International Civil Aviation Organization

WORKING PAPER

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

4D TRAJECTORY OPERATIONS IN SESAR

(Presented by the Presidency of the European Union on behalf of the European Union and its Member States[1]; by the other Member States of the European Civil Aviation Conference[2]; and by the Member States of EUROCONTROL)

SUMMARY

This paper provides a high level introduction to the concept of 4D trajectory operations, as described in the ICAO Global ATM Operational Concept. This concept is being further developed in SESAR including the specific requirements of the initial-4D operations (I-4D) already being demonstrated in Europe as part of the SESAR programme.

Action: The Conference is invited to agree to the recommendation in paragraph 7.

1. INTRODUCTION

1.1 The four-dimensional (4D) trajectory or business/mission trajectory is key to the concept of the future air traffic management (ATM) system being developed by the Single European Sky ATM Research (SESAR) programme in line with the operational needs expressed in ICAO Operational Data Link Panel (OPLINKP) and consistent with the ICAO aviation system block upgrade (ASBU) developments.

1.2 Airspace users will agree with air navigation service providers (ANSPs) and airport operators, the preferred trajectory for the flight in four dimensions (three spatial dimensions, plus time), from the early flight planning to the day of operations, where the various constraints of airspace and airport capacity are taken into account.

1.3 4D trajectories will bring key performance benefits. Better knowledge of the aircraft trajectories in the ground and network systems will improve safety as well as flight predictability and reduce the need for tactical interventions. The more efficient resource planning which this allows will in turn enable a more efficient utilisation of the available capacity both of airports and the airspace in general. For airspace users, 4D trajectories will allow the aircraft, with knowledge of the relevant constraints, to plan and fly the most optimal, cost-efficient flight profile, achieving better punctuality and flight efficiency as well as lower emissions.

[1] Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom. All these 27 States are also Members of ECAC.
[2] Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Croatia, Georgia, Iceland, Moldova, Monaco, Montenegro, Norway, San Marino, Serbia, Switzerland, The former Yugoslav Republic of Macedonia, Turkey and Ukraine.

2. 4D TRAJECTORIES

2.1 Once agreed, the 4D trajectory (‘business trajectory’ or BT for civil aviation and ‘mission trajectory’ or MT for military flights) becomes the reference which the airspace user agrees to fly and all the service providers agree to facilitate with their respective services unless changed for safety or tactical interventions.

2.2 In order for the 4D trajectory concept to operate appropriately, the ATM system relies on all actors having a consistent view of the planned trajectory and the constraints to be taken into account. Airborne and ground systems must be able to exchange trajectory information[3] and make it available to aircrew, controllers and demand capacity balancing management so that, together, they can best manage the trajectory of the flight while taking existing constraints into account. It is therefore essential that the proposed trajectory in the aircraft flight management system (FMS) is coordinated with the ground flight data processing systems (FDPS) and wider network systems.

2.3 This entails the systematic sharing of aircraft trajectories between all stakeholders participating in the ATM process to ensure that all partners have a common view of a flight and have access in real time to the most up to date data available to perform their tasks throughout the flight: from preparation through operations to post-disembarking.

2.4 A structure is needed to achieve the safe and efficient creation, amendment and distribution of the business/mission trajectory including the information content and quality, the actors involved, and the services associated with trajectory information access across all flight phases (e.g. creation, proposed revision and update processes).

2.5 The main challenge in implementing 4D trajectories lies in agreeing standard definitions, procedures and methodologies, as well as global standards for the exchange of 4D trajectory information. The interconnection of the aircraft and the ground systems through datalink is of course a key enabler of this concept, but equally the sharing of trajectory information between the ground systems and different stakeholders (ATC, airport, network manager etc.) also has to be considered. The role of SWIM services and infrastructure in enabling this concept is therefore also critical.[4]

3. INITIAL 4D OPERATIONS

3.1 Initial 4D (I-4D) is a major step towards full 4D operations. It represents the first step for arrival airport time prioritisation and en-route demand and capacity balancing, together with the deployment of initial trajectory based operations through use of a controlled times over (CTO) or controlled time of arrival (CTA) to improve sequencing of traffic and manage queues. This is consistent with the ASBU Module B1-40.

3.2 The application of initial 4D trajectory operations is improved by the use of the airline operational flight plan which is more detailed than the ATC flight plan and requires pre-planning and prior knowledge of flight intent as well as static and dynamic constraints in the ATM system (airspace reservations, capacity short falls, weather, etc.)[5].

3.3 I-4D operations focus predominantly on the last part of the cruise phase before top of descent and the descent phase, although the network and ATSUs are already beginning to sequence traffic through points in space/time ensuring orderly flows that facilitates use of CTO/CTA.

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[3] Air-Ground data communication developments are addressed under Agenda Item 1 through AN-Conf/12-WP/37,
[4] SWIM services and infrastructure are addressed under Agenda Item 3 through AN-Conf/12-WP/43.
[5] Future flight plan exchange issues are addressed under Agenda Item 3 through AN-Conf/12-WP/44.

3.4 The I-4D operations context can be summarised as follows:

a) the capability to obtain from the aircraft a reliable ETA window (ETA min/max) at a waypoint on the aircraft's current route; and

b) the capability to co-ordinate a (CTO/CTA), within that reliable ETA window, with all interested actors (ground or airborne) for the purpose of sequencing/spacing traffic at a specified waypoint.

3.5 CTA/CTO is regarded as one of the enablers to enhance predictability and efficiency within ATM operations by capitalising on the use of the FMS advanced required time of arrival (RTA) airborne capability. Present day airborne RTA capabilities promote time-coordinated operations, and the possibility to enable more flight-efficient, airborne-managed-operations.

3.6 During the flight, aircraft equipped for I-4D operation will share their on-board trajectory data according to the contract terms specified by the ANSP (e.g. via ADS-C EPP "extended projected profile") to feed the ground tools and thereby improve predictability. Initial 4D operations are limited to the provision of a single time constraint at a specific point (CTA/CTO), including monitoring of its trajectory conformance to the assigned constraint.

3.7 Where and when required, single time constraints (CTO/CTA) may be allocated to equipped aircraft on the basis of the estimated time window computed on board the aircraft on the fix specified by ATC or AMAN using air ground data link. It may not be necessary to generate and issue a CTA for every aircraft inbound to a TMA.

3.8 Trajectory information is synchronised between all equipped ATC centres involved in the handling of the trajectory by means of SWIM services and infrastructure. This will enable ATC centres involved with the flight handling to perform early pre-tactical planning through the usage of arrival management systems, thereby negotiating on CTAs and CTOs.

4. AIRCRAFT CAPABILITIES FOR I-4D TRAJECTORY OPERATIONS

4.1 Aircraft system capabilities required[6] to support I-4D trajectory management are:

a) CPDLC: the aircraft system shall support data link receipt of route clearances with time/speed/vertical constraints and transmission of the corresponding operational reply:

1) RTA capability supporting one RTA at a time; and

2) RTA adherence tolerance;

b) ADS-C: EPP report (up to 128 fix and computed way points with associated altitude/time/speed estimates and constraints, aircraft parameters such as gross weight and min/max speed) with all sending criteria (periodic, on request, on event);

c) ADS-C ETA min/max report at the fix specified in the ATC request;

d) improved on-board management of RTA using improved meteorological model (using more wind/temperature inputs from flight operations centre (FOC)), improved prediction of

[6] Air-Ground data communication developments are addressed under Agenda Item 1 through AN-Conf/12-WP/37

wind/temperature (using data from on-board sensor), computation of ETA min/max interval facilitating more reliable CTO/CTA allocation, improved RTA algorithm through wider RTA speed range and selectable RTA tolerance; and

e) A/G data link communications for the data exchange between aircraft and ground system such as enhanced satellite and terrestrial communication systems (e.g. advanced VDL).

5. GROUND SYSTEM CAPABILITIES FOR I-4D TRAJECTORY OPERATIONS

5.1 Ground system capabilities to support I-4D trajectory management which need to be considered are:

a) ADS-C to support contract management and the reception and ground use of the 4D trajectory data including ADS-C EPP and ETA min/max;

b) ADS-C MET Group data reception and forwarding via ATN;

c) CPDLC to enable the transmission of trajectory revisions through clearances;

d) CPDLC to support the uplink and revision of CTA;

e) ATM system (AMAN) computation of CTA with an accuracy of +/-10 seconds, on a metering point close to final approach fix (FAF);

f) Conflict detection tools that take account of imposed CTA;

g) enhanced arrival, departure and surface management tools (AMAN, DMAN, SMAN);

h) dynamic ATFCM using operational flight plan data from AOC;

i) ground network connectivity and ATC-ATC exchange of trajectory information;

j) A/G data-link communications for the data exchange between aircraft and Ground system such as enhanced satellite and terrestrial communication systems (e.g. advanced VDL).

6. STANDARDIZATION OF THE AIR/GROUND DATA EXCHANGES

6.1 EUROCAE WG78 and RTCA SC214 are jointly developing the standards for advanced ATS supported by data communication.

6.2 The operational needs expressed by SESAR, NEXTGEN and the ICAO OPLINK panel have been considered, in particular new air ground data exchanges required to support I-4D operations:

a) CPDLC message to support CTO/CTA allocation including required precision;

b) ADS-C extended projected profile (EPP) to support the automatic (periodic, event driven or on demand) downlink of trajectory data (1 to 128 published and/or computed waypoints with associated constraints and/or estimates in the 4 dimensions, etc.); and

c) ADS-C ETA min/max report to support the automatic downlink of the ETA min/max on the metering point indicated in the ATC request.

6.3 WG78/SC214 are standardising a number of other data communication services including D-TAXI (CPDLC) and D-OTIS (FIS).

7. RECOMMENDATIONS

7.1 The Conference is invited to:

a) note the content of the paper;

b) recommend that ICAO initiate the necessary SARPs developments to support Initial-4D operations to be in place by 2018; and

c) request ICAO to organize a multidisciplinary review of the 4D trajectory requirements for the necessary development of SARPS and guidance material to support the full 4D trajectory concept as per the ASBU blocks and module evolution.

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