

Supervision HMI

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AEON

ADVANCED ENGINE OFF NAVIGATION

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Abstract

This document, entitled “Supervision HMI”, is the deliverable D3.2 of the SESAR Exploratory Research Project AEON (Advanced Engine-off Navigation).

This document describes the Human-Machine Interface (HMI) for the tug fleet supervision on ground. The HMI consists in 1) an overview of the fleet of tugs and their current status; 2) a timeline presenting the allocation of tugs to aircraft from the towing algorithm (D.2.1) and several interaction techniques to update the allocation plan; 3) a set of interaction techniques for collaborative activities between the tug fleet manager (TFM) and the ground controllers (ATCO) to manage allocation requests and the impact on controllers' activities. The fleet supervision HMI can be used in conjunction with an Advanced Surface Management Guidance and Control System (A-SMGCS) tool presenting the tugs and aircraft positions on the airport map along with the planned trajectories.

This deliverable consists in the description of interaction techniques i.e. the sequence of actions and reactions between the graphical representation and the inputs from the end-user. The specifications of the interactions come in several forms, included in or accompanying this document: drawings, scenarios, and videos. The interactions have been designed and discussed with several stakeholders with ground control expertise at CDG.

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1 Introduction

1.1 Purpose and scope

AEON aims at fostering the usage of environmentally friendly ground operations techniques:

- Non autonomous taxiing such as TaxiBots
- Autonomous taxiing like Electric Green Taxi System
- Single Engine Taxiing as last option.

The project aims at defining a concept of operations focusing on engine-off taxiing techniques based on a set of dedicated tools such as fleet management for TaxiBots and supervision interfaces to support the operators and their collaboration.

This document describes the Human-Machine Interface (HMI) to supervise the fleet of non-autonomous taxiing vehicles on ground.

1.2 Related documents

This deliverable takes as input the research reported in deliverable D1.1 “Concept of Operations” [6], which provides the initial version of the SPR-INTEROP/OSED of the AEON SESAR Solution. The document D1.1 also identifies the initial set of safety, performance and human-machine interaction (HMI) requirements of the AEON solution for the specific use cases defined as relevant in D3.1 “Representative use cases definition”.

The supervision HMI presented in this document builds upon principles and guidelines identified in the *State-of-the-art on collaborative human-machine interactions* described in D1.3.

The supervision HMI will be evaluated in the final evaluation of the AEON solution and the results will be detailed in the D5.3 “HP Assessment Report”.

- Chapter 1 introduces the document, the relationship with other deliverables and its structure.
- Chapter 2 introduces the methodology followed to design the Supervision HMI.
- Chapter 3 describes the HMI architecture and its main components.
- Chapter 4 illustrates the envisioned use of this HMI through several scenarios.
- Chapter 5 describes the status of the video associated with this deliverable and the status of the HMIs presented.
- Chapter 6 summarizes the document.

The deliverable also includes videos showing the interaction techniques presented in the following chapters. These videos can be viewed at

<https://www.youtube.com/playlist?list=PLmoOZAxo1D0zchwHlvqFfm5Wlsvoru3iuw>.

1.3 Acronyms and terminology

The following table reports the acronyms used in this deliverable:

Term	Definition
A-CDM	Airport Collaborative Decision Making
AEON	Advanced Engine Off Navigation
ATCO	Air Traffic Controller
ATM	Air Traffic Management
CdG	Charles de Gaulle
CONOPS	Concept of Operations
DET	Double Engine Taxiing
EFB	Electronic Flight Bag
ENAC	Ecole Nationale de l'Aviation Civile
HMI	Human Machine Interface
IBT	In-Block Time
INTEROP	Interoperability Requirements
LDT	Landing Time
OBT	Off-Block Time
OSED	Operational Service and Environment Definition
SESAR	Single European Sky ATM Research
SET	Single Engine Taxiing
SJU	SESAR Joint Undertaking
TFM	Tug Fleet Manager
TMO	Taxi Mode of Operation
TOT	Take-Off Time
TUD	Technical University of Delft
WP	Work Package

Table 1: List of acronyms used in this document

AEON considers three classes of engine-off taxiing techniques to be used concurrently: single-engine taxiing solutions, hybrid towing taxiing solutions and autonomous taxiing solutions based on onboard electric engine solutions. For the sake of clarity, we will use the following terms in this document:

- **tug** to designate hybrid towing taxiing solutions named Dispatch Towing Vehicle Electric Taxiing System (DTVETS) in D.1.1.
- **electric taxi** to designate an autonomous taxiing solution embedded in landing gear/nose wheel gear named Nose Landing Gear Electric Taxiing System (NLGETS) and Main Landing Gear Electric Taxiing System (MLGETS) in D1.1.
- **tug drivers** to designate the drivers of the DTVETS that can operate them.

2 Methodology

A major concern while designing interactive systems is to reach a suitable level of usability for end-users. Usability is the “extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” [1]. Human-centered design is concerned with the design of such usable systems. HCD is “an approach to system design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques”. In particular, the design is based upon an explicit understanding of users, tasks and environments, and is driven and refined by user-centered evaluation.

Since the tug fleet manager is a new role with not clearly defined functions and responsibilities, we decided to involve as many airport stakeholders as possible including not only ATCOs but also ground handling, airport management or tug and electric landing gear manufacturers in an attempt to carefully position our design with respect to other existing activities. Figure 1 describes the user centered activities we have conducted.

A first step consisted in the investigation of different perspectives and suggestions through contextual inquiries with a variety of stakeholders with different backgrounds. We then conducted several internal design sessions which resulted in concept mock-ups which in turn were partially implemented, including the tugs strips presenting their status or the link between the supervision HMI and the A-SMGCS. A second step consisted in the creation of several prototypes to address the challenges rising from the interaction between the stakeholders, and between humans and the AEON artificial intelligence described in the considered use cases of D3.1. The iterative design of these prototypes was evaluated at several stages. We first demonstrated our early concept designs to the advisory board members which helped us refine our mockups. We then conducted two design workshops with pilots and ATCOs. The first workshop with pilots has allowed us to understand the challenges they may face with AEON concepts. The second workshop held with ground control instructors which have operated at CdG airport gave us the opportunity to explore the impact of increasing the traffic on the taxiways with a tug fleet on the ground controllers’ activity, and the collaboration aspects with a fleet manager role. These workshops resulted in improved design and interaction techniques for asynchronous coordination between the tug fleet manager and the ATCOs.

As a third step, an assessment was conducted to validate a first version of AEON tools. This assessment included realistic simulations with 4 pairs of experienced controllers in the ENAC facilities. Our goals were first to assess that the graphical elements visible on the A-SMGCS for the different taxiing techniques were understandable by the controllers and, second, to foster discussion on the tug fleet manager role and the coordination with the ATCOs. In particular, designers and ATCOs discussed together the knowledge required by the fleet manager role and how specific tasks such as suggesting routes or best points for coupling or uncoupling tugs and aircrafts could support these new activities. Based on the results of the assessment, another internal design iteration was performed.

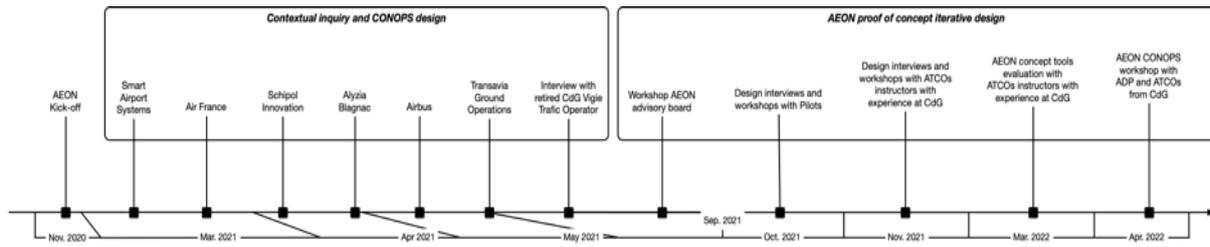


Figure 1: timeline of the design activities and the participants.

The following content in this deliverable is the current design outcomes. All the HMI design concepts will be presented again to ATCOs and various stakeholders during the intermediate evaluation activities planned at CdG and Schiphol in April and May before the final evaluation with the ACHIL platform at ENAC (WP5).

3 HMI architecture and components

This section introduces all the Human-Machine Interfaces designed for AEON. First, we present an overview of the interfaces and then present in more details each component and its interaction with other systems.

3.1 Overview

The envisioned activity of the TFM consists in supervising the tugs, monitoring and updating the AEON algorithmic allocation, and coordinating with the ground ATCOs for integrating AEON tugs path recommendations into the current traffic situation. It is assumed that the ground controllers will be responsible for answering calls from tug drivers and for giving route clearances toward the holding points by AEON intelligence or calls from the fleet manager for coupling or decoupling.

The overall architecture and the relationships between the fleet manager position and the other systems are illustrated in Figure 2. The envisioned position of the fleet manager is composed of two parts. First, a supervision HMI informs on the tugs availability, the tugs status and the tug allocation plan to arriving and departing aircrafts. Then, the TFM is provided with an A-SMGCS HMI which allows the spatial monitoring of all the vehicles on the apron and the taxiways, similarly to the tool used by ground ATCOs. An overview of the following HMIs can be viewed in the AEON video 2 entitled “AEON Prototype – Monitoring the tug status” (<https://youtu.be/OTDGScUV240>).

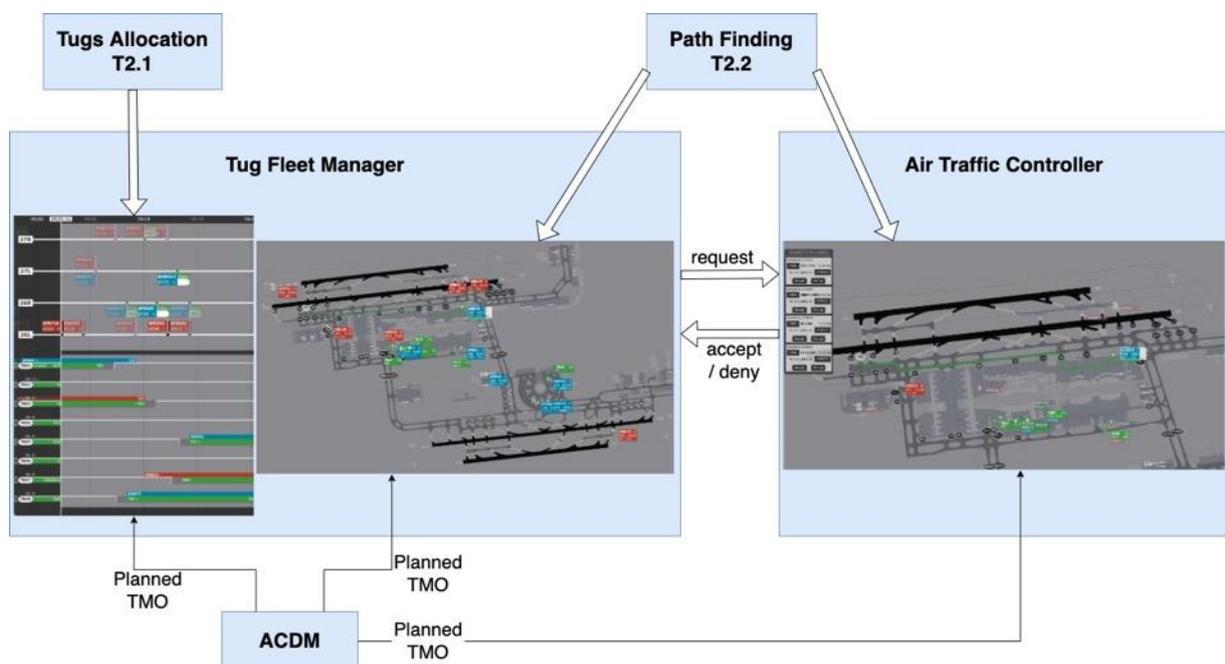


Figure 2: overview of the fleet manager HMIs and the interconnection with other systems.

Both fleet manager tools work together to support the localization of a specific aircraft or tug in any of the HMIs. The fleet manager tools are also interconnected to other systems such as 1) the ACDM which specifies the taxiing technique chosen with estimated time of departure or arrival, 2) the tug allocation algorithms developed in T2.1 for providing an allocation plan, 3) the path planning

algorithms developed in T2.2 to compute route suggestions when a request is made to the ground ATCO and 4) the ground ATCO's A-SMGCS to issue a route request that can be approved or refused.

3.2 The supervision HMI

The supervision HMI present a synoptic view of the status of fleet of tugs and their planned allocation to departing and arriving aircraft as presented in Figure 3. The HMI presents the data through a horizontal timeline with two main areas, top and bottom. The top area uses horizontal ribbons to present the planned departures and arrivals for each runway. All the departures and arrival items also display the taxi mode of the aircraft and in particular any tug request. In this example, the 4 runways are the ones of CdG airport (27R/L and 26R/L respectively). The bottom area uses horizontal lines to depict tugs planned allocation to aircrafts. Each line is associated to a tug, which ID and status are shown in the left area.



Figure 3: Supervision HMI with arriving and departing aircraft on the top and the available tugs underneath.

The allocation plan is computed by the allocation algorithm using data from the A-CDM and displayed in the supervision interface as visible in Figure 3. The role of the fleet manager is to validate this allocation plan based on the tugs' status and the condition of the traffic.

3.2.1 List of tugs and tug strips

A tug operation is composed of at least 4 phases: reach the coupling point at an appropriate time, couple to an aircraft, carry the aircraft (with control handover to the pilot) and detach from the aircraft. It is assumed that the tug driver will have to vacate the area so that the aircraft can reach the parking or the runway quickly or to prevent any traffic congestion.

The scheduling area of the supervision HMI (bottom) in Figure 3 presents all tugs available at the airport (or for a particular tug operator) with specific information to understand the status of each tug. For each tug a graphical element called tug strip displays the following elements:

- The callsign (TB01, TB02,...).

- The batteries charge level with a gauge.
- The current position on the airport.
- The type. It can be wide body (WB) or narrow body (NB).
- The types of aircraft it can function with, which can be medium (M) for narrow body aircrafts and heavy or jumbo (H, J) for wide body aircrafts.
- The status. It can be free, coupling, coupled or uncoupling. When the tug is coupled, a label over the tug callsign details the coupled aircraft's callsign and its type. The color of the label indicates if it is a departure (blue background) or arrival (red background) as currently in use at CdG.

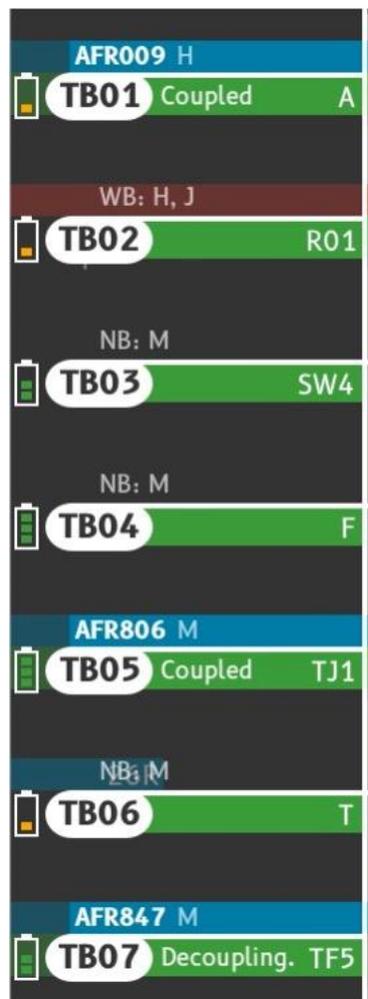


Figure 4: list of tugs and their status information

3.2.2 Runways timeline

The upper part of the supervision HMI (Figure 5) displays a timeline of all departing and arriving aircrafts for each runway in use. The aircraft position on the timeline is chosen according to the start of the taxiing phase to give a visual overview of the situation to the TFM. The labels indicate necessary information to facilitate the understanding of which aircraft needs a tug and where the coupling between a tug and an aircraft should take place. There are two possible situations:

- For departing aircraft that need to reach a runway for take-off, the tugs will need to reach the parking before the off-block time.
- For arriving aircraft that need to go to a parking, the tugs will need to reach a coupling area near the runway exits before the landing time.

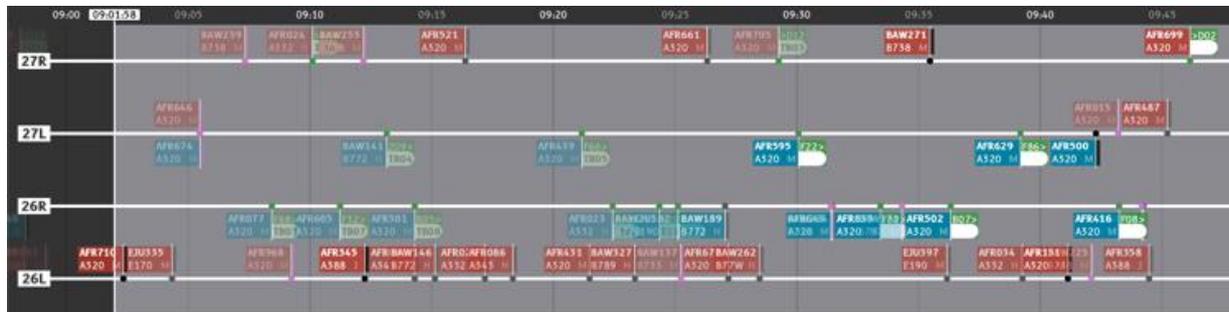


Figure 5: Aircraft on the timeline with the 4 runways of CDG

The aircraft are represented with labels featuring a colored background to indicate if they are departing (blue) or arriving (red) as in the A-SMGCS. Arrivals are displayed above the horizontal line materializing the runway and departures are displayed below as illustrated in Figure 6. In both cases, the labels are linked to the timeline with a vertical white line ending with a dot that specifies the beginning of the taxiing phase. The view is dynamic and updated every seconds. The timeline shows the present (left) and the future (right). Thus, the closer a flight is to the left (i.e. to the present), the closer its taxiing phase will start.



Figure 6: flight labels (2 departures in blue, 2 arrivals in red)

The label features several information such as the call sign, the type and the category of the aircraft. There are also indications for the different taxiing mode of operation (TMO) on the right of the label that are detailed in Figure 7:

- A green rectangle is used for tugs as in the A-SMGCS (Figure 7.a) with indication of the parking for departures and a coupling point for arrivals.
- A pink rectangle for electric taxiing technologies (Figure 7.b)
- A black rectangle for conventional taxiing with both engines (Figure 7.c)
- A grey rectangle for single engine taxiing (Figure 7.d)

The color is also replicated in the dot that links the label to the timeline to facilitate the understanding. The parking is also indicated as well as the assigned tug when defined.



Figure 7: Aircraft's labels on the runway's timeline indicating the chosen taxiing technique. Taxibot (a), Electric taxiing (b), Full Engine Taxiing (c), Single Engine Taxiing (d).

To indicate a quantity of emissions for a particular flight during the taxiing phase we use three levels of transparency that respectively indicates low, medium and high environmental impact. Figure 8 presents the levels of transparency of the aircraft label for different TMO. The aircraft using an electric taxiing technique or for the ones that have been assigned a tug, the label will have a highly transparency applied since they will not have a strong impact during taxiing (Figure 8.a & Figure 8.b). The aircraft using DET or SET have a medium transparency applied (Figure 8.c & Figure 8.d). Finally, aircraft with a planned tug service for taxiing but that does not have one assigned are completely



Figure 8: 3 levels of transparency. Electric engine (a) and assigned tug (b), DET (c) and SET (d), not assigned tug (e)

The right part of the labels is hidden by default for aircraft that are not towed by a tug to save space and reduce the occlusion of certain elements. When the user hovers a label, it is placed on top of the other and all the indications become fully visible. When a label is selected, it becomes fully opaque to facilitate reading. These mechanisms are meant to facilitate the identification of aircraft that need to be towed or the one that do not have a tug assigned.

3.2.3 Tugs timeline

Below the runway timeline, the tugs timeline displays the planned missions for each tug with a sequence of aircraft and recharging stations. Similarly to the runways timeline, the view is dynamic and has similar temporal behaviors presenting the present and the future. Figure 9 shows the tugs timeline with an existing allocation plan for the tugs. The allocation can be done by the system or manually.

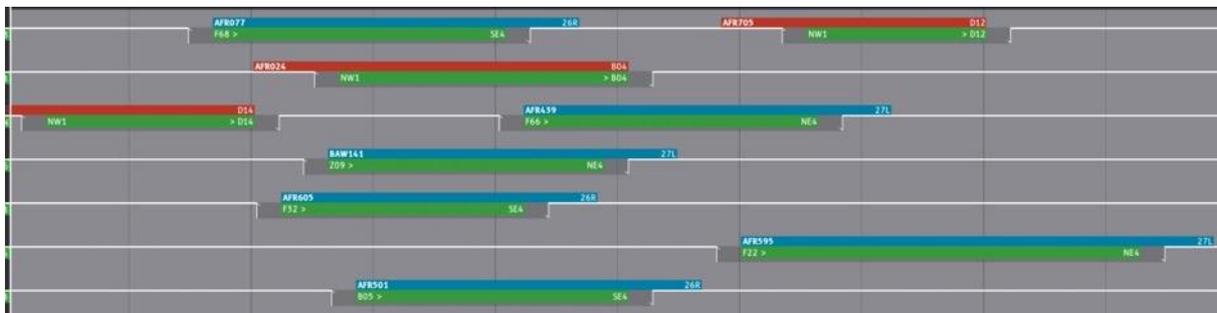


Figure 9: Tugs timeline

A tug mission is represented by a green rectangle, positioned in the timeline according to the taxiing time of the corresponding aircraft. Rectangles above the green rectangle represent the departing (blue) and arriving (red) aircraft taxiing time. On the green rectangle the coupling point name is displayed on the left and the decoupling point on the right. The duration of the coupling and the decoupling phases are represented with dark grey areas and white arrows as visible in Figure 10 and Figure 11.

Figure 10 depicts the representation for a departing flight. The rectangle appears at the off-block time (OBT) until the take-off time (TOT). The coupling is made at the parking before the OBT. The decoupling is made on a dedicated area near the runway. The aircraft will taxi on its own after decoupling with the tug.



Figure 10: Assigned mission for a departure flight

Figure 11 depicts the representation for an arriving flight. The rectangle appears at the landing time (LDT) until its in-block time (IBT). The aircraft taxi on its own until the coupling point near the runway exit. The decoupling is done on the parking after arriving.



Figure 11: Assigned mission for an arrival flight

3.2.4 Charging stations timeline

In the scheduling area, there will be an area dedicated to the charging stations. As for the tugs timelines, this area displays a timeline for each charging station of the airport that indicates the scheduled occupation by the tugs. Figure 12 shows such a timeline element for two charging stations (SB01 and SB02). This timeline is not yet integrated within the supervision HMI but will be located below the tugs allocation timelines.



Figure 12: Charging stations list

We created a visual link between the charging stations and the tugs timelines by displaying a pink line during the planned charging time of a tug. Figure 13 illustrates this link for a single charging stations and a single tug. The pink line is meant to indicate to the TFM that the tug will not be available for a specific period of time.



Figure 13: Purple feedback on the line of the tug TB04 timeline

3.3 A-SMGCS

3.3.1 TFM A-SMGCS

In addition to the supervision HMI, we envision that the TFM position will also have an A-SMGCS HMI similar to the one used by ground ATCOs displaying the whole airport map or a smaller part if they are multiple TFMs to cover the platform. The goal is to support TFM understanding the current situation in the airport and to locate the aircraft and tugs when required. Figure 14 shows the A-SMGCS HMI displaying South area of CdG with the current traffic.

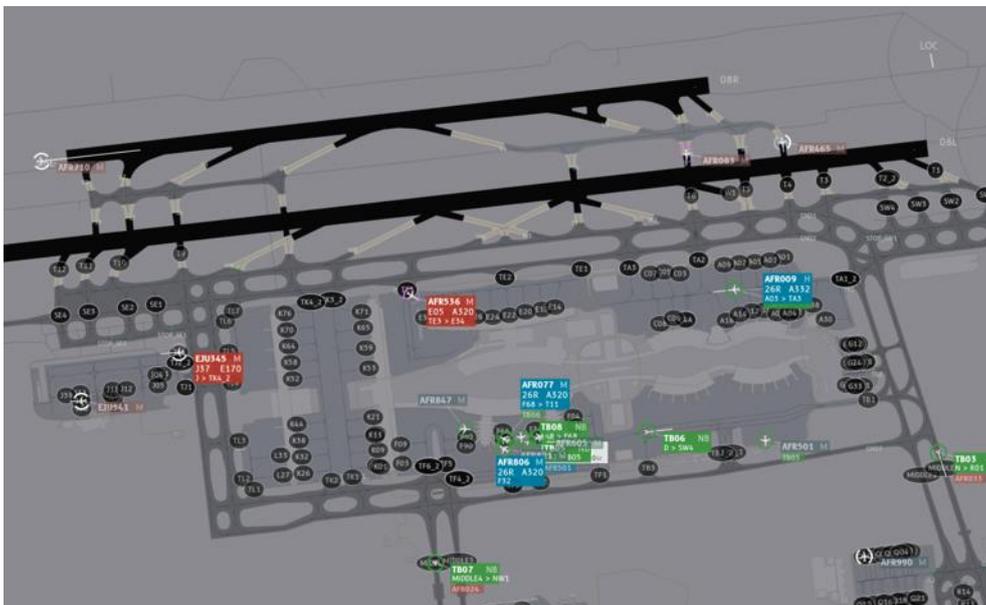


Figure 14: A-SMGCS HMI used by the TFM position

The A-SMGCS features include green labels to identify the tugs, in addition to the already existing blue (departing) and red (arriving) aircraft labels. Some interaction techniques have been specified to facilitate the identification of tugs or aircraft from one HMI to the other. Such techniques are described in section 4.1.3.

The TFM can edit route for tugs before sending a request (cf. 3.3.2) to the ground ATCO. The A-SMGCS HMI also supports the TFM to suggest a specific route that is different from the path planning algorithm as illustrated in Figure 15.



Figure 15: editing the route of TB06.

3.3.2 List of requests panel on the Ground ATCOs A-SMGCS

A request panel displays the tug taxiing requests from the TFM to the ground ATCO of the ground ATCO A-SMGCS. Figure 16: Requests Panel with shows the request panel with two taxiing requests sent by the TFM to the ground ATCO. A request displays the following information:

- The reception time of the request (top left)
- A button with the callsign of the concerned tug. Clicking the button select the tug label on the radar image and displays the suggested route between its current position and the coupling position.
- The start position of the tug and the end position separated by the character " > ".
- The expected coupling time, which implies that the tug should have arrived before this time
- A button with the callsign of the aircraft to be towed. Clicking the button select the aircraft on the radar image and displays the suggested route between its current position and the decoupling position.



Figure 16: Requests Panel with two requests

At the bottom of a request, there are two buttons, one for accepting the request and another for refusing the request. If accepted, the request disappears from the list and the tug mission is validated in the supervision HMI. If refused, the request disappears and the planned mission is canceled from the supervision HMI along with an alert indicating that this request has been refused.

3.3.3 Planned allocation of coupling and decoupling areas

As they are possibly limited coupling and decoupling areas on the airport platform the A-SMGCS integrates visual indications of the planned areas. The goal is to provide support for the ATCO in determining which decoupling point will be free for the tugs and aircrafts. When the user moves the mouse cursor over a holding point, a popup appears with the list of tracks (aircraft or tug) that are cleared to taxi to this point as presented in Figure 17. For each element of the list, the callsign of the track and the estimated time of arrival is displayed.

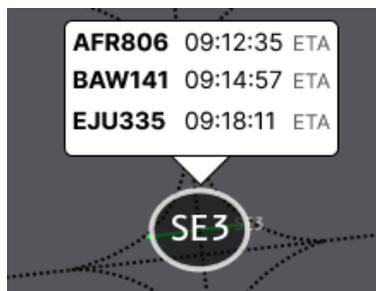


Figure 17: Popup indicating the aircrafts or tugs cleared to this point and their estimated time of arrival.

4 Scenarios and interactions

This section illustrates how the set of HMIs described in the previous sections enables users to perform their activities. We present 3 design scenarios i.e. scenarios with the envisioned sequence of interactions, together with descriptions of the actions performed by the user and reactions from the machine and explanations concerning the intention of the users. The scenarios are based on the use cases defined in D3.1 but have been simplified to better illustrate how users will interact with the interfaces.

4.1 Tug dispatching and allocation plan edition

This scenario illustrates how the tug fleet manager can assign tugs to aircraft and update the allocation plan either with the support of the AEON allocation algorithm (4.1.1) or manually (4.1.2).

4.1.1 Automatic re-allocation

In this scenario, the TFM wants to force the AEON system to compute an update of the allocation plan of all tugs from a specific time (09:10). This situation occurs because the operational situation has changed a lot from the previously planned allocation.

The TFM presses on the text “09:10” displayed above the timeline to define the time from which the allocation plan should be updated as illustrated in Figure 18. This action creates a white vertical bar under the mouse cursor that can be dragged horizontally to adjust the time from which the allocation needs to be updated. A button “UPDATE” is displayed just above the bar that triggers the algorithm when clicked and a label indicating WAITING appears. Once the algorithm finishes to compute, the allocation plan of all tugs from 09:10 is updated on the HMI as visible in Figure 19.

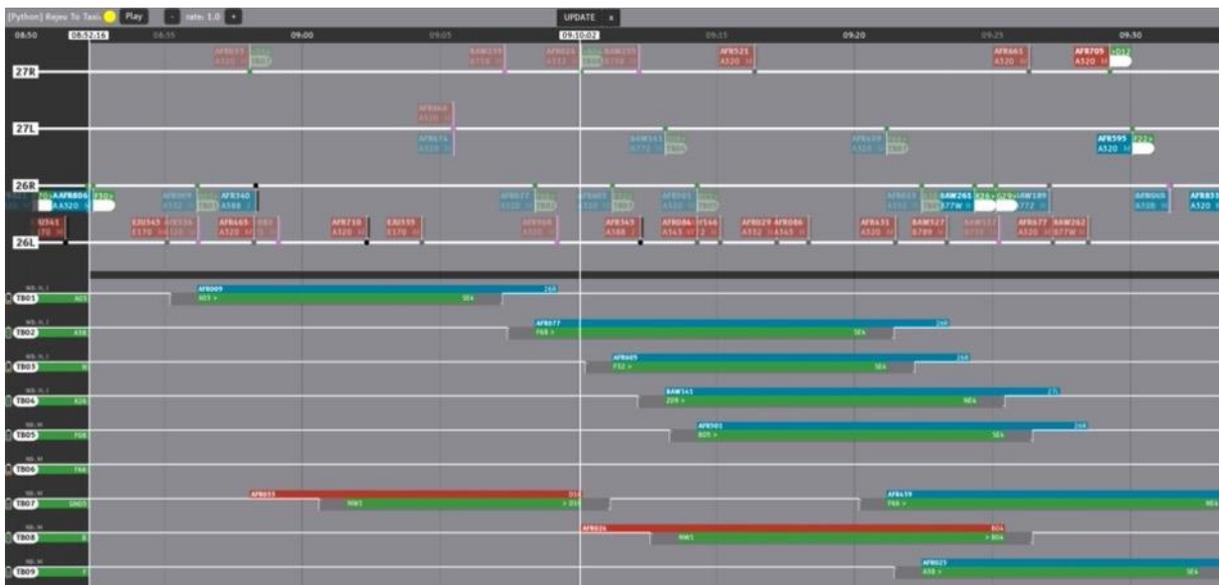


Figure 18: The operator set the recompute time to 09:10

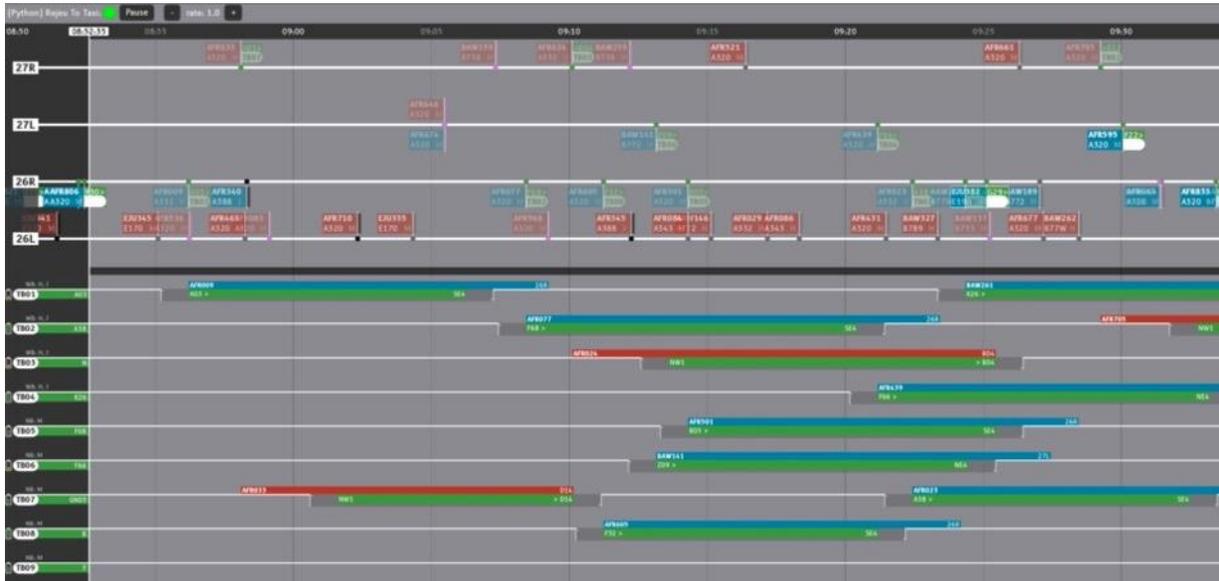


Figure 19: Allocation updated with the results from the algorithm from 09:10

4.1.2 Manual interactions

This scenario illustrates the manual edition of the allocation plan from the manual assignment of aircrafts to tugs and deletion of existing assignments. This scenario is also illustrated in the accompanying video “1 - Tug Dispatching” (<https://youtu.be/jMv8WOGweuU>).

In this scenario, the TFM starts by allocating the arrival AFR024 on runway 27R to the tug TB03. The TFM starts by pressing on the flight label AFR024 from the runway 27R timeline and then drags the label. This creates a ghost label under the mouse cursor and has a width that corresponds to the scheduled taxiing duration as visible in Figure 20 [6].



Figure 20: the ghost label (surrounded in yellow) corresponding to the flight AFR024 appears near the mouse cursor during the drag.

The TFM continues dragging over the tugs’ timelines and can only drop the label over a valid tug timeline, i.e. a tug that can tow the aircraft type of interest and that is available during the planned taxiing time. On drop, the AFR024 allocation on timeline of TB03 is completed by the tug scheduled allocation under the horizontal line: coupling duration, taxiing duration from coupling point NW1 to decoupling point B04 and decoupling duration. On the runway 27R timeline, the flight AFR024 label

has the same transparency as towed flights and the name “TB03” is displayed on the right part of the label as illustrated in Figure 21.

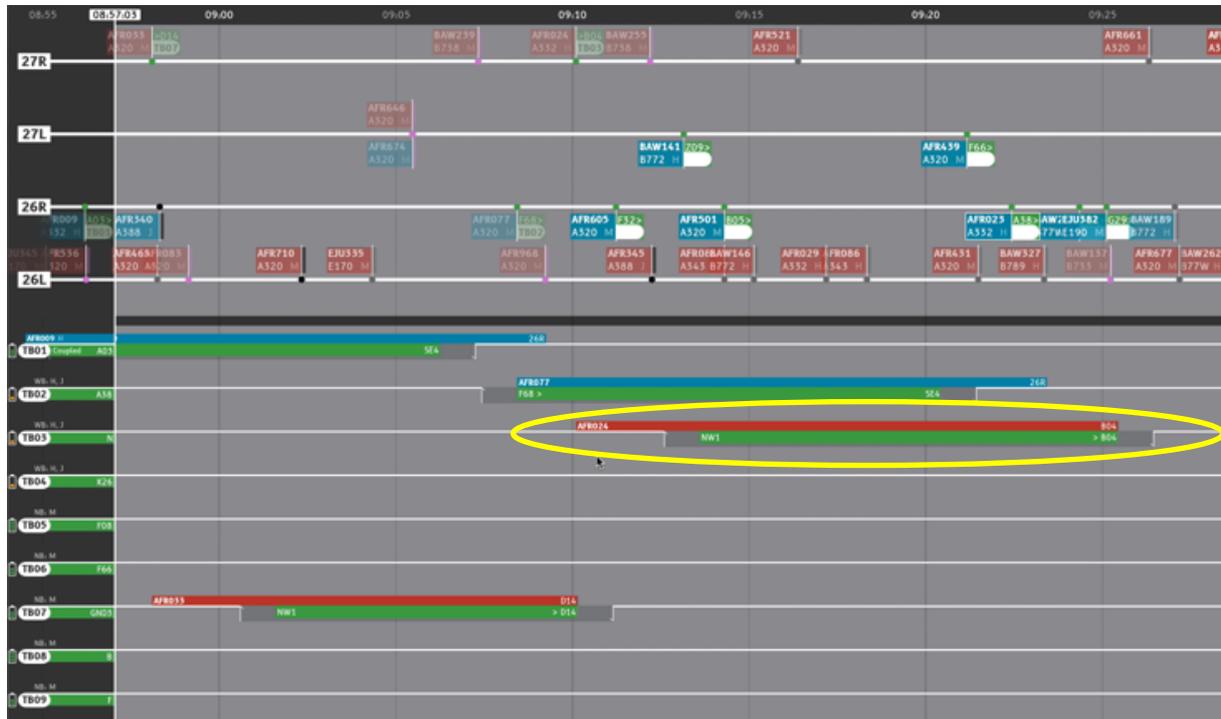


Figure 21: the flight AFR024 has been affected to the tug TB03 (circled in yellow).

Now, the TFM wants to cancel the departure flight AFR009 allocation from the tug TB07 on runway 26R. The TFM selects paired flight AFR009 and tug TB07 allocation on the tug TB07 timeline. Then, the TFM clicks on the cancel button that has appeared at the right side of the allocation (Figure 22). When the operator clicks on the cancel button, the tug TB07 allocation to the flight AFR009 is canceled and the TB07 timeline updated. On the runway 26R timeline, the flight AFR009 label becomes opaque and the name of the allocated tug is cleared on the right part of the label.

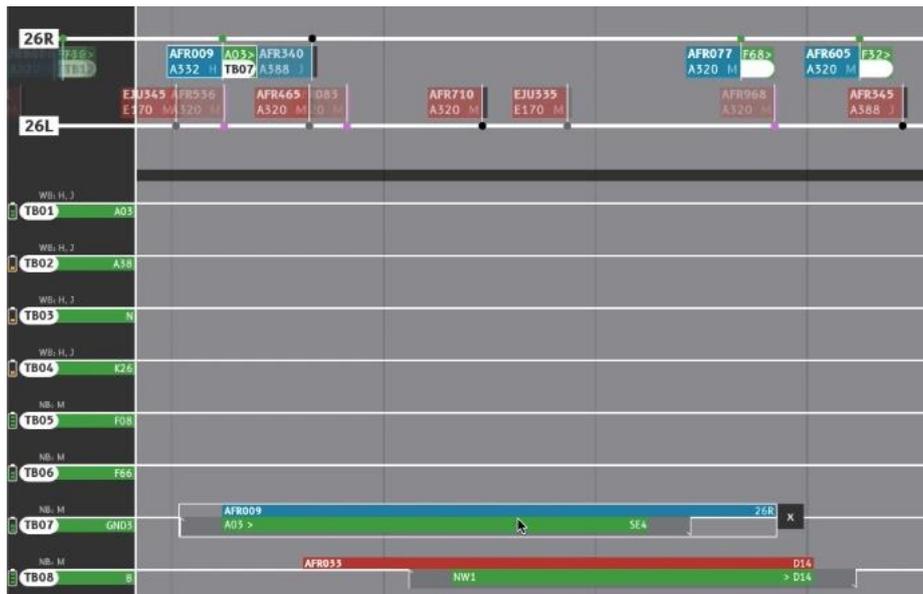


Figure 22: Affection of AFR009 and TB07 is selected

4.1.3 Locating a tug on the map or in the fleet manager

This scenario illustrates how the TFM can locate various elements between the supervision HMI and the A-SMGCS. This scenario is also illustrated in the accompanying video “3 – Locating elements across HMIs” (https://youtu.be/im5_oRAaDqk).

In this scenario, the TFM wants to locate the departure flight BAW141 on the A-SMGCS to find the closest tug available. The TFM presses on and holds the flight BAW141 label displayed on the runway 27L timeline (left window on Figure 23).

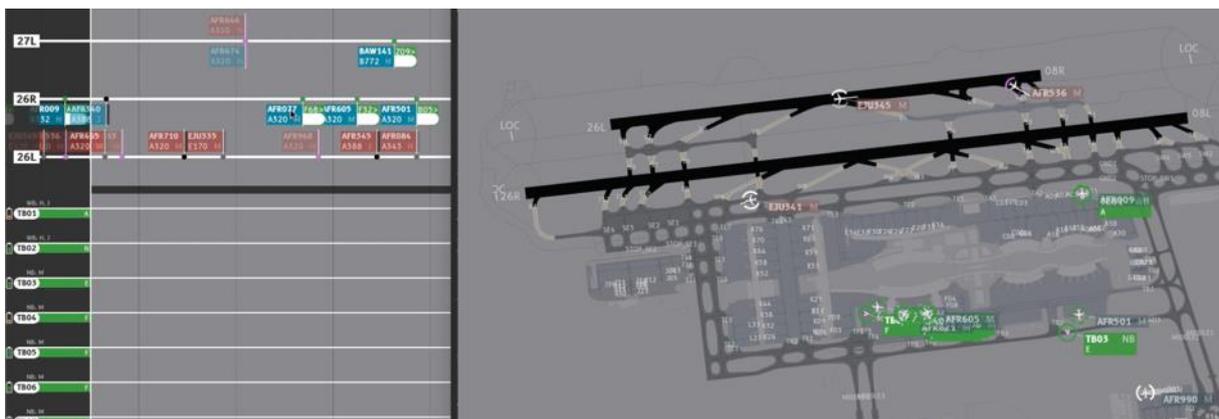


Figure 23: the windows of the 2 applications next to each other (left: supervision HMI, right: A-SMGCS)

Since the flight is visible on the A-SMGCS, a yellow circle centered on the aircraft appears as seen on Figure 24. An animation which varies the circle size helps the operator to localise the flight rapidly.



Figure 24: Animated circle centered on the track BAW141 of the A-SMGCS

If the flight is located outside the current view displayed on the A-SMGCS, a yellow arrow on the border of the view indicates where to drag the map to the flight location as illustrated in Figure 25. The arrow is animated to notify the user quickly.



Figure 25: Arrow on the border of the window of the A-SMGCS to indicate that the BAW141 is on the right.

In a similar way, the TFM can inquire about a tug allocation schedule from the A-SMGCS. For example, the TFM wants to locate the tug TB02 on the allocation plan as it is physically very close to the aircraft BAW141 on the A-SMGCS view. The TFM presses and holds the TB02 tug label displayed next to the flight label on the A-SMGCS view. In the Supervision HMI, the label size of the tug TB02 is animated to catch the TFM attention (Figure 26).



Figure 26: The label of the tug TB02 grows with an animation

4.2 Sending a request to ground ATCO

This scenario considers the collaboration between a TFM and a ground ATCO for integrating a tug into the ground ATCO plan. We have designed several alternative outcomes from manual to fully automatic in an attempt to discuss and explore the collaborative aspects between TFM and ground ATCOs during the intermediate evaluation sessions.

4.2.1 Automatic notification for each allocation

This scenario illustrates the automatic request to the ground ATCO when the TFM makes an allocation. Upon request, the ground ATCO receives a notification which can be processed at the controller's convenience. This scenario is also illustrated in video – "4 Taxiing request" (<https://youtu.be/TuArPXL-g9o>).

The TFM wants to allocate the tug TB03 to the departure flight BAW141. This implies that the tug will taxi from its current (or future) position to the parking where BAW141 is located, using the taxiways. The TFM will notify the ATCO about this planned allocation so that the ATCO can accept or not the taxi request given the current traffic situation and the workload.

The TFM drags the flight BAW141 label from the runway timeline and to the TB03 tug timeline (as seen in 4.1.2) to perform the allocation. When the allocation is made, the corresponding request appears in the requests panel on the ATCO's A-SMGCS as shown in Figure 27.

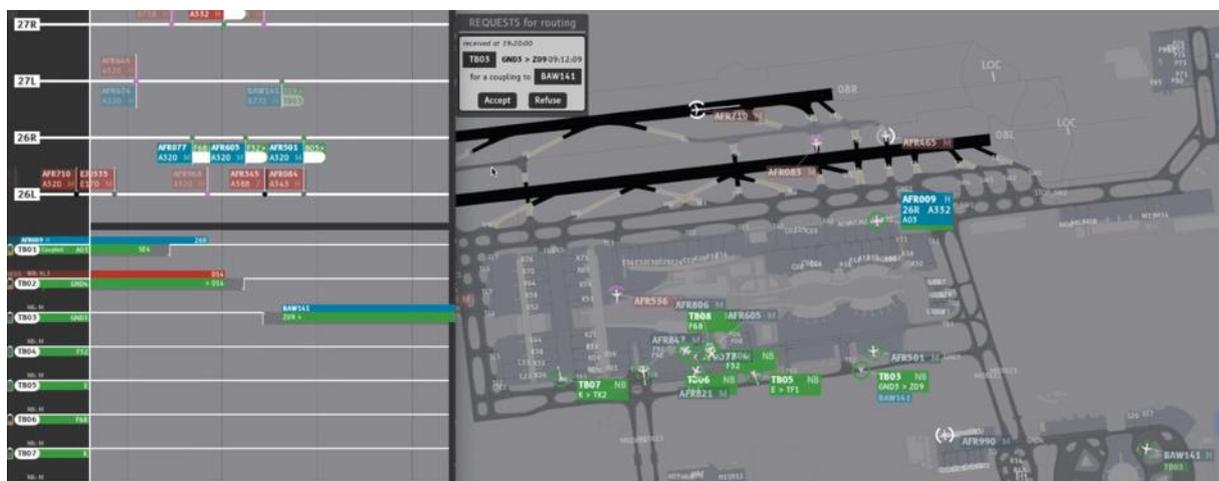


Figure 27: Request for TB03 (for a coupling to BAW141) appears in the list of the ATCO

The ground ATCO receives the TFM's taxi request and decides to locate the tug on the map. The ATCO presses the button labelled with the tug callsign to visualize the tug planned route as presented in Figure 28. The route starts from the TB03 current position and goes to the coupling position where the flight BAW141 is waiting (parking Z09).



Figure 28: The request route is displayed from current position of the TB03 to coupling position

If the ATCO considers that the planned route is manageable, the request is accepted by pressing the “Accept” button of the request. The request notification disappears from the list, the taxi allocation is validated and the timeline of the tug TB03 is updated on the TFM’s supervision view.

If the ATCO wants to refuse the request by pressing the “Refuse” button, the request is cleared from the request notification list and from the TB03 timeline in the TFM’s supervision view. The TFM then needs to assign the aircraft to another tug or to indicate that this aircraft will not be able to use a tug for taxiing in through the A-CDM tool.

4.2.2 Automatic notification for each allocation a few minutes in advance

This scenario is similar to the scenario described in section 4.2.1 but instead of emitting the taxiing requests as they are made by the TFM or by the allocation algorithm, the requests are sent automatically 10 minutes before the tug needs to start moving from its current position to the coupling point.

4.2.3 Manual notification for each allocation by the TFM

This scenario is similar to the scenario described in section 4.2.1 but instead of emitting the taxiing requests as they are made by the TFM or by the allocation algorithm, the requests are sent manually by the TFM.

For this scenario, some information was added in the supervision HMI to support the TFM performing the task and visualizing the taxiing time between the tug position and the target coupling point as illustrated in Figure 29. This is meant to represent the taxiing between the decoupling point from its

previous mission and the coupling point of the following one for which the tug driver will have to ask the ground ATCO a clearance.



Figure 29: Supervision tool with additional elements indicating the taxiing between the decoupling point from its previous mission and the coupling point of the following one.

In this scenario, the TFM wants to notify the ground ATCO that TB07 needs to taxi to the NW1 coupling point to couple with the arriving aircraft AFR033. As the taxi phase is scheduled in a few minutes, the TFM select the allocation block on the HMI and press the “Request Now” button to issue the request to the ground ATCO.

Then the TFM wants to plan some requests ahead as the schedule will be tight in 20 minutes. The TFM selects the TB08 next allocation block and press the “Request Ahead” button to schedule a request 10 minutes before the computed taxi start time.

The rest of the scenario is similar to the scenario described in section 4.2.1.

5 Status and elements

5.1 Deliverable items

Apart from this document, the deliverable includes four videos that demonstrate the following interaction:

- video “1 - Tug Dispatching” demonstrates how to manually update the allocation plan of tugs with aircraft interaction, i.e. to set or remove an allocation (<https://youtu.be/jMv8WOGweuU>).
- video “2 - Tug Status Monitoring” demonstrates the visual representations and animations that facilitate the understanding of coupling and uncoupling phases, and the tug fleet movements (<https://youtu.be/OTDGScUV240>).
- video “3 – Locating elements across HMIs” demonstrates how to locate tugs and aircrafts on the supervision HMI and the A-SMGCS (https://youtu.be/im5_oRAAdqk).
- video “4 – Taxiing request” demonstrates how the ground ATCO can accept or decline a request for tug taxiing (<https://youtu.be/TuArPXL-g9o>).

5.2 Status of interaction

All the interaction techniques in the scenarios and videos have been developed using the Djnn Framework [2] and the smala language¹. The departure and arrival schedule data are realistic and comes from CdG airport. The aircraft and tugs taxi routes are generated using a simulation engine. Since the tug allocation and the path planning algorithms are not yet integrated within our prototypes, we have used ad-hoc static allocation plans, performed manual allocations and used a shortest path planning algorithm that provided usable results for demonstration purpose.

Some elements are still missing in what we are envisioning. For instance, the tugs timeline should also display elements representing the maintenance schedule. In addition, the tugs unavailability between two allocations, i.e. when it is moving towards the next allocation location is not displayed yet although this will have an impact of the allocation and on the ground ATCOs workload. These elements are currently under design. We are exploring various alternatives as illustrated in section 4.2 to use the representation of the path between the tug position and its next towing assignment as an interactive element for making requests to the ground controller. We will also design path planning indicators within the A-SMGCS while specifying a route to inform the choices of the TFM. Indicators include the expected taxiing duration but also greenhouse gas emissions.

¹ <http://smala.io/>

We also collected indications during our tests with ground ATCOs that when assigning a coupling point to an aircraft, it would be valuable to visualize the already assigned coupling points. This is also currently under design.

6 Conclusion

We have described the supervision HMI that will be used by a tug fleet manager in accordance with the AEON envisioned CONOPS. The HMI provides interaction for updating, visualizing and editing the allocation of tugs to aircraft, refueling or maintenance and their details during operations. Specific interaction allows the tug fleet manager to locate the element on an A-SMGCS and to send coordination requests to the ground controllers.

We described the various components of the supervision HMI and illustrated their use with scenarios derived from our use cases. Apart from the document the deliverable includes four videos to better understand the dynamic aspects of the interactions.

This HMI is part of a larger set of tools including A-SMGCS and dedicated tools for pilots that will be assessed during the intermediate evaluation session and the final one in Toulouse by CdG controllers as part of WP5.

7 References

- [1] “ISO/TR 9241-100:2010(en), Ergonomics of human-system interaction — Part 100: Introduction to standards related to software ergonomics.” <https://www.iso.org/obp/ui/#iso:std:iso:tr:9241:-100:ed-1:v1:en> (accessed Apr. 25, 2022).
- [2] M. Magnaudet, S. Chatty, S. Conversy, S. Leriche, C. Picard, and D. Prun, “Djnn/Smala: A Conceptual Framework and a Language for Interaction-Oriented Programming,” *Proc ACM Hum-Comput Interact*, vol. 2, no. EICS, p. 12:1-12:27, Jun. 2018, doi: 10.1145/3229094.