A COMPARISON OF THE TWO ARRIVAL TRAFFIC SYNCHRONIZATION CONCEPTS ENVISIONED FOR NEXTGEN AND SESAR.

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KEYWORDS: SESAR, NextGen, TBO, 4D Trajectory

Abstract

This paper presents a comparison between the most relevant on-going activities in the creation and implementation of the Arrival Traffic Synchronisation Concept of Operations worldwide, by analysing and breaking down the requirements and approaches underlying the problem of 'tactical establishment and maintenance of a safe, orderly and efficient flow of air traffic' from the double viewpoint of NextGen and SESAR programs.

Focusing, in fact, on the final objective, both for NextGen and SESAR, of achieving 4D TBOs(Trajectory Based Operations), this paper compares how one of its constituting piece, Traffic Synchronisation Concept, is being defined, handled and finally implemented.

In the proposed analysis, motivations justifying the traffic synchronisation are presented first. Current status of the Arrival traffic management is presented and the terminology adopted to pose the Arrival Traffic Synchronization problem in NextGen and SESAR is discussed. This is followed by a detailed analysis of both, NextGen and SESAR programs approaches, in terms of requirements and concept elements and by a discussion focused on the differences and possible comparative advantages of each of them. Finally, some comparisons and preliminary conclusions about the implications of such differences are presented.

1. General Introduction

The global air traffic management (ATM) operational concept presents the ICAO vision of a future integrated, harmonized and globally interoperable ATM system which planning horizon is up to and beyond 2025 [1]. This operational concept describes the manner in which the ATM system will deliver services and benefits to airspace users by 2025.

This future ATM system is integrated by seven components, one of which, called "**Traffic Synchronization**", is described as the tactical management of queues, both on the ground and in the air, in order to establish and maintain a safe, orderly and efficient flow of air traffic. It contains the following major functions [2]:

- Departures Synchronization.
- Arrivals Synchronization.
- Interactions between arrivals and departures.

Currently there are many projects related to traffic synchronization that build on new technology or innovative concepts. The most relevant of these projects are:

- Queue-Management in Europe by SESAR's Joint-Undertaking [3], and
- Time Based Flow Management and extensions in the U.S.[4].

Differences and similarities between NextGen and SESAR are a matter of investigation worldwide with the aim to identify the most suitable approach for coping with the future air traffic needs and demands. There is a permanent joint effort between the FAA and

EUROCONTROL ([5,6]) to assess and compare the operational performance for the methods proposed by NextGen and SESAR [7,20,21]; and even the political institutions recommend to improve the information dissemination exchange between NextGen and SESAR to improve the interoperability of the two projects [8].

In that context, this paper compares, both for NextGen and SESAR, how one of its constituting piece, Traffic Synchronisation Concept, is being defined, handled and finally implemented.

In the SESAR ConOps (Concept of Operation), traffic synchronisation corresponds to the arrival component of the ATM process called "**queue management**" [2] and consists of the fine tuning of the position of an individual aircraft in the traffic flow, which will permit the optimisation of the use of the limited resource which is the runway. This fine tuning, which will be the evolution of current AMAN systems, is known as **Real Time Arrival Queue Management**. Currently the following concept elements are envisaged as part of this Real Time Arrival Queue Management:

- AMAN + Point Merge
- AMAN and Extended AMAN Horizon
- DMAN Multiple Airports
- I4D + CTA
- Integrated AMAN DMAN

On the other side, the concept of Traffic Synchronization will be implemented in NextGen through Time Based Flow Management (TBFM) program.

The overall goal of TBFM is to maximize use of available National Airspace System (NAS) resources, while minimizing delays and disruptions to aircraft operators and their customers, as well as reducing fuel burn and engine emissions thereby decreasing user operational costs. TBFM will support Traffic Flow Management (TFM) in satisfying the requirements identified in the Next Generation Air Transportation System (NextGen) Operational Improvements (OI) in the NextGen Implementation Plan. In particular it expands the role and scope of TMA, time-based metering (TBM) and contributes to the achievement of the following NextGen OI and Decision Points (DP) within the NAS Enterprise Architecture: [9]

- Point in Space Metering.
- Integrated Arrival Departure Airspace Management.
- Time-Based Metering using RNAV and RNP Route Assignments.
- TBFM Final Investment Decision.
- TBFM/Integrated Enterprise Solution (IES) Initial Investment Decision.
- TBFM/IES Final Investment Decision.

The TBFM has been conceived as an extension and improvement of a current tool call TMA. TMA is a decision support tool currently deployed and operational at all 20 ARTCCs, 30 TRACONs, and 29 ATCTs (24 of the 30 Core airports). This system was designed to make capacity constrained airspace more efficient by using TBM and it is used in the departure, en-route and arrival phases of a flight.

2. *Traffic Synchronization Concept*

The term Traffic Synchronization defined by ICAO is the management of the flow of traffic through merging and crossing points, such as traffic around major aerodromes or airways crossings. It currently includes the management and provision of queues both on ground and in the air. Traffic synchronization, as a function, is closely related to both demand/capacity balancing and separation provision and may in the future be indistinguishable from them. Traffic synchronization also concerns the aerodrome 'service' part of the concept [19].

Traffic synchronisation covers all aspects related to improve arrival/departure management and sequence building in en-route and TMA environments in order to achieve an optimum traffic sequence resulting in significantly less need for ATC tactical intervention, and the optimisation of climbing and descending traffic profiles. As a consequence flights are able to fly closer to their optimum trajectories bringing benefits across Predictability, Efficiency, Safety, Capacity, and Environment. This includes [16]:

- Development of harmonised procedures for advanced CDAs aiming at their progressive implementation in higher density traffic environments supported by new controller tools and 3D trajectory management;

- Development of continuous climb departure (CCD) routes and procedures for reducing noise in higher density traffic enabled by system support to trajectory management;

- Extension of arrival management horizon into the En-Route phase including the arrival management for multiple airports and the integration of departing traffic from airports within the extended arrival management horizon, especially in complex TMAs;

- Development of coupled AMAN and DMAN functions integrating surface management constraints;

- Development of DMAN functionalities from a Basic DMAN enhanced with pre-departure sequence information to DMAN for multiple airports supporting departure metering and coordination of traffic flows and their interactions from multiple airports to enable a constant delivery into the en-route phase of flight.

- Introduction of Point Merge procedures with support of an Advanced AMAN within extended TMAs for merging arrival flows and achieving Continuous Descent Approaches (CDA) from high level altitude in high level traffic demand environments;

- Development of computed and predicted single/multiple Controlled Time of Arrival (CTA), associated airborne technology and the appropriate ground-based system support especially for medium and high density operations and including military operations;

Development and consolidation of the “Airborne Spacing Sequencing & Merging Application" (ASPA S&M), including full integration of lateral and vertical aspects with the longitudinal dimension and CPDLC from both air and ground perspectives, and its combination with Arrival Management, Continuous Descent Approach and a P-RNAV route structure.

3. *Concepts Description*

NextGen and SESAR are built around the concept of performance-base operations. The descriptions of the next concepts are shared for SESAR and NextGen [10]:

- Trajectory-Based Operation (TBO): TBO operates gate-to-gate, extending benefits to all phases of flight operations. TBO uses the 4DT to both strategically manage and tactically control surface and airborne operations. Aircraft are handled by their trajectory. TBO cannot be all Closed, when a controller gives a new vector the operation stop being closed and start an Open Trajectory. TBO conformance is monitored both in the aircraft, which includes lateral deviations based on RNP, longitudinal based on flight progress in the FMS, vertical based on altimetry, and time from the FMS or other in-time aids.
  TBO starts with flight planning, the start of a 4DT goes through a process involving pre-negotiation, negotiation, an agreement accepting the trajectory, and execution of the 4DT.
- 4DT: Defined laterally and longitudinally by latitude and longitude, vertically by altitude and with time. Surface movement is a 3DT (lateral, longitudinal and time).
- Closed Trajectory: The ANSP automation, the controller, and the aircraft automation have the same view of what the aircraft is doing. There is agreement between automation on the ground and in the air, and actions are

synchronized. Closed Trajectories are accurate and kept updated so that there are defined limits of acceptable ambiguity between the air and the ground.

- Open Trajectory: The aircraft is no longer flying to an agreement with the automation. The aircraft and the ground are not in synchrony and the aircraft is flying off the agreed-upon trajectory for operational reasons like weather avoidance, a vector for sequencing or spacing, and/or a speed adjustment that will impact timing.
  Clearances for Open Trajectories would typically be used to maneuver in the airspace (tactical traffic conflicts, weather, etc.). Automation has a big problem in dealing with open trajectories because the uncertainties affect more than just the aircraft and may impact downstream flows.
- Uncertainty – Used throughout the report to describe the amount of variability in position in all three dimensions and time. Uncertainty from the cockpit perspective can be considered an area of containment, but from a conformance monitoring perspective it also includes anticipated non containment, especially in terms of time.
- Conformance monitoring: Is the process of assuring the aircraft is within a volume of airspace. This volume of airspace travels with the aircraft and the airspace boundaries and structure are defined by the aircraft's performance. It means that the volume of airspace is different according to the in-time operation of the aircraft. The conformance monitoring airspace is centered on the cleared flight track and its shape is bounded by the most uncertainty direction.
- Data link: For air-to-air, air-to-ground and ground-to-ground communications, TBO relies on multiple data links, ranging from delivery of advisory information to the actual loading of a new 4DT that affects the flight path of the aircraft. An aircraft may be connected to network-centric operations over multiple data links, but there is a specified, performance-driven path for the critical communication of 4DT information. The ANSP uses ADS-B position reporting for lateral and longitudinal progress, altitude for vertical and tools that measure the time progression for the flight track, and data link provides aircraft intent information.
- Time-Based Metering (TBM): TBM is a systemic means to dynamically manage demand/capacity imbalances via time, versus traditional static miles-in-trail (MIT) traffic management techniques. TBM can be applied in either the arrival and/or en route/departure domains. Controllers meter aircraft to meet TMA assigned STAs using the time information displayed in the meter list shown on the controller displays.
- Time-Based Flow Management (TBFM): TBFM expands the role and scope of TBM operations to provide benefits more widely throughout the NAS. TBFM will achieve and close the performance gap in transitioning TMA through the follow-on IES system fulfilling operational user needs.
- Horizontal performance: The most mature element of performance-based operations is satellite-based navigation and the use of area navigation, or RNAV. When RNAV is combined with performance monitoring and alerting in the cockpit, the aircraft can support RNP. Typical RNP values expected are RNP 10, RNP 4, RNP 2, RNP 1, RNP 0.3, and RNP 0.1. These lateral boundaries represent the 95 percent containment area. RNP is expressed in terms of lateral displacement in nautical miles (nm). Two times the RNP tolerance represents the safe containment area.

4. General Aspects of NextGen

The goal of NextGen is to significantly increase the safety, security, capacity, efficiency, and environmental compatibility of air transportation operations, and by doing so, to improve the overall economic well-being of the country. These benefits can be achieved through a combination of new procedures and advances in the technology deployed to manage passenger, air cargo, and air traffic operations [12].

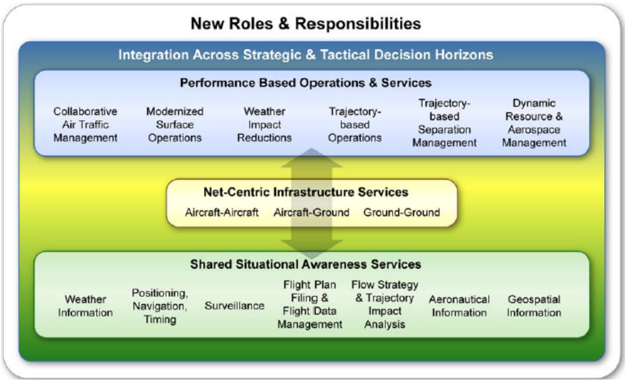

Fig. 1: Air Traffic Management Transformation [12].

As it has been explained above, NextGen's **TBO** concept is based on a combination of Closed and Open trajectories. TBO can operate with any precision, and that it is the predictability of conformance to the 4DT that is more important than the numerical value, but this value must be known. What TBO cannot tolerate is variability in performance [10].

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. 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) [11].

There are two types of time: absolute and relative. In absolute time, the aircraft is proceeding to a defined location in space at a prescribed time. In relative time, the aircraft is following another aircraft and is required to stay behind that aircraft measured in seconds or minutes. In high-density airport traffic situations, TBO delivers aircraft to each metering point of the path a variability of ±seconds, this value is based on reducing the arrival variability between operations to gain increased throughput, and requires research to achieve the actual value for performance [10].

Flight planning aspects of TBO are not detailed enough, although the concepts are under development TBO starts well before the flight plan and represents a significant level of coordination, information gathering, and calculation of fuel requirements to support the 4DT. The flight plan is a conglomeration of various aspects of the flight. It must navigate several areas to be a complete document. But many times, outside influences force changes that must be addressed, and the flight plan, by design, is a living document. It is frequently renegotiated with the AOC, flight deck, and ANSP [10].

In the **high-density Arrival/Departure Operations** scenario, it is necessary to achieve peak throughput performance at the busiest airports and in the busiest airspace. New procedures to improve airport surface movements, reduce spacing and separation requirements in place today, and better manage overall flows in and out of busy metropolitan airspace provide maximum use of the highest-demand airports.

Each **TBO scenario** is based on gate-to-gate flight segments that cover surface movement: takeoff/climb, en route, arrival, approach, touchdown and taxi-in [10].

- Surface movement: The intent is to reduce variability in surface movement by using trajectories with a single takeoff time performance working back to pushback, or start of taxi from a hardstand or gate. This expected takeoff time for surface movement extends the

TBO concept into flight with the actual takeoff time resetting the 4DT.

- Takeoff and Climb: The variability in climb will require protection of vertical blocks of airspace bounded by the uncertainty of climb performance; it depends on the aircraft type and takeoff weight. This will allow less uncertainty in providing airspace for the climb. This new concept will help save fuel, emissions, and optimize the operator/user's profile.
- En-route Cruise: Refinements will include a tighter coupling between airborne and ground automation, greater use of merging and spacing, some self separation, and a reduction in separation standards to three miles in some airspace based on navigation improvements and use of ADS-B.
- Arrival/Approach and Landing: Consistent with integrated arrival/departure airspace management there will be a number of pre-defined configurations for arrival/departure airspace. At high-density terminal areas, arrival time-based metering providing CTAs to RTA-capable, FMS-equipped aircraft, and there are metering advisories to controllers, RNAV/RNP procedures within the transition and terminal airspace is expected to be fully exploited, allowing for greater flexibility and increased throughput.

A very important concept of NextGen is the information-sharing component known as net centric infrastructure services or **net-centricity**. Its features allow NextGen to adapt to growth in operations as well as shifts in demand. This result in a system that minimizes duplication, achieves integration, and facilitates the concepts of distributed decision-making by ensuring that all decision elements, have exactly the same information upon which to base a decision, independent of when or where the decision is made [12].

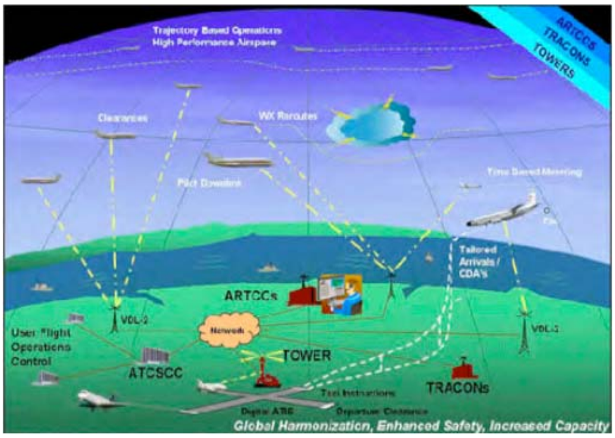

Fig. 2: FAA Data Communication ConOps Representation [11].

By assimilating **weather** into decision-making, weather information becomes an enabler for optimizing NextGen operations. Directly applying probabilistic weather information to ATM decision tools increases the effective use of weather information and minimizes the adverse effects of weather on operations [10].

Position, Navigation and Timing services (**PNT**) are provided where and when needed, in accordance with demand and safety considerations, to enable reliable aircraft operations in nearly all conditions. Instead of being driven by the geographic location of a ground-based navigational aid (NAVAID), PNT services allow operators to define the desired flight path based on their own objectives [12].

5. General Aspects of SESAR

SESAR outlines the essential operational and technological changes that are foreseen to provide SESAR contributions (besides other initiatives) to achieving the European SES performance objectives.

SESAR aims at developing the new generation air traffic management system capable of ensuring safety and efficiency of air transport throughout Europe over the next 30 years.

The main aspects addressed are related to:

- Queue management.
- Trajectory Based Operations.

Queue Management

Queue Management is the SESAR equivalent of Traffic Flow Management (TFM) and is described in terms of the existing developmental tools AMAN (Arrival Management) and DMAN (Departure Management). These constrained resource sequencing and delay assignment tools would operate independently at their respective terminals until overlap of controlled times due to exceptional demand/capacity mismatch. At that point, Collaborative Decision Making (CDM) is assumed to take over [17].

Tactical queue management aims to [14]:

- provide more efficient trajectories, thereby reducing fuel burn and emissions;
- improve wake vortex sequencing, thereby increasing runway throughput;
- improve the organization of the traffic, thereby increasing controller workload.

The main method of achieving these aims is by earlier planning of arrival and departure operations. Extending the AMAN Horizon therefore seeks to further increase these benefits. However, this is constrained by the need to adapt to uncertainties in runway conditions, meteorological conditions, and operations.

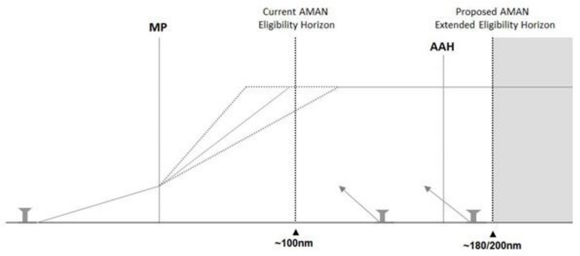

Fig. 3: AMAN Eligibility Horizon Extended from ~100nm to ~180-200nm [18]

As it has been mentioned before, the scope of Arrival Queue Management corresponds to the integration of arrivals into an efficient landing sequence. Formally, an "efficient landing sequence" may refer to a defined trade-off between capacity and flight efficiency or environmental objectives. This involves [14]:

- Planning the sequence (i.e. allocate landing runway if needed, define sequence order and required spacing);
- Implementing the sequence (including order and appropriate spacing); i.e. building it, and maintaining it.

Due to the progressive nature of the integration of arrival flows, intermediate sequences must generally be built, and traffic flows synchronized in view of achieving the global sequence towards the concerned runway(s). The above tasks may apply to an intermediate sequence (typically in En Route or E-TMA) or to the final runway sequence (in TMA or Approach airspace).

For the purpose of managing a sequence of arrival flights, to the runway or to an intermediate merging point, the following aspects can be distinguished [14]:

- Sequencing, i.e. ordering flights in the arrival sequence;
- Metering, i.e. regulating/smoothing the flows in order to anticipate their subsequent integration according to downstream capacity constraints;
- Providing separation between aircraft in the sequence.

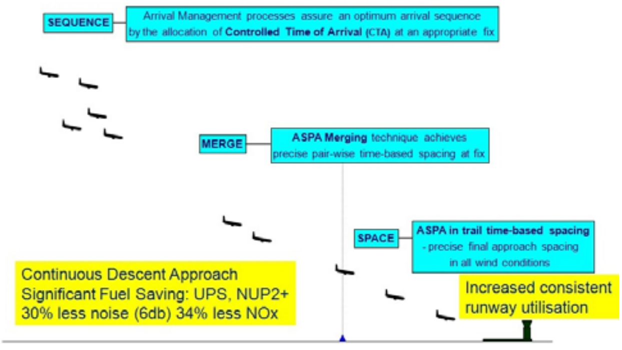

Fig 4: Queue Management [15]

A range of separation modes is available in SESAR to address various operational circumstances. These modes fall into 3 broad categories [13]:

- Conventional modes: modes that are essentially unchanged by SESAR.
- New ANSP Modes: new modes envisaged for SESAR that are purely applied by ATC
    - Precision Trajectory Clearances
    - Trajectory Control by Ground Based Speed Adjustment
- New Airborne Modes: new modes that involve the aircraft and in which the pilot is the separator either by delegation or, in unmanaged airspace, as the standard case.
    - Cooperative separation (ASAS-Separation)
    - Self-separation (ASAS-Self Separation)

Trajectory Based Operations

The SESAR target concept of operations 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, collaborative decision making processes and tactical operations will always be based on the latest trajectory data. A trajectory integrating ATM and airport constraints is elaborated and agreed for each flight, resulting in the trajectory that a user agrees to fly and the ANSP and Airports agree to facilitate.

This trajectory-based approach reconfirms three important characteristics of trajectories while also enhancing their significance and effects as a result of much improved data quality:

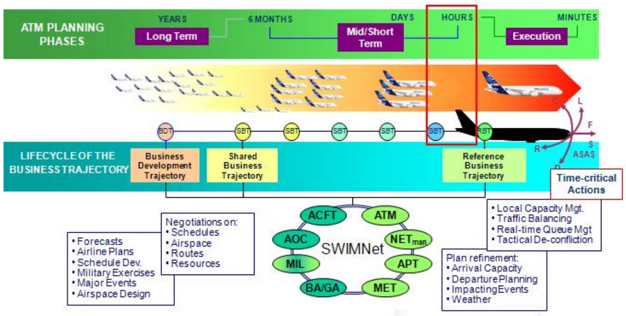

Fig. 5: Trajectories in all the ATM processes [15]

- **The Business/Mission Trajectory: Expressing the Specific Needs of Airspace Users [13]**

The trajectories represent the business/mission intentions of the airspace users. By safeguarding the integrity of the trajectories and minimising changes the concept ensures the best outcome for all users. Airlines, business, General Aviation and the military all have ‘business’ or ‘mission’ intentions, even if the terminology is different and their specific trajectories have different characteristics. The trajectory is always associated with all the other data needed to describe the flight. If the trajectory is based on cruise climb, this will be facilitated.

- **Trajectory Ownership [13]**

The airspace user owns the Business Trajectory, thus in normal circumstances the users have primary responsibility over their operation. In circumstances where ATM constraints (including those arising from infrastructural and environmental restrictions/regulations) need to be applied, the resolution that achieves the best business / mission outcome within these constraints is left to the individual user.
Typically constraints will be generated / released and taken into account by various ATM partners through CDM processes. The owners’ prerogatives do not affect ATC or Pilot tactical decision processes.

• 4D trajectories [13]

The business/mission trajectories will be described as well as executed with the required precision in all 4 dimensions. The trajectories will be shared and updated from the source(s) best suited to the prevailing operational circumstances and capabilities and the sources include the aircraft systems, flight operational control systems and ANSP trajectory predictors. The ability to generate trajectories in the ATM system from flight plan data will be retained for those flights that are unable to comply with SESAR trajectory management requirements.

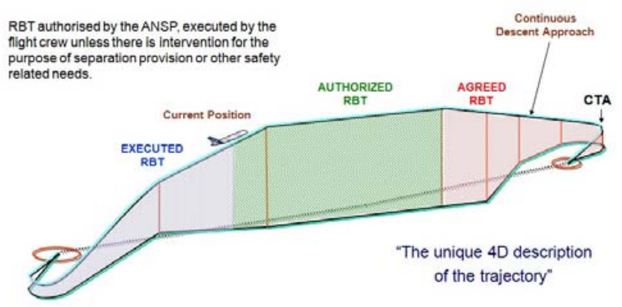

Fig. 6: Reference Business Trajectory (RBT) [15]

6. *Nextgen versus SESAR*

SESAR and NextGen differ in their implementation frameworks because they are tied to very different European and US industry structures.

NextGen tends to be closely tied to government in a hierarchical framework whereas SESAR appears to be a more collaborative approach, including, but not limited to, ATM ground activities. NextGen, while having a longer timeline to implement, takes a broader approach to transforming the entire air transportation system, including ground activities.

The main aspects covered by both concepts are the following:

- Flow Management: All stakeholders share the necessary information to ensure that the set of ATM services can be offered and delivered to the user. A set of Collaborative Decision Making must be integrated in the process.
- Weather: The main difference between SESAR and NextGen is the manner in which the weather data are obtained. SESAR will provide weather data coming from traditional sources, whereas NextGen get the data from a government service.
- Infraestructure Service: The SESAR concept is called SWIM, while NextGen introduce the data coming from a robust infrastructure.
- Information Servicies: A difference between the two organizations lies in the treatment of information. SESAR, being a more decentralized model, calls for the establishment of a Reference Model for data and data standardization. NextGen, envisioning a more centralized government approach
- SWIM: SESAR consideres that any aircraft is part of the SWIM, whereas NextGen introduces the concept of aircraft as a node.

For SESAR and Nextgen concepts, the change to operations includes shared situational awareness for more collaborative decision making and TBOs [7].

Some of the aspects addressed by NextGen are showed in the next figure.

Retain U.S. Leadership in Global Aviation	Expand Capacity
• Retain role as world leader in aviation • Reduce costs of aviation • Enable services tailored to traveler and shipper needs • Encourage performance-based, harmonized global standards for U.S. products and services	• Satisfy future growth in demand and operational diversity • Reduce transit time and increase predictability • Minimize impact of weather and other disruptions
Ensure Safety	**Protect the Environment**
• Maintain aviation's record as safest mode of transportation • Improve level of safety of U.S. air transportation system • Increase level of safety of worldwide air transportation system	• Reduce noise, emissions, and fuel consumption • Balance aviation's environmental impacts with other societal objectives
Ensure Our National Defense	**Secure the Nation**
• Provide for common defense while minimizing civilian constraints • Coordinate a national response to threats • Ensure global access to civilian airspace	• Mitigate new and varied threats • Ensure security efficiently serves demand • Tailor strategies to threats, balancing costs and privacy issues • Ensure traveler and shipper confidence in system security

Fig. 7: NextGen Goals and Objectives [12].

7. Conclusions

In this paper the concepts related to Arrival Traffic Synchronisation Concept of Operations and 4D TBOs (Trajectory Based Operations) have been addressed. Both of these concepts have been introduced from the point of view of NextGen and SESAR programs.

Both, SESAR and NextGen differ in their implementation frameworks because they are tied to very different European and US industry structures. Both organizations are embracing basic network centric concepts. The way in which each organization is implementing these is taking a different form.

The common vision of SESAR and NextGen organizations is to integrate and implement new technologies to improve air traffic management (ATM) performance. Both organizations combine increased automation with new procedures to achieve safety, capacity, environmental, and security benefits.

The main aspects related to both concepts have been addressed in this paper. Generally speaking several differences must be approach in medium term. But, in general terms, NextGen tends to be linked to government in a hierarchical framework, whereas SESAR seems to be a more collaborative approach, including ATM ground activities.

SESAR and the NextGen both have the same basic aim. Mainly this aim is to get more efficient use of airspace and better air safety. The implementation frameworks for each are different. The European approach based on a single, multi-stakeholder consortium and the US model requiring close internal coordination between various governments programs to ensure interoperability of components. The aspects related to interoperability must be addressed to avoid major differences.

Finally, the concepts introduced by both organizations must be closer in order to get a suitable arrival concept with the same aim. They introduce very similar concepts, and they require the total stakeholder involvement in the update processes.

Acknowledgements

This work has been developed under the Spanish Centre for Industrial Technological Development (CDTI) project INNPRONTA-ADAM in cooperation with Boeing Research & Technology Europe.

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