INTER-OPERATING SUPPORTING TOOLS FOR GREEN TAXIING OPERATIONS

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***Abstract*— This paper describes the supporting tools developed within the AEON project to support the introduction of greener taxiing techniques (tug vehicles, e-taxi and single engine taxiing) to reduce emissions at the ground level.**

Keywords: engine-off navigation; single-engine technique; autonomous taxiing solutions; non-autonomous taxiing solutions; hybrid tugs; electric engine; fuel consumption; emissions.

I. INTRODUCTION

The SESAR Advanced Engine-off Navigation project (AEON) aims at exploring the reduction of ground operations environmental impact based on the use of three classes of greener taxiing solutions: single engine taxiing solutions, hybrid towing taxiing solutions and electric engine solutions.

This approach requires a novel concept of operation and new support tools for sustainable airport ground operations to cope with the additional vehicles on the ground to tow aircraft, discrepancies between aircraft in terms of ground speed according to the taxiing technique and the management of the fleet of towing vehicles. In this paper we first describe the project context. Then, we introduce the AEON concept of operation that includes a new role responsible for the supervision of towing vehicles and the Human-Machine Interfaces for supporting Air Traffic Controllers and the Tug Fleet Manager to control and supervise the whole traffic.

II. THE PROJECT CONTEXT

Aircraft jet engines are made for flying, not taxiing. Using main engines for ground operations is inefficient and taxiing phase can represent from 10 to 30% of flight time in Europe [1]. Regarding fuel consumption, Stettler et al. estimated that taxiing to burn 36% of the fuel on a standard Landing and Take Off cycle [2]. They also estimated that the taxi phase accounts for 12% of NOx, 89% of CO and 91% of HC emissions.

Several alternatives are being developed to reduce fuel consumption and noxious emissions during ground operations [3]. They can be grouped in two categories: autonomous techniques in which the aircraft uses its own equipment such as electric engines in the rear or landing gear; and non-autonomous technique in which external equipment is used such as specifically designed tugs coupled to the aircraft and controlled by the pilot. While each of these solutions can help saving fuel, they all have advantages and drawbacks.

Autonomous electric taxiing aircraft have lower dynamic performances (speed and acceleration), nonautonomous solutions add new vehicles to be managed on the taxiways (empty tugs). However, all these techniques share the need for engines warmup and start management for departing aircraft. For this reason, Single Engine Taxiing (SET) is used mainly for taxi-in of arriving aircraft and almost never for departures [4].

The interconnected solutions were iteratively designed and assessed to enable an optimized allocation of a fleet of tugs to aircraft, centralized routing providing speed profiles to avoid conflicts, dedicated HMI for Air Traffic Controllers as well as a new role, the Tug Fleet Manager.

III. THE AEON CONCEPT OF OPERATIONS

Introducing engine-off taxiing techniques might have a strong impact on the airport capacity and the work of airports' operators due to specific path planning activities and tugs supervision [5]. The AEON concept of operations introduces solutions for using green taxiing techniques at strategic and tactical levels. The overall framework of our solution is presented in Figure 1.

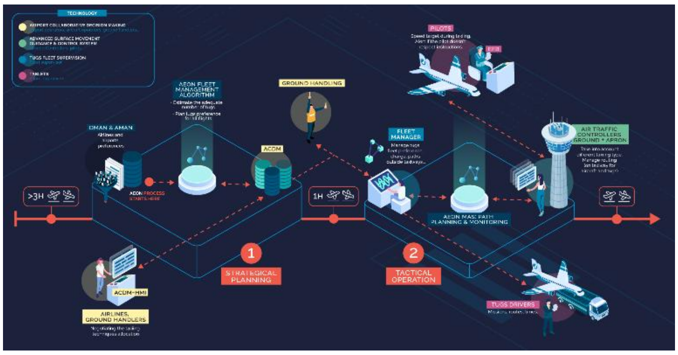

Figure 1. AEON preliminary concept of operations.

In the strategic phase, i.e., up to 1 hour before the flight is scheduled, we integrate with the airport collaborative decision making (A-CDM) platform a tool to support discussion and

Identify applicable sponsor/s here. *(sponsors)* negotiation of the desired taxi technique for the aircraft between the stakeholders. This choice will have an impact on the taxi speed and hence on the flight's in-block or off-block time. In addition, it also has an impact on the organization of ground handling activities (the tugs, marshallers... need to be available). Given these choices and tug availability, a first set of support algorithm computes an initial tug allocation plan.

In the tactical phase, i.e., during the operations, we introduce a multiagent system suggesting optimal routes for tugs and aircraft. The multi agent system uses flight plan and surveillance data to compute routes and speed profiles to avoid conflicts as well as stop and go at intersections. The path and speed information can be distributed to pilots and tug drivers via the Electronic Flight Bag. We also designed a radar image providing additional situation awareness elements to the ATCOs about the taxiing techniques and supporting the interaction with the optimal route suggestion algorithm. Finally, we designed a moving map for tug drivers and pilots to use the path and speed information.

The AEON concept also introduces a new role at the airport, the tug fleet manager (TFM), which is envisioned to be responsible for operating and maintaining the tugs. Throughout the day, the TFM ensures the best availability of the vehicle fleet by assigning tugs to arriving/departing aircraft, by monitoring their status (the state-of-charge of the battery, the availability of the tug to perform a towing task) and by handling operational delays of arriving/departing aircraft. The TFM will oversee the towing vehicles being on time to pick-up arriving/departing aircraft and tow these aircraft to the gates/runways. The TFM is also expected to assign towing vehicles to the specific aircraft. These assignments are supported by the dedicated algorithms for allocating vehicles to aircraft and for identifying efficient routes to follow. Once a towing mission is assigned, it becomes the joint responsibility of the TFM and ATCO to reach the aircraft to be towed on time for smooth operations.

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