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# TaCo

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## TAKE CONTROL – AUTOMATED SOLUTIONS FOR THE MANAGEMENT OF GROUND AIRPORT MOVEMENTS

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### Abstract

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TaCo project defines a framework for design, development, verification and future implementation of automated tools for airports with the involvement of end-users since the beginning (end-users programming of airport surface movements management). TaCo framework gives the controller the possibility of instructing automation with the rules, procedures and working methods that actually support his/her everyday work. This is done by means of an interactive platform (user-programming editor) that enables the definition of rules, procedures and working methods related to the management of surface movements in complex airports. The proposed approach gives the opportunity to tower ATCOs to program and test automation (and their interaction with it) based on their operational needs and using a simple visual language. This approach, opposed to a “traditional” engineering cycle where operational needs must be translated into functional requirements and then coded, tested and validated, reduces the risks of “lost in translation” and increases the efficiency, suitability and usability of automation.

This document provides a summary of the TaCo outcomes, along with the feedback obtained and lessons learned, to then conclude with further developments of TaCo in the ATM Community and in the integration of Exploratory Research projects into the SESAR mainstream and future SESAR 2020 Programme.

The opinions expressed herein reflect the authors’ view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.

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# 1 Executive Summary

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Airports are complex places, especially when it comes to managing the movements of aircraft and a myriad of service vehicles.

Automation is one of the key solution proposed and adopted by SESAR to tackle the challenges coming from the increase of capacity and complexity of the future ATM system, including airports.

The main contribution of TaCo project is a framework for design, development, verification and future implementation of automated tools for airports with the involvement of end-users since the beginning (end-users programming of airport surface movements management). TaCo framework gives the controller the possibility of instructing automation with the rules, procedures and working methods that actually support his/her everyday work. This is done by means of an interactive platform (user-programming editor) that enables the definition of rules, procedures and working methods related to the management of surface movements in complex airports. The proposed approach gives the opportunity to tower ATCOs to program and test automation (and their interaction with it) based on their operational needs and using a simple visual language. This approach, opposed to a “traditional” engineering cycle where operational needs must be translated into functional requirements and then coded, tested and validated, reduces the risks of “lost in translation” and increases the efficiency, suitability and usability of automation.

One of the main enablers for a fruitful collaboration between the end-user and the automation is the definition of operational strategies and related automation strategies (algorithms). The development of innovative algorithms for the optimization of routing paths and departure/arrival sequencing or for the minimization of fuel consumption are out of the scope of TaCo. On the other hand, the study of interactions needed to apply a certain strategy (or switch from one strategy to another under certain circumstances) in a hybrid human-automation system is one of the activities of the project.

The evaluation of TaCo’s framework involved both Malta International Airport (MIA) tower controllers (end-users) and external stakeholders coming from the airport domain during two distinct workshops.

Results show positive feedback from end-users as well as from external stakeholders. The introduction of automation strategies as the main support for handling the operations was considered beneficial and additional promising strategies were identified during the evaluation. Furthermore, such strategies were not only perceived as a support for optimization, but more in general, as an assistant for coping with specific situations.

Feedback on user programming framework pointed to the employment of such concept in offline mode, namely for planning the behaviour of the system considering known or plausible restrictions that are going to be in place during the time of the operations. Such logics would be then available during the actual management of the traffic, provided that the action plans can always be overridden by the controller.

TaCo contributes to the definition of a new SESAR Operational Improvement (OI) with the following outcomes:



- A framework for design, deployment and verification of automated tools for airports with the involvement of end-users (tower ATCOs) since the beginning (end-users programming of airport surface movements management)
- An approach to enhance the visibility of the level of automation in the tower environment and mitigations measures of transitions among different levels of automation support (towards visibility, awareness, transparency);
- Design guidelines for designers of similar hybrid human-automation environments and for designers of automation in such environments:
  - Continuum of usage and progressive disclosure
  - Space-based and event-based constructs
  - Make current state and future behaviour visible
  - Seamless AND seamful hybrid control

## 2 Project Overview

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### 2.1 Operational/Technical Context

TaCo project fits in the contest of area 1 “ATM Excellent Science and Outreach” of SESAR Exploratory Research, requiring a maturity level from Science to TRL1.

TaCo aims to define an automated system sufficiently powerful to both accomplish complex tasks involved in the management of surface movements in a major airport and self-assess its own ability to deal with non-nominal conditions. When needed, such system should be sensitive enough to transfer responsibilities for traffic management back to the controller, in a timely and graceful manner and in way that makes him/her comfortable with the inherited tasks.

Automation is one of the key solution proposed and adopted by SESAR to tackle the challenges coming from the increase of capacity and complexity of the future ATM system. On the one hand, the programme aims at substantially reducing controller task load per flight through a significant enhancement of integrated automation support, whilst simultaneously meeting the established safety and environmental goals. On the other hand, it is envisaged that human operators will remain at the core of the system (mainly with the role of overall system managers) using automated systems with the required degree of integrity and redundancy. TACO proposes a dove tailed process to facilitate the controller’s forward thinking, also in anticipation to A-CDM (Airport- Collaborative Decision Making) amongst others. TaCo project further explores an innovative application on existing solutions (such as MoTa “Modern Taxiing”, Djnn, LabyEdit etc.) with the aim to design and experiment a novel operational concept, strongly focused on the human-automation collaboration in managing ground traffic in an airport environment. The analyses are backed by feasibility considerations based on operational experience of the ATC expert involved in the project.

### 2.2 Project Scope and Objectives

TaCo aims to define an automated system sufficiently powerful to both accomplish complex tasks involved in the management of surface movements in a complex<sup>1</sup> airport and self-assess its own ability to deal with non-nominal conditions. When needed, such system should be sensitive enough to transfer responsibilities of traffic management back to the controller, in a timely and graceful manner and in way that makes him/her comfortable with the inherited tasks.

Automation is one of the key solution proposed and adopted by SESAR to tackle the challenges coming from the increase of capacity and complexity of the future ATM system. On the one hand, the programme aims at substantially reducing controller task load per flight through a significant enhancement of integrated automation support, whilst simultaneously meeting the established safety and environmental goals. On the other hand, it is envisaged that human operators will remain at the

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<sup>1</sup> Low Utilisation Simple Layout (LUSL) or High Utilisation Complex Layout (HUCL), following the definition provided in the European ATM Master Plan ([https://www.atmmasterplan.eu/performance\\_needs](https://www.atmmasterplan.eu/performance_needs))



core of the system (mainly with the role of overall system managers) using automated systems with the required degree of integrity and redundancy. TACO proposes a dove tailed process to facilitate the controller’s forward thinking, also in anticipation to A-CDM (Airport- Collaborative Decision Making) amongst others.

The main objectives of TaCo are the following:

- defining algorithms and solutions to automate and optimize both the decision making and implementation tasks for the controller involved in the ground movement of airport vehicles and aircraft;
- identifying and providing the controller with suitable and usable tools to supervise (monitor, tune and re-program) the system;
- studying the interaction between the human actors and the automation. Main focus will be on the identification of sensitive state transaction from a (fully) automated management system to conditions where the human is brought into the loop to handle situations where his/her cognitive resources are essential.

The involvement of final users and operational professionals is fundamental to achieve project objectives.

## 2.3 Work Performed

The first activity conducted in TaCo was the collection of background operational information about Malta International Airport, that is the project’s selected use case. The airport environment has been introduced in *D2.1- Problem definition* and introduced starting from a high-level description of roles, responsibilities and main duties of tower and ground Air Traffic Controllers. The project then addresses the specificities of Malta International Airport as the case study for TaCo. The main focus considers the factors of complexity<sup>2</sup> that have a major impact on the operations. The analysis of these complexity factors has been carried out through qualitative methods introduced by past studies conducted in European and US airports. The main input from D2.1 for the next stages of TaCo were the operational scenarios and operational needs. Through an active collaboration of operational experts from MATS, different realistic traffic configurations and scenarios for different runways’ configurations have been defined. Those were the “baseline” scenarios for TaCo that set the ground for the design and prototype of effective and suitable automation as well as human-machine collaboration strategies.

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<sup>2</sup> Low Utilisation Simple Layout (LUSL) or High Utilisation Complex Layout (HUCL), following the definition provided in the European ATM Master Plan ([https://www.atmmasterplan.eu/performance\\_needs](https://www.atmmasterplan.eu/performance_needs))



**Figure 1: Map representing runways, taxiways and aprons' position**

In parallel, task 2.2 started the collection of the state-of-the-art of end-user programming of reactive and autonomous systems. The main objective of this state of the art was to collect and classify input, techniques and innovative approaches coming from the fields that have conducted the more advanced studies on the topic. It included an analytical survey pertaining to Integrated Development Environments (Educational and Professional), Video Games, as they often include various means of automation for the gamer, and Music tools that range from preparation of scheduling of musical events to live, action-based sequencer during performances. It also included as much as possible considerations on interesting representations of, and interaction with automation. The results, published in D2.2 – State of the art, contributed to the definition of a common framework for the design of automated airport solutions. D2.2 – State of the art led also to the definition of some “research directions”, i.e. a set of high level requirements for authoring and operating automations support. The original research directions, as described in D2.2, are summarised in the following table:

**Table 1: Research directions elicited in D2.2**

RD1	<i>define programming language constructs relevant to ATCOs</i>
RD2	<i>make relevant programming language constructs usable by ATCOs</i>
RD3	<i>select relevant dimensions of EUP, EUD and EUSE for the task at hand</i>
RD4	<i>borrow relevant concepts from Programming by Example</i>

RD5	foster and develop an interactive, live programming environment based on MoTa
RD6	leverage the existing graphical environment
RD7	foster predictability with harbinger cues

During the project execution, and in particular during the writing of [8] for the UIST conference, a need to rephrase and re-organize the research directions emerged, aiming at a more concise and clear representation. The following re-formulation has been proposed in the paper:

**RD1: Take into account the existing scenarios**

*The new technologies must support the current work practices as identified during the user studies.*

**RD2: Define language constructs relevant to ATC**

*ATC includes activities such as planning, monitoring, reacting to contingencies. All these activities require that humans and machines interact. Hence, the new technologies must support interaction-oriented programming: events, dataflow, state-machines, states.*

**RD3: Make language constructs usable by ATCOs**

*As acknowledged by Berringer (see [8] for the reference background), an expertise tension exists in a two-dimensional continuum of job-related domain knowledge and system-related development knowledge. ATCOs might be lacking systems knowledge. Thus, solutions should strive to enable domain experts to modify or extend software without having a deep understanding of a computer system or coding skills.*

**RD4: Foster predictability and handover**

*Beyond notification, which is often too late, a challenge is to offer better representations of the status of automation and especially its ability to handle the current traffic. This should allow ATCOs to decide if they have to take control over the automation.*

**RD5: Foster efficient and scalable authoring**

*Since the number and complexity of automations might be high, the technology should scale up i.e. should be still usable with multiple and/or complex automations.*

The use of a User Centred Design approach to the design and development of an airport automation development environment, called Domain Specific Graphical Language (DSGL), was a key enabler for a successful involvement of the end-users in a process of incremental design, development and validation of the proposed solution. The work done in Work Package 3 and Work Package 4 was also guided by the Research Directions and led to the definition of a set of **automation design principles** to enhance the visibility of the level of automation in the tower environment, together with mitigations measures of transitions among different levels of automation support and human-machine (towards visibility, awareness, transparency) [4][5][6].

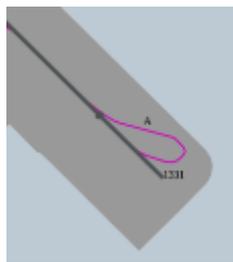
D3.1 describes the automation software that optimizes the sequence of aircraft departure according to high-level criteria defined in D2.1. In order to define a realistic representation of Malta Airport, a set of standard traffic rules (taxiways restrictions to certain aircraft types, preferred directions...) have been implemented. These traffic rules enable to generate realistic routing suggestions.

A rule is composed of a set of taxiways, a set of applicable conditions (wind direction, aircraft type, departure/arrival) and priority use level (recommended, not recommended, forbidden, both ways). The priority use level is used to build a weighted graph of the taxiways network, each priority being associated to a different weight.

Two types of rules needed to be defined:

- Actual operational rules that are applicable to the airport (aircraft types restrictions, one-way taxis...)
- Technical rules to overcome the map definition:
  - Most of the taxiways must be declared as “both ways” or else they would be used solely in the direction of their definition.
  - A turning back after backtracking must be declared as “recommended”, as opposed to the corresponding runway section that must be declared as not recommended.

For instance, on the runway threshold in Figure 2, the pink taxiway must be declared as recommended against the runway so that the routing suggestion makes the a/c take taxiway A to line up for departure.



**Figure 2: recommended taxiway**

D4.1 describes the Human-Machine Interface (HMI) to control the global automation strategy on the airport. The HMI consists in a set of interactors to select a peculiar strategy, to control the parameters of the algorithm, and to control the resulting sequence of departures in a Departure Manager. The selected global strategy is turned into parameters for the algorithm described in D3.1. This deliverable consists in the description of interactions 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 comply with the requirements and operational needs described in D2.1.

D4.2 deliverable includes the human-machine interface for the Domain Specific Graphical Language (DSGL) to author and operate automation of airport surface operations:

- mock-ups, drawings, screenshots and running interactive code of the different interactive parts
- usage scenarios that illustrate the sequence of state changes of the HMI according to user-triggered actions, with activity-oriented concerns (videos and/or storyboard)
- the rationale behind the design choices.

D5.1 describes the evaluation strategy and its results obtained mainly during the final stages of the project. The evaluation strategy is strictly connected to the user-centred design process and as such it has been translated into an iterative process that culminated in the final evaluation. The final evaluation involved both Malta International Airport (MIA) air traffic controllers and external

stakeholders coming from the airport domain during two distinct workshops. The conduction and results of these workshops are described in this document. Since the low TRL envisaged by TaCo, a qualitative approach was employed for both the end-users and the external stakeholder feedback.

## 2.4 Key Project Results

The main outcome of TaCo project is a framework for the design, development, verification and future implementation of automated tools for airports with the involvement of end-users since the initial ideas up to the advanced stages of the automation life-cycle. TaCo framework gives the controller the possibility of instructing automation with the rules, procedures and working methods that actually support his/her everyday work. This process enables a real “transfer of knowledge” (what to do and how to do something) from the human individual to the automation. This is done by means of an interactive platform (user-programming editor) that enables the definition of rules, procedures and working methods related to the management of surface movements in complex airports. The proposed approach gives the opportunity to tower ATCOs to program and test automation (and their interaction with it) based on their operational needs and using a simple visual language. This approach, opposed to a “traditional” engineering cycle where operational needs must be translated into functional requirements and then coded, tested and validated, reduces the risks of “lost in translation” and increases the efficiency, suitability and usability of automation.

One of the main enablers for a fruitful collaboration between the end-user and the automation is the definition of operational strategies and related automation strategies (algorithms). The development of innovative algorithms for the optimization of routing paths and departure/arrival sequencing or for the minimization of fuel consumption are out of the scope of TaCo. On the other hand, the study of interactions needed to apply a certain strategy (or switch from one strategy to another under certain circumstances) in a hybrid human-automation system is one of the activities of the project.

### 2.4.1 Applying different strategies

For the sake of comparison, we present two similar scenarios in which some of the steps or configurations are different. This shows how a strategy might lead to a different outcome than another strategy and illustrates how users cope with unplanned events.

All scenarios start with the same set of flights (Figure 3): 3 arrivals at 07:00:00 / 07:07:00 / 07:09:00 and 2 departures:

- AMC102: TOBT (target/requested off-block time) 07:04:30; Predicted taxiing time: 00:04:24
- RYR2955: TOBT 07:10:00; Predicted taxiing time: 00:03:58

All aircrafts belong to the “M” wake turbulence category, hence the separations between flights is 1 minute.

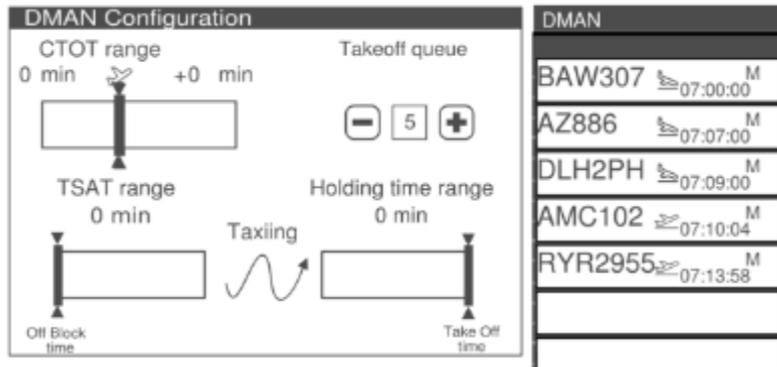


Figure 3: Initial situation

### 2.4.2 “Less fuel consumption” strategy

The supervisor selects the “less fuel consumption” strategy which mainly makes aircraft wait as much as possible at parking and start up the engines at the very last moment (see Figure 4 and Figure 5). Hence, selecting this strategy configures a 3mn waiting time after TOBT (TSAT is the actual time the aircraft leaves block). The algorithm computes a sequence in which AMC102 waits for 1mn10 at parking (TOBT=07:04:30 / TSAT = 07:05:40). This enables AMC102 to take off as soon as it arrives at the runway threshold.

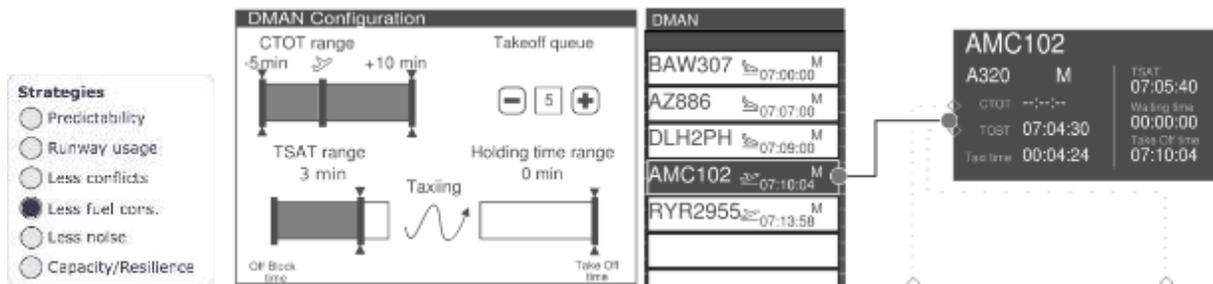


Figure 4: Status of DMAN after selection of the “less fuel consumption” strategy



Figure 5: Status of radar for the “less fuel consumption” strategy, AMC102 at parking

However, an unexpected event occurs: DLH2PH is 2 minutes late for arrival. Depending on the time the information on the delay is available, there may be two consequences:

- If the delay is known before 07:04:30 (i.e. AMC102 TOBT), AMC102 can start up sooner and take off between AZ886 and DLH2PH (see Figure 6);
- If the delay is known after 07:04:30, AMC 102 will not be on time to take off and the initial sequence is maintained i.e. it cannot be optimized.

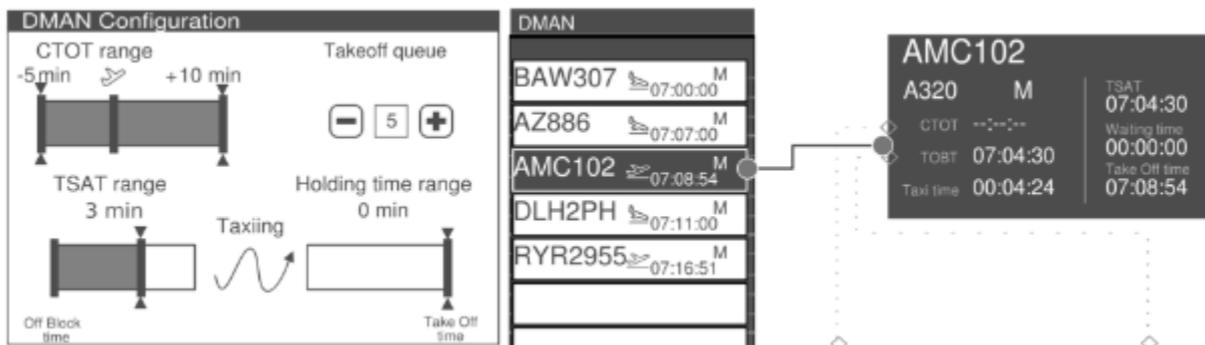


Figure 6: Status of DMAN after a delay occurred and the information arrived soon enough

### 2.4.3 “Runway usage” strategy

The supervisor selects the “runway usage” strategy which mainly makes aircraft start up as soon as possible on the parking, taxi and wait at the runway threshold i.e. burn fuel during wait (see Figure 7 and Figure 8). Hence, selecting this strategy configures a 3 minutes waiting time at the runway

threshold. The algorithm computes a sequence in which AMC102 starts up at 07:04:30 (TSAT = TOBT) and waits 1:10 minutes at runway (Waiting time = 00:01:10), burning fuel unnecessarily but being ready to depart.

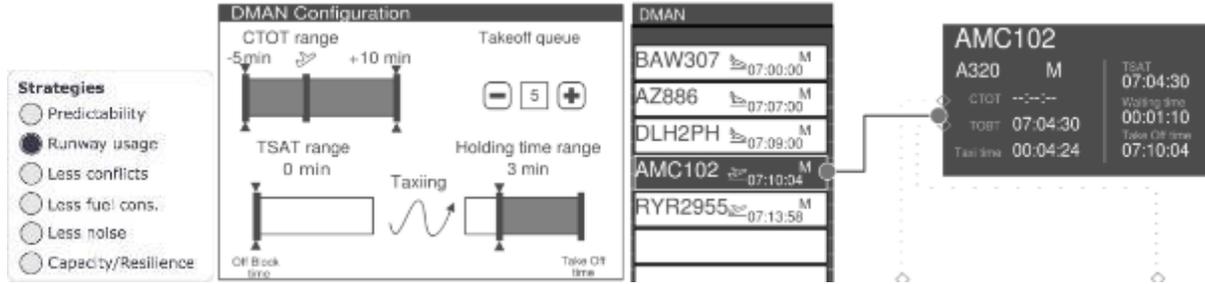


Figure 7: Status of DMAN after selection of the “runway usage” strategy



Figure 8: Status of radar for the “runway usage” strategy, AMC102 at runway holding point

However, an unexpected event occurs: DLH2PH is 2mn late for arrival. Since AMC 102 is already waiting at runway threshold, it can take off between AZ886 and DLH2PH (Figure 9).

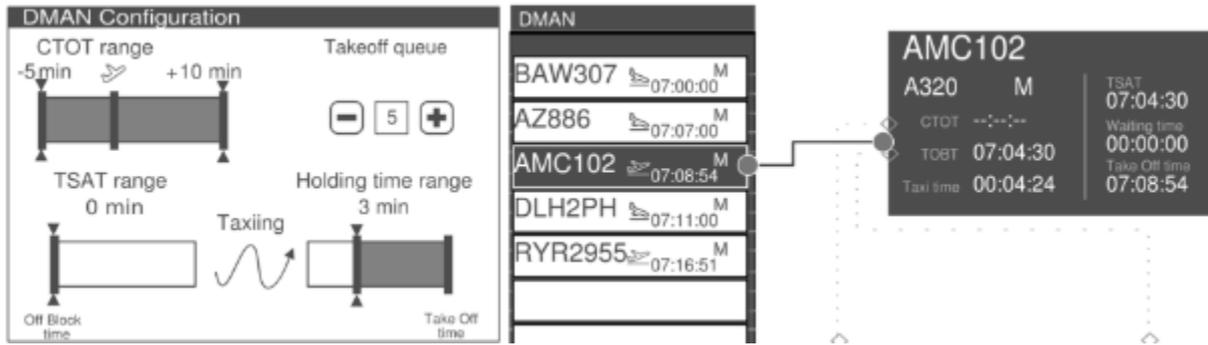


Figure 9: Status of DMAN after a delay occurred

### 2.4.4 Applying a strategy and solving unsolved constraints

This scenario shows how the supervisor chooses a strategy, how the algorithm is able to detect unsolved constraints, how the unsolved constraints are reported to the user through the HMI, how the HMI suggests possible means of resolution, and how the user changes the configuration of the DMAN to meet the constraints.

In the initial situation the controller uses a “maximize runway usage” strategy as illustrated in Figure 10.

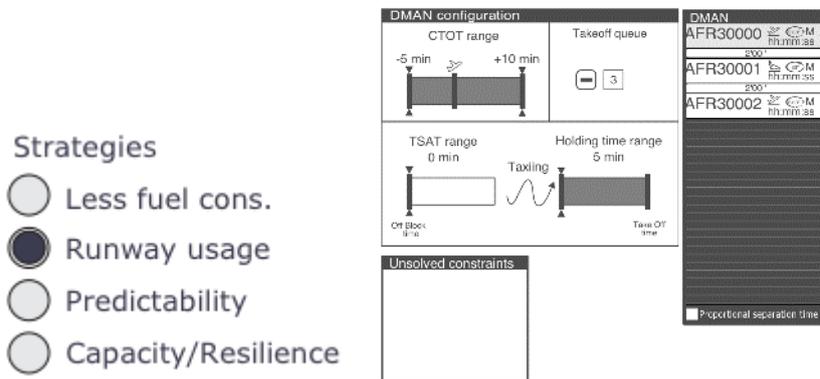


Figure 10: Initial condition with the Runway usage strategy applied to the DMAN.

As the traffic is decreasing, the controller decides to update the strategy to “less fuel consumption” instead of the previous one. She selects the strategy to apply its parameters to the DMAN as presented in Figure 11.

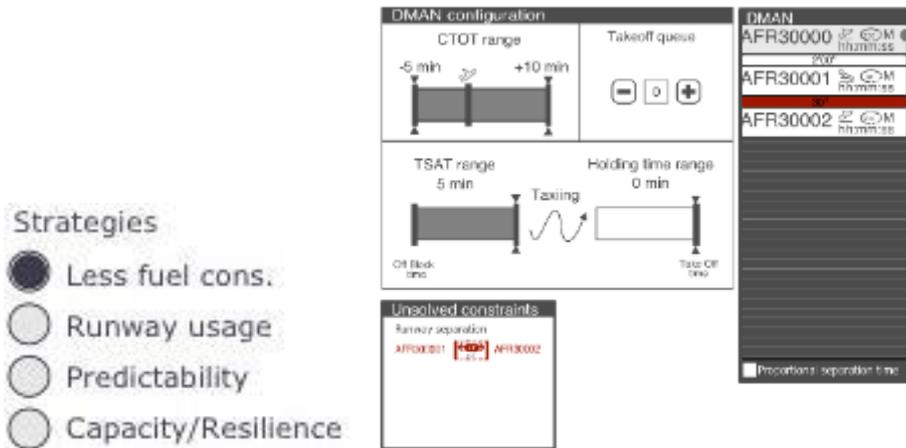


Figure 11: Applying the save fuel strategy raises unsolved constraints.

The newly computed sequence contains an unsolved constraint displayed in the dedicated panel. Here the separation time is too short between two flights. In addition to the unsolved constraints panel, the separation time in the sequence list is colored to help identifying the problem within the sequence.

The controller selects the problem in the constraints panel to get suggestions on how to solve it as presented in Figure 12. Once selected, animations emphasize possible changes to the DMAN configuration that would support problem resolutions. In this example, the take-off queue blinks to suggest increasing the queue before the runway and the holding time range is animated to suggest adding possible holding time for the flights.

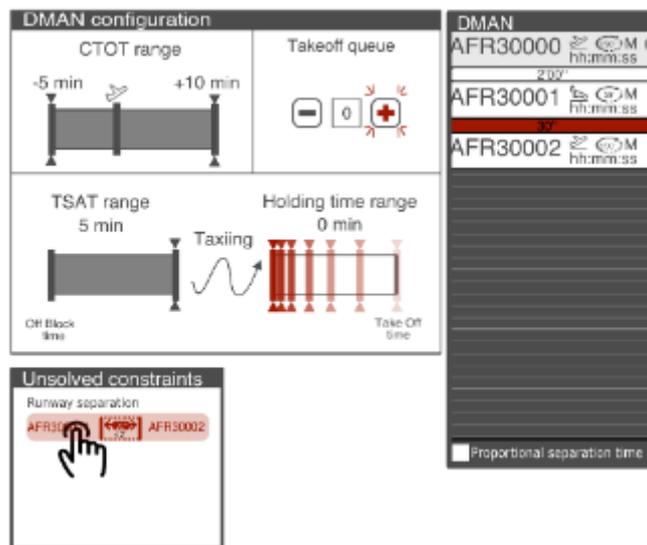


Figure 12: Selecting a problem to display possible actions for solving it. Animations are displayed in red.

Then, the controller decides to follow the suggestions and updates the parameters as presented in Figure 13. She allows one flight to be in the takeoff queue and increases the possible holding time to two minutes. This will allow the algorithm to find a sequence that preserves the minimum separation time between the two flights.

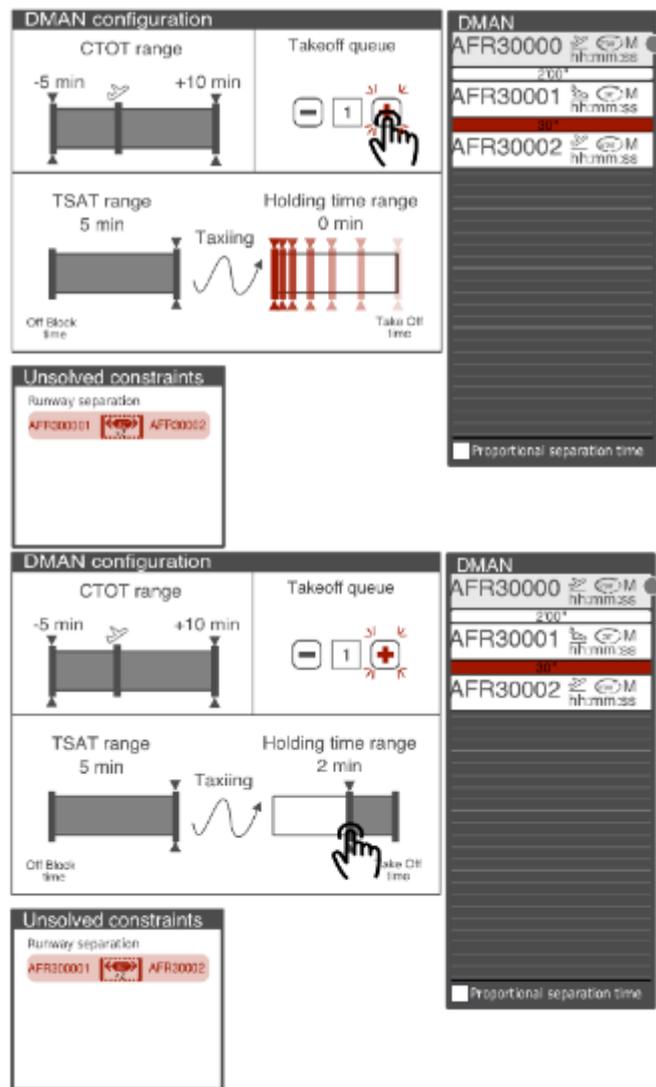


Figure 13: Updating the suggested configuration parameters manually.

Eventually, a new sequence without separation problems is computed and displayed in the sequence list as presented in Figure 14.

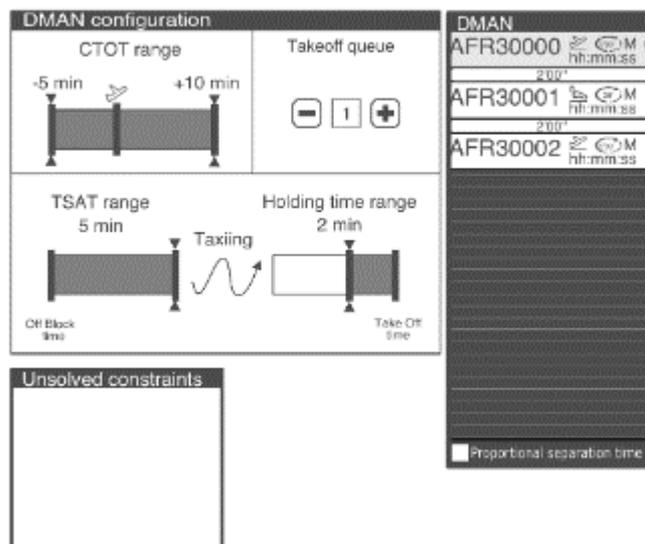


Figure 14: Updated DMAN configuration producing a new sequence without problem.

## 2.4.5 TaCo's approach to automation

TaCo's initial vision of human-automation collaboration involved the usage of innovative concepts such as:

- the presence of multiple autonomous agents (i.e. aircraft, vehicles etc.) that can be instructed to pursue a specific objective
- the user-programming techniques for
  - defining agents' behaviours and logic during the tactical phase
  - keeping the controllers engaged and "in-the-loop"
- the presence of intelligent modules capable of sensing the inability of the system to manage the current situation (or even better, predict this minutes ahead)
- the ability of such modules to recognize what operations are still controllable through the automation and how to gracefully shift back the control toward the human

Thanks to the results gathered along the whole project activities, it was possible to further refine these pillars of the TaCo concept and to adapt and integrate them towards a more mature and suitable concept. While some of the pieces have gone under minor tunings (i.e. the automation strategies were considered a valid support with very small modifications), others shown the need to be redesigned when explored with MATS air traffic controllers. These changes put together resulted in TaCo concept/approach that is here described.

The resulting TaCo approach envisages to cover the entire spectrum of the airport movements management operations, from the strategic stages to the tactical ones. TaCo stands from "Take Control", and the assumption is that controllers will be facilitated in keeping, taking or releasing the control if they are involved in the definition of the automation logics. This assumption is not different from the one defined at the beginning of the project. The real difference is the time frame envisaged for the definition of the automation logic, the usage of this logic and the support applying them. Put in concrete terms, TaCo approach translates in the following supports

Strategic/pre-tactical phase: (from 1 month to day before operations) during this phase, considering the planned flights and the fixed constraints in the airport environment, TaCo allows to setup the strategies to be used during the operations. This is done using the DSGL tools that can be applied to

- local areas of the airport
- specific flights
- specific times of the day (e.g. during peak hour)
- specific situations (e.g. when more than, see figure Figure 15)



**Figure 15 – Programming an automatic change of global strategy with the DSGL according to the number of flights at apron 9**

At this point, it is important to highlight that this process is essentially a translation and transfer of knowledge from the controller experience to the rules specified for planning the system behaviour.

The strategic and pre-tactical phase considers different aspects while approaching towards the pre-tactical side: for example, some of the constraints are fixed due to the structure of the environment and can be considered during the initial stages, while others will be known only some days before the operation forcing a re-planning of the logics.

The result of this stage is a set of rules/behaviours/logics linked to the expected traffic picture and that already the known constraints and complexity of the airport. Each of these rules has its own degree of autonomy depending on how it has been defined: for example, a rule stating that "runway usage optimization will be applied when the inbound + outbound traffic overcomes a given threshold" can be applied automatically, while more safety critical behaviours may require the confirmation or the explicit intervention of the controller.

Tactical Phase: during the tactical phase, the rules previously defined are proposed to the controllers depending on the actual situation. As described before, one of the properties defined at strategic level is the degree of autonomy of the behaviours. During this phase, controllers have a tool box of pre-set rules that they can decide to apply, tune or even discard depending on what is happening at the moment.



### 2.4.7 Stakeholders feedback

TaCo organised a final dissemination event at the International Airport of Malta in April 2018 (see Appendix A1.5 for details about the workshop and the participants). The main objective of the event was to share the project results with all the potential users and stakeholders including airport operators and ANSPs. Nonetheless, scientific results have been also presented to raise interest and feedbacks from the scientific community.

The following figures show the main results obtained during the workshop with the external stakeholders.

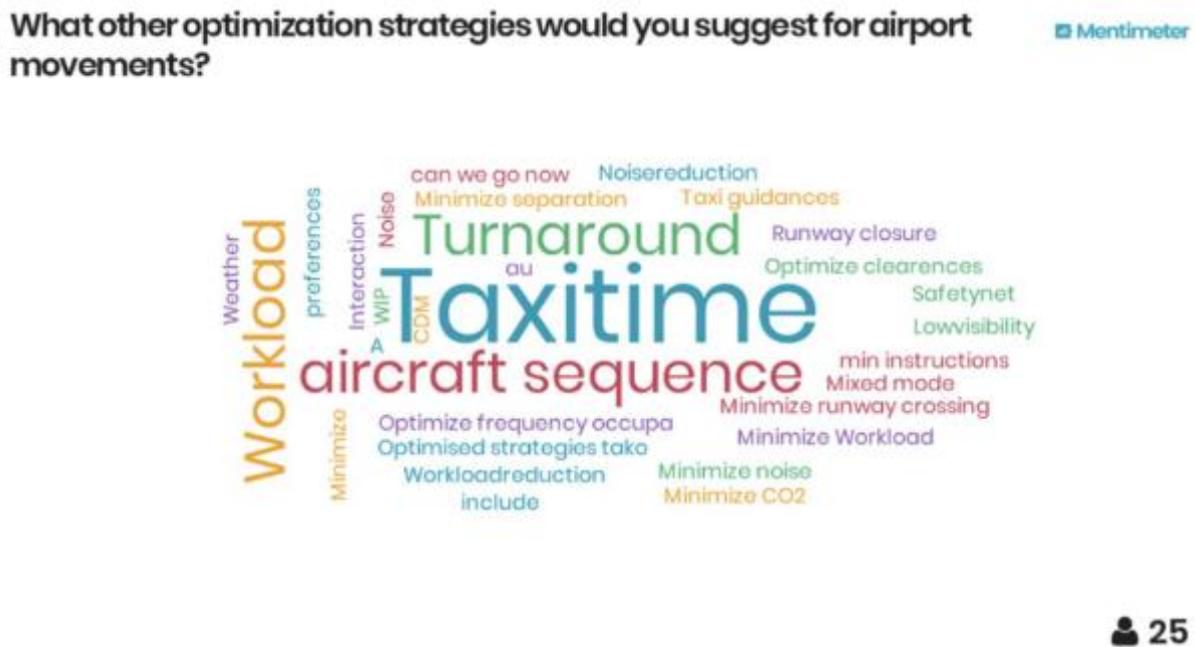


Figure 17 - Optimization strategies suggested during the workshop

Participants were asked to specify beneficial optimization strategies that were not implemented in TaCo. Among the keywords in the picture, bigger words represent the ones having a higher number of votes. It has to be noted however that the same concept/strategy expressed with slightly different wording would appear as a different keyword: for example, a strategy regarding workload optimization was specified by several people in different ways.

## Potential obstacles in the adoption of the TaCo concept

Mentimeter



28

Figure 18 - Potential obstacles identified

Among the obstacle against the introduction of TaCo participants mainly specified reasons related to money, integration, and interoperability with the existing systems.

## Potential safety issues in the adoption of the TaCo concept

Mentimeter



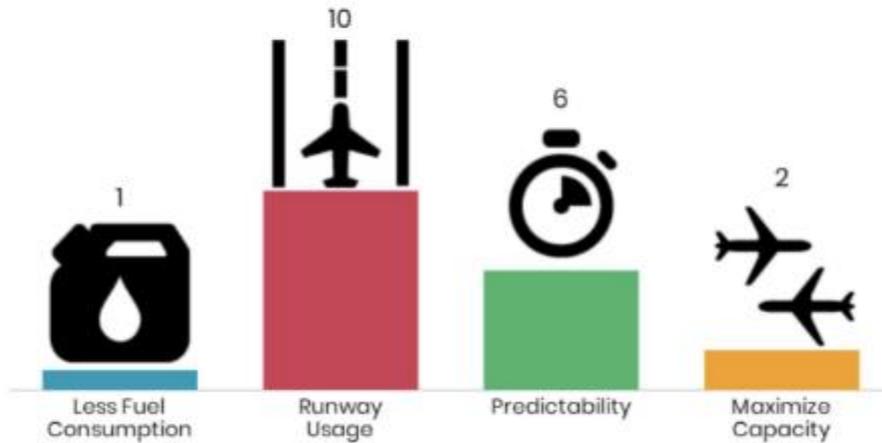
17

Figure 19 - Potential safety issues identified

Safety issues related to the introduction of TaCo were asked separately as the importance of the topic. A number of well-known issues related to the introduction of highly automated systems was specified by the participants, for example “human in the loop”, “misuse”, “loss of situation awareness”.

**In your opinion, what is the most promising optimization strategy in TaCo**

Mentimeter



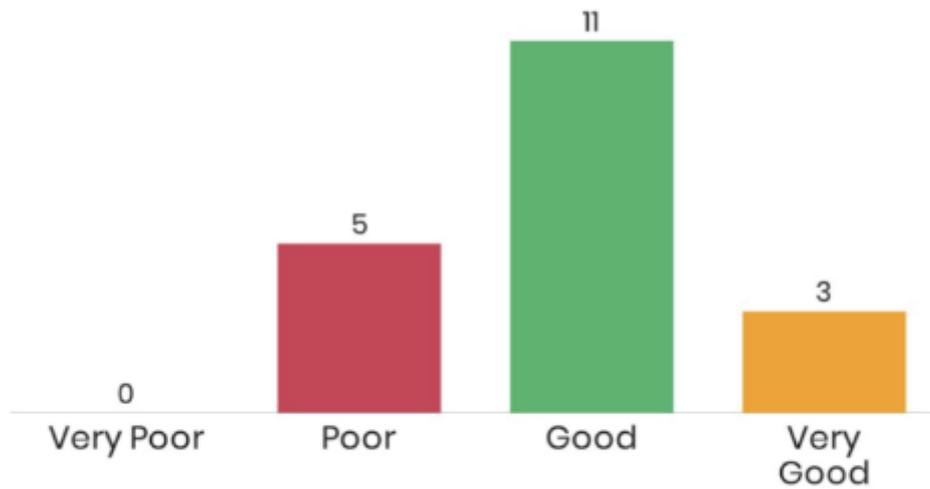
19

**Figure 20 - Most promising optimization strategy**

Participants were also asked to select the most promising automation strategy among the one already implemented in the TaCo prototype. Surprisingly, the “less fuel consumption” strategy was the one with less votes.

## Overall quality of the prototype's user interface

Mentimeter



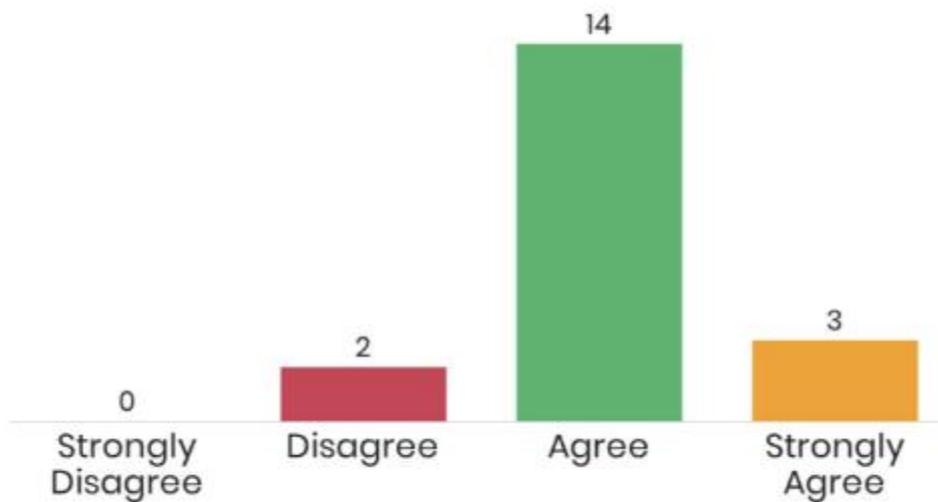
19

Figure 21 - Overall quality of the prototype's user interface

The overall quality of the prototype’s user interface was rated as good or very good by 14 participants on a total of 19.

## It would be easy to adapt TaCo to be used in other airports

Mentimeter



19

Figure 22 - Transferability of TaCo on other airports

Finally, participants were asked how difficult would be to transfer the TaCo concept and apply it to other airports. The general feedback show that this would be a feasible process. Further comments during the discussion pointed out that it wouldn't be a "research work" to transfer such concept.

## 2.5 Technical Deliverables

Reference	Title	Delivery Date <sup>3</sup>	Dissemination Level <sup>4</sup>
<b>Description</b>			
D1.1	Project Management Plan	24/10/2017	CO
D1.1 presents the Project Management Plan (PMP) of TaCo that complements the project information provided in the Grant Agreement and its Annex I - Description of Action, integrating in particular more detailed procedures, briefly describing the Communication and Dissemination Plans and implementing any additional refinement agreed at the Kick-off meeting.			
D1.2	Project Results Final Report	25/05/2018	PU
This publishable Final Project Results Report (this deliverable) covers all the research activities performed by the project. It provides sufficient detail about the scientific work performed, so that the reader can identify which deliverables might be of interest in case he wants to read more detail.			
D2.1	Problem Definition	15/11/2017	PU
This deliverable, together with "D2.2 – State of the art", paves the way to the research and design of innovative automation models and solutions as the core of TaCo. In addition, the document presents an overview of the placement of TaCo with respect to the Work Programme of SESAR. The airport environment is introduced starting from roles, responsibilities and duties of tower and ground ATCOs. The dissertation then addresses the specificities of Malta International Airport as the case study for TaCo. The main focus considers the factors of complexity that have a major impact on the operations. The analysis of these complexity factors is carried out through qualitative methods introduced by past studies conducted in European and US airports. The main input from D2.1 for the next stages of TaCo are the operational scenarios.			
D2.2	State of the art	15/02/2017	PU
This deliverable is concerned with the end-user programming of reactive and autonomous systems. The main objective of this state of the art is to collect and classify input, techniques and innovative approaches coming from the fields that have conducted the more advanced studies on the topic. The document includes an analytical survey pertaining to Integrated Development Environments (Educational and Professional), Video Games, as they often include various means of automation for the gamer, and Music tools that range from preparation of scheduling of musical events to live, action-based sequencer during performances. It also includes as much as			

<sup>3</sup> Delivery data of latest edition

<sup>4</sup> Public or Confidential

possible considerations on interesting representations of, and interaction with automation. The result contributes to the definition of a common framework for the design of automated airport solutions.

D3.1	Automation Library	07/02/2018	CO
<p>This document describes the automation software that optimizes the sequence of aircraft departure according to high-level criteria defined in D2.1. The software is a library, a component of a larger simulation setup. The library employs a set of traffic rules specific to the Luqa airport (ICAO LMML). The traffic rules have been described in a document that the library parses and uses to compute the aircraft trajectories. Then the library optimizes the set of trajectories by relying on a simulated annealing algorithm. Together with this document, the deliverable includes an archive file containing the java implementation and an example of its usage.</p> <p><b>NOTE: the consortium decided, by joint agreement among the Members, to make this deliverable publicly available at <a href="http://www.tacoproject.eu/deliverables/">http://www.tacoproject.eu/deliverables/</a>. The decision has been communicated to SJU during the close-out meeting of the project.</b></p>			
D4.1	HMI Global Strategy	22/02/2018	CO
<p>This document describes the Human-Machine Interface (HMI) to control the global automation strategy on the airport. The HMI consists in a set of interactors to select a peculiar strategy, to control the parameters of the algorithm, and to control the resulting sequence of departures in a Departure Manager. The selected global strategy is turned into parameters for the algorithm described in D3.1. This deliverable consists in the description of interactions 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 comply with the requirements and operational needs described in defined in D2.1.</p> <p><b>NOTE: the consortium decided, by joint agreement among the Members, to make this deliverable publicly available at <a href="http://www.tacoproject.eu/deliverables/">http://www.tacoproject.eu/deliverables/</a>. The decision has been communicated to SJU during the close-out meeting of the project.</b></p>			
D4.2	DSGL for airport automation		CO
<p>The deliverable will include the human-machine interface for the global strategy:</p> <ul style="list-style-type: none"> <li>- mock-ups, drawings, screenshots and running interactive code of the different interactive parts</li> <li>- usage scenarios that illustrate the sequence of state changes of the HMI according to user-triggered actions, with activity-oriented concerns (videos and/or storyboard)</li> <li>- the rationale behind the design choices.</li> </ul> <p><b>NOTE: the consortium decided, by joint agreement among the Members, to make this deliverable publicly available at <a href="http://www.tacoproject.eu/deliverables/">http://www.tacoproject.eu/deliverables/</a>. The decision has been communicated to SJU during the close-out meeting of the project.</b></p>			
D5.1	Evaluation Report	22/05/2018	PU
<p>This document describes the evaluation strategy and its results obtained mainly during the final stages of the project. The evaluation strategy is strictly connected to the user-centred design process and as such it has been translated into an iterative process that culminated in the final evaluation. The final evaluation involved both Malta International Airport (MIA) air traffic controllers and external stakeholders coming from the airport domain during two distinct workshops. The conduction and results of these workshops are described in this document. Since the low TRL envisaged by TaCo, a qualitative approach was employed for both the end-users and the external stakeholder feedback.</p>			
D6.1	POPD Requirement No. 2	28/07/2016	CO
<p>Justification is given in case of collection and/or processing of personal sensitive data.</p>			
D6.2	POPD Requirement No. 1	28/07/2016	CO



Detailed information is here provided on the procedures that will be implemented for data collection, storage, protection, retention and destruction and confirmation that they comply with national and EU legislation.

D6.3	POPD Requirement No. 4	07/09/2016	CO
Copies of ethical approvals for the collection of personal data by the competent University Data Protection Officer / National Data Protection authority are here submitted.			
D6.4	POPD Requirement No. 3	28/07/2016	CO
Detailed information is here provided on the informed consent procedures that will be implemented.			

**Table 2: Project Deliverables**

## 3 Links to SESAR Programme

### 3.1 Contribution to the ATM Master Plan

Airports are complex places, especially when it comes to managing the movements of aircraft and a myriad of service vehicles.

Automation is one of the key solution proposed and adopted by SESAR to tackle the challenges coming from the increase of capacity and complexity of the future ATM system, including airports (as explicitly recalled by the H2020 Topic addressed by TaCo, that is Automation in ATM [11]).

The main contribution of TaCo project to the European ATM Master Plan [10] is a framework for the design, development, verification and future implementation of automated tools for airports with the involvement of end-users since the initial ideas up to the advanced stages of the automation life-cycle. The proposed framework is called “end-users programming of airport surface movements management”. The outcome of TaCo is a “framework”<sup>5</sup> as it provides three main building blocks for future development of automated tools for airport surface management:

- **A reproducible methodology**, based on User Centred Design principles [7], that was built upon the following pillars:
  - User engagement and co-design: taking advantage of the presence of MATS in the consortium, it was possible to reach and directly involve the ATCOs in the early design phases. This allowed to smooth the first stages of context understanding and user requirements specification.
  - Work scenarios: the context of the operations (i.e. MIA environment) was specified directly with and by the users during the first workshop in Toulouse. The shape of the context description was a set of so called “work scenarios” or “use cases” (see deliverable D2.1 Automated Airport for more details) describing the current and most meaningful situations representing a potentially difficult task that could be supported by the automation. Work scenarios represent a hybrid asset containing both the context description and the user needs.
  - Design scenarios: based on the information collected through the work scenarios, a set of so called “design scenarios” was produced introducing potential support solution that TaCo could provide to the controllers. Design scenarios were produced again through a co-design process with the controllers who expressed their ideas on the solutions in a second workshop in Malta. Both the work and design scenarios were generated using paper mockups containing the airport representation and

<sup>5</sup>Cambridge Dictionary definition of “framework”:

- a. a supporting structure around which something can be built
- b. a system of rules, ideas, or beliefs that is used to plan or decide something (e.g. “a legal framework for resolving disputes”)



reproducing typical situations for the controllers (see deliverables D4.1 and D4.2 for more details on design scenarios).

- **Final evaluation:** A subset of the design scenarios was then translated and implemented into the TaCo prototype that was evaluated at the end of the project during a dedicated workshop in Malta.
- **An airport automation development environment**, called Domain Specific Graphical Language (DSGL) [6], to author and operate automation of surface operations. The DSGL consists in a set of graphical objects that can be added over the airport map and connected to specify automation.  
Automation designed and developed within the TaCo framework gives the controller the possibility of instructing automation with the rules, procedures and working methods that actually support his/her everyday work. This is done by means of an interactive platform (user-programming editor) that enables the definition of rules, procedures and working methods related to the management of surface movements in complex airports. The proposed approach gives the opportunity to tower ATCOs to program and test automation (and their interaction with it) based on their operational needs and using a simple visual language. This approach, opposed to a “traditional” engineering cycle where operational needs must be translated into functional requirements and then coded, tested and validated, reduces the risks of “lost in translation” and increases the efficiency, suitability and usability of automation. A dedicated HMI acting as an Integrated Development Environment (IDE) supports authoring, testing and operating programs created with the DSGL.
- **Automation design principles** to enhance the visibility of the level of automation in the tower environment and mitigations measures of transitions among different levels of automation support and human-machine (towards visibility, awareness, transparency). These human-automation and automation-human “handover strategies” have been designed and evaluated with the users and integrated in the DSGL IDE and in the global strategy HMI [5][6][7].

The Technology Readiness Level (TRL) of the proposed Operational Improvement is low, being the study still at the stage of feasibility study. An early demonstrator has been produced and evaluated with the users [5][6][7], and the final assessment of the OI maturity, based on the criteria provided by SJU, is TRL 1 (see Table 4 for the details about the assessment).

Code	Name	Project contribution	Maturity at project start	Maturity at project end
Not yet defined	Not yet defined	TaCo contributes to the identified OI with the following outcomes: <ul style="list-style-type: none"> <li>● A framework for the design, development, verification and future implementation of automated tools for airports with the involvement of end-users since the initial ideas up to the advanced stages of the</li> </ul>	TRL 0	TRL 1

		<p>automation life-cycle. The proposed framework is called “end-users programming of airport surface movements management”.</p> <ul style="list-style-type: none"> <li>• An approach to enhance the visibility of the level of automation in the tower environment and mitigations measures of transitions among different levels of automation support (towards visibility, awareness, transparency);</li> <li>• Design guidelines for designers of similar hybrid human-automation environments and for designers of automation in such environments: <ul style="list-style-type: none"> <li>○ Continuum of usage and progressive disclosure</li> <li>○ Space-based and event-based constructs</li> <li>○ Make current state and future behaviour visible</li> <li>○ Seamless AND seamful hybrid control</li> </ul> </li> </ul>	
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**Table 3: Project Maturity**

## 3.2 Maturity Assessment

The following table gives details about the Maturity Assessment of TaCo contribution. The scheme here applied is the Exploratory Research Fund / Application Oriented Research Maturity Assessment, meaning a progress of the proposed solution from TRL 0 to TRL 1.



Table 4: ER Fund / AO Research Maturity Assessment

ID	Criteria	Satisfaction	Rationale - Link to deliverables - Comments
TRL-1.1	Has the ATM problem/challenge/need(s) that innovation would contribute to solve been identified? Where does the problem lie?	Achieved	Environment: airport ground activities Target users: Tower ATCos for ATM airport operators for ground handling operations Problem addressed: Design and operation of automation support to ATCos dealing with complex ground operations The main input from D2.1 for the next stages of TaCo were the operational scenarios and operational needs. Through an active collaboration of operational experts from MATS, different realistic traffic configurations and scenarios for different runways' configurations have been defined. Those were the "baseline" scenarios for TaCo that set the ground for the design and demonstration of an effective and suitable approach to automation as well as human-machine collaboration strategies.
TRL-1.2	Has the ATM problem/challenge/need(s) been quantified?	Partial - Non Blocking	In "D2.1 - Problem definition" some realistic scenarios have been defined with operational experts from MATS. These scenarios include realistic estimations of airport traffic levels in MIA and their potential evolution in the future. However, a fully quantitative assessment of the impact of the identified levels of traffic on TaCo solution has not been carried out and will be part of the future work on the solution.





<p>TRL-1.3</p>	<p>Are potential weaknesses and constraints identified related to the exploratory topic/solution under research?                  - The problem/challenge/need under research may be bound by certain constraints, such as time, geographical location, environment, cost of solutions or others.</p>	<p>Achieved</p>	<p>Is TaCo applicable everywhere? Yes, but further development is needed to make the solution scalable:                  - Work on the local optimization of the strategies (e.g. more complex airports would need more focus on computational resources)                  - Some of the proposed tools are strictly bound by the airport layout; the development of more flexible solutions may be needed</p> <p>Are there technical constraints?                  - Every vehicle should be tracked in real time (e.g. by ADS-B), but it may be mitigated (some form of “non-cooperativeness” may be managed by the system)</p> <p>Which costs?                  - Financial costs not yet estimated, operational costs reduced by the use of end-user programming (the system is instructed directly by controllers and operational experts)</p> <p>Is additional training needed?                  Some additional training is required. Indications collected during the evaluation with the final users identified some training gaps. A full assessment of the gaps has not been carried out, as the maturity level of the proposed demonstrator is still low. Anyhow, the preliminary judgement by operational experts identified the amount of additional training as reasonable (see D5.1).</p>
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TRL-1.4	Has the concept/technology under research defined, described, analysed and reported?	Achieved	<p>The state of the art of user programming techniques is described in D2.2.</p> <p>The research work done and the TaCo solution are described in the following deliverables:</p> <ul style="list-style-type: none"> <li>main optimization algorithms and automation strategies behind the functioning of TaCo are described and analysed in D3.1</li> <li>HMI solutions including man-automation handover considerations are presented and explained in D4.1 and D4.2;</li> <li>acceptability and usability considerations by the end users (ATCOs) and external stakeholders are included in D5.1</li> </ul>
TRL-1.5	Do fundamental research results show contribution to the Programme strategic objectives e.g. performance ambitions identified at the ATM MP Level?	Partial - Non Blocking	<p>TaCo identified a potential impact of the proposed solution on several SESAR KPAs. In particular, the automation strategies proposed by TaCo (see D4.1) may have positive impacts on: predictability, operational efficiency, environment, capacity.</p> <p>Due to the low level of maturity of the proposed solution, it has not been possible to make a proper assessment of the potential impact of TaCo on the mentioned KPAs, but a first judgement by end-users and external stakeholders captured the opportunity to further explore the potential benefit of TaCo on the identified areas and performance ambitions.</p>





TRL-1.6	<p>Do the obtained results from the fundamental research activities suggest innovative solutions/concepts/ capabilities?</p> <ul style="list-style-type: none"> <li>- What are these new capabilities?</li> <li>- Can they be technically implemented?</li> </ul>	Achieved	<p>The automation strategies implemented in TaCo, together with the novel interaction modes introduced by the project (end-user programming, visibility of automation, man-machine handover optimisation) bring new opportunities to optimise efficiency, safety and environmental impact of ground control operations in ATM. In particular, the participation of end-users and operational experts by MATS since the very early phases of design ensures that the final outcomes of the project, although at a low level of maturity, are in line with expectations of airport traffic controllers.</p> <p>The TaCo solution comes with a low-maturity demonstrator (see D4.1, D4.2). The demonstrator does not fully implement every single functionality, but it can be used as proof-of-concept for further investigations about feasibility of the concept. The main technical constraint identified is that every vehicle should be tracked in real time (e.g. by ADS-B), but it may be mitigated (some form of “non-cooperativeness” may be managed by the system).</p>
TRL-1.7	Are physical laws and assumptions used in the innovative concept/technology defined?	Not Applicable for TaCo project	Not Applicable for TaCo project



TRL-1.8	<p>Have the potential strengths and benefits identified? Have the potential limitations and disbenefits identified?</p> <p>- Qualitative assessment on potential benefits/limitations. This will help orientate future validation activities. It may be that quantitative information already exists, in which case it should be used if possible.</p>	Achieved	<p>Strengths and benefits have been identified with the end users (MATS ATCos) and with external stakeholders (at the final event). A full description of this activity can be found in D5.1 - Evaluation report.</p> <p>Limitation: Strong assumptions on technologies (all the aircraft/vehicles are trackable and full data link is available)</p> <p>Mitigation: full development of the solution is foreseen on medium-long term (5-10 years), enablers will be available</p>
TRL-1.9	<p>Have Initial scientific observations been reported in technical reports (or journals/conference papers)?</p>	Achieved	<p>Project outcomes have been presented at Sesar Innovation Days 2017 and 2018. Currently, a paper submitted to the UIST2018 (ACM User Interface Software and Technology Symposium) conference is under review.</p>
TRL-1.10	<p>Have the research hypothesis been formulated and documented?</p>	Achieved	<p>Research directions are available in D2.2 - state of the art:</p> <ul style="list-style-type: none"> <li>RD1 define programming language constructs relevant to ATCos</li> <li>RD2 make relevant programming language constructs usable by ATCos</li> <li>RD3 select relevant dimensions of EUP, EUD and EUSE for the task at hand</li> <li>RD4 borrow relevant concepts from Programming by Example</li> <li>RD5 foster and develop an interactive, live programming environment based on MoTa</li> <li>RD6 leverage the existing graphical environment</li> <li>RD7 foster predictability with harbinger cues</li> </ul>





<p>TRL-1.11</p>	<p>Is there further scientific research possible and necessary in the future?</p>	<p>Achieved</p>	<p>Some needs for further research emerged during project execution. Part of these needs arose within the consortium, while other have been formulated by the external stakeholders during the project final event (see D5.1):</p> <p>Basic research (TRL 0-1)                  Integration with other phases of the flight (same approach to handover strategies for other phases/ATM processes where automation is increasing, e.g. en-route? User programming for approach controllers?)                  Is it possible to fully describe all the operations manual by use of the DSSL? (is the language airport-complete? Is it airport-correct?)                  Link with physiological measures in nominal or handover situations (cognitive workload, stress, etc.)</p> <p>Towards higher TRLs                  Full experimentation of the TaCo approach in an operational environment (real time simulations with real traffic)                  How to extend the results to other airports (scalability of the approach towards higher complexities)                  How to integrate TaCo approach with airport safety nets (TaCo can be used to describe/instruct complex and interdependent behaviours, i.e. design the interactions among different systems)                  How to apply the same automation design/deployment/verification approach to already delivered solutions (e.g. A-SMGCS)</p>
<p>TRL-1.12</p>	<p>Are stakeholder's interested about the technology (customer, funding source, etc.)?</p>	<p>Achieved</p>	<p>The good interest shown by the external stakeholders is made available in "D5.1 - evaluation report", that describes the outcomes of TaCo final event.</p>



## 4 Conclusion and Lessons Learned

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### 4.1 Conclusions

TaCo contributes to the definition of a new SESAR Operational Improvement (OI) with the following outcomes:

- A framework for the design, development, verification and future implementation of automated tools for airports with the involvement of end-users since the initial ideas up to the advanced stages of the automation life-cycle. The proposed framework is called “end-users programming of airport surface movements management”.
- An approach to enhance the visibility of the level of automation in the tower environment and mitigations measures of transitions among different levels of automation support (towards visibility, awareness, transparency);
- Design guidelines for designers of similar hybrid human-automation environments and for designers of automation in such environments:
  - Continuum of usage and progressive disclosure
  - Space-based and event-based constructs
  - Make current state and future behaviour visible
  - Seamless AND seamful hybrid control

The research moved its steps from the definition of a set of use cases and related operational needs [2] for the ground movements of International Airport of Malta. The activity has been carried out in collaboration with tower controllers and operational experts and led to the definition of 8 use cases and 5 Operational Needs (with some sub-needs).

Use cases are provided as storyboards: a chronological sequence of events and actions, illustrated with graphics and commented with text. The objective of use cases was to share operational knowledge about specific situations that controllers deal with during their day-to-day job and they consider complex tasks worthy of some kind of automation support. An example of Use Case is provided hereafter:

### Use Case 3 – Runway 13 – multiple arrivals and multiple departures

This use case describes the parameters ATCOs consider and their actions, when inserting multiple departures into a flow of arrivals. One departing flight goes to CDG and has a time slot to respect. The objectives of the ATCOs are to minimize delay for departing flights and make room in aprons to handle the arriving flights.

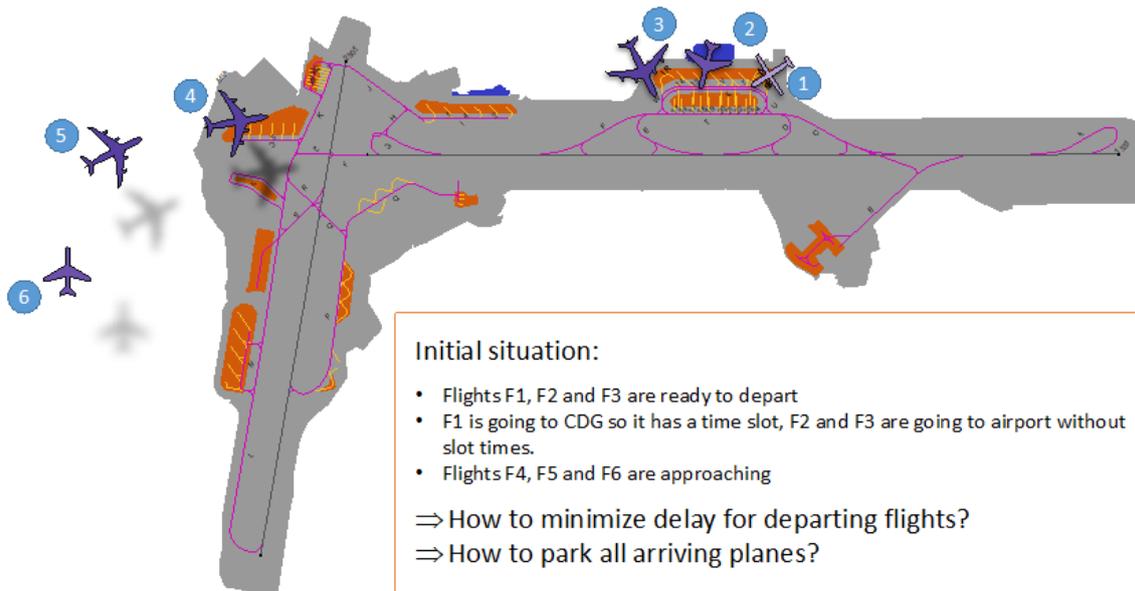


Figure 23: Example of TaCo Use Case

The operational needs are, instead, high level operational requirements that summarize ATM ground operations at Malta International Airport. From TaCo perspective, operational needs define the specific tasks and responsibilities of tower controllers. They are the starting point for the identification of the areas where controllers could mostly benefit from an automated support of their tasks. The following table shows one of the identified Operational Needs. The complete list can be found in [2].

**O.N. 04.1 Coordination between the ADC and GMC for international IFR departures**

Identifier	REQ-TACO-OSED-ON.04100
Title	Coordination between the ADC and GMC for international IFR departures
Requirement	<p>The GMC shall insert the following inputs in particular system for IFR departures, a process that should be interfaced for TaCo.</p> <ul style="list-style-type: none"> <li>• The CTOT in the text field of the electronic strip and on the relevant plaque as soon as</li> <li>• the CTOT is issued on CITO and any subsequent changes; and</li> <li>• The departure clearance for all IFR departures using the departure clearance menu</li> <li>• Contents of standard departure clearance for international VFR and IFR departures</li> </ul>

	<p>Standard clearances for departing aircraft shall contain the following items:</p> <ul style="list-style-type: none"> <li>• aircraft identification;</li> <li>• clearance limit, normally destination aerodrome;</li> <li>• designator of the assigned SID.</li> <li>• cleared level;</li> <li>• allocated SSR code;</li> <li>• any other necessary instructions or information not contained in the SID description;</li> <li>• CTOT (if applicable);</li> <li>• earliest taxi time (10min before CTOT) if applicable</li> </ul> <p>The above is acknowledged to be quite time consuming on the frequency, but it might also be beneficial for the other listeners.</p> <p>TaCo acknowledges that the level that this project explores is at science level and further in-depth studies would be appropriate for the TaCo future.</p>
Status	<In Progress>
Rationale	Departures information has to be shared between ADC and GMC
Category	<Operational>

The collaborative approach to requirements and needs collection, together with some preliminary automation design activities helped the consortium to close the activities of Work Package 2 with the definition of some clear Research Directions (see Section 2.3). These directions worked as reference methodological framework for the design and development of the new TaCo OI.

The use of a User Centred Design approach to the design and development of an airport automation development environment, called Domain Specific Graphical Language (DSGL), was a key enabler for a successful involvement of the end-users in a process of incremental design, development and validation of the proposed solution. See [8] for a full description of the process.

The work done in Work Package 3 and Work Package 4 was also guided by the Research Directions and led to the definition of a set of **automation design principles** to enhance the visibility of the level of automation in the tower environment, together with mitigations measures of transitions among different levels of automation support and human-machine (towards visibility, awareness, transparency) [4][5][6]. The same automation design principles may have application in other projects dealing with the design and validation of automated support tools in ATC or in other safety-critical domains.

The final evaluation of the outcomes involved both Malta International Airport (MIA) tower controllers and external stakeholders coming from the airport domain during two distinct workshops. The conduction and results of these workshops are described in D5.1. Since the low TRL envisaged by TaCo, a qualitative approach was employed for both the end-users and the external stakeholder feedback.

Results show positive feedback from end-users as well as from external stakeholders. The introduction of automation strategies as the main support for handling the operations was considered beneficial and additional promising strategies were identified during the evaluation. Furthermore, such strategies were not only perceived as a support for optimization, but more in general, as an assistant for coping with specific situations.

Feedback on user programming framework pointed to the employment of such concept in offline mode, namely for planning the behaviour of the system considering known or plausible restrictions that are going to be in place during the time of the operations. Such logics would be then available during the actual management of the traffic, provided that the action plans can always be overridden by the controller.

In order to further validate the results and progressing the identified OI towards higher TRLs it is recommended to plan future activities of full experimentation of the TaCo approach in an operational environment (i.e. real time simulations with real traffic).

## 4.2 Recommendations for future R&D activities (Next steps)

Some needs for further research emerged during the project execution. Part of these needs arose within the consortium during the design, development and evaluation of the TaCo solutions, while others emerged by the external stakeholders during the project final event (see D5.1) and during the dissemination events.

### 4.2.1 Basic research (TRL 0-1)

One possible future step of TaCo is its integration with other phases of the flight. It emerged the possibility to apply the same approach to handover strategies for other phases of the flight and/or other ATM processes where automation is increasing. Would it be possible to apply the user programming approach to the en-route phase and/or for approach controllers? One possible field of research would be the possibility to design “adaptive” safety nets, i.e. tools with functionalities, behaviours and levels of automation that may be defined by the controller at run-time, based on the operational needs actually experienced in a certain moment (e.g. different configurations of the airspace, levels of traffic, complexity, etc.). This would extend and generalize the approach already tested with the taxiway stop-bars in TaCo (see D4.2).

Another open research question coming from TaCo is whether it would be possible or not to fully describe all the operations manual of any by use of the DSGL, and possibly do it with an automated approach. D2.1 describes the “digitalization” and verification of the operations manual of the airport: the airport rules and procedures that may be implemented and visualized through an interactive map of the airport. The encoded airport rules can be used by the automation, i.e. through TaCo the controller is able to directly “manipulate” the rules and procedures of the airport. This digitalization has been made by manually encoding some of the rules and procedures of LMML within the interactive maps. It would be beneficial for ATM R&D investigating to what extent the digitalization of an airport could be made simple and scalable, possibly with the help of automated tools to reduce the workload needed to translate paper-based rules and procedures into interactive maps.

The collaboration with STRESS project [9] highlighted the possibility to link TaCo outcomes with physiological measures in nominal or handover situations (how high is the cognitive workload or the



stress related to the human-automation handover? May these measurements help to design and develop more efficient and effective user programmed airport automation?).

#### 4.2.2 Towards higher TRLs

The following possible future steps towards higher levels of technology readiness (TRL) have been identified and are considered worthy of further investigation by the TaCo consortium:

- Full experimentation of the TaCo approach in an operational environment (real time simulations with real traffic)
- How to extend the results to other airports (scalability of the approach towards higher complexities and/or size of airports)
- How to integrate TaCo approach with airport safety nets (TaCo can be used to describe/instruct complex and interdependent behaviours, i.e. design the interactions among different systems)
- How to apply the same automation design/deployment/verification approach to already delivered solutions (e.g. A-SMGCS)

## 5 References

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### 5.1 Project Deliverables

- [1] D1.2 Project Results Final Report, v2.0, 2018 - <http://www.tacoproject.eu/deliverables/>
- [2] D2.1 Problem Definition, v2.1, 2017 - <http://www.tacoproject.eu/deliverables/>
- [3] D2.2 State of the art, v1.1, 2017 - <http://www.tacoproject.eu/deliverables/>
- [4] D3.1 Automation Library, v1.1., 2018 - <http://www.tacoproject.eu/deliverables/>
- [5] D4.1 HMI Global Strategy, v1.0, 2018 - <http://www.tacoproject.eu/deliverables/>
- [6] D4.2 DSGL for airport automation, v1.1, 2018 - <http://www.tacoproject.eu/deliverables/>
- [7] D5.1 Evaluation Report, v1.0, 2018 - <http://www.tacoproject.eu/deliverables/>

### 5.2 Project Publications

- [8] “A Domain-Specific Graphical Language for Authoring and Operating Airport Automations” – accepted at UIST2018, 31st ACM User Interface Software and Technology Symposium, Berlin, 14-17 October 2018

### 5.3 Other

- [9] STRESS project – [www.stressproject.eu](http://www.stressproject.eu)
- [10] European ATM Master Plan - <https://www.atmmasterplan.eu/>
- [11] Automation in ATM call for proposals - <http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/sesar-01-2015.html>

## Appendix A

### A.1 Communication and Dissemination report

Dissemination represents one of the core activities of the TaCo project.

Our dissemination strategy is based on the identification of groups of stakeholders who may be interested in the project findings, and on the personalization of the communication message for the stakeholder characteristics in terms of content, style and information support.

According to the Dissemination Plan (please refer to Section 7.2 of the Project Management Plan), this document aims at reporting the different communication and dissemination actions carried out along the whole duration of the TaCo project.

The main communication and dissemination actions carried out for these 2 years are the following:

- Dissemination towards the SESAR and H2020 programs, leading to a close collaboration with other European research projects, resulting in the elaboration of coordinated factsheets and in the joint application for the Common dissemination booster service;
- Dissemination towards general public, with the TaCo project website and social networks;
- Dissemination towards scientific community, through the publication and the presentation of research work elaborated to contribute to the TaCo project;
- Dissemination towards the Air Traffic Management and Airports community, through the collaboration with Airport Council International Europe.

#### A.1.1 Dissemination towards SESAR and H2020 programs

##### *SESAR Innovation Days*

TaCo took part in the 6<sup>th</sup> and 7<sup>th</sup> **SESAR Innovation Days (SIDs)**, held at the University of Delft (The Netherlands) and of Belgrade (Serbia) respectively at the end of November to present the latest long-term research in the field of air traffic management. The SIDs are Europe's largest ATM research focused event, with more than 250 participants from both the academic and industrial ATM community.

SESAR Innovation Days are the main vehicle for SESAR Joint Undertaking to share progress and disseminate results of its exploratory research programme. Unlike other scientific events in air traffic management research, SESAR Innovation Days focus explicitly on long-term and innovative research.

The event featured papers and presentations selected based on an open call for contributions, a poster exhibition, a series of workshops, and a networking event, which provided participants opportunities to learn about interesting projects and to meet like-minded researchers. In this framework, **TaCo actively took part in both editions presenting a factsheet (Figure 24), a poster (Figure 25, Figure 26) and an exhibit.**



Figure 24: TaCo factsheet at SID 2016

**Links with other EU funded research projects**

As strongly recommended by SESAR, a fruitful collaboration has been initiated with other EU funded research projects for sharing information, discussing results and providing a holistic approach on emerging challenges. In particular, TaCo coordinates part of its dissemination activities with STRESS and MOTO, two H2020 projects dealing with future automation in ATM and its impacts on human performances.

**STRESS and MOTO**

The European ATM system is expected to face challenging situations, with the growth of air traffic, the increase of its complexity, the introduction of innovative concepts and increased automation. The role and tasks of air traffic controllers (ATCOs) will change in the future and it is vital to enhance the comprehension of human responses to their role changing, that is, from active control to monitoring of complex situations and managing unexpected system disruptions.

Therefore, STRESS<sup>6</sup> (Human Performance neurometrics toolbox for highly automated systems design) addresses Human Performance (HP) in future SESAR scenarios. It aims at identifying and validating neurophysiological indexes for monitoring in real-time the controllers’ mental state; at using them to study the impact of advanced highly automated system on controllers’ performance envelope; at providing automation design guidelines to support human performance during safe transitions from high levels of automation to low levels, and vice versa.

<sup>6</sup> <http://www.stressproject.eu/>



MOTO<sup>7</sup> (“Embodied reMOte Tower”) project is using various sensory techniques to introduce auditory and vibro-tactile stimuli into the remote towered environment. Partners are measuring the impact of these stimuli on air traffic controllers, in terms of situational awareness, a sense of presence and performance. The aim then is to develop augmented reality solutions that incorporate these stimuli to help controllers become fully immersed in the remote tower environment, enhancing their ability to manage traffic safely and efficiently.

These projects have in common the exploration of automation (although they are characterised by different approaches to automation and in different operational environments) and the focus on its consequences, as emphasised by the posters presented at SIDs 2016 and SID2017.

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<sup>7</sup> <http://www.moto-project.eu/>



Automation cannot be defined at design time only. Smooth handover to humans and user programming are keys to manage unusual situations.

**OBJECTIVES**

TaCo aims to define an automated system able to both support ground and tower controllers' tasks in airport operations and assess its own ability to deal with non-anticipated situations. When needed, it should be sensitive enough to transfer responsibilities and tasks back to the controller, in a timely and graceful manner that make a human comfortable with the inherited tasks.

**METHOD**

TaCo generates user centred approach to automation design for facilitating the controller's forward thinking, in line with the ACIM (Airport-Traffic Flow Control Decision Making) Multi-International Airport (MIA) as a main case study to define:

- + the ability of the system to assess the situation and negotiate the need for human intervention;
- + graceful handover of tasks to the controller;
- + algorithms and schemes for operators' gate behaviour of the system based on its systems;
- + the availability of software for user programming for monitoring and controlling the system behaviour.

**OUTCOMES**

- + Analysis of ground operations in MIA and definition of scenarios where automation supports the controller;
- + Proof of concept of automated support task (e.g. sequencing, conflict detection and resolution);
- + Interaction model for the automation transfer and human-automation handover of control;
- + Evaluation of the concept according to the expected technology maturity level (TRL3).

The main objective of MOTO is to identify the key multimodal stimuli required on RTO to enhance the sense of Presence experienced by ATCOs.

**OBJECTIVES**

1. Assessment of the role of multimodal acquisition of information in current control tower operations;
2. Definition of user requirements to reconstruct multimodal perception in a remote tower simulation platform and development of augmented multimodal interfaces;
3. Definition of brain physiological indexes, customized for Remote Tower operations, to monitor aspects of Human Performance;
4. Validation of the above mentioned results in real-life ATM operational conditions through simulation facilities in live-like RTO and augmented RTO scenarios and in radically changed ones.

**METHOD**

- + Visual, acoustic and vibration information measurement in Real Air Traffic Control Towers;
- + Sense of presence measurements;
- + Neurophysiological measurements.

**OUTCOMES**

- + Sense of embedded cognition in tower operations;
- + Requirements for more realistic multimodal remote tower platforms;
- + Multimodal solutions to improve ATCO performance;
- + Neuro-physiological classifiers to monitor human performance in Towers, in particular in RTO context.

STRESS supports the transition to higher automation levels in aviation, by addressing, analysing and mitigating its impact on the Human Performance aspects associated to the future role of Air Traffic Controllers in the context of future SESAR scenarios.

**OBJECTIVES**

1. To identify and validate neurophysiological indexes for monitoring in real-time the controller's mental state;
2. To use them to study the impact of advanced highly automated system on controllers' performance envelope;
3. To provide automation design guidelines to support human performance during safe transitions from high levels of automation to low levels, and reversions.

**METHOD**

- + Measurement of neurophysiological indexes in simulated ATM environment;
- + Iterative approach.

**OUTCOMES**

- + Future scenarios;
- + Neurophysiological indexes;
- + Human Performance knowledge in future scenarios;
- + Automation design guidelines.



Figure 25: MOTO, STRESS and TaCO presented a poster at SIDs 2016

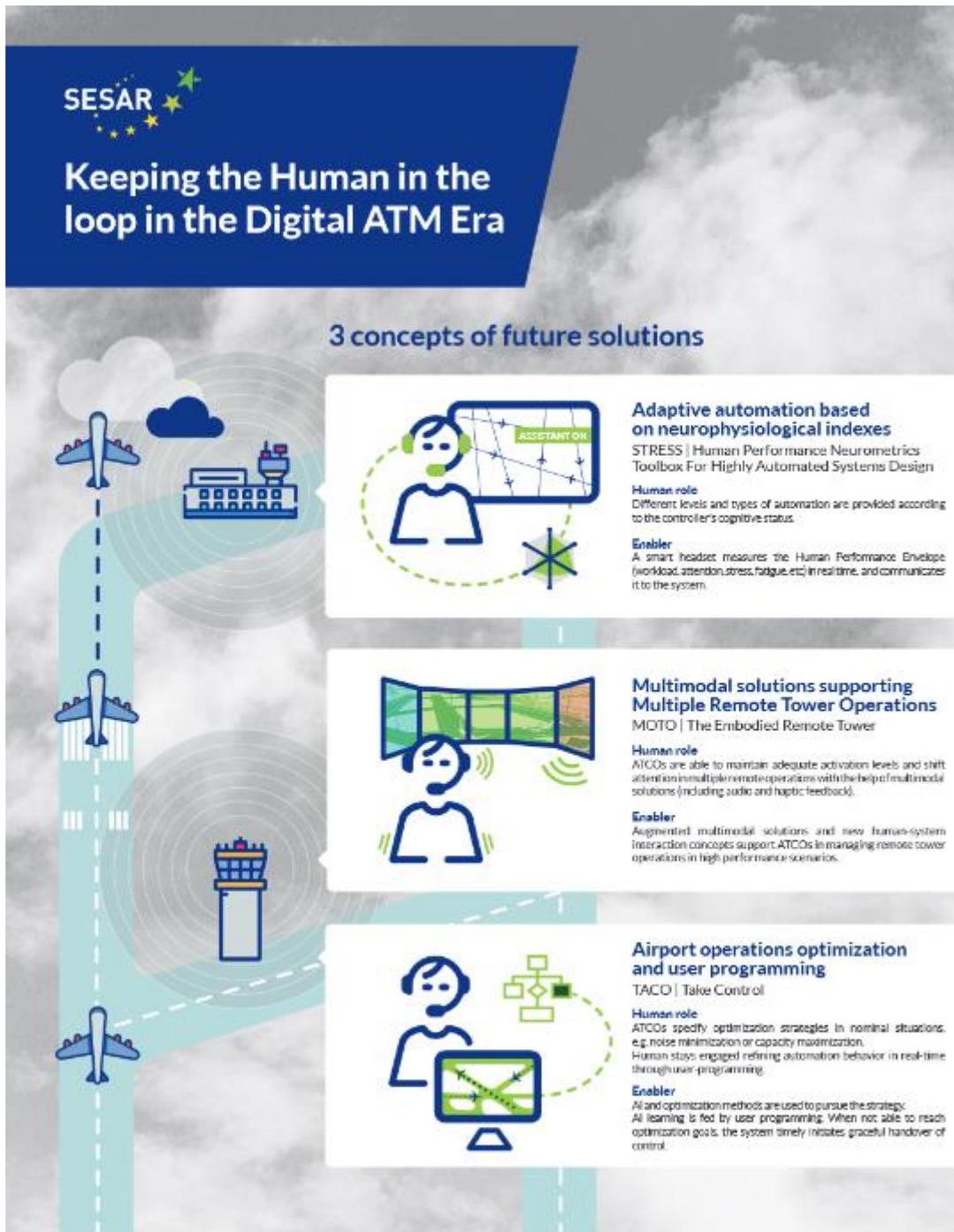


Figure 26: MOTO, STRESS and TaCo presented a poster at SIDs 2017

In order to highlight these common aspects, the projects take any chance to cross-reference each other and produced a coordinated set of factsheets to present at SIDs 2017.

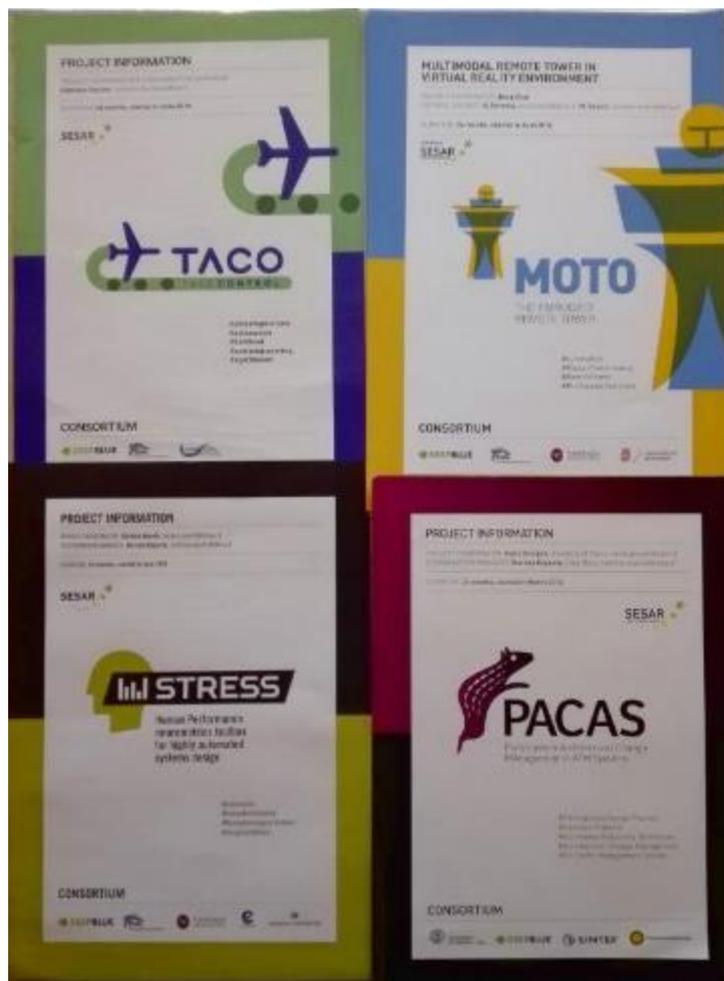


Figure 27: TaCo, PACAS, STRESS and MOTO presented coordinated factsheets at SIDs 2017

The poster and the factsheet have been the main tools to support TaCo exhibit at SID 2017, together with an informative short video presented during a dedicated session.

### Common dissemination booster

The Common Dissemination Booster (CDB) is a brand-new service from the European Commission available to all European, National, Regional funded Research & Innovation (R&I) projects (H2020, FP7 or other). The booster encourages projects to come together to identify a common portfolio of results and shows them how best to disseminate to end-users, with an eye on exploitation opportunities.

The service is available only to groups of projects. TaCo clustered, as cluster leader, with STRESS, PACAS and MOTO and submitted for two services:

1. **CDB Service 4 Dissemination Capacity Building:** learn the necessary skills to improve dissemination. Learn how to articulate what your portfolio of results is about and what your CDB Project Group can offer to its specific target audience in a clear and easy to understand language.
2. **CDB Service 5 Dissemination Campaign Management:** dissemination campaign in practice. Get valuable professional support for delivering effectively your joint dissemination



campaigns: the CDB will accompany your CDB Project Group across an extended period giving specific assistance for your joint dissemination campaigns.

The application was accepted at the end of October 2017. TaCo is waiting for the CDB Service to get in touch with additional details from the external experts.

### A.1.2 Dissemination towards the general public

TaCo project deals with many different stakeholders. For this reason, the communication of project results to a broader community of users is one of the project's inherent objectives.

A strategic communication relies on the clarification of targets, audience and message before deciding which media to use to transmit the message. Therefore, TaCo matched the messages to communicate with the target audience, and then with the means to use. This was fundamental to increase the possibility of achieving awareness across the multi-layered community to which TaCo refers.

TaCo identified the general public as one target audience. This cluster includes people and groups interested in the topic in general, such as workers in the ATM field. An audience with this level of interest recognises the importance of the project's research and the benefits that may derive from it. Therefore, this audience looks for clear, useful, non-technical information. In fact, the main source of information for this group are the website, social networks, flyers and brochures, and online articles as well as printed ones.

#### *TaCo Project website*

##### **TaCo Project website features**

The project website<sup>8</sup> has an essential role in the dissemination as the principal means of communication of the TaCo objectives, activities and results. Its target public consists of the general public as well as of specialists, potential users, politicians and public funding authorities.

From a graphical point of view, the website maintains coherency with the project's visual style and logo which had to be graphically appealing and manageable. The logo is the basis for the project graphical identity and the trait d'union of the project, which makes each element of the graphical identity immediately ascribed to the project, helping to consistently communicate and disseminate the project.

TaCo project website have been developed by using Wordpress<sup>9</sup>, that is one of the most supported and worldwide used open source Content Management Systems.

The visual identity of the project is conceived with the aim of visually emphasizing the acronym of the project and arousing curiosity.

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<sup>8</sup> <http://www.tacoproject.eu/>

<sup>9</sup> <http://wordpress.org>



From a technical perspective, the logo is versatile and can be applied across a variety of mediums and applications. It is provided in vector format, to ensure that it can be scaled to any size, maintaining its features and its legibility.



Figure 28 - The TaCo logo.

The website is consistent with the logo and its characteristics. In order to facilitate the users in searching the information and comprehend the contents, particular attention was given to the website's usability and simplicity. The information follows a logical and significant categorisation, and the pages' layout is simple, with clear sections and texts.

The main page's layout consists of four main blocks:

1. Header, including the project logo and the main menu;
2. An image of Malta Airport with the name of the project and links to the project's objectives and structure;
3. Content area, showing all the main contents (main menu) in one page.



Figure 29: Scheme of the main TaCo webpage

In addition to the main page, a page collecting all the public deliverables of the project have been created.

The objective of keeping the website continuously live and updated has been addressed by the creation of a “news&events” module.

## LATEST NEWS AND EVENTS



**SAVE-THE-DATE 11TH APRIL, MALTA – TACOFINAL WORKSHOP**

Save-the-date: TaCo Final Workshop Supporting air traffic controllers in complex airport environments through automation 11 April, Malta Airport. Encouraging new ideas and fresh thinking is critical for Innovation In aviation in order to respond to the growing demand for air travel and to the increasing number of air vehicles, such as drones, taking to the [...]



**TACO @ SESAR INNOVATION DAYS 2017**

TaCo will participate in the next SESAR Innovation Days in Belgrade (28-30/11/2017). You will find us at the demos and posters area, together with our other automation-related projects STRESS and MOTO with a poster entitled "Keeping human in the loop in the Digital AIM era". Come find us to learn about our latest progress on [...]



**TACO @ART (AGENCY RESEARCH TEAM) WORKSHOP**

TaCo, along with other projects like MOTO and STRESS, will take part in the next workshop organised by EUROCONTROL's Agency Research Team (ART) and taking place on the 24th of October in Vienna at Frequentis headquarters. The workshop focuses on Automation in Air Traffic Management (ATM) and specifically addressing aspects of higher degrees of automation and autonomy in ATM, including: airport and surface management, [...]



**TACO INTERMEDIATE REVIEW MEETING**

The 4th of July, the TaCo intermediate review meeting will be hosted by Deep Blue. The purpose of the Intermediate Review Meeting is to assess the Progress since the kick-off meeting and to steer the Project in order to achieve the expected quality and maturity at the Final Review & Close-Out Meeting.

Figure 30: news and events section

The events & news section is updated regularly with all the latest public information about TaCo. This includes, for example, project’s progress, status of the activities, and any other relevant communication. It also announces when new material is available in the download section.

By clicking on a selected news or event, the users may reach a dedicated page containing information, images and useful links.

## Save-the-date 11th April, Malta – TaCoFinal Workshop

Posted on *February 15, 2018*

Save-the-date: TaCo Final Workshop

Supporting air traffic controllers in complex airport environments through automation

11 April, Malta Airport

Encouraging new ideas and fresh thinking is critical for **innovation in aviation** in order to respond to the **growing demand for air travel** and to the **increasing number of air vehicles**, such as drones, taking to the skies. That is why the SESAR Joint Undertaking supports exploratory research and has created an innovation pipeline in the research programme that transforms innovative ideas into solutions to increase the performance of air traffic management (ATM).

TaCo (Take Control) is a SESAR Exploratory Research project dealing with **ground traffic management in complex airports**. The TaCo consortium, led by Deep Blue and including Ecole Nationale de l'Aviation Civile (ENAC) and Malta Air Traffic Services (MATS), invites you to participate to the **project's final workshop** in Malta next April.

We will present the project results and demonstrate through an interactive prototype how to **support ATCOs** in managing complex airport environments. The TaCo prototype makes use of highly automated functions for **guiding the controllers** towards an optimized management of the movements: for example, it supports them in maximizing the usage of the runway, or minimizing the global fuel consumption. Moreover, it allows to define the behaviour of specific parts of the airport through innovative user-programming techniques.

The project members will guide you through the most representative **use cases** of the International Airport of Malta and you will have the chance to contribute to an innovative concept by giving your feedback to the consortium.

TaCo's event precedes the workshop organised in Malta Airport on 12th April by ACI Europe and the SESAR Joint Undertaking.

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 For more info on SESAR exploratory research: <http://www.sesarju.eu/approach/development>

Participation is free of charge.

[View the agenda](#) and [click here to register](#).

For any question contact [damiano.taurino@dblue.it](mailto:damiano.taurino@dblue.it)

For now, MARK YOUR DIARY!

Figure 31 example of a news on the website

The “project structure” section of the main page offers a dashboard to monitor the progress on the main activities of the project, as shown in the image below.

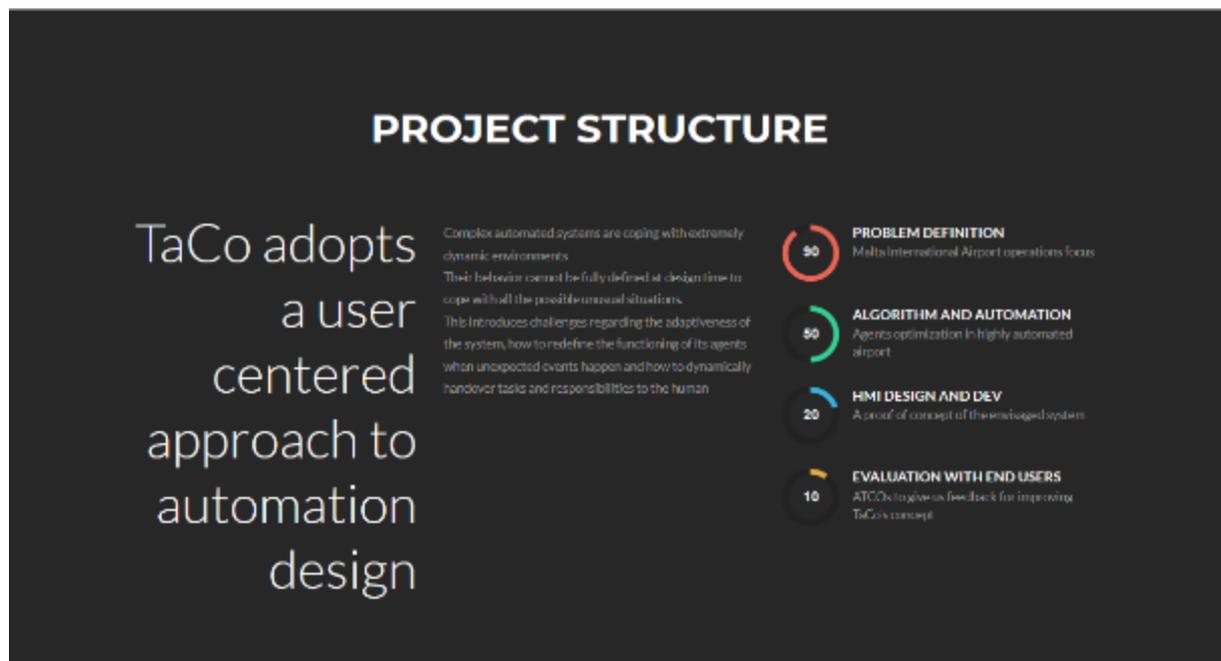


Figure 32: project structure and progress as shown in the main page of TaCo website

The Consortium is presented in the website, with logos and roles of the participants. Hovering a logo with the mouse allows the user to see a short description of the participant organisation.

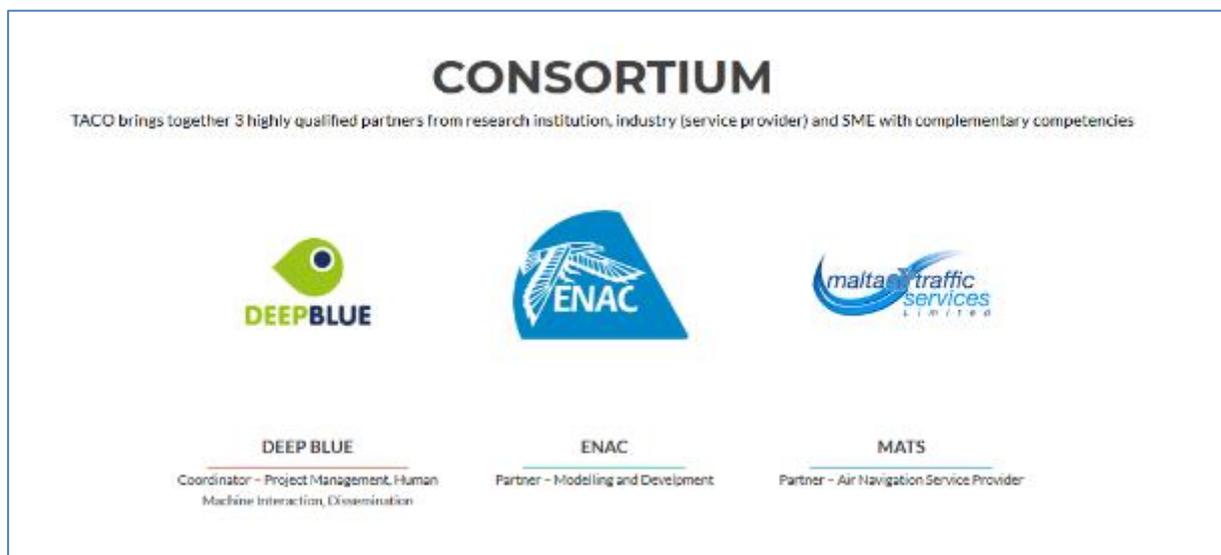


Figure 33: TaCo consortium as presented in the website

Finally, a module for contacts has been integrated in the website, with the opportunity for the user to send a message to the dissemination manager of TaCo (Damiano Taurino).

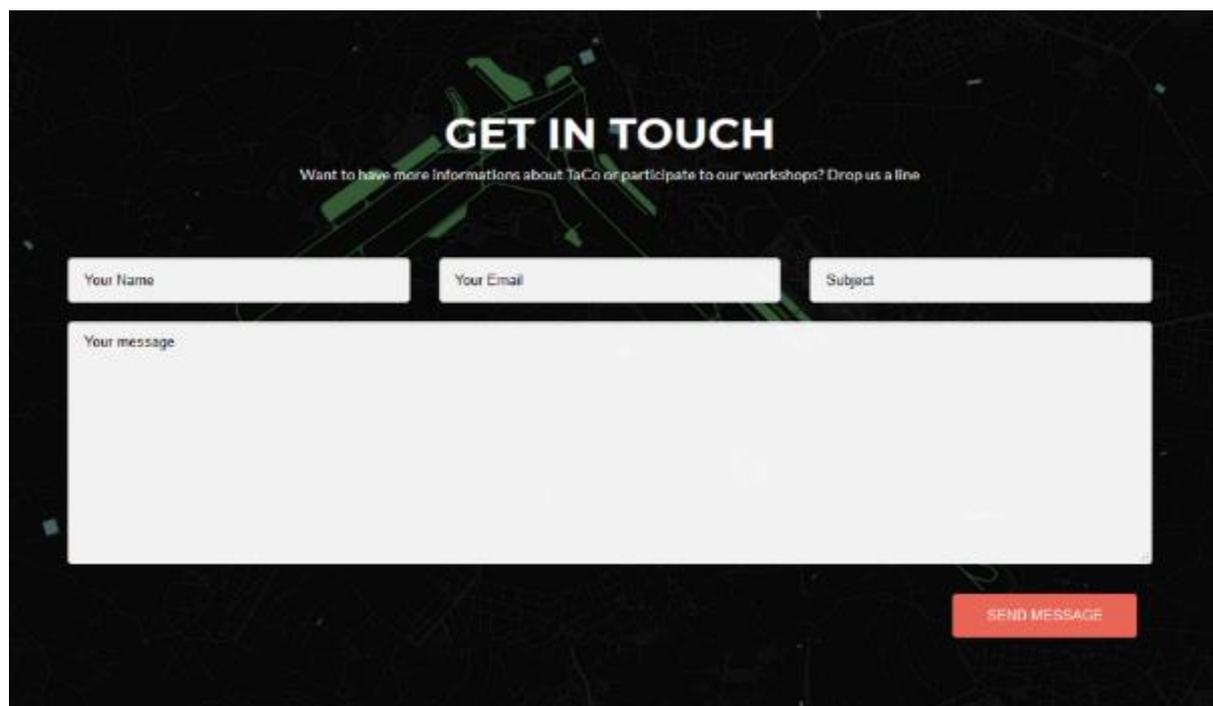


Figure 34: contact module of TaCo website

### TaCo Project position on search engines

Search Engine Optimisation guidelines provided by the Wordpress community<sup>10</sup> have been considered while designing and implementing the website and its content.

The position of TaCo website on some keywords in well-known search engines (e.g. Google) is one of the parameters to monitor in order to assess the success of the dissemination. This is not a particularly accurate way of determining success, as this parameter changes minute to minute and depends on many different factors, including the searcher's online behaviour. Nevertheless, it is a stick indication of whether TaCo is associated to keywords that are relevant to the project.

The following table presents the TaCo website ranking for specific words (keyword column). For each keyword, it indicates in which position is the website (rank column) and in which page of the results (results page column). A SEO utility (Google Ranking Check - Ajax Release 3.1) generated the data on the 16<sup>th</sup> of May 2018, referring to Google.com (language: English).

Table 5: TaCo position on search engines

Keyword	Rank	Results page
taco project	14	2

<sup>10</sup> [https://codex.wordpress.org/Search\\_Engine\\_Optimization\\_for\\_Wordpress](https://codex.wordpress.org/Search_Engine_Optimization_for_Wordpress)

taco air traffic management	5	1
taco automation	6	1
taco project airport	2	1
taco research project	3	1
airport automation project	23	3
airport atm automation	27	3
atm automation project	18	2

### **TaCo Project in social networks**

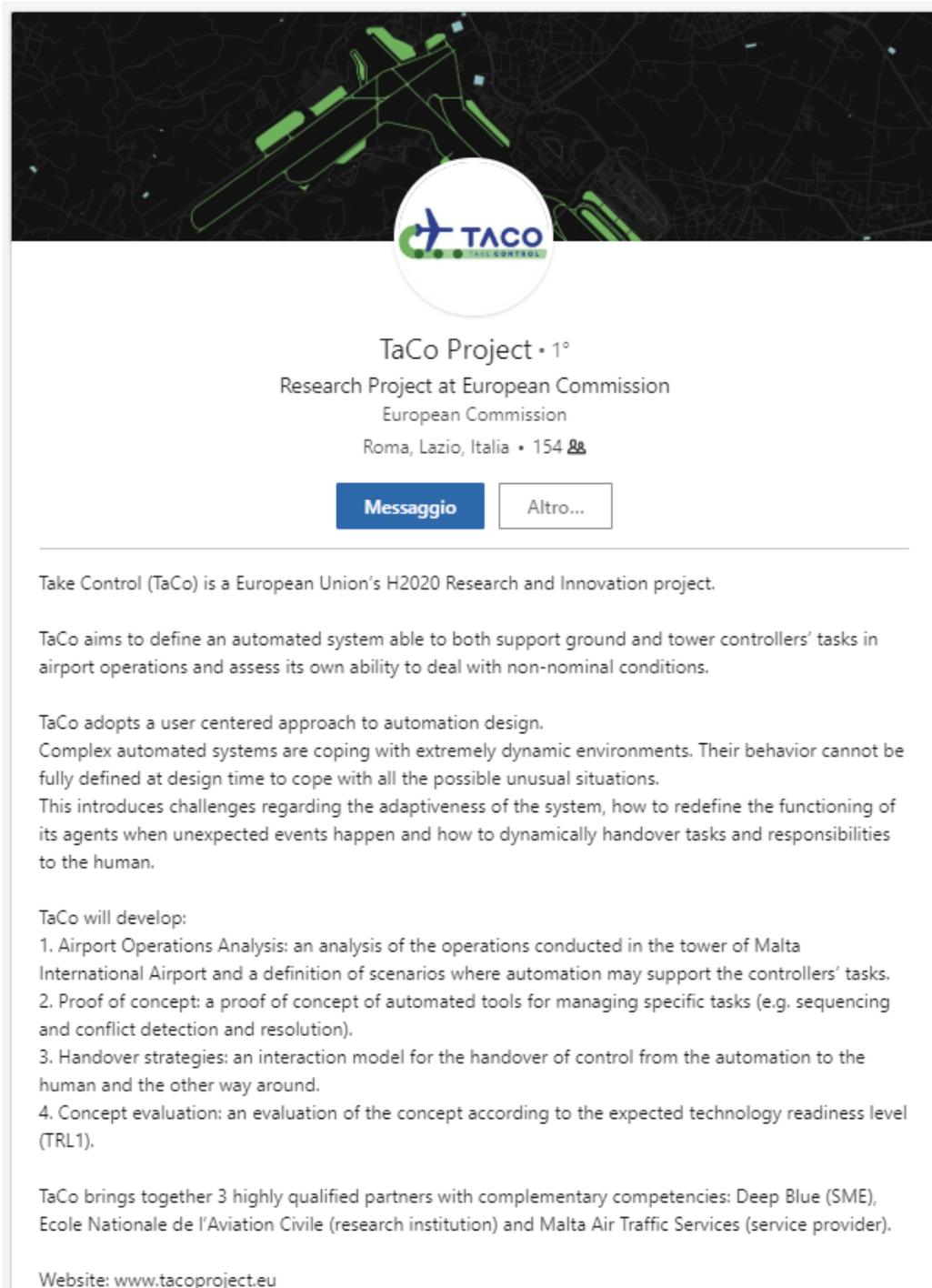
TaCo has an account and is active on LinkedIn. LinkedIn<sup>11</sup>, as a professional social network, helps in attracting people of interest that can exchange information and discuss about the project and its findings (this may also involve the partners of the Consortium).

### **TaCo LinkedIn profile**

TaCo started posting on LinkedIn in June 2017 and publishes regular updates. The updates mainly reflect the news posted on the website. Therefore, they concern the release of documents, the announcement of events involving TaCo, and news on project's achievements, as well as any interaction with other projects.

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<sup>11</sup> TaCo on LinkedIn: <https://it.linkedin.com/in/taco-project>



**TaCo Project • 1°**  
 Research Project at European Commission  
 European Commission  
 Roma, Lazio, Italia • 154 

[Messaggio](#) [Altro...](#)

Take Control (TaCo) is a European Union's H2020 Research and Innovation project.

TaCo aims to define an automated system able to both support ground and tower controllers' tasks in airport operations and assess its own ability to deal with non-nominal conditions.

TaCo adopts a user centered approach to automation design.  
 Complex automated systems are coping with extremely dynamic environments. Their behavior cannot be fully defined at design time to cope with all the possible unusual situations.  
 This introduces challenges regarding the adaptiveness of the system, how to redefine the functioning of its agents when unexpected events happen and how to dynamically handover tasks and responsibilities to the human.

TaCo will develop:

1. Airport Operations Analysis: an analysis of the operations conducted in the tower of Malta International Airport and a definition of scenarios where automation may support the controllers' tasks.
2. Proof of concept: a proof of concept of automated tools for managing specific tasks (e.g. sequencing and conflict detection and resolution).
3. Handover strategies: an interaction model for the handover of control from the automation to the human and the other way around.
4. Concept evaluation: an evaluation of the concept according to the expected technology readiness level (TRL1).

TaCo brings together 3 highly qualified partners with complementary competencies: Deep Blue (SME), Ecole Nationale de l'Aviation Civile (research institution) and Malta Air Traffic Services (service provider).

Website: [www.tacoproject.eu](http://www.tacoproject.eu)

**Figure 35: TaCo on LinkedIn**

In these years TaCo published 35 updates that reached 157 followers on LinkedIn with a total of 5600 visualisations.

### Activity on other social media

Founding Members



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Twitter has been identified as another social media where the project could disseminate its news and outcomes. The scope of TaCo is quite too specialized for the general Twitter audience, so the consortium decided not to create a TaCo profile there. It has been agreed instead to spread the most important project contents and updates through the Twitter profiles of the project member organizations.



Figure 36: example of Twitter post about TaCo

## News

In order to reach a wider range of stakeholders, TaCo fostered a continuous share of information with SJU, the European Commission and some key partners. This activity led to the publications of several on-line news about project outcomes and activities. The following list contain some of these news:

<http://www.airport-business.com/2018/03/taking-fresh-look-airport-operations/>

<http://www.atc-network.com/atc-news/european-commission/why-taco>

[https://www.cordis.europa.eu/result/rcn/200922\\_en.html](https://www.cordis.europa.eu/result/rcn/200922_en.html)

<https://www.sesarju.eu/node/2972>

Founding Members



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<https://www.sesarju.eu/news/aci-europe-sesar-workshop-exploring-innovative-technologies-airport-operations>

<https://dblue.it/news/taco-final-workshop-malta/>

### A.1.3 Dissemination towards the scientific community

#### Project publications

Authors	Title	Journal
Stéphane Conversy, Jermie Garcia, Damiano Taurino, Giuseppe Frau, Johan Debattista	Vizir: A Domain-Specific Graphical Language for Authoring and Operating Airport Automations  <i>The paper has passed the first selection, but the final decision on its acceptance for the conference is still pending</i>	UIST 2018 - 31st ACM User Interface Software and Technology Symposium

#### Agency Research Team (ART) workshop on Automation in Air Traffic Management

TaCo was invited to present its preliminary results at the “Automation in Air Traffic Management<sup>12</sup>” workshop, taking place in Vienna, on the 24<sup>th</sup> of October 2017. It was organised by the Agency Research Team (ART) that is an advisory body of the EUROCONTROL Agency. ART focusses specifically on the Agency’s contribution to the SESAR programme, ACARE initiatives and Flightpath 2050, ensuring convergence of initiatives, alignment with Air Navigation Service Provider (ANSP) requirements and the non-duplication of resources. Its embraces issues specific to ATM while addressing influencing factors and the impact air transport and aerospace have on ATM, including societal considerations and the integration of transport modes.

Over 40 researchers attended the event's nine presentations in three sessions:

- Tower and Surface Management,
- The Air Transport System, and
- Automation and Human Factors.

TaCo took part to the presentation on “Neurophysiological indexes to take control of future automation systems” illustrating all the synergies between TaCo, STRESS and MOTO and how the human-automation handover strategies could be integrated into the HP case.

<sup>12</sup> <http://www.eurocontrol.int/events/agency-research-team-workshop-automation-air-traffic-management>

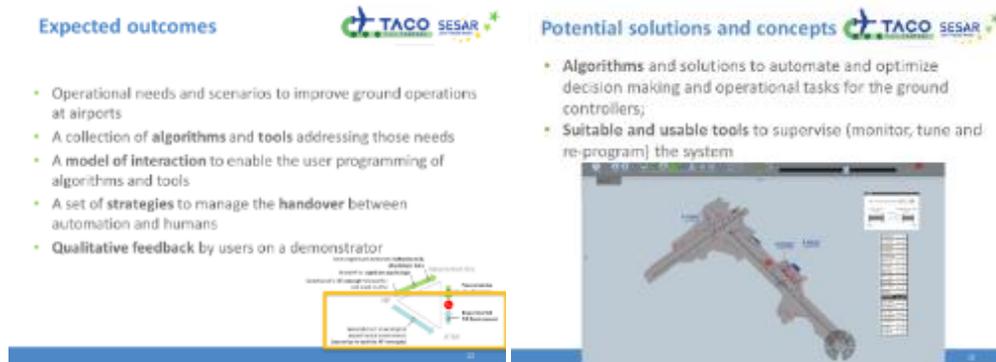


Figure 37: two slides of TaCo presentation at ART Workshop

### Air Navigation Convention 2018 (University of Bucharest)

The 9th Edition of Air Navigation Convention: "Sharing the Sky: Beyond Performance and Success" was held in Bucharest on 15 - 16 March in the Rectorate of the "Politehnica" University of Bucharest. During the event, the latest projects and news regarding communication, navigation, surveillance, safety, human factors and cybersecurity were presented and discussed. TaCo was present and brought forward the Human Factors aspect in the discussions, highlighting the importance of getting the human operator back in the automation loop. The consortium received a good feedback from the students, who were curious about this aspect and how Human Performance aspects are integrated in the TaCo project.



Figure 38: a moment of the Air Navigation Convention 2018 (Bucharest)

## A.1.4 Dissemination towards the Air Traffic Management community

### World ATM Congress 2017

TaCo took part in the **World ATM Congress (WAC) 2017**, taking place in Madrid, 7-9<sup>th</sup> of March 2017. World ATM Congress brings together the entire global community of air traffic management to discuss the latest ATM trends and developments.

In such context, TaCo was invited and took part into a **public workshop on the “SESAR 2020 Exploratory Research: Human Factors supporting Automation in ATM”**. The workshop presented different approaches to analysing human factors in highly automated ATC environments and proposing solutions to address potential adverse effects as well. The workshop aimed at:

- Offering an overview of the progress made in the exploration of the automation and human factors field;
- Sharing information on the latest state of the art in the exploratory research on automation;
- Enabling cooperation between the different projects by identifying synergies and complementarities among them;
- Identifying further developments in automation to serve as a reference for the exploratory research programme.

In order to achieve the workshop’s goals, **different SESAR Exploratory Research projects dealing with Human factors in automation presented their results**. The event included:

- Five projects on Automation, robotics and autonomy presenting their research on the effects of automation on human factors (AUTOPACE, TACO, AGENT, STRESS, MINIMA).
- Two projects on High-performing airport operations presenting its human factors assessment on augmented reality application (RETINA) and the exploration of key multimodal stimuli to enhance the sense of presence experience by ATCOs in remote towers (MOTO).
- A project within the Innovative ATM architecture, presenting how the ATM system could appropriately implement the achievements the project identified in automation (PACAS).



Figure 39: WAC 2017, public workshop on the “SESAR 2020 Exploratory Research: Human Factors supporting Automation in ATM”

The event represented a great opportunity for close interactions with manufacturers, operators and all other stakeholders interested in the topics of automation and human performance. It was also a precious occasion to exchange valuable information and create a fruitful spirit of cooperation.

### World ATM Congress 2018

TaCo took part in the **World ATM Congress (WAC) 2017**, taking place in Madrid, 6-8<sup>th</sup> of March 2018.

In that occasion, TaCo project was selected as part of the “SESAR walking tour”, within the session “Spotlight on airport operations”. The walking tour gives project the opportunity to present their results in a ten minutes demonstration to a wide range of stakeholders guided by SJU. In that occasion, the project had the first opportunity to show an integrated demonstrator of the capabilities of TaCo solution, including both the global strategy HMI and the Domain Specific Graphical Language (DSGL) HMI (see project deliverables D4.1 and D4.2). The opportunity to interact with the demonstrator has been given also to the public present at WAC during the three days of exhibition.



Figure 40: the set-up of TaCo at WAC 2018, including an immersive out-of-the window view from the Malta Tower

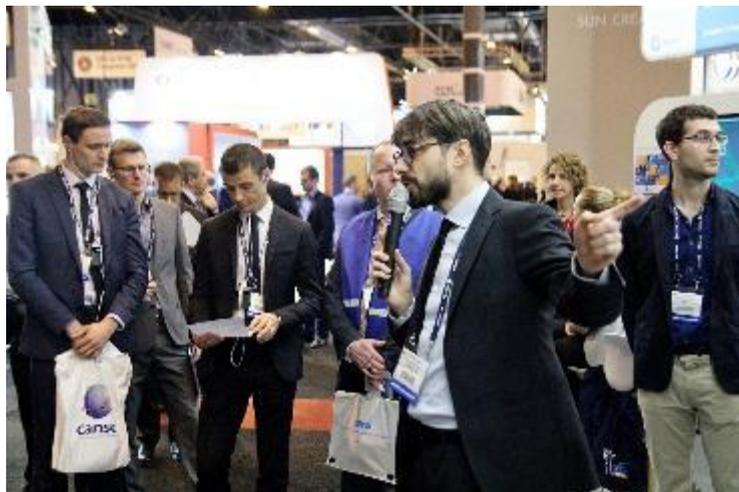


Figure 41: a moment of TaCo presentation at the SESAR walking tour



Figure 42: interaction with TaCo demonstrator at WAC 2018



Figure 43: a detail of TaCo global HMI presented on a tablet at WAC 2018

### ACI Europe-SESAR Workshop “Exploring new concepts in air traffic management and airports”

TaCo was invited to the workshop organised by ACI Europe SESAR and SESAR Joint Undertaking that was held in Malta International Airport the 12<sup>th</sup> of April 2018<sup>13</sup>.

<sup>13</sup><https://storify.com/ACIEUROPE/aci-europe-sesar-workshop>

<https://www.sesarju.eu/node/2972>

The workshop addressed promising results from a number of SESAR exploratory projects on topics addressing aspects of airport operations, as well as the broader ATM value chain. Topics to be presented will include: (1) Augmented/virtual reality and enhanced vision technologies; (2) Automation; (3) Complexity and data science; (4) Economics and market analysis; and (5) Enhanced environment & meteorology solutions.

The focus of TaCo presentation was on human-automation collaboration for the optimisation of ground operations at complex airports.

### A.1.5 TaCo Final Dissemination event

TaCo organised a final dissemination event at the International Airport of Malta in April 2018. The main objective of the event was to share the project results with all the potential users and stakeholders including airport operators and ANSPs. Nonetheless, scientific results have been also presented to raise interest and feedbacks from the scientific community. The final dissemination event of TaCo was organised the day before SESAR-ACI Europe workshop that took place at the same location (see section 0).

#### Agenda

The event has been thought as a full day workshop. In order to better fit the needs of the participants, the morning session has been oriented more on scientific outcomes of the project, while the afternoon session has been designed to better fit the operational needs and the benefits coming by the use of TaCo in a real airport environment.

#### Participants

Participants have been invited by the consortium members among their contacts and extending the invitation to the participants to the following SESAR-ACI Europe workshop. The announcement of the event has been put on the website as well, in order to collect subscriptions by the visitors. A table with the list of participants is shown below. It can be seen that a wide range of stakeholders has been reached (airport operators, ANSPs, airlines, industry, research), in accordance with the dissemination objectives defined in the Communication and dissemination plan.

Name	Organization	Type of stakeholder
Damiano Taurino	Deep Blue	Consortium member
Duarte Gouveia	ACI-EUROPE	Airports association
Jason Gauci	University of Malta	Research/Academia
Dirk Schaefer	EUROCONTROL	ATM intergovernmental organisation
Federico Petrocchi	Enav	Air Navigation Service Provider
Jaroslaw Niewinski	PANSA	Air Navigation Service Provider

Roberto Weger	SITTI	Systems manufacturer
Martin Dalmas	Malta International Airport	Airport operator
Noel Friggieri	Malta International Airport	Airport operator
Luca Crecco	SESAR JU	Project officer
Mr. Maximilian Hartwig	Flughafen Muenchen GmbH / Munich Airport	Airport operator
Sara Bagassi	University of Bologna	Research/Academia
Krzysztof Kalaman	PANSA	Air Navigation Service Provider
Anne Bruss	Fraport AG	Airport operator
Valerio Cappellazzo	EUROCONTROL	ATM intergovernmental organisation
Kurt Eschbacher	University of Salzburg	Research/Academia
Sebastian Hentrich	Fraport AG Operational Planning	Airport operator
Steve Burchill	SBworkdesign Ltd	SME/Industry
Daniel Liebhart	ETF	Air Traffic Controllers trade unions
Jennifer Sykes	Heathrow airport	Airport operator
Roland Guraly	Slot Consulting Ltd.	SME/Industry
Michele Altieri	ATCEUC	Air Traffic Controllers trade unions
Francesco Modafferi	ATCEUC	Air Traffic Controllers trade unions
Kari Osterberg	Finnish Meteorological Institute	Meteo Service provider
Vojin Tomic	University of Belgrade, Faculty of Transport and Traffic Engineering	Research/Academia
Zeljko Gojko	ATCEUC - CATCU	Air Traffic Controllers trade unions
Giuseppe PILLIRONE	Air France	Airline
Trevor Darmanin	Malta Flying	Aviation Training organisation

Ana Ferreira	Deep Blue	MOTO project
Giuseppe Frau	Deep Blue	Consortium member
Mathieu Cousy	ENAC	Consortium member
Stephane Conversy	ENAC	Consortium member
Joe Degiorgio	MATS	Consortium member

Figure 44: participants to TaCo final dissemination event

### Workshop activities

The morning session focused on the scientific outcomes of the project. In particular, the presentations introduced the user programming techniques, the innovative approach and algorithms used to define and compute automation strategies and the user centred process used to design the solutions.



Figure 45: one of the presentations in the morning session of TaCo final workshop

At the end of the morning session, a brainstorming has been done with the participants. Due to the high number of participants and to time limitations, the consortium decided to support this activity by means of an interactive application<sup>14</sup> able to collect live feedbacks by the users during a discussion. In

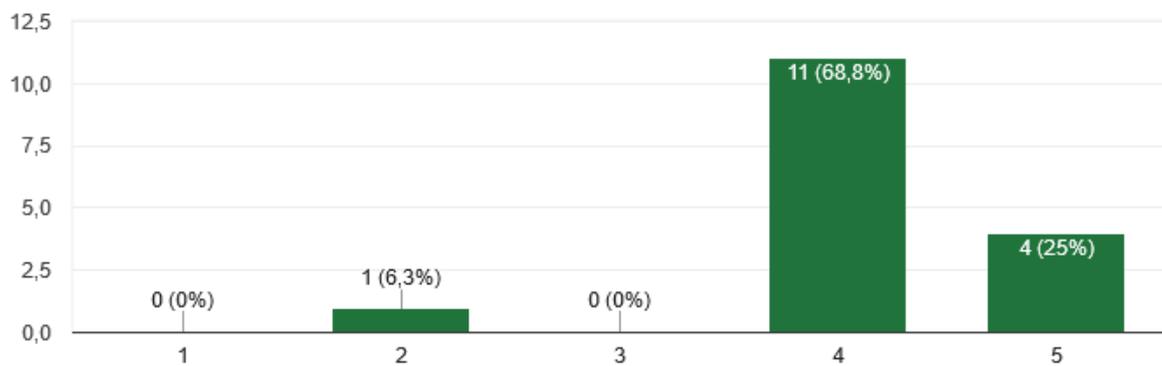
<sup>14</sup> Mentimeter, <https://www.mentimeter.com/>

general, the feedback by the audience was good in terms of acceptability and overall quality of the proposed solutions. The optimisation of runway usage has been ranked as the most promising optimisation strategy among the ones already implemented, as well as minimizing taxi time and reducing controller’s workload were proposed as possible strategies to be further investigated.

**Feedback of the participants**

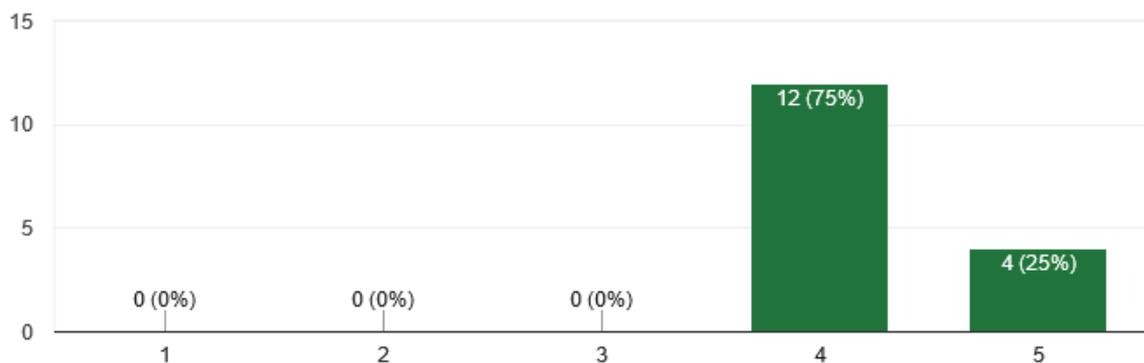
**I was satisfied with the quality of the presentations and they helped me in understanding the TaCo concepts**

16 risposte



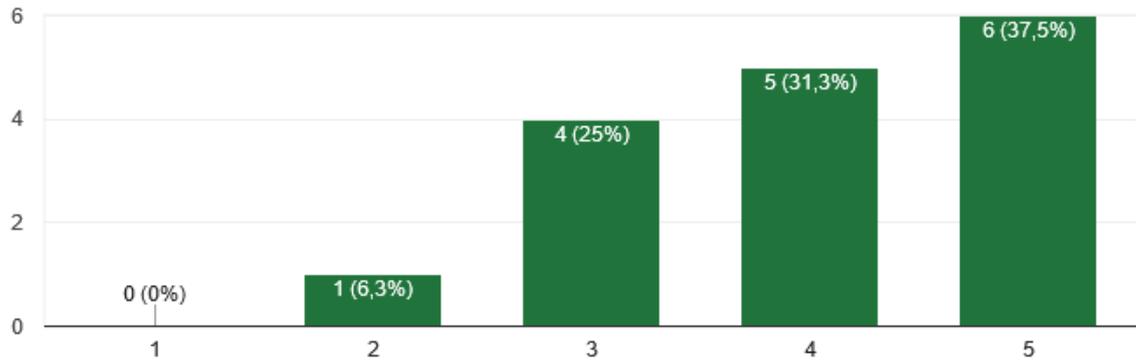
**The demo helped me in understanding the role of TaCo in the management of the airport operations**

16 risposte



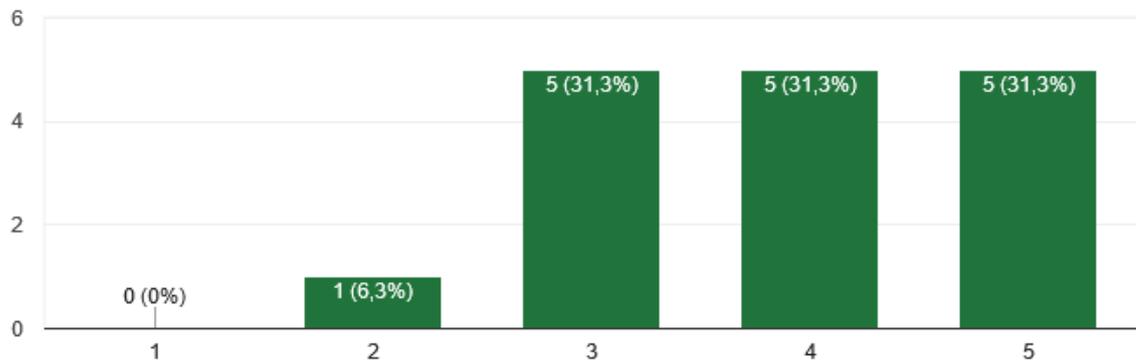
### The timing and composition of the agenda were suitable for a full day workshop

16 risposte



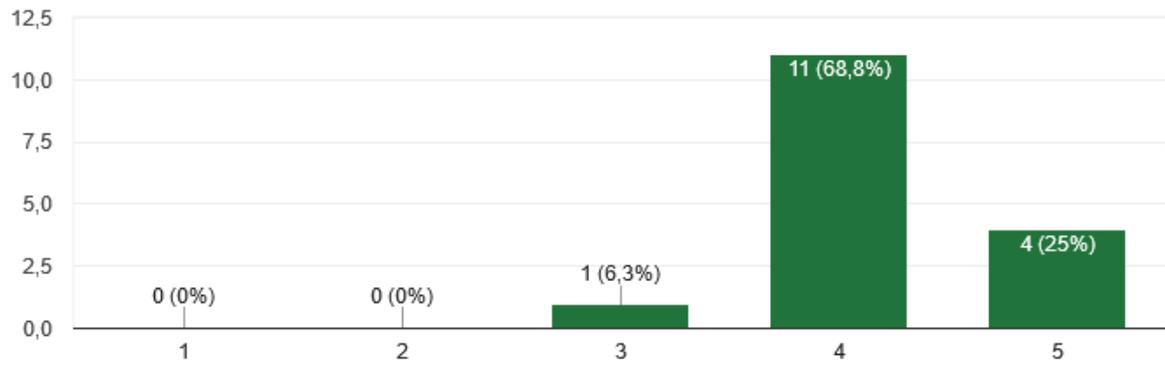
### Please rate the overall quality of the logistics (room, facilities, catering)

16 risposte



## Please rate the overall quality of the workshop

16 risposte



## Further Comments

1 risposta

Very well done to all involved. An ideal application to improve aviation efficiency.

## Appendix B

### B.1 Glossary of terms

Term	Definition	Source of the definition
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Table 6: Glossary

### B.2 Acronyms and Terminology

Term	Definition
<b>ADC</b>	Aerodrome Controller
<b>A-SMGCS</b>	Advanced Surface Movement Guidance and Control System
<b>ATCO</b>	Air Traffic Control Officer
<b>ATM</b>	Air Traffic Management
<b>CFMU</b>	Central Flow Management Unit
<b>CTOT</b>	Calculated Take Off Time
<b>DMAN</b>	Departure Manager
<b>DSGL</b>	Domain Specific Graphical Language
<b>EEC</b>	Eurocontrol
<b>ENAC</b>	Ecole Nationale de l'Aviation Civile
<b>GMC</b>	Ground Movement Controller
<b>HMI</b>	Human Machine Interface
<b>ICAO</b>	International Civil Aviation Organization
<b>IDE</b>	Integrated Development Environment
<b>LMML</b>	Malta International Airport
<b>MATS</b>	Malta Air Traffic Services
<b>SESAR</b>	Single European Sky ATM Research Programme
<b>SJU</b>	SESAR Joint Undertaking (Agency of the European Commission)
<b>TOBT</b>	Target Off Block Time
<b>TSAT</b>	Target Start up Approval Time

Table 7: Acronyms and terminology

