COLLABORATIVE TRAJECTORY OPTIONS PROGRAM: PRESENT AND FUTURE SCOPE

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ABSTRACT

Collaborative Trajectory Options Program (CTOP) aims to improve the Air Traffic Management (ATM) considering National Airspace System (NAS) users business goals, particularities faced by each flight and airspace restrictions, making this process more flexible and financially stable for those involved. In CTOP, airlines share their route preferences with Air Control Authority, combining delay and reroute. Current solutions for this problem are based on Greedy methods and Game theory. There is potential space to improve. When CTOP is created each airline might decide its strategy without knowledge about other airline's flights. This paper examines CTOP and identifies important strategic changes to ATM adopting this philosophy, particularly in Brazil.

Keywords: CTOP, Collaborative Trajectory Options, ATM, Air Traffic Management.

1. INTRODUCTION

According to the recent research from Boeing (2015), in the next 20 years, the demand of civil aviation market is by 38,050 airplanes. In addition, by Airbus (2015), the airlines will demand for more than 32,600 new aircrafts (freighter and passenger) for the same period. Single-aisle airplanes are expected to command the largest share of the new deliveries, with an estimated need of 26,730 airplanes.

Figure 1 highlights the total airplanes in service worldwide between 2014 and 2035.

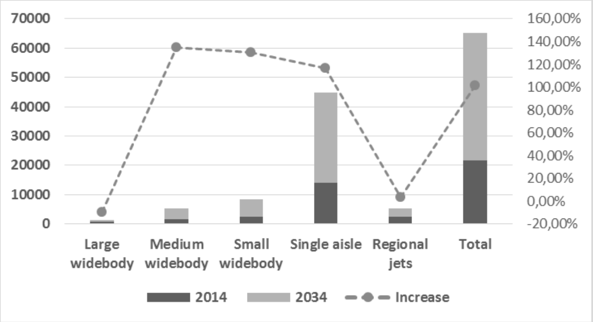


Figure 1: Airplanes in service 2014 to 2034

Source: Adapted from BOEING, 2015

The total fleet is expected to double in 15 years, with the medium and small widebody and the single aisle doubling its fleet worldwide.

In this context, some cities are expected to concentrate the air demand with long-haul and regional traffic, creating global hubs. According to Little (2013), the air traffic growth is concentrated within a few global cities. In Latin America, since 2007, 45% of the traffic growth is accounted by just 10 airports. These airports are not just transport hub exchanges but they arise as the cornerstone of new urban and economic global centers. Figure 2 shows the concentration of 2012 long-haul traffic among global hubs.

Delay is one of the consequences of this flight concentration and is a constant problem in the majority of the big airports around the world. In 2014, the average delay per delayed (ADD) flight in Europe was 26 minutes per flight. In 2013, 7,9% of all flights in Brazil were delayed more than 30 minutes, and 3,1% were delayed more than 60 minutes. In 2010, 24% of all flights in Europe and 18% of all flights in USA were delayed more than 15 minutes (ANAC, 2014; EUROCONTROL, 2015).

Figure 3 shows the primary delay causes for 2014 in Europe.

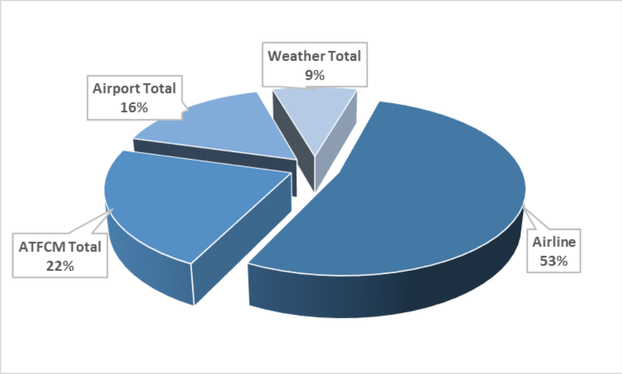


Figure 3: Primary delay causes in Europe in 2014

Source: Adapted from Eurocontrol, 2015.

Figure 3 highlights that more than half of delays are due airline factors such as technical problems, baggage delays, passenger’s related problems. The second largest portion (22%) is duo Air Traffic Flow Control Management (ATFCM) problems such as in the airports, en-route and weather related. The third largest portion is related to the Airport problems (16%) and the last portion is related to the Weather (9%). Figure 4 shows the subset of ATFCM delays (EUROCONTROL, 2015).

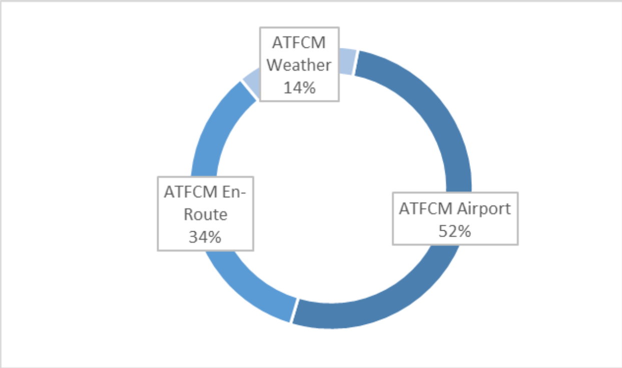


Figure 4: ATFCM delay in Europe in 2014

Source: Adapted from Eurocontrol, 2015.

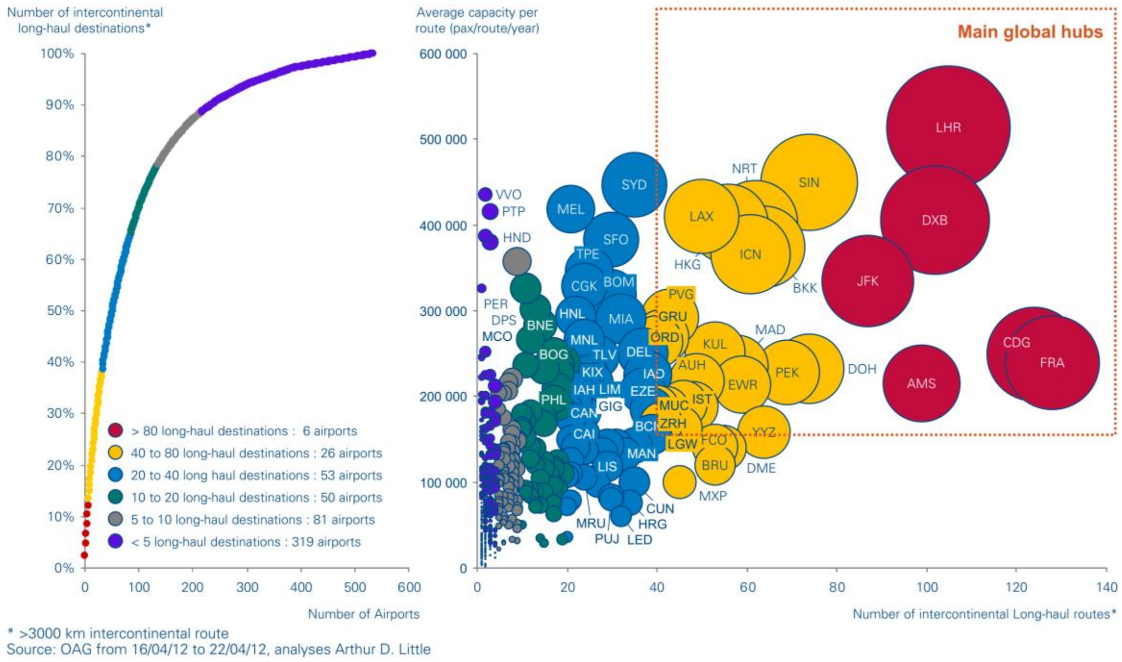


Figure 2: Concentration of 2012 long-haul traffic among global hubs

Source: LITTLE, 2013.

Due a capacity constraint, there is a growing necessity for changes in the air traffic system in order to accommodate the increased traffic demand.

The fundamental shift in ATM paradigm will be from clearance-based ATC to trajectory-based ATC operations. This new type of trajectory will include new constraints, for example Target Time of Arrival (TTA), that will improve its predictability, and as consequence, facilitate Air Traffic Controllers´s work (ENEA; PORRRETA, 2012).

According to Enea and Porreta (2012), there are differences in the capacity constraints for the USA and Europe. For US, the major capacity constraints are founded at major airports and in the Terminal Airspace around them. In the other hand, in Europe the en-route airspace presents capacity constraints.

According to SESAR ATM Target Concept (2007), there are four performance objectives:

- Air Space designed for more capacity, with an increase of 73% in 2020, when compared to the 2005 panorama. In the long term, there will be a three times more air space capacity.

- Improve three times more in air safety for 2020 and an increase of ten times in the longer term.

- Decrease of 10% less environmental impact / flight due to ATM

- Decrease of 50% less ATM costs per flight.

As Booker (2008) reminds, Air Traffic Management (ATM) is foremost about safety. In author words “in an imaginary world in which colliding aircraft suffered no damage whatsoever there would be little need for ATM.”

The objective of this paper is to analyze the Collaborative Trajectory Options Program in present and future scopes, showing the main components of this program.

This paper is organized as follows: Section 2 describes the cooperative environment between airlines and air traffic authorities. Section 3 presents the

Collaborative Air Traffic Management (CATM), and explains the Collaborative Decision-Making Program and the Air Traffic Flow Management. Section 4 describes the Trajectory-Based Operations explaining the Collaborative Trajectory Options Program, Trajectory Options Set, the Four-Dimension Trajectory and the System Wide Information Management. Section 5 presents Future Scope for the program and Section 6 presents the conclusion of this paper.

2. A COOPERATIVE ENVIRONMENT BETWEEN AIRLINES AND AIR TRAFFIC AUTHORITIES

In 2003 during the Eleventh Air Navigation Conference, it was agreed upon ICAO members that it was necessary to evolve towards a more collaborative environment. Key to this philosophy adopted is the notion of global information utilization, management and interchange. This new philosophy aims to evolve to a holistic, cooperative and collaborative decision-making environment. Although the differences between the members and the actions are balanced to achieve equity and access (ICAO, 2005).

Figure 5 shows the components in an ATM concept and emphasizes the holistic environment.

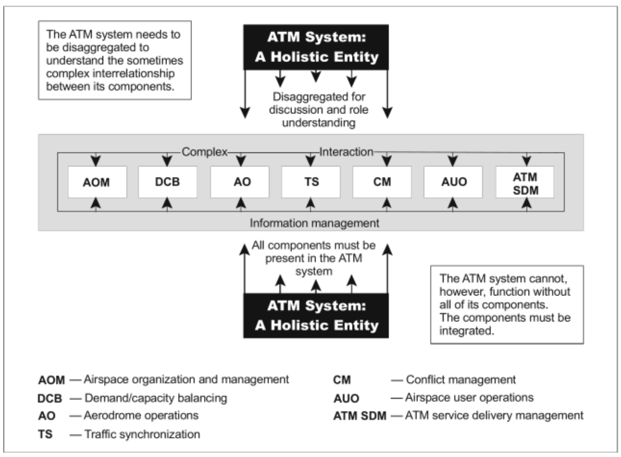


Figure 5: ATM concepts components

Source: ICAO, 2005.

According to ICAO (2005), the following members comprises the ATM community: aerodrome community; airspace providers; airspace users; ATM service providers; ATM support industry; International Civil Aviation Organization (ICAO); regulatory authorities; and States. All actors are integrated in a network performance as highlighted in Figure 6.

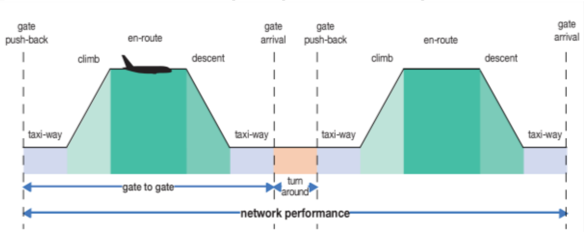


Figure 6: Network performance in ATM

Source: SESAR, 2007.

In this context of collaboration arises the Collaborative Air Traffic Management (CATM).

3. COLLABORATIVE AIR TRAFFIC MANAGEMENT (CATM)

According to Nolan (2011), Collaborative Air Traffic Management is an attempt to accommodate aircraft operator preferences to the maximum extent possible with restrictions imposed only when an actual operational need exists.

CATM tries to adjust ATC system to meet real-time demand. The main objective is to give the aircraft operator the opportunity to participate in the decisions rather than the Air Traffic Control Authority arbitrary defines the restrictions. This means that all airspace operators are able to work together and collaborate on the decisions made (NOLAN, 2011).

The first implementation of CATM is the Collaborative Decision-Making (CDM).

3.1. Collaborative Decision-Making (CDM)

Collaborative Decision-Making (CDM) began in US in 1993 when FAA and major users of the Air Space started a cooperative environment. Before 1993, FAA used flight schedules published in the Official Airline Guide (OAG) to forecast preliminary air traffic demand prior to operator's route request. The milestone of CDM was when industry agreed to share its information, providing real-time, day-of-operations schedules (TRB, 2015).

According to Wambasganss (page 02; 2001):

"In February of 1993, a demonstration was arranged at the Headquarters building of the Air Transport Association (ATA) involving representatives of all the major airlines and FAA personnel from both the operational and system development communities. This meeting is widely viewed as the beginning of CDM. It started with many fireworks; airlines not trusting their competitors and all of them absolutely despising FAA. And the FAA considering the airlines a nuisance, and a bunch of cheaters who did not care about the system. But at this meeting something changed, and the notion that booth the service provider (FAA) and system users (airlines) could benefit from cooperation first took hold. "

But was just in 1995 that CDM was officially launch in US, when FAA and the industry group defined roles and responsibilities and the foundation for a collaborative air traffic management system was laid (TRB, 2015).

Figure 7 shows the CDM program development timeline.

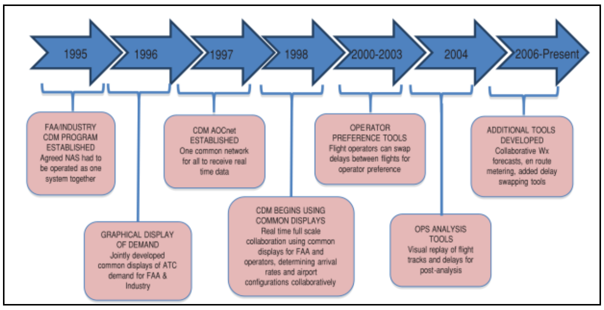


Figure 7: CDM program development timeline

Source: TRB, 2015.

A conceptual framework that is known as the pillars of CDM is shown in Figure 8.

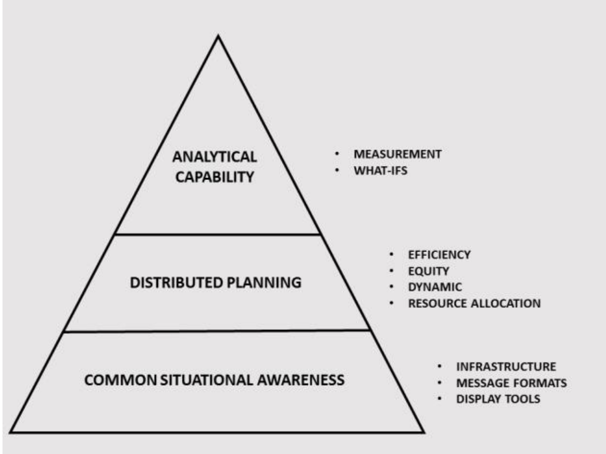


Figure 8: The pillars of CDM

Source: WAMBASGANSS, 2001.

According to Wambasganss (2001):

- **Common Situational Awareness:** means that all parties must know the constraints, with a shared view of the constraints in the system.
- **Distributed Planning:** means that all parties must be able to react to the constrains with the ability to react to the constraints in a manner where decisions are made at the most appropriate point.
- **Analytical Capability:** means that must measure what happened in order to improve the system and is the pillar of the collaborative paradigm.

In Europe CDM was implemented in early 2000´s as Airport CDM (A-CDM). This difference is due virtually all European airports have slot controls and scheduled operations generally are within airport capacities (BALL, 2015; EUROCONTROL, 2012). Today, CDM is well developed in Europe and USA (BALL; HOFFMAN; MUKHERJEE, 2010; ARRUDA; WEIGANG; MILEA, 2015)

Allied with this collaborative environment, it was created Air Traffic Flow Management (ATFM) Programs to reduce the scale and cost during times of adverse weather and heavy traffic demand.

3.2. Air Traffic Flow Management (ATFM)

According to ICAO (2014), Air Traffic Flow Management (ATFM) is a function of Air Traffic Management (ATM) established with the objective of contributing to a safe, orderly and expeditious flow of traffic while minimizing delays. The purpose of ATFM is to balance air traffic demand with airspace and/or capacity to ensure the most efficient use of the airspace system.

To achieve those objectives of optimum flow traffic, the following measures include, but are not limited to (ICAO, 2014):

a) Allocating and updating departure slots;

b) Allocating and updating arrival slots;

c) Allocating and updating en-route slots;

d) Re-routing of traffic;

e) Alternate flight profiles;

f) Minutes-in-trail assignments;

g) Mile-in-trail assignments;

h) Airborne holding; and

i) Ground-holding.

According to Kim and Hansen (2015), ATFM programs developed to handle problems in the en-route airspace have been quite successful in mitigating the cost of disruptions, although their success has been limited due to inflexibilities in incorporating flight operator´s specific needs and adapting to changing weather and traffic conditions.

In recent years, the NextGen and SESAR programs are looking for a shift in the ATC method moving for Trajectory-Based Operations (TBO). Linked to this, FAA has recently implemented a new ATFM program called Collaborative Trajectory Options Program (CTOP). (FAA, 2014; KIM; HANSEN, 2015; CRUCIOL; CLARKE; WEIGANG , 2015).

4. TRAJECTORY-BASED OPERATIONS

According to Nolan (2011), a trajectory can be defined as the four-dimensional flight path of an aircraft through space and time (4D).

The TBO concept means a move from base method ATC to a trajectory-based system of air traffic management (ATM). In this new concept, aircraft will be assigned flexible and negotiated trajectories and the ATC will have to manage those routes, with the air traffic controllers performing a strategic traffic flow coordinator.

This will allow a maximum utilization of available airspace and providing advanced navigational capabilities for those aircrafts flying for example RNP trajectories.

For operating in this new concept, it will be necessary that:

- Aircraft will be required to transmit and receive aircraft and navigational data in a precise manner;
- New surveillance equipment;
- Improved aircraft avionics capabilities;
- Advanced automation systems; and
- Automated conflict probes.

According to Aslinger, Leber and Hopkins (2012), enabling TBO requires interactive and integrated decisions and control actions spanning each time horizon to include Capacity Management; Flow Contingency Management and Trajectory Management. For the authors, a critical requirement is the Air Navigation Service Provider (ANSP) enabling the stakeholder access and common awareness of the Air Traffic System capacity and constraints, in the present and future (predicted) situation.

CTOP provide through Trajectory Option Set (TOS) an initial foundation of the TBO (ASLINGER; LEBER; HOPKINS, 2012).

Figure 9 shows the actual hierarchy of the Trajectory-Based Operations Concept.

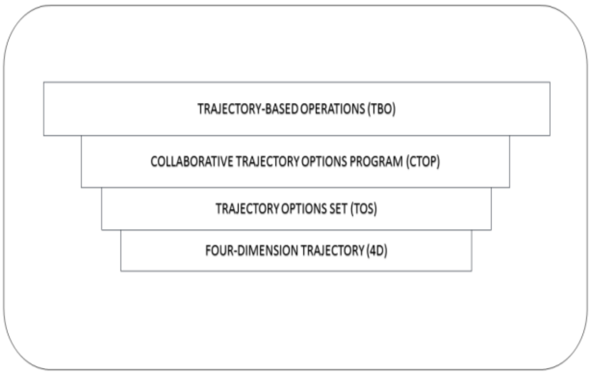


Figure 9: Hierarchy of the Trajectory-Based Operations Concept

TBO is the new ATC concept that moves from a base method to a trajectory-based method. Collaborative Trajectory Options Program (CTOP) is one of the Air Traffic Management (ATM) initiatives and it is associated with the idea of a constrained area. Inside the CTOP, there is the Trajectory Options Set (TOS) a set of trajectories that are chosen by the airlines in a constrained area and the Four-Dimension Trajectory (4D) that is a flight path of an aircraft through space (three-dimension) and time (one-dimension).

4.1. Collaborative Trajectory Options Program (CTOP)

According to FAA (2014), CTOP is connected with the idea of a constrained area. CTOP is one of many new traffic management initiatives been developed within Collaborative Air Traffic Management Technologies (CATMT) and is part of the NextGen and SESAR initiatives.

For FAA (2014), CTOP is a method of managing demand through constrained airspace. In CTOP, customers are allowed to communicate their preferences in a Trajectory Options Set (TOS). The customers can choose between route and delay.

CTOP is used anywhere there is a constraint in the air traffic system. The most common constraints are:

- Weather (thunderstorms)
- Air traffic volume

The CTOP program provides greater flexibility for the airspace planner in managing capacity by allowing ground delays and re-routes to be considered together.

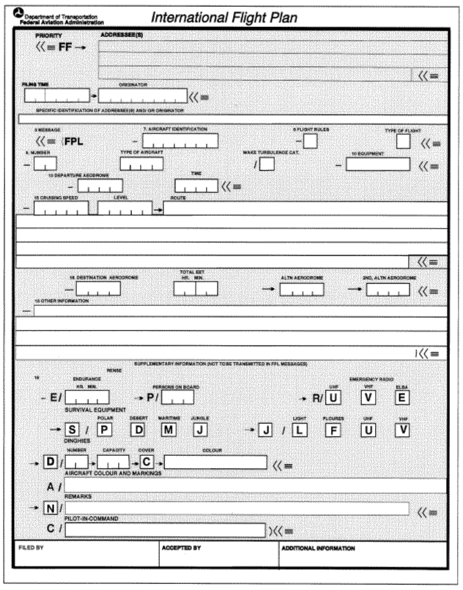
According to Kim and Hansen (2015), CTOP has the similarities of the previous en route ATFM programs with the difference that it considers flight operator´s submitted en-route resources preferences.

4.2. Trajectory Options Set (TOS)

A Trajectory Options Set (TOS) will allow the customer to manage a flight by telling the Air Traffic Control the route and delay options that the clients are willing to accept. At the TOS, it may contain multiple trajectories options, with a different route, altitude or speed per trajectory.

The difference between a Flight Plan and a TOS is that the Flight Plan contains a single request with a defined route, altitude and speed. TOS may contain multiple trajectory options, with each one of the options, containing a different route, altitude or speed (FAA, 2014).

According to Nolan (2011), in the current air traffic control system (ATCS) the pilot determines through a Flight Plan the flight´s objective (destination airport) and to reach it, deciding which route is best, proposed altitude, cruising airspeed, time of departure, climb and descent profiles. An example of a flight plan form is shown in Figure 10.


International Flight Plan

Department of Transportation
Federal Aviation Administration

PRIORITY
ADDRESSEE(S)
FF
FPL
A /
C /
FILED BY
ACCEPTED BY
ADDITIONAL INFORMATION

Figure 10: Flight plan form

Source: FAA, 2014.

To control an airplane while flying, the pilot can be interrogate by the air traffic controller if the parameters requested in the flight plan form are maintained or can determine the aircraft´s flight profile by interpreting the flight track, azimuth and altitude information displayed on the radar scope as shown in Figure 11.

Figure 11: Air controller in a Terminal Radar Approach Control Facilities (TRACON)

Source: FAA, 2015

In the current ATC configuration, the system aims to satisfy each pilot´s request for a specific route or altitude, it may be necessary to apply procedural restrictions to ensure positive aircraft separation. The constant use of air space restrictions results in increased fuel use; increased flight times, loss of flexibility, and, occasionally, reduced traffic flow (NOLAN, 2011).

In the other hand, great care must also be taken not to overload the air controller. The routine imposition of procedural restrictions reduces the controller´s workload, and consequently decreasing the potential loss of separation between aircrafts and decreasing the amount of planes flying in an area (NOLAN, 2011).

According to Nolan (2011), these procedural restrictions tend to keep an aircraft at inefficient altitudes. Since the constrained aspect is the controller´s capacity to coordinate clearances and predict separation conflicts, and not airspace saturation, an automated process would reduce the need for rigid procedural restrictions on system capacity.

In this aspect, manual air traffic control procedures need to be improved with computer-based decision support systems if the ATC is to become more efficient and capable. The aircraft separation is, nowadays human dependent, maintained by air traffic controllers who use radar screens to visualize aircraft flight paths, make subjective judgements as to future aircraft positions and potential conflicts, and mentally develop alternate flight paths (NOLAN, 2011).

The operators must express their preference among different flight options and must be expressed in terms of a Relative Trajectory Cost (RTC). Each option will be evaluated based on customer preference expressed through the use of the RTC (FAA, 2014).

The RTC of a flight option is an expression of the number minutes of delay that would have to be imposed upon the operator´s most preferred trajectory option before some other flight option becomes a desirable alternative (ASLINGER; LEBER; HOPKINS, 2012).

Figure 12 shows an example of RTC in a CTOP environment. In this example, provided by FAA (2014), there is one flight from Denver International Airport (DEN) to Washington Dulles International Airport

Unique Flight Data

ACID	ORIG	DEST	IGTD	TYPE	ERTD
ABC123	DEN	IAD	05/1945	B757	05/1957

TRAJ_OPTION

RTC	RMNT	TVST	TVET	Route	ALT	SPEED
0				GLD SLN J24 MCI J24 STL J134 FLM J24 HVQ SHNON2	350	435
25				GLD SLN J24 MCI J80 VHP APE AIR J162 MGW VERNI ESL SHNON2	350	435
35				PLAIN4 HCT J128 OBH J10 IOW BDF J64 WHETT J30 APE AIR MGW MGW121 VERNI ESL ROYIL2	310	430
50		1945	2145	YELLO6 HANKI OBH J10 IOW BDF J64 WHETT J30 APE AIR MGW MGW121 VERNI ESL ROYIL2	350	425
65		2030	2200	YELLO6 HANKI ONL J148 MCW J16 BAE J34 AIR MGW MGW121 VERNI ESL ROYIL2	310	430
90	45	1945	2145	PIKES4 PUB J28 ICT FAM J78 HVQ SHNON2 DEN PIKES4 PUB TBE BGD IRW FSM BNA BKW ROYIL2 IAD	350	435
120	45	2045	2245	PIKES4 PUB TBE BGD IRW FSM BNA BKW ROYIL2	350	440

IGTD – Initial Gate Time of Departure; ERTD – Earliest Runway Time of Departure;
RTC – Relative Trajectory Cost RMNT- Required Minimum Notification Time;
TVST – Trajectory Valid Start Time; TVET- Trajectory Valid End Time

Optional values provided by the Flight Operator

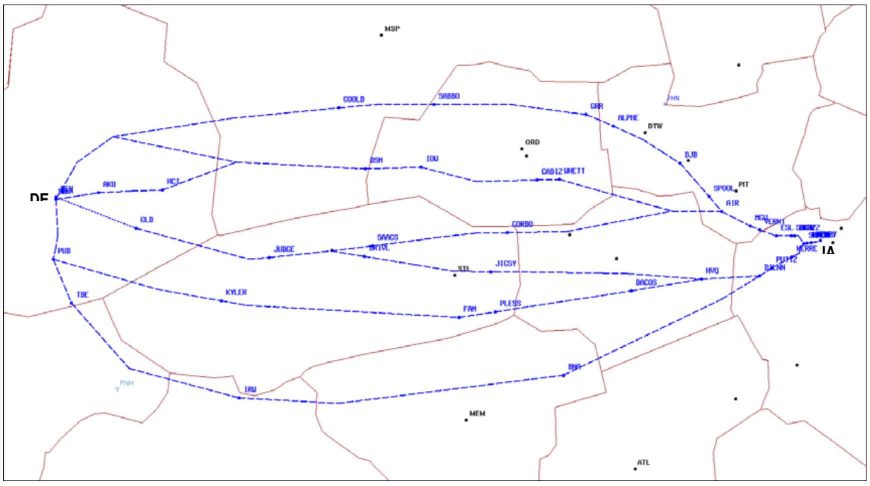


Figure 12: Relative Trajectory Cost (RTC) in a CTOP environment

Source: FAA, 2015

(IAD). The airline provided seven options to fly this route, and each one with its RTC. It is important to mentioning that the altitude and the speed can vary in each route, as chosen by the operator.

Upon submitting a TOS, the CTOP and CACR algorithms assign routes and/or ground delay to flights by attempting to provide the operator a minimum adjusted cost. The minimum adjusted cost is the sum of the delay assigned to a flight plus its RTC, while ensuring that traffic is limited within the program Flow Constrained Area (FCA) to an specified capacity (ASLINGER; LEBER; HOPKINS, 2012).

According to Aslinger, Leber and Hopkins (2012), the currently limitation of the CTOP program are:

- The programs reside in the outer control loop of TFMS. The TFMS is limited in its **predictability** and **accuracy;**
- The program misses the dynamics events in its vision;
- The program lack the situational awareness and constraint information of the inner control loop. This characteristic is necessary to evaluate

the suitability of trajectory options in a tactical environment;

- Duo the focus of the program is during adverse events, the program misses potential opportunities, resources and potential efficiencies.

- Operator misses to correct evaluate and rank trajectories option based on their **corporate policies, business models,** and **environmental and cost considerations.**

According to Aslinger, Leber and Hopkins (2012), with CTOP still in development and most of the benefits for the airlines are still limited and unquantified; several questions arise about its adoption and implementation:

- With the Air Control Authorities lack to determine flight preferences, and with no guarantee those preferences will be honored; the main question is: will operators make the necessary investments in their flight planning systems?

- With the uncertainty about the viability of the TOS and CTOP program: will the airlines attempt to verified the system capabilities and choices with many submitted trajectories?

- With uncertainty as to which trajectories CTOP will assign; will the airlines continually re-plan if they dislike the results?

The fundamental principle behind CTOP and TOS is the Four-Dimension Trajectory (4D).

4.3. Four-dimension trajectory (4D)

4D-Trajectory is the pillar of a new ATM whereby time–based operations progress to a trajectory-based operations and in long term achieve performance-based operations.

According to Enea and Porreta (2012), a 4D-Trajectory (4DT) is defined as a precise description of an aircraft path in space and time. The waypoints are used to represent specific steps along the path, and is earth-referenced with a proper latitude and longitude.

What distinguishes a 4DT is that the path contains altitude description for each waypoint and indications about the time at which the trajectory will be executed. Some waypoints in the 4DT path may be associated with Controlled Time of Arrivals (CTA) or Required Time of Arrival (RTA).

For a CTA it may assigned a Target Time of Arrivals (TTA). The aircraft must meet this TTA requirement within a specified time of tolerance. The CTA represent a time windows for the aircraft to pass through a specific waypoint. It is normally used to regulate traffic flows entering congested en route or arrival/departure airspace. The main idea is stablish a sequence of spatial and temporal windows. This sequence will represent milestones to meet during the flight execution.

To achieve the desired RTA, aircraft´s speed must be adjusted and regulated along the trajectory to arrive at a specific waypoint at a specified time, improving the predictability of the aircraft-flying path. The problem is that the time of arrival over a fixed point is not a function of aircraft´s airspeed alone, but it depends upon the winds and temperature that the aircraft will encounter in its route (KLOSTER; WICMAN, 2008).

In Europe, in the SESAR program, the 4DT is sometimes called Reference Business Trajectory (RBT). It is used the term reference because once a trajectory is chosen, it will become the reference trajectory which the airspace user agrees to fly and all the service providers agree to facilitate with their respective services. This difference of name is basically due the European consortium want to call for a more collaborative environment, with trajectories that are agreed between all the ATM stakeholders, for example ATC, Airports, Airlines, Military and General

Aviation. This 4DT will be executed gate-to-gate by aircraft (ENEA; PORRRETA, 2012).

SESAR and NextGen core concept is to structure ATM around aircraft Trajectory Based Operations. To achieve this milestone, it is necessary the accuracy / reliability of aircraft achieve 4D-Trajectory; Accuracy / speed of passing information via data link; huge improvements in surveillance capabilities; automation and decision support tool capabilities and huge improvements in computer / equipment processing power and speed (BROOKER, 2008).

The 4D concept is consistent within ICAO Aviation System Block Upgrade (ASBU) and with ICAO Global Air Navigation Plan and Global Air Traffic Management Operational Concept. Some authors divide the 4D-Trajectory in two phases: Initial 4D-Trajectories (I4DT) and Full 4D-Trajectories (4DT) (MUTUEL; PARICAUD; NERI, 2013).

According to Mutuel, Paricaud and Neri (2013), the objective of an I4DT is to optimize the arrival phase of a flight at an airport. To achieve this goal, the airborne and ground trajectories must be synchronized around a common unique reference designated by a 2D point or Metering Fix (MF) and a time constraint. The trajectory negotiation process begins when the aircraft is about 200 NM or 40 minutes from its destination. The negotiation is made via data link between the ATC and the aircraft and includes the Standard Terminal Arrival Route (STAR) and approach procedures applicable to the metering fix. The final 4D-Trajectory is a lateral route with altitude, speed and time constraints over waypoints in the trajectory.

For the implementation of the I4DT function onboard, the following avionics system are necessary:

- Cockpit display systems: it must display relevant data related to the engagement and monitoring of the 4DT.

- Flight Management System: the computed onboard prediction and the system performance requirements are consistent.

- Communication System: able to manage the ADS-Contract and the Controller-Pilot Data Link Communication (CPDLC) applications.

Allowing this entire collaborative environment is necessary an information management platform.

4.4. System Wide Information Management (SWIM)

All the detailed trajectory information will be shared between all the stakeholders through a System Wide Information Management (SWIM) platform. It is a network where all the information are shared amongst authorized users (ENEA; PORRRETA, 2012).

SWIN will provides the infrastructure and services to deliver network-enabled information access to a multitude of ATM system users. The system must integrate with a variety of legacy sub-system over many years. Figure 13 shows the nature and scope of SWIN (BROOKER, 2007).

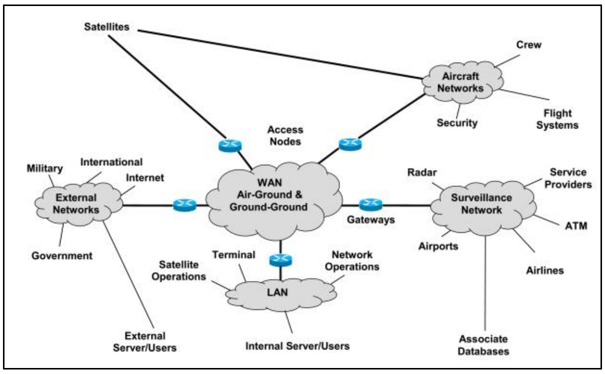


Figure 13: Nature and scope of SWIN

Source: BROOKER, 2007.

According to Klooster and Wichman (2008), SWIN is described as a framework enabling authorized applications and services to reliably and securely share information. SWIN will allow the necessary trajectory functions exchange functions. This will permit a system coordinated 4D trajectory plans.

5. FUTURE SCOPE

According to Enea and Porreta (2012), in order to achieve the TBO environment, the following technologies are considered necessary:

- **<u>Advanced Flight Management System (FMS) capabilities</u>**: 4DTcan only exist with accurate Controlled Time of Arrival (CTA) capabilities. These CTA capabilities will need that the FMS presents features that are more advanced. The key factors that impact in the system accuracy are the wind and temperature data.

- **<u>Data communication</u>**: the voice communication channel between ATC and cockpit will not be sufficient to handle the amount of traffic. It will be necessary to introduce Data communication, and it will decrease the controller´s workload.

  One of the key aspects is the balance between the new airspace capacity and the controller task load. ATM system depends critically on the rate that controllers can process aircraft through airspace sectors (BROOKER, 2008).

- **<u>ADS-B</u>**: this technology will replace the RADAR as surveillance instrument. The implementation of ADS-B out (on the ground) and ADS-B in (on board of the aircraft).

- **<u>Air Traffic Control Decision Support Tools</u>**: necessity to implement Decision Support Tools (DST) for air traffic controllers. DST will be necessary to provide air traffic controllers with acceptable levels of workload. DST will have to handle with the trajectories predicted for the system, and allow to share and negotiate 4DT and keep the traffic separated. They will be able to have the capability of conflict detection and resolution.

The most important metrics for results comparison in the 4D trajectories in the key performance areas (ENEA; PORRRETA, 2012):

- Safety: aircraft separations; losses of separations; conflict false alarm.

- Efficiency and Environment Impact: delay per aircraft; number of fulfilled Target Windows (TW).

- Capacity: number of aircraft in the sector per hour; instantaneous number of aircraft; ATC number of instructions; Sector capacity; revenue passenger miles.

- Predictability: planned flight time divided by flight time in the sector; number of fulfilled Target Windows (TW); target point (TP) accuracy; schedule conformance; CTA/RTA accuracy.

- ATC Workload Acceptability: number of ATC controllers required per traffic level; mental demand; effort; frustration; performance; instantaneous self-assessment workload; NASA-Task Load Index; Air Traffic workload input technique; subjective rating scale.

6. POSSIBLE IMPLEMENTATIONS IN BRAZIL

The CTOP, which started at march 2014, is a new concept for Traffic Flow Management (TFM). However, some characteristics could be brought to Brazilian in order to be implemented, as a future program.

In Brazil, there is a publication by DECEA (Department of Airspace Control) which defines the “preferential” routes. According to this document, (DECEA, 2010), the application of preferential routes IFR has the objective of optimizing the airspace’s use and allowing the better planning of flights. Also, it use intends to reach the better use of aircraft’s RNAV navigation systems in order to keep the air traffic flow and its high safety standards.

These preferential routes could be used as initial routes in the TOS since they are the most advantageous for both the air traffic service (ATS) provider and the airline companies. Since these routes represent the optimized routes, they represent for airline companies the fastest routes representing lesser cost, and for ATS provider it represents that flights will follow routes which are contained in sectors which could absorb the increase in traffic flow.

Another important step towards the CTOP implementation would an observation airspace’s characteristics, such as certain regions which present degraded weather conditions at some times of the year. This could be done through assessment of meteorological maps and through the experience of air traffic controllers and other workers in the sector. This analysis would allow to identify the most common constrained areas in the Brazilian airspace and it would an initial step in order to create the alternative routes to be part of the TOS.

Then, the use of fast-time simulation could allow identifying the cost of each trajectory relative to one another. Different cost could be evaluated such as travelling time and fuel burn and they would compound the relative cost for each trajectory.

Validating the trajectories with all stakeholders is an important step in order to ensure that TOS satisfy their preferences

7. CONCLUSION

In 15 years, to total commercial fleet is expected to double and some cities are expected to concentrate the air demand with long-haul and regional traffic creating global hubs.

Delay is one of the consequences of this flight concentration and due a capacity constraint; there is a growing necessity for changes in the air traffic system in order to accommodate the increased traffic demand.

The fundamental change will be from clearance-based ATC to trajectory-based ATC operations and Collaborative Trajectory Options Program

CTOP aims to improve the Air Traffic Management considering National Airspace System users business goals, particularities faced by each flight and airspace restrictions, making this process more flexible and financially stable for those involved.

New ways of designing the Air Traffic space and new technologies must be thought arising as an important field of research.

There is a long way ahead. More research is undergoing to permit the all the capabilities needed in SESAR and NextGen operational.

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