

# A COMPARISON OF 4D-TRAJECTORY OPERATIONS ENVISIONED FOR NEXTGEN AND SESAR, SOME PRELIMINARY FINDINGS

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## Abstract

*This paper presents a comparison between the concepts underlying 4D Trajectory Based Operations (TBOs) from the double viewpoint of NextGen and SESAR programs. In the proposed analysis, motivations justifying the introduction of 4D TBOs are presented first. After that, the different and similar technologies that are being applied to support 4D TBOs are discussed. This is followed by a discussion focused on the results obtained from different human-in-the-loop simulation activities. In addition, preliminary flight trials activities, planned and partly executed for concepts' refinement and final validation, are also discussed. These validation activities, carried out on both NextGen and SESAR sides, aim to assess the impact of the aforementioned supporting technologies on both pilots and Air Traffic Controllers. This impact will actually be a key element for the effective implementation of 4D TBOs. Early benefits identified for SESAR and NextGen are described next. Finally, some comparisons and preliminary conclusions are presented.*

## 1 INTRODUCTION

The global air transportation system is a corner stone part of the world economy. A steady growth in air traffic is necessary to support the economic growth and produce economic wealth by itself. In order to accommodate this increased

traffic demand, the system will have to radically change from the current one. In the next fifteen years the global air transportation system will transform more than it did in the past sixty years. It is also envisaged that this transformation process will be led by the US and Europe, as the NextGen ([1, 3]) and SESAR ([2, 4]) programs are actually the most significant initiatives that are being developed to support the new era of air transportation.

Specifically, both programs deal with the same problem, as current Air Traffic Control (ATC) procedures and technologies will not be able to accommodate the increased traffic demand while maintaining the same levels of safety. The solution to this problem will require a radical change in the whole Air Traffic Management (ATM) system. More in detail, the fundamental shift in paradigm will be from clearance-based ATC to trajectory-based ATC operations. The key element of Trajectory Based Operations (TBOs) is actually an agreement between an airline and the ATM system about the trajectory that will be followed by an aircraft. The negotiated trajectory will satisfy many of the airline preferences, with particular attention to fuel consumption reduction. However, this trajectory will also include additional constraints that will improve its predictability, thus facilitating the work of Air Traffic Controllers (ATCos). A typical example of such constraints is the fulfillment of assigned Target Time of Arrivals (TTAs) at signifi-

cant points of the route. In this case, the term "4D TBOs" is normally used to identify this type of operations. Once the aircraft is cleared to fly the negotiated trajectory, the ATC function will be only of trajectory management [5]. Specifically, ATCos will assist as much as possible the aircraft in the execution of the negotiated trajectory, while maintaining at the same time the separation with other traffic. These approaches are actually expected to lead to different Concept of Operations (ConOps) and different operational performance for the two programs.

Differences and similarities between NextGen and SESAR are currently being investigated to identify the most suitable approach for a number of different problems or situations. For example, operational performance for the methods proposed by NextGen and SESAR are continuously evaluated and compared by the Performance Review Commission (PRC), a joint effort between the FAA and EUROCONTROL ([6, 7]). Furthermore, NextGen and SESAR's ConOps have been also compared in a recent study [8]. Even the U.S. Government Accountability Office (GAO) has recommended to improve the information dissemination exchange between NextGen and SESAR to improve the interoperability of the two projects [9]. In that context, this paper presents a slightly different point of view. Focusing, in fact, on the final objective, both for NextGen and SESAR, of achieving 4D TBOs, it compares how its constituting piece, the 4D Trajectory (4DT) [10], is being defined, handled and finally implemented.

The paper is structured as follows: first the terminology adopted to define a 4D Trajectory (4DT) in NextGen and SESAR is discussed. Then, the objectives of 4D TBOs are analyzed. The technology enablers are described next. This includes Flight Management System (FMS) advanced capabilities, Data Communications, Automatic Dependent Surveillance Broadcast (ADS-B) and ATC Decision Support Tools (DSTs). After that, a discussion focused on the results obtained from different human-in-the-loop simulation (HITL) activities is presented.

The objective of these activities is the assessment of the impact of the aforementioned technology enablers for 4D TBOs on practices and working methods of both pilots and ATCos. As such an impact will be a key element for the effective implementation of 4D TBOs. The metrics used to assess possible benefits are also introduced. Finally, the advance of the implementation plans is presented, together with some preliminary conclusions.

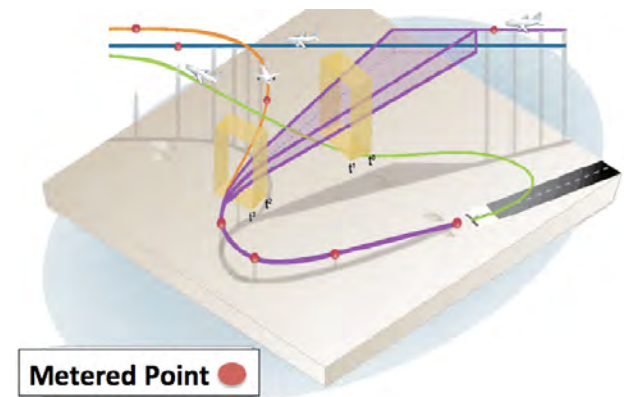


Fig. 1 4D Trajectory Representation in Nextgen [1]

## 2 TERMINOLOGY

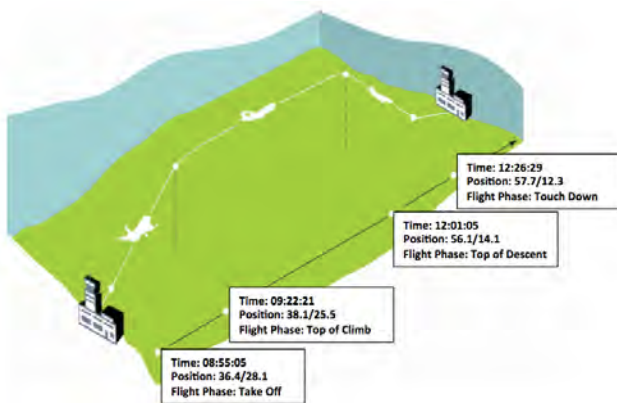
### 2.1 NextGen

In NextGen a 4DT is defined as a precise description of an aircraft path in space and time. This description includes the "centerline" of the path, using Waypoints (WPs) to represent specific steps along the path, together with appropriate buffers to describe the associated position uncertainty (See Figure 1). The path is earth-referenced (i.e. latitude and longitude specifications are given for each WPs). Furthermore, the path contains altitude descriptions for each WPs and suitable indications about the time(s) at which the trajectory will be executed. The required level of specificity of the 4DT depends on the flight-operating environment. Some of the WPs in a 4DT path may be associated with Controlled Time of Arrivals (CTAs). Each CTA is

defined by a TTA requirement that must be met by the aircraft within a specified time tolerance. Therefore, CTAs actually represent time "windows" for the aircraft to cross specific waypoints and are used when needed to regulate traffic flows entering congested en route or arrival/departure airspace [1].

**2.2 SESAR**

In the context of SESAR, airspace users will agree a preferred trajectory with Air Navigation Service Providers (ANSPs) and airport operators (Figure 2). The negotiated trajectory is expressed in four dimensions (three spatial dimensions, plus time) and takes into account all possible constraints due to limited airspace and/or airport capacity. For that reason, it may be subject to changes from early planning to the day of operations. The negotiated 4DT is called "Reference Business Trajectory" (RBT), where the term "Reference" indicates that, once the trajectory is agreed, it will become the reference trajectory which the airspace user agrees to fly and all the service providers agree to facilitate with their respective services [2, 11].

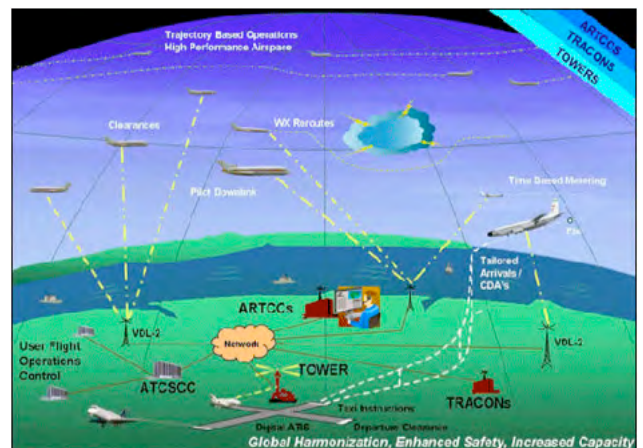


**Fig. 2** 4D Trajectory Representation in SESAR [11]

**2.3 Comparison**

Although the basic concept is fundamentally the same, in SESAR the term "Business Trajectory",

not present in NextGen, is introduced. The emphasis that the European consortium wants to put is on the agreement between all the ATM stakeholders (ATC, Airports, Airlines, Cockpit, Military, etc.) on the 4DT to be executed gate-to-gate by the aircraft. This detailed trajectory information will be shared between all the stakeholders through a System Wide Information Management (SWIM) [2]. This is a network-enabled access where all the information relevant to 4D TBOs are shared amongst authorized users. The same strategy for information management is envisioned by NextGen. Therefore, both NextGen and SESAR will have to deal with identical problems in terms of communications infrastructure requirements, protocols definition, and security aspects.



**Fig. 3** FAA Data Communication ConOps Representation [12]

**3 DIFFERENT AND SIMILAR OBJECTIVES**

In the FAA and EUROCONTROL's visions SESAR and NextGen will be both fully operational by 2025. It will not be easy to meet this schedule considering the paradigm shift that the ATM environment will go through to achieve this goal and the slow adjustments ATM usually undergoes. Moreover the different nature of the

airspace, very fragmented in Europe, and homogeneous in the US, has to be considered as a limiting factor for SESAR. On the other hand capacity constraints in the US occur primarily at major airports and in the terminal airspace around them, while in Europe it is the en route airspace which poses the biggest capacity limitations [13]. The operational objective of NextGen is to achieve performance-based operations in which regulations and procedural requirements are described in performance terms rather than in terms of specific technology or equipment [1]. Similar concepts are basic also for SESAR [4] to align the future ATM operations to the ICAO standards [14]. The analysis of these concepts, clearly indicates that the utilization of reliable 4DTs is paramount for both SESAR and NexGen [15].

#### 4 CONCEPTS TO ACHIEVE BOTH: TECHNOLOGY ENABLERS

In order to achieve TBOs the following technologies are considered necessary [3, 16]:

##### 4.1 Advanced FMS Capabilities

The concept of 4DT incorporating the temporal dimension into operations cannot exist without accurate Controlled Time of Arrival (CTA) capabilities. These capabilities will be achieved utilizing the FMS with more advanced features. In [17] the results of field tests performed at the Stockholm-Arlanda Airport for EUROCONTROL CASSIS project proved that current generation avionics can achieve CTA with 4 seconds accuracy at the approach fix (19 nautical miles from the runway), and less than 15 seconds at the runway threshold. The key factors impacting the accuracy of the CTAs were the wind data available to the FMS, the speed and altitude constraints, and configuration for landing. The extension of the FMS' Required Time of Arrival (RTA) capabilities, to achieve 4DT negotiation between cockpit and ATM, has also been studied [18]. Although the negotiation mechanism still needs to be refined these capabilities will be a key part of NextGen and SESAR concepts for TBOs.

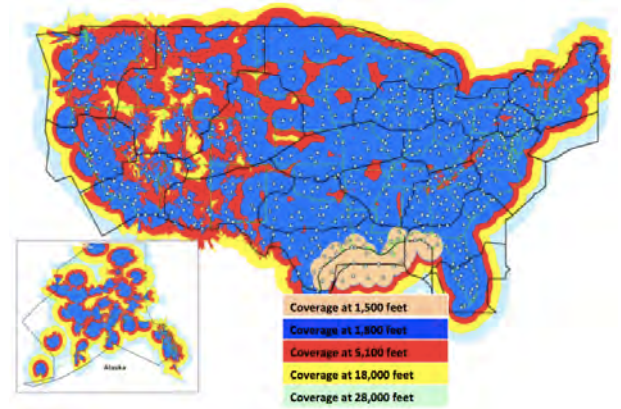


Fig. 4 ADS-B Deployment in the US in 2013 [19]

##### 4.2 Data Communication

To make 4DT negotiation feasible the voice communication channel between ATC and cockpit will not be sufficient. As a consequence, the introduction of Data Communication (Figure 4) technologies, becomes necessary to enable 4D TBOs. The implementation of these technologies will be done in three segments (short-, mid- and far-term) in Europe whereas only in two segments (mid- and far-term) in the US [10, 12, 20]. Data Communication implementation feasibility has been studied by the FAA since the nineties [21, 22], proving through human-in-the-loop (HITL) simulations the benefits for controllers' workload. Benefits in terms of airport capacity have also been studied [23]. Moreover an example of how Data Communication (ACARS) can be used to share 4DTs was presented in [17]. The RTCA SC-214/EUROCAE WG-78 joint committee has been tasked to develop the requirements for the advanced data communication service denominated 4DTRAD. This service will enable the negotiation and synchronization of trajectory data between ground and air systems [20, 24].

##### 4.3 ADS-B

In order to replace Second World War RADAR technologies, advanced surveillance capabilities

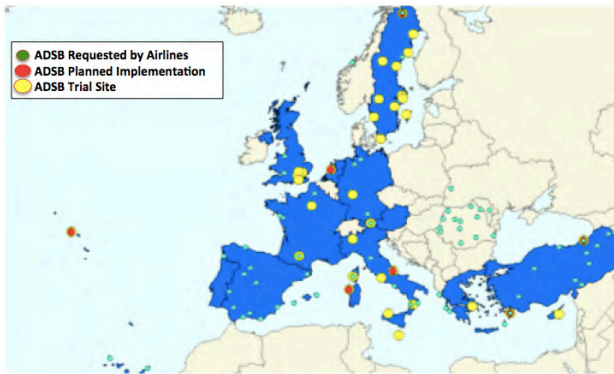


Fig. 5 European ADS-B Validation sites [25]

will be important parts of both SESAR (under the CASCADE program) and NextGen [19, 25]. The implementation of ADS-B (in and out) is already at an advanced stage. The satellite-based technology will be used both on the ground (ADS-B out) for surveillance and on board of the aircraft (ADS-B in) for augmented traffic situational awareness. The RADAR-based surveillance network will remain only as a back-up system for the new system. A method of safety analysis for ADS-B applications, agreed upon by American and European’s standard bodies, was presented in [26]. The methodology was applied to the ”Enhanced Air Traffic Services in Non Radar Areas using ADS-B surveillance” (ADS-B-NRA) and showed how requirements on ground and airborne equipment for safe operations can be accepted internationally. The benefit of the implementation of ADS-B in en-route operations was also evaluated in [27]. The analysis showed how different airspace environment (Gulf of Mexico, Alaska) need different analysis approaches. One of the biggest challenge identified will be to meet the same system performance with visual and instrumental conditions. Figure 4 and 5 show the ADS-B coverage in the US (different color for different altitudes covered) and the European ADS-B validation sites in Europe.

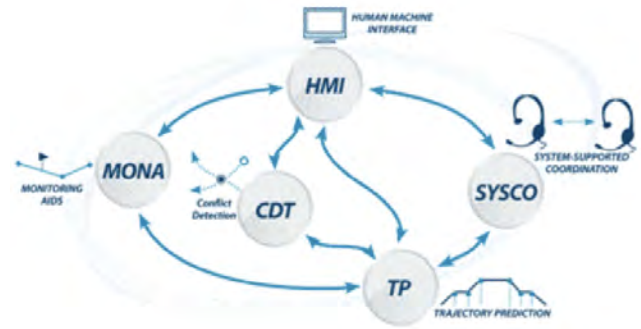


Fig. 6 FASTI Components Breakdown [28]

#### 4.4 Air Traffic Control Decision Support Tools

Another fundamental piece of the puzzle to enable 4D TBOs operations is the implementation of Decision Support Tools (DSTs) for air traffic controllers. In order to manage the increased traffic that SESAR and NextGen will accommodate it will be necessary to provide controllers with DSTs to keep their workload within acceptable levels while at the same time maintaining the current level of safety. These DSTs are based on trajectory prediction capabilities that will allow them to share and negotiate 4DT data keeping traffic safely separated. The type of data that will be shared to achieve system interoperability is not completely defined yet [29, 30, 31]. Nonetheless, a detailed data definition will be necessary to provide ATC with these new capabilities [5].

Conflict detection and resolution (CD&R) capabilities to support air traffic controllers in the separation assurance task have been studied since the early nineties in the US [32]. More recently MITRE CAASD has developed CD&R capabilities to support the FAA and the en-route DSTs that is being deployed to support NextGen (URET/ERAM) [33, 34]. In parallel researchers at NASA Ames Research Center have been developing a concept to apply 4D TBOs in which pilots configure the FMS settings from clearances issued by the controllers or computed by the FMS to meet time constraints. The resulting trajectories are then shared with the ground through Data Communication or recreated by a

ground-based system to support controllers in their CD&R tasks [35]. This concept differs from the European one of 4D tubes developed under the PHARE project [36]. Some of the basic issues that remain in relying on DSTs, are the uncertainty that is intrinsic in the trajectory prediction process [37], and the utilization of intent information in CD&R [38, 39]. The set of CD&R capabilities for SESAR are developed under the FASTI project [28] and summarized in Figure 6. It is interesting to notice that no automatic conflict resolution capabilities are envisioned in this project, not even on very far term timeline. Automatic conflict resolution is instead part of the Advanced Airspace Concept (AAC) developed by NASA Ames [40].

## 5 PRELIMINARY RESULTS OF HUMAN-IN-THE-LOOP SIMULATIONS AND FLIGHT TRIALS

### 5.1 US Results

To evaluate the operational acceptability of Performance-based ATM, in which 4DTs are shared between all the ATM users, MITRE CAASD supported the FAA in a series of HITL simulations. The results of the experiments showed that en route and terminal area concepts are feasible and demonstrated reduced controllers workload. The amount of traffic safely handled was increased with same number or fewer controllers [41]. Terminal area merging traffic was evaluated in a HITL simulation performed by NASA Ames to evaluate the acceptability of new controllers DSTs. The simulation proved that the DSTs enabled controllers to keep aircraft on their Area Navigation (RNAV) routes, and also achieved good schedule conformance through advised speed clearances. The DSTs under evaluation did not increase the controllers workload or decreased the throughput. The results also suggested that data-linked path adjustments exchanging 4DTs may be useful to absorb large delays [42].

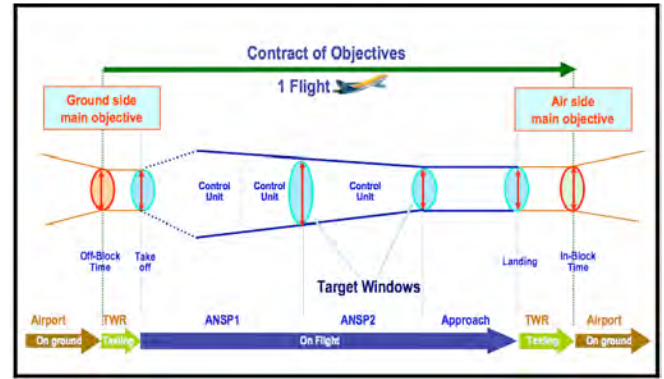


Fig. 7 SESAR Contract of Objectives [43]

### 5.2 EU Results

The concept of Contract-of-Objectives (CoO) analyzed by EUROCONTROL in the HITL discussed in [43] has a very tight relationship with 4D TBOs. The basic idea is to establish a sequence of spatial and temporal (4D) windows which represent milestones to meet during the flight execution. This 4D intervals are called Target Windows (TWs) and will be fundamental elements of future ATM. Through the application of TWs it will be possible to implement the "Business Trajectory" envisioned in SESAR (Figure 7). Moreover, also with 2X traffic conditions, the efficiency of the system increased and the ATC workload remained acceptable. As part of the initial validation activities, the SESAR programme has introduced Time Based Operations (TiBOs) as a preliminary steps toward TBOs. Specifically, in TiBOs, a TW is specified by ATC for only one waypoint of an aircraft flight plan.

First applications of TiBOs include initial four-dimensional (I-4D) flight operations, where airborne computed predictions for the aircraft trajectory are sent to the ground systems and used by an Arrival Manager (AMAN) to create, far in advance, a sequence for all aircraft converging to a merging point in a congested area. As a result of this coordination with the ground systems, each aircraft of the sequence is allocated a time constraint at the merging point. As a compensation for meeting such a constraint, the aircraft is allowed to fly its optimum profile up to that point, i.e. without any vectoring instruc-

tion from the controller. This agreement is referred to as "4D Contract" and its compliancy is continuously checked from both the aircraft and the ATC sides using suitable monitoring and prediction tools. Possible contingencies or unexpected events may actually prevent the aircraft from meeting time constraint. In this case, the 4D Contract can be re-negotiated; if no further agreement is possible, the aircraft will be vectored to the merging point, thus losing the privilege of flying its optimum profile.

In the framework of the SESAR programme, a number of activities are currently ongoing for validation of the I-4D concept. On 10 February 2012, an Airbus A320 test aircraft flew from Toulouse to Copenhagen and Stockholm and then back to Toulouse testing I-4D flight operations. The trial successfully verified that the aircraft FMS and the ground automation systems were able to implement the I-4D technique through data link interoperability. The trial also aimed to validate how information exchanged is displayed to the controller and the pilot and which tools should be adapted to use this new information to its full extent. It is underlined that system interoperability is actually a key element for I-4D operations. Only if the same information is available at the same time to both aircrew and controllers, the trajectory of a flight can be best managed while taking into account all existing constraints [44].

Further validation activities for the I-4D concept are planned in the forthcoming months to refine the technology, adjust operational procedures and explore ways to further enhance the tools and the operational concept. If the validations are conclusive by the end of 2013, industrialisation could follow and some pre-operational deployment could start in 2018.

## 6 RESULTS COMPARISON

### 6.1 Metrics Used

The most important benefits that both the FAA and EUROCONTROL expect from the complete

implementation of 4D TBOs can be summarized in the following Key Performance Areas (KPA):

1. Safety
2. Efficiency/Environmental Impact
3. Capacity
4. Predictability
5. ATC Workload Acceptability

In order to assess the level of safety some of the metrics that have been used include:

- Aircraft separations [17, 34, 35, 42, 43, 45]
- Losses of separation [34, 40, 42, 43, 46]
- Conflict false alarms [34, 40]

To assess efficiency/environmental impact:

- Delay per aircraft [40, 47, 48]
- Number of fulfilled TWs [43]
- Planned flight time divided by flight time in the sector [43]
- Fuel consumption [47]

To assess capacity:

- Number of aircraft in the sector/hr [21, 22, 43, 49]
- Instantaneous number of aircraft [43]
- ATC number of instructions [43]
- Sector capacity [47]
- Revenue Passenger Miles (RPM) [47]

To assess predictability:

- Planned flight time divided by flight time in the sector [38]
- Number of fulfilled TWs [43]
- TP accuracy [34, 40]

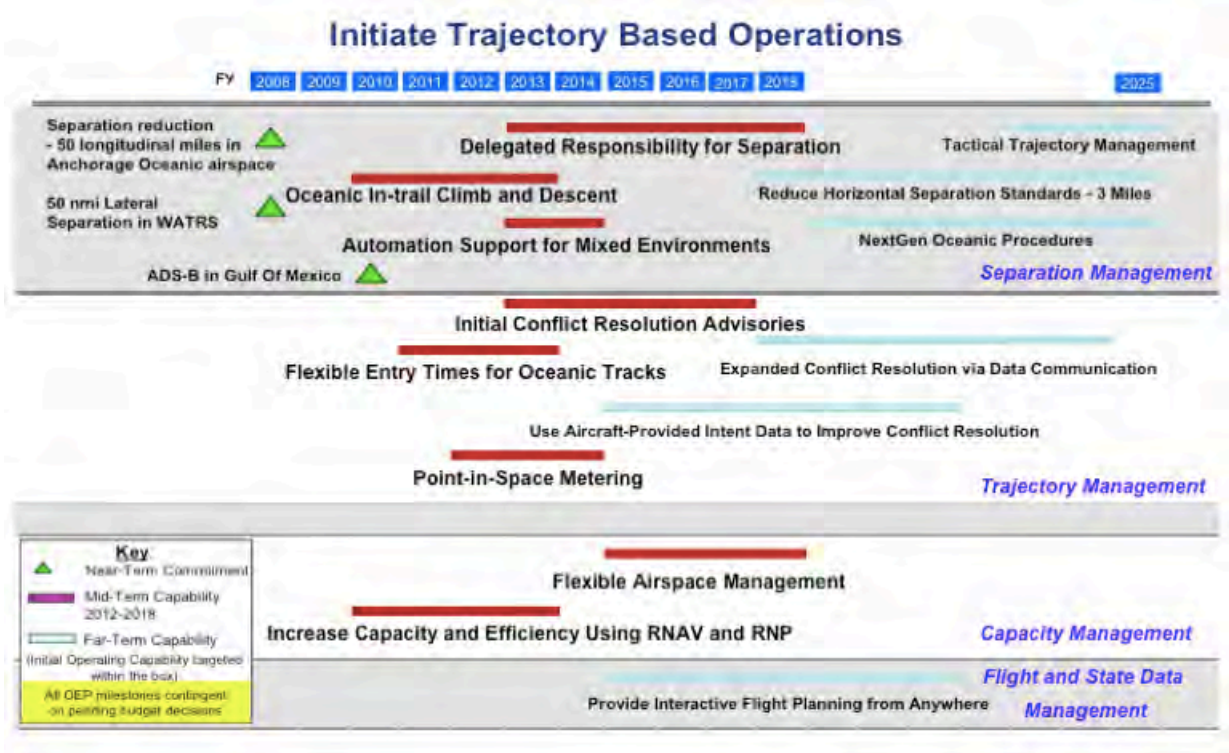


Fig. 8 NextGen Implementation Timeline [50]

- Schedule conformance [42]
- CTA/RTA accuracy [17, 18]

To assess ATC workload:

- Number of ATC controllers required per traffic level [46]
- Mental demand [35]
- Effort [35]
- Frustration [35]
- Performance [35]
- Instantaneous Self-Assessment Workload (ISA) [43]
- NASA-Task Load Index (NASA-TLX) [41, 43]
- Air Traffic Workload Input Technique (ATWIT) [41]
- Subjective rating scale [21, 22]

## 6.2 Early Estimated Benefits

In this section early benefit of the individual technologies necessary to enable 4D TBOs, and of the overall benefits of SESAR and NextGen, from recent studies, will be briefly discussed.

1. Automated Airspace Concept (AAC): In [49] the capacity benefit of the implementation of the AAC in en-route airspace are discussed. The most important benefit achievable is the relieve, from the separation assurance responsibility, for the controllers that is claimed to have the biggest impact on workload. As a result, a doubling of the capacity of individual sectors appears achievable to the authors of the study.
2. 4DTRAD (data link): Although not precisely quantified, in [30] benefits both for airborne and ground side users are expected from the application of Data Communication technologies in Europe. The most remarkable categories where benefits



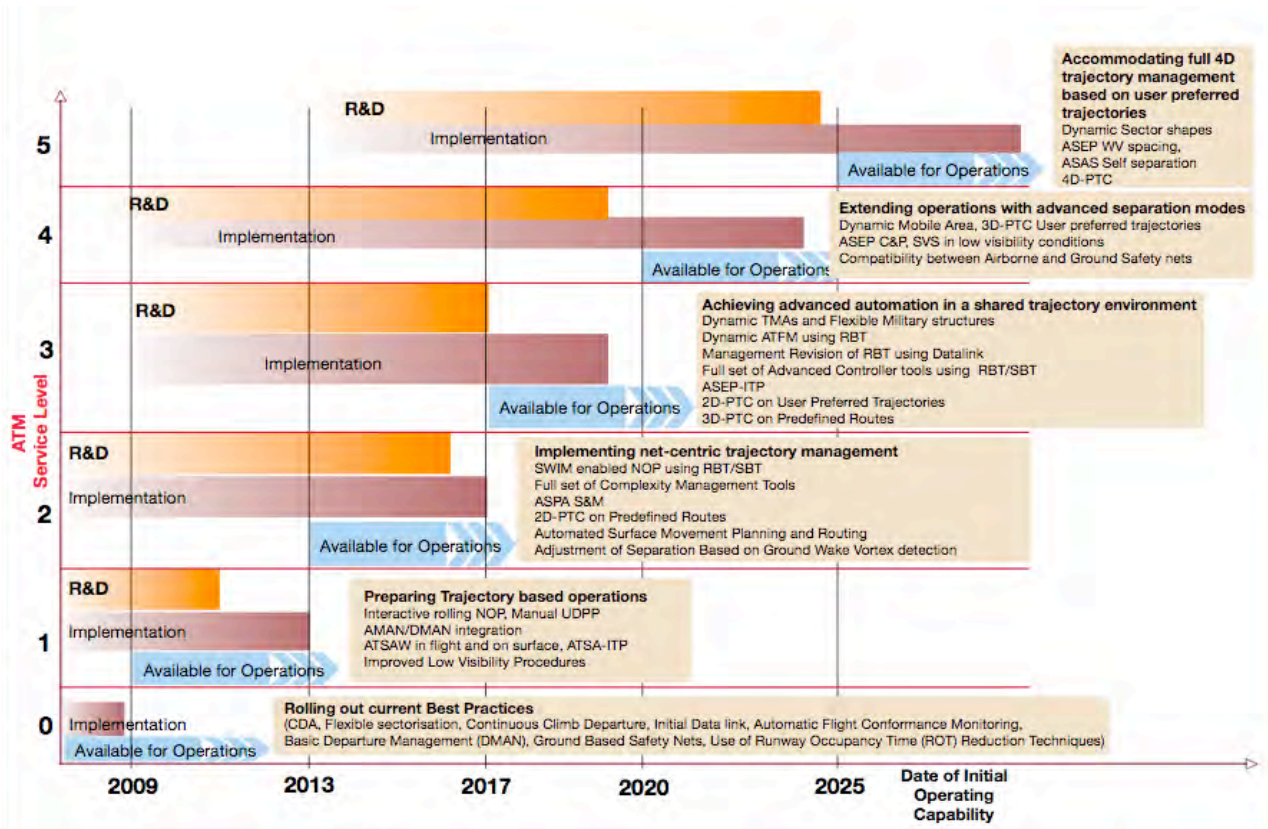


Fig. 9 SESAR Implementation Timeline [4]

can be achieved are: flight efficiency, better sequencing in terminal area, increased predictability of the trajectory that will be actually flown, reduced frequency congestion, improved predictability of the ATM system, and enabling of 4DT data exchange.

3. Conflict resolution capability: The benefits envisioned by the FAA with the introduction of advanced conflict resolution capabilities were summarized in [5]. Key area of improvement were: reduced delays due to increased sector capacity, reduced maneuvering and consequent fuel burn, reduced altitude restrictions, and increased use of direct routes between city pairs.
4. Early benefits for the implementation of en-route trajectory negotiation in a trajectory-based ATC concept were presented in [47]. Increased sector capacity of up to 10% and cumulative fuel consump-

tion savings up to \$ 770 millions achievable in 2030.

5. Overall benefits of SESAR: To ensure a commercially sustainable high quality air transport service to the European community, the SESAR project improvements are considered beneficial for the European environment, economic growth, and competitiveness [16].
6. Overall benefits of NextGen (mid-term): The FAA estimates that by 2018, NextGen will reduce total flight delays by about 21 percent while providing \$22 billion in cumulative benefits to the traveling public, aircraft operators and the FAA. In the process, more than 1.4 billion gallons of fuel will be saved during this period, cutting carbon dioxide emissions by nearly 14 million tons. These estimates assume that flight operations will increase 19 percent at 35 major U.S. airports between 2009 and

2018, as projected in the FAA's 2009 traffic forecast [3].

## 7 ADVANCEMENT OF IMPLEMENTATION PLANS

SESAR and NextGen differ in their implementation plans (Figure 8-9) because they are strictly connected to different European and American industry structure. NextGen tends to be closely tied to the (unique) government framework. On the contrary, SESAR, given the nature of European political structure, appears to be a more collaborative approach. Therefore NextGen supports a more centralized approach whereas SESAR a more distributed one [8]. NextGen's timeline (Figure 8) foresees complete trajectory management by 2025 with expanded conflict resolution capabilities that will rely heavily on Data Communication technologies. SESAR's operational concept places the "Business trajectory" at the core of the system, with the aim to execute each flight as close as possible to the intention of the user with the timeline set for 2025 (Figure 9).

Some highlights in NextGen implementation were achieved with the complete deployment of ADS-B technologies over the Gulf of Mexico which allowed ATC surveillance to be offered to an area that was not covered before. Moreover in 2010 the Collaborative Departure Queue Management (CDQM) system was tested in Memphis to implement better taxi-out operations [51]. This system can support better use of 4DT data on the ground together with better surveillance that was already implemented at New York JFK Airport with Airport Surface Detection Equipment, Model X (ASDE-X) system [52].

SESAR's implementation of Data Communication technologies has already advanced to effective deployment in the Maastricht Upper Area Control (MUAC) Centre where clearances are uplinked by the ATC and requests were downlinked by the aircraft crew [53]. Moreover the Atlantic Interoperability Initiative to Reduce Emissions (AIRE), a joint effort between the FAA and the European Union Commission, performed field tests with commercial aircraft to support

green operations. 4DT precision and Continuous Descent Approach (CDA) were tested in a transatlantic flights between USA and Europe. Key enabler such as advanced FMS capabilities to achieve RTAs, and ATC DSTs, were used in these experimental flights [54]. The results of the first i-4D flight were already discussed in Section 5.2 [44].

## 8 PRELIMINARY CONCLUSIONS

Preliminary results of this analysis show how very similar concepts for SESAR and NextGen are being achieved with slightly different methodologies and technologies. The real challenge will be to make these two systems interoperable in the last step of their implementation.

What this study has identified is a different "philosophical" approach for the implementation of 4D TBOs. The most significant difference regards the calculation of the initial time constraint (CTA) that the aircraft have to meet. In the I-4D proposed for SESAR [44], the CTA negotiation is based on possible limitations associated with aircraft performance and environmental conditions (e.g. wind field). Specifically, such a negotiation is always initiated by the aircraft which down-links an Extended Projected Profile (EPP) where airborne estimations for ETA, minimum ETA ( $ETA_{min}$ ) and maximum ETA ( $ETA_{max}$ ) are provided for each of the remaining waypoints of the flight plan (Figure 10). The EPP information actually represents a summary of what is estimated to be feasible for the aircraft. Therefore, for a given waypoint, the ATC system will propose to the aircraft only CTA constraints which are consistent with the  $[ETA_{min}; ETA_{max}]$  interval.

This approach assumes that the aircraft has the best knowledge of his future trajectory and therefore the trajectory predicted by the FMS is the most accurate. Once the final CTA constraint is agreed upon, the aircraft will meet it through the RTA capability of the FMS. On the other hand, in the concept proposed for NextGen

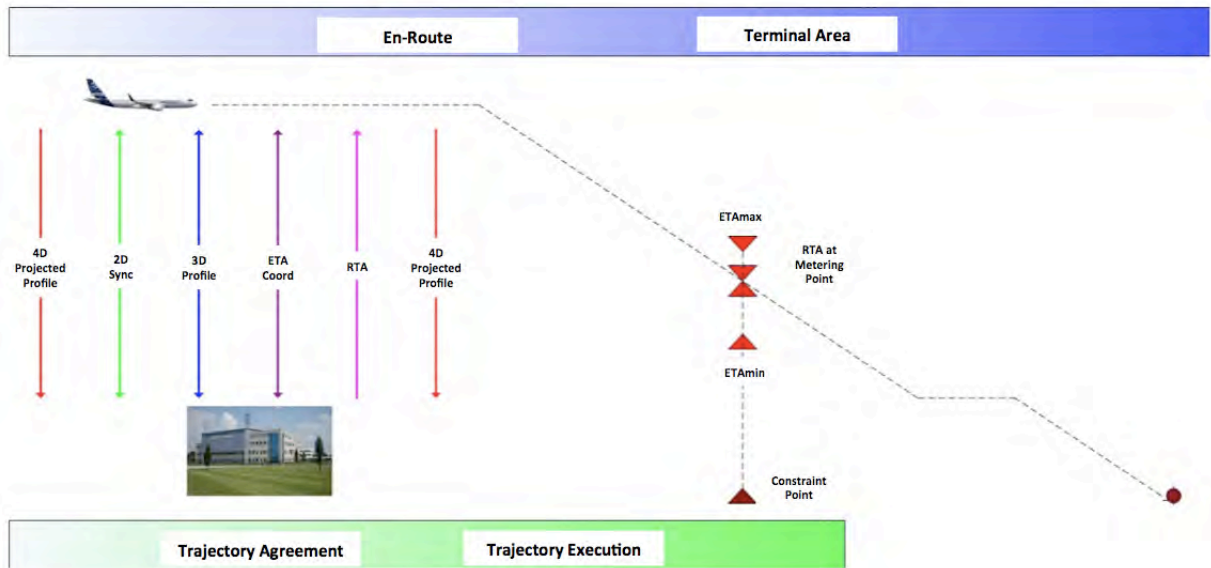


Fig. 10 I-4D Concept Representation [44]

[1, 55] the ground system calculates the first CTA, uplinks it to the aircraft and start the negotiation. This because it is assumed that the ground system has a better knowledge of the traffic, and therefore has a better situational awareness. After the CTA has been agreed upon, the aircraft will meet it using the RTA capabilities of the FMS.

In this context, It is interesting to report a slightly different "philosophical" approach that is been carried out in Australia [56]. In Fact, to improve the predictability of the aircraft to the ground system, the RTA capability of the FMS is not used, because although it improves the accuracy at the constraint (CTA) location, it reduces the ability of the ground system to predict the descent profile. This because the cost index, among other parameters used by the FMS, are unknown on the ground. The results of these different research approaches should be considered to find an optimal way to achieve 4D TBOs.

Another critical aspect that must be resolved by the SESAR Consortium for the complete implementation of 4D TBOs will be how to exchange the trajectory data between different airspace sectors controlled by different ANSPs. The interoperability of ground DSTs to achieve this goal must be evaluated and tested before the 2025 timeline. This problem still needs to be ad-

dressed by the FAA as well, but it can be assumed that it will be less of an issue. Nonetheless to completely benefit from 4D TBOs this problem cannot be neglected.

More research is undergoing to develop these preliminary findings into more solid results, to refine operational concepts and to identify more specific problems associated with human, equipment and procedures.

## 9 ACKNOWLEDGMENT

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