International Civil Aviation Organization

WORKING PAPER

TWELFTH AIR NAVIGATION CONFERENCE

Montréal, 19 to 30 November 2012

Agenda Item 5: Efficient flight paths – through trajectory-based operations
5.2: Improved traffic synchronization through 4D trajectory-based operations (TBO)

AVIATION SYSTEM BLOCK UPGRADE MODULES RELATING TO TRAJECTORY-BASED OPERATIONS

(Presented by the Secretariat)

EXECUTIVE SUMMARY

The 37th Session of the ICAO Assembly directed ICAO to increase its efforts to meet global needs for airspace interoperability while maintaining its focus on safety. To this end, a planning framework for global harmonization and interoperability named the aviation system block upgrades (ASBU) is proposed to the Conference for incorporation into the Fourth Edition of the *Global Air Navigation Plan.*

The ASBU framework includes modules over a series of blocks, supported by technology roadmaps, which serve to progressively enhance many aspects of civil aviation operations. This paper presents the modules relating to trajectory-based operations (TBO), which comprise:

a) B0-40 & B1-40 – Data link surveillance and communications supporting TBO; and

b) B3-05 – 4D trajectory-based operations – 4D TRAD.

Action: The Conference is invited to agree to the recommendation in paragraph 3.

Strategic Objectives:	This working paper relates to the Safety Strategic Objective.
Financial implications:	The cost impacts for these modules are expected to be moderate and are anticipated to be borne predominantly by the ANSPs on the basis that pre-requisite operator capabilities, such as performance-based navigation (PBN) and controller-pilot data link communications (CPDLC), are attributable to those programs rather than to TBO. However, based on preliminary indications, the benefits of implementing these modules could be substantial for overall global system performance and, when implemented, the benefits are expected to far outweigh the costs.
References:	Doc 9958, *Assembly Resolutions in Force (as of 8 October 2010)* Doc 9854, *Global Air Traffic Management Operational Concept* Doc 9750, *Global Air Navigation Plan* AN-Conf/12-WP/3 AN-Conf/12-WP/18

1. INTRODUCTION

1.1 The next edition of the *Global Air Navigation Plan* (Doc 9750, GANP), will be presented to the ICAO Assembly in 2013 for approval. The draft GANP, and the aviation system block upgrade (ASBU) strategy it establishes, proposes that future air navigation technology and procedure improvements are organized and based on a consultative strategic approach that coordinates specific global performance capabilities and the flexible upgrade timelines associated with each component.

1.2 The ASBU modules are organized into flexible and scalable building blocks that can be implemented depending on the operational need, while recognizing that implementation of a particular module is not mandatory in all areas or circumstances. The approach adopted is not limiting and recognizes that deployment in addition to the material described in the ASBUs may also take place or be necessary. The broad timescales associated with the ASBU framework (Block 0 = 2013, Block 1 = 2018, Block 2 = 2023, Block 3 = 2028) are intended only to depict the initial readiness of all components, including ICAO Standards and Recommended practices (SARPS), needed for deployment and do not imply a mandated State or regional implementation timeframe. The ASBU framework with supporting technology roadmaps ensures that State and regional implementation planning and deployment activities can be undertaken with the confidence that all components necessary for a particular deployment will be available within the ASBU dates mentioned.

1.3 A move from the present air traffic management (ATM) model (where the present location of the aircraft is known) to a trajectory-based management concept (where the future location of the aircraft is also known) is fundamental to increasing the efficiency of flight paths. By using shared dynamic trajectory information to facilitate wide area collaborative decision-making (CDM) between adjacent air navigation service providers (ANSPs) in the same and neighbouring flight information regions (FIRs), the ATM system will be able to analyze and accurately predict future situations based on three-dimensional and ultimately four-dimensional parameters including time. To support the steps towards 4D trajectory-based operations the following two planning threads, as described in the appendices to this paper and illustrated in the attached Figure 1, are proposed for inclusion in the ASBU framework:

a) data link surveillance and communications supporting TBO; and

b) 4D trajectory-based operations (4D TRAD).

2. ASBU MODULES – TRAJECTORY BASED OPERATIONS

Overall strategy

2.1 The Global ATM concept, implemented through regional programmes, foresees air traffic control (ATC) becoming traffic management by trajectory. The aim is to increase user flexibility and maximize operating efficiencies while increasing system capacity and improving safety levels. The future ATM system is expected to evolve to support concept requirements which will:

a) entail systematic sharing of aircraft trajectory data between actors in the ATM process;

b) ensure that all actors have a common view of a flight and have access to the most accurate data available;

c) allow operations respecting the airspace users' individual business cases; and

d) improve the performance of aeronautical search and rescue services.

2.2 The deployment of 4D TRAD globally based on Block 3 timeframes will see the combination of many of the capabilities previously implemented via the ASBU modules, including those which optimize individual trajectories, traffic flows and the use of scarce resources such as airspace and airport movement areas, into a holistic operational environment. Mixed levels of aircraft performance and air crew authorizations could be accommodated by real-time sharing of accurate data through mechanisms such as flight and flow – information for a collaborative environment (FF-ICE) and system-wide information management (SWIM). Aircraft can communicate actual and intent information to the ATC automation and the automated ATC problem prediction and resolution capabilities will leverage airborne capabilities by supporting user-preferred flight plans and minimizing changes to those plans as aircraft traverse the airspace. The basis for all operations should be the accurate four dimensional trajectories that are continuously shared amongst affected stakeholders.

2.3 The required steps towards 4D TRAD development are directly linked to the level of maturity of the technologies and operational improvements required, with all steps driven by the need to optimize the flight profile in all phases. Elemental requirements are those related to the precision of navigation in all dimensions including time and the capacity to continuously communicate two way trajectory data between the airborne and ground platforms. From Block 3, the aircraft should be able to adhere strictly to, and exchange information about, its 4D trajectory. Ground systems should support traffic flow management automation and time-based metering, integrated sequencing and augmented surveillance capabilities to continuously predict the demand and capacity of all ATM system resources and generate optimal solutions.

Incremental development

2.4 Starting with Block 0, the structured optimization of flight profiles will be achieved by using PBN-based airspace and arrival/departure procedures to allow aircraft to fly the preferred profile using continuous descent operations (CDO) and continuous climb operations (CCO). CDO and CCO are functional subsets of overall trajectory-based operations (TBO); and are described in greater detail in AN-Conf/12-WP/18.

2.5 The implementation of an initial set of data link applications for surveillance and communications which support flexible routing, reduced separation and improved safety is a first step for close air-to-ground coordination. Automatic dependent surveillance — contract (ADS-C) and controller-pilot data link communications (CPDLC) capabilities over oceanic and remote areas, as well as continental CPDLC, are essential components of this initial set of data link applications.

2.6 In the next phase (Block 1), in addition to accurate lateral navigation, vertical navigation capabilities contribute to terminal airspace design by requiring aircraft to also maintain an accurate vertical path during descent, allowing construction of vertically bounded corridors to support traffic flows. The download of trajectory information enabled by additional air-ground data link applications coupled with use of airborne required time of arrival (RTA) capabilities should enable de-confliction of traffic merging or 'choke' points and permit traffic synchronisation and monitoring. Additional operational improvements result through data link operational terminal information service (D-OTIS), departure clearance (DCL) and data link taxi (DTAXI) applications.

2.7 With Block 2, arrival procedures are further enhanced to include CDO with 4D elements. In busy airspace, these enhancements will incorporate airspace complexity, air traffic workload and procedure design elements. The aircraft's ability to accurately fly an optimized arrival, coupled with the state and intent information sent from the aircraft to ATC automation, will increase accuracy of trajectory modelling and problem prediction. ATM automation will continuously review the demand and capacity of all system resources and identify when the congestion risk for any particular resource (e.g. airport or airspace) is predicted to exceed a pre-determined threshold. Action will then be proposed, for example in the form of just-in-time reroutes and metering times, to alleviate congested resources.

Technology requirements

2.8 Trajectory based operations need a performance-based navigation (PBN) compatible operational environment. As such, PBN technology requirements with enhanced avionics capabilities will also serve the TBO environment. Evolving data link to ATN Baseline 2 for air-ground data communication and enhancing performance of ground-ground communications (including AIDC) towards internet protocol are necessary actions. The development of standards and coordinated implementation of a common time reference for all systems, in the air and on the ground, would provide a basis for the synchronisation of all operational information.

2.9 From Block 2, where all improvements are related to close coordination, synchronised operations and full use of 4D trajectories, the implementation of SWIM and full FF-ICE will play a key role. Technology requirements and the linkages between the various Blocks and modules of the ASBU framework are detailed in the Technology Roadmaps that constitute part of the draft Fourth Edition of the *Global Air Navigation Plan* (GANP) (AN-Conf/12-WP/3 refers).

Deployment considerations

2.10 Deployment of TBO can take place on a local or regional basis and benefits are immediate. However, to deliver the full promise of 4D TRAD, widespread implementation is necessary, preferably on a global basis. The reliance on area navigation (RNAV) and required navigation performance (RNP) capabilities requires the continued development of PBN provisions as well as increased PBN implementation worldwide. ICAO provisions and guidance material are also necessary to support trajectory modelling and trajectory information exchange, and enhanced provisions for data link applications and messages to serve a common continental and oceanic baseline are required.

2.11 The routine exchange of complex ATC clearances on ground-ground and air-ground links is an everyday aspect of TBO that needs to be completed seamlessly. Full implementation of ATS interfacility data communications (AIDC) as the normal means of automated ground-ground communication between ATS units are an essential first step.

2.12 Airborne and ground equipage enabling 4D applications are essential to ensure interoperability. Similarly, the transition from the 2012 flight plan through FF-ICE/1 into FIXM and Flight Object, and ultimately to SWIM, will need to be carefully managed to progressively benefit from TBO.

3. **CONCLUSION**

3.1 The ASBUs describe ways to apply the concepts defined in the *Global Air Traffic Management Operational Concept* (Doc 9854) to achieve local and regional performance improvements. The ultimate goal is global interoperability. Safety and efficiency demand this level of interoperability and harmonization, which must be achieved at a reasonable cost with commensurate benefits. The Conference is invited to agree to the following recommendation:

Recommendation 5/x - ICAO aviation system block upgrades (ASBUs) relating to trajectory-based operations

That the Conference:

a) urge States to support development by ICAO of Standards and Recommended Practices and guidance material related to trajectory-based operations;

b) recommend that States implement, according to their operational needs, the aviation system block upgrade module relating to trajectory-based operations included in Block 0, as presented in Appendix A;

c) endorse the aviation system block upgrade module relating to trajectory-based operations included in Block 1, as presented in Appendix B, and recommend that ICAO use it as the basis of its work programme on the subject;

d) endorse the aviation system block upgrade module relating to 4D trajectory-based operations included in Block 3, as presented in Appendix C, as the strategic direction for this subject; and

e) request ICAO to include, following further development and editorial review, the aviation system block upgrade module relating to 4D trajectory-based operations in the draft Fourth Edition of the *Global Air Navigation Plan*.

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Figure 1. Block upgrade modules covered in this working paper