have to be very careful. Usually controllers do not want to change their role in ATC from main operator to being supervisor of an automated system. Controllers like to maintain quite direct control over aircraft and the possibility to make the decisions.

Further implementation of automation in ATC must be preceded by analysis of impact on controller workload and study if results are not only those expected, regarding workload reduction, but also those desired in order to have a satisfied workforce.

3.4.2. Responsibility.

Although new procedures and technologies that represent increases in automation are being considered as means of meeting projected increases in air traffic, human controllers are expected to maintain responsibility for the safe and efficient flow of air traffic for the foreseeable future. No matter how well the system is engineered and tested, some level of system unreliability (or some degree of system failure) seems to be inevitable.

The ATC licence authorizes the ATCO to provide or supervise the air traffic service within the air space under control of the facility. Controllers must also notify anomalies or limitations observed in air traffic during their work, take part or full control of those tasks that are delegated to him by facility manager during absence, and take care of the on-the-job training of candidates for controllers when there is not specific training job in the facility.

The pilot is legally responsible for the safety of the aircraft and its passengers while the controller is legally responsible for the safety of the air traffic control instructions. No matter how well the boundary between these responsibilities is defined, ambiguities can arise. When both the pilot and the controller are implementing air traffic control instructions that are presented on screens in the cockpit and the air traffic control workspace, but have been derived from software in the air or on the ground, the issues of legal responsibility can become quite complex. The ultimate reason for the retention of humans in aircraft cockpits and in air traffic control systems may be their legal responsibilities rather than considerations of ATC, of human factors, of technology, or of aviation (Hopkin, 1995).

ATCOs know how much is at stake with every decision they make but they cannot and they do not dwell on these decisions. According to the words of Colleen Spring and Demetrios Liadis, two controllers of the Dulles airport (Washington D.C., USA)[5], controllers really do not have time to sit and think about each individual airplane and how their decisions affect all the lives of those people, they are thinking

[5] Video “Inside Air Traffic Control”.

about aircraft characteristics, thinking about call-signs and about separation. Controllers know what is at stake and the ramifications of what they do and what they say, but controllers usually do not realize it when they are in the middle of a task. Controllers do not think either that it is a videogame or that, for example, that plane is a 747 holding 240 people or that the other one is a DC 9 and may have 120. Emotions are not involved until the moment something goes wrong, then is the moment when they feel reality.

ATCOs are responsible for the safety and well being of large numbers of individuals by keeping distances between aircraft and being constantly alert to the possibility of an aircraft emergency. Speed in reaction is always necessary but calm co-ordinated actions are essential in this type of situation. Controllers are responsible for aiding pilots in reaching their destination, but furthermore for giving assistance and information required by pilots in order to solve the emergency.

However, controllers are responsible for more tasks than those described before. They also take care of doing preparation work before the flights take off. They will be responsible for checking weather statistics at the current airport and the future destination to ensure the safest route of travel and issue any possible weather delays. These individuals will also need to prepare specific flight information prior to the flight taking off.

ATCOs do not only issue orders to pilots, also to ground workers at the airport or airline. They have to give instructions in order to ensure that airplanes receive workers for picking up the baggage or for technical maintenance of the plane. Controllers also contact fire departments in cases of emergency or the adequate personnel in cases of obstacles in the runway that could affect the normal running of aircraft.

Lastly, ATCOs must ensure that they are doing their jobs in strict compliance with law and regulations. They will also need to comply with specific airport or centre rules while working at that particular facility.

3.4.3. Stress.

The ATCO profession has been called the most stressful job in the world. One mistake by a controller, one moment of forgetfulness, one slip of the tongue can mean disaster. It is possible incidents such as those of September 11th that make stress the major concern for ATCOs.

The great responsibility that rests on controllers' shoulders in conjunction with the great amount of workload which these people often have to cope with, make the job very demanding and stressful.

The most commonly accepted definition of stress, attributed to Richard S. Lazarus is that stress is a condition or feeling experienced when a person perceives that demands exceed the personal and social resources the individual is able to mobilize. People feel little stress when they have the time, experience and resources to manage a situation, but they feel great stress when they think they cannot handle it according to what is being demanded of them. Because it is a matter of what the people feel, it depends on the person to feel more or less stress.

Hans Selye also identified that stress is not necessarily something bad. Although it is usually assumed as a negative experience (distress) that should be eliminated, it is not always like this and stress can also have a positive impact (eustress). For example, the stress related with exhilarating, creative successful work is beneficial, while that of failure, humiliation or infection is detrimental (Seyle, 1956).

The response to stress is the unspecific response of the organism to any change, internal or external, through which the organism prepares itself to react to the possible demand generated as consequence of the new situation (Labrador, 1996). This response comes with the purpose of making extra resources available in order to handle this new "stressful" situation. Once the demand is being solved, the organism should return to its normal state. The response itself is not bad, but if it is too frequent, too intense or lasts too long, then it can have negative consequences as the human body has gone beyond its normal capacity of performance.

Stress can be associated with work but also with life events, such as family separation, and with situations such as periodic and proficiency checks. Even positive life events, such as a wedding or the birth of a child, can induce stress in normal life.

At work, stress for an ATCO can come from many different sources. The main sources are the operative aspects of the job, traffic load peaks, time pressure, and conflict resolution, which give no respite. Sometimes stress can come from the equipment, because the reliability, the large quantity of it or its age, either because equipment is too old for the high traffic demands or because is too sophisticated and for this reason is mistrusted or insufficiently understood by the operator.

The shift work is also a source of stress due to lack of sleep or rest. Role conflicts can also generate stress for several reasons, for instance, management is not supportive of or sympathetic to needs and requirements, unjust or ignorant attitudes towards controllers from outside the profession. Also working alongside inexperienced colleagues may cause stress, because the controller feels obliged to monitor the activities of colleagues to ensure safety.

More similar to other jobs, in ATC unfavourable work conditions can be a source of stress for workers, including pay and financial security, career prospects and development, promotion and retirement conditions, as well as in the case of lack of control over the work, due to lack of knowledge or training, ageing and burnout.

The consequences of these sources of stress may differ widely depending on factors such as age of the controller, lifestyle, work experience, personality traits, attitude toward work, motivation and physical and mental health.

The majority of consequences may be attributed to long term stress related symptoms. These may include:

- Headaches.
- Chronic fatigue.
- Heart burn.
- Indigestion.
- Hypertension.
- Chest pain.
- Coronary heart disease.
- Diabetes.

- Peptic ulcers.
- Sexual disorders.

It is important for an ATCO to learn to recognize his own personal signs of stress and those of his colleagues. Such signs can be talking too fast or too loud, stammering, sweating, increased heart rate, concentration difficulties, bad moods, frequent oversight and error, and others. Because ATC is a team effort, controllers should help each other to reduce stress before it gets out of control. Therefore, the first step needed is to recognize when stress appears. Apart from the above and medical evidences, some other such as self-medication, excessive drinking, absenteeism or depression for no apparent reason may show the possibility of stress in the individual controller.

The controller under stress may show decrements in performance and be well aware of them, or make strenuous and successful efforts to prevent or disguise the effects of stress on performance, at the cost of increased tiredness and anxiety. The time-scale of the controller's work planning may shorten, and the consequent anxiety can lead to frequent and obsessive rechecking of details and to rigidity in the formulation and the implementation of solutions to problems (Hopkin, 1999).

The alleviation of stress of any of the mentioned factors can differ greatly. While those related with work procedures can be alleviated by changes in some aspect of the ATC system, such as equipment, training, new procedures or the workspace, to solve others related to working conditions, changes in management are to be considered. Those cases of stress due to individual and many times totally unrelated to ATC causes but affecting controllers' performance, usually require individual treatment. Contrary to what could be thought, a permanent or temporary change to a different duty or job, may add stress rather than alleviate it, because there is still need to deal with the root causes.

Some of the techniques an individual can take to reduce or even get over stress are the following:

- Breathing techniques, when anxiety, fatigue, chronic tiredness, etc.

- Progressive relaxation techniques, used in cases of depression, headaches, insomnia, etc.
- Stoppage of thinking techniques, used against fears, obsessions, etc.
- Problem confrontation techniques, used also against fear and anxiety but in certain situations.
- Assertive confrontation techniques, used with communication problems and anxiety in personal situations.
- Feedback techniques, used with general anxiety problems, hypertension, headaches, back pain and similar effects.

The correct training and preparation to help control stress, could contribute to improve the state of persons in their occupations and work placement, and to achieve satisfaction. This would not only benefit the ATC organization or the individual but also would contribute to a healthier, more stimulating and gratifying social and family life, affecting the whole environment of the controller.

Basically it would prevent the burnout, which refers to the syndrome of professional weakening seen in professionals submitted to chronic emotional stress and whose main characteristics are physical and include exhaustion, cool and impersonal attitude to others and feelings of dissatisfaction with the work. This burnout syndrome constantly threats both the individuals and the organization.

3.5. Teamwork and Communications.

Although the work of an ATCO has always been seen as an individual job, the whole environment of ATC involves the work of a team composed of controllers in the same or different facilities and pilots or cockpit crew in general. This teamwork and the associated communications are critically important for safe and efficient air traffic. So far, pilots' involvement in ATC has not been considered in this work, it will be only in this part where, because of the communications between them and controllers, some of the tasks done by pilots will be mentioned.

3.5.1. Teamwork.

Many decisions in air traffic control are collaborative. For example, controllers in adjacent sectors may need to develop a joint strategy for avoiding a future conflict that affects aircraft in both sectors. A controller may issue an instruction to a pilot that the latter finds difficult to accept, or the pilot may make an urgent emergency request that the controller finds difficult or unsafe to grant. That is the reason why decision making may be viewed as collaborative, and some of it as negotiated, but always as part of an agreement between different members of a single team.

Fig. 7 illustrates an example of possible teamwork relations which a single operational controller might identify from his individual point of view (Barbarino, M., 1996).

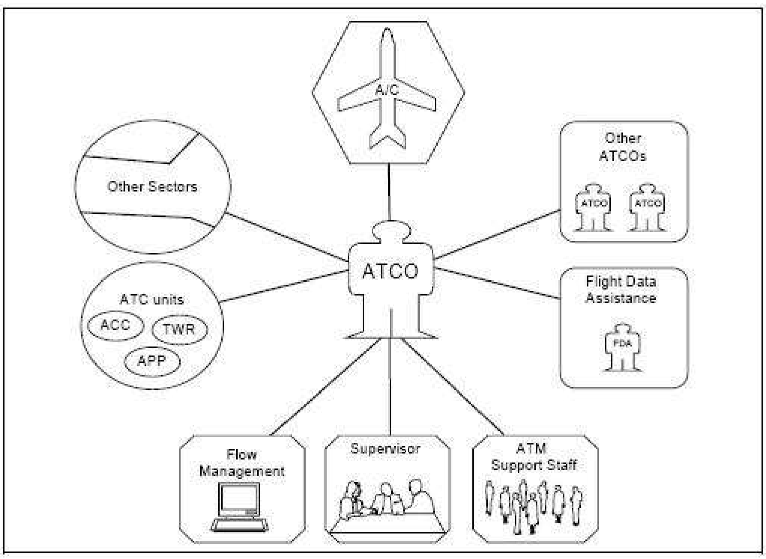

Fig. 7. Teamwork relations in ATC.

The key of good teamwork is effective participation. Teamwork improves:

- Productivity.
- Quality.
- Creativity.
- Commitment to achieve objectives.
- Quality of life at work.
- Decision making.

In teamwork, several people agree to contribute with their knowledge, skills, experience and their willingness to obtain synergy, which is the result of the coordination of efforts and which exceeds the result obtained from working independently. Teamwork allows improving the personal contribution of each member of the group, making him more effective.

In a team it is always important for every member to become familiar with the others, so they learn to trust in each other and rely on each other when they are overloaded. On the other hand, when team members become too familiar with team colleagues, efficiency can be damaged because of too much reliability on others' performance amongst other reasons. For this reason, ATC teams should not be too well established. This is very easy in the case of pilots, as it is very hard that pilots repeat a situation with the same team of controllers, so they always rely first on their own good performance and then trust the controllers when instructions are received. In the case of controllers who are with each other in the same or annex sector, team members should rotate or change every now and then, so although controllers do become familiar with each other's work, they do not take the performance of colleagues for granted, and they ensure their own good performance as well.

However, more attention needs to be focused on this important area, because there are incidents and accidents in which inadequate teamwork has been shown. Therefore, also during training, teamwork should be one of the aspects to be focussed on. The goal is to achieve a team with the same situation awareness. According to the definition given by Endsley, situation awareness is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995).

Situation awareness includes, ideally, an understanding of the current and future trajectories of all aircraft within the sector, some representation of traffic about to flow into the sector, awareness of other relevant but possibly changing conditions, such as weather and equipment status, and an understanding of how all the factors affect the achievement of ATC goals and constraints.

It is especially in on-the-job training where the training in teamwork has to be most intensely. On-the-job training constitutes the major means of socializing and qualifying new controllers as well as maintaining job competence. At this stage, instructors are usually fully qualified in the technical aspects of the controller function, but they do not receive systematic instruction in how to evaluate, instruct in, or reinforce team skills (National Research Council, 1997).

One of the key concepts in teamwork is leadership. A leader is a person whose ideas and actions influence the thought and the behaviour of others. Through the use of example and persuasion, and an understanding of the goals and desires of the group, the leader becomes a means of change and influence.

It is important to establish the difference between leadership, which is acquired, and authority, which is assigned. An optimal situation exists when the two are combined.

Leadership involves teamwork, and the quality of a leader depends on the success of the leader's relationship with the team. Leadership skills should be developed for all through proper training (Civil Aviation Authority, 2002). There are four different types of identified leadership styles: democratic, consultative, directive and autocratic. According to a survey held by FAA, the majority of controllers would prefer a consultative leadership style, in which leaders seek the opinions of subordinates, issues are discussed in group and objectives are set and tasks assigned together. However, most ATCOs reported experiencing autocratic leadership offering little consultation and explanation of actions. Under this kind of leadership, the leader sets the objectives, controls every activity step by step, evaluates the work and has the last word in every discussion.

Differences in results can be very obvious. Autocratic leadership, whilst quite effective in the presence of the boss, it can be very inefficient in his absence, furthermore no synergy is usually achieved, the work is primarily done as result of fear and the morale is often down. In the case of consultative leadership, greater

interest in the job is developed, more originality, good spirit and good performance is achieved even when the boss is absent because the team keeps working normally.
The profile of a leader should have characteristics such as:

- Does not force others.
- Understands the needs of teamwork and coordinates the knowledge and techniques of the team.
- Emotionally and intellectually future oriented, not stuck to the past.
- Willing to assume responsibilities and start new missions. Very creative.
- Good at resolving conflicts and finding consensus.
- Good motivator, encouraging other people to give their best.
- They do what it is expected from them, overcoming difficulties.
- Respecting others, which contributes them being respected by other.

With all these characteristics good leaders can manage ATCOs' teams in order to divide tasks, find an agreement and achieve the best performance together with the help of pilots.

Automation in ATC has lead somehow to less teamwork. Now, controllers rely more on the information displayed in front of them than on what the colleagues can tell him via radio. Computer systems provide more detailed information about the aircraft so teamwork and the importance of coordination have been reduced.
However, teamwork is still very important and ATCOs should cross check all information with pilots and colleagues in order to avoid any risk of system failure.
Therefore, team-related automation issues must also be considered during team training, as well as the correct evaluation of the impact of automation components on team performance before adopting such systems. As an example of good teamwork between cockpit crew and controllers, the case of the United Airlines Flight 232, where the plane lost all hydraulic systems and flight controls due to the catastrophic failure of an engine. During the in-flight emergency, the flight crew worked with controllers to select an alternate airport and to mobilize emergency units prior to the attempted landing. In this instance, there was appropriate exchange of information and also sensitivity to workload issues and emotional support needs (National Research Council, 1997).

With the right teamwork, incidents and accidents can be reduced. Such incidents as those that happen when resolving emergencies when there is a lack of delegation of tasks due to the lack of confidence in the team or colleagues, or also incidents without apparent cause when relation and communication problems between team members exist.

3.5.2. Communications.

Communications have been mentioned often as the reason of air traffic accidents. Effective communication, which includes all transfer of information, is essential for the safe operation of flights. Therefore communications between controllers and between controller and cockpit crew are very important in order to provide a smooth, safe and flowing air traffic service. Between 1976 and 2000, more than 1100 passengers and crew lost their lives in accidents in which investigators determined that language had played a contributory role (Mathews, E., 2004)

To the controller, the most familiar way of communication is speech, but the message may be transferred by speech, by the written word, by a variety of symbols and displays or by non-verbal means such as gestures and body language. The information transmission within the ATC system can become complex and elaborate. Nowadays, by automated computations, a great deal of information is transmitted, stored, updated and processed. There is far too much information available for any human to absorb all of it, and it is far too detailed for most ATC tasks.

The quality and effectiveness of communication is determined by its intelligibility, the degree to which the intended message is understood by the receiver.

It is the task of human factors to prevent communication errors. This task includes the explanation of common communication problems as well as the reinforcement of a standard of language to ensure the error-free transmission of a message and its correct interpretation. Ambiguous, misleading, inappropriate or poorly constructed communication, combined with expectancy, have been listed as elements causing many accidents. Expectations influence perceptions. We see or hear what we expect to perceive, and this tendency allows the perception of expected and routine events to proceed rapidly and with minimal effort. Yet such expectation can be a source of vulnerability when events occur that are not expected, especially when these events are not perceptually salient or occur under conditions of high workload.

There are several hazards which reduce the quality of communications:

- Failures during the transmitting process (e.g. the sending of unclear or ambiguous messages, language problems).
- Difficulties caused by the medium of transmission (e.g. background noises or distortion of the information).
- Failures during receiving (e.g. the expectation of another message, wrong interpretation of the incoming message or even its disregard).
- Failures due to interference between the rational and emotional levels of communication (e.g. arguments).
- Physical problems in listening or speaking (e.g. impaired hearing or wearing of the oxygen mask).

The international aviation language is English, therefore every voice communication must be held in English. In most countries they can be also held in the local language prior request from the pilot. Such is the case of Spain, where communication can be done in Spanish when the pilot chooses to do so. The language used in aviation has a very specific vocabulary and very reduced, and with sentences whose meaning is regulated by aviation authorities (ICAO, EUROCONTROL). This “phraseology” allows having short and understandable communications between pilot and controllers without misunderstandings. Phraseologies should be used whenever possible and plain language when phraseologies do not suffice.

With this goal, introduction of language proficiency rating scale has been done to assess the ability of controllers and pilots to use English adequately in international operations, as well as recurrent language training and testing of language skills. All this will help to ensure that personnel everywhere acquire and maintain the minimum level of proficiency consistent with safety (Mathews, E., 2004).

This level of proficiency must be accomplished by both native and non-native speakers. Also native English speakers must learn the “aviation English” and adapt to the requirements and phraseology, ensuring that their variety of English is comprehensible to the international aeronautical community.

When pilots and ATCOs speak to one another in the professional context, the exchange usually takes place in a prescribed, coded language, which is the "phraseology". The phrases used in radiotelephony are designed to make the communicative function between the ground and aircraft and also between controllers as concise and brief as possible, with the emphasis on accurate content as opposed to linguistic form. As the airspace is increasingly busy, there is little time for chatter or conventional politeness. The brevity and conciseness of the communication is accomplished partly by using formulaic and predetermined sentence fragments as opposed to complete sentences. Typically, grammatical markers, such as determiners ("the" or "a") and auxiliary verbs are deleted, a feature making ATC communications markedly different from natural language.

The best known example of misunderstood communications took place in Tenerife (Canary Islands, Spain) in 1977, when two Boeings 747 met on the runway with heavy loss of life. When the co-pilot of one of the Boeings, a KLM, asked for clearance before taking off, he radioed "ready for take off" and "waiting for our ATC clearance". The KLM crew then received a clearance which specified the aircraft's departure route and gave instructions which stated what to do after take-off (the word take-off itself was part of the clearance), but not an explicit, distinct statement saying that they were cleared for take off. The KLM co-pilot read the clearance back to the controller completing the readback with the statement "we're now at take-off" or "we're now uh...taking off" (the exact wording of his statement was not clear) indicating to the controller that they were beginning their take-off roll. The controller initially responded with "O.K.", terminology which, although commonly used, is nonstandard, which the KLM crew heard clearly and reinforced their misinterpretation that they indeed had explicit take-off clearance. The controller's response of "O.K." to the co-pilot's nonstandard statement that they were "now at take-off" was likely due to his misinterpretation that they were in take-off position, and ready to begin the roll when take-off clearance was received, but not actually in the process of take-off. The controller then immediately added "Stand by for take-off, I will call you", indicating that the controller had never intended the clearance to be interpreted as a take-off clearance.

However, a simultaneous radio call from the other Boeing’s, a Pan Am, crew at that precise moment caused mutual interference on the radio frequency and all that was audible in the KLM cockpit was a heterodyne beat tone, making the crucial latter portion of the tower's response inaudible to the KLM pilots. The Pan Am crew’s transmission, which was also critical, was reporting that “We’re still taxiing down the runway, the Clipper 1736.” This message was also blocked by the heterodyne and inaudible to the KLM crew. Either message, if broadcast separately, would have been audible in the KLM cockpit and given the KLM crew time to abort its take-off.

Due to the fog, the KLM crew was not able to see the Pan Am 747 taxiing on the runway ahead of them. In addition, neither of the aircraft could be seen from the control tower, and the airport was not equipped with ground radar.

While the KLM crew had started its take-off roll, the tower instructed the Pan Am crew to “report when runway clear”. The crew replied: “OK, we'll report when we're clear”. On hearing this, the KLM flight engineer expressed his concern about the Pan Am not being clear of the runway by asking the pilots if the Pan Am was not clear. However, the captain, focused on the takeoff and under the impression that they had take-off clearance, emphatically replied yes and continued with the take-off. The result was the collision of both planes and the death of 583 people, making it the worst accident in aviation history (Wikipedia).

In this accident there were many the factors that lead to the disaster, including weather conditions, small airport with not enough infrastructures, lack of personnel at that moment in the airport and a bomb in a near airport that made this two and many other planes land in Tenerife, causing the block by several parked airplanes of the runway where the taxiing did normally take place, leaving only one free runway for both taxiing and landing and take-off. However, it can be seen very clearly how important communications are. The controllers was also blamed of not having a good enough command of English as one of the causes, but the use of nonstandard phraseology was one of the main issues. Since then, this special language was greatly developed in order to avoid such misunderstandings as well as communications equipment was improved to broadcast separately and be able to hear several conversation at a same time.

One characteristic of the phraseology is that is not tied to any particular culture or local variety of English. All novice pilots and ATCOs begin at the same place, not knowing what the phrases are or how to employ them. With practice, they eventually become fluent in the use of ATC phraseology (Mitsutomi, M., 2004).

The voice communication should be according to the ICAO standards, which are shown in Table 2**¡Error! No se encuentra el origen de la referencia.**:

Table 2. ICAO rating scale for language proficiency at the operational level.

PRONUNCIATION	STRUCTURE	VOCABULARY	FLUENCY	COMPREHENSION	INTERACTIONS
Pronunciation, stress, rhythm and intonation are influenced by the first language or regional variation but only sometimes interfere with ease of understanding	Basic grammatical structures and sentence patterns are used creatively and are usually well controlled. Errors may occur, particularly in unusual or unexpected circumstances but rarely interfere with meaning.	Vocabulary range and accuracy are usually sufficient to communicate effectively on common, concrete, and work-related topics. Can often paraphrase successfully when lacking vocabulary in unusual or unexpected circumstances.	Produces stretches of language at an appropriate tempo. There may be occasional loss of fluency on transition from rehearsed or formulaic speech to spontaneous interaction, but this does not prevent effective communication. Can make limited use of discourse markers or connectors. Filler are not distracting.	Comprehension is mostly accurate on common, concrete, and work-related topics when the accent or variety used is sufficiently intelligible for an international community of users. When the speaker is confronted with a linguistic or situational complication or an unexpected turn of events, comprehension may be slower or require clarification strategies.	Responses are usually immediate, appropriate, and informative. Initiates and maintains exchanges even when dealing with an unexpected turn of events. Deals adequately with apparent misunderstandings by checking, confirming or clarifying.

Besides mastery of phraseology, pilots and controllers must possess an intimate understanding of ATC, including its own language, with vocabulary and concepts not readily understood by people who are not accustomed to it. They must have studied English for specific purposes to understand its specialized and explicit vocabulary and expressions; which is known as English for specific purpose. Furthermore, pilots and ATCOs must be able to achieve mutual understanding through the use of plain or general language to get their messages heard and understood, and have the ability to communicate when there is no prescribed script, such as ATC phraseology. This type is known as English for general purposes. It is safe to assume that everyone in the cockpit and either in tower or control centre has mastered at least the basics of ATC communication because it is part of the training, but what cannot be assumed is that this same personnel have basic conversational ability in general English, as it is not commonly regulated in many training facilities (Mitsutomi, M., 2004).

For aviation communication to be successful, pilots and ATCOs must be competent and fluent users of all three types of English. First, they must absolutely dominate the phraseology. But for those times when the ATC phraseology is not appropriate, general English is needed.

In order to communicate correctly and get the message through and received by the pilot, more than a good command of English is needed and are several the measures an ATCOs should take in order to achieve a good understanding of his instructions. For example, a controller should not give more than three pieces of information in a single transmission, otherwise the pilot will not be able to memorize it all and act accordingly. The complexity of the controller's transmission has a direct effect on the pilot's ability to remember it. It has been proved that there are fewer readback errors and request for repeats with short and simple transmissions.
Also, ATCOs should avoid issuing strings of instructions to different aircraft, because a pilot's memory for an instruction is hindered by other pieces of information presented before and after it. Further, when the instruction given is different from what the pilot was told to expect, the difference must be emphasized. Good readbacks are very important in communications in order to ensure the good understanding of every instruction, also because catching readback errors is a very difficult task, because as previously mentioned, we all see or hear what we are expecting to perceive (Cardosi, K.M., 1999).

The speed rate of speaking must be constant and relatively slow. Speaking quickly may seem like a timesaver, but it can backfire. It has been tested that the rate of pilot readback errors doubled when the same controller issued the same complex clearances in a moderately faster speaking voice (Burki-Cohen, J., 1998). In relation with this issue, manoeuvres for traffic avoidance took almost twice as long to complete if the controller had to repeat part or all of the clearance. Therefore it is of vital importance, that instructions are spoken clearly in order to avoid repetitions as it will save a lot of time and will be much safer.

Not much has been done in automation related to communication and more specifically with speech. Everyday there is more and more information directed to controllers and they have to handle it. Automation of communication systems, and especially speech recognition systems, can help controllers to manage the great amount of messages they receive in peak times. With the help of computers or similar systems, messages from pilots or other controllers could all be recorded simultaneously as the transmitter wants to send it, and then they could be displayed as soon as the controller has time and, more importantly, already prioritized. With speech recognition systems, messages could be ordered according to their importance based on some key words, so emergency instructions are handled before routine tasks.

Automation could also help controllers by issuing all the phraseology and routine instructions and letting the human force deal with the non-standard cases where knowledge, experience and often improvisation are required.

4. CONCLUSION.

After this study where we have gone from the basics of ATC and the air traffic industry in general to a more concise concept of what human factors mean and the deeper knowledge of some of the most relevant human factors regarding ATCOs performance, we are now in the position where some conclusions or results can be drawn.

The need for a human factor lies in that they should anticipate and resolve those problems that are not recognized in time, and so must be resolved retrospectively with less satisfactory but more costly palliative. With this purpose the limitations and capabilities of human beings have been studied in this thesis and it has been seen that research and development is nowadays too focussed on systems. Systems should be developed according to their users and not the other way around where the operator adapts to the machine. The relation liveware-hardware is here the main issue, and as it was seen in the SHEL model, liveware must be the central and more important part to which all the others should adapt.

It is in the need to cope with the new capacity and safety regulations where new technologies are sought. Humans will remain the centre of the whole system, but in its relation with the environment and its changing characteristics new software and hardware parts are needed in order to be able to cope with the new scene.

Through selection and training we have been able to see how the different nations are preparing their ATCOs, but also the need for a standardized method can be seen; these will let controllers from any part of the world work at any facility around the globe. These requirements of globalization of the ATCO's workplace come from the everyday more globalized world in which we live and from the use of the same air traffic legislation that is being imposed first in European airspace by the European Community, and hopefully soon will apply to all skies. In a globalized world where airlines work around the planet, ATCO should also be able to develop their career where they choose and also able to change facilities if he needs to.

It probably cannot be said directly that one selection and training process is better than other. The training will always depend on what is done previously in the selection process, so according to this, the standardization of the whole process should be done in order to be applicable in every country willing to be part of this unified ATC system. Training processes will require more or less time depending on the pre-requisites of the candidates, but training organization should make sure that no steps are missed during this procedure. With the purpose to make it equal for all candidates, selection should not be made based on previous knowledge but on capabilities, skills and attitudes, which is one of the most important points in the performance of an ATCO. Knowledge can be always acquired if the right team of teachers and the right equipment is available and if the candidate is sufficiently qualified and motivated for this venture.

The great responsibility ATCO has to deal with along with a less than optimal workload, brings stress into the controller's life. Stress is many times needed for people to perform correctly and in time, but an excess of it, especially of distress, can be very dangerous for the health and well-being of controllers. ATCOs need to learn how to control this stress, how to use it in the right way to help them achieve a better performance but at the same time not to let it get involved in their personal and private life. Stress must be used at work and to work, otherwise it will cause damage on the individual's life, health and family. Controllers have to cope with a high level of responsibility and it will continue like this in the future, as automated equipment will not be taken as responsible for failures. There will always a need to have someone as the responsible in the case of incidents or accidents.
Therefore, and as responsibility of ATCOs is very hard to decrease, overload at work seems to be the way to control and somehow solve the stress problem. Workload depends greatly on the experience, skills and knowledge of the controller, it is for this reason that the selection and training stages in a controller's life are very important in order to have people that are able to cope with a greater capacity and at the same time have a lower level of workload. Controllers must keep their workload at a steady as possible level; trying not to have big peaks of work in certain hours of the day. For this purpose, there is a need for commitment by the managers who are responsible for dividing tasks between controllers according to the different shifts and traffic demand. With a more stable situation, controllers do not need to have so much stress to perform but also they can react better to exceptional situations or emergencies, as they have a completely stabilized scenario.

Although automation has been always seen as the solution to high workload and that the technological developments have been impressive, there is also little doubt that automation is far from being able to do the whole job of ATC or even some of its most critical aspects, and especially to detect when the system itself is failing and what to do in the case of such failure.
The human is seen as an important element in the system for this reason, to monitor the automation, to act as supervisory controller over the subordinate subsystems, and to be able to step in when the automation fails. Humans are thought to be more flexible, adaptable, and creative than automation and thus better able to respond to changing or unpredictable circumstances. Given that no automation technology, equipment or its human designer can foresee all possibilities in such an environment, the controller's experience and judgement will be needed to cope with these conditions.
There are great challenges in the application of automation in the different fields of ATC and especially related to human factors. It has been seen how automation can have effect in many different situations and not always in a positive way. In such a specialized world as ATC, it is very hard to reach a good level of performance through automation without at the same time taking over some of the tasks ATCOs probably enjoy the most, which are the direct contacts with airplanes and the management of a complete air traffic scene. For this reason, special care has to be taken when developing new systems able to cope with the future traffic demands but without restricting or reducing too much the job of ATCOs, changing their role to one where their main objective is to monitor the performance of automated computers or equipment.

It is as this point when the right managerial skills are needed to put in place. ATCOs have acquired a reputation in some countries as quite a difficult workforce to manage, because of intransigence, managerial ineptitude or mutual failures communicating. Managers of such a group much show sympathy to them and at the same time understand their needs. Management must explain controllers why certain changes are essential to maintain an efficient service, and the cost constraints on those changes, and at the same time ATCOs should express their real needs in the workspace. Controllers need to understand as well, that management must meet financial and political objectives, and that they must ensure that all aspects of the system are robust, reliable, serviceable and maintainable and meet or exceed the specifications, and comply with international and national constraints, standards, rules and regulations.

Management of controller's team must work in the direction of improving ATCO's working conditions ensuring they are satisfactory for the personnel, and must also work as public relations to give promotion and publicity of the profession, to make people understand the job and what involves, so all stakeholders of the air traffic industry, from airline managers or crew members to passengers all around the globe have a better view of this particular profession. Furthermore, management have among the practical objectives, the attraction of a continuous supply of qualified and motivated candidates to become ATCOs, who have realistic and well-informed expectations about the jobs for which they are applying, who know all the requirements they need to fulfil and who are not scared of taking on great responsibility.

It is been said that to make mistakes is human, but there is an obvious need to decrease the chance of this to happen. Although is been estimated that each ATCO makes several errors every hour, literally hundreds of errors per day but very few serious incidents per week, month or even per year. Millions of errors are therefore made before a serious incident or an accident occurs. Human factors help to develop positive attitudes and behaviours towards teamwork skills and human performance in ATC helping to reduce the number or minimise the impact of teamwork related errors within in the system.

ATC needs strategies for the best use of all available resources, which basically are people, equipment and information, to optimise the safety and efficiency of air traffic service operations.

Through a good manage of team, the correct distribution of tasks and achievement of good teamwork, many of the problems human factors are facing in ATC can be solved or at least reduced. The benefits of such group work could be seen in the management of stress, in the quick, easy and right decision making of controllers, in the good end of communications, in the lower impact of new automation or

procedures introduced, as work can be more easily shared, the common understanding of situation awareness and summarizing reduce the number of teamwork related incidents, reduce the consequences of unavoidable errors, enhance task efficiency, enhance sense of working as a part of a larger and more efficient team and finally increase job satisfaction of the team members, the Air Traffic Controllers.
In order to achieve this good team performance, elements such as communication and leadership, delegation of tasks and appropriate workload distribution, the establishment of priorities, monitoring and cross checking, management of distraction and avoidance of preoccupation are important characteristics that need to be dealt with and that have many implications, not only for safety but also for the efficiency of the operations.

Therefore, and to conclude, it can be said that human factors have a wide range of applications whose branches reach all aspects of the job and environment of ATCOs. When applying human factors to an industry such as ATC, it is necessary to do so with a global view of the different aspects which will be affected in order to achieve the goals intended. As well, the application of automation techniques will affect the workforce, because new procedures and technology will certainly change the roles and functions of controller tasks and teamwork. However, plans for some future ATM system concentrate primarily on support and computer assistance tools for the tasks of controllers rather then replacing them. ATC systems will remain human centred for the foreseeable future.

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Austro Control. http://www.austrocontrol.at/en

Civil Aviation Authority. http://www.caa.co.uk/

Deutsche Flugsicherung. http://www.dfs.de/dfs/internet/english/index.html

EUROCONTROL. http://www.eurocontrol.int

Federal Aviation Administration. http://www.faa.gov/

ICAO. http://www.icao.int/anb/humanfactors

Ministerio de Fomento (Spain).
http://www.fomento.es/MFOM/LANG_CASTELLANO/DIRECCIONES_GENERALES/AVIACION_CIVIL

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USA Schools. http://www.atccti.com/ctischoo.html.

Purdue university. http://www2.tech.purdue.edu/at/courses/plans_of_study/aminfo/CTI.html

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LIST OF ABBREVIATIONS.

ACC – Air Control Centre (similar to ARTCC).

AENA – Aeropuertos Españoles y Navegación Aérea (Spanish Airports and Aviation).

ARTCC - Air Route Traffic Control Centre.

ATC – Air Traffic Control.

ATCO – Air Traffic Controller.

ATCT – Airport Traffic Control Tower.

ATM – Air Traffic Management.

DFS – Deutsche Flugsicherung.

FAA – Federal Aviation Administration.

FL – Flight Level.

GMT – Greenwich Mean Time.

ICAO - International Civil Aviation Organization

ICM – Instrument Meteorological Conditions.

IFR – Instrumental Flight Rules.

LTM - Long Term Memory.

NATS – National Air Traffic Services.

REM – Rapid Eye Movement.

STM – Short Term Memory.

STSS – Short Term Sensory Store.

TRACON – Terminal Radar Approach CONtrol.

UTC - Universal Time Coordinated.

UK – United Kingdom.

USA – United States of America.

VCM – Visual Meteorological Conditions.

VFR – Visual Flight Rules.

VOR - VHF Omnidirectional Range.