CONTRACT-BASED AIR TRANSPORTATION SYSTEM TO FULFIL THE ARRIVING-ON-TIME OBJECTIVE

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Abstract

The Contract-based Air Transportation System (CATS) Project proposes an innovative air traffic management (ATM) solution able to face the challenge of traffic growth (for 2012+), and improves the efficiency of the European air transportation system.

The CATS project will assess a new ATM paradigm based on an innovative operational concept: the contract of objectives (CoO). This concept introduces a new way of managing ATM using mutually agreed objectives, leading to a market-driven air transportation system (ATS). It addresses the air transport supply chain by reconciling operational links between air and ground services. This enhanced link between ground and air is expected to improve efficiency by increasing system predictability (allowing actors to organise themselves to be more cost efficient) and punctuality (arriving on time at the destination). Objectives are negotiated and assigned through collaborative decision-making processes. CATS proposes, through applying the CoO, one of the possible implementations of the SESAR business trajectory.

The CATS Consortium[1], consisting of some main stakeholders in the air transportation system, submitted a proposal to the European Commission, through a call in the Sixth Framework Programme. The aim of the CATS project is to develop and assess the concepts of the contract of objectives and target windows from various perspectives.

The validation will be accomplished through three human-in-the-loop (HIL) experiments, focusing on the evaluation of this CoO concept between ATCOs, between ATCOs and aircrew, and lastly between all the actors (airports, airlines, ANSPs., etc.) involved in the renegotiation process, if the CoO cannot be met. The assessment will focus on system performances [8], while evaluating the impact of this CoO in terms of human performances (to see if the contribution of the human to overall system performances is within expected capabilities) and safety. Particular attention will be paid to the cost-benefit analysis and the legal implications. The validation will ensure that the resulting concept provides some substantial benefits and is "fit for purpose".

1 Introduction

The Vision for 20202 and the ACARE Strategic Research Agenda (ACARE SRA II) [1] forecasted that air traffic in Europe may almost triple in the 2002/2020 timeframe. SESAR D2 [4] also states that the Air Transport will continue to grow and demand facing challenges, even if SESAR D5 [6] targeted the increase of Instrumental Flight Rules (IFR) flights in Europe around 73% compare to the 2005 level. Considering the current ATM system, there is a clear need for more capacity, more efficiency and more safety. The ACARE SRA II also stresses the

[1] Frequentis, EUROCONTROL, Air France Consulting, ENAV SpA, SkySoft ATM, Unique, University of Leiden, Eidgenössische Technische Hochschule Zürich, Università degli Studi di Trieste.

[2] According to the Group of Personalities report entitled "Vision for 2020", traffic will triple, and 95% of flights will be within 15 minutes of their schedule, in all weather conditions.

inability of the current ATM system to cope with such growth figures unless radical changes are made. This makes it clear that measures are needed in order to meet these objectives.

Air transport business stimulates national economies, global trade and tourism [6]. Business imperatives will always push for cutting costs, and stronger competition and liberalisation will continue to be a challenge for businesses, and an opportunity for new cost-models (e.g. low costs airlines). The air transport supply chain as a whole, therefore, needs to become more cost-efficient. Since the ATS supply chain is a complex one involving many partners (such as airports, airlines and ANSPs), these business imperatives will have to be supported and shared by everyone, even if their interests or costs-models are different. Even ANSPs will not be able to avoid these radical changes, but the need to retain safety as the prime objective will remain. “Business as usual” was not retained as an option by SESAR [3].

Across from this challenge, management of the uncertainty and the 4D-trajectories is also essential. An abundance of articles dealing with these topics were edited, and studied in the CATS State of the Art [9]. The main idea was that the Flight Management System (FMS) accuracy fully contributes to the precision during the execution phase [10][11][15][16]. An ATM system based on 4D trajectory management will hopefully benefit from this prediction [12][14], allowing to reduce trajectories’ uncertainty [15]. Most of the literature dealing with respect to a time of arrival [17][16] are focused on aircraft performance during the execution phase (airside). Another documented idea was to increase automation within the groundside to reduce ATCOs’ workload [13][15], which are reaching their limits and therefore impeding an increase of capacity. Focusing not only on the execution phase, but on all phases of the ATM system, should bring essential benefits when obtaining a future efficient and cost-effective ATM system, as shown by SESAR D2 [4]. The ATM is a layered planning system [18][5], reaching through the different phases the optimisation and the safety of the overall system. Accuracy of the airborne equipment will allow to manage precise trajectories in the execution phase, but as uncertainty is still inherent in ATM [2][19], the question arises whether we are complying with what was planned? The link between planning and execution phases seems also to be a big challenge for the future ATM system.

As stated by SESAR [3], the future system should be performance-based. It should integrate ground and airborne segments more closely, respect schedule integrity and enhance interoperability. As mentioned above, the air transport supply chain involves many different service providers, which very often are not aware of the overall target, sometimes disagree with, and do not share the same objectives. Despite there are a number of initiatives for developing collaborative decision-making systems at airport level, the actors mostly optimise their own processes locally in accordance with their own constraints and business objectives, sometimes without considering the global system optimisation. The promotion of highly collaborative and system-wide approaches seems to be a promising approach to achieve overall system optimisation and it will lead to different and better distribution of constraints across the system. The CATS concept proposes in the ATS a transition from means-based management to performance-based management (a contract-based system).

2 Concept overview

CATS is based on concepts initiated during the EUROCONTROL Experimental Centre’s Paradigm SHIFT Project [2], namely the contract of objectives (CoO) and associated target windows (TWs).

The purpose of the CoO is to create an operational link between all air navigation actors (airlines, airports and ANSPs). The CoO represents a formal and collaborative commitment between all the actors in the ATS. It establishes the role as well as the tasks and responsibilities of each of them based on well-defined, agreed and shared objectives. These objectives represent the commitment of each actor to deliver a particular aircraft inside temporal and spatial intervals, called target windows (TWs). These commitments are agreed upon all involved actors for specific transfer of responsibility areas (e.g. between 2 ACCs). Then, each actor will be fully accountable for its own achievements. The ultimate objective of the CoO is punctuality at the destination, while improving the system efficiency and predictability by means of enhanced collaboration between air transport actors.

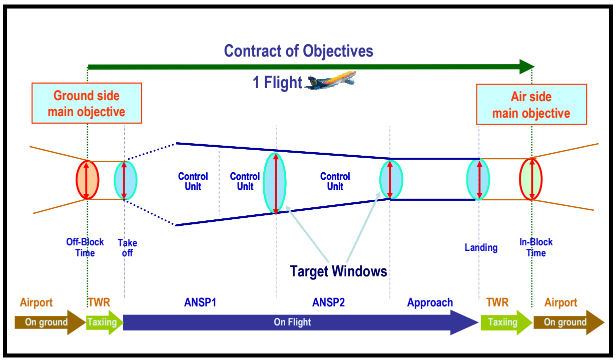

Figure 1: Contract of objectives

In order to formalise the contract of objectives and its refinement for each local actor, a concrete manifestation of the CoO is proposed through the target window. TWs create a common language between all the involved operators, and also between the planning and operational phases. Instead of precise 4D points, the TW is expressed in terms of temporal and spatial intervals. They are defined on the basis of transfer of responsibility areas (Figure 1). Their sizes and locations reflect negotiated objectives resulting from downstream constraints, such as punctuality at the destination, runway capacity, congested en-route areas or aircraft performance. TWs provide room for manoeuvre to ensure resilience in case of disruption and conflict management and, lastly, impose constraints only if necessary. Uncertainty will always be a component of the system and can never be entirely erased. The CATS concept proposes, instead of removing this uncertainty, to keep it under control by managing disruption via the size of the TWs and to limit the side effects of any disruption. Divergence from this planning (either to operational issues or owing to uncertainty) still remains possible, but if so it triggers a specific decision-making process, called renegotiation, at a system-wide level.

These TWs are negotiated, utilizing a collaborative decision-making (CDM) process supported by system-wide information management (SWIM), in terms of punctuality at the destination, taking into account all actors' constraints. This negotiation process can be described as follows:

- long-term planning phase (from years to months): development of an initial schedule, not overly detailed, constituted by TWs at departure and arrival airports, taking into account infrastructural and environmental constraints;
- medium-term planning phase (from months to days): development of business trajectories and negotiation of TWs through an iterative process; integration of weather predictions;
- short-term planning phase (from days to hours before the execution phase): continuous refinement of the TWs up to CoO signature.

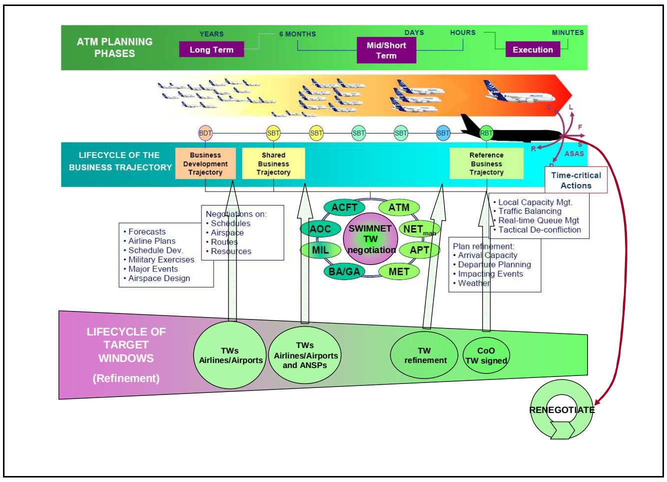

Figure 2: TW lifecycle

Then, the execution phase of the flight can start. The contract of objectives gives the controller and aircrew a means of managing the imprecision inherent in air traffic in accordance with their own objectives. The crews' objectives, therefore, are to adhere to an arrival schedule defined through TWs. Controllers, on the other hand, must ensure aircraft safety while keeping aircraft within the envelope defined in the contract, which guarantees that the contract will be observed.

If, for any reason (weather, etc.), one of the TWs can not be fulfilled, a renegotiation process will start between the impacted actors, resulting in a new CoO. The renegotiation process is performed with the actors using SWIM network facilities. The corresponding communication services are optimized (the amount of exchanged data minimized) to avoid the saturation of the SWIM network. A revision, involving the proposed change of a Target Window, may be proposed by ANSP, airport, airline or aircrew. Several important principles are applicable here:

- When the time horizon allows, the revision of the TW should use a CDM process involving all the concerned actors and mainly the airspace user to ensure the best possible business outcome;
- In certain cases, e.g. if a TW renegotiation involves only two centres, the process is simplified (point-to-point). The outcome of the TW renegotiation process is then made available using the SWIM network;
- When the situation is urgent, the controllers may decide to immediately and locally revise the trajectory for safety and separation purposes, without applying a CDM process.

The SESAR CONOPS [5] changes the approach of ATM to a performance-based approach. Trajectory-based operations ensure that the actual trajectory flown by the airspace user is close to its intended one, integrating ATM and airport constraints. The proposed CoO consists of a collection of TWs at each area, where responsibility between actors is transferred. The Business Trajectory (proposed by SESAR [5]) should then go through these different TWs, in order to ensure the system's predictability (compliance between what is planned and what is flown) and overall efficiency.

3 Project overview

The main aim of the CATS Project is to assess the CoO and associated TWs by involving the major actors in the supply chain (i.e. airlines, airports, and ANSPs). The Project will focus on the operational assessment of the CoO and on the systemic assessment of both the CoO and the TWs.

The first stage of the project was devoted to defining, in conjunction with ATS community partners, the operational concept scenarios linked to the CoO, and to describe the objectives and requirements of the operational assessment performed through HIL experiments.

The second step of the project is devoted to the assessment of the concept. The proposed assessments are expected to contribute to the SESAR concept. The CATS project re-uses some of the key performance area (KPA) defined by SESAR D2 [4] on the basis of the 11 KPAs identified by ICAO. CATS covers four of them, the Safety, Capacity, Efficiency and Predictability KPAs. The Performance Framework, proposed by Episode3 Project [8], is the basis for all validation activities performed within CATS. This allows for a comparison between the various research projects.

The idea is first to analyse how the proposed CoO and the associated TWs will impact the system performance regarding these selected KPAs. Therefore, also the contribution of humans to the overall system performance will be analyzed. Apart from this "operational" approach, a systemic assessment will also be performed, highlighting the benefits for the overall air transport system.

The so-called systemic assessments will concentrate on three aspects:

- Safety and risk assessment: the aim is to develop a model-based assessment strategy for the key elements of the concept based on the TWs. The strategy will revolve around case studies which will attempt to identify both typical and risk-sensitive scenarios which may occur with the TW concept. The case studies will be modelled formally, and analysed using analytical and simulation tools.

- Benefit assessment: the introduction of a contract-based ATS will impact all the actors in the system. A cost-benefit analysis will be carried out for the various stakeholders at three hierarchical levels: strategic, organisational and operational. Clearly, feedback loops from lower to upper levels may be envisaged. The study will be carried out by means of mathematical, statistical and simulation models.
- Legal assessment: the objective is to establish a legal framework governing service provision for ATM activities in the multipartite relationship between airlines, airports and ANSPs. The CoO should be implemented through target agreements and/or service-level agreements between all the actors. As a corollary, liability in the event of non-performance needs to be examined.

In the meantime, the operational approach will focus on three main validation objectives:

- Evaluation of the impact of the CoO between ATCOs: on the basis of the requirements and needs described during the concept definition, the acceptability and impact of the CoO, mainly by means of the TW, are evaluated in the context of the transfer of responsibility area between two ANSPs. The evaluation environment is restricted to two en-route controller working positions (CWPs) managing the traffic and coordinating the aircraft (i.e. the transfer mechanism). Particular attention will be paid to human-factor issues, since fulfilling the contract requires an additional task for controllers.
- Evaluation of the impact of the CoO between ATCOs and aircrew: the acceptability and impact of the CoO, as expressed mainly by means of the TW, are evaluated in the context of the interaction between an ATCO and the aircrew in a given sector. The evaluation environment is built around an ATCO working position and a pseudo-pilot position. Particular attention will be paid to controller and pilot human-factor issues, and the distribution of roles and tasks between ground and aircraft.
- Evaluation of the renegotiation process involving ATM actors (airlines, airports and ANSPs): this is the evaluation of the renegotiation mechanism involving all ATM actors if a CoO is not fulfilled. The evaluation environment is based on the previous environments deployed (i.e. ATCOs and pseudo-pilot positions) and gaming exercises through mock-ups of an airline operational centre, airport command centre and ANSP command centre. Particular attention will be given to the collaborative methods and mechanisms which should be initiated.

The first experiment, focusing on the impact of the contract of objectives and associated TWs between ATCOs, will be a Human In the Loop simulation, run in October 2008 in Geneva (at SkySoft’s premises), and will involve ENAV air traffic controllers. The hypotheses to validate through this assessment are:

- CoO implementation allows safe operations.
- CoO is still manageable even with increase of traffic as foreseen in 2020.
- CoO implementation affects positively the aircraft outputs in the sector (flight duration ...).
- Implementation of TWs ensures the respect of schedule.
- TWs integrate flexibility to cope with uncertainty.

- The working methods offered to ATCOs, as a result of the CoO implementation, are feasible and acceptable (task sharing, role and responsibility, as well as the offered support tools).
- Implementation of CoO does not impose significant additional workload to ATCOs.

The key performance indicators to measure will be extracted from EP3 performance Framework [8] and the assessments will be fully in line with the E-OCVM [6] methodology.

4 Expected benefits

At a conceptual level, the CoO and TWs can be regarded as an operational way of achieving the establishment of the ATM performance partnership recommended by SESAR [4]. TWs represent a possible means by which all the stakeholders can share a unique and impartial view of each other's priorities. Thus, they ensure a common translation and representation of the performance targets to be achieved by the overall ATM chain.

At a second more operational level, TWs unequivocally identify the transfer of responsibility areas between partners, and at the same time they constitute a way of managing uncertainty and monitoring disruptions. Measurement of compliance with TWs established during the negotiation process could represent a new and reliable metric for assessing the quality of a provided service.

The CATS Project represents one possible solution to another issue highlighted in SESAR D2 [4], namely the need to determine "*how to deal with business trajectories in the strategic, tactical and operational phases of flight*", since the CoO is a possible way of implementing the business trajectory, the notion around the future ATM system will be designed.

CoO and TW concepts are expected to directly bring the following substantial benefits to the ATM system:

- <u>More punctuality at the destination</u> (arrival-on-time concept): the CoO concept proposed in the CATS Project is designed to achieve an ultimate goal, namely arrival on time at the destination airport. Through the CoO, aircrew, controllers and airports share the same goal for the flight represented by an agreed contract. The synergy between the air and ground components is thus reinforced. Airlines will reduce delay-related costs and optimise their aircraft turn-around times. Airports will be able to optimise their ground operations. Even though the efficiency design target identified by SESAR applies to on-time departure, a strong correlation between punctuality at departure and at the destination clearly exists. It would be interesting to evaluate this correlation during the assessment process.
- <u>Optimisation of scarce resources</u>: during the design/drafting of the contract, through the Network Operational Plan (NOP), the actors' constraints will be taken into account in the collaborative process. Airlines will indicate their economic and technical constraints (i.e. business trajectories) in the negotiation. This will allow airlines and other actors to respond appropriately to the initial demand well coordinated with their constraints. Airports will be able to optimise runway use (through better scheduling) and thus improve throughput. Furthermore, their constraints will be integrated at an early stage of the collaborative process. ANSPs will be able to optimise their resources, since they will be responsible both for their local airspace design and for working methods in fulfilling contracts previously agreed with other actors. Furthermore, during the drafting process for the CoO,

they will be involved at an early stage and thus be able to indicate their constraints in the trade-off mechanism. This optimisation of resources will bring benefits in the key performance areas of cost-effectiveness and efficiency, since the enhanced allocation of scarce resources among actors will positively impact the efficiency of the entire air-transport supply chain.

- Improved predictability: the TWs are designed taking into account aircraft technical constraints, with built-in scope for disruption management aiming to achieve the ultimate target of the CoO, which is "arrival on time at the destination". Each actor knows its part of the contract, i.e. those TWs it must fulfil. Airlines will be able to rely on their schedules, as predictability will be improved, and they should get a better pay-off from their fleet. Airports will also be able to rely on their schedules, and so optimisation of ground operations will be possible. This will not only enhance the quality of service delivered to users (i.e. both airlines and passengers) but also improve the infrastructure pay-off. ANSPs will have ensured consistent airspace design and provide the necessary manpower in line with the expected level of traffic. Controllers will be able to better anticipate the traffic by having a global view of the system (the TW defines the constraints for punctuality at the destination). In line with SESAR requirements, variability of flight duration will be kept to a minimum, and service disruptions will be promptly managed and solved by the actors involved through the renegotiation process.
- Reduced overall costs: this aspect is closely linked to previously mentioned benefits, as optimisation of resources and improved predictability naturally lead to reduced costs. Airlines will be able to place more trust in scheduling. This will allow them to improve turn-around patterns, and thus improve their response to passenger demand. Airlines will be able to fly as close as possible to their business trajectories, and will then benefit from a trajectory-based organisation. Airports will get a better approach and better scheduling of their ground operations, and will thus be able to dedicate the right number of resources to service provision, which in turn will lead to cost-efficiency. ANSPs will be able to better anticipate airspace opening arrangements and design as well as manpower needs, which will allow them to adjust the size of their teams so as to improve efficiency. The cost-effectiveness of the system deserves detailed investigation to ensure that cost improvement is achieved via this concept.
- Reduced environmental impacts: like cost reductions, environmental benefits are mostly linked to better use of resources and improved predictability. Airlines will state their preferred routes on the basis of economic business models, and thus minimise fuel consumption and improve the "seat/fuel consumption" ratio. Airports will be able to improve ground operations (through improved predictability). This will reduce stand-by time on taxiways, which will in turn lead to a decrease in pollutant emissions at airports. Airports’ environmental constraints will be integrated into the CoO definition and the business trajectories.

5 Conclusion

The primary aim of implementing the Contract of Objectives is to work towards real punctuality in aircraft arrivals at and departures from airports. The financial component aims not only to satisfy airline requirements but also to enable, in global terms, the most cost-effective organization possible for all the actors. It is therefore through the financial constraints of these actors, whether they be airlines, airports or navigation bodies, that the user will reap the benefits, via the fare price inclusive of tax. As this CoO is a consensual trade-off issued from negotiation between all the actors, even if the economical models of this different actors change, this proposed concept will be still viable.

These same CoO also allow all traffic management operational methods, which are bound up with the specific characteristics of the various types of traffic and local areas, to become truly adaptable.

The management through the CoO is only a concept. Proof of concept requires now assessments regarding the systemic and operational issues. The CATS Consortium works in this way for establishing fitness for purpose of the proposed concept, based on evidences.

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