REPORT D1.2.2

CATS Concept of Operation

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EXECUTIVE SUMMARY

Air traffic, expected initially to triple by 2025, will continue to grow at about 5% annually [18]. However, the current Air Traffic Management (ATM) system is very close to its functional limits, and with the tools and procedures in use today the increase of capacity is fundamentally limited. As advocated by the European Commission, the future of ATM requires improvements with regard to capacity, punctuality, efficiency, the environment and safety. SESAR (Single European Sky ATM Research Programme) was launched to respond to these issues.

The SESAR target concept proposes a service-oriented approach, based on a performance partnership amongst stakeholders, to get the best outcome for each flight. The main driving principle is the concept of a Business Trajectory representing the users' intentions, which are known and facilitated by all stakeholders. All partners in the ATM network will share trajectory information in real time to the extent required from the earliest trajectory development phase through operations and post-operation activities. ATM planning, collaborative-decision-making processes and tactical operations will always be based on the latest trajectory data. A trajectory integrating ATM and airport constraints is drawn up and agreed for each flight, resulting in a trajectory which the user agrees to fly and the ANSP and airports agree to facilitate.

CATS (Contract-based Air Transportation System) introduces a new element to the 4D trajectory management, the "Contract of Objectives", negotiated and agreed by all parties for an individual flight. This Contract of Objectives (CoO) defines objectives applicable to a flight and links actors together through agreed interfaces, called Target Windows (TWs). These TWs not only facilitate compliance with the arrival time at destination, but also integrate ATM constraints and contain built-in margins for flexibility and disruptive-factors management.

In this context, CATS provides an innovative approach to assessing the impact for an en-route controller and a pilot when respecting the Contract of Objectives, or in other words, Control Time Over (CTO) and/or Target Time of Arrival (TTA). The CATS Project proposes one of the possible solutions for the implementation of the SESAR Business Trajectory.

At the same time, with the introduction of TWs, CATS proposes real support for the European Commission in monitoring the performance of the ATM actors.

The main objectives of the CATS Project are to assess the operational acceptability of the CoO/TW management and to prove the benefits and limitations/recommendations of the CoO implementation.

The expected benefits are firstly, respect of and adherence to flight schedules, and the improvement of predictability, and secondly, the optimised use of the scarce resources of all ATM actors.

Using the layered planning of ATM operations derived from SESAR, the objective of this document is to describe TW and CoO development. Key concept elements and the detailed roles of ATM actors will be also developed. The link with SESAR's high-level operational concept will also be clearly highlighted. The CATS concept description will form the basis of the scheduled validation.

1 Introduction

1.1 CATS Project

The Contract-based Air Transportation System (CATS) Project was selected during the 4th call of the European Commission FP6. It was begun in early November 2007 for a period of three years. The CATS Project proposes an integrated decoupling ATM organisation, where all the actors negotiate and agree on their own objectives. This organisation is based on shared responsibility between the various actors. The transfer of responsibility between them has been made explicit and formally contracted. This will reinforce the shared view of the Reference Business Trajectory (RBT) and also the punctuality of arrivals.

The new Air Traffic Management (ATM) paradigm proposed by CATS is based on SESAR concept [6] and proposes one of the possible implementations of the Business Trajectory, namely the Contract of Objectives (CoO). This proposal introduces an innovative way of managing ATM by mutually-agreed objectives leading to a market-driven Air Transportation System (ATS). These objectives represent the commitment of each actor to deliver a particular aircraft inside temporal and spatial intervals, called Target Windows (TWs).

It addresses the entire air transport supply chain by reconciling operational links between air and ground services and thus enhances efficiency by increasing the predictability of the entire air traffic situation for all ATM actors. Objective assignment and negotiation is carried out on the basis of the Collaborative Decision-Making (CDM) process, aiming at establishing the operational agreement (the right balance between productivity and safety). The context in which aviation is operated is changing rapidly, shifting focus from capacity growth to flight efficiency, environmental impact and cost reduction [18]. Building a new ATM system not only dealing with the current objectives but also supporting the future ones is the real challenge endorsed by CATS through the negotiation of TWs where all actors' constraints, current or future, are taken into account, supporting the business evolution.

A guaranteed performance is offered to the airline by the air traffic management system to ensure punctuality at destination.

CATS' main concern is to facilitate operational improvements and airspace users' benefits. The aim of the CATS concept of operations is to improve overall system efficiency by means of enhanced collaboration focused on the same goal, namely punctuality at destination.

The objectives presented below reflect the focus of the proposed project:

- <u>Link ATM actors together through agreed objectives and interfaces</u>: Reconciliation of Air Navigation Service Providers (ANSPs), airlines and airports by ensuring mutual awareness of the constraints (i.e. TWs) imposed by each actor and thus allowing the ultimate target (i.e. punctuality at destination) to be focused on. If these constraints are shared, everyone is aware of the possible options for adaptation in relation to the current flight, thus enabling an efficient CDM process.

- Integrate flexibility to cope with uncertainties: TW modelling respects technical-level constraints (e.g. aircraft performance, en-route control limitations) and offers scope for sufficient flexibility when disruptions occur. It gives Air Traffic Controllers (ATCOs) and aircrew a tool with which to manage uncertainties arising while a flight is airborne, whilst still respecting the original schedule.
- Coordination of actors' resources in order to deliver the best service: The CoO is the fundamental unit of the collaborative planning process, and is established, agreed and shared by all the actors. Under normal circumstances, this contract represents a "guarantee of service results" from the actors involved in the flight. Each actor is thus able to mobilise the relevant resources and infrastructure to deliver the appropriate service.
- Enhanced collaboration through the Single European Sky: The CoO and its representation though TWs represent a commitment between actors to agreed interfaces. The air traffic network is highly sensitive to changes (the butterfly effect), so in order to be efficient it needs to be considered at a regional level (i.e. on a European scale).

The main aim of the CATS Project is to experimentally assess the operational validity of the Contract of Objectives proposal.

This will be achieved by:

- defining the interfaces (TWs) between various actors and operators:
  - ATCOs from various ANSPs involved with airborne flight
  - ATCO and air crew involved with airborne flight
  - Airport, airline and ANSP during the renegotiation process
- assessing, through Human-In-the-Loop experiments, the operational acceptability and technical feasibility, particularly in the event of renegotiation
- evaluating the impact of the CoO in terms of human factor issues, safety and operators' workload
- evaluating the benefits (cost business analysis, safety & risk analysis) and the legal implications.

The "Concept of Operations" covers the en-route flight phase. It will:

- describe the concept,
- identify the main ATM actors and their needs
- describe the changes within the ATM components,
- outline the expected high-level improvements,
- stress the link with the SESAR Programme.

The purpose of this document is to update the initial version of Concept of Operation Definition (D1.2.1). This document represents the CATS Project delivery D 1.2.2 part of the WP1 as defined in the DOW [2]. It will be consistent with the European Operational Concept Validation Methodology (E-OCVM).

CATS will investigate the potential impact of the CoO for the 2020 horizon. It should be noted that the Concept of Operations delivered here presents the global view of the operational solution, from the planning phases to the execution of the flight. The CATS operational assessments foreseen in WP2 will focus on the execution part of flight, while the systemic assessments will take a more global approach.

This CATS Concept of Operations report is intended for both CATS Management and all other project stakeholders. It provides information about the CATS Concept of Operations.

The concept description will provide the basis needed for further research and development. Additionally, the concept will provide the operational context for the development of different experiments. It will also be an input document for SESAR.

1.2 Document structure

The document is divided into seven chapters:

- Chapter 1 provides some general information about this document;
- Chapter 2 presents the constraints of the ATM system anticipated for 2020;
- Chapter 3 describes the problems;
- Chapter 4 describes the proposed operational solutions;
- Chapter 5 describes how the CATS elements fit in with SESAR concepts;
- Chapter 6 describes the targeted ATM performance requirements;
- Chapter 7 presents the references used in this document.

1.3 Assumptions

It should be noted that the Operational Concept delivered by SESAR [6] is the basis for this document. This deliverable will present a *Concept of Operations*, providing an additional point of view with which to describe the concept because it specifically addresses ATM aspects such as punctuality at destination, predictability and efficiency. Concepts of Operations are used to find solutions to specific needs/objectives and their main purpose is to provide a common way to represent these solutions and thus be available to all the different concept levels.

Details of some enablers (like SWIM, CDM, etc.), since they form part of the SESAR Programme between now and 2020, will not be further defined here. CATS will benefit from these improvements.

CATS considers the SESAR assumptions of a well-planned and stable NOP, where data are made available for all users (e.g. through System-Wide Information Management) in order to establish a "common view" of the air traffic situation and its planned evolution at any specific time.

The CATS Project aims to validate the impact of CoO implementation. This validation will demonstrate the operational acceptability of TW management and also prove the benefits and limitations of CoO implementation. The main assumption of the operational assessments (WP2.1) is that the CoOs have already been negotiated. This validation will be done during the execution phase, also called En-route phase of the Trajectory Execution in the ATM Lifecycle [25]. A more global assessment is also foreseen in WP2.2, which will establish the benefits at the level of the overall system, including the planning phases.

This document presents the CATS Concept of Operations, focused on the proposed Contract of Objectives (CoO) and associated TWs.

1.4 Document evolution & approval

Revisions to the Concept of Operations document will be done through periodic reviews, mainly after the performance of the experiments and with all the project partners.

As described in Concept of Operations iterative improvement process (Figure 1), lessons learned from the previous assessments will update the Concept of Operation definition and the Validation Strategy:

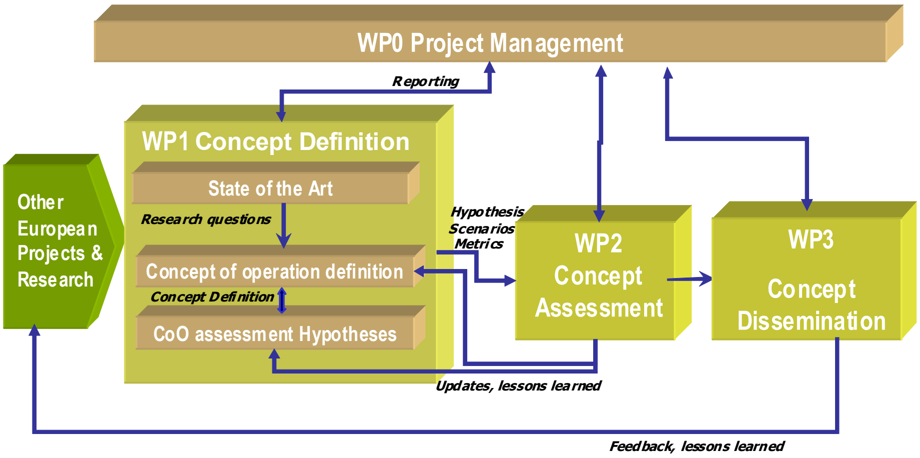


Figure 1: Concept of Operations iterative improvement process

1.5 Definitions, abbreviations and acronyms

ACC	Area Control Centre
AOC	Airline Operational Centre
AMAN	Arrival Manager
ANSP	Air Navigation Service Provider
AOC	Airline Operator Company
APTOCC	Airport Operational Control Centre
ATC	Air Traffic Control
ATCO	Air Traffic Controllers
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATM-NMF	Air Traffic Management Network Management Function
ATS	Air Traffic Services

ATSU	Air Traffic Services Unit
BT	Business Trajectory
CATS	Contract-based Air Transportation System
CB	Cumulo-Nimbus
CDM	Collaborative Decision-Making
CONOPS	Concept of Operations
CoO	Contract of Objectives
CTA	Control Time of Arrival (when in AMAN horizon)
CTO	Control Time Over
CWP	Control Working Position
ECAC	European Civil Aviation Conference
E-OCVM	European Operational Concept Validation Methodology
EXE	Executive Controller
FMS	Flight Management System
FTS	Fast-Time Simulation
GAT	General Air Traffic
HF	Human Factors
HIL	Human In the Loop
HMI	Human Machine Interface
IFR	Instrument Flight Rules
KPA	Key Performance Area
MTCD	Medium-Term Conflict Detection
NOP	Network Operational Plan
PC	Planner Controller
RBT	The Business Trajectory which the airspace user agrees to fly and the ANSP agrees to facilitate. Most times indicated in the RBT are estimates, some may be target times of arrival (TTA) to facilitate planning and some may be constraints (Controlled Time of Arrival - CTA). The RBT consists of a 2D route, altitude and time constraints when required, altitude, time and speed estimates at way points and trajectory change points.
RTA	Required Time of Arrival
RTS	Real-Time Simulation
SESAR	Single European Sky Applied Research
STCA	Short-Term Conflict Detection
SWIM	System Wide Information Management
TC	Tactical Controller
TTA	Target Time of Arrival
TWs	Target Windows

UDPP	User Driven Prioritisation Process

2 European ATM system - 2020 constraints

Without listing all the conclusions of SESAR D1 [4], it is important to highlight the main SESAR elements taken into account in its delivery.

First, the analysis of current ATM system indicates that:

- the ATM system is a network with a huge diversity in terms of flight profiles, aircraft, airlines, airports, airspace, ANSPs, etc;
- fragmentation of the ATM system impacts its level of performance because it is not sufficiently adjusted to sustained schedules;
- service on a "first come, first served" basis reduces the performance in terms of punctuality;
- there is a paradox between global "trans-state" airline organisation and local "state-based" ATM organisation;
- insufficient functional integration between ATM stakeholders results in delays which lead airlines to include buffers within their schedules. Decisions are often taken in isolation, producing constraints that may have an impact on others;
- pilots currently have a limited situational awareness of the air traffic, which can potentially affect their own flight and restrict them from taking a more pro-active role in the ATM process.

Air traffic (number of flights) is expected to triple by 2025 compared to the current situation. However, the current air traffic management system is being operated very close to its functional and capacity limits. This will inevitably lead to future airport and en-route congestion and a significant increase in traffic restrictions. Punctuality remains, for the time being, relatively poor (22% of all arrival delays exceeded 15 minutes in 2007). The overall delay (en-route and airports) incurred costs of about € 1,300 M [12]. The figure below shows the most delay-generating air traffic control centres [12].

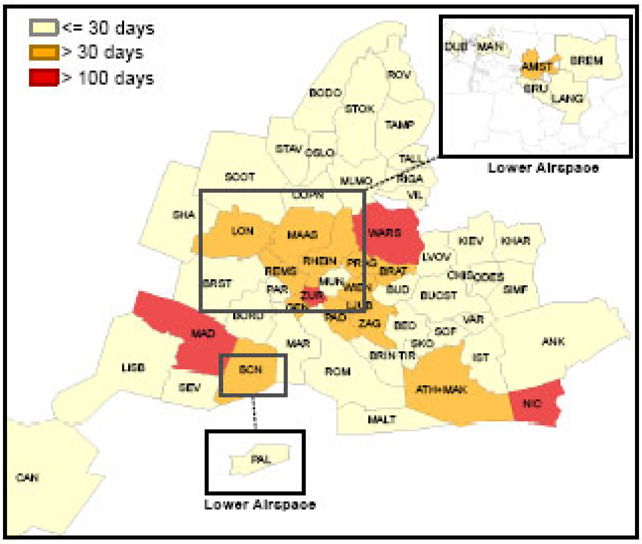


Figure 2: The most delay-generating air traffic control centres

The lack of predictability of events and corresponding warnings exacerbates problems related to the flow of traffic en-route and in terminal airspace. Furthermore, airspace users and ATM service providers optimise their operations independently within their local domains which leads to inefficiency on the global scale. This lack of predictability when making decisions means e.g. that "centralised" flow regulation and slot-allocation action taken to protect sectors from overload can actually lead to further inefficiency and result in a significant loss of slots.

PRR8 [8] identified flight efficiency "as a major contributor to ATM performance: en-route horizontal inefficiencies alone are estimated at € 1,000 M - € 1,500 M per annum". Furthermore, it suggests that "improved predictability of air transport would generate high added-value: compressing half of the flight durations on average by 5 minutes would be worth some € 1,000 M per annum in better use of airline and airport resources".

The Single European Sky 2 [12] initiatives will enforce binding performance targets on the ATM actors. Such commitments are presented below (Figure 3).

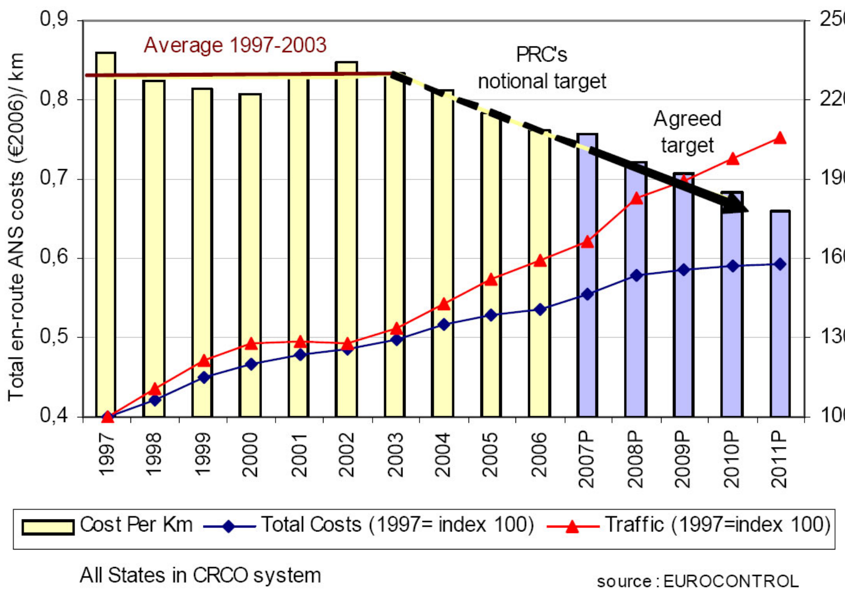


Figure 3: Commitments to meet agreed cost-effectiveness targets are a significant step forward

As specified in Article 11 of the proposed SES II Regulation (COM/2008/0388) [16] the European Commission (or designated body) will improve the performance of air navigation services by setting up a performance scheme, including periodic review and monitoring of performances. The CATS concept proposes a framework for this monitoring, through the fulfilment of the TWs.

The lack of integrated processes and procedures together with intrinsic limited airport capacity for safety reasons and long implementation lead-times typical of new supporting technological solutions has put significant pressure on gates, taxiways and runways at peak times with an associated impact on airspace user operations.

Considering the above, the SESAR operational concept proposes to concentrate on:

- providing high schedule integrity, of course with preserved high levels of safety and capacity;
- providing a high level of integration between the various stakeholders;
- guaranteeing the schedule, assuming a Network Plan of ATM in which the "common operating philosophy" is shared by all partners, comprising information and decision processes. The Network Plan needs to create a more codified set of explicit interactions that specify services, requirements and obligations for all partners, i.e. with respect to:
  - sharing data and implementing cooperative decision making
  - integrating airborne side and ground side
  - improved use of resources
  - common single functional architecture which defines the needed information flows
- greater operational ATM capacity and flexibility;
- addressing the human factors aspects as early as possible, i.e.:
  - Adherence to a human-centred system
  - Definition of a performance-based regulation supported by appropriate standards.

The SESAR target concept presented by D3 [6] is a trajectory-based concept. All partners in the ATM network will share trajectory information in real time to the extent required from the earliest trajectory development phase through operations and post-operation activities. ATM planning, CDM processes and tactical operations will always be based on the latest trajectory data. A trajectory integrating ATM and airport constraints is drawn up and agreed for each flight, resulting in a trajectory which the user agrees to fly and the ANSPs and airports agree to facilitate.

Trajectory-based operations imply a new approach to airspace design and management in order to avoid, whenever possible, airspace becoming a constraint on the trajectories. Airspace user preferred routing, without pre-defined routes, will be applicable everywhere. The only exception to that general rule applies in some terminal areas and below a designated level in some en-route areas where sufficient capacity can only be provided through the use of structured routes, which at the same time will reduce holding queues in the air and on the ground. However, such structured routes will only be activated when needed.

The challenges that need to be dealt with when addressing these constraints include all these components relevant for improving schedule integrity, of course with preserved high levels of safety and efficiency.

3 Problem identification

Air transport is a production system that only exists because it meets cost-benefit criteria. In this context, air navigation is a link in a chain of production that meets financial, safety and efficiency targets. Safety is and remains the highest priority in aviation and the provision of air traffic services plays a key role in preserving safety, but better results in terms of cost-efficiency must be achieved. The context in which aviation is operated is changing rapidly, whereas the future ATM system should be able to embrace current and future challenges. Future business imperatives will become even more urgent and therefore solutions are sought to the expected future increase in air traffic. The performance criteria adopted for the navigation system are twofold:

- To meet the needs of the users, i.e. the airlines should meet the needs of the passengers
- If the user needs cannot be fully met, then the operational constraints must be imposed, but the original requirements of the users should be compromised as little as possible and the best possible prediction of the required changes and their impact should be made. This prediction is necessary to give other transport system operators sufficient information to manage the resulting changes/modifications within their domain as well as possible, respecting the operational constraints and profitability requirements from other domains

Therefore, the mission of air navigation can be summarised as organising and monitoring air traffic effectively and safely in order to ensure punctual arrival and cost effectiveness.

3.1.1 Aircraft operating cycle

Air navigation is concerned with the flight segment of aircraft, but the ground segment (aircraft management at the airports) cannot be ignored. Accordingly, a flight segment gains operational significance only by establishing a connection with the ground segments:

- the "departure" ground segment up to the moment when the management of the flight segment begins;
- the "arrival" ground segment after the flight segment, where the consistency and operational validity of the particular flight with respect to the airline and its customers can be assessed.

At this stage, it would be worthwhile to introduce the concept of flight rotations, which is an operational concept for the airline, insofar as it represents both an operational approach (i.e. the means of achieving planned results) and continuity between the ground and flight segments of the aircraft.

The operating cycle of an aircraft can be regarded as a loop divided into a "ground" part and an "air" part (Figure 4) separated by the taxiing stage. For the destination airport, it is important to know the aircraft's off-block time at the previous (departure-) airport, allowing the destination airport to better plan the time of arrival at the block, and then organising all the ground operations (catering, refuelling, etc.). Yet, in an air navigation context, it is equally important for airlines to be able to predict the on-block time on the destination airport. Aligning the arrival times with an airline's flight schedules for the following flights is one aspect of optimising the system's performance and efficiency, since efficient ground management of hubs and aircraft rotation satisfies both the customers' and the airline's needs and goals. Moreover, knowing the arrival time more precisely facilitates aircraft reception at destination airports and is therefore an enabler for efficient Airport CDM.

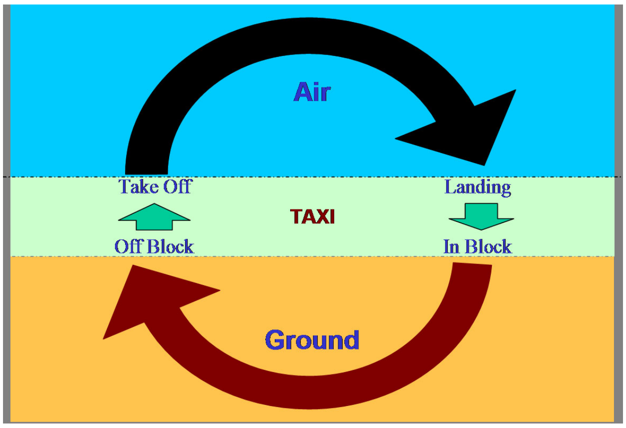


Figure 4: Operating cycle of an aircraft

The loop makes clear how important it is to increase the consistency and operational synchronisation between the ground and air components of the aircraft operating cycle, since the point of exit from one component is the point of entry into another (during the "ground" phase the previous flight ends and the following one starts).

One criterion for air traffic system productivity is therefore degree of adherence to optimum aircraft arrival times at destination airports. This criterion may be added (a local criterion) to the two existing paramount criteria: capacity and safety.

ATM is therefore central to the aircraft's life cycle because:

- it comprises aircraft ("air" component) negotiations and decision-making with airports and airlines (representing the "ground" component);
- it provides management and adjustment mechanisms during taxiing phases;
- finally, ATM provides the management and regulation mechanisms for the "air" component.

3.1.2 Disruptions and uncertainty

ATM is continuously subject to disruptions and uncertainty management is a key requirement for the future. Disruptions can be classified into ad hoc (meteorology, sudden limitation of runway capacity, aircraft failure, etc.), constant imprecision (inaccuracy of technology), and system-wide problems generated over interfaces between the various components of the system (Air Traffic Flow Management (ATFM) vs. Air traffic Control (ATC), and ATC vs. aircraft crew).

The future air traffic management system needs to present a set of solutions considering the levels of uncertainty and the required efficiency in relation to the nature of each disruptive factor. The decision-making within the system should not be constrained if this brings no operational benefits, otherwise it will be too rigid and therefore incapable of managing the variability inherent in the air transport system.

One of the challenges of the future ATM system will be to ensure compliance between the plan and the actual flight by managing this uncertainty. State of the Art [9] demonstrates that accuracy could easily be achieved during the execution phase, through the Flight Management System (FMS), but the real challenge is to link the planning with the execution phases. As studied by Gwiggner & all [13], even if all controllable uncertainties in flow planning were eliminated, systematic gaps between the number of planned and observed traffic in a sector would remain.

According to SESAR, principles like "first in, first served", which aim to expedite traffic rather than adhere to a planned trajectory, should be removed from the future system.

3.1.3 Partitioned airspace

European airspace is partitioned and managed by 27 different ANSPs. Each of these manages its own route network and applies its specific working methods; this limits the performance of overall traffic capacity and flow management, in particular at the level of the interfaces between the actors/networks involved. Sectors are mainly designed according to national borders rather than to traffic flows.

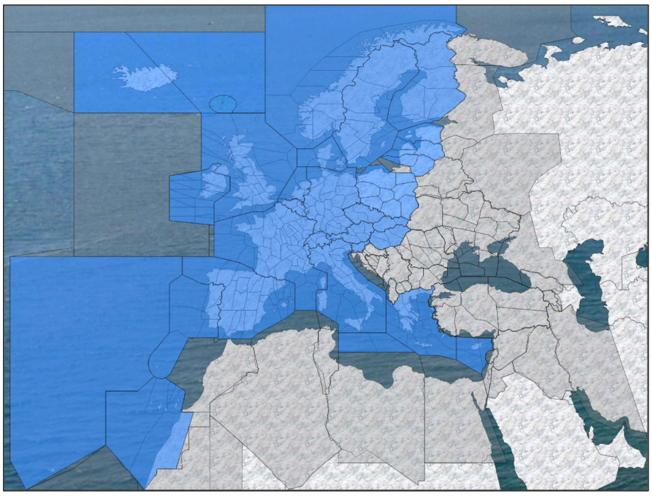


Figure 5: Airspace fragmentation

The annual cost of such fragmentation is estimated by SES2 [12] to be about €1 billion. An integrated approach to traffic management at European or even global level appears to be the only possible means of substantially increasing traffic efficiency. Functional and operational continuity between the ANSPs involved is vital if the entire operating cycle of an aircraft is taken into account, thereby achieving a better awareness of air traffic as a whole. The defragmentation of European airspace will provide more opportunity for more direct routes. Europe's current operational concept is ground-based. Declared airspace capacity and runway acceptance rates are managed through delay and regulation restrictions via an implementation of the Central Flow Management (CFM) concept. However, airport processes and procedures are not integrated into CFM and the existing system is unresponsive to real-time events. Moreover, airspace users and ANSPs currently optimise their operations independently, which leads to further system inefficiencies.

And even at local level (e.g. on a CWP) the awareness of operators is specific rather than global: controllers have no notion of the downstream consequences of the actions they take at local level.

3.1.4 Scarce resources

In spite of some congested sectors, the sky itself is not the major scarce resource of ATM. Airport take-off and landing capacities constitute genuine major bottlenecks. Without increasing these capacities, it will be impossible to respond to the expected increase in air traffic. The largest European airports are already operating at their maximum capacity and will be able to support additional movements only with careful further optimisation of take-off and landing sequences.

As stated in SESAR [4]: "The current ATM System has humans at the centre of virtually all activities and this has been at the heart of providing safe, high quality air navigation services. However, expectations are that in some cases the human will not be able to deal with the future level of traffic and its complexity in the same way as is done today. There is a need for a paradigm shift in the current concept of operations to break through the "capacity barrier"".

So the limited human operator's workload could be also seen as a scarce resource.

3.1.5 Arriving on time

As advocated by SES2 [12], instead of the departure time, the arrival time should become the main reference for the future flight-planning schemes and systems, aiming at reducing or avoiding holdings.

The various operators of the ATM system have to deal with different degrees of unpredictability of a flight. Within the gate-to-gate context, this unpredictability is a consequence of different factors leading to the deviations of an executed flight with respect to the planned flight.

Sometimes, a follow-on flight is delayed owing to a late arrival of an aircraft, or to departure delays imposed by the CFMU. In this last case, air traffic controllers trying to optimise flows in their own sectors may have an adverse impact on the overload management actions initiated by the CFMU. Indeed, controllers have no clear idea about how their actions impact CFMU planning.

Arriving on time requires a realistic block/flight time, a punctual departure at the previous airport and the adequate en-route handling of the flight within the TW envelope.

The tolerance of the target time of arrival (TTA) window should be as small as manageable and should encounter the minimum queuing time in the holding pattern or arrival sequence, to keep up the pressure in the arrival stream. This will be the main issue of the TW modelling calculation.

At many airports the taxi time from the stand/gate "off block" to the departure runway in use can vary greatly in terms of aircraft start-up procedure (remote or dock stand), in terms of the runway-in-use concept (long or short distance between stand/gate and runway) and in terms of metrological conditions (winter – aircraft de-icing on a remote de-icing facility). The variable taxi time at the departing airport must be taken into consideration when optimising arrival time at the destination airport.

The characteristics of the punctuality measurements currently in use are inadequate. A new method of punctuality measurement must be introduced to verify the arriving-on-time element. Milestones like touch-down time, on-block time at arrival airport and off-block as well as take-off times at the departing airport must be measured to validate the (estimated) duration of the various flight phases.

4 Operational solutions

4.1 Introduction

The CATS operational solution addresses the problems identified above by exploring the strategy explained below.

A new way of enhancing traffic efficiency is to improve functional and operational continuity in aircraft management, both on the ground and in the air, aiming to meet safety and productivity objectives. Functional continuity has an airspace dimension (heterogeneity of European airspace) and a time dimension (from flight planning to flight execution). Within the CATS Project, it is proposed to bring together all the ATM involved components by means of a Contract of Objectives.

The purpose of the Contract of Objectives is to build an operational link between all the involved ATM actors (airlines, airports, ANSPs or FABs) identifying the role and the resulting redistribution of tasks for each actor in relation to a clear, well-defined objective which is accepted by all concerned actors.

This CoO is general, of course, and will be commonly defined by all the involved actors while taking into consideration each actor's specific characteristics and workload. It has the merit, however, of creating a common basis between the actors which will enable them to interact and adapt to the operational circumstances and constraints without losing sight either of the global objective, which ensures productivity, or of interactions with the other actors. The challenge is to define a common operationally-required minimum situational awareness among the actors sufficient to achieve the right balance between efficiency and the remaining safety margin when making their decisions.

Behind these recommendations one can recognise the concept of the contract, which is increasingly common in the literature on that subject. Examples are the four-dimensional contract suggested in the framework of the PHARE Project, the ACARE recommendations [9] and the shared vision for airports in order to predict airport departures as accurately as possible. The contracts mentioned so far have a local dimension as they involve only a limited number of actors instead of all the actors in the ATM system.

For this reason, it is helpful to propose a global contract that is valid for the "flight" segment. This contract must facilitate functional and operational continuity between aircraft and the ground segment, since it is a-priori compatible with the objectives of the destination airport. It also plays a role in integrating the flight segment into the rest of the ATM system by creating "bonds of reciprocal responsibility" between the airlines, the aircrew and other ATM components. It is clear that the concept proposes to contract for performance and not for safety. The primacy of safety in the delivery of services exists regardless of performance. Safety is regulated under public law at various levels (ICAO, EUROCONTROL, EASA, and States) and will not be contracted.

This concept is fully in line with the operational concept of SESAR, where the operational performance targets for an individual flight are expressed as gate-to-gate parameters, including runway, taxiway, in-flight planning and operations, as well as the airport gate assignment.

CoOs will allow not only punctuality at destination but also a better organisation for the involved actors. The link between the planning and execution phases, as demonstrated in the State of the Art [9], is one of the weaknesses of the current ATM system and could be improved by the implementation of CoOs, mainly owing to the fact that margins to cope with inherent uncertainty are part of it. CATS covers all aspects of ANS performance that are relevant to the airspace users. This model also covers cost–effectiveness and operational efficiency that extends far beyond punctuality alone.

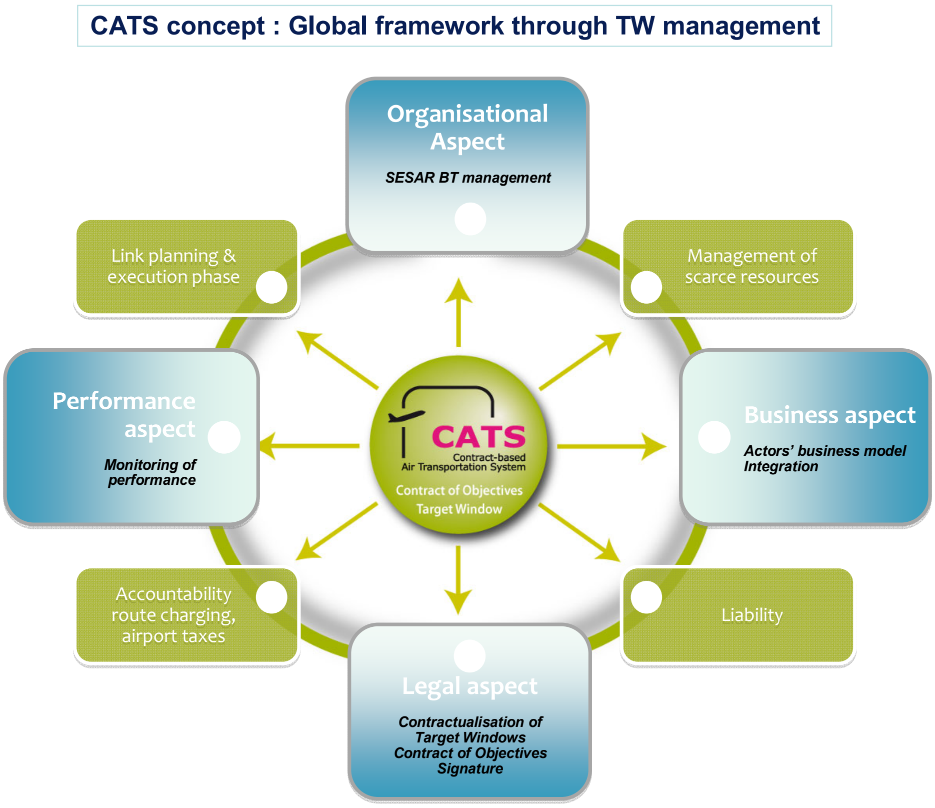


Figure 6: A global framework

The aim of this chapter is to present one of the possible solutions for the implementation of the SESAR Business Trajectory operational concept. By implementing a CoO, all operational stakeholders are aware of the Business Trajectory through the use of TWs.

This document discusses the global scope, covering ATM planning tasks, flight performance and the management of traffic flows. Nevertheless, the CATS operational assessments will focus only on the execution phase of flight, as they are supposed to assess the impact of this CoO on the operators' activity.

4.2 Leading characteristics

4.2.1 Drivers

The SESAR CONOPS [6] shall be seen in the context of the ATM system being one Enterprise system of services delivered by all concerned stakeholders to the efficient execution of 4D trajectory. Consequently, the main change from the current way of ATM operations is the change from airspace-based concept of operations to a trajectory-based system. The need to establish a performance-based ATM system is the main driver of this change. The trajectory-based concept of operations ensures that the airspace user flies its trajectory as close as possible to its declared intent, while still respecting ATM- and airport-imposed constraints.

Trajectory-based operations are the core of the SESAR concept enabling:

- Enhanced predictive capabilities and reactivity of the network with the objective of taking most strategic ATM actions prior to departure
- Information sharing and collaborative process providing more flexibility for the airspace users when changes are required

The notion of Reference Business Trajectory (RBT) advocated by SESAR is the basis of the CATS concept. The definition of RBT given by SESAR is "…the business trajectory which the airspace user agrees to fly and the ANSP agrees to facilitate". The RBT consists of a 2D route, altitude and time constraints when required, altitude, time and speed estimates at way points and trajectory change points. The times indicated in the RBT are mostly estimates, some may be target time (TTA) to facilitate planning and some may be constraints (CTA) [19]. RBT parameters (such as times, levels, speeds, position coordinates, and their accuracy requirements) for a given point in space are available in the NOP. The parameter has the status of an "estimate" or "target". CATS proposes the TWs as these RBT targets, located at the transfer area of responsibility, in order to facilitate the overall organisation of the system. The CATS operational solution is one of the possible solutions for the implementation of the SESAR Business Trajectory. The main idea is that ATCOs will continue to manage flights with a safety-first objective as in today's system; the flights will be managed also taking into account the planned targets, represented by the CoO, shared through the NOP.

4.2.2 Foundations

The main foundations of the CATS concept of operations are the CoO and TWs.

The Contract of Objectives, and associated Target Windows, could be seen as organisational elements, constraining the initial Business Trajectory, so as to achieve efficiency and planning goals. Without a clear transfer of responsibility between actors, it will be difficult to ensure the full achievement of the planned BT. Furthermore, the air traffic controllers and all other ATM actors should be informed about the impact of their actions on the overall performance of the concerned flight and on the other flights.

The Contract of Objectives represents a formal and collaborative commitment of ATM actors (airlines, airports, ANSPs or FABs) to the performance of the particular flight - with the ultimate target: punctuality at destination - establishing their roles and tasks with respect to that flight. This will also lead to an improved common awareness among all actors.

The Contract of Objectives is associated with a single flight. It defines an arrival-time envelope for the aircraft (Figure 6); the envelope will be compatible with predicted air traffic capacity at that moment. Further, CoOs contain built-in margins providing the flexibility required for managing disruptive factors. These margins are compatible with those of the other components of the ATM system. The Contract of Objectives is therefore a flight envelope defined on the basis of:

- the aircraft's room for manoeuvre (commercial flight envelope);
- predictions relating to en-route ATC limitations;

- the objective to be attained (punctuality). The room for manoeuvre becomes smaller the closer (in time) one comes to the final objective.

The Contract of Objectives gives both the controller and aircrew the means of managing the imprecision inherent in air traffic while remaining in accordance with their own local objectives. As presented in chapter 3.1.2, ATM is continuously subject to disruptions. It would therefore seem difficult to erase this uncertainty and have a planning which is absolutely equal to execution. Margins for dealing with inherent disruptions will be part of the TW calculation. The prediction of the flight may not be needed all along the route (as with full 4D trajectory management) but at each transfer of responsibility of the flight, allowing the different involved actors to optimise their own organisation. The crews' major objective is to adhere to the planned arrival schedule; controllers, on the other hand, must ensure aircraft safety (safe separation) while still allowing the aircraft to remain within the envelope defined in the contract, which guarantees that the contract's objective will be fulfilled.

The Contract of Objectives is linked with the aircraft's operating cycle and complements Airport CDM mechanisms. Airport CDM mechanisms try to optimise the use of ground resources and to accurately predict an off-block time. This in turn allows for refining the Contract of Objectives. The major CoO objective is not to adhere to a take-off time, but rather to adhere to an arrival slot agreed with the airline and the airport. The allocation of arrival slots takes account of the following:

- Runway constraints at airports.
- Reception constraints and airline network and hub constraints.
- En-route ATC constraints.

The benefits for the airline when having a Contract of Objectives are twofold:

- The ATM system must ensure that the aircraft lands at the destination airport at the scheduled time. Adhering to a flight schedule is no longer the concern only of the aircraft's crew and the airline dispatcher. The air traffic control team and the aircraft's crew are able to work in synergy.
- Since the aircraft's guaranteed arrival time is known at the moment it departs, the airline can plan its resources for ground-based management of the aircraft at the destination airport and optimise the management of its hubs and operations. The same applies to the airport resource management.

The Contracts of Objectives are drafted on the basis of criteria relating to traffic capacity, traffic fluency and safety. The drafting of the Contracts of Objectives does not take account of traffic safe separation. During the planning (or negotiation) phase, the trajectories are not de-conflicted. Nevertheless a notion of non-overloaded controlled area is taken into account by the TWs calculation. Sector capacity will be one of the ANSPs/FABs constraints during TWs negotiations. But TWs give more relevant information on probabilistic aircraft position. So potential overloaded areas based on TWs position and size (e.g. TWs overlapping at the same time), could be known in advance and actions (e.g. reorganisation of sectors, size of TWs or traffic flows rerouting…) should be taken before the end of the negotiation process. This organisational added value will also give a major added safety net element without doing traffic de-bunching or de-conflicting during the planning phases. Separation insurance remains the responsibility of air traffic control, i.e. the operators currently associated with air navigation. The Contracts of Objectives provide inputs about the airspace for air traffic controllers to perform properly their task of ensuring aircraft separation. Separation management remains an ATCO task, even if the CoO concept will benefit from the SESAR potential separation modes.

Through the Contract of Objectives, air traffic control is given the opportunity to go further in terms of providing service instead of "capacity and safety" alone. There is now a commitment that a flight schedule will be adhered to at the destination airport. This means that ATC is responsible for managing traffic during the flight and can apply priorities among aircraft as appropriate, in order to fulfil Contracts of Objectives. Information about the aircraft's final intentions, therefore, makes it possible to manage and plan its room for manoeuvres earlier in order to account for disruptive factors. ATC thus plays an active part in managing the flight by proposing solutions which meet airlines' operational targets and therefore indirectly also the requirements of the passengers.

To ensure a global coherence between ANSPs concerned with the airside, intermediate objectives have to be derived and negotiated from the Contract of Objectives. The Target Windows (TWs) define milestones along the particular flight, marking out traffic progress. These intermediate objectives are assigned to actors (e.g. ANSPs/FABs) and have the following purposes:

- They constrain traffic progress in term of considering boundaries.
- They create a strong link between the flight planning phase and ATC tactical operations, increasing the robustness of the whole system. The nature of the link has to preserve the ATC initiative, and windows are to be calculated according to the balance between constraints, disruptions and costs.
- The collaborative planning based on common objectives permits the technical and economical diversity of ANSPs to be taken into account while still giving guaranties for the schedule punctuality. TWs provide added value to technical (especially if two adjacent actors are working with different modes of operations, e.g. structured routes and free routes) and economical (as TWs are the results of a real trade-off of the actors' economical constraints) organisations.

TWs represent a common planning mechanism and create a "common language" to be used by all involved operators, providing a link between the planning and the ATC operations. TWs are a tool which defines efficiency objectives for the operators, and provides a monitoring possibility at tactical and strategic levels, enabling them to deal with disruptions in a timely way and with a clear view of the situation. Instead of precise 4D points without any tolerance, they are expressed in terms of intervals of adaptable width centred at these 4D points. The interval size and position reflect constraints imposed by downstream components (remaining part of the flight), such as punctuality at destination, runway capacity at the destination airport, or congested en-route areas through which the flight will pass. The room for adaptation of TWs left to ATC operations ensures resilience to disruptions, while making sure that ATC applies constraints only when necessary. Even if such a planning frame is very flexible, operational divergence of the actual flight with respect to the planned one is still possible, and triggers a specific decision process at strategic level called renegotiation.

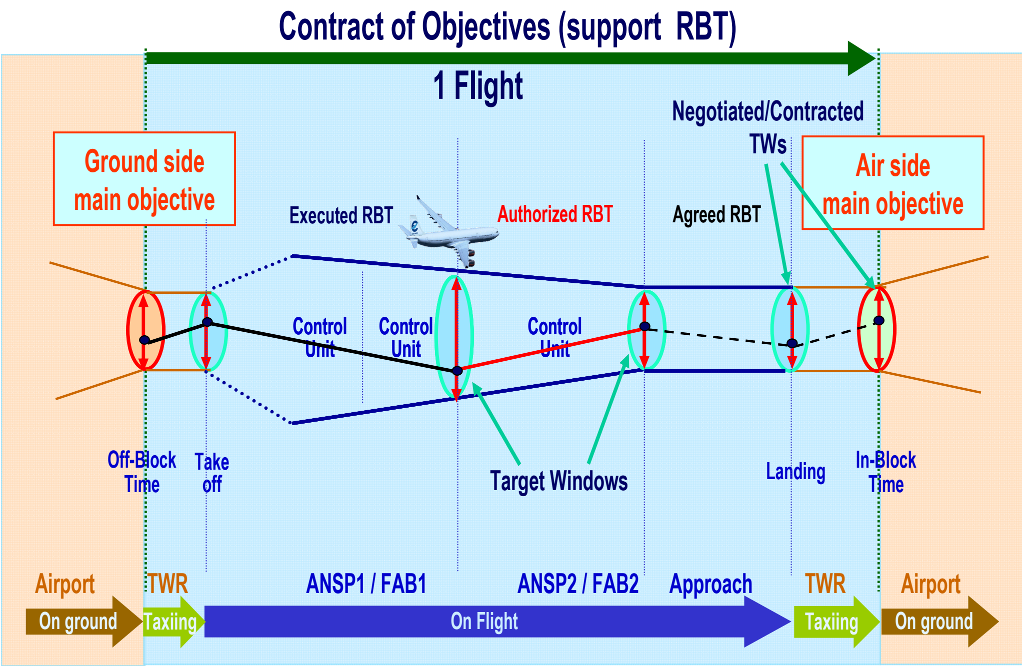


Figure 7: Contract of Objectives and Target Windows

It should be noticed that, as presented Figure 7, TWs are defined between actors (e.g. ANSPs/FABs, airports, etc.). Nevertheless, ANSPs/FABs organised into sectors could easily apply the model of TWs inside their own business, in order to better manage the traffic.

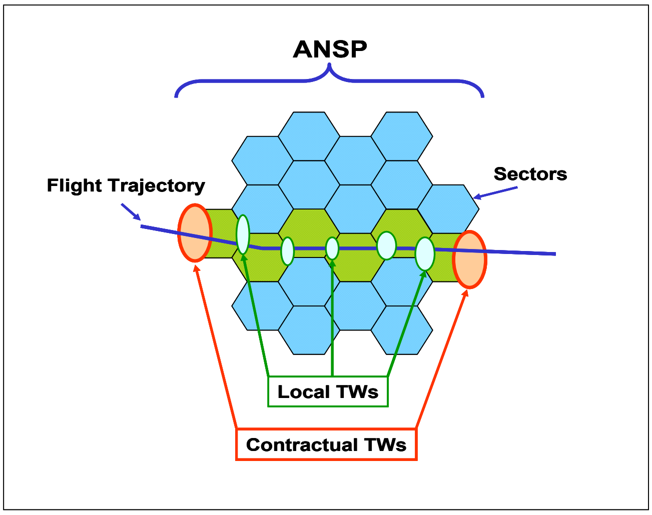


Figure 8: Local ANSP organisation

Only the contractual TWs, as presented in Figure 8, will be considered as part of the CoO, disseminated through the System Wide Information Management (SWIM) to all the concerned actors. The local TWs are internal to the ANSP/FAB.

The grade of fulfilment of TWs could also be seen as an operational tool to monitor the performances of the air navigation services, as advocated by the EC in its COM/2008/0388 proposal [16].

4.2.3 Enablers

Exchange of information between actors has always played a vital role within ATM and is required from the planning process to the execution of the flight. The Contracts of Objectives and Target Windows are examples of such shared information. Access to this information and the most suitable form for presenting it to the users are some of the challenges to overcome.

A method for secure sharing relevant ATM information with the required quality and timeliness is an essential enabler to the CATS proposal.

There are two fundamental processes involved in communication among airspace users when sharing the proposed Contract of Objectives and TWs: notification and co-ordination. For these processes, a series of appropriate messages has been designed to eliminate the need for verbal human-human communication.

In the environment proposed by SESAR, these processes will be based on coordination using data-link as the prime means of communications between ground and air. Future Air/Ground data-link will be able to support the exchange of trajectories, TWs and complex clearances. This will in turn reduce the need for corrective ATC actions and therefore the entire communication workload per flight.

The Business Trajectory (BT) and the TWs are shared in the known common format between the involved actors through the SWIM network and are updated as previously described. Automated systems in each Air Traffic Service Unit (ATSU) will extract relevant data from the shared BT and TWs to be used again by different ATM processes in place, e.g. data display, conflict detection, etc.

All the decisions are made through the CDM process, using the shared information provided via SWIM. Having a better understanding of the global network effect of their local decisions and vice versa, the quality of each actor's decisions is improved. Even if the airspace user remains the owner of the BT, it should be noticed that the CATS proposal is not an organisation by constraints, where the ANSPs give the constraints and airspace users adapt the trajectories to these constraints. CATS proposes a framework where the decisions are negotiated through the CDM process.

Automated ATM conflict detection systems, advocated by SESAR [6], will identify potential conflicts with other flights on any trajectory segment thanks to the availability of all relevant trajectory information. Therefore, problems will be identified and appropriate solutions implemented across the airspace as a continuum rather than locally – the best solution being determined by interaction between automated processes – via CoO renegotiation.

The main enablers supporting the CoO in the SESAR environment are:

- the CDM mechanism, supported by SWIM, allowing data sharing between airspace users/service providers (i.e. ground ATC/ATM systems, airborne Flight Management System (FMS), airline automation, airport automation);

- aircraft equipped with:
  - high-quality air-ground technical data link system;
  - data-link applications (i.e. ADS-C, CPDLC, ADS-B/out and ADS-B/in) and services (e.g. COTRAC, FLIPCY, FLIPINT);
  - TW monitoring and renegotiation tools, including "what-if" HMI;
  - FMS capable of conducting the flight along the agreed BT while respecting the TW constraints;
- ground systems providing:
  - data-link applications supported by SWIM;
  - 4D trajectory uplink/downlink;
  - clearance to proceed along the next trajectory segment;
  - enhanced monitoring and resolution tools to the controller;
  - trajectory prediction and renegotiation tools;
  - Medium-Term Conflict Detection (MTCD);
  - TW monitoring and renegotiation tools, including "what-if" HMI.

The most important characteristic visible from the SESAR context is the real-time trajectory management, i.e. the sharing of trajectories, TWs and all relevant environment information based on SWIM.

4.2.4 Facilitating the Business Trajectory

4.2.4.1 Building the network planning

As advocated by SESAR [6], several key enablers support the development of the Contract of Objectives and Target Windows:

- All ATM partners share the Contract of Objective information (including TW information) and other relevant ATM information (e.g. weather).
- The net-centric system, which supports information sharing, allows the ATM partners to provide or consume information. The concept of System Wide Information Management (SWIM) meets such a goal, and is compliant with the concepts of building and executing the Contract of Objectives. Along the CoO's life cycle, the information coming from airspace users, airports, ANSPs/FABs, separators, and the aircraft itself is shared by all partners in order to build and execute the flight.
- Decisions are taken by the involved actors through a CDM process. The CDM principle is applied to each ATM process, but will not interfere with the safety- and time-critical separation function (separation decisions must be taken locally in the ATC domain; there is no time for CDM). Non time-critical trajectory changes will be made through CDM. CDM is essential in the building of CoOs in order to:
  - take into account all relevant information available from any involved partner;
  - ensure that the balance between airspace user needs and airspace and airport constraints will be as efficient as possible;

  - publish local decisions and get a global shared agreement on the local decisions;
  - develop a common situation awareness of the air traffic and other relevant factors (weather) and have a better understanding of the network effects on decisions;
  - facilitate the adaptation to changes before the CoO is concluded and to unexpected events during its execution.
- The solution proposed to achieve an agreed and stable balancing between demand and capacity is the CoO. CoOs result from a collaborative layered planning, based on CDM, coordinated by a network management function. The network management function is supported by the Network Operations Plan (NOP), as proposed by SESAR in Deliverable D3, which facilitates the processes need to reach agreement on demand and capacity balancing.

Network planning explains how airspace and airport resources are managed, and how the various partners interact to achieve stable network operations to optimise the accommodation of the Contract of Objectives. The purpose of network planning is to design the Network Operational Plan (NOP) from which the CoO and TWs will be available for all ATM partners.

The Contract of Objectives is designed with the participation of all actors (airlines, airports, ATM/ATC providers) respecting:

- the global requirements of the air transport system and all its partners;
- the individual requirements of the particular flight.

CoO and TWs are CATS Project proposals to fulfil the SESAR airspace solutions in order to obtain a service-oriented approach under various conditions:

- managed or unmanaged airspace,
- ANSP or airspace user as flight separator,
- fixed route structure, flexible routes or no routes.

ATM planning phases must take into account the balance between the airspace resources, the airport resources and the airspace user demands. Of course, as long as safety requirements are met, the airspace user demands are the first priority in order to satisfy the economical model of the air transportation system.

Nevertheless, airport resources and runways capacities are probably the scarcest resources of the ATM management. This means that network planning and the entire ATM system should be optimised to deliver ATM services in such a way as to satisfy the airspace user demands, and fulfil the planned contracts.

Network planning is a continuous process which starts one year before CoO delivery. It uses the operational experience accumulated by the actors in the previous years. Network planning allows the CoOs to be drafted and designed following a refinement and enhancement process. As the process progresses, network planning yields an increasingly precise assessment of both the demand and the available resources. This requires two levels of decision:

- Strategic level: at this level, objectives will be defined which must be achieved by all the actors involved in defining the traffic (i.e. the initial demand) and managing resources. As the deadline for the application of this strategy approaches, it is reevaluated and the necessary refinements are introduced. In general, there is a need to refine these objectives and to ensure that they are not questioned unless strictly necessary. Objectives remain ATM system-wide. They are thus large-scale objectives (i.e. with significant granularity) which describe in a transparent manner each actor's obligations with regard to the others. In short, it is the strategic level which will allow all the interfaces between the various actors to be established in order to meet the known demand. For a given flight trajectory, the Contract of Objectives represents the final product at this level. The Contract of Objectives takes into account already-known disruptions, both exogenous (e.g. weather-related) and endogenous (e.g. linked to airport operations) that may affect the real situation in the future.

- Tactical level: at this level, the detailed means required to achieve the objectives resulting from the commonly agreed strategy will be defined and organised. But tactical operators will also provide to the strategic-level all the information relevant for the negotiations. Thus, it becomes clear that refining the strategic objectives allows for a similar mechanism to be applied at the tactical level. The establishment of a master plan for each actor at a local level will be refined in parallel to support the operational agreement.

In order to avoid any kind of blocking during the network planning process, if the CDM process does not yield the expected results, a regional decision-making body, known as the ATM Network Management Function (ATM-NMF) [6], will manage the strategic and tactical levels. This function will be the regional coordinator/decision maker to ensure that safe and effective solutions are reached which optimise the planning and operation on the European Network as a whole. The ATM-NMF will ensure that solutions are designed early enough to deliver the agreed outcomes. The ATM-NMF has the responsibility to ensure that, based on the current view, the future performance of the system will remain stable and efficient, especially when confronted with unexpected changes. The ATM-NMF will collaborate with all ATM partners in a transparent manner to ensure that a layered planning approach is achieved at regional and sub-regional or local level. Finally, it will also play a role in monitoring the smooth functioning of Network Operations Plan *ex post facto* (i.e. post-analysis) and will be able to take disciplinary action, if necessary, against actors who have not complied with the agreed Contracts of Objectives. Indeed, the planning process has to be continuously improved in order to enhance efficiency, safety, and the overall performance of the Network. In this way, a continuous post-analysis process has to be implemented to:

- analyse the performance level of network planning,
- identify difficulties, bottlenecks, and failures,
- learn from past experience, and
- propose recommendations in order to enhance efficiency.

Therefore, each actor will be able to obtain and analyse performance data for its own contribution. The post-flight analysis process will be under the responsibility of the ATM NMF.

This proposal is a concrete way of regularly monitoring the performance of air navigation services as proposed by the EU Commission through the setting of a performance framework [16].

4.2.4.2 The network planning process

The CoO and TW life cycle (presented below) describes the various planning phases needed to build the Contract of Objectives.

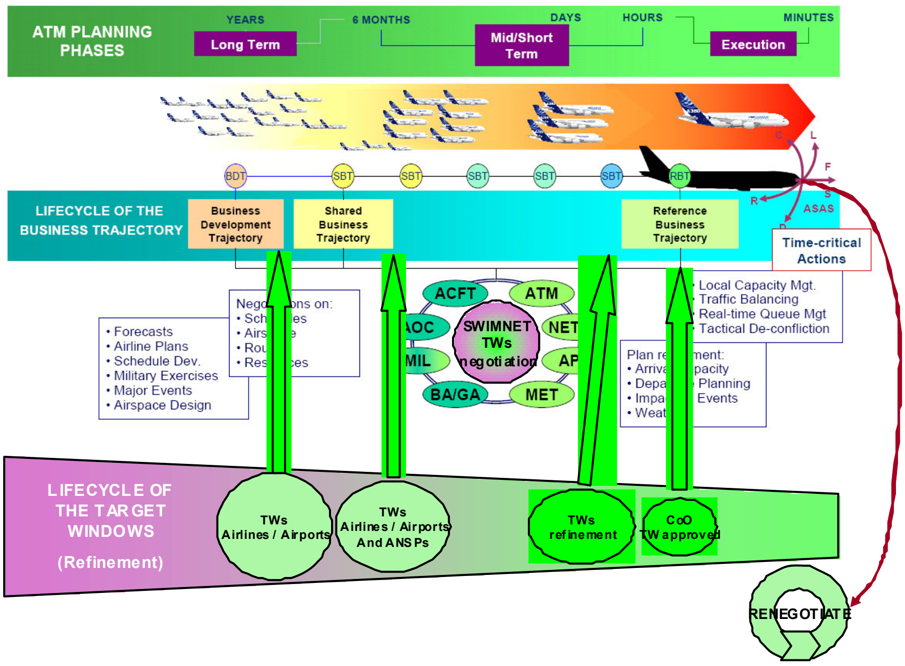


Figure 9: CoO and TW life cycle

4.2.4.2.1 Long-term planning phase (from years to six months before, according to SESAR D3 [6])

The first step of network planning is the elicitation of the airspace user demand. According to their planned schedules and the experience of the previous years regarding scheduled and unscheduled flights, a first draft of the airspace user demand is made available to all ATM partners.

In a second step, airports assess their planned runway capacity, taking into account seasonal variability, expected events, and weather tendencies. This step can be described as the airport resource planning process which proposes an initial plan for the slot coordination process. The first set of TWs, related to departure and arrival airports, are then defined.

In order to ensure safe and efficient traffic, user demands and airports resources must be well matched. If there is no mismatch between demands and resources, the initial plans are published, reviewed and accepted by all partners. If there are mismatches, a negotiation process is engaged between airports and users until satisfactory solutions are found. If an agreement cannot be found between airspace users and airports, the ATM-NMF plays its role of moderator, facilitator or decision maker. In all cases, CoO drafting is being done at regional or sub-regional level under the supervision of the ATM-NMF. The solutions are, at this level of the network Planning process, strategic.

Two basic mechanisms are used during the negotiation process in order to resolve the mismatches:

- changes to a flight schedule;
- reassessment (increase) of the proposed runway capacity by an airport. This is not, of course, a question of the maximum airport capacity, but rather of the initial assessment of the capacity proposed at the start of the process.

The entire network planning process is based on the priority assignment to meet, under safe and efficient conditions, the user demands.

This negotiation phase between airports and airspace users is required owing to the airports constraints. Runways are the most inflexible resource; it is therefore logical to take this limiting factor into account during the initial phase of the network planning process. This Business Development Trajectory is progressively enriched and refined on a bi-lateral basis by the airlines and airports, but is not yet shared by all the actors, mainly for business reasons. The transition between this phase and the second one occurs when airspace users' flight intentions are stable enough to be published to all other actors involved.

4.2.4.2.2 Medium-term planning phase (from six months to some days before, according to SESAR D3 [6])

Once the initial plan is designed, it is shared by (made available to) all ATM partners. Flight intentions are known in the form of Shared Business Trajectory and TWs related to departure and arrival airports. The ANSPs/FABs now try to adapt the airspace structure and their working methods suitable to the airspace user demands. The purpose is to avoid airspace bottlenecks, and to adjust the ANSP/FAB resources available to fit demand. The system will, however, be permanently optimised in order to satisfy demand as far as possible.

ANSPs/FABs develop their strategies on the basis of the Business Trajectory. After the negotiation phase between all the actors the Reference Business Trajectory is produced, i.e. the trajectory which the airspace user agrees to fly and the ANSP agrees to facilitate [6]. The CoO consists of a collection of TWs at each responsibility transfer between actors. The SESAR Business Trajectory (BT) goes through these TWs in order to ensure the predictability (compliance between the plan and the actual flight) and efficiency of the overall air transportation system.

During this phase, it is important to stress that the resources must match the demand. The network planning process is refined during this phase by considering two specific factors:

- the operational expertise of air navigation actors who, from their past experience, when faced with similar situations, will be able to propose by analogy a range of possible responses;
- historical air traffic data, which make it possible to estimate the range within which demand and resources will fluctuate. From this phase onwards, very general data relating to meteorological forecasts or the nature of the traffic are also taken into account.

The outcome of the medium-term planning phase is the Network Operation Plan (NOP), in which TWs are designed for each trajectory. The NOP is at a strategic level, but the tactical aspects of the operations begin to be introduced. As a consequence, network planning may already integrate a number of future disruptions if they are known in the medium term, and can therefore be incorporated into the process of refining airport, ANSP/FAB and airspace user resources. Such disruptions may include:

- meteorological phenomena;
- airport operations:
  - maintenance/repair due to an incident;
  - unavailability of staff;
- economic or political aspects:
  - inadequate predictions with regard to seat sales;
  - political instability in a country or region;
- airline operations:
  - unavailability of aircraft;
  - unavailability of staff;
- ANSP/FAB operations:
  - maintenance/repair of equipment due to an incident;
  - closure/restriction of airspace (e.g. military areas, air shows);
  - unavailability of staff;
  - external operations, such as VIP flights.

Along the network planning process, the exchange of information between all ATM partners is continuous, and the solutions, in terms of CoO and TW, are agreed by all. If an agreement cannot be found between ATM partners, the ATM-NMF [6] plays the role of moderator or decision maker. In all cases, CoO drafting is being done under the supervision of the ATM-NMF, at regional or sub-regional level. When there is a mismatch between capacity and demand, the ATM-NMF may ask for the User Driven Prioritisation Process (UDPP) [6] to be initiated. A new set of measures will then be proposed and made visible via the network planning process.

The network planning medium-term process lasts from the end of the first phase until the day of operations. During this time, the trajectories and TWs are refined, enhanced, and updated in relation to new information coming from traffic and operational conditions forecasts (airports, users, and ANSPs). The medium-term planning phase can be mapped onto the SESAR negotiation phase.

4.2.4.2.3 Short-term planning phase (from days to hours/minutes before, according to SESAR D3 [6])

This part of the ATM planning process is the last phase of process which allows network planning to deliver updated CoOs and TWs just before the flight departs. This phase allows for final refinements, enhancements and updating in the NOP according to information on the day of operations (planned or from the current operations). The main objective of this phase is the management of short-term disruptions coming from the operational environment. The aim is to optimally adapt the particular CoO to the last disruptions, because it is now costly (or even impossible, under extreme time constraints) to renegotiate system-wide changes via NOP.

This phase is at tactical level for managing airspace users' demands while considering the real traffic.

The CoOs delivered to the ATM partners are agreed by all of them. They are distributed and approved by the ATM network management function, which has the final responsibility to ensure agreement and visibility between partners. They are shared by all the involved actors through the SWIM.

The CoOs and TWs are the outcomes of the NOP. The NOP is a dynamic tool along the whole network planning process, which ensures a common view of the network situation. The NOP is a dynamic rolling plan for continuous operations (rather than a series of discrete daily plans) which draws on the latest available information being shared in the system. The NOP facilitates the processes needed to reach agreement on demand and capacity.

4.2.4.3 Execution of a flight through a Contract of Objectives

The CoO is finalised, approved and distributed just before the flight departure (15-20 minutes before off-block time, when the FMS is uploaded and pilots sign the flight documents). The signature of this contract is defined when the "Delivery of start up approval" occurs in a CDM airport, or when the departure clearance is given in case of non-CDM airport.

During flight execution, ATC clearances will be issued to authorise the aircrew to fly over the next portion of the RBT. Thus, at any given time, the RBT can be broken down into three main components/segments:

- executed: already-flown portion of the RBT (i.e. prior to the current time/current position of the aircraft);
- authorised: portion of the RBT (cleared trajectory) along which the flight crew has been cleared to proceed by the controller (i.e. the RBT part from the current aircraft position up to the end of the cleared segment(s));
- agreed: the remaining portion of the RBT beyond the end of the cleared segment that has not yet been authorised.

The RBT itself, as proposed by SESAR [6], should not be considered as a clearance, thus the progress of the flight will be managed by the pilot, following successive ATC clearances, which may include either open- or closed-loop manoeuvres requested by air traffic controllers. Nevertheless, ATC clearances are supposed to be "inside" the agreed TWs, ensuring ATC compliance with the agreed CoO.

The CoO is defined as a set of TWs, which in turn define, for each interface between actors, the estimated 4D margins of the flight in order to fulfil the TTA or the queue-management demands. The CoO is built to cope with the permanent evolution of the ATM situation. However, the CoO adaptation margins may be insufficient, and the CoO for a particular flight may itself have to evolve – be modified - during its execution. The process by which the CoO evolves is called the renegotiation process. The new renegotiated CoO becomes the new common reference to be executed on the air and ground sides. The renegotiation process is triggered by different actors/events:

- aircrew or controllers, when it becomes evident that at least one TW cannot be fulfilled;
- ground or airspace users, when new events significantly deviate from the primary foundations of the NOP.

This renegotiation process is defined in chapter 4.2.4.5.

The ANSP will issue clearances and instructions to the airspace user which either authorise the user to fly over successive segments of the RBT or cause the existing RBT to be revised. Similarly, the airspace user will follow the authorised part of the RBT and respect any constraints. If a TW is not fulfilled, the renegotiation process between ATM actors will produce a new RBT. The future segments of the old RBT will be updated with their new TWs and executed.

The flight execution to fulfil TWs and respect RBT depends on the airspace category, i.e. whether the airspace is managed or unmanaged:

- The pre-determined aircraft separator of the managed airspace is the ANSP. Consequently, the monitoring of the CoO execution is also under the responsibility of the ANSP. The role of the separator may be temporarily delegated to the aircrew with adequate onboard and ground equipment, and pre-defined rules. The ANSP's highest priority is safety; the controller monitors the traffic and ensures that the required minimum separation is maintained by issuing appropriate clearances and instructions to pilots. But the controller has also the responsibility of achieving the agreed CoO. This means that the ANSP has to manage the traffic and solve potential conflicts as usual, as well as integrating an additional goal: achieving the CoO. The ANSP's instructions to the aircrew now aim to simultaneously fulfil the CoO and to prevent or solve conflicts. As usual, all ANSP orders will be validated and must be accepted by aircrews before execution. ANSP instructions should be generally accepted by aircrews as long as they are compatible with CoO fulfilment, except in the event of any on-board event that is unknown to the ANSP. As the ANSP traffic management strategy integrates both safety and CoO fulfilment, it seems difficult to give the aircrew the responsibility for the CoO fulfilment. If the ANSP anticipates that the CoO will not be fulfilled at the next TW, it must initiate a revision of the RBT through the renegotiation process. Nevertheless, as TW objectives are visible to the pilot, the aircrew can also anticipate a deviation from the planned TW and ask the controller to act.
- The pre-determined separator of aircraft in the unmanaged airspace is the airspace user. The execution of the RBT is also the airspace user's responsibility. Safety remains the highest airspace user priority, but they are now also responsible for achieving the CoO. Airspace users have to integrate the objective of CoO fulfilment into the way they manage their own safety by respecting separation minima with other aircraft. Airspace users are then responsible for initiating an RBT revision if they anticipate that the CoO will not be fulfilled at the next TW. The process by which a new RBT segment and CoO are drawn up is the renegotiation process, as presented in chapter 4.2.4.5.
- TWs could be seen as interfaces between airspace categories for transferring responsibility between separators. The CoO allows for operational continuity to be assumed between managed and unmanaged airspace, by clearly defining and identifying who has the responsibility in terms of safety and the achievement of the CoO, and how to transfer it.
- Through the implementation of the CoO, all operational stakeholders are aware of the results of the agreed RBT and its framework application is shown in straightforward terms of time and cross-border information by the use of TWs.

4.2.4.4 Conflict management

As stated previously, the CoO will contract performances but never safety: separation and de-confliction tactical tasks with a short time horizon will basically remain the same as today. On the ground, the Executive Controller is the person in charge of flight safety, even if the flight crew (ICAO) remains the ultimate responsible entity for the safe execution of the flight. The introduction of the CoO and the TW is also expected to have some beneficial effects on conflict management. We group these anticipated benefits into two classes:

- Traffic predictability and reduced uncertainty: TWs increase the predictability of flights, since they provide more detailed information on the future evolution of current traffic, as well as on the intentions of aircraft entering the system in the near future. This information can be used by controllers and their decision-support tools to improve predictions about the future position of aircraft and to provide more accurate and timely conflict information and suggestions on how conflicts can be more effectively resolved.
- Controlled flexibility: The CoO and TWs have built-in margins for disruptions to allow some flexibility for dealing with unexpected events. During the execution of the flight, the actual position of the aircraft will normally be somewhere within the envelope defined by the TW. The extra margins between the actual aircraft position and the TW envelope can then be systematically exploited by conflict resolution algorithms to unambiguously define the limits of conflict-resolution actions which respect the CoO and TWs. Such conflict-resolution actions will have no follow-on effects on the system as long as they respect these constraints and will not affect the final performance agreed and stated in the CoO. On the contrary, any impossibility of resolution within these limits will trigger the CoO renegotiation.

In addition to specific advantages offered by the CoO and TWs in the context of conflict management, the CATS concept will of course also benefit from generic improvements in the related area foreseen under the SESAR concept. These include:

- additional sources of information (such as flight parameters or 4D trajectories predicted on-board) that will facilitate the ground-based trajectory prediction, conflict detection and resolution tasks. Such information can be made available via air-ground data-link and distributed to the relevant ground actors through the ground SWIM network;
- some new separation modes introduced in the SESAR environment, such as self-separation and 4D contracts. This will be fully compatible with CoO implementation, as the responsibility to achieve the CoO is linked with the pre-determined separator;
- a more automated situation/conformance monitoring than currently available, as envisaged by SESAR [6]. The conflict management function will have a longer look-ahead horizon than today, thanks to supporting tools such as MTCD. Some tools will offer multiple alternative solutions to solve potential conflicts. ATCOs will have the possibility of testing potential resolution strategies via "what if" tools, of determining potential impact on TWs and then triggering the CoO renegotiation process, if necessary.

4.2.4.5 Renegotiation

The SESAR concept is founded on the basis of system-wide distribution of the latest, most precise trajectory information. In the SESAR environment this data may be shared via the SWIM network for the benefit of external ATM processes. TWs, which implement the Contract of Objectives, are also advertised to all ATM users using the capabilities of the SWIM network; SWIM is nevertheless expected to be able to handle only a limited amount of data.

If a TW cannot be fulfilled by an actor during the flight execution, a revision of this TW is unavoidable. This process is called renegotiation and is performed with the other actors using SWIM network facilities. The corresponding communications services are optimised (the amount of exchanged data minimised) to avoid the saturation of the SWIM network.

The reasons, why a TW could not be reached, are manifold:

- Weather disruptions (unplanned wind)
- Airspace capacity shortfall (weather, military area…)
- Airport capacity shortfall (runway closure, de-icing, delays…)
- Change in airline priority (swap slots)
- Conflict management (as safety remains the first priority)
- Flight failure or incident (windshield crack).

A revision should be initiated but the time available to perform this revision or the impact of renegotiation processes could be different for each reason above.

To detail the renegotiation processes, we categorise them according to the kind of actor that initiates them, considering the time available to perform this revision and its possible impact.

A revision, involving the proposed change on a TW, 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 actors concerned and most importantly 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 is available through the SWIM;
- when the situation is urgent, the controllers may decide to immediately perform a local revision of the trajectory for safety and separation purposes, without using CDM.

Figure 10 below presents a generic renegotiation process description, showing the different levels of renegotiation, the left part dealing with operators (pilots and controllers) when the time is critical or the renegotiation involved only two ACCs and the pilot, the right part dealing with all actors (airlines, airports and ANSPs) to ensure the solution is not only the best for the impacted aircraft but also for the overall system.

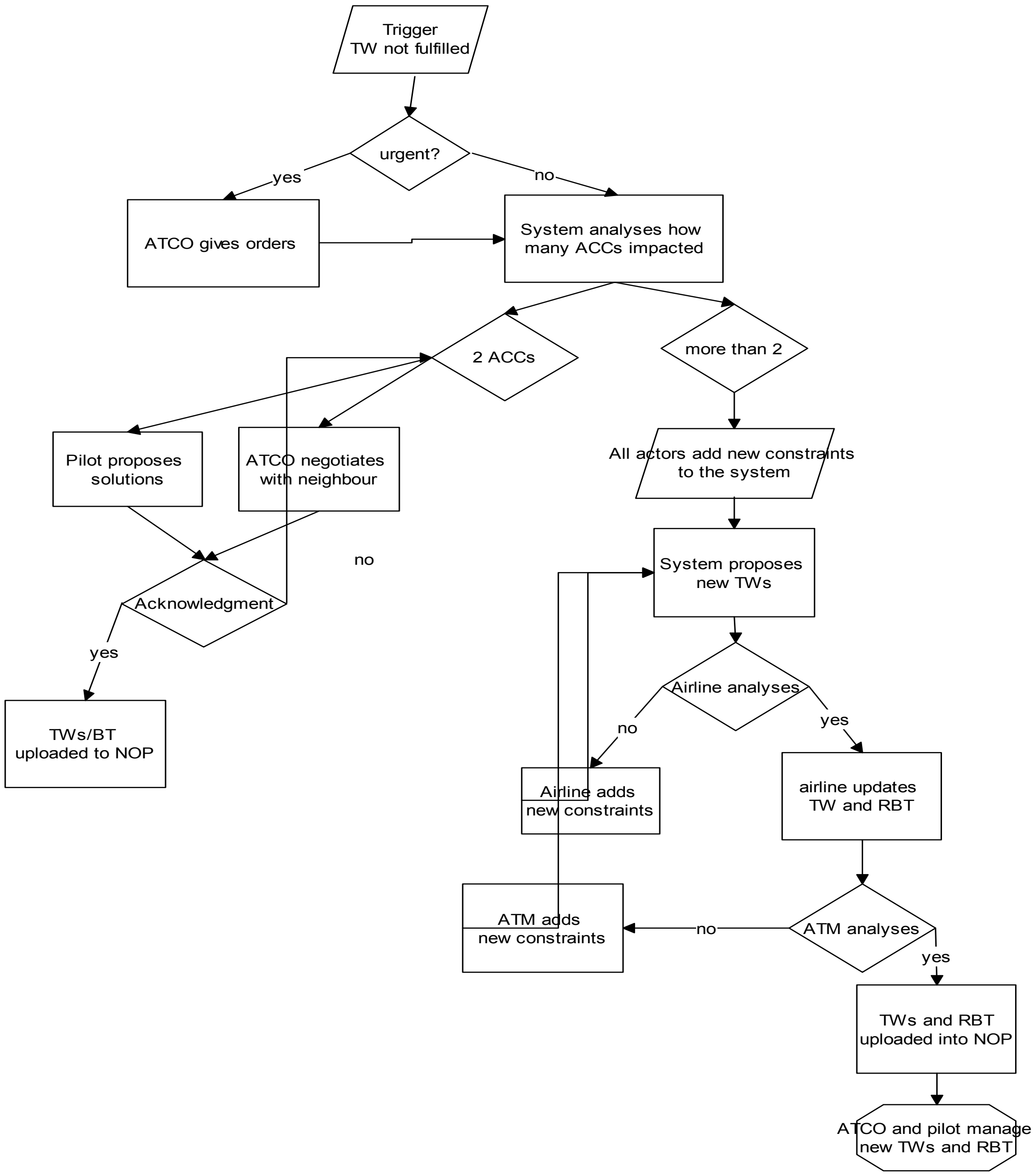


Figure 10: Renegotiation Generic Process

The level of detail of the revision process will depend on the level of urgency and the configuration of impacted users. In most cases, renegotiations will be local to several ATSUs and no CDM will be required. If the revision requires an immediate change in flight path, the process will be shortened as follows: a high priority revision will be proposed, including the authorisation to proceed - the only possible responses from the flight crew in this case will be to accept or reject. In the unlikely event of proposal rejection – the situation will be resolved by using voice communication.

Nevertheless, the renegotiation of the trajectory should benefit to the overall system efficiency and not only for the impacted aircraft. This is why CATS proposes a flexible framework where some functions are best handled by a centralised decision making process (e.g. when renegotiation impacts more than two ANSPs and also an airport), while specified responsibilities are best delegated to distributed operators for a maximum system effectiveness (e.g. renegotiation involves only two ANSPs). It is clear that the effectiveness and feasibility of a CDM process during the execution phase is a crucial point, tackled in WP2.1.3. Moreover the capability offered by a real sharing of data amongst ATM actors will allow a better anticipation of the problems, leading to the possibility of a CDM process in advance.

4.2.4.5.1 Ground-initiated revision

If the controller, supported by automation, identifies a potential conflict, its resolution may require a revision of the trajectory part beyond the current point. The selected conflict resolution should provide the best overall solution while guaranteeing the safety and simultaneously respecting the CoO. The conflict resolution process will result in a new conflict-free "proposed" trajectory beyond the actual point. But if the next TW can not be respected according to this new trajectory, coordination is performed over the SWIM network with the next actor and may need to be extended to several actors (e.g. if the next centre can not fulfil its new TW). A CDM process with the appropriate actors should be set up prior to the trajectory being proposed to the flight crew. When the proposed revision is agreed, the renegotiation process is closed and new TWs are notified to all users, through the NOP, using the SWIM network.

Airports could also initiate a renegotiation of a CoO, e.g. if runway-capacity shortfall is suddenly identified. All the CoOs addressing this destination airport would then have to be renegotiated. Airspace users will be informed through the NOP and may initiate a User-Driven Priority Process (UDPP) as described by SESAR D3 [6] and renegotiate new TWs with the destination airport. A CDM process will be set up with all impacted actors; the new CoO will be signed and then distributed to all actors via SWIM.

4.2.4.5.2 Air-initiated revision

Flight crew may also be unable to comply with the TWs during the flight. This can occur e.g. owing to weather conditions, forcing the flight to diverge from the planned TW. This can also occur to avoid a Cumulo-Nimbus (CB) or turbulence. In these cases the flight crew supported by airborne or ground airline automation will request a revised trajectory. The controller, also supported by the ATC automation, will evaluate the revision proposed by the flight crew or airborne automation and assess if it is conflict-free. There may be a need for some of the processes applicable to the ground-initiated revision (section 4.2.4.5.1) to come to an agreement on the change of the RBT and TW which will finally be published as a new agreed RBT and TWs.

4.2.4.5.3 Airspace-user-initiated revision

A request for CoO revision may also be initiated by the airspace user (rather airline or military organisation than directly the flight crew). This can be a result of an UDPP, where, for example, an airline decides to swap a slot between two of their flights at the same airport. This will also trigger a CDM process involving all appropriate actors and result in a new agreed RBT with sets of TWs. The new CoO will then be shared through the NOP, via SWIM.

4.2.4.5.4 Process

This paragraph describes the process of the renegotiation through the CDM.

The collaboration decision making refers to a set of applications aimed at improving flight operations through the increased involvement of ATM actors in the process of air traffic management [27]. The benefits of such approach have been proved by the CDM activity in USA through the Ground Delay Program Enhancement, as well as the CDM implementation in European airports [28].

The renegotiation process proposed for the CATS concept is a collective decision process, encompassing different mechanisms and steps:

- Selection of each actors' priorities and constraints
- Formulation of these constraints
- Evaluation of the proposed choices or options
- Choice or compromise between options
- Implementation of the solution.

This process involves different actors, with different objectives and this could also lead to power issues, as each actor will interact with the others regarding its own economical model, its resources, its preferences, …. and most of the times some of these data are not shared and known by the others actors.

We could describe, for example, what are the parameters for an airline to be taken into account in case of aircraft diversion. The alternate airport is chosen according to several criteria, determined by three airline's departments:

- OPS
  - Limitations: runway and taxiway strength, landing and take-off
  - Operational minimums (visibility and ceiling)
  - Field and route charts published
  - Field included in the FMS database
  - Field included in the operational flight plan calculator database
  - De-icing available
- LOGEX:
  - Airline destination station
  - Airline's partners destination station
  - Handling contract for ground operations
  - Re-routing of passengers by all ways of transportation: plane, boat, train or busses
  - Catering contract
- FUEL:
  - Refuelling contract and billing

For an airport, the main parameter will be the handling occupancy, and for the ANSP the runway capacity as well as the sectors capacity.

The goal of the renegotiation process is to be able to go from individual actors' strategies through a coherent solution, efficient for the overall system.

4.2.4.5.5 Supporting tools

Most of the current projects consider the renegotiation of trajectories during the execution phase, only between the crew and the controller. To do so, their main concerns [24] are to synchronise the trajectory predictors used in the different support tools and developed independently, in order to decrease the inconsistencies between predicted trajectories.

Through the room of manoeuvre introduced in the TWs calculation, CATS concept does not force to a harmonization of all available tools. TWs size, through its calculation, integrates the tools' uncertainty.

To support the renegotiation, the SWIM and data-link exchanges, proposed by SESAR (Figure 9) will be essential and complemented by specific tools to support the collaborative decision making process on TWs renegotiation, for example to formulate the different actors constraints, or to show them the different options.

4.2.5 Roles and responsibilities

Even if there is a paradigm shift built on a SWIM environment involving all actors, centred on a shared vision of the mission supported by Trajectory Based Operations, many of today's practices will remain in place. However, there may be a different distribution of tasks between actors.

At this stage of the study, the purpose is to maintain liability in the context of the CoO in principle with the airline. Further research carried out under WP2.2.3 should confirm this. This is also in line with SESAR, where the RBT is owned by the airline.

However, through the implementation of the CoO framework, the airline could, in the event of damages, seek recourse to others actors pursuant to a legal platform created by the CoO, allowing attribution of liability to the actor concerned though the airline in the event of non-performance. Various specific circumstances (strikes, weather disruptions, etc.) could also be specified in the CoO. More detailed explanations will be available through WP2.2.3 deliveries.

4.2.5.1 Airline Operational Centre (AOC)

The AOC is responsible for carrying out the operational schedule of the flights operated by the airline and arbitrates in the event of a major disruption related to a particular flight in order to comply with the airline's commitments to its customers as closely as possible (see also: liability for delay [21]). This is the reason why, regarding the current regulations, the airspace user remains responsible for the CoO achievement.

To achieve this, the AOC:

- coordinates the operational functions of its own various corporate departments (Scheduling, Maintenance, Flight Operations, Ground Operations, Commercial, Cargo, Upper Management, Security);
- coordinates with:
    - ANSPs and
    - Airport Operational Control Centre (APTOCC)

in order to:

- ensure compliance with safety and security regulations;
- guarantee the RTA at the gate by using all potential operational means, under its own control or under other actors' control;
- minimise the consequences of operating incidents on customers;
- minimise the economic impact of irregularities to the airline business;
- organise alternative travel arrangements for passengers and cargo, where necessary;
- handle the dispatch of spare parts and equipment under optimum conditions to external service units.

The AOC defines a schedule-adjustment strategy for the airline. It circulates operational information within and outside the company. The AOC also activates the airline's Crisis Command Centre, when necessary.

The AOC is a focal point for the negotiation and renegotiation of the CoO and respective TWs. The AOC must have all the information available to be able to agree on CoOs and TWs. It will also be responsible for communicating the impact of their CDM decisions to the flight crew.

With their flight planning system, the AOC will take into account all the data available through the SWIM to develop their Business Trajectories and publish them for sharing. The ALOOC will be in charge of analysing the consequences of changes within the ATM situation on their operations and will also be the owner of the UDPP process in the event of a capacity shortfall. In this case, it will decide, choose and prioritise flights.

4.2.5.2 Flight crew

Currently, pilots have the obligation to:

- guarantee the safety of the aircraft, as well as for the aircrew and passengers during the mission;
- execute the mission, as defined by the aircraft operator (user manuals, airline instructions);
- comply with legislation and regulations applying to aeronautical traffic, national and international legislation and operational rules in order to execute the mission.

When executing their missions, pilots must comply with the efficiency and productivity goals of the airline.

Regarding the concept of operations promoted by CATS, controller and pilot will subscribe to the same goal of achieving the RBT and respecting the CoO and TWs.

This will be enabled by:

- new tasks;
- longer look-ahead for tools;
- closed-loop clearances;
- air-ground data-link and ground and airborne automation.

Therefore, the cockpit crew has to share TW objectives as far as TW objectives are visible to the pilot.

Since the TWs are agreed, the pilot will operate the aircraft in accordance with this CoO in order to meet the TWs.

Additionally, he/she must provide the others with information about e.g. deviation from the agreed FPL, the limits of necessary adjustments during flight, observed flight or weather constraints, minor deviations (CBs, turbulence, etc.), in-flight level change, fuel-management problems, required diversion to an alternate airport due to weather conditions, medical or commercial reasons, or because of emergency landing.

4.2.5.3 Executive, planning controller

Current operations are defined by the ICAO PANS-ATM. However, variations in the working methods may occur, which are regulated according to regional/national policies.

Regarding the current operations:

- ATC service as defined by ICAO Document 4444 has as its major objective to prevent collisions between aircraft while expediting and maintaining an orderly flow of traffic; this objective will be preserved in the proposed concept of operations, even if the implementation of the CoO may represent a new challenge to ATCOs, as they should adhere to the CoO.
- En-route operations are related to the control of airborne aircraft inside a geographical portion of airspace (generally located in-between departure and arrival terminal areas) with respect to the objective stated above.
- A Sector is the part of airspace in which services will be provided and is nominally under the responsibility of, usually, two operators:
    - Executive Controller, who separates and sequences flights located within his/her sector (i.e. his/her area of responsibility) by issuing clearances and providing instructions to pilots;
    - Planning Controller, who checks the planned flight trajectory crossing the sector for potential separation risk, and coordinates entry/exit conditions in order to obtain conflict-free trajectories.
    - The controller's global task is to manage the traffic in order to avoid collisions between aircraft. This prime objective will remain the same while introducing the CoO and TW concept.
    - To fulfil his/her task, the controller must integrate the incoming flights, detect and resolve potential conflicts, monitor the solutions, coordinate with the adjacent sectors and manage the frequency, responding to crews' requests.
    - The proposed CoO approach may change some of these tasks, not fundamentally but in terms of the way they are achieved. For example, implementation of TWs increases the Planning Controller's situational awareness, while integrating the flights. This could induce some modifications in the task-sharing between Planning and Executive controllers. This task redistribution will be covered through different assessments. The Planning Controller will become a multi-sector planner in the en-route environment. He/she will be supported by various tools such as MTCD. The Executive Controller will continue to separate flights and issue some instructions to

pilots for conflict resolutions, taking into account the TWs. He/she will also facilitate flights according to TWs.

- The responsibility for separation is "ground-based" while, for managed airspace, delegation to the aircraft is exceptionally made.

For both ATCOs the introduction of the CoO should be seen as a simple way to monitor and manage the expected traffic profile - as a result of the agreed trajectory - rather than controlling the traffic. The monitoring phase of the CoO shouldn't add to the workload since it can be considered as an extension of the ATCO's current task of monitoring aircraft entry/exit points and coordinated FLs. This has been confirmed by the assessment done through HIL1 [15]. On the other hand, when an aircraft deviates from the TW, the ATCO should manage this deviation locally (reduce its impact on the rest of the trajectory) by providing i.e. a short-cut. This action might be seen as an extension of a task currently carried out by the ATCO when he/she acts to comply with an AMAN advisory. But when traffic becomes heavy or the supporting system fails, will controllers be able to provide not only a safe but also a performance-related service? This will be one of the main questions to be answered throughout the validation.

The option chosen by the CATS Consortium is mainly that Safety will remain the first priority and will never be contracted. The ATC role will still be to manage safely the traffic with the surrounding traffic, and if this is possible to take into account in his/her decision the compatibility with the next TW. This is clearly a strong point regarding the legal aspects.

But it should also be noted that representing the final objective of each flight on the operators' working position allows each operator to be aware of this objective and act accordingly. At present, for example, aircraft under CFMU slot regulation may, because of an overload in an en-route sector, be refused to take a direct route by one of the previous controllers in order to accelerate the traffic. However this will have the effect of nullifying the regulation. The need to consider the system as a whole and the consequences of their actions on the system have been one of the conclusions of the ATCOs involved in TTA studies [14].

Although the concept of the Contract of Objectives represents one avenue for developing the future ATM system, it is clearly insufficient on its own and must be envisaged within the broader framework of a volume of airspace and a set of working methods, in order to allow an assessment of the benefits it could bring. Shaping the airspace optimally and selecting the working methods will, of course, depend on which development hypotheses are selected in relation to the nature and quantity of the traffic.

Obviously, the introduction of additional operational tasks that would in turn enable the CoO would mean that operators will have to process additional information and use additional communications services. The results of the first experiment [15] showed that TWs added less constraint than imagined and this additional workload was counterbalanced by a real increase in situational awareness. Nevertheless, specific tools to enhance cooperation between the controller teams are needed. Relations with other ATM actors, in particular with aircraft, will change, and this will also require the development of tools, interfaces and the appropriate working methods.

Both flight crews and ATCOs have knowledge of TWs. Adherence with the TWs should be shared between pilots and ATCOs. The challenge is therefore to integrate this information (TWs and RBT) into the current operator's Human-Machine Interface. The global status of the flight in relation to the TWs should be displayed on operator's HMIs. The figures below present some of the display options proposed to the ATCOs during the first experiment.

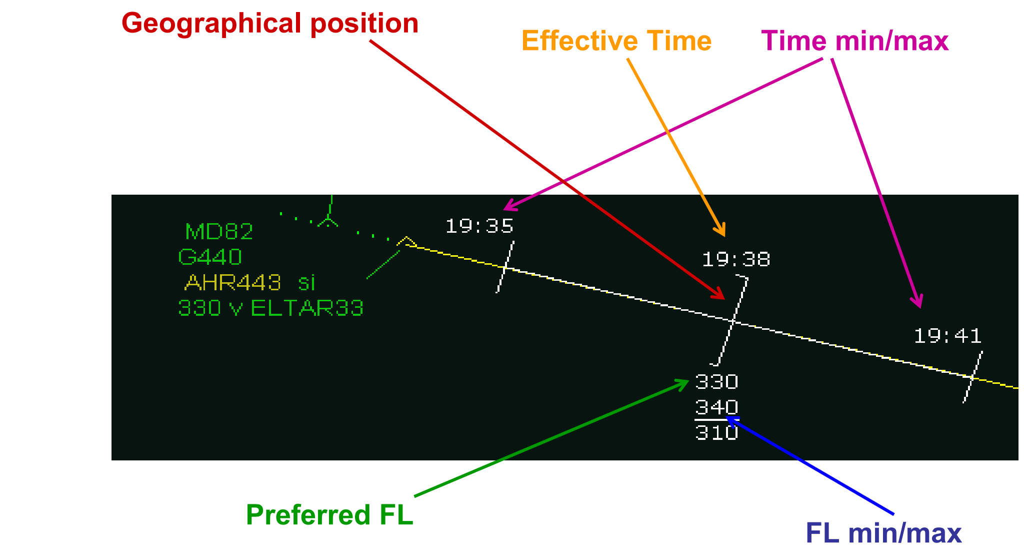


Figure 11: Proposed HMI for adjacent TWs

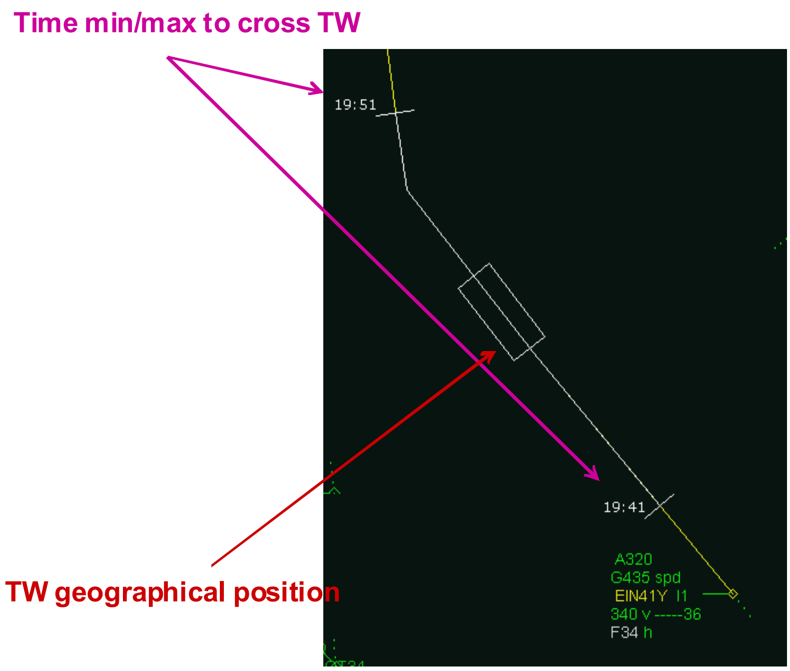


Figure 12: Proposed HMI for superimposed TWs

Additional information, specifying the exact deviation from TWs would be useful to help ATCOs perform the appropriate actions. HMI requirements will be further detailed in D2.1.4.x.

4.2.5.4 Airport operational staff

With the CoO method, the closer relationship between IATA and ICAO flight information data will become feasible. At present, IATA and ICAO flight plans are not correlated. So flights can currently depart or land without respecting the airport slot by sending the ICAO flight plan to the CFMU which then ignores the airport slot. This will no more be the case with the proposed CoO concept, where the two different flight plans will be combined into one common Contract of Objectives.

The agreed CoO should be displayed like a normal flight plan to the airport operational staff. It will be shared by all the actors. Requested but not yet agreed CoOs or CoOs outside of the agreed scope should be presented at one glance to the airport operational staff.

Requested and agreed but not yet executed CoOs should be fully charged (as if they had been executed). This is to discourage users from announcing artificial air traffic demand and to increase the effectiveness and throughput of the entire ATM system.

Airport operations are comparable with a production line in a factory. Various factors located at the air- and landside of an airport can impact (support or disturb) the whole airport production. The processes on landside directly influence the related airside productivity and vice versa.

Many different service providers are responsible for CoO preparation and/or execution. Therefore, an airport CDM network is a prerequisite to providing all airport stakeholders with all necessary information to give them a common situational awareness. Timely and accurate shared information on real-time events supports decision-making about whether and how the airport operation could reduce the gap between the planning and execution of the CoO.

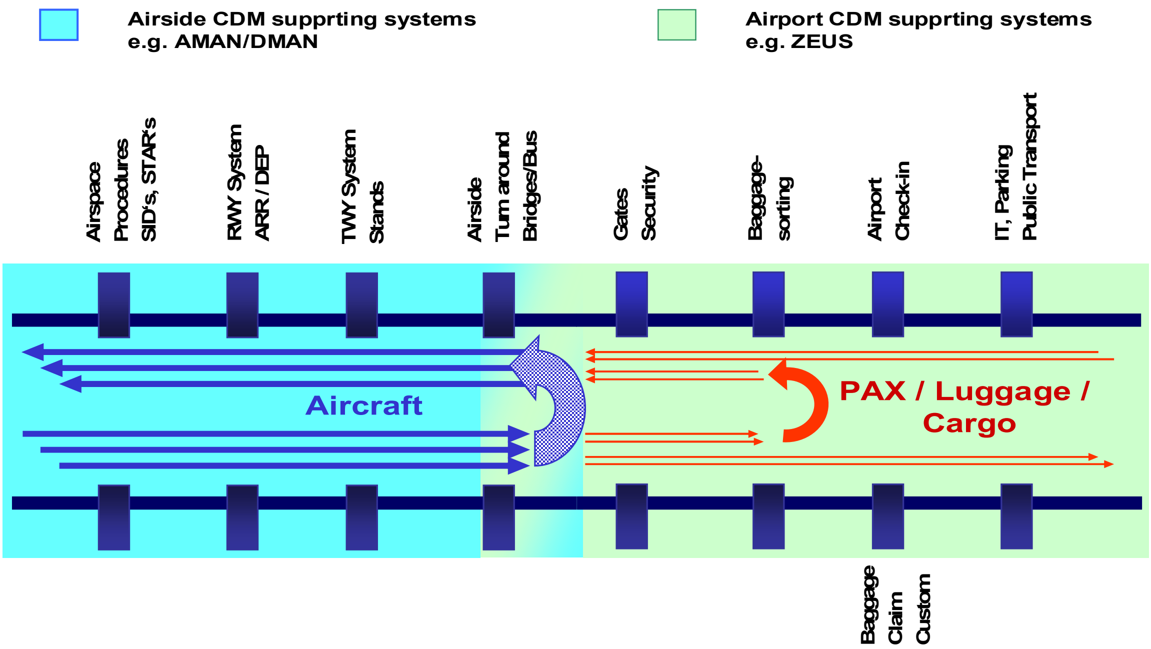


Figure 13: CDM@airport

The CDM at European airports should be implemented according the EUROCONTROL Airport CDM Implementation Manual [11].

In addition to an optimal allocation of airport resources, airline operators should provide information on the number of passengers and/or cargo per flight to the responsible service providers. These figures help to allocate the right number of personnel for security, customs, immigration, passenger and ground-handling at the airport.

Expanding airport CDM to the external ATM actors will produce benefits for all of them and will further increase the efficiency of the entire ATM system.

4.2.5.5 State and military aircraft

Defence agencies will be part of the CDM process from the early planning phases. First, with the coordination of airspace requirements for the military, training flights will be published through the NOP: the agreed reservation data, through the Flexible Use of Airspace (FUA) concept.

Beside the planned airspace utilisation, military operations also may plan their operational missions, sometimes under the Instrument Flight Rules (IFR). The flight plan constitutes the "Mission Trajectory", as advocated by SESAR [6]. For these mission trajectories, time may be crucial; timeslots over targets cannot be ignored or changed. This is the reason why the military mission trajectory should be differentiated from the Business Trajectory. Military operations must retain tactical freedom to meet their operational objectives. Except when operating as General Air Traffic (GAT), military aircraft will not be subject to flow control measures. For some specific missions, e.g. to enforce national security and deal with non-compliant aircraft, military aircraft will be given priority over civil aircraft.

The CoO could be seen as a target to reach by military aircraft when switching to GAT operations, and flying as GAT. Regarding air defence operations, which have specific airspace, planning and control requirements, the CoO is out of the scope.

A close collaboration between the Wing Operations Centre and the ANSPs will be a prerogative to creating a real civil-military system which satisfies both civil and military mission requirements.

4.2.5.6 Non EU airspace users

The CATS proposal is in line with the SESAR work program, but the need for changes is not only a European issue.

SESAR shares with NextGen [23] the same view of the future ATM system, able to improve safety, increase operations and efficiency, and better performance.

Multilateral partnerships could be developed with non EU airspace users to ensure development of procedures, allowing them best conditions for accessing to the CoO, as this is done today for transatlantic rendezvous point.

4.2.6 Expected benefits

At conceptual level, CoOs and TWs can be regarded as an operational method with which to achieve the establishment of the **ATM Performance Partnership** recommended by SESAR [5]. TWs represent the means by which all stakeholders can share a unique and objective view of each other's priorities, thus ensuring a common translation and representation of the performance targets to be achieved by the overall ATM chain.

On a second, more operational, level TWs clearly identify the transfer of responsibility areas between partners and at the same time provide a method for managing uncertainties and monitoring disruptions. Measuring the degree of compliance of the actual trajectory with the TWs established during the negotiation process can represent a new and reliable metric to be used for assessing the quality of the provided ATM service. The CoO could be seen as the operational method and legal platform to establish the monitoring of performances as advocated by SES II [16], and the ensuing liabilities.

The CATS Project represents one possible solution to another issue highlighted in SESAR D2 [5], namely the necessity of determining "*how to deal with business trajectories in the strategic, tactical and operational phases of flight*". The CoO is a possible way of implementing the Business Trajectory, the notion around which the future ATM system would be designed.

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

- More punctuality at destination (arrival-on-time concept): The CoO concept proposed in the CATS Project is designed to achieve an ultimate goal: arrival on time at the destination airport. Through the CoO, aircrew, controllers and airports share the same goal for the flight on the basis of an agreed contract. The synergy between the air and ground components is thus re-enforced.
  - Airlines will reduce delay-related costs and optimise their aircraft turn-arounds.
  - Airports will be able to optimise their ground operations.

- Even though the efficiency design target identified by SESAR is on the on-time departure, a very strong correlation between punctuality at departure and at destination clearly exists that would be interesting to evaluate during the assessment process.

- Optimisation of scarce resources: During the design/drafting of the CoO, through the NOP, the actors' constraints will be taken into account in the collaborative process.
  - Airlines will indicate their economical and technical constraints (i.e. Business Trajectories) during the negotiation and so indicate their constraints in the trade-off process. This will allow the airlines and the other actors to respond appropriately to the initial demand in line with their constraints.
  - Airports will be able to optimise runway use (through better scheduling) and thus improve throughput. Furthermore, their constraints will be integrated into the early stage of the collaborative process.
  - ANSPs/FABs will be able to optimise their resources, since they will be responsible both for their local airspace design and for working methods in fulfilling the contracts previously agreed with other actors. Furthermore, during the drafting process for the CoO, they will be involved at an early stage and will 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 the 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 with regard to the ultimate target of the CoO, namely "arrival on time at destination". Each actor knows its part of the contract: the TWs they have to commonly achieve.
  - Airlines will be able to rely on their schedules, as predictability will be improved, and they should thus get a better pay-off from their fleet (more seat-miles).
  - 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/FABs will have ensured consistent airspace design and provided 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 destination).
  - In line with SESAR requirements, variability of flight duration will be bound to minimum levels and service disruptions will be promptly managed and resolved 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 the 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 closely as possible to their Business Trajectories, and will therefore 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 provide the right manpower resources for service provision, which will in turn 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 adapt the size of their teams so as to improve efficiency.
    - The cost-effectiveness of the system deserves deep investigation to ensure that a cost improvement is achieved via this concept. A proper incentive mechanism will be developed to allow any possible gap between costs and benefits for the virtuous stakeholders to be properly filled.
- <u>Reduced environmental impact</u>: Like cost reductions, environmental benefits are mostly linked to the better use of resources and improved predictability.
    - Airlines will state their preferred routes based on economic business models, and thus minimise fuel consumption and optimise the "seat/fuel consumption" ratio.
    - Airports will be able to improve ground operations (through improved predictability). This will reduce standby time on taxiways, which will in turn lead to a decrease in pollutant emissions at airports. Airports' environmental constraints will be integrated in the CoO definition and the Business Trajectories.
    - The atmospheric impact of each flight will be noticeably reduced owing to the improved predictability and optimisation of the operations both on-ground and en-route, in compliance with the legal and sustainability frameworks in place at the time of implementation, as required by SESAR.

It is important to highlight that the ambitious performance targets set by SESAR [5] will be reached by the future ATM system only if a series of different new concepts, enabled by new technologies and working methods, are implemented in the coming years according to the SESAR deployment sequence. CoOs and TWs must be regarded as just one operational support tool to be used for negotiating, managing and monitoring the execution of the Business Trajectory. They will help to achieve, but will not constitute alone, the SESAR Target Concept. The Validation Strategy and Plan [22] will describe more precisely the KPA and Indicators chosen to assess CATS benefits.

The economic impact of the CoO on the various stakeholders may vary depending on the type of contract established among them. For instance, reward and/or penalty schemes for meeting or not meeting the contract must be assessed. Other options include the possibility for an actor to "pay more" to be granted larger flexibility, i.e., larger TWs. The development of performance-based contracts is already usual practice in some domains of the air transportation supply chain, namely, between airlines and handling companies at the airports.

Specific opportunities to provide economic regulation in ATM are addressed by EC Regulation No. 1794/2006 laying down a common charging scheme for air navigation services. Among the several features introduced by this regulation, there is the first opening to incentive schemes based on en-route charges: "Member States may establish or approve incentive schemes consisting of financial advantages or disadvantages applied on a non-discriminatory and transparent basis […] resulting in a different calculation of charges […] When a Member State decides to apply an incentive scheme […] in respect of users of air navigation services, it shall, […], modulate charges incurred by them in order to reflect efforts made by these users to optimise the use of air navigation services, to reduce the overall costs of these services and to increase their efficiency, in particular by decreasing charges according to airborne equipment that increases capacity or to offsetting the inconvenience of choosing less congested routings."

This new distinctive feature provides an operational instrument to ANSPs/FABs to deal with the congestion problem they face on a daily basis and a tool with which to potentially "shift" flights to less congested routes, thus leading to further benefits for the remaining traffic. Hence, TWs may be established not only to minimise, say, airline costs, but also to promote the efficiency of the entire ATM system (see also 4.2.7).

European Commission Regulation (EC) No. 1794/2006 proposes (as is already the case with airports) a common charges scheme for air navigation services. As one possible way to implement such as scheme, the EU Commission might consider basing the routes-charges scheme on the performance monitoring achieved through the TW fulfilment. This could also take the form of a reward-and-penalty scheme.

Other economic aspects of the CoO may be linked with CDM protocols identified in SESAR as key enablers for future ATM improvements. In this context, TWs trading schemes can also be envisaged.

4.2.7 Liability and accountability

As highlighted by SESAR [4], aviation is a valuable aspect of the European economy. This report recommended that airspace users, airports and ANSPs create a more explicit set of relationships that specifies the services, requirements and obligations which need to exist between them so that they become integrated "partners" in the future ATM System.

The Contract of Objectives is a common commitment of all actors of air transport. The CoO is the result of a collaborative process involving all the actors and integrating relevant constraints to assume the foreseen traffic. Each of these actors then has the responsibility to mobilise the relevant resources and establish the adequate organisation to execute and fulfil the CoO. The means by which each actor reaches the desired results are represented by the TWs. TWs integrate negotiated and agreed room for manoeuvres/local adjustments of actors, sized according to the local organisation that manages the traffic. As the actors are involved with the organisation of the traffic, they implicitly accept to be responsible/accountable for CoO achievement.

Of course, the accountability is assessed in the scope of normal operations and identifiable resources during the elaboration phase of Contracts of Objectives. If a TW cannot be fulfilled by an actor, a post-analysis process will determine the causes in order to on one hand define the responsibilities and on the other hand, improve the Contract of Objectives elaboration process. This post-flight analysis will be performed to measure the achieved performance against the objective in order to improve overall network performance. This could also allow the monitoring of ATM actors, as described in [16]. The roles of the actors are clearly defined (4.2.5). The notion of accountability ensures then that all actors will play the game and the execution phase will stick with planning.

Liability and accountability, proposed by CATS, relate to compliance with the Contract of Objectives. These issues are linked to the commercial aspect of the contract, considering the balance between gain and service in relation to the legal implications for the actors. The word accountability is not linked, as proposed by [10], to the concepts of safety or legal responsibility, e.g. who takes what decision and then, and who is responsible in the event of an accident. CoOs have no impact on responsibility relative to the safety aspects between pilots and controllers defined by ICAO. Separation tasks (carried out by the pilot or controller) and the related safety rules are not affected by the CoO. Flight safety will remain the first priority of pilots and controllers.

Liability and accountability are linked in terms of the legal, economic and operational field.

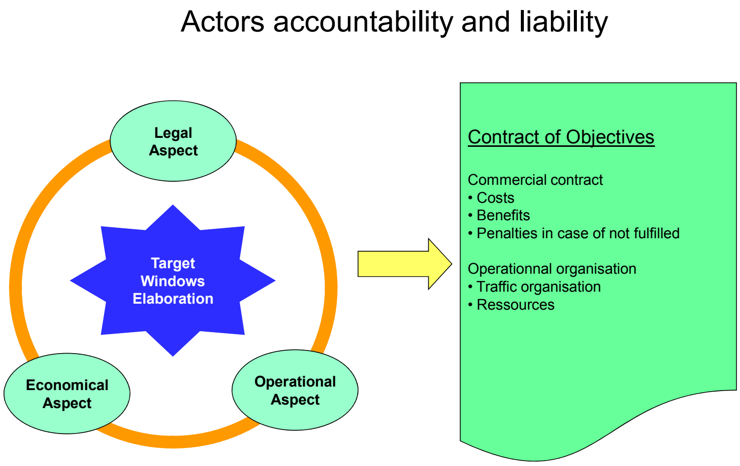


Figure 14: Actors' accountability and liability

Liability and accountability are linked to the different economical model put in place by each actor to assume the ATM service. Concerning the air phase of the flights, route charges are one of the major elements to consider as financial resources to assume the en-route service. To build a viable ATM economic system, all economic actor models have to be connected in order to manage internally the impact of the services they provide to one another. These connections are made by the TW of the CoO.

Particular attention will be paid to these topics in CATS WP2.2.2 and WP2.2.3.

5 SESAR concept addressed in this document

This chapter presents the high-level operational principles of the SESAR Programme, related to the CATS improvements. Some of the SESAR Operational Improvements (OIs) will form the basis of the work of CATS assessment activities.

The European Commission proposed to modernise the current ATM structure [12] in order to cope with anticipated traffic growth in a safe and sustainable manner, dealing with performance and environmental challenges. As explained previously, the CoO framework could be an operational solution allowing air navigation performance to be monitored [16].

The technological evolution of current ATM will be supported by the SESAR Programme. The SESAR approach refers to different frameworks:

- The performance framework, composed of 11 Key Performances Areas which need to be validated (6)
- The business framework, focusing on the Business Trajectory (4.2.2)
- The regulatory framework, supporting the changes in role and responsibility (4.2.7)

5.1 Scope of the concept of operations

The execution of an individual flight can be expressed in distinctive events (segments) from push-back from the gate to the arrival at the gate, which includes taxiing, take-off, climb, en-route, descent and taxiing to the gate. The scope of the SESAR CONOPS [6] also considers the flight-planning phases and post-flight activities (i.e. gate-to-gate).

The operational performance targets for an individual flight are expressed as gate-to-gate parameters. While this includes the runway, taxiway and gate assignment planning and operations, it does not include the turnaround ground-handling process at the airport.

CATS' concept of operations will in its description also consider the same gate-to-gate approach, however the assessment of the Contract of Objectives will only focus on the en-route phase of the flight, as defined in [25]. Nevertheless, the CATS concept of operations will also include in its description the ground turn-around, through the airports' TWs.

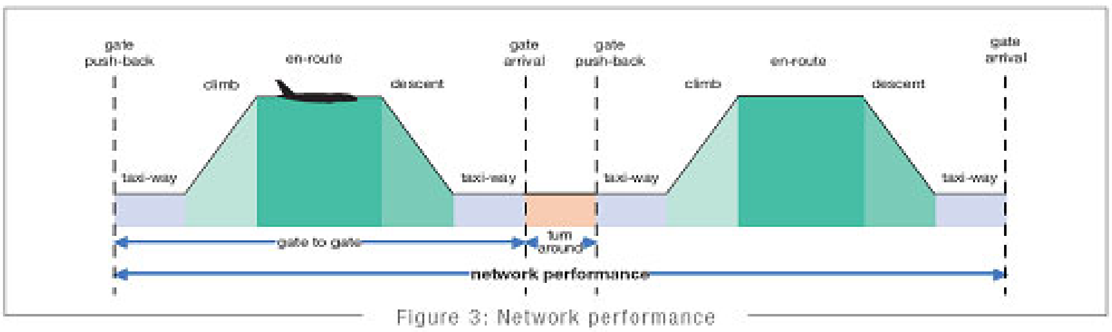


Figure 15: SESAR network performance

The CATS concept covers the complete ATM Life Cycle, from long term planning through flight execution, as well as post flight analysis, if we consider the CoO achievement analysis could be a way to improve the CoO process and also to monitor the ATM actors' performance.

5.2 New services delivered to airspace users

SESAR's stakeholders agree that, in order to strengthen the air transport value chain, airspace user requirements need to be better accommodated. To this end, each single flight will be executed as close as possible to the intention of its owner. This is the main driving principle for the SESAR Concept, which is centred on the characteristic of the Business Trajectory representing an airspace user's intention with respect to a given flight. The air traffic management services necessary to execute this trajectory will ensure that it is carried out safely and in a cost-efficient manner within the current infrastructural and environmental constraints. This is a new vision of the services to be delivered to airspace users.

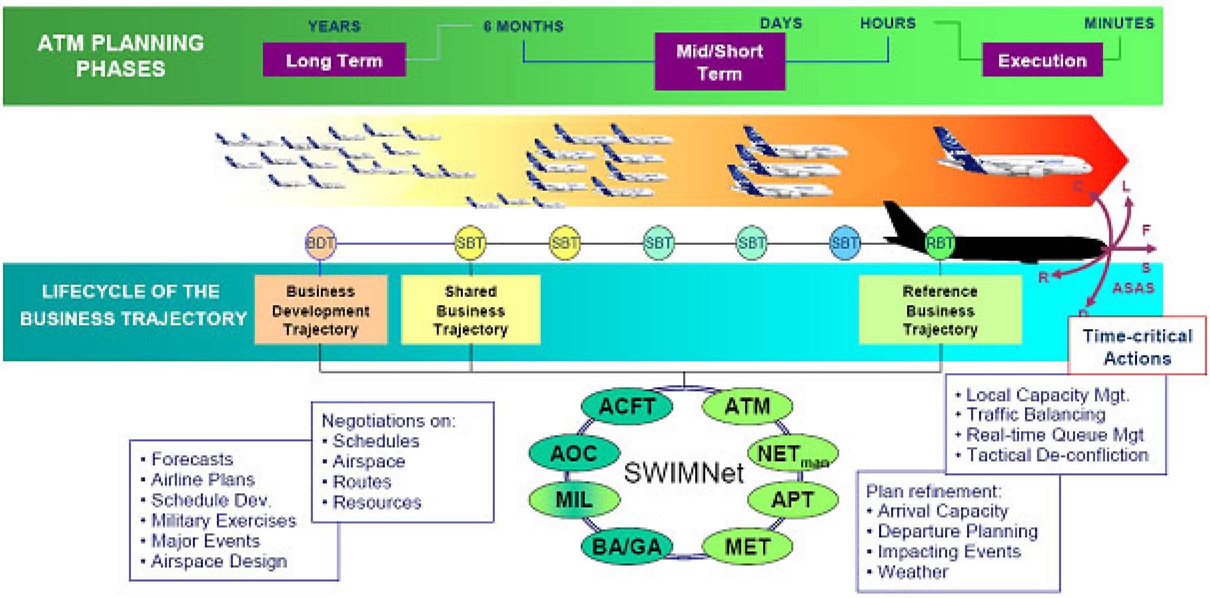


Figure 16: Business Trajectory Life cycle promoted by SESAR

The CATS Project is fully in line with the SESAR approach of collaborative refinement of Business Trajectories, as described in D3 [6]. CoOs could be seen as a possible solution to implementing the Business Trajectory.

As the TWs are the results of a negotiation process among stakeholders not only in the different planning phases but also in the execution phase in case of renegotiation, the CoO implementation will answer to the SESAR requirement of improvement of equity, by ensuring that more options are available that the first-come-first-served.

It should be noted that CATS assessments refer only to the execution of the flight, even if the CATS concept includes more, e.g. negotiation of the contracts during the planning phase. One of the assumptions of the CATS assessment is that CoOs are designed through a collaborative process, like the NOP described in chapter 4.2.4.1. The assessment foreseen in the CATS WP2.1 will therefore focus on the execution of the flight within the CoO.

5.3 Related SESAR Operational Improvements

As the European ATS is operating close to its limits and is facing traffic growth, the SESAR CONOPS [6] proposes a paradigm shift.

To achieve the capacity targets promoted by the D2 [5], this paradigm shift will be supported by:

- Business Trajectory management (trajectory-based concept);
- new separation modes;
- wide availability of controller support tools;
- collaborative planning and network management;
- improvement of airport processes.

The CATS Project does not consider all these categories of changes, but will focus on the trajectory-based concept, even if some improvements proposed by SESAR, such as SWIM, could be seen as enablers.

In SESAR, the transition from the current system to the targeted ATM concept is structured around a sequence of implementation packages, associated with operational areas, Lines of Changes. And for each Line of Change, Operational Improvements (OI) are described and contribute individually to the performance target.

Operational Improvements (OI) proposed by SESAR [7] represent major stages for the operational concept deployment. The following table captures the SESAR OIs that are potentially relevant to the work of CATS assessment activities.

Operational Concept Step	Description
L05-01 Management & revision of RBT	
Successive authorisation of Reference Business Trajectory(RBT) segments using data-link [AUO-0302]	Controllers' clearances are sent to the pilot by data-link for the successive segments of the Reference Business/Mission Trajectory (RBT) throughout the flight (this includes taxi route in case of surface operations). Pilot requests to the controller for start-up, push-back, taxi, take-off clearances, etc. are also transmitted by data-link.
Revision of Reference Business Trajectory (RBT) using data-link [AUO-0303]	The pilot is automatically notified by data-link of trajectory change proposals (route including taxi route, altitude, time and associated performance requirements as needed) resulting from ATM constraints arising from, for example, ad hoc airspace restrictions or the closing of a runway. ATM constraints may also be expressed in terms of requests such as RTA in support of AMAN operation or runway exit in support of BTV operation. On the other hand, the controller is notified by data-link of aircraft preferences in terms of STAR, ETA, ETA min/max, runway exit, etc.
L07-01 Arrival traffic synchronisation	
Controlled Time of Arrival (CTA)	The CTA (Controlled Time of Arrival) is an ATM-imposed

Operational Concept Step	Description
through use of data-link [TS-0103]	time constraint on a defined merging point associated with an arrival runway. The CTA (which includes wake-vortex optimisation) is calculated after the flight is airborne and published to the relevant controllers, arrival airport systems, user systems and the pilot. All partners in the system work towards achieving the CTA.
Multiple Controlled times of Over-fly (CTOs) through use of data-link [TS-0106]	The CTOs (Controlled Times of Over-fly) are ATM-imposed time constraints set on successive defined merging points for queue-management purposes. The CTOs are computed by the ground actors on the basis of the estimated times provided by the airspace user (airline operation centre or flight crew). They have to be met by the aircraft with the required performance.

Table 1: Operational Improvements addressed by CATS

OI Step	Description
L05-03 Enlarging ATC planning	
Sector team operations adapted to new roles for Tactical and Planning Controllers [CM-0301]	Depending on local needs, new operating procedures are in place such as the Planning Controller providing support to a number of Tactical Controllers operating in different adjacent sectors. In this configuration, the Planning Controller filters predicted conflicts with a focus on conflict-free trajectories to alleviate or smooth the tactical workload of the Tactical Controllers, thus ensuring that potentially critical traffic situations and the associated workload are manageable for the TCs at the time of occurrence.
L02-09 Increasing flexibility of airspace configuration	
Transfer of area of responsibility for trajectory management [SDM-0202]	Improved interoperability allows areas of responsibility to be transferred between ATSUs according to demand identified through the publication of the RBT.
L05-04 Moving to coordination-free environment	
Coordination-free transfer of control through use of shared trajectory [CM-0402]	A single version of the current aircraft clearance and its RBT is simultaneously available in all sectors. The aircraft's current trajectory when down-linked permits the each receiving ATCO to identify any inconsistencies between the expected (as per flight plan) aircraft performance and its actual performance.

Table 2: Operational Improvements potentially addressed by CATS

Regarding these OIs, the assessment foreseen during the CATS Project [2] will mainly evaluate the impact of the execution of a RBT (L05-01), while measuring the potential effects of the arrival traffic synchronisation (L07-01).

The L05-01 will be supported by the three HIL experiments, validating some human-machine interfaces to represent the BT (on-board and on-ground side), assessing the workload of the operators, evaluating the need of supporting tools and alerts.

The L07-01 will be also supported by the three HIL experiments, assessing the location of CTA and CTO, tools to present CTO on board, work-sharing between ATCOs and crews. The work done in WP2.2.1 and WP2.2.4 will also provide significant information regarding time tolerance and CTO computations. In this context, CATS is an approach to assess whether it is possible for an en-route controller and a pilot to observe the Contract of Objectives, or in other words, to evaluate the achievement of Business Trajectories with CTO and/or TTA, as requested by the SESAR Programme.

The three HILs will also study the cooperation between ATCOs and the potential change in role between a team (L05-03).

The transfer of responsibility, through defined and agreed TWs will improve interoperability while making it more dynamic. This will also allow a good transition towards a coordination-free environment (L05-04).

In other words, regarding the ATM Operational Concept Components, CATS concept description will refer to the Trajectory Management when the operational assessments will focus on traffic synchronisation [25].

5.4 Related SESAR Concept Story Board

The SESAR definition phase gave us the key concept thread for the future: the business trajectory management. To achieve its deployment, SESAR proposes through the Concept Story Board [20], an incremental approach, based on three steps, also called service levels:

- Time-based operation (Step 1)
- Trajectory-based operation (Step 2)
- Performance based operation (Step 3)

The core of these services levels will be ATM Operational Services, as described Figure 17.

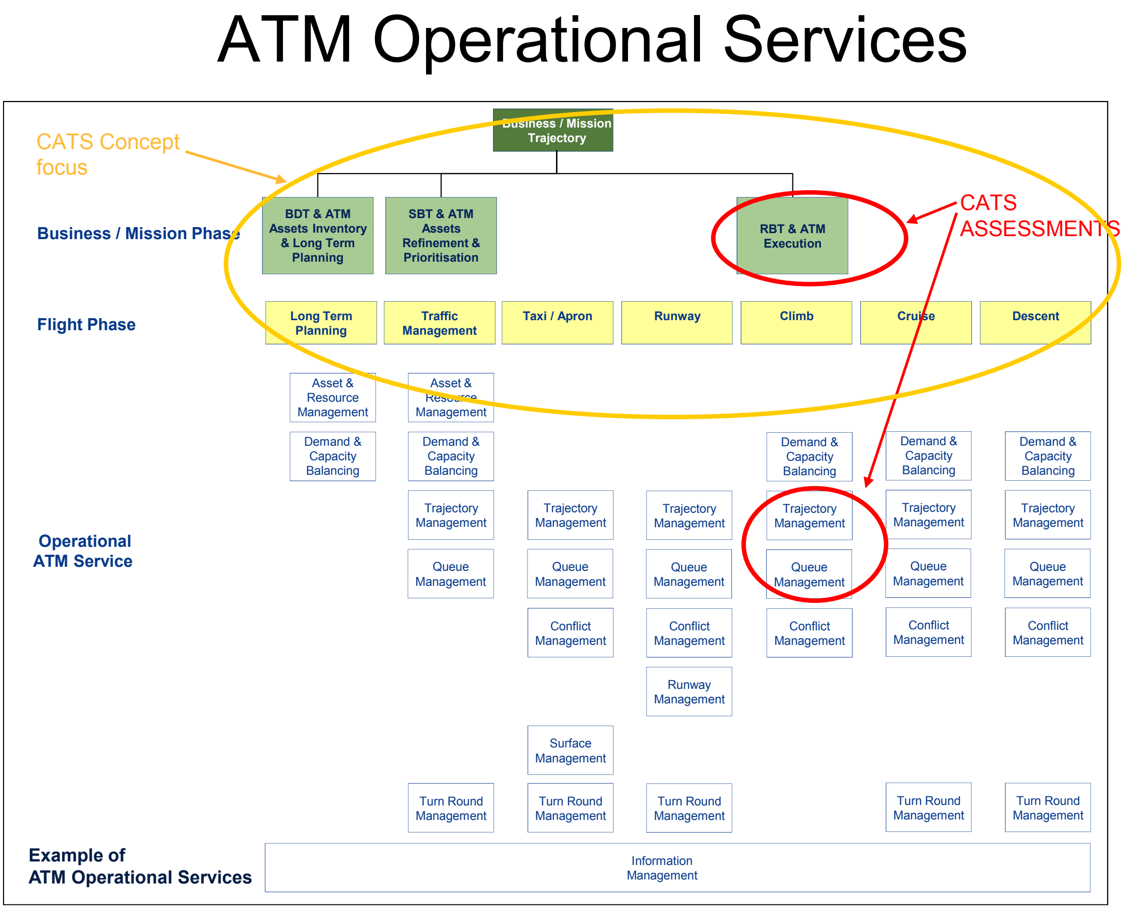


Figure 17: CATS assessment focus regarding the ATM Operational Services

Regarding the Operational Improvements (5.3) and the SESAR Story Board [20], the CATS assessments, as shown

Figure 17, will mainly address the Trajectory management and the Queue management, part of the Operational ATM Services, and will particularly address the following operational concept steps:

Operational Concept Step	Evaluated by CATS WP	Comments
Step 0 - Baseline		
Voice Controller-Pilot Communications (En Route) Complemented by Data Link[AUO-0301]	WP2.1.2	HIL2 intents to see what kind of communication is needed between ATCO and Crew when dealing with CoO, in order to draw some recommendations for messages, if possible. Not only the procedural enablers will be tackled during the

Operational Concept Step	Evaluated by CATS WP	Comments
		experiment but also the human enablers, to verify acceptability of proposed procedures.
Sector Team Operations Adapted to New Roles for Tactical and Planning Controllers [CM-0301]	WP2.2.4 WP2.1.1 & WP2.1.2 WP2.2.3 WP2.2.1	The CTA and AMAN horizon constraint are integrated in CATS by the TWs calculation. All ATM actors work towards achieving these TWs, which represent the negotiated objectives resulting from downstream constraints, such as punctuality, runway capacity, congested en-route areas or aircraft performances. Specific attention will be paid to human enablers, in order to see if the concept is feasible and acceptable, as well as procedure, to identify responsibilities in issuing TWs. Liability around the CoO and achievement of TWs will be studied regarding the current and foreseen institutional enablers, as well as Safety issues will be tackled.
Step1 - Time based Operations		
Controlled Time of Arrival (CTA) through use of datalink [TS-0103]	WP2.2.4 WP2.1.1 & WP2.1.2 WP2.2.3 WP2.2.1	The CTA and AMAN horizon constraint are integrated in CATS by the TWs calculation. All ATM actors work towards achieving these TWs, which represent the negotiated objectives resulting from downstream constraints, such as punctuality, runway capacity, congested en-route areas or aircraft performances. Specific attention will be paid to human enablers, in order to see if the concept is feasible and acceptable, as well as procedure, to identify responsibilities in issuing TWs. Liability around the CoO and achievement of TWs will be studied regarding the current and foreseen institutional enablers, as well as Safety issues will be tackled.

Operational Concept Step	Evaluated by CATS WP	Comments
Step 2 –Trajectory Based Operations		
Successive Authorization of Reference Business Trajectory(RBT) Segments using Data link [AUO-0302]	WP2.1.1 WP2.1.2 & WP2.1.3 WP2.1.2 & WP2.1.3	ATC procedures to follow BT and TWs have been tested during HIL1 experiment, validating some human-machine interfaces to represent the BT (on ground side), assessing the workload of the operators, evaluating the need of supporting tools and alerts. Human enablers such as acceptability of the concept have been tackled. Controller's normal clearances are sent to the crew for the successive segments of the Reference Business Trajectory (RBT) along the flight progress. Human-machine interfaces (on ground and air side) will be tested. Not only the procedural enablers will be tackled during the experiment but also the human enablers, to verify acceptability of proposed procedures. The controller will be able to see aircraft preferences in terms of top of descend or climb, downlink by datalink.
Revision of Reference Business Trajectory (RBT) using Data link [AUO-0303]	WP2.1.3 WP2.2.3	In case of renegotiation of the CoO, the pilot could be notified by datalink of the new CoO (new trajectory + TWs). On the other hand, the controller will be able to see aircraft preferences in terms of top of descend or climb, downlink by datalink. Specific CDM procedures will be evaluated at actors' level (airport, airline and ANSP). Institutional investigations will be performed to see the potential changes in regulation and the liability issues.
Coordination-free Transfer of Control through use of Shared Trajectory [CM-	WP2.1.1 & WP2.1.2	The transfer of responsibility, through defined and agreed TWs will improve interoperability while making it more dynamic.

Operational Concept Step	Evaluated by CATS WP	Comments
0402]		BT and TWs are available to all actors and allows the validation of proposed transfer without specific coordination, or only in non-nominal situation. Some of these non nominal situations (non fulfilment of TWs due to a Cb) have been tested during HIL1. Specific attention will be paid for procedures in HIL2, also regarding if the crew is able to monitor the fulfilment of TWs.
Multiple Controlled times of Over-fly (CTOs) through use of data link [TS-0106]	WP2.2.4 WP2.1.1 & WP2.1.2 WP2.2.3 WP2.2.1	The CTOs (Controlled Times of Over-fly) are ATM imposed time constraints set on successive defined merging points for queue management purposes. For CATS concept, these CTOs are integrated by the TWs calculation, when the ground actors computed their constraints. It should be noted that in TWs not only time could represent the constraints, but really a 4D envelop. Procedural enablers, such as HMI for ATCO or Cockpit display will be tackled. Liability around the CoO and achievement of TWs will be studied regarding the current and foreseen institutional enablers. Time tolerance will also be evaluated, with regard on safety.
Step 3 – Performance based operations		
Transfer of area of responsibility for trajectory management [SDM-0202]	WP2.1.1 & WP2.1.2	The TWs, negotiated and known by all actors, located at the transfer of responsibilities between ATSUs, improved the flexibility of this transfer of responsibility, allowing different control procedures without any impact on adjacent units. This TW is unique for each aircraft and not located at a

Operational Concept Step	Evaluated by CATS WP	Comments
		specific transfer beacon.

Table 3: SESAR operational concept steps and how CATS fits in

The development of the CATS concept of operations follows the main points of the SESAR concept story board, as it is based on performance, focused on the business trajectory and followed an incremental approach.

The CoO framework, through the fulfilment of TWs, will also propose to the European Commission a way to monitor air navigation services performance [16].

Finally, as the aviation world is changing rapidly, the CoO concept proposes a system not focused on a single business model, or one technical improvement, but a real framework able to support the future key developments and considerations.

6 Targeted ATM performance requirements

As described in [5], the SESAR vision proposes a performance-based ATM system, based on agreed targets. The different aspects of ATM performance defined by SESAR are represented through 11 Key Performance Areas (KPA). These KPA are interdependent and will be the basis of project assessment.

6.1 Key Performance Areas (KPA)

The CATS Project re-uses the KPA framework defined by SESAR D2 [5] based on the 11 KPAs identified by ICAO. The KPA framework is the basis for all the validation within the CATS Project. It is worth noting that CATS assessment is focused on the en-route airspace.

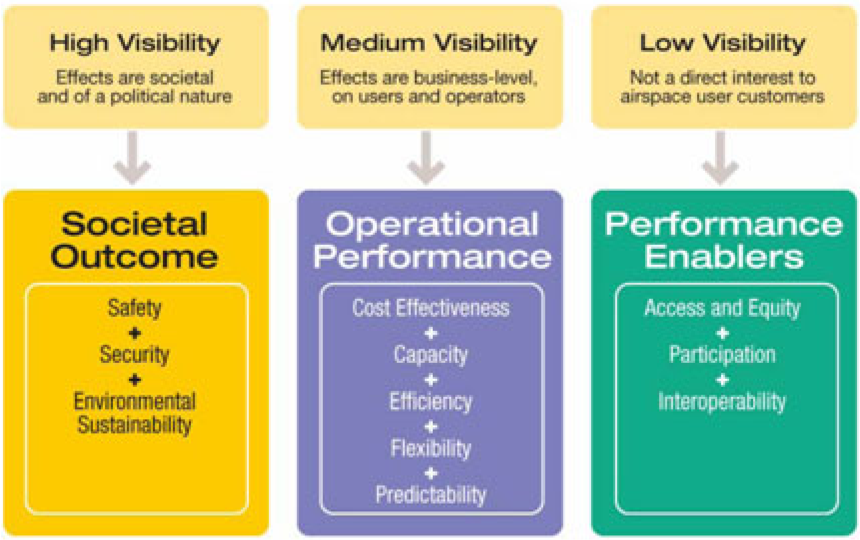


Figure 18: SESAR KPAs

Significant gains are anticipated by the implementation of the CoO (see Table 4). But as explained in section 5.3, the CATS assessments will mainly focus on the impact of the CoO and TWs through the trajectory-based operations. Consequently, the CATS assessments will measure the contribution of the CoO and associated TWs to achieving parts of the SESAR KPAs, even if not all the SESAR components are applicable.

The following table lists the KPAs and presents the potential impact of implementation of CoOs and TWs on them.

	Expectation	Focus Area	*SESAR Description*[1] and application to CATS
Societal	**Safety**	ATM-related safety outcome	*The number of ATM-induced accidents and serious or risk-bearing incidents should not increase and, where possible, should decrease, as a result of the introduction of SESAR concepts. In order to maintain a constant accident rate the overall safety level would have to improve by a factor of x3 in order to meet the safety objective of traffic levels in 2020.* **TW**s and **CoOs** reduce uncertainty about the intents and future actions of aircraft, allowing better traffic delivery to next unit. This facilitates the deployment and increases the efficiency of advanced trajectory prediction, conflict detection and conflict resolution support tools. TWs calculation allows a pre smoothing of traffic, smoothing ATCOs' workload. **TW**s have built-in disruption margins. It is thus possible to unequivocally define the limits of controller action that will minimise (or eliminate) impact on the Business Trajectory. Safety situations which cannot be resolved within these limits flag cases when ground-initiated revision will be necessary.
	Environmental Sustainability	• Environment constraint management • Best ATM practice in environmental management • Compliance with environmental rules • Atmospheric impact • Noise impact	*The ATM system should contribute to the protection of the environment by considering noise, gaseous emissions, and other environmental issues in the implementation and operation of the global ATM system.* Environmental sustainability is closely related to efficiency. Non-optimal operations and several constraints should be avoided through the application of **TW**s, in compliance with the legislative framework applied. **CoO**s are the final output of a collaborative negotiation process, and will comply with the associated environmental constraints (i.e. airport environmental constraints).
Operational	**Cost effectiveness**	• Direct cost of gate-to-gate ATM • Direct cost of ATM providers	*The ATM system should be cost-effective, while balancing the varied interests of the ATM community. The cost of service to airspace users should always be considered when evaluating any proposal to improve ATM service quality or performance. ICAO guidelines regarding user charging policies and principles should be followed.*

[1] Performance Objectives and Targets RPT0708-001-01-01

Expectation	Focus Area	*SESAR Description*[1] and application to CATS
	• Indirect costs	**CoO**s represent an improvement in airport operations (i.e. turn-around in-block time and off-block time are predictable) leading to cost benefits for both airlines and airports (e.g. through reduced delays and optimised use of gates). The **TW**s are defined taking into account the various actors' inherent "parameters" (e.g. preferred/economically desired routes, staff optimisation, avionics specifications, etc.). • Direct cost of gate-to-gate ATM is expected to increase during the first period, owing to the investment costs afforded by stakeholders in the pre-implementation and implementation phases. Then a reduction is expected, owing to increased operational efficiency which will overcome the possible slight increase in operating costs. • Direct cost of ATM providers is expected to slightly increase, rather than decrease, owing to the additional workload for ATCOs. • Indirect costs are expected to decrease due to the enhancement in efficiency, flexibility and predictability KPAs.
Capacity	• Airspace capacity • Airport capacity • Network capacity	*The global ATM system should exploit the inherent capacity to meet airspace user demand at peak times and locations while minimising restrictions on traffic flow. To respond to future growth, capacity must increase, along with corresponding increases in efficiency, flexibility, and predictability while ensuring that there are no adverse impacts to safety and giving due consideration to the environment. The ATM system must be resilient to service disruption, and the resulting temporary loss of capacity.* Capacity is not expected to be directly affected by the application of the **CoO** and **TW** concepts. Improvements in this KPA may come from the releasing of some unused latent capacity, resulting from the increase of global efficiency. **CoOs** are finalised at a time close to the actual execution of flights. They take into account current traffic patterns and capacity distribution.
Efficiency	• Temporal efficiency • Fuel efficiency • Mission effectiveness	*Efficiency addresses the operational and economic cost-effectiveness of gate-to-gate flight operations from a single-flight perspective. Airspace users want to depart and arrive at the times they select and fly the trajectory they determine to be optimum in all phases of flight.* **TW**s represent potentially "acceptable" alternatives defined in terms of intervals on the transfer of responsibility areas. Operations can thus be adapted in line with real-life events in order to obtain the agreed preferred trajectory. • Temporal efficiency is expected to increase owing to the new shared objective of respecting **TWs**. The use of TWs agreed by all actors should optimise the duration of the flight. TWs calculation is based on arrival time, facilitating temporal efficiency, in term of punctuality and less deviation from block to block time.

	Expectation	Focus Area	*SESAR Description*[1] and application to CATS
			• Fuel efficiency, which is directly related to flight-duration efficiency, should increase owing to the fact that the trajectories agreed will no longer be based on a fixed-route structure (except in high-density areas such as TMAs), but will be proposed by users on the basis of their commercial preferences, thus leading to less lateral and vertical deviations from optimum trajectories.
	Flexibility	• Business Trajectory update flexibility for scheduled and non scheduled flights • Flexible access-on-demand for non-scheduled flights • Service location flexibility • Suitability for military requirements	*Flexibility addresses the ability of all airspace users to modify flight trajectories dynamically and adjust departure and arrival times, thereby permitting them to exploit operational opportunities as they occur.* If a **CoO** is not fulfilled for whatever reason (e.g. airport closure, serious weather conditions, etc.), the renegotiation mechanism is triggered. This process operates at global level to ensure better solutions at network level. The network and schedule can then be adapted to the new traffic pattern. As stated above, **TW**s are designed to provide scope for action and allow flights to be quickly adapted to new traffic patterns. Negotiation and renegotiation processes represent the operational mechanisms to promptly and efficiently deal with sudden changes in demand and capacity at both tactical and operational levels. In addition the built-in disruption margins, **TWs** allow a further grade of flexibility to be integrated into operations. These processes, coupled with the possibility of swapping airport slots between aircraft belonging to the same company, will bring great flexibility.
	Predictability	• On-time operation • Service-disruption effect • Knock-on effect	*Predictability refers to the ability of the airspace users and ATM service providers to provide consistent and dependable levels of performance. Predictability is essential to airspace users as they develop and operate their schedules. It measures the ability to control the variability of deviation between actually flown 4D trajectories in relation to the RBTs.* **CoO**s are major enablers for predictability, as all the actors involved jointly agree to comply with them and to "deliver" flights in accordance with them, allowing better punctuality. **TW**s allow each actor to verify its own operations in relation to the agreed contract and thus ensure global predictability as soon as it is able to "deliver" the flight in accordance with them. Predictability is enhanced for all users based on common information-sharing. • The number of on-time operations should increase owing to the agreed objectives and time-dimension presented by **TWs** • Service disruption will be managed in the most efficient way owing to the renegotiation process • The knock-on effects will be controlled and promptly reduced to the minimum through the

	Expectation	Focus Area	*SESAR Description*[1] and application to CATS
			continuous sharing of information regarding compliance with the **CoO**, agreed by all partners
Enablers	**Interoperability**	• Homogeneous traffic flows • Non-discriminatory traffic flows • Application of global standards and uniform principles • Technical and operational interoperability of aircraft and ATM system	*The ATM system should be based on global standards and uniform principles to ensure the technical and operational interoperability of ATM systems and facilitate homogeneous and non-discriminatory global and regional traffic flows.* **TW**s represent negotiated and agreed contractual interfaces between actors and constitute a common standard ensuring the operational interoperability and continuity of the system. All aircraft with the minimum equipage requirements will be integrated into the en-route airspace. There will be no segregation.

Table 4: SESAR KPA description and how CATS fits in

6.2 Human performances

As the CATS project aims to assess the Operational Usability [26] of the CoO concept and to complement the analysis of how the proposed CoO and associated TWs will impact the system performance regarding selected Key Performance Areas, it has also been decided to analyse human performance linked with CoO implementation.

The aim of the second objective is to see if the contribution of the human-to-overall system performance is within expected capabilities (workload, situational awareness, working methods, acceptability, etc.) and does not reach human limits. Human performance could be seen as an enabler to reaching system performance.

Four validation goals were identified:

- to assess the feasibility and acceptability of the working methods linked to CoO execution;
- to assess the impact of CoO execution on ATCOs' and aircrews' performance;
- to assess the impact of CoOs on ATCOs' and aircrews' activity;
- to assess strategic decisions in the event of renegotiation and their impacts on traffic.

Various techniques will be used, such as observations, interviews, recorded data (i.e. R/T communications, number of STCAs, etc.), questionnaires and self-assessments, as explained in D1.3.1.

Both of these performances will be analysed through the various HIL experiments conducted in WP2.1.

7 Transition

To introduce the CoO, some costs are implied, like in any initialisation of a new process. Some investments may need to be done for introducing the CoO and some training may be needed. Analysis of benefits and costs will be further studied in WP2.2.2.

Nevertheless, most of these investments could not be attributable exclusively to the implementation of CoO; most of them (i.e. SWIM, NOP…) are linked with the general implementation of the new ATM target concept foreseen by SESAR and will not be evocated in the followings.

7.1 Technical transition

One of the major interests of the current CATS operational assessment is that the CATS prototype was developed on a real operational environment. The operational stripless environment used in Skyguide Geneva was used as the basis for the CATS project.

The present CATS prototype, developed with the target operators in the loop, consists of a target window calculation module (TWM) and simulation modules for trajectory prediction input, controller clearance input, flight plan input and initial target window input. The calculated target window states are outputs to the controller HMI.

In order to perform a technical transition to an operational system the following tasks have to be performed, all based on the existing target window module (TWM) implementation:

- Create a functional specification for TWM module describing which services the module shall offer.
- Create a system architecture description describing how the TWM services shall be implemented as a stand-alone module, based on the current prototype, with clearly delimited standardized interfaces to the external input and output systems necessary for its operation (as opposed to the present simulated input modules).
- In parallel with the specifications, perform a System Safety Analysis using the EUROCONTROL SAM methodology and produce a Safety Case arguing the safe operations of the TWM. This analysis shall be targeted towards a SWAL level which must be agreed upon by both the customer and supplier of the TWM module.
- Refactor and reorganize the code of the existing prototype according to the established architecture to create a stand-alone TWM module with clearly defined external interfaces and test it with real or simulated data.

7.2 Human transition

Regarding the SESAR [6] and the chapter 4.2.5, the tasks for the controller and the pilots will remain quite the same. The change is introduces by the addition of new element, the respect of the CoO and associated TWs. There is then no need for new competence; just a small training is required regarding the HMI adaptation.

On the other hand, there is a reorientation of the ATM system logic: the trajectory is the core of the system, the common reference between all actors. Pilots and controllers will facilitate the adherence of the trajectory and CoO, working on a more global environment, supported by System Wide Information Management. This induces a change of culture as the ATCOs become part of the system and share with the crew the efficiency of the flight. Even if the recognition of the ATCO's know-how remains, goal of an ATCO is no more to expedite the traffic as he/she wants regarding his/her airspace, but to perform their usual tasks trying to respect the exit TWs and considering TWs in conflict resolution, ensuring then the best system efficiency.

The operational viability of the proposed concept will be established through the analysis of the user acceptance, the human factors and safety issues performed in WP2.1. The potential benefits have been demonstrated through the preliminary benefit assessment done in WP2.2.2 and through the indicators achieved in WP2.1.1 and WP2.1.2.

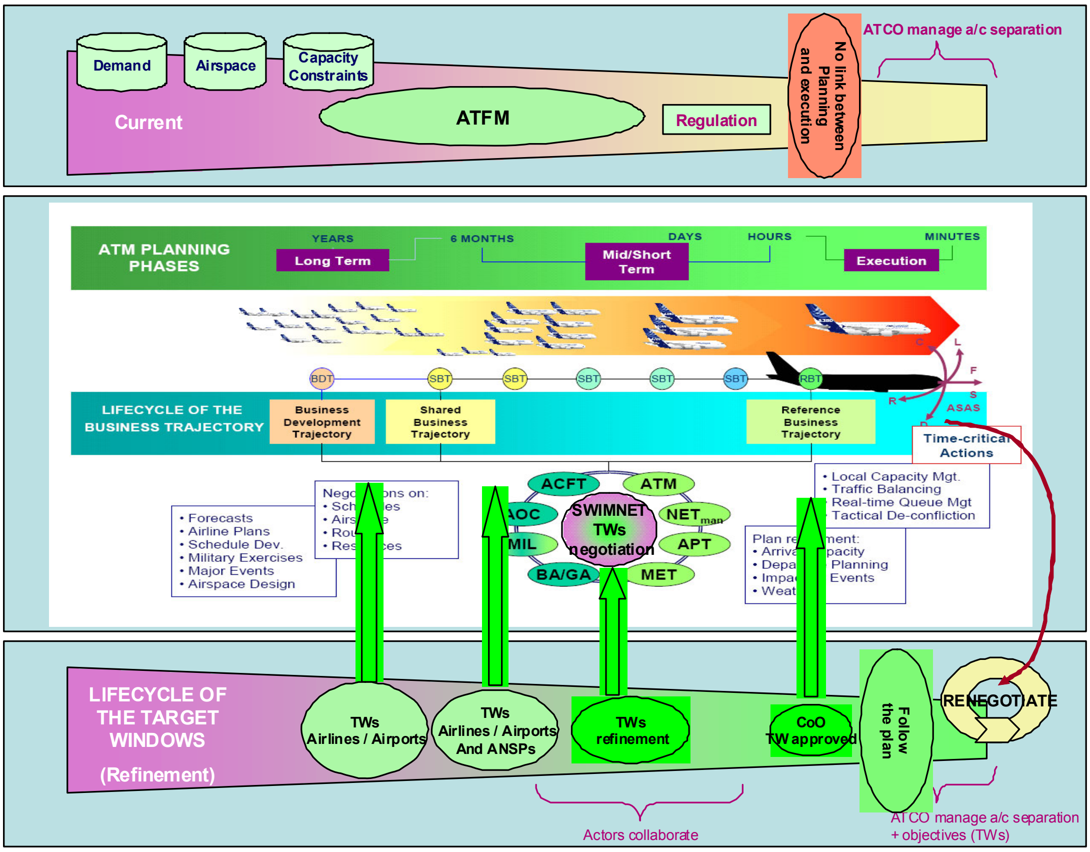
Finally, SESAR plans to give more automation to the ATCOs tasks. Hopefully CATS will benefit from these improvements, but it is quite difficult for the time being to characterize the proposed future automation and then, envisage a transition plan.

7.3 Institutional transition

CATS improves the manpower planning and is designed to improve the development of European regulations and policies, through WP2.2.3. This part of the study will ensure that the CATS concept fits well into the foreseen regulatory and performance frameworks, avoiding duplication or contradiction.

As outlined in the chapters covering WP2.2.3, the new "CATS regime" must comply with the requirements made under the SES/SESAR regimes. Also, as the proposals pertaining to the "CATS regime" touch relations with non-EC carriers which may be governed by global agreements, the relationship between the proposed "CATS regime" and global arrangements will be examined.

8 Summary of the changes with the current system



The CoO proposed by CATS is a real trade-off between all the actors, and not only a sharing of data, or a concatenation of constraints resulting of ground delays. Starting from the airspace users' demand, without constraints, the CoO integrates the negotiated room of manoeuvre at the transfer of responsibility between actors and contractualising them. This has a real impact as well on legal as on economical issues, if we envisage a reward /penalty scheme. This particular topic should be further studied within WP2.2.3 and WP2.2.2. Nevertheless, the CATS Consortium was aware of the necessity of examining the impact of the regulatory aspects on the CoO implementation.

Regarding the economic and performance issues, the framework (Figure 6) proposed by CATS could also be a means for the monitoring of the performance foreseen by SES2.

The awareness of the pilot and controller is enhanced; the shared objectives are presented on their working positions, and are the subject of their work. Optimisation is no more done locally (e.g. controller offering a direct route) but in a global way, achieving the most efficiency for the system.

Through the fulfilment of the TWs, the link between planning phase and execution phase is ensured. CATS proposal is a plan-based operation approach , where the idea is to fly what have been planned, negotiated and agreed, as opposed to the current "first come-first served" approach or a full 4D implementation, based on 4D capable avionics and data-link, that are too reactive in our view. This link between planning and execution phases let the possibility to all the actors to optimise their own local resources to better match the global constraints and demand.

Finally, a retro-feedback or a post analysis of the operations of a day, will not only bring important information on the TWs negotiation itself, but also support a real deployment of a performance scheme, allowing the monitoring of actors' performance.

9 Conclusion

The aim of the CATS concept is to improve system efficiency and predictability by means of enhanced collaboration between air transport actors, focused on the same goal: punctuality at destination, allowing them to better anticipate their needs and to organise their resources.

By managing the uncertainty inherent in ATM, the proposed TWs create a real link between the planning and execution phases, and a real adherence to RBTs.

This document presents the key concept elements and their link with the SESAR Programme. Through the implementation of the CoO, all operational actors are aware of the results of the Business Trajectory, regarding time, FL and cross-border areas, shown by the use of TWs. All aspects of ANS performance that are relevant to airspace users are covered, from the cost-effectiveness to the operational efficiency, so beyond punctuality alone.

The proposed concept is in line with SES2 proposals. CATS sets up an operational framework, based on a performance partnership amongst stakeholders, to get the best outcome for each flight, allowing the EC to monitor air navigation services performance through the fulfilment of the TWs. CATS concept supports the deployment of performance framework. It could be seen as an alternative to a State driven performance scheme.

The CATS proposed concept is a real framework for existing business models and future sustainable air traffic management. The context in which aviation operates is changing rapidly, with the focus shifting from capacity growth to flight efficiency, environmental impact, and cost reduction. Building a new ATM system to manage current objectives, while supporting future scenarios, is the challenge addressed by CATS. In the CATS concept, this is accomplished through the negotiation of TWs, where all the actors' constraints, current and future, are taken into account, while supporting business evolution. The Contract of Objectives (CoO) concept proposes a system that is not focused on a single business model, or specific technical improvements, but instead offers a framework able to support future key considerations and developments, for sustainable air traffic management.

This deliverable is the revised version of the initial concept description, the second delivery of D1.2.2. It has been updated after the first and second HIL experiment and will be further updated and revised after the last validation experiment has been carried out. This description of the Concept of Operations will be the basis of the validation, planned in WP2 and prepared in WP1.3.

10 References

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