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D3.2 Integrated risk framework

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Authoring & Approval

Authors of the document

Name / Beneficiary	Position / Title	Date
Carlo Abate / Deep Blue	Work Package Leader / PhD	08.07.2022
Elizabeth Humm / Deep Blue	Project Team Member / PhD	20.06.2022

Reviewers internal to the project

Name / Beneficiary	Position / Title	Date
Lukas Beller / TUM	Project Coordinator / M.Sc.	11.07.2022

Reviewers external to the project

Name / Beneficiary	Position / Title	Date

Approved for submission to the SJU By - Representatives of all beneficiaries involved in the project

Name / Beneficiary	Position / Title	Date
Carlo Abate / Deep Blue	Work Package Leader / PhD	15.07.2022
Lukas Beller / TUM	Project Coordinator / M.Sc.	15.07.2022

Rejected By - Representatives of beneficiaries involved in the project

Name and/or Beneficiary	Position / Title	Date

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SafeOPS

SAFEOPS - FROM PREDICTION TO DECISION SUPPORT. STRENGTHENING SAFE AND SCALABLE ATM SERVICES THROUGH AUTOMATED RISK ANALYTICS BASED ON OPERATIONAL DATA FROM AVIATION STAKEHOLDERS.

This Deliverable is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 892919 under European Union’s Horizon 2020 research and innovation programme.

Abstract

The present deliverable concludes the activities of SafeOPS Work Package 3, whose overall objective was to develop a risk framework to assess the benefits and hazards, which result from the introduction of predictive analytics in the specific context of go-around operations. The new risk framework is based on Eurocontrol’s Accident-Incident Model (AIM), which was identified in Task 3.1 as best suited for the purpose. The AIM templates were subsequently expanded in Task 3.2 to meet the scope of SafeOPS.

The first step was to identify the functions performed by the air traffic controllers that guarantee the safety of operations during go arounds. In summary, these functions are: runway monitoring for the detection and prevention of potential runway conflicts, separation monitoring to guarantee that the minimum distance is always maintained among airborne aircraft, wake vortex encounter avoidance, and the prevention of the risk of Controlled Flight Into Terrain.

The second step was to identify, in the existing AIM templates of the risk models associated with these functions, the elements and base events that would be affected by the go-around forecasts delivered by the SafeOPS tool. This activity lead to the creation of a new, enhanced version of the AIM risk models. The expert judgement of a group of air traffic controllers was subsequently leveraged to assess the extent to which the affected elements are impacted by the SafeOPS tool and to semi-qualitatively measure the benefits or disadvantages for safety brought by the go-around predictions. This analysis included the lessons learnt in Task 3.3 which investigated the Human Factors aspects related to the provision of statistical information to air traffic controllers.

The results of the analysis show that the go-around predictions of the SafeOPS generally support the functions of the air traffic controllers, by heighten their situational awareness and increasing the available time to monitor the airborne and ground traffic situation, determine the consequences of an eventual missed-approach procedure, make a plan for resolving the situation, and maintain a set of alternative plans to react to every foreseeable development of the events. The potential unwanted effects of the go-around predictions are considered highly unlikely and much smaller than the expected benefits. The main one is that the predictions are mistakenly interpreted not as probabilistic

forecasts but as an exact information, thus potentially inducing excessive confidence or conflicting clearances.

In conclusion, the new risk framework is effective in identifying the events and actions that are impacted by the SafeOPS predictive tool. Two aspects make information generated by artificial intelligence challenging to convey: the statistical nature of the information and the fact that the processes which produced it are often non-transparent. This latter aspect is particularly relevant to build trust in the tool's prediction. Even if in high-workload traffic situations they might lack the time to check why a go-around is being predicted, the controllers do want to know the causes of the predictions to gain insight into the way the tool works. For example, if flight crews repeatedly report the presence of strong crosswinds during final approach, and subsequently the signalled cause of a predicted go around is 'wind', the controllers will be more prone to trust the tool. The probabilistic forecasts produced by the tool are challenging for the air traffic controllers because, especially during high-intensity operations, they would rather have exact situational information to act upon than an event probability which they are not sure how to react to. To meet this need, the SafeOPS tool is designed to predict missed approaches with high precision (90%, hence a predicted go around will most likely happen) at the expense of the recall (that is, about 20% of all go arounds are predicted). In this way, the air traffic controllers can confidently interpret a go-around prediction as almost certain. In summary, two conditions for the acceptance of this and future AI applications for decision support, are: (i) that the air traffic controller can rely on the accuracy of the predictions, because in their experience the forecasts are mostly correct, and (ii) that they receive training and clear guidelines on the appropriate measures to take depending on the available information

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1 Introduction

1.1 The SafeOPS project

SafeOPS investigates the impact of possible artificial-intelligence (AI) based decision-support systems on routine air-traffic operations. The scenario selected in SafeOPS for this investigation is the missed approach of a landing aircraft and the subsequent go-around. The go-around scenario has a number of uncertainties and safety critical factors associated with it. It is therefore an ideal candidate for studying the integration of a predictive technology, with the aim of providing greater support to Air Traffic Controllers (ATCOs) in managing aircraft.

1.2 WP3 in SafeOPS context

One aspect of the incorporation of a predictive technology in the air traffic operating environment, is the risk associated with the technology insertion, management and use. Therefore, it is critical to assess and manage this risk. Work Package 3 (WP3) of the SafeOPS project is assigned to the investigation of this risk, structured as a ‘Risk Framework’. The Risk Framework being developed in SafeOPS aims to analyse the impact of the technology on the safety of the current system.

The Risk Framework task in WP3 has been broken into three component parts which are aimed at bringing into the project current knowledge and experience of risk modelling, actual risk qualification and quantification in the case if the SafeOPS technology and also the deeper exploration of Human Factors related to the integration of an AI decision tool in the ATC system.

According to this, the three components in WP3 are as follows:

Task 3.1: Benchmarking of Existing Risk Models

Existing risk models have been reviewed and considered as suitable candidates for use in the SafeOPS project. This has included models currently being used in ATM safety management systems (SMS) and previously published research conducted in SESAR and other European research projects. The user requirements from previous SafeOPS work packages were used as valuable inputs to this task. The outcome was a review of models for potential use in SafeOPS and the recommendation of Eurocontrol’s Accident-Incident Model (AIM) framework as the best one for the needs of this project.

Task 3.2: Development of an Integrated Risk Model

This task builds on AIM, which is adapted, developed and integrated to account for the existence of the predictive technological solution and all aspects related to its operational deployment within Air Traffic Control (ATC). Both adoption of the model and its development require the involvement of subject matter experts to evaluate the fitness to both the technology solution and the environment in which it will operate, but also to populate the aspect of the risk model that might be required as additions for the SafeOPS tool. Furthermore, a close connection to the development of the predictive AI algorithms will be important, as these algorithms will provide one major input to the risk framework.

Task 3.3: Analysis of the Human Factors Impact of Real Time Risk Information Provision

This task assessed the risks associated with the provision of real time probabilistic information to end users. It focused on assessing possible dysfunctional interactions between humans, tools and procedures by looking at aspects such as reliability, trustworthiness, meaningfulness and display design of the information provided.

The present document addresses the final phase of the process, Task 3.2 (although it has the label of Task 3.2, it is the final task in the three that comprise WP3), namely the development of an Integrated Risk Model. This task was conducted last in order to benefit from the knowledge gained in Tasks 3.1 and 3.3.

1.3 Aim and Scope of the present study

This review aims to provide analysis and discussion of the safety considerations and consequences of integrating a go-around predictive tool.

In order to meet this aim, this study has the following objectives:

1. Identify the operations, decisions and actions which are impacted by the presence of the SafeOPS tool;
2. Describe and integrate these components into the risk model which has been recommended in Task 3.1 for use in SafeOPS, namely the Accident-Incident Model (AIM) model;
3. Describe how the individual elements of the model change after introducing the SafeOPS tool.

According to this, the risk analysis in this review will follow the methodology used in the AIM model and so it is a development of that model for the purpose of the SafeOPS tool. The AIM model provides individual templates for a number of accident types which can be used as a basis for identifying where and how the change to the system will impact on the safety being achieved in the existing system. Therefore, there is an assumption in this study that the templates in AIM are up to date, accurate and complete in terms of articulated risk in the system.

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2 A Model for go-around operations

2.1 Modelling approach

2.1.1 Accident Incident Model (AIM)

The Accident-Incident Model (AIM) is a top down, barrier-based quantitative model, designed to capture the increase or decrease of risk introduced by a change in an Air Traffic Management (ATM) system, or part of it. In the case of SafeOPS, this is an ideal model to aid the analysis of the change of risk associated with the integration of the SafeOPS tool. AIM achieves this by providing individual templates for a number of accident types which can be used as a basis for identifying where and how the change to the system will impact on the safety being achieved in the existing system. The discussions with the air traffic controllers during the workshops dedicated to analysing the tasks they perform during the approach, take-off, and eventually missed-approach phases, enabled us to identify the most relevant templates to this project, from the latest release of AIM [1]:

- Mid-Air Collision (MAC) Risk in Final Approach
- Wake Induced Risk on Final Approach
- Runway (RWY) Collision Risk
- Runway Excursion Risk
- Controlled Flight Into Terrain (CFIT) Risk

The risks of potential separation or wake vortex problems were explicitly mentioned by the controllers of both airports as something they are always monitoring and came out in all use cases [2], thus the choice of the first two templates in the list. The hierarchical task analysis performed in Task 3.3 [3] clarified that many of the ATCOs' tasks involve the monitoring and clearances of the movements of aircraft and vehicles on the runway. Consequently, the model templates for the runway incursion (which could potentially escalate to runway collision) and excursion were considered relevant. Finally, the CFIT template was included in the list with the aim of generalising the outcomes of the project to all airports. Indeed, that ATC commands might lead to a conflict with terrain is not an immediate risk at the locations of Airport 1 and 2, even in a situation where the ATCO needs to give vectoring instructions to the aircraft. However, in general this could pose an urgent threat in airports located in the vicinity of mountains or other obstacles.

The use of AIM requires the identification of the parts in the relevant templates that would be impacted on by any change to the system. Subsequently, it is possible to explore how safety could be increased, decreased or remain the same with the addition of a new solution. The structure of a simplified fault tree associated with an AIM model is shown in Figure 1 as an example.

A fault tree is a diagram of a system's evolution from its normal, "safe" status, usually represented at the bottom, to an incident or accident, usually visualised at the top. Safety barriers (green-filled rectangles in Figure 1) are in place to ensure that the level of hazard within the system is always under control and does not increase. If the barriers succeed, the operations are carried out safely as intended. When a safety barrier fails, the system progresses through a sequence of increasingly hazardous situations (the yellow-filled ellipses in Figure 1). These are also called 'precursors' (of the incident or accident). The progression stops when another safety barrier successfully prevents the level of hazard from escalating further.

The high-level safety barriers can be decomposed into several elements, in an increasing level of detail. These elements (the black rectangles in Figure 1) represent the actual actions and tasks performed by the ATCO and pilots/drivers in achieving the barrier. In fault trees, these elements constitute the 'contributing factors' to a barrier failure, and hence are represented as failures of an instrument or staff to perform its function. For example, two possible contributing factors to the failure of the "Runway management" barrier (Figure 2) are "Inappropriate or missing surveillance data" (instrumental failure) and "Inadequate use of surveillance data" (human failure). Each contributing factor is identified by a unique alpha-numeric code in which the letters identify the barrier and the numbers characterise the level of depth at which the barrier has been decomposed. For example, the barrier "Runway Management" in Figure 2 goes as low as to Level 5. The elements which are not further decomposed are called 'base events' or 'initiators'.

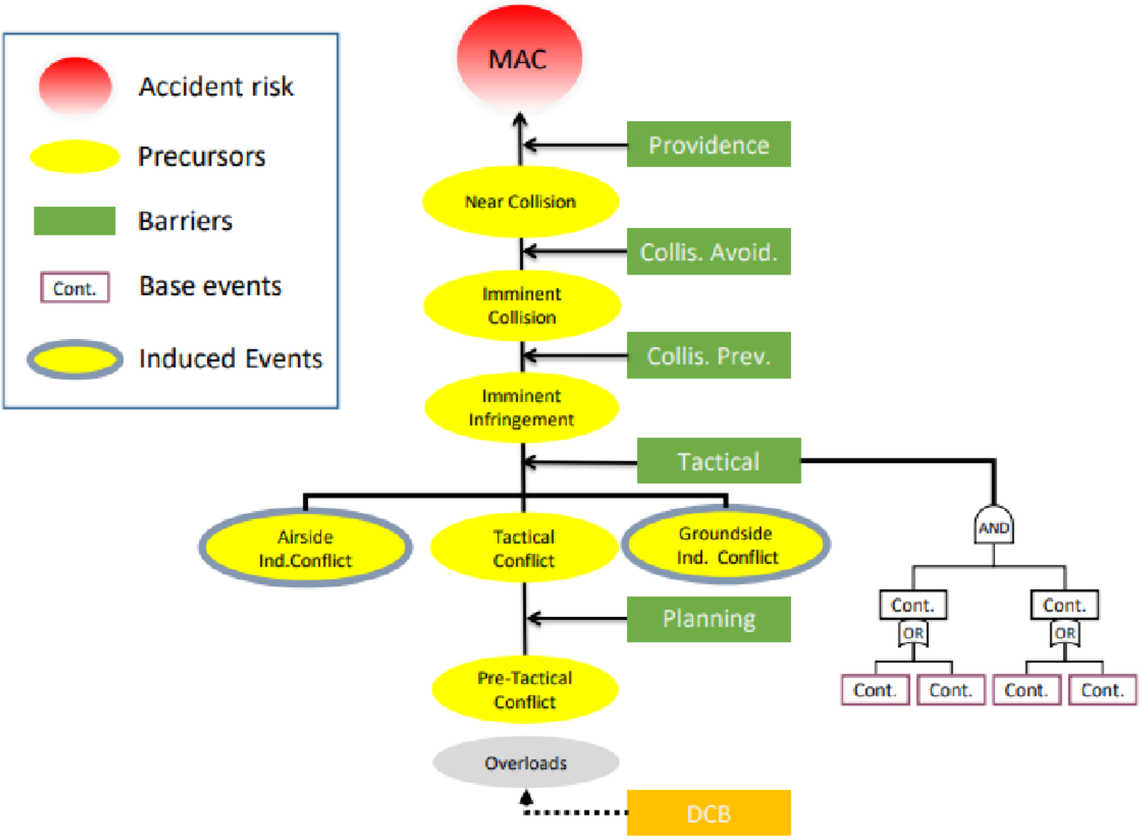

Figure 1. Main elements of the AIM barrier models illustrated with a simplified Mid-Air Collision template.

The contributing factors in a fault tree are interconnected through Boolean gates. When an element is built of lower-level components which are connected through an 'AND' gate, this indicates that that element will only fail if all the lower-level components fail. For example, in the "Runway Management" function, the event "Inappropriate clearance […] is provided by ATC and executed by AC/vehicle" is the combination of two components that both have to fail for the whole barrier to fail. Namely, the ATCO has to issue the wrong clearance AND this has to go unnoticed by the pilot/driver who executes the manoeuvre. When two (or more) lower-level components of a given higher-level element are connected by an 'OR' gate, this indicates that the failure of either component is sufficient for the higher-level element to fail.

The success or failure rates of each barrier are determined by the combination of occurrence probabilities of all contributing factors. Because the AIM follows the Boolean logic, the failure rates of the events are added or multiplied depending on the gate type and under the assumption that distinct contributing factors at the same Level are independent. Consequently, if the failure of an event A depends on the failure of two base events B and C linked through an AND gate, the failure probability of A is the product of the failure probabilities of B and C. By contrast, if B and C are linked through an OR gate, this means that A *succeeds* only if both B and C *succeed*. Hence, the success probability of A is the product of the success probabilities of B and C. Conversely, the failure probability of A is the complement of the product of the complements of the failure probabilities of B and C.

2.1.2 Considerations for assessing the SafeOPS tool

One of the purposes of the AIM risk framework is to support safety impact assessments of operational changes. The SafeOPS risk framework builds on AIM to assess the impact of adding the SafeOPS predictive tool in the traffic management for approach and missed approach handling. The safety impact of the tool is assessed at the level of the identified AIM model (at the barrier, contributors and precursors level). Because the research nature of the SafeOPS project and the consequent low maturity of the tool, the impact assessment mostly builds on the expert judgement of the ATCOs that evaluate the tool's impact in different operations semi-quantitatively on a Likert scale.

One important aspect of this assessment exercise has to be emphasised. When attempting to identify the 'touch' points in the AIM risk model, at which the SafeOPS tool impacts on the current risk (as described in the AIM templates), it is important to fully understand the purpose of the go-around manoeuvre. The go-around manoeuvre and associated procedures are not, and should not be considered, an accident or incident, or a precursor. In fact, a go-around is a barrier in the sense of risk reduction and prevention other potentially hazardous situations, for example a separation infringement or runway conflict. Thus, in order to assess the impact of the SafeOPS tool, the model 'touch' point that we must concentrate on is the barrier and beneath that, the associated fault tree.

Therefore, in this study, it has been appropriate to dissect the task performed by the ATCO which is the go-around and then identify the accidents/incidents that the go-around is aimed at preventing. Subsequently, it has been investigated whether the addition of the SafeOPS tool acts as an enhancement or a hinderance of the safety barrier(s) represented by the go-around. The following discussion is focussed on deepening and describing this process.

2.2 Overview of the relevant ATCO's tasks during go-around

ATCOs are continuously performing a variety of tasks that guarantee the safety of airborne and ground operations. In that, the go-around phase is no different as the ATCO is continuing to monitor that the aircraft has performed the missed-approach procedure (MAP) correctly. The ATCO will only intervene in case they identify the initiators of a potentially hazardous situation. Each hazardous situation, if not timely detected and resolved by the ATCOs (or by the pilots), can potentially escalate towards a conflict or even an incident or accident. The chain of events that can encourage the evolution from an initial, "normal" situation, towards an accident/incident can be schematically described using risk models. In these risk models, one function that an ATCO and the ATM procedures can fulfil. is that of being a "safety barrier". These 'barriers' keep operational hazards under control and prevent them from developing into potentially dangerous events.

In this section, we briefly summarise the main activities which the ATCOs perform before and during the go-around manoeuvre to ensure the safety of all actors involved (see also Figure 2).

Runway management and monitoring. In short, runway management from the point of view of the ATCOs consists of two main tasks:

a. Ensure that the runway is used by only one aircraft, vehicle, or personnel at the time, and
b. Issuing the necessary clearances to make sure this happens.

The ATCOs constantly perform visual checks on the runway and on the ground radar to ensure it is not occupied whenever a clearance must be issued for take-off, landing or runway crossing. In high-traffic conditions, when it might be necessary for pilots to execute the take-off manoeuvre promptly and efficiently, the ATCOs monitor the electronic flight strip system (EFSS) closely, to ensure that the departing aircraft is marked as "ready", and eventually communicating with the flight crew to ensure

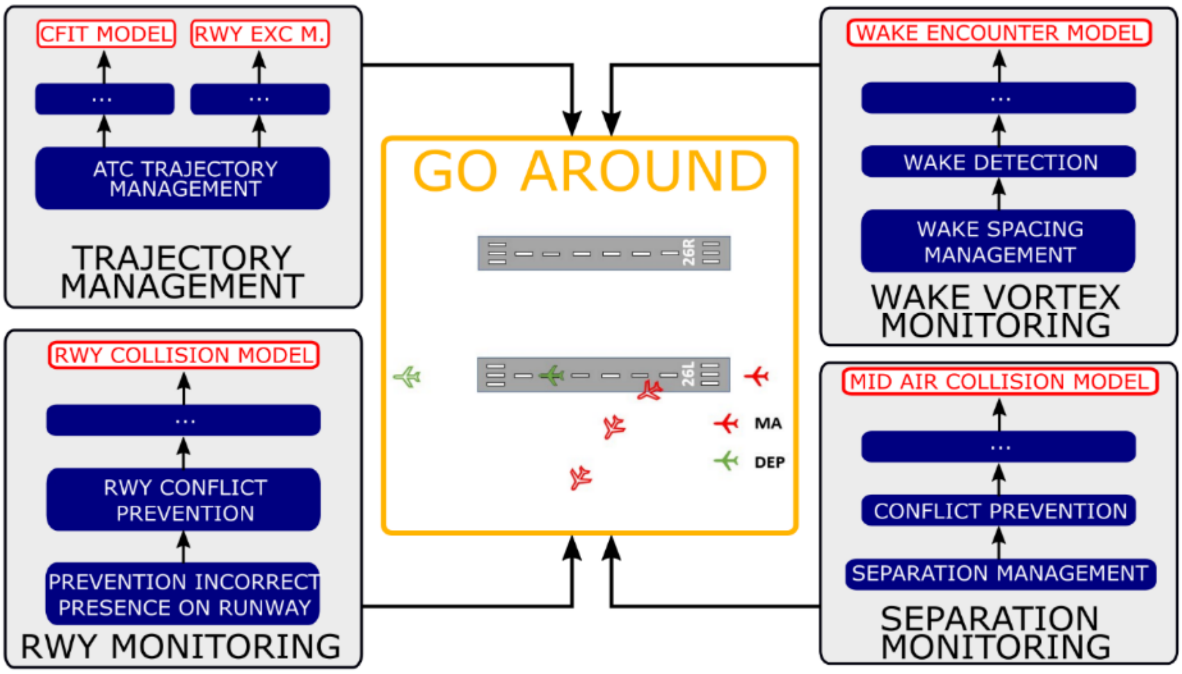

Figure 2. Functions fulfilled by the ATCOs during go-around operations. Appropriate risk models can be used to describe the ATCO's functions in terms of barriers that prevent hazardous situations from occurring.

that they are empowered to act rapidly. During normal operations, before the flight crew of the upcoming inbound aircraft has communicated the initiation of a go-around, the ATCO monitors the runway to ensure that it is not occupied at the time he/she issues the landing clearance. If there is crossing traffic, or a departing aircraft lined up for take-off, the ATCO gives the appropriate instructions to ensure that the runway is vacated in the due time. Eventually, if the aircraft does not take-off rapidly enough, or if there is any traffic on the runway, the ATCO detects the potential conflict, informs the approaching aircraft that the runway is blocked and will therefore instruct a go-around.

Separation monitoring. The ATCOs always guarantee traffic separation. In particular during the go-around, this might require the ATCO to identify potential conflicts between the standard missed approach procedure and the trajectories of other traffic in the area.

Wake vortex monitoring. While guaranteeing the traffic separation, the ATCOs also monitor the wake category of the A/C in the area to ensure that a lighter-type A/C does not encounter the wake vortex generated by a heavier A/C. During go-around this might become relevant depending on the wake categories and climbing performance of the departing A/C which is taking-off and of the A/C which is going around, especially in case of late go-arounds. The ATCO continuously monitors the EFSS and radar to identify these situations and instructs the involved A/C accordingly to prevent potential wake problems.

Trajectory management. To ensure separation and avoid wake vortex problems, the ATCOs might have to actively give instructions to the traffic in the area, for example by telling the departing A/C to climb straight ahead, or by telling the go-around to perform a non-standard MAP, or in some cases by cancelling the take-off clearance if necessary. Vectoring the traffic is a complex task for which the ATCOs need to be aware of the characteristics of the surroundings to guarantee the safety of operations even in presence of hills, mountains, buildings, etc. and avoid the potential hazard of CFIT.

The risk templates used to characterise these functions are described in Sect. 2.3. The discussion of how these models are exploited, in order to determine the impact of the SafeOPS tool, is presented in Sect. 3.

2.3 Available risk templates

In the following, the AIM templates are presented which describe the risks related to the functions summarised in the previous section. In particular, Figure 3Figure 5 show the AIM fault trees associated with these risk models. Note that Figure 3Figure 5 do not show the AIM fault trees in their entirety but only the portion that is relevant to go-around operations. Functions performed by the ATCO act as safety barriers, and each barrier is decomposed in multiple building blocks that, if they fail, become the contributing factors or precursors of the overall barrier failure.

In Figure 3Figure 5, the high-level safety functions and barriers are represented as blue- and green-filled rectangles, respectively. Base events which involve a human error are normally shown as a green rectangle. The dashed lines that do not end in a base event indicate that the original AIM diagram has additional elements which are not shown because they are not relevant to the context of the present analysis. Note that the maturity level of the available AIM templates varies. The more mature templates include the estimated failure rates of the individual events (e.g. the "Mid-Air Collision in Final Approach" risk model in Figure 4) whereas in other cases this information is not present (e.g. the "Runway Collision" risk model in Figure 3) because the development process is still ongoing and possibly not enough data is available to validate the models [4].

"Runway Collision" risk model.

Figure 3 shows the portion of the AIM "Runway Collision" risk model which is relevant to go-around operations, namely the "Runway Management" function fulfilled by the ATCOs. The diagram shows the possible reasons why the barrier might fail when the ATCO issues an inappropriate clearance (for crossing, take-off or landing) and this instigates a runway incursion. This is relevant in the SafeOPS context because, for example, a landing clearance for a wrong or closed runway (RWY) might actually be the trigger of a go-around, if the pilot notices the error in time and discontinues the approach. In current operations, a potentially hazardous situation might occur if an inappropriate clearance is provided by an ATCO and subsequently executed by the aircraft or vehicle, for example a clearance on the wrong or a closed runway. This is a rare event that could potentially occur because of a cascade of one or more of the following contributing factors:

1. Inadequate or incorrect information is provided to the ATCO for him to assess the situation (for example the surveillance data are incorrect or missing, the flight plan data or the runway status information are unavailable or incorrect, the pilot/driver provides inadequate position reporting, etc.).
2. Even when provided with appropriate information, the ATCO makes an error in assessing the situation.
3. There is inadequate or incorrect communication and coordination between ATCOs and pilots/drivers and this results in an incorrect presence on the runway.

Mid-Air Collision in Final Approach" and "Wake-induced risk on Final Approach" risk models.

The aspects related with the detection, prevention and resolution of conflicts during go-arounds in the "Mid-Air Collision (MAC) in Final Approach" risk model is shown in Figure 4. The diagram describes the contributing factors which may cause infringements of the minimum radar separation rule during standard or non-standard missed-approach procedures. The failure to maintain the minimum separation in this situation might subsequently become the precursor of more severe safety issues (e.g. a mid-air conflict, an imminent collision, a near MAC and finally a MAC) which are described in the full AIM template [1]. A conceptually similar model is shown in Figure 6 which describes the risk of a wake-vortex encounter. Also in this case, the model considers the final approach phase because the focus is on the situation that might evolve from a missed approach, and the main contributing factors are related to an ineffective management of the separation scheme that would guarantee the avoidance of wake encounters.

"Controlled Flight Into Terrain" risk model and Runway Excursion.

The elements contributing to the risk of "Controlled Flight Into Terrain" (CFIT) are shown in Figure 5. The relevance in the SafeOPS context is explained because the ATCO in the case of a non-standard missed-approach procedure might end up giving instructions to manoeuvre near the terrain or obstacles. An incorrect or misunderstood instruction at this point might cause the failure of the "ATC flight management barrier". This would result in the event of "Flight towards terrain commanded by ATC", which is one of the earliest precursors of the CFIT accident.

An aspect that it is currently not considered in any of the AIM templates is the ATC management of the take-off phase while the aircraft is still on the ground. Indeed, the "Runway Collision" model describes the possible risks when the departing aircraft is on the ground and might incur in conflicts with other aircraft or vehicles, whereas after take-off the possible unwanted outcomes are investigated in the "Mid-Air Collision in Initial Departure". The situation in which a departure clearance is rejected while rolling when it has not yet taken off is not modelled. This situation, however, could potentially be relevant if the SafeOPS tool were used in operations (cf Sect. 3.4). This additional element could arguably be included in a new "Runway Excursion" template modelling the risk of runway excursion in the initial departure. Possibly because such event is very unlikely and there is not enough data to quantify the contributing factors, such an AIM template currently does not exist, and a "Runway Excursion" model is only available for the landing phase.

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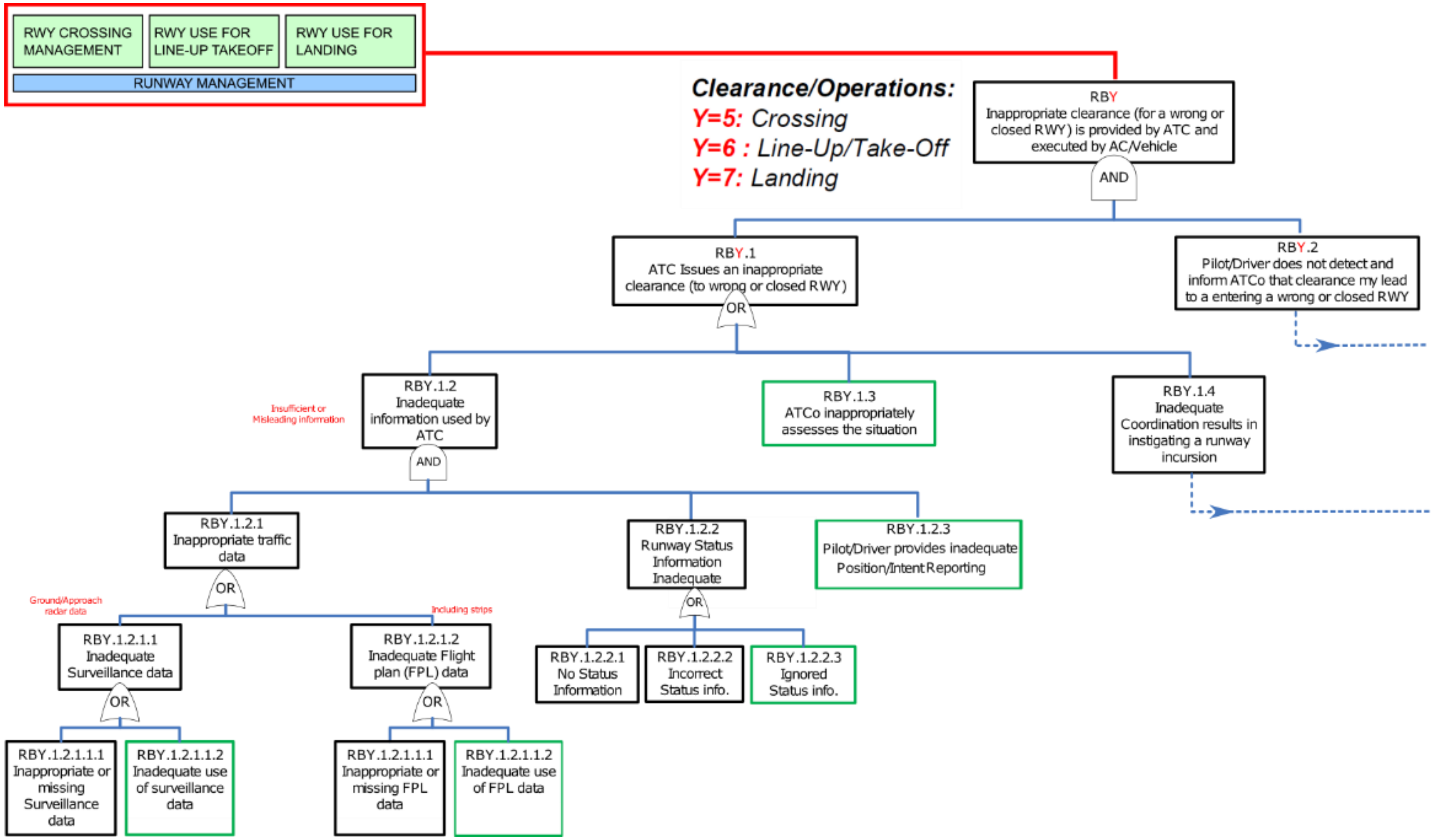

Figure 3. Portion of the AIM “Runway Collision” risk model relevant in the SafeOPS context.

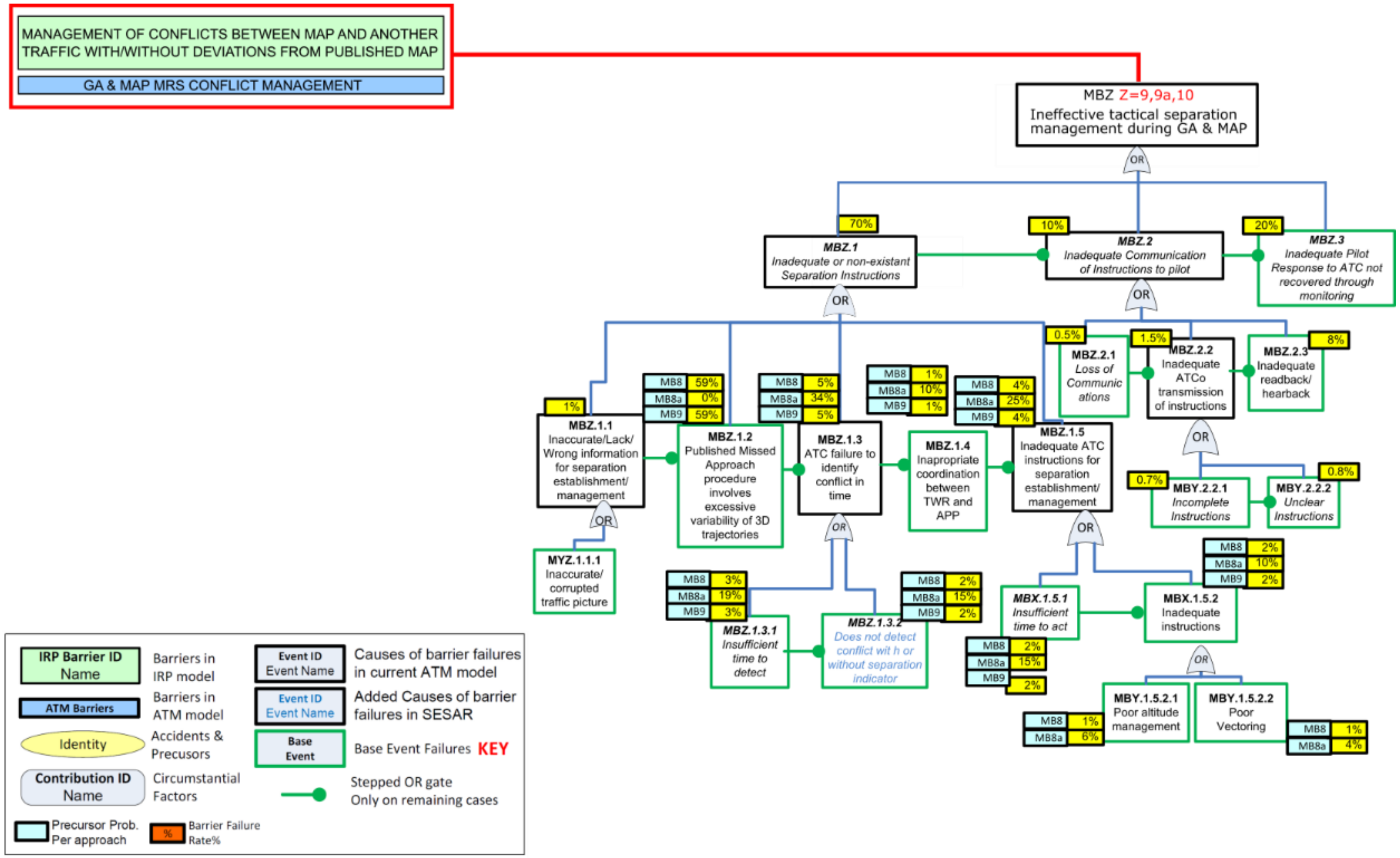

Figure 4. Portion of the "Mid-Air Collision risk in Final Approach" risk model relevant in the SafeOPS context.

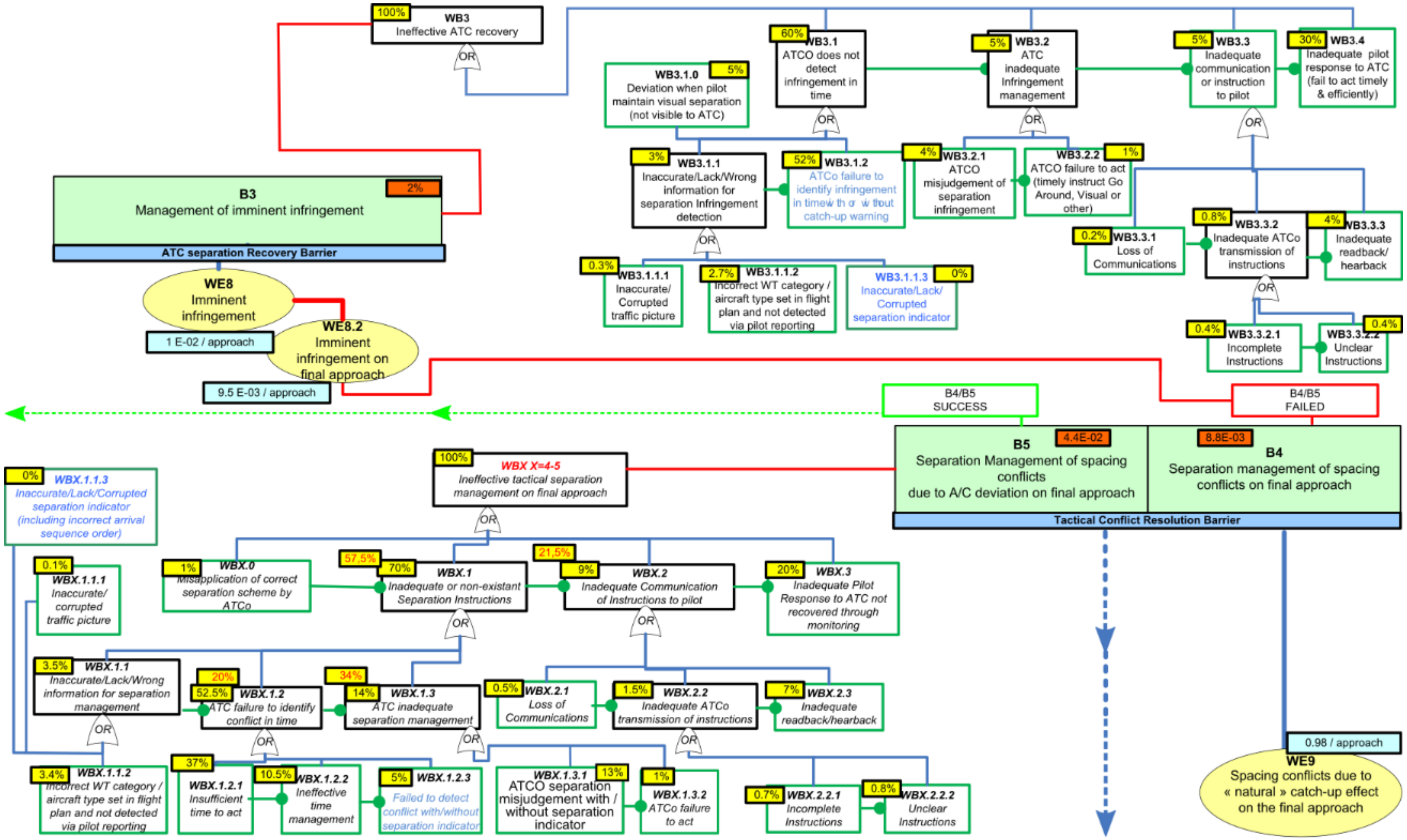

Figure 5. Portion of the "Wake Vortex on Final Approach" risk model relevant in the SafeOPS context.

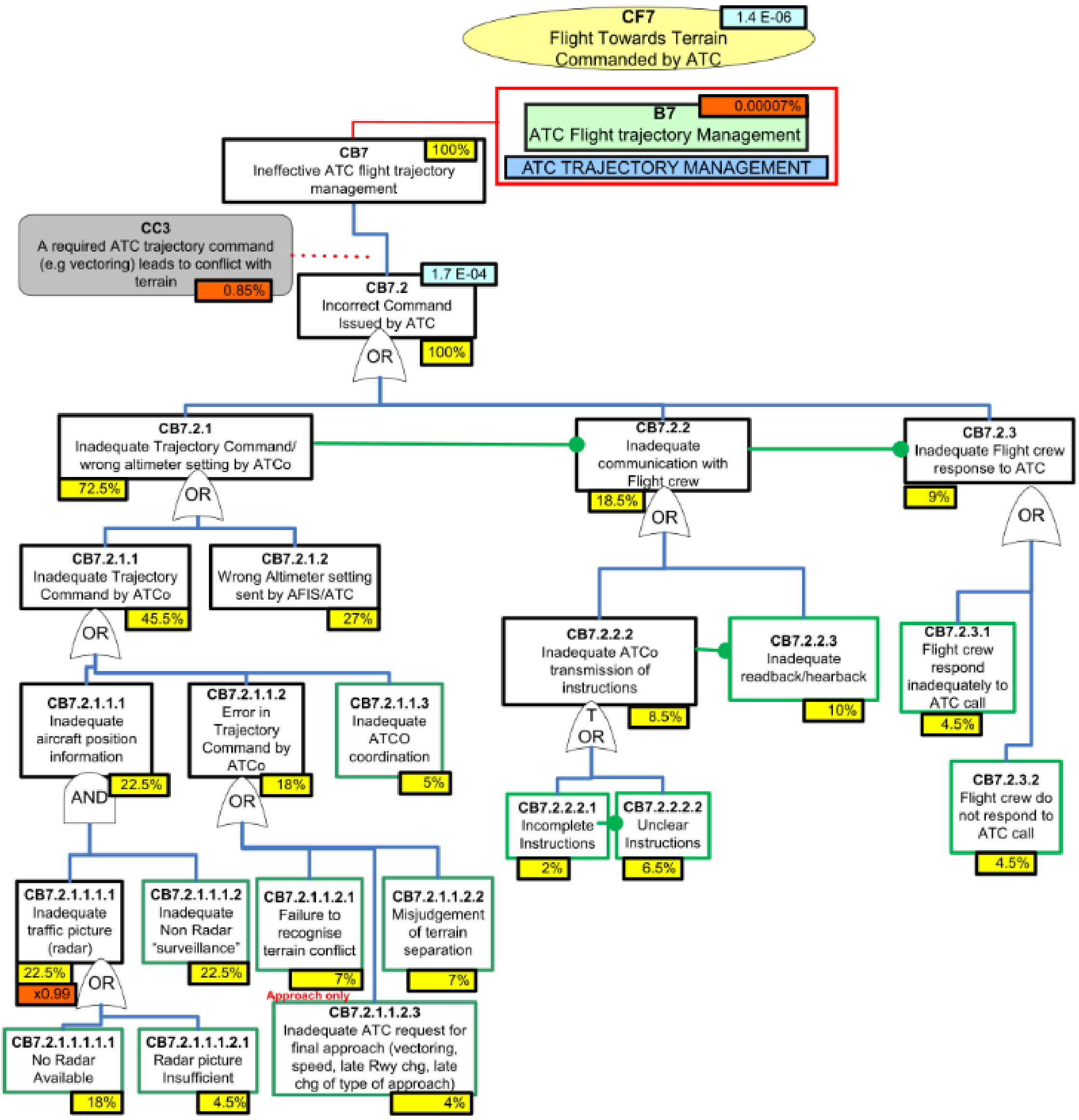

Figure 6. Portion of the "Controlled Flight Into Terrain" risk model relevant in the SafeOPS context.

3 Impact of the go-around predictions on operations

With the risk models described in Section 2.3, we analysed how the go-around predictions generated by the SafeOPS tool might potentially impact the safety of operations. The preliminary results of our analysis were discussed by the SafeOPS consortium with four ATCOs in two dedicated workshop sessions held on the 6th of April 2022 at Airport 2 and on the 10th of May at Airport 1, respectively. After a revision of the outcomes based on the ATCOs' feedback, the assessment was presented to two other ATCOs for a double purpose: (1) qualitatively validate the results of our analysis, and (2) semi-quantitatively estimate the impact on safety of the SafeOPS tool measuring the ATCOs' expert feedback on a Likert scale, whose two extremes, 1 and 7, mean “Not at all” and “A significant amount”, respectively. Because the SafeOPS tool has not the maturity level to be directly tested by the ATCOs, it is not possible to quantify its impact in human-in-the-loop simulations of a real operational environment. However, order-of-magnitude estimates can be obtained by building on risk assessment methodologies used in aviation and other domains [5]–[7], and on the ATCOs' expertise. The present deliverable includes all the received input and presents the final results.

The discussions with the ATCOs made soon clear that every traffic situation is different. Hence, it is not always possible to generalise and reason in terms of “a typical go-around scenario” in “normal conditions”. In our analysis, we therefore considered the following characteristics of the operational environment:

1. The traffic situation is busy and ATCOs are working with relatively small gaps (e.g. about 4NM for Medium Type Aircraft and 5-6 NM in case of wake turbulence category differences) in between two subsequent landing aircraft.

2. If a go-around is predicted, the precision of this prediction is between 80% -90% [8]. The closer the prediction is made to the runway threshold, the higher the precision tends to be [9].

3. If a go-aroundis predicted, this is shown when the approaching aircraft is at a distance of approximately 4 – 6 NM from the runway. An example of how the prediction could be displayed on the ATCO's radar screen is in Figure 7. The “go-around” label disappears after the aircraft has either completed the go-around procedure or it has landed (in case of a false prediction).

4. The SafeOPS tool presently predicts approximately 20% of all go-arounds [8]. This means that if no go-around prediction is given for an inbound flight, it is possible that a go-around eventually occurs. By contrast, if the tool predicts that a flight will go-around, this prediction will very likely be correct (see point 2).

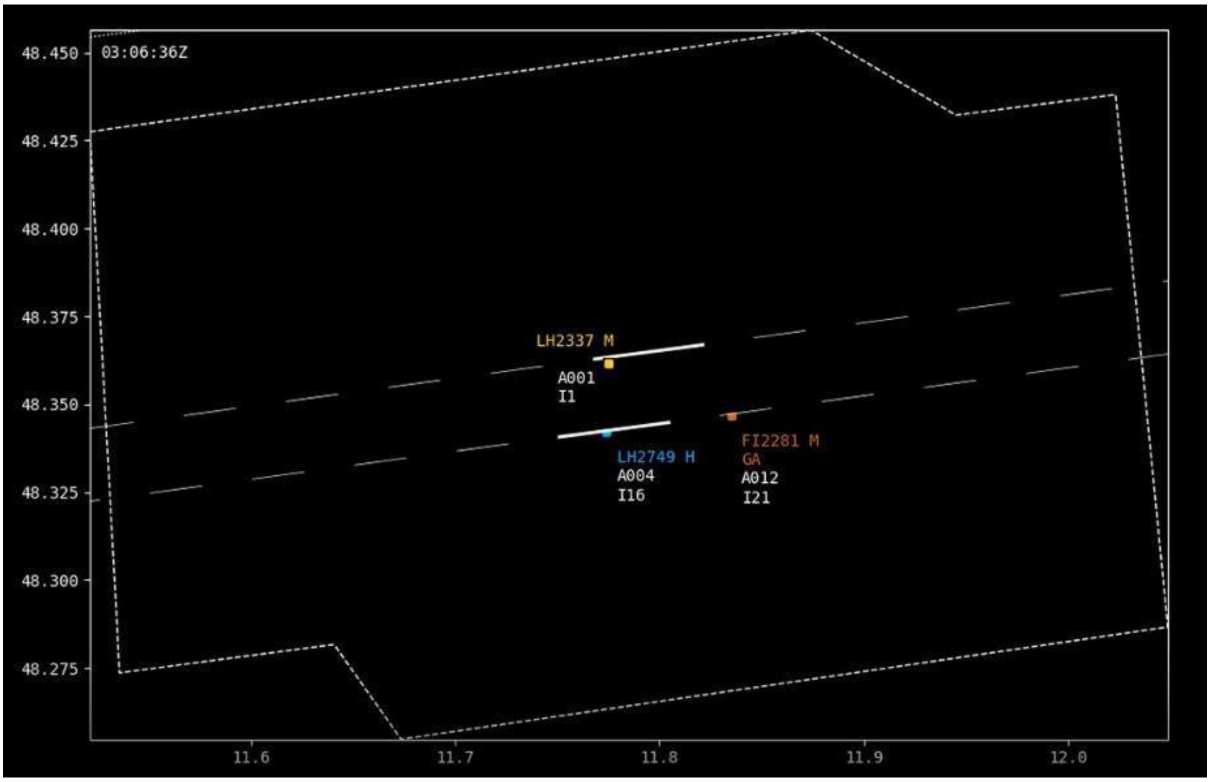

Figure 7. Simulation of traffic at the Airport 2. Landing and departing aircraft are indicated in yellow and cyan, respectively. The aircraft predicted to perform the GA is shown in orange and with the 'GA' label.

3.1 Runway management and prevention of Runway Incursions

The go-around predictions generated by the SafeOPS tool could impact the ATCOs' management of the runway in multiple ways. Figure 8 shows the events and contributing factors that are added to the original "Runway Management" barrier of the AIM "Runway Collision" risk model (purple rectangles). The element "RBY.1.2.4 – Misleading go-around prediction" is added to the group of contributing factors that build the RBY.1.2 barrier "Inadequate information used by ATC". The rationale is the following. Although it is known that the information delivered by the SafeOPS tool is probabilistic, the ATCOs will use it in their decision making. Hence, the options they consider and the alternative plans they mentally build to respond to possible evolutions of the system will be influenced by the tool's forecasts, even if it is known that by design there is always a chance that the situation will not evolve as predicted. In addition, the possibility that the information generated by tool induces an incorrect assessment of the situation is captured by the barrier "RBY.1.3 – ATCO inappropriately assesses the situation", which is not split in two components. The first one "RBY.1.3.1 – go-around prediction leads to incorrect situation assessment" describes the possibility that the ATCO misjudges the situation as a result of the information generated by the SafeOPS tool, whereas "RBY.1.3.1 – ATCO has incorrect mental map of the situation" covers all other possibilities that were originally included in "RBY.1.3".

The following example illustrates how the tool's prediction could induce a risk in the operations from the point of view of the ATCO. If the next incoming flight is predicted by the tool to go around, the ATCO would assess the traffic situation assuming that a go-around is (almost) certain. She/he would build a mental map of the current situation and how it is expected to evolve, and subsequently she/he would make a plan of how to manage the traffic based on this assessment. What happens if the tool's prediction is "incorrect"? This would be a case of "Inadequate information" being provided to the ATCO (RBY.1.2.4). As a result, the ATCO might decide for example to issue a runway crossing clearance because of the expectation that the runway will not be in use as the inbound aircraft is predicted to go around ("incorrect situation assessment", RBY.1.3.1). This hypothetical situation could have the following consequences. As the approaching aircraft is executing the landing, the runway is blocked by another traffic. If the ATCO or pilot do not react to promptly resolve the situation, there is the potential for a runway conflict. This hazardous situation was induced by the delivery of a go-around prediction turned out to be incorrect and would not have existed without the SafeOPS tool. However, it should be noted that this entire situation is very unlikely to occur. Had the arrival already been cleared for landing, it would be a violation to issue another clearance for the same runway, hence no ATCO would ever do so. If the arrival were on final approach and very close but for some reason not yet cleared, the ATCO would also not issue a runway crossing clearance because this decision would violate two principles that all ATCOs are trained to follow, namely "never base control on assumption" (in this case, the assumption that the aircraft is about to discontinue the approach) and "never clear a potential conflict". By contrast, the ATCOs might issue a runway crossing clearance when the time gap before the expected landing is large enough and with the intention of issuing the landing clearance afterwards on short final. In this case, the ATCO would allow the crossing and inform the pilots about the situation. In this way, they are made aware that they will be called back shortly, they will be cleared for landing relatively late, and the only restriction for a landing clearance is a crossing traffic, nothing else. Note that this management choice would be possible also without the SafeOPS tool, which would not have a particular impact in this case.

The scenario is different if no go-around prediction is delivered for the next approaching aircraft. In this case, the ATCO will assume that this aircraft will land, similarly to what happens in present-day operations. However, the SafeOPS tool might encourage an increased level of confidence in the ATCO, that the aircraft is going to land, when there is still a possibility that it could go-around (recall that the SafeOPS tool predicts about 20% of go-arounds). This is a misuse of the information being provided by the tool, or in this situation a misuse of an 'absence' of information by the ATCO (as in Sect. 2.3 point 2). The result of this might be a lack of, or complacency on behalf of the ATCO to plan for the possibly go-around. For example, ATCOs are trained to always have a 'plan B' in their minds, just in case the aircraft discontinues the approach and starts a go-around. If, however, the tool induces an inflated sense of confidence in the ATCO, that the approaching flight will definitely land, then the ATCO might end up not formulating a clear 'plan B' or not being ready to coordinate with other ATCOs/pilots/drivers in relation to the go-around aircraft. Thus, resulting in a potential runway conflict. However, all five ATCOs interviewed on this specific possibility replied that they would always mentally prepare for an unpredicted go-around, regardless of what the tool indicates. In particular, two ATCOs were asked to quantify how likely it is that a go-around prediction indication (or absence of it) will mislead them on a Likert scale from "1 – Not at all" to "7 – Significantly". Their answer were 1 and 2, respectively, indicating that indeed the possible risks captured by the model in Figure 8 are theoretically possible but very rare.

Another possible way in which the tool might negatively impact the ATCOs is that the go-around prediction distracts the ATCO, who therefore does not notice other important information (e.g. the runway status or other sources of information), inappropriately assesses the situation, or does not adequately coordinate the actions with the other actors, all of which can potentially instigate an incorrect presence on the runway. The two ATCOs interviewed about it, indicated on the one-to-seven Likert scale that this is unlikely (answers: 2 and 3, respectively). In commenting the answer, one of them added that the signal of a possible go around would not effectively distract from other urgent tasks but, in the worst case, trigger a more active preplanning of how to react to the go-around, which would cost in terms of workload more effort than in current operations.

The ATCOs identified several positive aspects of the tool with respect of the runway management. In particular, they expect the predictions of go-arounds will bring a minor increase in their situational awareness and thus support them in their task by also gaining a small amount of additional time to perform the monitoring and management of runway movement. One of the two ATCOs that filled the questionnaire noted instead that the time necessary to monitor the tool's predictions and to mentally elaborate the appropriate plans to react might actually cause a minor reduction of the time normally available to perform all the other tasks under the ATCOs' direct responsibility. This feedback does not refer to runway management specifically but also to the other considered functions. However, this point of view is in slight contradiction with the general opinions expressed by the other ATCOs. It is also partly inconsistent with the ATCO's own answer to the question whether the tool's predictions could distract from higher priority tasks, which was definitely negative (either 1 or 2 in all five investigated functions).

3.2 Separation management and prevention of separation problems

After the pilot-induced go-around is started, the ATCO is informed by the inbound aircraft that the approach has been discontinued. Because the missed approach (MA) is a high-workload phase for the flight crew, this information might reach the ATCO several tens of seconds after the go-around started. Although the ATCO might have noticed indications of the onset of a go-around (e.g. the change in speed and descent rate from the radar screen or the change in bank angle if visual contact is established), the response actions effectively start after the missed-approach call from the pilot has been acknowledged. The ATCO checks the distance, speed, intended trajectory and wake category of the surrounding traffic, particularly the departure in front that has just taken off and any VFR flights in the area. During this procedure, the ATCO will guarantee separation for example by instructing the pilot to perform a non-standard missed approach procedure. Alternatively, the ATCO can tell the departure to maintain the ascent below a certain altitude or to climb straight ahead, thus delaying a planned turn towards a direction that intersects the trajectory of the published missed approach. In addition, the ATCO has to coordinate actions with the other controllers and adjacent sectors, to update the flight status information in the EFSS, to monitor that the go-around is executed as instructed, and to transfer the aircraft to the radio frequency of the responsible to re-integrate the aircraft into the arrival sequence for another approach.

The go-around predictions generated by the SafeOPS tool impact on the ATCOs general situational awareness and on the available time to perform their tasks (cf. Figure 9, purple circles). As previously mentioned, ATCOs are trained to always have a plan to handle go-around already in their mind. However, with the correct prediction of a go-around delivered by the tool at a distance of 4 NM, the ATCO will be afforded more time to make a mental map of the traffic situation, issue the necessary instructions and listen to the readbacks. In principle, if the ATCO makes a plan in which a non-standard missed approach procedure should be followed, the instructions could possibly be anticipated to before the go-around has actually started, because the ATCO could inform the pilot that "in case of go-around, turn immediately towards heading X" or similar. Similarly, the ATCO could decide to pre-emptively instruct the departing aircraft in front of the potential go-around to climb straight ahead and limit the climb below a certain level. In the questionnaire, the two ATCOs indicated that the tool's prediction will bring a minor increase of the situational awareness (5 of the one-to-seven Likert scale) and a moderate increase of the available time to perform the task. In summary, the tool will to some extent increase the probability of success of the barriers related to forming an accurate traffic picture

(MYZ.1.1.1), time detect and act (MBZ.1.3.1 and MBX.1.5.1), and instruct the pilots correctly (MBX.1.5.2).

No negative consequences are expected for the task of guaranteeing the separation in the case of incorrect predictions. Indeed, the go-around prediction only draws the attention of the ATCOs on a potential event, giving them more time to elaborate the alternative “plan B”, “plan C” and so on. If the approaching aircraft actually lands, the ATCOs will simply stick to their original “plan A”. In turn, a situation in which there is an unpredicted go-around would be the exactly the same as the current situation of a flight crew induced go-around. In this case, the only potential negative consequence is the one also described in Sect.3.1, that is, the absence of a go-around prediction from the SafeOPS tool might encourage an increased level of confidence in the ATCO, that the approaching aircraft is going to land. As mentioned above, however, this would be a misuse of the SafeOPS tool which is designed to minimise the ‘false positives’ (that means: if it predicts that an approaching aircraft will go around, such approaching aircraft will most likely go around) but this comes at the price of having a relatively high percentage of ‘false negatives’ (that means: the tool will correctly identify about 20% of the A/C which will perform a go-around, while it will not raise any warning for the other 80% [8]). However, we also note that this misuse of the SafeOPS tool is possible but we consider it highly unlikely because (a) the ATCOs are trained to *always* have multiple plans to resolve any potential situation, and (b) should the tool be used in real operations, the ATCOs will be also trained to correctly interpret the meaning of the predictions.

3.3 Prevention of Wake Vortex encounters

To manage separation and avoid possible wake vortex encounters, ATCOs have to, not only continuously monitor the evolution of traffic, but also to always keep in mind the class of all aircraft and its wake generating potential. The decisions of what separation to allow between traffic generally depends on the aircraft type of the departing and approaching aircraft. Especially when gaps are short, time is critical, because as soon as the ATCO is informed about the initiation of the go-around, she/he needs to promptly check the characteristics and performance of the traffic involved, detect the potential problem and eventually instruct the flight crew on how to avoid the wake of the preceding aircraft, while also ensuring safety of operations against the hazards described in the previous sections. As for the separation management, the go-around prediction draws the ATCOs’ attention on the approaching aircraft and the possible situation and give her/him more time to check aircraft types, their speeds and performances, and elaborate a plan to guarantee safety. With more time, there is less chance for errors in reading or remembering the information, building an action plan, and conveying the information. The relevant elements of the AIM risk model that are impacted by the provision of go-around predictions are shown in Figure 10. The ATCOs found that a go-around prediction would bring minor to moderate support (5 and 6 on the Likert scale) to the performance of the task of avoiding wake encounters by providing more time to identify the potential issue and thus an increased awareness (5 on the Likert scale) of the situation and its potential evolution. In particular, one ATCO appreciated the possibility to hold a departure if a missed approach procedure is very likely. This would be an improvement compared to current operations, in which working under the assumption that every approach is a potential missed approach would require a huge spacing to let a wake categorized heavy aircraft depart in front of a medium or even a light type. This way of operating would cause delays and reduced traffic capacity. Consequently, ATCOs do more often give conditional instructions of immediate turns in case of a go-around. If the missed approach happens within the last 2NM of the approach phase, this often means steep turns or high climb rates for the aircraft because there is not much flying time anymore until it reaches the area of wakes of the preceding aircraft.

Hence, the go-around prediction would allow to take precautionary decisions in specific cases, reducing the risk of wake encounters.

3.4 Prevention of controlled flight into the terrain

The elements of the risk model that could be impacted by the go-around prediction are marked by purple circles in Figure 11. They involve errors or inadequacies in the trajectory commands transmitted by the ATCO. Although ATCOs are unlikely to make mistakes during a rather canonical operation such as go-arounds, time pressure can become a critical factor. Especially if the go-around is communicated late, the ATCO might have very little time to take decisions. This might increase the chance of errors, which would result in particularly challenging circumstances for ATCOs working at airports in the vicinity of hills, mountains or even particularly high buildings. As for the prevention of separation problems, also in this case the expected impact of the go-around predictions generated by the SafeOPS tool is to give the ATCOs more time to perform their tasks. In particular, the prediction would raise the ATCO's awareness of the potential problem and give her/him more time to detect potential problems and elaborate one or more plans to resolve the situation. In this situation, the ATCO could also think of issuing conditional instructions "should a go-around be necessary" to the flight crew, so that also the pilot eventually has more time to mentally prepare to follow a non-standard missed-approach procedure. The ATCOs attributed minor to no gain (respectively, 5 and 4 on the one-to-seven Likert scale) in terms of risk reduction of human error during the transmission of trajectory commands during go-around management. They also indicated that there are no other possible sources of additional risk in this context, for example because of distraction or a false positive or false negative. In summary, according to the ATCOs' expert judgement, the SafeOPS tool does not have a particular impact on safety in this case, neither positive nor negative.

3.5 Prevention of Runway excursion problems

The situation considered in this case is as follows:

- The departure immediately ahead of the next approaching aircraft is cleared for take-off.
- The SafeOPS tool shows the go-around sign, i.e. the APP will go around with a probability >90%.
- On the runway, the departing aircraft has started rolling but it has not yet reached the maximum speed at which a rejected take-off can be initiated (V1).

Consequently, the tool prediction can potentially be the initiator the following hazardous situation. The ATCO might decide to cancel the take-off clearance to avoid having two airborne aircraft. There are human errors associated with this action, for example:

- There is a chance that the assessment of the situation was incorrect, e.g. the aircraft is already at a too high speed;
- The communication with the flight crew was inadequate;
- The flight crew did not react quickly enough/did not execute the instructions as expected or timely;

This situation could result in a rejected take-off that occurs at such a speed that there is a runway excursion. The go-around prediction could therefore instigate an event that did not exist without the tool. When asked about this scenario, all ATCOs replied that it is a very abstract possibility that would very likely never occur in practice. The most important reason is that they all recognise an aborted take-off as a very complex situation to manage for both the flight crew and the ATCO, certainly more workload-intensive than handling two aircraft in the air, even with tight gaps. Consequently, ATCOs would not want to cause such situation any more often than absolutely necessary, and certainly not just as a precautionary measure because of a possible future separation conflict. In addition, an aircraft which aborted its take-off has often problems of brake overheating, even at low speeds. This might cause a fire or (more likely) large delays, because the flight crew has to wait for the brakes to cool down again. The only hypothetical scenario that the ATCOs could think of, in which they would consider cancelling a rolling take-off and let the aircraft vacate the runway without departing would be if there is a clear risk that the landing pilots might not follow the instructions or the situation can evolve into an emergency. This might for example occur if the “missed-approach-sector" is blocked by some kind of VFR-Traffic (crosser, police/rescue helicopter), or the approaching aircraft is having manoeuvring or communication issues. This combination of unfortunate circumstances would make the risk of a runway excursion less severe than that of a potential mid-air conflict or collision. However, the ATCOs concluded that this scenario is very speculative and unlikely to happen in real operations, so the additional risk created by the SafeOPS predictions is actually very low.

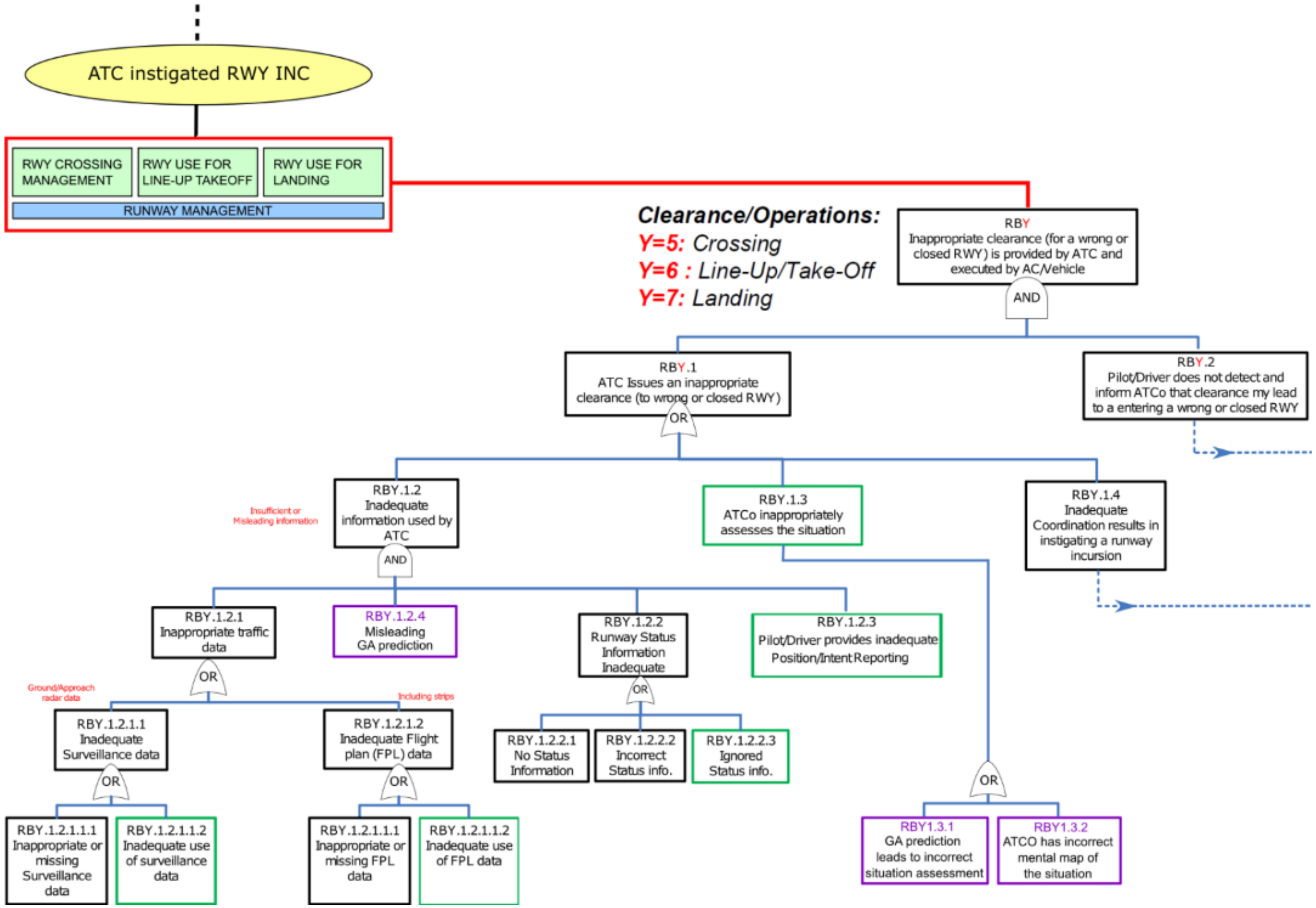

Figure 8. Modified AIM "Runway Collision" model that shows the impact of the SafeOPS predictions on the "Runway management" barrier. The purple rectangles are the newly-added contributors.

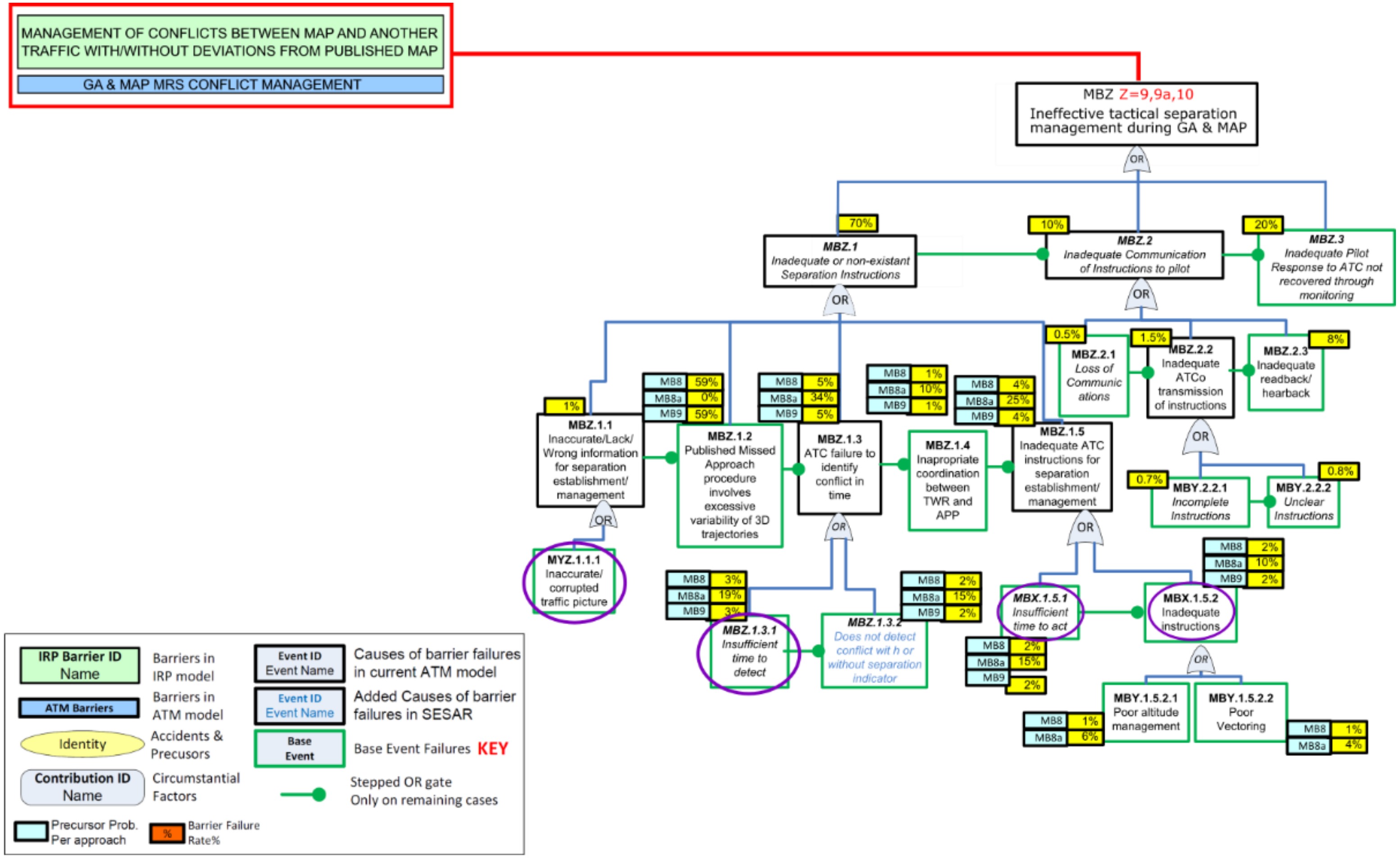

Figure 9. Modified AIM "Mid-Air Collision during Final Approach" model that shows the impact of the SafeOPS predictions on the separation-management barrier. The elements in the purple circles are impacted by the availability of the SafeOPS predictions.

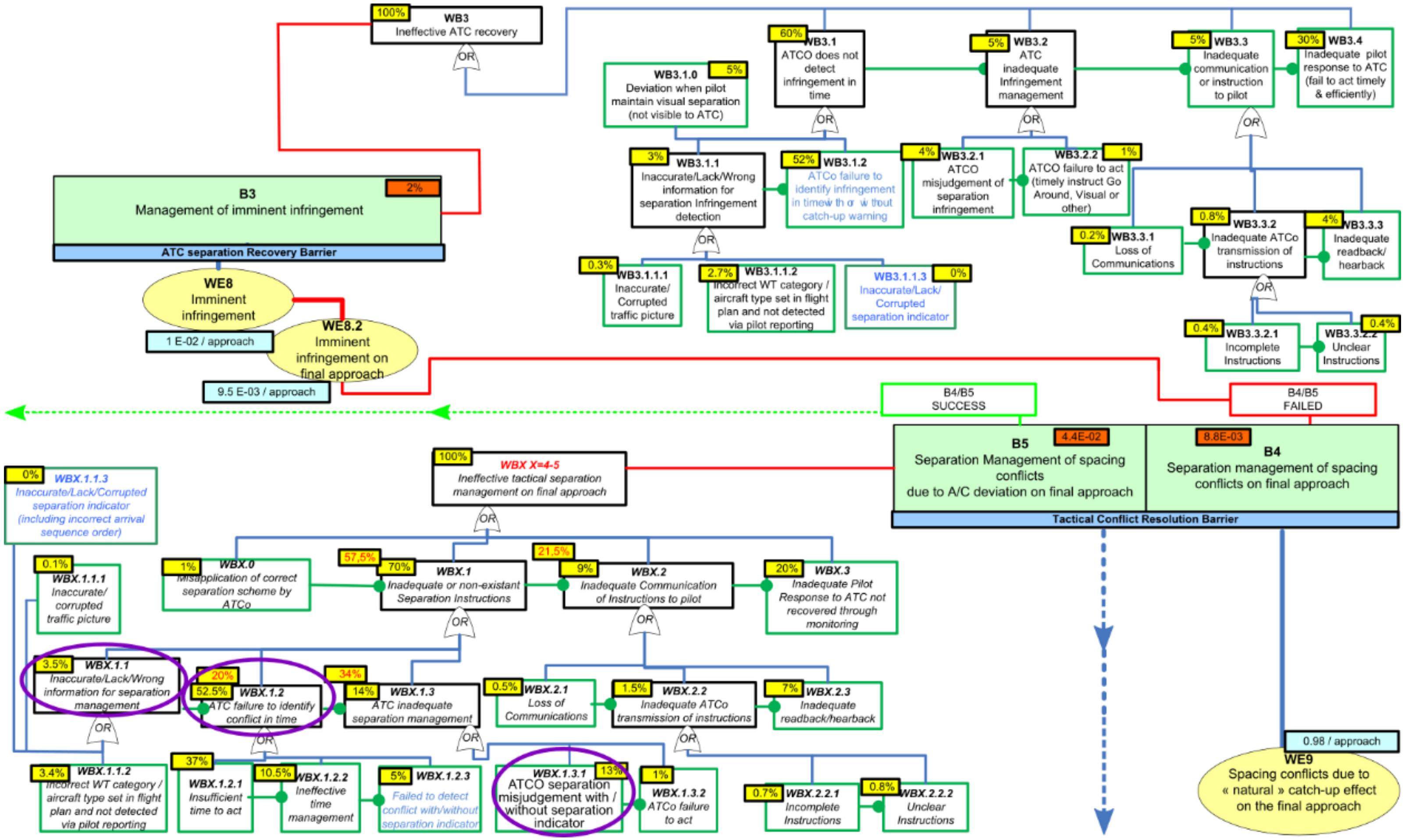

Figure 10. Modified AIM "Wake Vortex on Final Approach" model that shows the impact of the SafeOPS predictions on the separation-management barrier. The elements in the purple circles are impacted by the availability of the SafeOPS predictions.

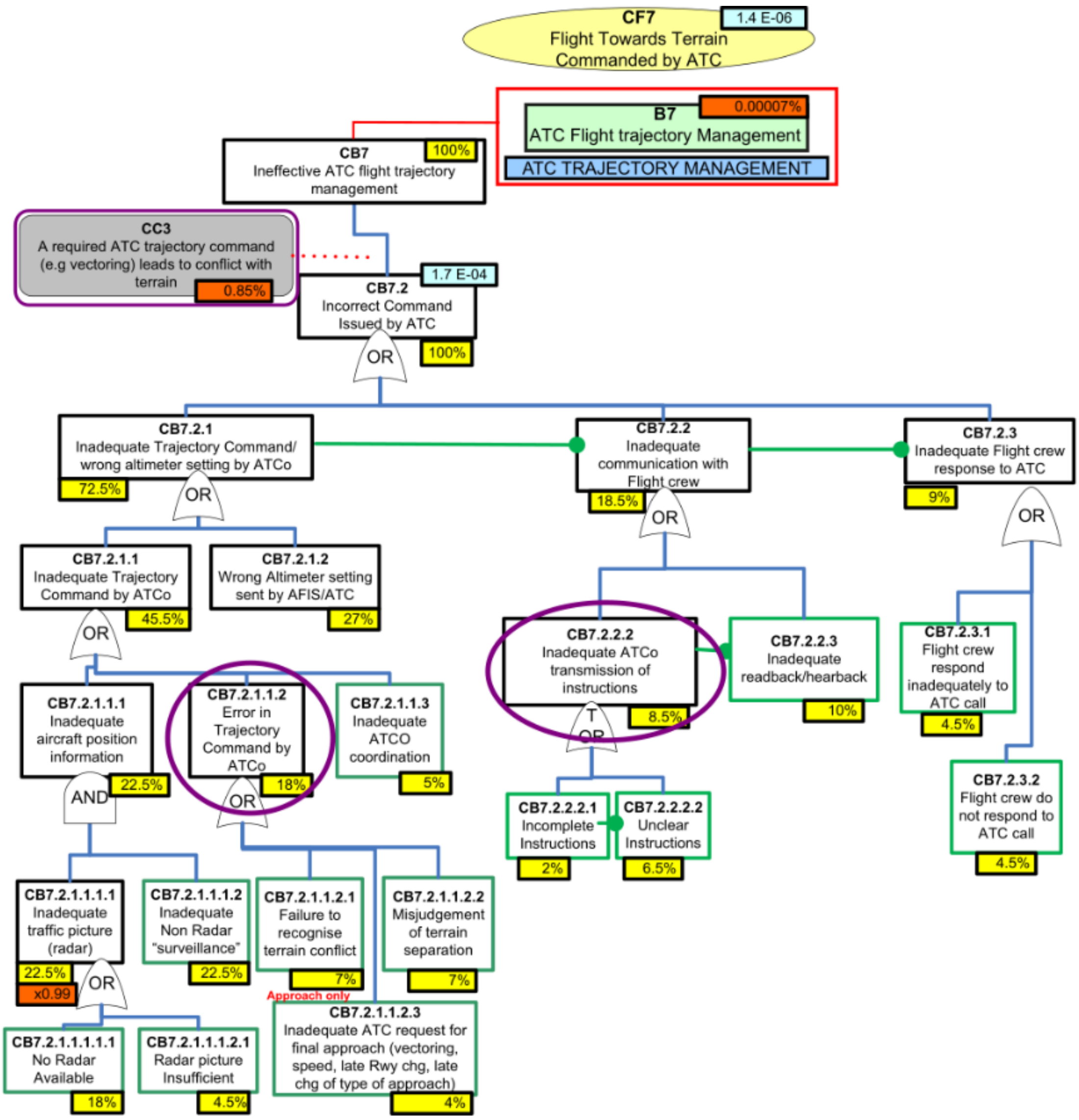

Figure 11. Modified AIM "Controlled Flight Into Terrain" model that shows the impact of the SafeOPS predictions on the trajectory-management barrier. The elements in the purple circles are impacted by the availability of the SafeOPS predictions.

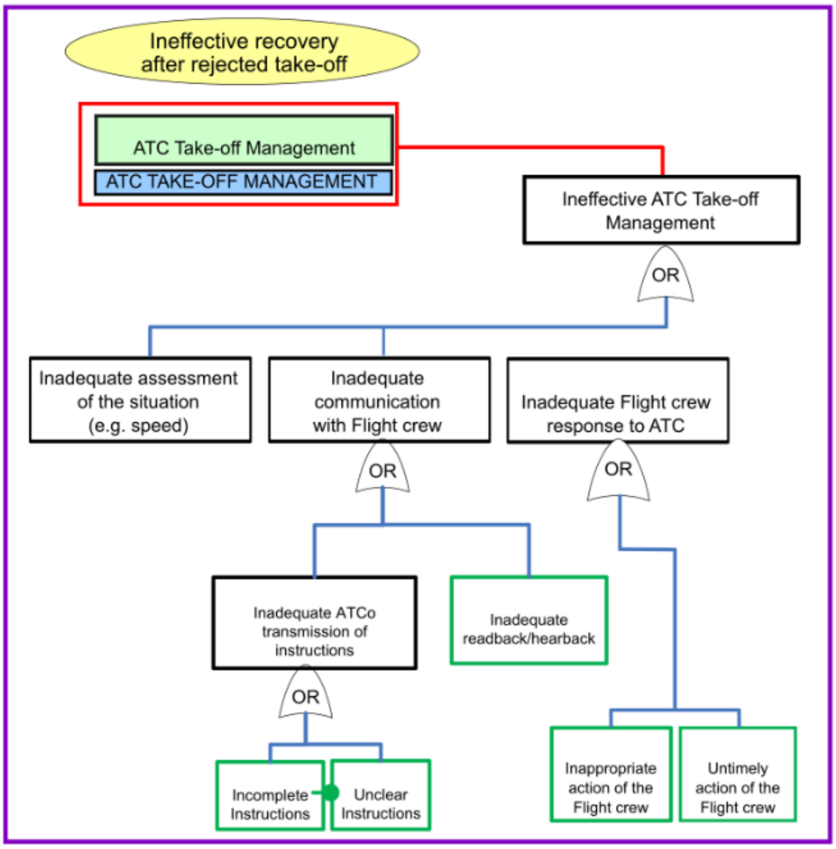

Figure 12. Proposed model of the Runway Excursion risk in case of rejected take-off.

4 Discussion

4.1 Use of the risk framework

The models presented in the previous sections can be used to describe the main contributing factors to risk during the management of a missed-approach procedure in presence of the SafeOPS predictive tool. In principle, these models could be used to inform the ATCOs in real time about the emerging "risk picture". For example, it could be used to highlight the main hazards the ATCOs should focus on when elaborating their alternative plans to manage the traffic in case of a go-around. However, this possible use of the risk models was definitely rejected by the ATCOs for multiple reasons. The first is that a go-around is not considered a high-risk situation but a rather normal operation. Indeed, while the ATCOs acknowledge that they always need to be ready to react promptly in case a go-around occurs, they know that this procedure does not cause immediate threats to safety. Consequently, in all the interviews they expressed the requirement that the tool predictions are concise, do not clutter the radar screen, and do not distract them from other more urgent issues. Some ATCOs conceded that additional information related to the main drivers of the tool prediction (e.g. the aircraft descent parameters, the weather conditions, etc.) or the risk would be interesting to know and could be displayed upon request by interacting with the radar screen (e.g. by clicking on the callsign) [3]. However, time is the main practical limitation to actually access this information. If a go-around has started, the ATCOs have to rapidly perform several tasks of monitoring, coordination and communication, the plan of actions is already formed in their mind and they would not want to spend time looking for additional information. If the SafeOPS predictive tool informed them a few minutes in advance, the general opinion is that they would spend this additional time to observe the situation and make their own judgement rather than trusting an automated system to tell them what to prioritise. The situation would be different if the information delivered by the tool were deterministic, as for example the various conflict alert systems that are in place. By contrast, the mental effort necessary to understand the meaning of the probabilistic information about the potential hazard resulting from a go-around, which is not an emergency manoeuvre and might eventually not happen, is considered too high compared to the benefits this additional information would bring them.

The risk models can instead be useful "offline" for training purposes and in the post-event debriefing analysis. In this case, the ATCOs find it useful to thoroughly describe all the possible outcomes of their decision and to compare different options. They would use this insight to be better prepared when a go-around occurs and take better decisions on how to manage the traffic. Indeed, this kind of analyses are regularly carried out before and after an operation shift, as part of the continuous training the ATCOs go through to maintain their high standard of performance. The information generated by the risk models could therefore be used to enhance such analytical exercises, increase the awareness about threats and mitigation measures during go-around operations, and foster best practises.

To adequately measure the impact of the go-around predictions it would be necessary to design a simulation in which multiple controllers manage traffic with and without the SafeOPS tool. While this is beyond the scope of the project, as the tool has a relatively low maturity, the interviews with the ATCOs and the questionnaires they filled indicate that minor to moderate benefits can be expected in terms of safety in all functions the ATCOs fulfil. In addition, the ANSP's Safety Management Team at an airport can use expert judgement to quantify the base events and contributing factors in the newly-developed risk framework. To do so, the following procedure based on the HEART methodology was proposed by Eurocontrol in the context of the SAFEMODE project [5]. The first step consists in

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identifying the generic type of tasks the ATCOs perform according to a revised version of the HEART taxonomy specifically tailored for aviation. Generic task types span from *"Totally unfamiliar task, performed at speed with no real idea of likely consequences"* to *"Completely familiar, well-designed, highly-practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated, highly trained and experienced persons, totally aware of the implications of failure"*. A nominal human error probability is associated to each of these generic task types. The next step consists in quantifying the impact of circumstantial factors, such as unfamiliarity with the situation, time pressure, workload, fatigue, weather, organisational aspects, etc. These circumstantial factors will increase the probability of human errors. Once the failure probabilities of the different events are assigned, the success probabilities of the barriers impacted by the SafeOPS tool can be calculated and compared to current operations to evaluate the overall increase or decrease in safety. In general, the SafeOPS tool does not modify the actual base events (with few exceptions, e.g. the runway excursion case) but plays a beneficial role in reducing the impact of the circumstantial factors. The expert judgement of the Safety Management Team could then be exploited to appropriately quantify the role of these circumstantial factors, which might significantly vary according to the characteristics of the airport (typical traffic conditions, weather, safety culture in the organisation and so on). From this assessment, it would be finally possible to the measure the mitigating effect of the SafeOPS predictions.

4.2 Considerations over the SafeOPS tool

The results of Section 3 show that the impact of the SafeOPS tool on the operations is mostly positive. The main benefits it brings are that it increases the situational awareness of the ATCOs and it gives them more time to get an accurate and complete picture of the traffic and to perform their tasks. This makes human errors less likely, increases the chances that potential conflicts are identified and that effective plans are made to anticipate or resolve potentially hazardous situations. From this point of view, the deployment of the SafeOPS tool for decision support will contribute to increase the overall safety of the system.

Section 3 also identifies some potential drawbacks of the SafeOPS predictive tool, as follows:

- To induce unsafe behaviours, such as issuing clearances based on an inflated confidence that an inbound aircraft will definitely go-around or land, depending on the forecasts (with possible consequences on the decisions for runway, separation and wake management), and
- The instigation of a runway excursion in an attempt to cancel a take-off clearance.

These negative effects of the SafeOPS tool are considered highly unlikely to happen. An unsafe behaviour resulting from the situation described in the first item would be a proactive misuse of the tool. To make it happen, a controller should make two fundamental operational errors. First, the probabilistic predictions would have to be used as if they were deterministic detections of what the aircraft will do. In addition, the information would have to be used to issue clearances when more precautionary options are available. As ATCOs are always prioritising safety, the overall possibility of this to happen is almost non-existent. In a similar way, also the instigation of a runway excursion is hardly possible as the ATCOs would only resort to it in a very peculiar combination of emergency circumstances (cf. Sect. 3.5). However, mitigation measures can be put in place to further reduce the (already low) likelihood of this unwanted use of the go-around predictions. Clear guidelines will be produced which unequivocally state that the SafeOPS tool (or future developments of the SafeOPS concept) shall not be used as landing predictor and the appearance of a go-around flag on the radar screen does not necessarily imply that a go-around will actually start. Similarly, the detailed circumstances in which a rejected take-off is not advisable will be specified. A basic draft of the Concept of Operations envisioned for the tool will be anticipated in deliverable “D2.2: Impact evaluation of the developed decision support tools for ATM”. Should the SafeOPS tool reach the level of maturity necessary to be used in real operations, specific training sessions on its use are foreseen to be necessary for all air-traffic controllers.

A relevant aspect analysed in the SafeOPS project is the way ATCOs consider probabilistic information. Several controllers expressed concern about how to effectively use the tool’s predictions. Because they acknowledged that a 100%-accurate forecast would be impossible, the ATCOs expressed the preference to set a relatively high threshold to signal a go-around, so that they could consider a missed approach “almost certain” [3]. Alternatively, they required clear guidelines on how to react to go-around predictions with low or intermediate probability (e.g. less than 50% or between 50% and 80%). Therefore, one conclusion of this WP3 is that, at least in the specific case of go-arounds, ATCOs would rather have a piece of information that comes in but is (almost) certain than a probability that they would find hard to interpret in the limited time they have available to elaborate their plan of actions. A significant aspect is also the tool reliability. Obviously, the impact of the go-around predictions on safety depends on how often they turn out to be correct. With the current performance [8], the ATCOs overall identified minor to moderate benefits to their tasks and a consequent enhancement in safety can be expected. Should the performance of the tool improve, especially in predicting a higher proportion of go-arounds, the benefits for safety will also increase. However, in this case there would also be the risk of misuse of the information, namely that the absence of go-around sign is misinterpreted as a landing confirmation.

The main lessons learnt in the risk assessment of the SafeOPS tool throughout WP3 are the following:

- A tool based on algorithm of artificial intelligence that predicts go-arounds could be in general well received by the ATCOs, as they see a benefit in gaining additional information ahead of time about how the traffic situation is going to evolve.

- The explainability of the predictions is important especially at an initial stage to build trust in the tool. However, because go-around typically happen in conditions of time shortage, the ATCOs do not necessarily need to access the explanations in real time. If after using the tool they find that it is mostly accurate, they are more likely to accept the predictions without questioning it, and possibly check the factors that lead to those predictions *after* the traffic situation has been resolved, instead of review them *before*, to decide on an action plan. Indeed, the factors that lead the tool to forecast a go-around are considered important to gain insight into the way the tool works and the extent to which they can rely on its forecasts. The ATCOs’ trust in the tool builds therefore primarily on their direct experience of its accuracy during operations but also on their understanding of the drivers of the prediction. Pragmatically, air traffic controllers prefer to know (from direct experience but also from explicit guidelines and training provided to them) that under certain conditions the go-around prediction is almost certainly true. In all other cases they will just behave as they presently do, that is, thinking that a missed approach can always happen and hence being ready to react. In this framework, the causes of the predictions are a means to reinforce their confidence that the forecasted go-around will actually happen. For example, if on one day many flights communicated the presence of strong winds on final approach, and one aircraft is predicted to go around with the main reason being “wind”, they will tend to trust the tool more.

- Delivering risk information to the ATCOs in real time is not feasible, as they want to be focused on the evolution of the traffic and perceive any information that is not strictly necessary as a distraction. The feedback would be different in a situation of immediate emergency, about which the ATCOs would want to be informed. This is not the case for go-around operations.

- The risk information are considered useful in preparation for operations, especially in days when the traffic and weather conditions are expected to make go-around relatively more likely. Also, they can be used in post-operation analyses, to discuss why certain decisions were taken, what other options could have been, and to evaluate the consequences of different choices. However, it should also be noted that the AIM format is quite complex to read and not all ATCOs are familiar with the fault-tree logic. Therefore, the risk framework is well suited for analysing go-around operations within a Safety Management Team but it might need to be simplified for a more general use.

- The risk framework developed within the WP3 of SafeOPS can effectively describe the impact of the SafeOPS tool. In this project, the impact was evaluated semi-quantitatively. To get more precise quantitative estimates of the tool's impact in different operations, the input of the experts of an ANSP Safety Management Team is essential. They have the necessary knowledge to correctly assign the probability of different circumstantial factors that vary depending on the location. An additional step in this direction is to set up a simulation environment in which air traffic controllers can test a more mature version of the tool capable of analysing the real time data as available in real operations. Measuring for example the variations in the frequency of the successes or failures of specific barriers in the risk models will make it possible to quantify the benefits brought to safety by the go-around predictions.

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5 Conclusion and Outlook

SafeOPS Work Package 3 developed a risk framework to assess the benefits, disadvantages and hazards, which result from the introduction of predictive analytics in ATM, and applied it to the specific case of go-around operations. The conclusions that can be drawn from this analysis are summarised as follows. First, with the new risk framework based on Eurocontrol's Accident-Incident Models it is possible to effectively identify the base events that are impacted by the introduction of the SafeOPS predictive tool. While the risk framework was developed to study the consequences of probabilistic predictions about future go-arounds delivered to air traffic controllers, the same methodology in the future can be also applied to other applications or tools powered by artificial intelligence.

The go-around predictions are in general beneficial to the air traffic controllers, as their situational awareness is consequently heightened. Also, they have a minor or moderate increase in the available time to monitor the airborne and ground traffic situation, make a mental map of the flights or vehicles which might be affected by an eventual missed-approach procedure, decide how to resolve the situation, and maintain a set of alternative plans to react to every foreseeable development of the events. There are also some possible unwanted effects of the go-around predictions, although these are all considered highly unlikely. The main one is that the predictions are mistakenly interpreted not as probabilistic forecasts but as deterministic descriptions of what is going to happen. This might potentially induce excessive confidence or conflicting clearances. However, the air traffic controllers consider the support provided by the SafeOPS tool and the consequent safety benefits to be larger than the potential disadvantages. A more detailed measure of the quantitative impact of the SafeOPS tool on operation safety will require to perform real-time simulations of air traffic management with and without the tool, to evaluate if and how the air traffic controllers modify their actions in response to a go-around prediction (or absence of it).

The two aspects that make the data of artificial-intelligence algorithms challenging to convey are the statistical nature of the information and the opacity of the processes that generated such data. Because missed approaches often occur in circumstances of high workload and time shortage, knowing why the tool predicted a go around is not considered a priority. Indeed, during operations the air traffic controllers want to focus as much as possible on the traffic evolution and the actions they have to take, minimising possible sources of distraction. However, the controllers do want to know the causes of the predictions to gain insight into the way the tool works and the extent to which they can rely on its forecasts. Hence, these have to be accessible if time allows. Their trust in the tool builds therefore primarily on their direct experience of its accuracy during operations but also on their understanding of the factors that lead to the prediction. The statistical nature of the tool's forecasts is a challenge for the air traffic controllers because, especially during high-intensity operations, they have little time to ponder whether the next flight will actually go around given the probability shown by the SafeOPS tool. The solution chosen in the SafeOPS project was to build an algorithm that does not predict all go-arounds (recall is around 20%) but it is very precise (precision is 90%). In this way, the air traffic controllers can confidently interpret a go-around prediction as almost certain. A possible future development of the SafeOPS tool is to deliver regular updates on the go-around probability for each flight as it approaches. This feature has not been analysed in the context of the risk assessment although it has already been tested with a version of the tool predicting the go-around probability at 8, 6, 4 and 2 NM from the threshold. The precondition to make this solution acceptable by the air traffic controllers would be to provide specific training on how to handle this information, with clear guidelines of what are the appropriate measures to take depending on the displayed probability.

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References

[1] Eurocontrol, "Accident Incident Models Release 2020 - April 2020," *STELLAR*, 2020. https://stellar.sesarju.eu/ (accessed Jun. 17, 2022).

[2] SafeOPS Consortium, "D2.1 - Development of Use Cases , User Stories and Requirements," 2021. [Online]. Available: https://innaxis-comm.s3.eu-central-1.amazonaws.com/SafeOPS/SafeOPS_D2.1_v00.02.00.pdf.

[3] SafeOPS Consortium, "D3.3 Human Factors Analysis of the Impact of Providing Probabilistic Risk Information in Real Time," 2022.

[4] SAFEMODE Collaboration, "D4.2 Risk models of major accident types in both domains Document Details," 2022.

[5] SAFEMODE Collaboration, "D4.1 Risk framework (methodology) for the development of different safety models incorporating Human Factors in both transport modes," 2020.

[6] B. Kirwan, "The validation of three human reliability quantification techniques — THERP, HEART and JHEDI: Part 1 — technique descriptions and validation issues," *Appl. Ergon.*, vol. 27, no. 6, pp. 359–373, Dec. 1996, doi: 10.1016/S0003-6870(96)00044-0.

[7] B. Kirwan, R. Kennedy, S. Taylor-Adams, and B. Lambert, "The validation of three Human Reliability Quantification techniques — THERP, HEART and JHEDI: Part II — Results of validation exercise," *Appl. Ergon.*, vol. 28, no. 1, pp. 17–25, Feb. 1997, doi: 10.1016/S0003-6870(96)00045-2.

[8] SafeOPS Consortium, "D4.1 - Complete data pipeline description and ML solution," 2022.

[9] SafeOPS Consortium, "D4.2 Human interpretability framework for the selected user stories," 2022.

Appendix A Summary of the Workshop Q&A with ATCOs

The following table summarises the feedback received by five ATCOs during two workshops organised at Airport 1 (on 10/05/2022) and Airport 2 (on 06/04/2022).

Table 1. Summary of the ATCOs' feedback about the SafeOPS risk models.

Question	ATCOs' feedback
Functions performed by the ATCOs	
Do you think that our description of the ATCO's functions (cf. Sect.2.2) captures all relevant aspects of your working routine that could be impacted on, by the presence of the SafeOPS tool predicting GAs? Are there other tasks/aspects that are missing?	All ATCOs confirmed that the described functions are all relevant when managing landings and missed-approach procedures. Airport 2 ATCOs pointed out that the CFIT risk is a rather abstract possibility at their location, although they recognise that there might be other airports where this is a concrete eventuality.
Runway Management and prevention of Runway Incursions	
Do you think the modified "Runway Management" barrier in the "Runway Collision" (cf. Figure 8) risk model adequately represents the impact of the SafeOPS GA predictions?	All ATCOs agreed that the elements represented in purple in the "Runway Management" barrier are relevant to capture the impact of the GA predictions to their routine.
Is it exhaustive of all possibilities? Can you think about other ways in which the GA predictions can create potentially hazardous situations?	The ATCOs think the model covers all possibilities of errors or misunderstanding of the tool predictions. One ATCO pointed out that the potential hazards discussed in the context of runway management and issued clearances are rather theoretical and unlikely to happen in practice.
Do you think the SafeOPS GA predictions are overall beneficial or detrimental to your tasks of Runway Management?	All ATCOs see a benefit in terms of general situational awareness. Two ATCOs said that they would have more time to think whether to give a clearance. Other ATCOs said that in practice the function of runway monitoring would remain unchanged.
Separation Management and prevention of separation problems	
Do you think the modified "GA and MAP Conflict Management" barrier in the "Mid-Air Collision during Final Approach" (cf. Figure 9) risk model adequately represents the impact of the SafeOPS GA predictions?	All ATCOs agreed that the risk model covers all relevant aspects that play a role in this function and the elements highlighted in purple capture the impact of the GA predictions to their routine.

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Question	ATCOs' feedback
Is it exhaustive of all possibilities? Can you think about other ways in which the GA predictions can create potentially hazardous situations?	The ATCOs think the model covers all possibilities. In this case, the ATCOs think that a false positive or false negative would not cause separation problems.
Do you think the SafeOPS GA predictions are overall beneficial or detrimental to your tasks of Separation Management?	All ATCOs agree that the GA predictions would attract the attention of the inbound flight, thus increasing the situational awareness and the amount of time available to elaborate a plan in case of GA.
Prevention of Wake Vortex encounters	
*Do you think the modified "Separation management of spacing conflicts on final approach" barrier in the "*Wake Vortex on Final Approach*" risk model (cf. Figure 10) adequately represents the impact of the SafeOPS GA predictions?*	The ATCOs think the risk model covers all relevant aspects of this function and the elements highlighted in purple capture the impact of the GA predictions to their routine.
Is it exhaustive of all possibilities? Can you think about other ways in which the GA predictions can create potentially hazardous situations?	The ATCOs think the model covers all possibilities. Because the main effect of the GA predictions is to raise the situational awareness, no potentially hazardous consequence is expected.
Do you think the SafeOPS GA predictions are overall beneficial or detrimental to your tasks of Wake encounter Management?	All ATCOs agree that the GA predictions would attract the attention of the inbound flight, thus triggering the attention on the (possible) difference in wake category between the approaching and departing flights. This is beneficial as it gives more time to evaluate the situation and elaborate resolution plans.
Prevention of Controlled Flight Into Terrain	
*Do you think the modified "ATC Flight Trajectory Management" barrier in the "*Controlled Flight Into Terrain*" risk model (cf. Figure 11) adequately represents the impact of the SafeOPS GA predictions?*	The ATCOs think the risk model covers all relevant aspects of this function and the elements highlighted in purple (and levels below) capture the impact of the GA predictions to their routine.
Is it exhaustive of all possibilities? Can you think about other ways in which the GA predictions can create potentially hazardous situations?	The ATCOs think the model covers all possibilities and hazards connected to this function. However, the ATCOs considered this situation as abstract because there are no obstacles in the vicinity of the two airports. One ATCO of Airport 1 acknowledges that the Taunus area is in the direction of a missed approach on an early right turn so the aircraft climb performance should be considered.
Do you think the SafeOPS GA predictions are overall beneficial or detrimental to your tasks of CFIT Management?	The ATCOs think that the GA predictions do not have particular effects on these tasks at Airports 1 and 2 but acknowledge that the tool could be beneficial at other locations.

Question	ATCOs' feedback
Prevention of Runway Excursion problems	
Do you think the modified "ATC Take-Off Management" barrier in the proposed "Runway Excursion" risk model (cf. Figure 12) adequately represents the impact of the SafeOPS GA predictions?	The ATCO think the proposed barriers is exhaustive of all possibilities and represent the potential situation that might happen in this situation, which is however considered highly unlikely.
Is it exhaustive of all possibilities? Can you think about other ways in which the GA predictions can create potentially hazardous situations?	
Do you think the SafeOPS GA predictions are overall beneficial or detrimental to your tasks of Take-off Management?	2 ATCOs acknowledge that the represented evolution of the events is theoretically possible. However, all ATCOs said that cancelling a take-off clearance when an aircraft is already rolling is something they would very rarely do in general, and only in a situation of emergency, because of the potential problems it creates to safety and capacity. In the context of a predicted GA they would most likely let the departure continue the take off and, in case of a GA, have a plan ready to guarantee the separation between aircraft.
General feedback on the risk models	
Do you think the way the risk models convey the information about risk and how initiating events might escalate is clear?	3/5 ATCOs found that the risk models are overly complicated. When guided through the events, they had no difficulty in understanding the logic of the models, the way to read them and the connections between different barriers and events. However they think they are impractical to use. 2/5 ATCOs (with prior expertise in safety and risk assessment) found the models clear and think they can be used to analyse the events after the operations.
Would you find useful to receive information about risk and potential consequences of different decisions in real time during the operations?	All ATCOs agreed that during operations there is not enough time to receive risk information, especially in handling a possible missed approach, which is not a safety critical situation. 3 ATCOs suggested that this information could be delivered during ad-hoc training, in post-operations debriefings, or in preparatory meetings before operations.

Appendix B Validation questionnaire

After reviewing the inputs on the risk models received by the air traffic controllers during the dedicated workshops, a report was prepared and presented to two additional ATCOs that were not involved in the discussion. This section presents their answers.

Respondent #1

- **Do you think that in our description of the ATCO tasks (Sect. 2.2) we captured all the aspects of your working routine that could be impacted on, by the presence of the SafeOPS tool predicting GAs?**

  X Yes ☐No

- **If you replied "no" to the previous question, which aspects are missing?**

Let us now focus on the actions you perform in *Runway Management And Prevention Of Runway Incursions* and all relevant aspects that play a role in these tasks.

- **Do you think the description we made of the possible impact of the SafeOPS tool is,**
  - **Clear?** **X Yes** **□No**
  - **Exhaustive of all possibilities?** **□Yes** **X No**

- **If you replied "no" to the previous question, which aspects are not clear or missing?**

In aviation it is never possible to consider all possibilities – you always find a special case where the situation is different to all former experiences. **A GA prediction might also cause some delay, e.g. if I hold back a departure clearance to avoid separation problems, when, without the prediction tool, I would have let the departure go in front of the APP**

- **Can you think about *other* ways in which the GA predictions can create potentially hazardous situations?**

Every non-standard situation might evolve to a potentially hazardous situation. If I start to turn DEP from their SID or stop them in climb or if I give any instructions to VFR (especially to the non-commercial ones, who often are unsure of what to do or are unable to grasp the situation) it might come to misunderstandings or human errors. Without the prediction tool I

only use these instructions if really necessary, with the tool, I might use them a little more often

- **Can you think about *other* ways in which the GA predictions can be beneficial for the ATCOs in their function?**

I think you already mentioned them

Please rate the following on a scale of 1-7

7.	How much does the presence of the GA prediction indictor **distract you from higher priority tasks**?					
1 **Not at all**	**2**	**<u>3</u>**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						
the active preplanning costs me more capacity than just draw a loose plan B						

8.	How much does the GA prediction indictor **mislead you?**					
1 **Not at all**	**<u>2</u>**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

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9.	How much does the presence of the GA prediction indictor **impacts on your situational awareness?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

10.	How much does the presence of the GA prediction indictor **affects the amount of time you have to perform your task(s)?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

11.	How does the presence of the GA prediction indictor **support you in your task(s)**?					
1 Significant Hindrance	**2** Moderate Hindrance	**3** Minor Hindrance	**4** No Change	**5** Minor Support	**6** Moderate Support	**7** Significant Support
Additional Comments:						

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Let us now focus on the actions you perform in *Separation management and prevention of separation problems* and all relevant aspects that play a role in these tasks.

- Do you think the description we made of the possible impact of the SafeOPS tool is,
  - Clear? X Yes ☐No
  - Exhaustive of all possibilities? ☐Yes X No

- If you replied "no" to the previous question, which aspects are not clear or missing?

See answer of question 4 E.g. did you think about the consequences of early "in case of" instructions to the FC? Maybe my preplanning influences the pilots decision, whether to perform a GA or not

- Can you think about *other* ways in which the GA predictions can create potentially hazardous situations?

- Can you think about *other* ways in which the GA predictions can be beneficial for the ATCOs in their function?

Please rate the following on a scale of 1-7

16.	How much does the presence of the GA prediction indictor **distract you from higher priority tasks**?					
1 Not at all	<u>2</u>	3	4	5	6	7 A significant amount
Additional Comments:						

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17.	How much does the GA prediction indictor **mislead you?**					
1 **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

18.	How much does the presence of the GA prediction indictor **impacts on your situational awareness?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

19.	How much does the presence of the GA prediction indictor **affects the amount of time you have to perform your task(s)?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

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20.	How does the presence of the GA prediction indictor **support you in your task(s)**?					
1 Significant Hindrance	2 Moderate Hindrance	3 Minor Hindrance	4 No Change	5 Minor Support	6 Moderate Support	7 Significant Support
Additional Comments:						
If the prediction is correct, it supports me in my tasks and time management, if it is a false positive, it costs me time and capacity without any need						

Let us now focus on the actions you perform in *Prevention of Runway excursion problems* and all relevant aspects that play a role in these tasks.

- **Do you think the description we made of the possible impact of the SafeOPS tool is,**
  - **Clear?** X Yes □No
  - **Exhaustive of all possibilities?** □Yes X No

- **If you replied "no" to the previous question, which aspects are not clear or missing?**

Aborted T/Os and runway excursions are very complex situations for both, ATCO and Crew – you do not want to cause such situations any more often than absolutely necessary

- **Can you think about *other* ways in which the GA predictions can create potentially hazardous situations?**

More often than an excursion, the DEP which aborted T/O has problems with hot brakes, even at low speeds. This might cause a fire or (more likely) a huge delay, because the crew has to wait for the brakes to cool down again. A few weeks ago, I had an aborted T/O at about 90kts (outside temperature around 18 degrees) - they had to wait about 30 Minutes until they were able to depart again. I think the airline would not be pleased if I instruct an abortion just precautionary because there might be a possible conflict later on

- **Can you think about *other* ways in which the GA predictions can be beneficial for the ATCOs in their function?**

I might stop the DEP before reaching a speed of high risks

Please rate the following on a scale of 1-7

24.	How much does the presence of the GA prediction indictor **distract you from higher priority tasks**?					
1 Not at all	**2**	**3**	**4**	**5**	**6**	**7** A significant amount
Additional Comments:						

25.	How much does the GA prediction indictor **mislead you?**					
1 Not at all	**2**	**3**	**4**	**5**	**6**	**7** A significant amount
Additional Comments:						

26.	How much does the presence of the GA prediction indictor **impacts on your situational awareness?**

1 Significant reduction	2 Moderate reduction	3 Minor reduction	4 No Change	5 Minor increase	6 Moderate increase	7 Significant increase
Additional Comments:						

27.	How much does the presence of the GA prediction indictor **affects the amount of time you have to perform your task(s)?**

1 Significant reduction	2 Moderate reduction	3 Minor reduction	4 No Change	5 Minor increase	6 Moderate increase	7 Significant increase
Additional Comments:						

28.	How does the presence of the GA prediction indictor **support you in your task(s)**?

1 Significant Hindrance	2 Moderate Hindrance	3 Minor Hindrance	4 No Change	5 Minor Support	6 Moderate Support	7 Significant Support
Additional Comments:						

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Let us now focus on the actions you perform in *Prevention of Controlled flight into the terrain* and all relevant aspects that play a role in these tasks.

- **Do you think the description we made of the possible impact of the SafeOPS tool is,**
  - **Clear?** **X Yes** **□No**
  - **Exhaustive of all possibilities?** **X Yes** **□No**

- **If you replied "no" to the previous question, which aspects are not clear or missing?**

- **Can you think about *other* ways in which the GA predictions can create potentially hazardous situations?**

I do not consider a CFIT as direct or immediate problem caused or prevented by the prediction and my following actions (in Airport 2)

- **Can you think about *other* ways in which the GA predictions can be beneficial for the ATCOs in their function?**

Please rate the following on a scale of 1-7

32.	How much does the presence of the GA prediction indictor **distract you from higher priority tasks**?					
1 **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

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33.	How much does the GA prediction indictor **mislead you?**					
1 **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

34.	How much does the presence of the GA prediction indictor **impacts on your situational awareness?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

35.	How much does the presence of the GA prediction indictor **affects the amount of time you have to perform your task(s)?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

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36.	How does the presence of the GA prediction indictor **support you in your task(s)**?					
1 Significant Hindrance	**2** Moderate Hindrance	**3** Minor Hindrance	**4** No Change	**5** Minor Support	**6** Moderate Support	**7** Significant Support
Additional Comments:						

Let us now focus on the actions you perform in *Prevention of Wake Vortex encounters* and all relevant aspects that play a role in these tasks.

- **Do you think the description we made of the possible impact of the SafeOPS tool is,**
  - **Clear?** **X Yes** **□No**
  - **Exhaustive of all possibilities?** X **Yes** **□No**

- **If you replied "no" to the previous question, which aspects are not clear or missing?**

- **Can you think about *other* ways in which the GA predictions can create potentially hazardous situations?**

- **Can you think about *other* ways in which the GA predictions can be beneficial for the ATCOs in their function?**

I am able to hold my departure if a MAP is almost sure. If I worked like every APP is a potential MAP, I would need a huge spacing to let a Heavy depart in front of a medium or even a light type. That would cause delay. That's why we do not consider the MAP but plan to give instructions for immediate turns in case of MAP. If the MAP takes within the last 2NM of the

APP, this often means steep turns or high climb rates for the acft because there is not much flying time anymore until it reaches the area of wakes of the preceding.

Please rate the following on a scale of 1-7

41.	How much does the presence of the GA prediction indictor **distract you from higher priority tasks**?					
1 **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

42.	How much does the GA prediction indictor **mislead you?**					
1 **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

43.	How much does the presence of the GA prediction indictor **impacts on your situational awareness?**

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1 Significant reduction	2 Moderate reduction	3 Minor reduction	4 No Change	5 Minor increase	<u>6</u> Moderate increase	7 Significant increase
Additional Comments:						

44.	How much does the presence of the GA prediction indictor **affects the amount of time you have to perform your task(s)?**

1 Significant reduction	2 Moderate reduction	3 Minor reduction	4 No Change	5 Minor increase	6 Moderate increase	<u>7</u> Significant increase
Additional Comments:						

45.	How does the presence of the GA prediction indictor **support you in your task(s)**?

1 Significant Hindrance	2 Moderate Hindrance	3 Minor Hindrance	4 No Change	5 Minor Support	<u>6</u> Moderate Support	7 Significant Support
Additional Comments:						

Respondent #2

- **Do you think that in our description of the ATCO tasks (Sect. 2.2) we captured all the aspects of your working routine that could be impacted on, by the presence of the SafeOPS tool predicting GAs?**

XYes ☐No

- **If you replied "no" to the previous question, which aspects are missing?**

Let us now focus on the actions you perform in *Runway Management And Prevention Of Runway Incursions* and all relevant aspects that play a role in these tasks.

- **Do you think the description we made of the possible impact of the SafeOPS tool is,**
  - **Clear?** **xYes □No**
  - **Exhaustive of all possibilities?** **xYes □No**

- **If you replied "no" to the previous question, which aspects are not clear or missing?**

But point 1 won't take place. 2 principles of ATC stand in the way of this, "never base control on assumption" and "never clear a conflict".

- **Can you think about *other* ways in which the GA predictions can create potentially hazardous situations?**

- **Can you think about *other* ways in which the GA predictions can be beneficial for the ATCOs in their function?**

Please rate the following on a scale of 1-7

7.	How much does the presence of the GA prediction indictor **distract you from higher priority tasks**?					
1 **Not at all**	**2 X**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

8.	How much does the GA prediction indictor **mislead you?**					
1 X **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

9.	How much does the presence of the GA prediction indictor **impacts on your situational awareness?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5 X** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

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10.	How much does the presence of the GA prediction indictor **affects the amount of time you have to perform your task(s)?**					
1 Significant reduction	**2** Moderate reduction	**3 X** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

11.	How does the presence of the GA prediction indictor **support you in your task(s)**?					
1 Significant Hindrance	**2** Moderate Hindrance	**3** Minor Hindrance	**4** No Change	**5 X** Minor Support	**6** Moderate Support	**7** Significant Support
Additional Comments:						

Let us now focus on the actions you perform in *Separation management and prevention of separation problems* and all relevant aspects that play a role in these tasks.

- **Do you think the description we made of the possible impact of the SafeOPS tool is,**
  - **Clear?** **xYes** **□No**
  - **Exhaustive of all possibilities?** **xYes** **□No**
- **If you replied "no" to the previous question, which aspects are not clear or missing?**

- **Can you think about *other* ways in which the GA predictions can create potentially hazardous situations?**

- **Can you think about *other* ways in which the GA predictions can be beneficial for the ATCOs in their function?**

Please rate the following on a scale of 1-7

16.	How much does the presence of the GA prediction indictor **distract you from higher priority tasks**?					
1 **Not at all**	**2 X**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

17.	How much does the GA prediction indictor **mislead you?**					
1 X **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

18.	How much does the presence of the GA prediction indictor **impacts on your situational awareness?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5 X** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

19.	How much does the presence of the GA prediction indictor **affects the amount of time you have to perform your task(s)?**					
1 Significant reduction	**2** Moderate reduction	**3 X** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

20.	How does the presence of the GA prediction indictor **support you in your task(s)**?					
1 Significant Hindrance	**2** Moderate Hindrance	**3** Minor Hindrance	**4** No Change	**5 X** Minor Support	**6** Moderate Support	**7** Significant Support
Additional Comments:						

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Let us now focus on the actions you perform in *Prevention of Runway excursion problems* and all relevant aspects that play a role in these tasks.

- **Do you think the description we made of the possible impact of the SafeOPS tool is,**
  - **Clear?** **xYes** **□No**
  - **Exhaustive of all possibilities?** **xYes** **□No**

- **If you replied "no" to the previous question, which aspects are not clear or missing?**

- **Can you think about *other* ways in which the GA predictions can create potentially hazardous situations?**

- **Can you think about *other* ways in which the GA predictions can be beneficial for the ATCOs in their function?**

Please rate the following on a scale of 1-7

24.	How much does the presence of the GA prediction indictor **distract you from higher priority tasks**?					
1 **Not at all**	**2 X**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

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25.	How much does the GA prediction indictor **mislead you?**					
1 X **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

26.	How much does the presence of the GA prediction indictor **impacts on your situational awareness?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5 X** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

27.	How much does the presence of the GA prediction indictor **affects the amount of time you have to perform your task(s)?**					
1 Significant reduction	**2** Moderate reduction	**3 X** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

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28.	How does the presence of the GA prediction indictor **support you in your task(s)**?					
1 Significant Hindrance	2 Moderate Hindrance	3 Minor Hindrance	4 No Change	5 X Minor Support	6 Moderate Support	7 Significant Support
Additional Comments:						

Let us now focus on the actions you perform in *Prevention of Controlled flight into the terrain* and all relevant aspects that play a role in these tasks.

- **Do you think the description we made of the possible impact of the SafeOPS tool is,**
  - **Clear?** **xYes □No**
  - **Exhaustive of all possibilities?** **xYes □No**

- **If you replied "no" to the previous question, which aspects are not clear or missing?**

- **Can you think about *other* ways in which the GA predictions can create potentially hazardous situations?**

- **Can you think about *other* ways in which the GA predictions can be beneficial for the ATCOs in their function?**

Please rate the following on a scale of 1-7

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32.	How much does the presence of the GA prediction indictor **distract you from higher priority tasks**?					
1 **Not at all**	**2 X**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

33.	How much does the GA prediction indictor **mislead you?**					
1 X **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

34.	How much does the presence of the GA prediction indictor **impacts on your situational awareness?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5 X** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

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35.	How much does the presence of the GA prediction indictor **affects the amount of time you have to perform your task(s)?**					
1 Significant reduction	**2** Moderate reduction	**3 X** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

36.	How does the presence of the GA prediction indictor **support you in your task(s)**?					
1 Significant Hindrance	**2** Moderate Hindrance	**3** Minor Hindrance	**4** No Change	**5 X** Minor Support	**6** Moderate Support	**7** Significant Support
Additional Comments:						

Let us now focus on the actions you perform in *Prevention of Wake Vortex encounters* and all relevant aspects that play a role in these tasks.

- **Do you think the description we made of the possible impact of the SafeOPS tool is,**
  - **Clear?** **xYes** **□No**
  - **Exhaustive of all possibilities?** **xYes** **□No**

- **If you replied "no" to the previous question, which aspects are not clear or missing?**

- **Can you think about *other* ways in which the GA predictions can create potentially hazardous situations?**

- **Can you think about *other* ways in which the GA predictions can be beneficial for the ATCOs in their function?**

Please rate the following on a scale of 1-7

41.	How much does the presence of the GA prediction indictor **distract you from higher priority tasks**?					
1 X **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

42.	How much does the GA prediction indictor **mislead you?**					
1 X **Not at all**	**2**	**3**	**4**	**5**	**6**	**7** **A significant amount**
Additional Comments:						

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43.	How much does the presence of the GA prediction indictor **impacts on your situational awareness?**					
1 Significant reduction	**2** Moderate reduction	**3** Minor reduction	**4** No Change	**5 X** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

44.	How much does the presence of the GA prediction indictor **affects the amount of time you have to perform your task(s)?**					
1 Significant reduction	**2** Moderate reduction	**3 X** Minor reduction	**4** No Change	**5** Minor increase	**6** Moderate increase	**7** Significant increase
Additional Comments:						

45.	How does the presence of the GA prediction indictor **support you in your task(s)**?					
1 Significant Hindrance	**2** Moderate Hindrance	**3** Minor Hindrance	**4** No Change	**5 X** Minor Support	**6** Moderate Support	**7** Significant Support
Additional Comments:						

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