LR-CAS

Long Range - Conflict Avoidance System

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The current air transport system has modified the old concepts of distance and time. Old fashioned safety and efficiency methods may be compromised in this new panorama, in which the air traffic is dramatically increasing. Moreover, one of the weakest points is the resolutions of potential collisions. Why do not we solve the potential conflicts in advance? LR-CAS may be the solution for most of these problems.

Introduction

Nowadays, air transport has become the most profitable transport system, and has produced a lot of benefits to the modern society. Forecasts indicate that it will continue growing rapidly. This growth will affect the management system and it will be a great opportunity for all the firms in the aeronautical sector. Talking about the main challenges that Europe and North America have to achieved are:

- Quality and affordability in the products and services.
- Reducing the environmental impact.
- Safety and confidence of passengers and society in the commercial aviation.
- More efficiency of the air transport system.
- Security involves economics, services and companies.

The different ways to get these objectives could be the following:

- Research infrastructures.
- Competitive supply chain.
- Certification and qualification processes.
- Education systems.
- Trans-European energy.

We are now halfway to 2030 and a great deal of initiatives has been started, but the result still not present. This initiative is carried out by two main projects:

- SESAR *(Single European Sky ATM Research Programme)*, which aims to develop a new-generation air traffic management system based in three different points: definition phase, development phase and deployment phase. Its main objectives are reducing in a 10 % the environmental impact, increase by a factor of 10 the safety, triple the capacity of the system, and reduce in a half the operative and management costs.
- NextGen *(The Next Generation Air Transportation System)*, which proposes to transform Americas air traffic control system from an aging ground- based system to a satellite-based system. Its main goals are to reduce the environmental impact, be more proactive about preventing accidents with advanced safety management, to get the right information to the right person at the right time, make a better use of airports, and improve and accommodate future needs of air while strengthening the economy.

The developing process follow by air navigation is in essence not different to the one happen in other transport media, in the sense that the vehicle is becoming more friendly with the crew and with the test of the time. Moreover, when the number increases up to the point that in certain spaces saturation is made, the nature of the challenges has also change. The challenges of air navigation along the history have been:

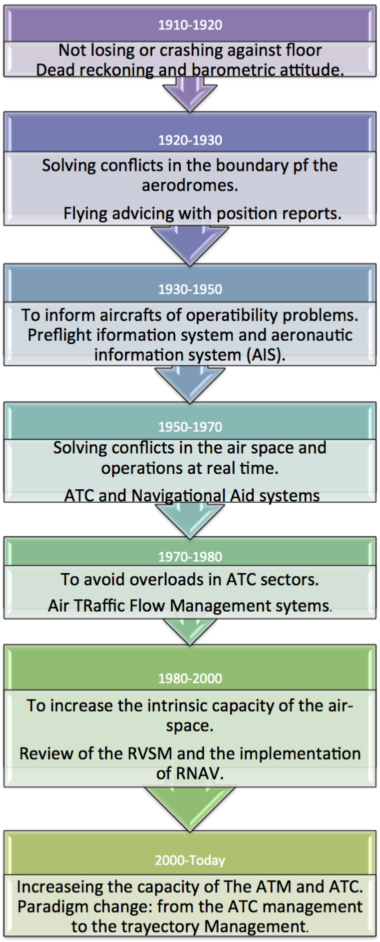

Figure 1: *Challenges of air navigation.Based on the book Navegacion aerea, Saez Nieto, Garceta*

As flying is the result of both technology and human skills, Air Traffic management (ATM) is about the process, procedures and resources which come into play to make sure that aircraft are safely guided in the skies and on the ground.

For the ATM system and its users to operate at their full potential, pertinent information needs to be available when and where required. Todays ATM system comprises a wide variety of applications developed over time for specific purposes. It is characterized by many custom communication protocols, each with its own self-contained information systems: on board the aircraft, in the air traffic control center, etc. the expected increase in aviation capacity demands, economic pressure and attention to aviations environmental impact means that all players will rely more than ever before on accurate and timely information.

Such information must be organized and provided through flexible means that support system-wide interoperability and secured seamless information access and exchange. In short, what is needed is a System Wide Information Management (SWIM).

SWIM

SWIM introduces a paradigm change in the way information is managed. With this system, information is made available and processed through services, which need to conform standards and to be registered ,so that services are known (discoverable) and accessible (usable). SWIM significantly changes the information sharing process as it shown in this figure:

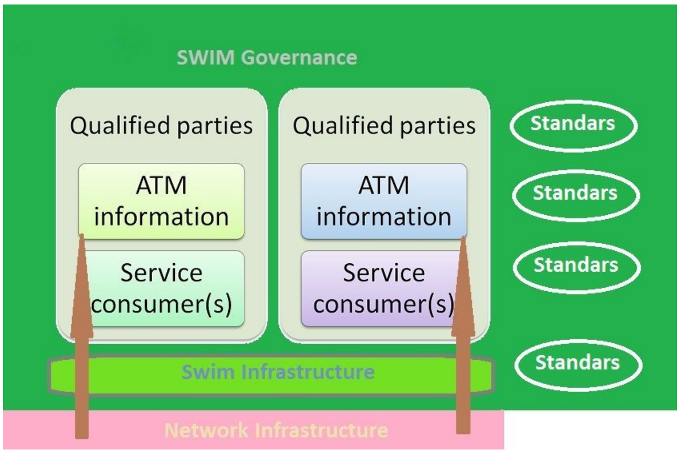

Figure 2: *SWIM structure.Image modified from a SESAR advertisement.*

It can be said the SWIM is a model of information, service and management supported by a technical infrastructure.

Currently, the main pillars of Swim are the Governance, the Compliance Framework, the Security and the Prototypes development.

The implementation of SWIM is not a big-bang replacement of the existing ATM environment, but rather an evolutionary process based on a gradual transition towards a service-oriented European ATM system. The adoption of SWIM will be flexible, fostering increased levels of collaboration in business domains and enabling supporting systems to interact in an interoperable and standardized way.

SWIM can be defined as an information technology infrastructure that will operate in the background to provide data to authorized users. Moreover, the main objectives of this system are to implement a service-Oriented Architecture in the Airspace System, allow creating new system interfaces more quickly and more cheaply than is possible today and facilitating to increased data sharing. However, SWIM is not a set of avionics equipment, a substitute for the National Airspace System modernization program or a telecom program.

This system facilitates more efficient sharing of air traffic management system information such as airport surface movement information, flight planning information, airspace restriction, weather information, and traffic flow management information.

SWIM principles are:

- *Separation of information provision / consumption:* In the ATM network, almost every participant is a producer as well as a consumer of information. The key issue is to decouple producers of information from the possible consumers in such a way that the number and nature of the consumers can evolve through time.
- *Loose system coupling:* Where each of its components has, or makes use of, little or no knowledge of the definitions of other separate components. By doing this, the barriers between systems and applications are removed, and interfaces are compatible.
- *Using open standards:* An open standard is one that is publicly available and has various rights to use associated with it. The terms "open" and "standard" have a wide range of meanings associated with their usage
- *Using Service Oriented Architecture:* Driven by analysis of business processes and needs functionality is developed, packaged and implemented as a suite of interoperable services that can be used in a flexible way within multiple separate systems from several business domains.

The information exchange system and real-time communication is extremely important for the optimization and improvement of the air space system. Just as the Internet has brought a revolution as information exchange system and a new means of communication, which has given the opportunity to a new generation in terms of business, trade, social relations, develop of communication ways SWIM intended to mean a revolution, similar than Internet has meant for the contemporary society, referring to the world of aviation.

The aeronautic sector and all the companies related to him has notice the importance of SWIM for the future of aviation, this is why SESAR and NextGen have special sections for the research and development of this important system.

SWIM is the central tasks for achieving the goals proposed for 2030 horizon; a great deal of new projects are based or has supposed the existence and operation of data link communication system for its perfect performance, this is why SWIM should play an important role and may be useful for a multitude of devices and subsystems, some of which are already under development.

The development of these technologies in the industrial aspect is mainly performed by the two great general projects in the two most congested airspaces: Europe with SESAR, and North America with NextGen.

<u>In SESAR</u> [1]

- *Swim Wp:* Firstly to prototype and validate some of the newer SWIM concepts. And organize the commonly shared information and develop and deploy the associated changes in the different user systems and applications. (Noracon, Thales and Selex) [2]
- *WP 14:* Following-up the SWIM-SUIT project activities and deliverables in order to identify the applicability of the results to the SESAR Work Programme and in particular the ability to support the Intranet for ATM concept of operations by:
  - Demonstrating an Inter-system seamless exchange of data in the SESAR ATM environment using SWIM test platform to validate concepts.
  - Providing SWIM test platforms (Thales, Selex)
- *WP 8:* it will contribute to the ATM Master Plan Achievement by establishing the framework which defines seamless information interchange between all providers and users of shared ATM information, so as to enable the assembly of the best possible integrated 4D picture of the past, present and (planned) future state of the ATM situation. (Noracon)

<u>In NextGen</u>

- *RITA:* The John A. Volpe National Transportation Systems Center, provide aviation expertise

[1] SESAR Workpackages
[2] System Wide Information Management

and coordination with the SWIM Program. The Volpe team was tasked with developing a SWIM-compliant Integrated Terminal Weather Service (ITWS) Prototype.

- *MIT Lincoln Labs:* is developing the SWIM-compliant Corridor Integrated Weather Service (CIWS) Prototype. SWIM's Flight Data Publication Service (FDPS) is also being developed at Volpe.

These are some of the partners of NextGen, however there exist a great deal of companies working with NextGen to the research and implementation of SWIM. Looking forward, there exist other lines of investigation focused in the development of new concepts and ideas much more abstract than the industrial development, included on an academic framework. Some examples are:

- *Pilot Interaction with TCAS and Air Traffic Control* [1]
- *Datalink Communication in Flight Deck Operations* [2]
- *Using Data Communications to Manage Tailored Arrivals in the Terminal Domain: A Feasibility Study* [3]
- *Multiple Aircraft Deconicted Path Planning with Weather Avoidance Constraints* [4]
- *Automatic Commercial Aircraft-Collision Avoidance in Free Flight* [5]

The research and development of SWIM is usually performed to specific uses basing on the concept of datalink communication and Swim as technological support, this is why most of the projects are much focused. We are to go indeed about TCAS and avoidance collision systems related with SWIM. First, we have to describe and get familiar with this system.

TCAS

A traffic collision avoidance system or traffic alert and collision avoidance system (known as TCAS) is a system, which avoids aircraft collision and it was design to reduce the incidence of mid-air collisions between aircraft. This system is based on secondary surveillance radar (SSR) transponder signals, and operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft. TCAS involves communication between all aircraft equipped with an appropriate transponder. Each TCAS-equipped aircraft interrogates all other aircraft in a determined range about their position, and all other aircraft reply to other interrogations. Moreover, this system builds a 3D map of aircraft in the airspace, incorporating their range, altitude and bearing. Them, by extrapolating current range and altitude difference to anticipated future values, it determines if a potential collision threat exists.

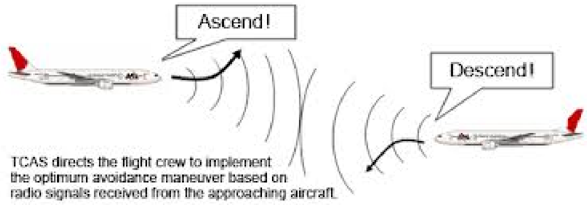

Figure 3: *How TCAS works. Based on the book: Instrumentation, , Nordian*

With these findings in mind, scientist began to explore the possibilities of developing a new piece of equipment and installing it in aircraft to protect against midair collisions. The research became known as Airborne Collision Avoidance System research or ACAS. One of the earliest collision avoidance systems that was proposed, developed in the 1950s.[6] Another type system, developed by Bendix Radio in the late 50s and early 60s(bendix system),operated with a small UHF(Ultra High Frecuency). During the development of the Bendix system, Dr. John Smiley Morrell discovered and first used the concept of Tau. Tau is based on time, not distance. Numerous other systems were considered for development. Eliminate Range-zero System (EROS) was developed for fast moving, fighter-type aircraft. Since the mid 70s, efforts have concentrated on the use of hardware already installed on most aircraft, namely the transponder of the Air Traffic Control Radar Beacon System (ATCRBS). These systems became known as the Beacon Collision Avoidance System or BCAS. However, with the electronic and navigational capabilities that exist today, there is hope for a passive TCAS system. This is because in some instances, aircraft know exactly where they are if navigating with INS, Loran-C, or GPS. In this case a passive system would only need to receive a signal from one ground interrogator. Building on this and other work, the FAA launched the TCAS program in 1981. Currently, there are three versions of the TCAS system in use or in some stage of development; TCAS I, II, III and IV. [3]

TCAS I, the simplest of the systems, is less ex-

[3] TCAS: ManeuveringAircraft in the Horizontal Plane

pensive but also less capable than the others. It was designed primarily for general aviation use. TCAS II on the other hand is a more comprehensive system than TCAS I. This system was required to be installed on all commercial air carriers operating in the United States by December 31, 1993.Since this system costs up to $200,000 per aircraft, manufacturers have built in an upgrade capability to the next generation TCAS III. This system will be virtually the same as TCAS II but will allow pilots who receive RAs (Resolution Advisiry) to execute lateral deviations to evade intruders. [4]

- *TCAS I:* it constitute the basic level. It only provides TA (Traffic Advisores). It need a transponder of Mode A.
- *TCAS II:*It provides TA (Traffic Advisories) and RA(Resolution Advosories). This resolutions are only in vertical plane (ascent/descent), and can generate coordinates resolutions for three different aircrafts at the same time.
- *TCAS III:* It also provides TA and RA but is implemented with horizontal plane, not only vertical.
- *TCAS IV:* It uses additional information encoded by the target aircraft in the Mode S transponder reply (i.e. target encodes its own position into the transponder signal) to generate a horizontal resolution to an RA. In addition, some reliable source of position (such as Inertial Navigation System or GPS) is needed on the target aircraft in order for it to be encoded.As a result of these issues, the TCAS IV concept was abandoned as ADS-B development started.

[5]

Secondly, the safety aspects of TCAS are going to be introduced. Safety studies on this system estimate that the system improves safety in the airspace by a factor between 3 and 5. Although, it is also true that the remaining risk is that TCAS may induce midair collisions, in particular, this depends on the accuracy of the threat aircrafts reported altitude and on the expectation that the threat aircraft will not make an abrupt maneuver that defeat the TCAS Resolution Advisory. (RA) As we have mentioned the benefits of the current TCAS related to safety are self-evident, although the full technical and operational potential of the system is not fully exploited due to limitations in current implementations. Some of them are:

- TCAS II uses Mode C information to determine vertical separation on other traffic. It would provide erroneous altitude information, an erroneous Resolution Advisory command to climb or descent may result.
- TCAS is limited to supporting only vertical separation advisories, more complex traffic conflict scenarios may however be more easily and efficient remedied by also making use of lateral resolution maneuvers; this applies in particular to traffic conflicts with marginal terrain clearance, or conflict scenarios that are similarly restricted by vertical constraints.
- TCAS lacks automated facilities to enable pilots to easily report and acknowledge reception of a RA to ATC, so that voice radio is currently the only option to do so, which however additionally increases pilot and ATC workload, as well as frequency congestion during critical situations.
- In the same context, situational awareness of ATC depends on exact information about aircraft maneuvering, especially during conflict scenarios that may possibly cause or contribute to new conflicts by deviating from planned routing, so automatically visualizing issued resolution advisories and recalculating the traffic situation within the affected sector would obviously help ATC in updating and maintaining situational awareness even during unplanned, ad hoc routing changes induced by separation conflicts.
- TCAS displays today are often primarily range-based, as such they only show the traffic situation within a configurable range of miles/feet, however under certain circumstances a "time-based" representation (i.e. within the next xx minutes) might be more intuitive.
- Lack of terrain/ground and obstacle awareness, which might be critical for creating feasible (non-dangerous, in the context of terrain clearance) and useful resolution advisories (i.e. prevent extreme descent instructions if close to terrain.
- TCAS is primarily extrapolation-oriented, as such it is using algorithms trying to approximate 4D trajectory prediction using the "flight path history", in order to assess and evaluate

[4]If you are interested in finding more information about the TCAS' history: Traffic Alert/Collision Avoidance System

[5]To obtain more information related with these aspects of TCAS: Sistema de Alerta de Trafico y Evasion de Colision

the current traffic situation within an aircraft's proximity, however the degree of data- reliability and usefulness could be significantly improved by enhancing said information with limited access to relevant flight plan information, as well as to relevant ATC instructions to get a more comprehensive picture of other traffic's (route) plans and intentions, so that flight path predictions would no longer be merely based on estimations but rather actual aircraft routing (FMSflight plan) and ATC instructions. If TCAS is modified to use data that is used by other systems, care will be required to ensure that the risks of common failure modes are sufficiently small.

- The information TCAS receives isn't necessarily true. If a conflicting plane is transmitting a false altitude, TCAS will still treat the altitude as correct and provide, or not provide, RA's based on that information.
- TCAS requires that both conflicting aircraft have transponders. If one aircraft doesn't have a transponder, then it will not alert TCAS as there is no information being transmitted.
- TCAS is not fitted to many smaller aircraft mainly due to the high costs involved (between $25,000 and $150,000). Many smaller personal business jets for example, are currently not legally required to have TCAS installed, even though they fly in the same airspace as larger aircraft that are required to have proper TCAS equipment on board. The TCAS system can only perform at its true operational potential once all aircraft in any given airspace have a properly working TCAS unit on board.

In order to overcome certain amount of these limitations the FAA (Federal Aviation Administration) is developing a new collision avoidance logic based on dynamic programming [6]

The new system LR-CAS (Long Range-Conflict avoidance system

Nowadays the prevention and solution of conflicts for the potential collisions have several drawbacks (mentioned before). The main goals of research and development on this area are to detect potential conflicts and to avoid its appearance; it is a real necessity to improve the efficiency of the system. Taking advantage of datalink communication and SWIM, the use of the new system LR-CAS will solve a great deal of this drawbacks, improving traffic flow capacity, safety, time losses and fuel consumption. The new system LR-CAS is based on the information provided by SWIM, the position and attitude of the aircrafts in the airspace, to detect potential conflicts with a large time horizon.

- Knowing the future position of the aircraft thought the SWIM database and using special Earth facilities, it will be able to detect possible conflicts several minutes in advance, before any real conflict happens affecting the trajectories of the aircrafts or the capacity of the airspace.
- Once the possible conflict is detected, the system calculates automatically the optimal modification of the aircraft trajectories involved in the potential conflicts. It is strictly required an automatic reliable trajectory calculator that bases its operation on dynamic programming and optimal control[7] .Then, some seconds after detecting the potential conflict, the new trajectory is approved.
- The next step is to upload and send the resolution to the bases of SWIM and the aircraft involved; This new trajectory appears on the cockpit navigation display to inform the corresponding pilots. Moreover, an alert emerges.
- The pilot via FMS should accept the maneuver and can choose between taking the controls to proceed or leave the automatic control to follow the maneuver. If the pilot does not respond in a period of time in which the efficiency and/or safety can be compromised, LR-CAS takes control of the aircraft and a master warning appears to inform the pilot that LR-CAS is operating.
- Then, a report about the success of the maneuver is sent to the system.

The key point of our new system is the trajectory calculator: it should work taking into account the complex system of aircraft as a whole, and make modifications without being prejudicial to the system, in other words, a cooperative solution, as a pre-tactial one.It is also completely necessary the use of SWIM as database being enough reliable and accurate.

To optimize the capacity and increase the efficiency, the trajectories are thought in the way that the

[6]For more information about dynamic programming: Dynamic Programming and optimal control

[7] Optimal control

aircraft involved, once they have been modify, get out of the sector on the same point at the same time. This statement is crucial to LR-CAS to work 100% efficient.

Our system also uses T-CAS as backup system,that in case of a wrong decision of LR-CAS or a failure could continue working independently.

It can be said that LR-CAS has different levels of automatization[8] depending on the step. At the decision-making level, the computer does the whole job and and it tells the human what it did. At the maneuvering level, the computer selects the action and informs the human in time to stop it.

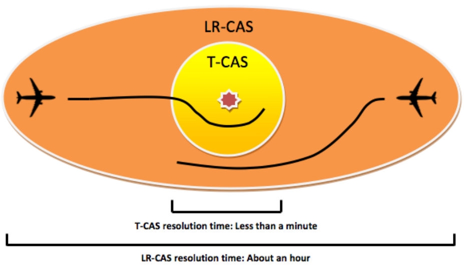

Figure 4: *LR-CAS and T-CAS working areas. Based on the pre-tactical theory.*

The advantages of this new system are:

- Increase safety: avoiding appearance of conflicts.
- Increase efficiency of the airspace.
- Decreasing fuel consumption and environmental impact on potential conflict resolution.
- Decrease time on sector ,in case of possible conflict, comparing it with the present resolution conflict time.
- Increase the precision on surveillance: by using SWIM.
- The aircrafts equipped with LR-CAS do not transport any heavy device onboard.

And the disadvantages are:

- LR-CAS fully depends on the correct working of SWIM.
- Dependence on automatized systems.
- All aircraft must be equipped with "glass cockpit" to use LR-CAS.

[8] Automatization levels

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