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WORKING PAPER

AIR TRAFFIC MANAGEMENT REQUIREMENTS AND PERFORMANCE PANEL (ATMRPP)

TWENTY SEVENTH WORKING GROUP MEETING

Montreal, Canada, 27 to 31 October 2014

Agenda Item 1: Trajectory Based Operations (TBO)

Sharing Trajectory Predictions in TBO

(Presented by Henk Hof, prepared by Philippe Leplae)

SUMMARY

This paper outlines the basic architectural principles for trajectory information sharing in TBO, including ground-ground trajectory exchange as well as RTCA SC-227/ EUROCAE WG-78 recently standardized air-ground downlinking of the Extended Projected Profile (EPP).

The paper details how the main ATM actors maintain separate trajectories that are computed to serve different purposes and thus may be computed with different options regarding the forecast of future events affecting a flight.

The various validation activities undertaken in SESAR to assess the benefits of trajectory sharing are explained. Although these validation activities are still ongoing, they already show that sharing trajectory data must be complemented with information regarding the constraints that were used to build the trajectory.

The outcome of this validation is used to determine priorities for implementing the sharing of data when building a transition path towards TBO.

A second SESAR paper examines the temporal aspect of TBO. It considers the level of adherence that Airspace Users must achieve to ensure that TBO functions to the benefit of Airspace Users and ATM network alike.

This paper builds on SESAR’s earlier presented ATMRPP working papers WP601 (Toulouse, March 2014) and WP632 (Tokyo, July 2014).

1. INTRODUCTION

The change to the TBO concept is underpinned by a notion of one reference trajectory shared between all ATM actors. However, if we look at the current situation, where all stakeholders maintain independent views of the trajectory, the path towards the TBO end goal is not straightforward. SESAR has used its initial SWIM implementation in order to facilitate the exchange of these trajectory views, in order to assess the feasibility of a transition path towards TBO. Today each actor maintains the ability to construct a 4D path from the input data received and the rules of reconciliation of these various views are not defined. This paper considers these issues which are in fact architecture issues stemming from the discussion in WP601, ICAO ATMRPP, Toulouse 2014.

2. DISCUSSION

2.1 List of trajectories

The following trajectories are computed by the main actors of the ATM network:

- The FOC (Flight Operation Centre) computes an optimal trajectory calculated with full range of inputs: full Meteorological model, detailed Aircraft Type and specification, Airline business rules, Weight, however it is missing some information on the operational constraints that ATC may apply to facilitate the 4D trajectory execution. The goal of this trajectory is to optimize all economic criteria to define the optimum route associated to a cost index.
- The aircraft FMS computes an optimal trajectory with limited range of inputs: simple meteorological model (no regular update); detailed aircraft Type; actual Weight; cost index but implemented slightly differently from the FOC; similarly to the FOC, the FMS has little information on downstream constraints, usually entered later as clearances are issued.
- The ASP (being an Air Traffic Centre or also, in the case of Europe, the Network Manager- NM[1]) computes a trajectory on their domain of interest, with precise knowledge of the local conditions, but using sometimes different constraint set depending on the purpose of the calculation (NM and ATC have different calculation, some tools such as Arrival Manager-AMAN, Medium Term Conflict Detection- MTCD, local traffic flow management tools may have their own calculation). Different systems may take different assumptions when computing a trajectory based on their mission:
    - Flow management system need to take some conservative assumptions in order to detect sector overload. They may then choose to apply constraints in order to ensure an aircraft will be counted in the “problem” sector in case of doubt.
    - ATC systems primary use of the TP is to distribute flight information to sectors
    - MTCD tool will use a trajectory including the most recent tactical entries whereas an AMAN will use a more strategic view of the flight. For that reason different option may be chosen regarding the applicability of a given constraint by these tools and by the main ATC TP.
    - In the case of open loop instructions given by a controller, various strategies may be applied to come back to the planned route, when trying to infer the resulting trajectory.

Today these various trajectories co-exist in various systems and are poorly updated with data from other actors. Some data sharing exist regarding the constraints, but as shown on the example below, data can be different, either because of lack of coordination, or because some stakeholders select different constraint set when estimating the most likely trajectory.

[1] Known in the past as “CFMU” or Central Flow Management Unit

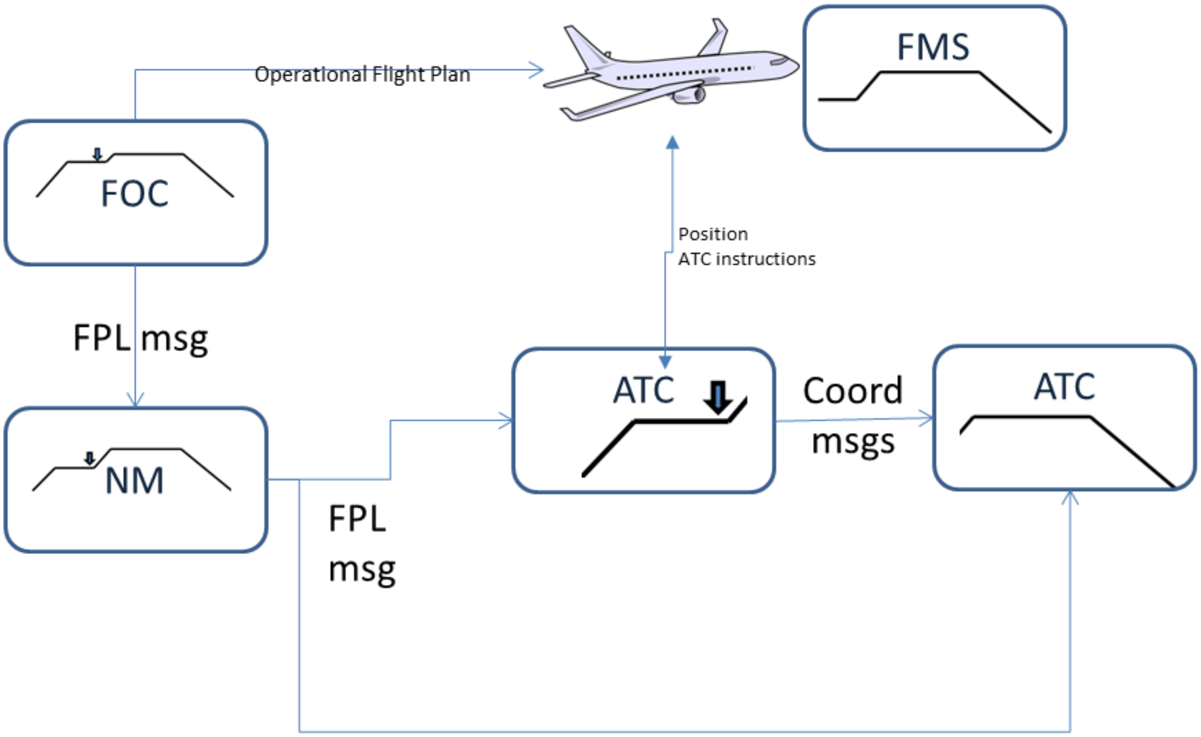

Figure 1: Trajectories held by different stakeholders

The FOC can compute a very accurate trajectory that will be used to develop the operational flight plan; however, this trajectory is conveyed through the ICAO FPL message, with limited ability to convey a full trajectory. The information will be “lost” for NM (and consequently for ATC), and to a certain extent for the aircraft FMS, as we cannot control the way the pilot enters his flight plan into the FMS.
In the same manner, information exchanged with the various ATC systems relies on FPL-like messages and does not allow conveying fully the trajectory information

2.2 Validation activities

The SESAR programme include a number of trials relate to the exchange of trajectory data to improve the predictability of traffic and support specific ATC tools. The red arrows of the figure below show where these exchanges are evaluated. FIXM will be used to carry the EXFPL information exchanged between FOC and NM.

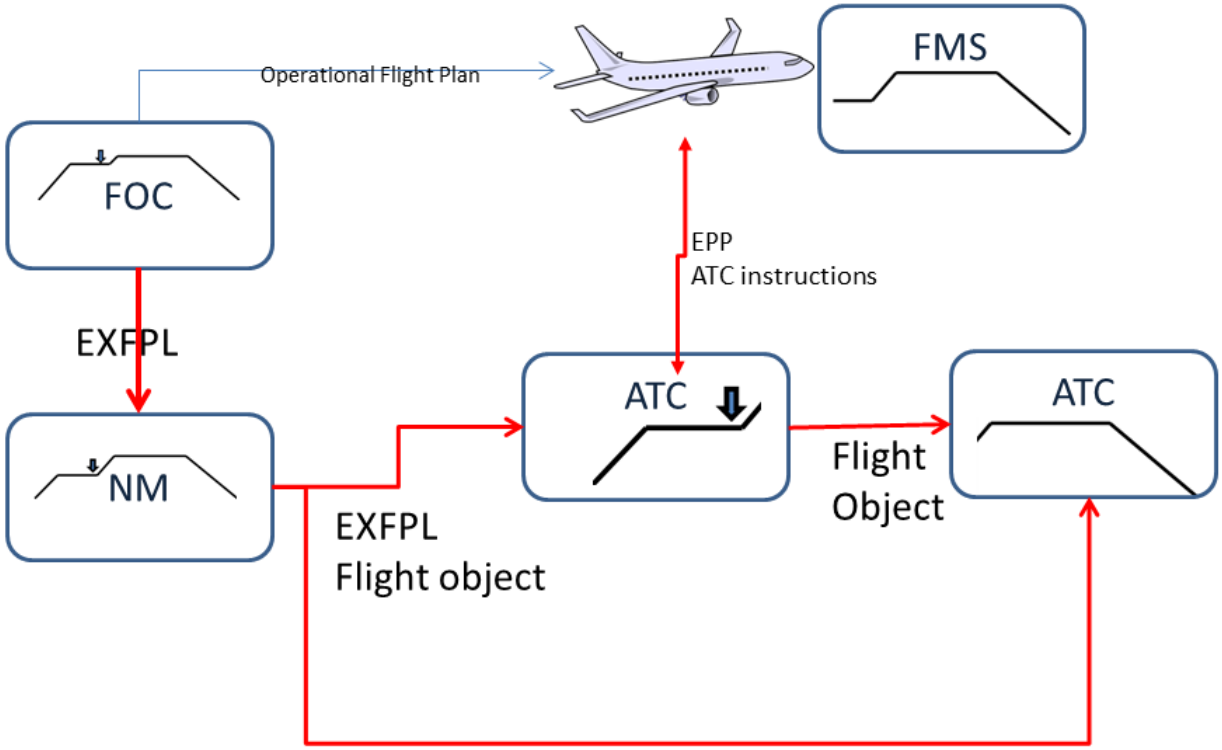

Figure 2: 4D trajectory exchanges validated in SESAR

The difficulty is that each actor computes a trajectory for itself with different source data. When receiving a supposedly "better" trajectory, there is no knowledge of the exact data source that was used by the provider of the trajectory, thus it is difficult to apply directly the received 4D trajectory to update its own information. This limitation was encountered in reception of EXFPL trajectory as well as EPP trajectory.
Here are more details on these trials:

1. EXFPL or "Extended Flight Plan" is used to convey additional information from the FOC. The additional information includes a 4D trajectory, aircraft mass and temperature on the trajectory points, as well as optional climb/descent performance data. The R&D done regarding these exchanges will be useful to define what should go into FIXM. The trials so far have shown that it would be necessary to better define the strategy on which constraints to apply in the FOC and NM to better use the information provided by the airline. This is the subject of further validation planned in 2015.

2. NM and ATC have implemented the Flight Object interconnection to support additional exchanges especially the computed trajectory and a flight script that is an interpretation of the flight constraints. This should provide means of keeping a better synchronization of both trajectories and will be validated in 2015. The Flight Object technology will be used to convey additional information such as the EXFPL data provided by the airline. One of the difficulties in combining NM and ATC information is to define rules of precedence of the constraints maintained by each actor, and define eligibility rules on modification. It is estimated that these issues will be a topic for validation runs to be organized in the next 2 years at least. The Flight Object exchanged between NM and ATC are based on an extension of the ED133 standard, described in the following paragraph. This extension will be incorporated in a future revision of this standard.

3. Flight Object is also used to improve inter-operability between ATC systems, by providing additional information to what is contained in standard coordination[2] messages over an FIR boundary. Initial trials have been carried out in 2013 and more are planned next year. These trials, while clearly showing the benefits to controllers of this improved interoperability, have also highlighted the challenge of tightly coupling Flight Data Processing from various vendors to fully align the trajectories. Flight Object exchanges being validated in SESAR are based on ED133, a EUROCAE standard.

4. The Extended Projected Profile - EPP reflects the airborne predicted trajectory (up to 128 waypoints) according to the active flight plan. It has recently been standardized by RTCA SC-227/ EUROCAE WG-78. It can be downlinked upon specific request set by the ground when specifying the ADS-C contract. Analyses have been done on the use of aircraft trajectory data (EPP) by ground Trajectory predictors. This has shown the benefits that can be derived from this additional data (for instance in assessing an arrival estimate or predicting a climb profile). Benefits are dependent on how well the active flight plan reflects the trajectory that will be flown. For instance a pilot may have no knowledge of an exit level on the next FIR boundary until it is in contact with the controller in charge of the sector where he will climb/descent to that level, or may know which exit level to expect, but not be aware of when he will receive the corresponding climb/descent clearance. This obviously limits the accuracy horizon of the EPP data. Synchronization of standard sector transfer levels (Often referred to in Europe as Profile Tuning Restrictions – PTR's) as well as clearances that are known on the ground before they can actually be delivered could make EPP more useful for ground TP enhancement.

   In addition to the evaluation above, live trials encompassing the systematic recording of EPP data are going to be done in the next 2 years to assess the accuracy of the EPP, for instance in climb/descent phase.

2.3 Inclusion of constraints in the 4D trajectory

The above has brought to the fore the need for the various actors to exchange constraint data together with the resulting trajectory to enhance interoperability. This permits that each recipient of trajectory data is able to assess how to incorporate the information with its own data. If we admit that it will not be possible to obtain perfect knowledge of all future events that may affect a flight, the need for managing constraints in a dynamic way will still exist in TBO. For that and also when considering a transition path, we need to evaluate all constraints used by different stakeholders, and establish some rules on how to use them, for instance to enable prioritizing various constraints set on the trajectory. The following types of constraints are an example of what need to be considered:

- Airspace user constraints:
  - ETA min/max
  - Cost index and speed regime
- Operational constraints linked to ATC operations.
- Military airspace status
- Weather resulting in constrained airspace
- Weather resulting in optimized trajectory
- Noise abatement procedures
- Flow measure (Take off time, Target Time on a point, miles in trail, level capping, rerouting, etc…)
- Traffic synchronization constraints

[2] Europe currently uses OLDI protocol for internal coordination, protocol which is quite similar to AIDC.

These constraints need to be exchanged and considered when using updates from other actors, using an agreed prioritization, which will vary with the flight phases.
Note that the current provisions being prepared for FF-ICE/1 already establish that constraints are supposed to be exchanged with flight plan data in the planning phase

2.4 Future work

The next validation activities in SESAR will allow an assessment of the exact data that is needed to be exchanged, and the resulting benefits in terms of accuracy of prediction and flight performance. Looking at the above, it is obvious that some proposed trajectory exchange may lead to redundant information. The future SESAR validation will contribute to clarify the exact needs and the best options.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note and review the contents of this information paper;

b) monitor the results of future SESAR validation and take due account of the limitations expressed here when establishing the TBO concept

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