International Civil Aviation Organization

Thirty-Sixth Meeting of the Asia/Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG/36)

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Agenda Item 2: **Global and Inter Regional Activities**

TRAJECTORY BASED OPERATIONS (TBO): EXPLORING THE EUROPEAN EXPERIENCE AND POTENTIAL SYNERGIES FOR ASIA PACIFIC

(Presented by EASA)

SUMMARY

This paper outlines Europe's approach to Trajectory-Based Operations (TBO), which is embedded within a phased and collaborative roadmap under the SESAR and Single European Sky (SES) frameworks. It presents the European experience as one possible reference point for addressing shared air traffic management (ATM) challenges, such as capacity constraints, environmental sustainability, and operational efficiency. The paper also identifies potential areas for technical cooperation and dialogue with Asia Pacific stakeholders.

Strategic Objectives:

B*:* ***Air Navigation Capacity and Efficiency*** *— Increase the capacity and improve the efficiency of the global aviation system*

E*:* ***Environmental Protection*** *— Minimize the adverse environment effects of civil aviation activities.*

1. INTRODUCTION

1.1 Trajectory-Based Operations (TBO) represents a paradigm shift in air traffic management, centring on the entire four-dimensional trajectory of a flight – from planning through to execution. As recognised by ICAO, TBO seeks to enhance safety, predictability, and efficiency by enabling continuous, data-driven adjustments to aircraft trajectories.

1.2 While the pace and pathways of TBO implementation vary globally, Europe has taken a structured, long-term approach under the SESAR programme and the Single European Sky (SES) initiative.

1.3 This paper presents the European experience and highlights potential opportunities for knowledge exchange and voluntary collaboration in the Asia Pacific region.

2.   DISCUSSION

The European Approach to TBO

2.1   In Europe, TBO is a key component of a broad, strategic framework for modernising Air Traffic Management (ATM). This framework, embodied in the European ATM Master Plan – commonly referred to as the "plan" – lays out the vision and priorities for developing the Digital European Sky[1], with the ultimate aim of making Europe among the most efficient and environmentally friendly airspaces in the world by 2045.

2.2   The plan places digital innovation and environmental sustainability at its heart. It is built around five strategic technological pillars driving transformational change: TBO, increased data volumes, enhanced automation, advanced human-machine collaboration, and dynamic airspace management. Complementing these pillars is a transition toward a cloud-based service-oriented architecture (SOA). This shift – from managing physical assets to delivering agile services – accelerates the deployment of new features and enhances the seamless interoperability of operations, airspace systems, and technologies across air navigation service providers (ANSPs) and their partners.

2.3   Since 2008, the SESAR programme has driven extensive research and development to advance TBO, resulting in measurable improvements[2], such as increased sector capacity and reduced controller workload, and it has successfully paved the way for cross-border operations with a unified operational vision. Complementing these research activities, EUROCONTROL, as the Network Manager, implemented the initial set of FF-ICE/R1 services in 2024, laying the operational foundation for TBO through improved pre-departure trajectory sharing and collaborative planning — becoming the global pioneer in implementing this capability.

2.4   The 2025 update of the European ATM Master Plan now incorporates a comprehensive TBO roadmap (**Figure 1**), which has been shared with the Air Traffic Management Requirements and Performance Panel (ATMRPP)[3] in the form of an Information Paper, as part of ongoing technical dialogue on ATM evolution. While the roadmap reflects European planning assumptions and priorities, it identifies globally relevant concepts and highlights the importance of robust international cooperation for successful implementation. Rather than redefining ICAO's conceptual framework, the roadmap introduces three broad stakeholder groupings – network, ATC, and regional TBO – as a means to help streamline research and implementation activities within Europe. It sets out a phased approach towards advanced TBO, with defined milestones and coordinated roles, and may serve as a reference point to inform regional efforts towards greater interoperability and harmonisation. Key aspects of the European TBO roadmap include:

a)   *Phase 1 (by 2030):* Establishes foundational regulatory and operational frameworks through the Common Project 1 (CP1) regulation[4]. This phase emphasises integrating airport operations plan (AOP) and iAOP airport into the network, deploying the first sets of Flight and Flow Information for a Collaborative Environment (FF-ICE) services, and initial trajectory information sharing.

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[1] https://www.easa.europa.eu/en/domains/environment/eaer/air-traffic-management-and-operations/sesar-towards-digital-european-sky
[2] https://www.eurocontrol.int/event/global-tbo-symposium
[3] https://www.icao.int/about-icao/AirNavigationCommission/Pages/anc-technical-panels.aspx
[4] The Common Project (CP1) regulation is the European Commission Implementing Regulation (EU) 2021/116. All European regulations are available online in all official EU languages at https://eur-lex.europa.eu/

b)   *Phase 2 (by 2035):* This phase involves the implementation of enhanced conflict detection and resolution tools aided by ADS-C data downlinked from the aircraft, implementation of upgraded CPDLC clearances in en-route, dynamic Route Availability Document (RAD), increased provision of trajectory updates by ANSPs and airports to the network, the full deployment of the improved operational air traffic flight plan, full FF-ICE/R1 (beyond CP1 services), and seamless cross-border ATC–ATC coordination.

c)   *Phase 3 (by 2045):* Moves toward implementing SESAR's advanced TBO functionalities, with the aim to optimise both flight planning and execution. This phase will harness the full potential of FF-ICE, including the deployment of FF-ICE/Release 2 (R2) – an important evolution enabling richer and more dynamic trajectory data exchange. Other advancements include the use of advanced ATS-B2 with complex clearance capabilities extending into lower airspace and airport surfaces, real-time synchronisation of network trajectories, integration of connected systems such as the Flight Management System (FMS), Electronic Flight Bag (EFB), and Airline Operations Communications (AOC), digitisation of Letters of Agreement (LoA), and a shift toward a dynamic "RAD by exception" model – together creating a more agile and efficient air traffic management ecosystem.

2.5   The European TBO roadmap illustrated in **Figure 1** provides a timeline for development and deployment activities addressing network, air traffic control, and intra-regional aspects of TBO, from the 2025 deployment baseline toward the 2045 vision. To support implementation planning, the European ATM Master Plan introduces three stakeholder-based groupings – Network TBO, ATC TBO, and Regional TBO – which serve to organise roles and responsibilities across the various phases of flight. While these categories are not formal subdivisions within ICAO's global TBO Concept, they are consistent with it and provide a practical means of structuring deployment activities within Europe. Specifically:

a)   *Network TBO* encompasses trajectory management between flight operations centres (FOC) and the Network Manager (NM), supported by local ATFM units at ANSPs, particularly during the pre-departure and post-departure phases.

b)   *ATC TBO* involves trajectory management between flight decks and ATC units during the tactical (post-departure) phase through an increase in the level of automation of ATC enabled by the advanced use of CPDLC (Controller-Pilot Datalink Communication).

c)   *Regional TBO* covers intra-European coordination between the NM, ANSPs, and airports – typically not involving the FOC or flight deck – to enhance pre-departure and post-departure synchronisation across regional nodes.

2.6   These three areas help facilitate a systematic and interoperable implementation of TBO in alignment with ICAO's vision, while reflecting the organisational realities of the European ATM environment.
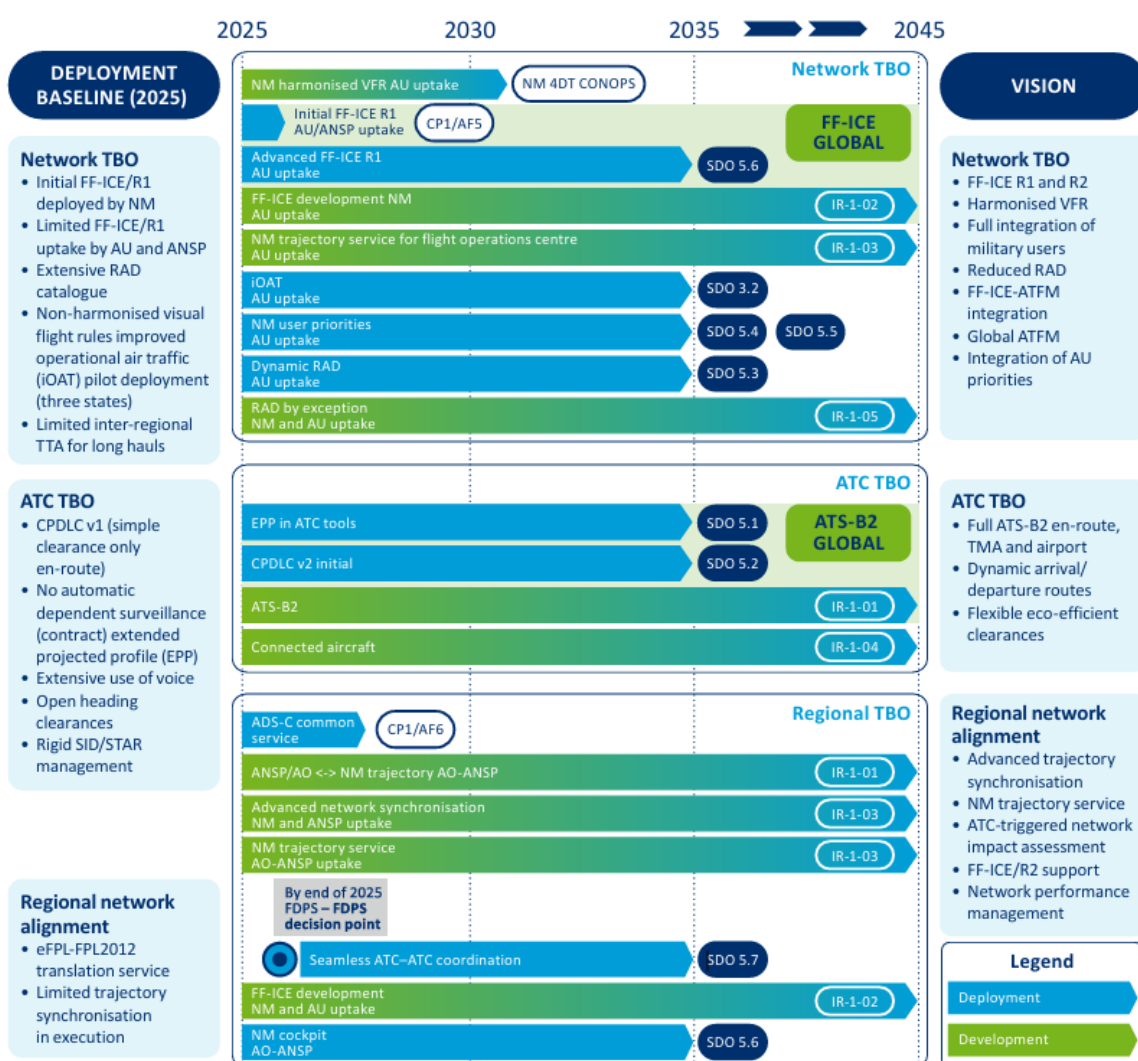
Figure 1. European TBO Roadmap

2.7   The roadmap illustrates that although the implementation of TBO is technology agnostic, its success depends on robust improvements in communications. By leveraging SWIM-enabled data sharing and real-time trajectory management tools, Europe aims to achieve a high degree of integration across the Network Manager (NM), ANSPs, and airspace users.

2.8   Europe's model emphasises the development of ATC automation in the ATC TBO thread, involving ANSPs and the flight deck, in parallel with the Network TBO thread, where responsibilities are shared among diverse stakeholders – including flight operations centres, local ATFM units, and airspace users in an integrated approach supported by EUROCONTROL's role as the Regional Network Manager. The simultaneous progression of ATC TBO and Network TBO ensures that every phase of a flight – whether managed at the pre-departure, en-route, or strategic and tactical post-departure stage – is optimised for safety and efficiency.

Relevance for the Asia Pacific Region

2.9   The Asia Pacific region is witnessing an unprecedented surge in air travel, which brings with it significant challenges. This situation highlights the importance of optimising capacity, harmonising diverse traffic-management approaches, and modernising operational procedures, ensuring that regional initiatives, including TBO, are aligned with the ICAO's Global Air Navigation Plan (GANP) and the Asia/Pacific Seamless ANS Plan. As the ICAO-recognised regional platform for promoting seamless and harmonised ATM in the APAC region, APANPIRG (Asia/Pacific Air Navigation Planning and Implementation Regional Group) plays a central coordinating role in the development and implementation of TBO. APANPIRG provides the governance framework and, through its sub-groups, ensures effective monitoring and decision-making to align regional efforts with ICAO's GANP and the Seamless ANS Plan.

2.10   While TBO can support safety and efficiency, its success depends on consistent ANSP coordination and reliable data quality. Acknowledging the need for effective coordination among ANSPs, the Asia and Pacific (APAC) Air Navigation Service Provider Committee (AAC) was established in 2022 to strengthen collaboration between ANSPs and their respective aviation authorities. The AAC serves as a collaborative forum where ANSPs exchange best practices, address operational challenges, and propose solutions. Technical discussions on TBO capability development are elevated through this platform and subsequently reported to APANPIRG, which reviews the inputs, incorporates them into regional planning, and issues conclusions and decisions that provide guidance to States and ANSPs.

2.11   Implementing TBO in the Asia Pacific region offers regionally relevant benefits that respond to the Asia Pacific's operational and geographic diversity. First, TBO can address capacity imbalances in rapidly growing airspaces by enabling more precise flight planning and real-time trajectory adjustments both strategically (Network TBO) and tactically (ATC TBO). The enhanced accuracy in flight operations not only enhances safety but also reduces delays and fuel consumption, contributing to environmental sustainability. In addition, TBO leverages advanced data-sharing frameworks such as SWIM and FF-ICE (supporting Network TBO) and ATS B2 (supporting ATC TBO), which can be particularly effective in resolving APAC's decentralised information flows and ensuring real-time, coordinated decision-making despite varying regional or national standards.

2.12   Finally, as APAC economies place a growing emphasis on environmental sustainability, TBO's ability to optimise routes and reduce fuel burn not only cuts operational costs but also supports regional green initiatives. These tailored benefits uniquely position TBO as a critical enabler for modernising ATM across the Asia Pacific region.

Supporting Cooperation Between Europe and the Asia Pacific

2.13   The European Union welcomes opportunities to collaborate with APAC partners by providing:

a)   Technical and regulatory support: Sharing insights from Europe's phased roadmap – ranging from the CP1 regulatory measures to advanced connected aircraft integration – can help APAC stakeholders modernise their operational systems and update their ATM plans. Initiatives such as the EU-ASEAN Sustainable Connectivity Package (SCOPE) Aviation Partnership Project (APP)[5], along with support from EUROCONTROL and the SESAR expertise network, can support pilot projects and capacity-building initiatives.

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[5] https://www.easa.europa.eu/en/domains/international-cooperation/technical-cooperation-projects/eu-asean-sustainable-connectivity

      b)   Framework for collaboration: By promoting EU involvement in the APANPIRG contributory bodies and related Ad Hoc Groups, a structured platform for continuous technical and regulatory dialogue can be established. This would facilitate the exchange of best practices and foster gradual harmonisation between European and APAC systems with global standards.

3. ACTION BY THE CONFERENCE

3.1   The Meeting is invited to:

      a)   Note the European approach to TBO as one of several global experiences that may offer useful insights for modernising air traffic management.

      b)   Encourage bilateral and multilateral exchanges between APAC and European stakeholders, including technical workshops under the APANPIRG contributory bodies, such as the ATM/SG, ATFM and A-CDM/SG, and related Ad Hoc Groups.

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