NM Top 5 Safety Priorities
Safety Functions Map Analysis
of European A and B severity safety incidents
2022 data sample

1. DOCUMENT OVERVIEW AND CONCLUSIONS

The main purpose of this report is to document the process and the results of the Safety Functions Maps analysis of European A and B severity incidents, which was performed in 2023 within the context of Network Manager Safety Prioritisation Process. The analysis is based on 2022 incident data sample built by the occurrence data provided by European ANSPs.

This analysis also provides information regarding barrier resilience. In this SAFMAP analysis the resilience is addressed by identifying the barrier that stopped an incident from propagating further on the accident trajectory. This is particularly relevant to barriers presented at the top of the SAFMAP model because if an incident is prevented by one of these top barriers it would, most probably, be with severity A or B. Therefore, the information in the sample is very representative of the top barrier resilience performance. Additionally, information is presented on how barriers failed to stop an event propagating further and causing a more severe safety effect. This is particularly relevant to the barriers presented at the bottom levels of the model.

The document structure is as follows:

- Section 2 describes the analysed incident sample.
- Section 3 outlines the used analytical process.
- Section 4 provides a summary of the SAFMAP analysis of the incidents involving en-route separation minima infringement.
- Section 5 provides a summary of the SAFMAP analysis of the TMA/CTR incidents involving separation minima infringement.
- Section 6 provides a summary of the SAFMAP analysis of the runway incursion incidents.

Based on the conclusions of the incident data analysis, the following topics are selected as safety priorities:

- **"Controller Blind Spot".**
- "**Restricted airspace infringement".**
- **"Controlled airspace infringement".**
- **"Controller detection of potential runway conflict".**
- **"Flight without transponder or with dysfunctional one".**

It is to be noted that, comparing to 2022 safety priorities, there is one new priority ("Restricted airspace infringement") and one of the 2022 priorities was transferred to the list of issues to be monitored ("ACAS RA not followed"). The reason for proposing "Restricted airspace infringement" as a safety priority is provided later in this report. "ACAS RA not followed" is suggested not to be retained as a safety priority because there are no incidents associated with it in the 2022 sample. However, considering the criticality of the scenario involving "ACAS RA not followed" and the fact that, generally, the occurrences involving ACAS are not systematically assessed if RAs were flown correctly, it is suggested to retain "ACAS RA not followed" in the list of issues to be monitored.

Additionally, based on the conclusions of the incident data analysis, it is selected to monitor the risk associated with:

- **"ACAS RA not followed".**
- **"Altitude deviation".**
- **"On-the-job-training".**
- "**High controller workload**".
- **"Synchronisation of successive arriving to land and of arriving to land and departing aircraft".**
- **"VFR/IFR incidents in TMA/CTR airspace".**
- **"Non-commercial flights in TMA/CTR airspace".**
- **"Inadequate ATC teamwork".**
- **"Pilot/driver induced incorrect entry onto the runway protected area".**
- **"Incorrect presence of non-commercial flight aircraft on the runway protected area".**
- **"Incorrect presence of vehicles on the runway protected area".**
- **"Incorrect presence on the runway protected area that could have been prevented by stop bars".**

2. INCIDENT SAMPLE

2.1. Geographical representativeness of the sample

The SAFMAP review sample is judged to be representative for the purpose of identifying Top 5 priorities for the Network Manager based on its geographical representativeness. The SAFMAP review of incidents involved **25 Air Navigation Service Providers** (see Figure 2-1).

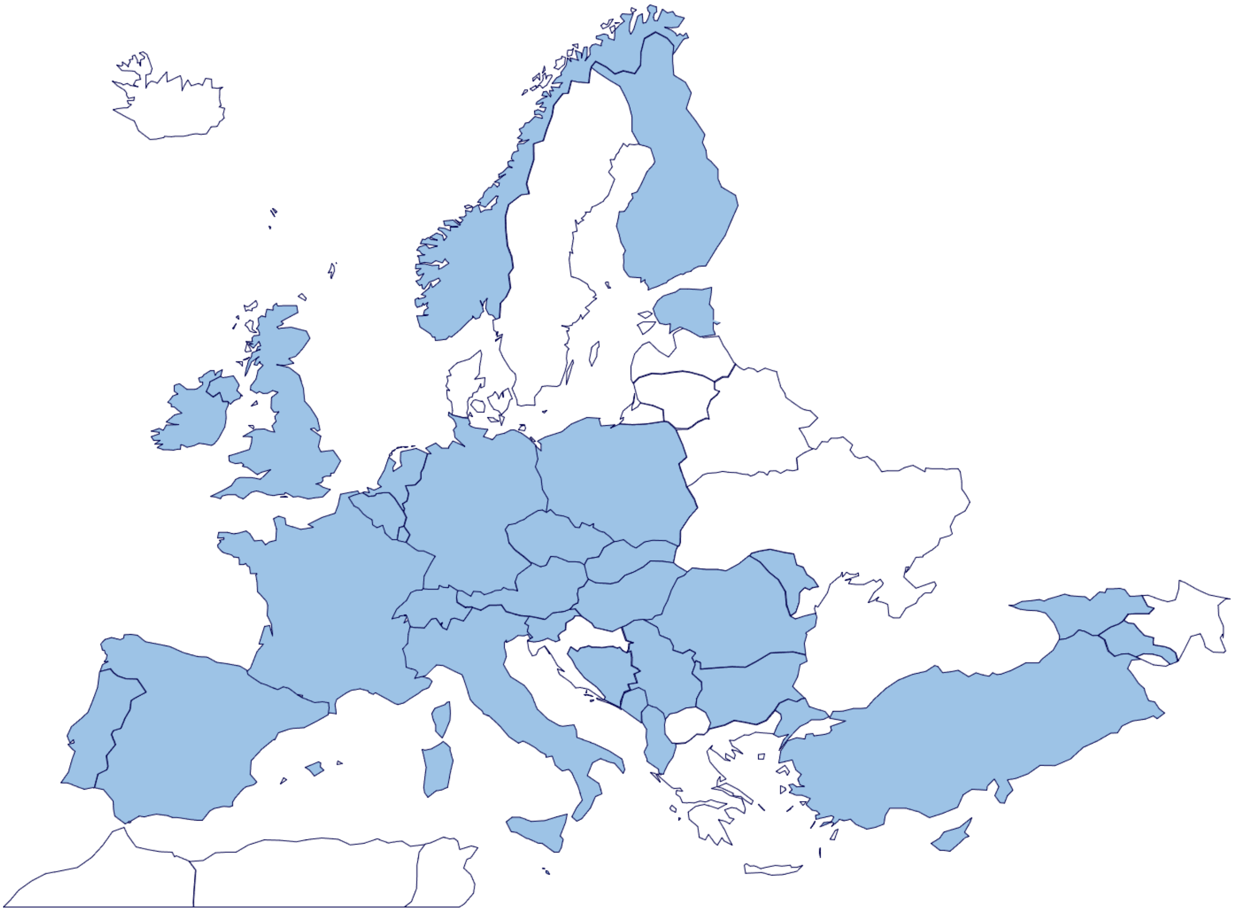

Figure 2-1: Participating ANSPs

2.2. *Sample description*

The analysed sample covers the three types of safety risk occurrences selected by EUROCONTROL Operational safety group (SAFOPS) and Safety Team:

- Separation minima infringement en-route.
- Separation minima infringement in TMA/CTR airspace.
- Runway incursion.

Other risks with ATC influence on the risk, such as CFIT, collision on the ground etc. are not part of the prioritisation process for the moment.

In total, **203 incidents of severity A or B**, collected during the sessions with ANSP representatives, were analysed. In particular, the data sample illustrated in Figure 2-2 includes:

- **60 separation minima infringements in the en-route phase of flight**, 8 of which have been classified as severity A and 52 as severity B incidents - – see the on-line dashboard here[1];.
- **102 TMA/CTR related separation minima infringements**, 7 of which have been classified as severity A and 95 as severity B incidents - - see the on-line dashboard here; .
- **41 runway incursions**, 6 of which have been classified as severity A and 35 as severity B incidents - – see the on-line dashboard here.

Figure 2-2: Analysed data sample

This report contains the description of the specific findings that were judged important for the purpose of Network Manager Safety Prioritisation Process. However, the data samples contain much more contextual information that can be found of interest. Therefore, the above-referenced dashboards provide access to the data samples to those that maybe interested to further analyse the collected information.

[1] Third-party cookies need to be enabled for the browser.

3. THE SAFETY FUNCTIONS MAP ANALYSIS PROCESS

3.1. Introduction to the Safety Function Maps

The SAFMAPs are barrier models based on a structured documentation of the available defences against particular unwanted accident outcomes. These barriers are either part of the ATM system (ground and/or airborne component) or can impact the safety performance of ATM and/or aircraft navigation.

Each discrete barrier is considered as a safety function. The functions used are rather generic, for example the function “Pilot/driver detection of potential RWY conflict and prevention of incorrect entry onto the RWY protected area” does not specify the actual means to implement this function such as stop-bars, runway guard lights or runway entry lights.

Similarly, “Prevention of overlooking potentially conflicting aircraft when issuing clearance or instruction” does not specify the actual means to implement this function such as MTCD, ATCO structured scan of their situation display, team member support, short-term conflict probe or Cleared Flight Level (CFL) processing and alerting by the STCA. Some functions are provided by procedures, some by technical systems and some by a combination of both.

A principle applied to the construction of SAFMAPs was to include all barriers which are available and ‘used by someone’ in the industry. This means that SAFMAPs serve also as a repository of best practices that are not necessarily required by regulations. Examples of these are the use of short-term conflict probes, A-SMGCS level 2 functions or runway status lights.

SAFMAPs are hierarchical structures in which each higher-level structure (function) can be decomposed into several lower-level structures (functions). The highest levels are called basic safety functions. Each of these basic functions is then decomposed into more detailed Level 1 safety functions and, in the same manner, each of these Level 1 safety functions may be further decomposed into several Level 2 safety functions. At present, Level 4 is the most detailed specification and not all safety function levels are necessarily decomposed to the same extent. A function is decomposed further, only if there is a need demonstrated by the occurrence of several incidents that have illustrated different ways in which a particular function can be implemented and/or challenged.

The following examples are provided as a means to illustrate this structure using the Mid-air collision SAFMAP. It has 6 basic safety functions and hereafter is illustrated the decomposition of one of these functions, notably “ATC Tactical Separation Assurance”:

- “Conflict-free ATC clearances and instructions” is an example of a Level 1 safety function.
- “Prevention of overlooking potentially conflicting aircraft when issuing clearance or instruction” is an example of a Level 2 Safety Function.

Starting with each basic safety function, the progressive decomposition of each safety function level into a more detailed lower-level results in the 'mapping' of how the safety function components at each lower level collectively provide the redundancy which delivers the higher-level safety function.

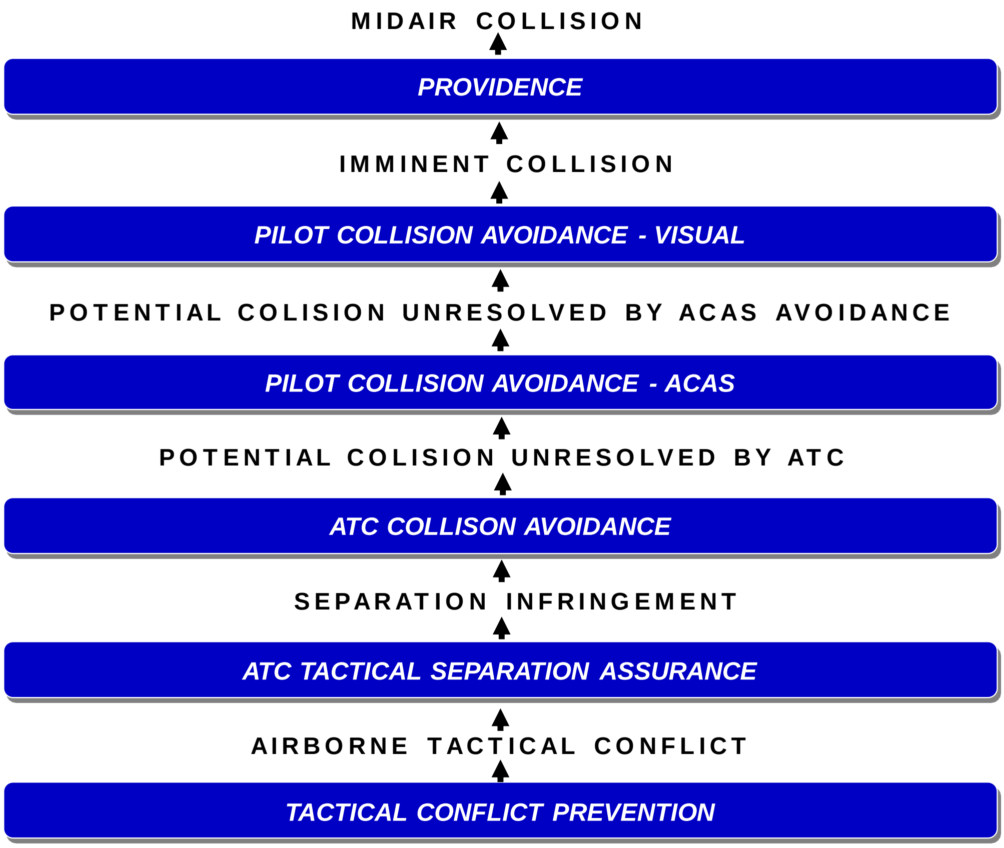

Figure 3-1: SAFMAP basic safety functions

When an incident is reviewed with the help of a SAFMAP, the objective is to identify all relevant safety functions. The process is not limited only to identifying the functions that failed (to stop the event producing effect of higher severity), but also those functions that worked and provided resilience. The following qualifications for a function are possible:

- Not challenged but available.
- Challenged and failed.
- Challenged and worked.
- Not challenged but not available.
- Not applicable to the scenario.

In this way, each incident is described in terms of qualified sequence of safety functions – failed, worked, not challenged or not applicable. This creates a very elaborate description of what happened in the particular scenario – what was observable. This can be called descriptive factor analysis for the description does not go into an elaboration of why things happened, or in other words, what the explanatory factors are.

It is to be noted that very often there is not sufficient information available in the investigation report or provided during the data collection workshop discussions to systematically qualify the performance of all safety functions. Therefore, the information for some of them is either missing or a function is qualified without any contextual information.

3.2. How to read the barrier model

Figure 3-2 illustrates an example of the graphics used to analyse and present incident data; in this case, it is the barrier model for runway collision.

The background arrow depicts the direction in which the incidents develop. Each incident is depicted as a circle before the barrier, which stopped its further propagation. All the barriers underneath the incident were already "crossed" by the developing event – meaning that the barriers failed. The fill colour, also shown in the Legend of the figures, illustrates how the conflicting trajectories were created - how the first barrier failed.

The big grey numbers on the left-hand side are an indicator of the overall number of incidents prevented by a given basic barrier.

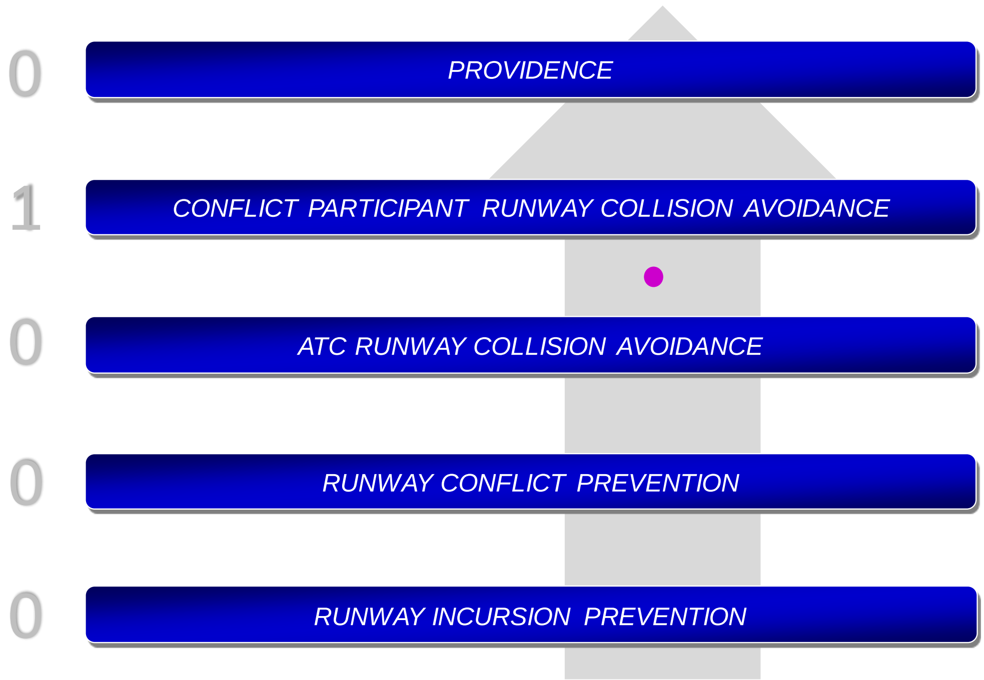

Figure 3-2: Incident data presentation example

In some figures there is information about incidents that were stopped between two barriers but not by the barrier itself. This is depicted by a technical thinner "barrier" than the "real barrier" and the text "No need".

4. EN-ROUTE SEPARATION MINIMA INFRINGEMENTS – SUMMARY ANALYSIS

4.1. *Overall barrier performance – en-route*

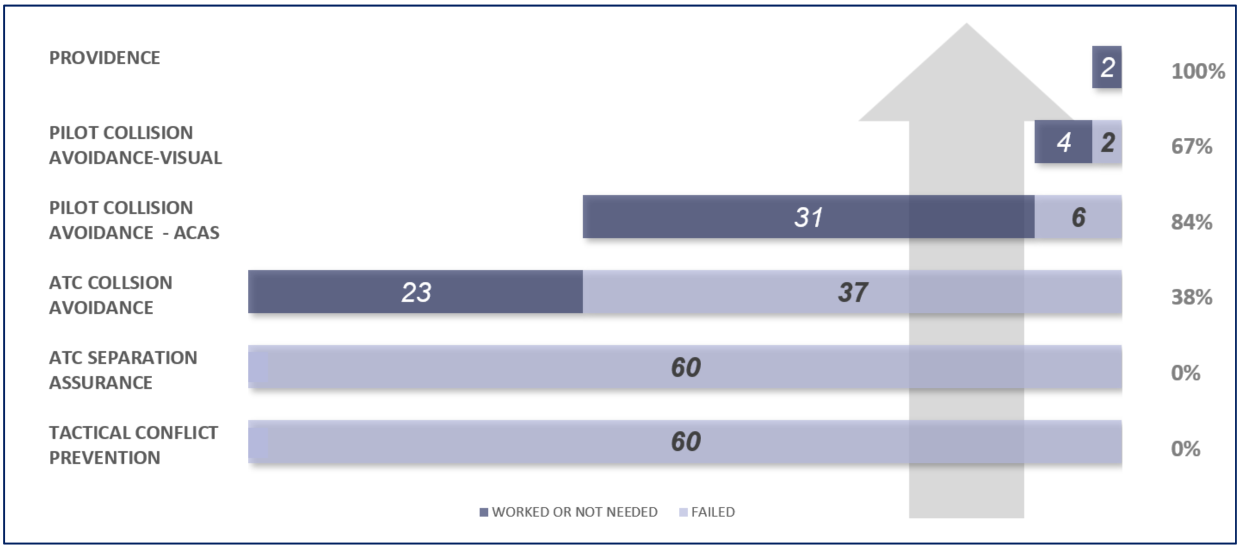

Figure 4-1: Overall barrier performance

- ❑ Performance of the basic barrier “Tactical conflict prevention”: challenged 60 times, failed in 60 cases. This is not a surprise, due to the high severity (A and B) of the events included in the analysed data sample. In order to obtain a more reliable information about the barrier strength, incidents of lower severity (e.g. C, D and E) should be analysed, too.
- ❑ Performance of the basic barrier “ATC separation assurance”: challenged 60 times, failed in 60 cases.
- ❑ Performance of the basic barrier “ATC collision avoidance”: challenged 60 times, failed in 37 cases (62%) and worked or was not needed in 23 cases (38% success).
- ❑ Performance of the basic barrier “Pilot collision avoidance - ACAS”: challenged 37 times, failed in 6 cases (16%) and worked or was not needed in 31 cases (84% success). From the 6 times this basic safety barrier failed, in 5 of the events the initiator was restricted airspace infringement where the hazard was a firing range or another transponder non-equipped aircraft and in one incident an altitude deviation was caused by aircraft altimeter error, which prevented the correct functioning of the ACAS system.
- ❑ Performance of the basic barrier “Visual collision avoidance”: challenged 6 times, failed in 2 cases (33%) and was not needed in 4 case (67% success).
- ❑ Performance of the basic barrier “Providence”: challenged 2 times and worked in both cases (100% success).

4.2. Performance of first barrier "Tactical Conflict Prevention"

The figure below shows the distribution of the failure scenarios for the first barrier.

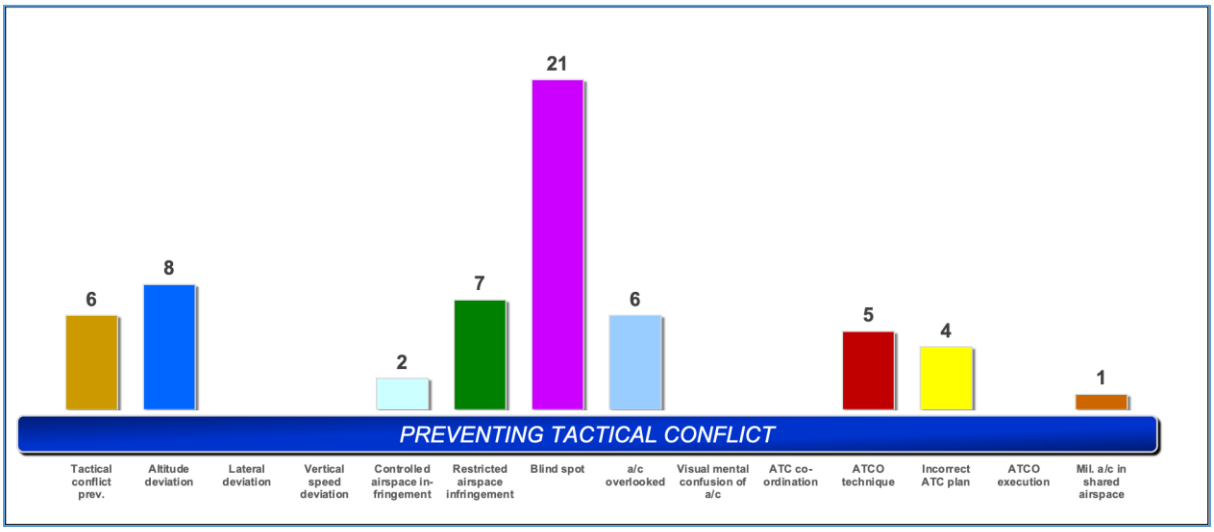

Figure 4-2: Barrier failure scenarios

Performance of the basic barrier "Tactical Conflict Prevention" - failed in all 60 analysed events:

- In 21 incidents (35% of the data sample) the conflict was generated by "Blind spot" – ATCO overlooking a potentially conflicting proximate aircraft when clearing or instructing another one.
- In 8 incidents (13% of the data sample) the conflict was generated by "Altitude deviation".
- In 7 incidents (12% of the data sample) the conflict was generated by a "Restricted airspace infringement ".
- In 6 incidents (10% of the data sample) the conflict was generated by Pre-tactical conflict not prevented by the "ATC tactical planning".
- In 6 incidents (10% of the data sample) the conflict was generated by "ATCO overlooking an aircraft" while clearing or instructing another one which was not proximate.
- In 5 incidents (8% of the data sample) the conflict was generated by "Inadequate ATCO controlling technique".
- In 4 incidents (7% of the data sample) the conflict was generated by "Incorrect ATCO plan".
- In 2 incidents (3% of the data sample) the conflict was generated by "Controlled airspace infringement".
- In 1 incident (2% of the data sample) the conflict was generated by "Military flights in shared airspace".

It is worth noting that overlooking a conflicting aircraft ("Blind spot" and "ATCO overlooking an aircraft") accounts for almost half (45%) of the events included in the 2022 en-route incident sample.

4.3. Barriers' resilience per initiator

Figure 4-3: Barriers' resilience to initiators

Figure 4-3 illustrates the resilience of the barriers to the different initiators. The following can be noted:

- The initiator of the incidents that were stopped at the "Providence" barrier is "Restricted airspace infringement".
- The initiators of the incidents that were stopped at the "Pilot collision avoidance - Visual" technical barrier are "Restricted airspace infringement" and "Altitude deviation".
- Most of the incidents initiated by "Blind spot", "Altitude deviation" and "Restricted airspace infringement" were stopped at the "Pilot collision avoidance - ACAS" barrier.
- At difference to the "Blind spot" events, most of the incidents initiated by "Overlooked aircraft" were stopped at the "ATC collision avoidance" barrier. This could be explained by the additional time the ATCO has to identify and resolve the conflicting situation.

4.4. *"Blind Spot" events*

Figure 4-4: Blind spot events

As mentioned above, "blind spot" was by far the most frequent initiator for the occurrences in the sample. Figure 4-4 provides insight into the blind spot incidents. The following was identified:

- 2/3 of the events (14) crossed the ATC separation assurance and collision avoidance barriers and all of them were stopped at the "Pilot collision avoidance - ACAS" barrier.
- Despite the shortage of time associated to "Blind spot" events, ATCOs were able to resolve 1/3 of the conflicting situations.

Considering the criticality of the incidents and the fact that "Blind spot" is consistently the most frequent initiator during the last years, it is suggested to retain "Controller Blind Spot" as a safety priority.

Figure 4-5: Blind spot events most frequent scenario

Specific insights into blind spot incidents can be seen in Figure 4-5:

- 61% of the analysed “Blind spot” events involved the scenario of ATCO overlooking the conflicting aircraft when issuing a level clearance to meet a standing sector exit constraint or filed flight level in the flight plan.

4.5. Restricted airspace infringement events

Figure 4-6: Restricted airspace infringement events

Figure 4-4 provides insight into the restricted airspace infringement incidents. The following was identified:

- The restricted airspace infringement incidents are the events of highest safety criticality in the analysed 2022 en-route incident data sample.
- Most of the restricted airspace infringement incidents passed the “ACAS collision avoidance” barrier and were stopped at the “Pilot collision avoidance – Visual” barrier or at the “Providence” barrier.

Considering the criticality of the “Restricted airspace infringement” incidents, it is suggested to include it as a safety priority.

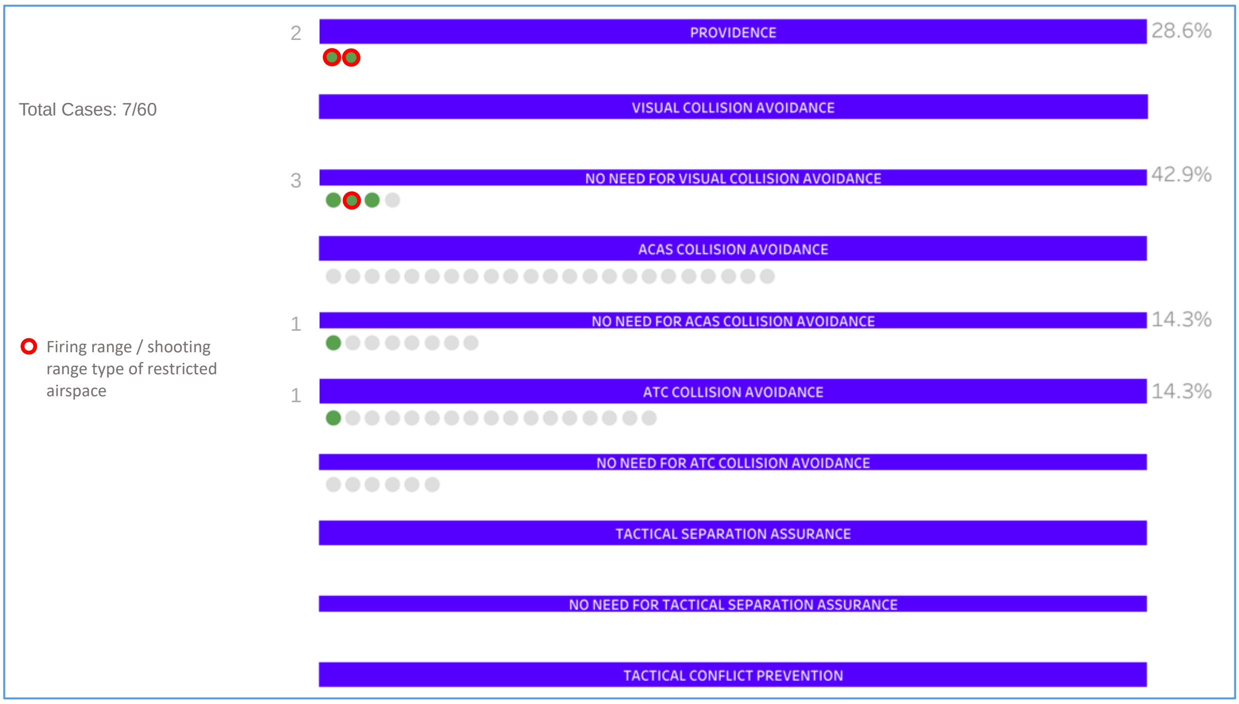

Figure 4-7: Restricted airspace infringement most critical scenario

Specific insights into restricted airspace infringement incidents can be seen in Figure 4-7:

- 3 out of the 7 analysed “Restricted airspace infringement” events involved infringement of firing range/shooting areas, where the pilot collision avoidance barriers can be considered unavailable. These 3 events are among the most critical ones in the sample.

4.6. Altitude deviation events

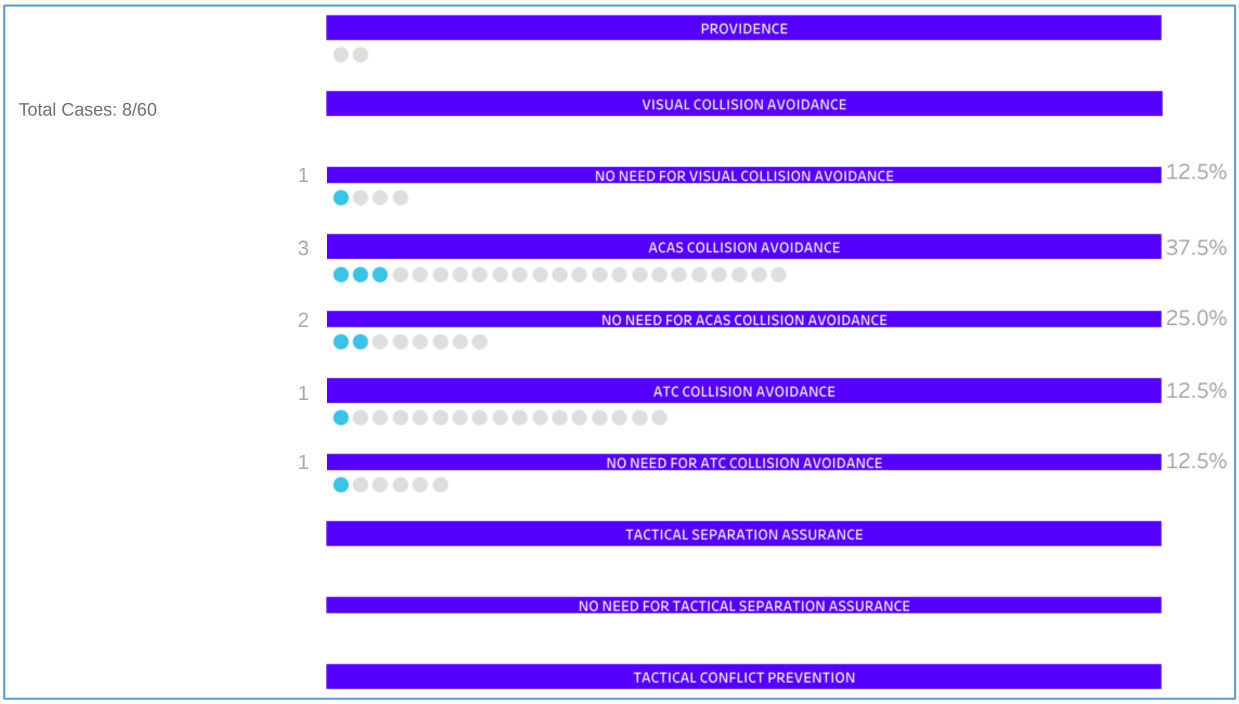

Figure 4-8: Restricted airspace infringement events

Figure 4-8 provides insight into the altitude deviation incidents. The following was identified:

- The altitude deviation events are of rather high safety criticality in the analysed 2022 en-route incident data sample – 75% of the events crossed the ATC-related barriers. This could be explained by the lack of time for conflict prevention by ATC in case of altitude deviation in proximity of another aircraft.
- Nearly 2/3 of the events were stopped at the “Pilot collision avoidance - ACAS” barrier.

Considering the share and safety criticality of the “Altitude deviation” incidents, it is suggested to monitor the risk associated with it.

4.7. *Contextual factor analysis – En route*

This section presents the results of the analysis of the typical contextual factors, for which information was available in the description of the occurrences included in the 2022 en-route data sample. Two contextual factors were selected for their significance: high workload, and on-the-job training.

4.7.1. *High Workload*

Figure 4-9: Restricted airspace infringement events

Figure 4-8 illustrates the incidents associated with reported high controller workload.

The following can be noted:

- The incidents, in which workload was reported to be a factor make 15% of the analysed 2022 en-route data sample.
- Half of those incidents are of high safety criticality, i.e. were stopped at the "Pilot collision avoidance - ACAS" barrier.

Considering the significance of the incidents associated with high workload, it is suggested high workload to be monitored for the risk associated with it.

4.7.2. *Incidents involving OJT*

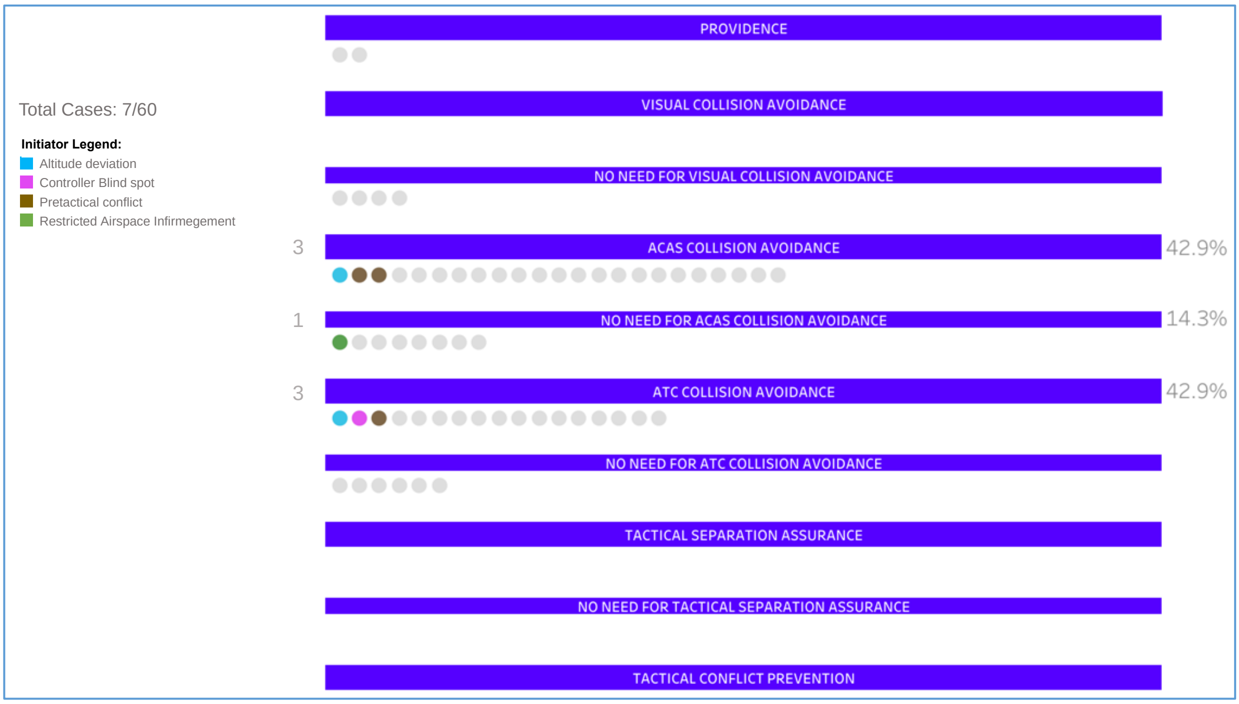

Figure 4-10: OJT

Figure 4-10 illustrates the incidents associated with reported in-position training (OJT).

The following can be noted:

- The incidents, in which OJT was reported to be a factor make 12% of the analysed 2022 en-route data sample.
- Half of those incidents are of high safety criticality, i.e. were stopped at the “Pilot collision avoidance - ACAS” barrier.

Considering the significance of the incidents associated with on-the-job-training, it is suggested on-the-job-training to be monitored for the risk associated with it.

5. TMA/CTR INCIDENTS OF SEPARATION MINIMA INFRINGEMENT – SUMMARY ANALYSIS

5.1. Overall barrier performance – TMA/CTR

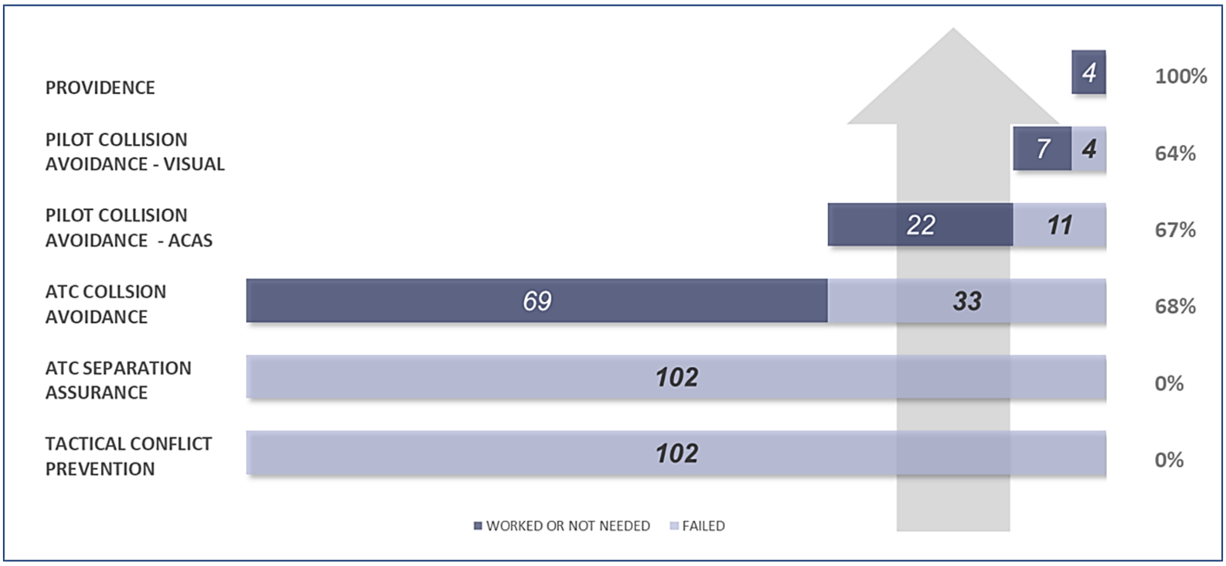

Figure 5-1: Overall barrier performance

- Performance of the basic barrier "Tactical conflict prevention": challenged 102 times, failed in all 102 cases. This is not a surprise, due to the high severity (A and B) of the events included in the analysed data sample. In order to obtain a more reliable information about the barrier strength, incidents of lower severity (e.g. C, D and E) should be analysed, too.
- Performance of the basic barrier "ATC separation assurance": challenged 102 times, failed in all 102 cases.
- Performance of the basic barrier "ATC collision avoidance": challenged 102 times, failed in 33 cases (32%) and worked or was not needed in 69 cases (68% success).
- Performance of the basic barrier "Pilot collision avoidance - ACAS": challenged 33 times, failed in 11 cases (33%) and worked or was not needed in 22 cases (67% success). In all 11 times this basic safety barrier failed, the ACAS system was unavailable for various reasons.
- Performance of the basic barrier "Pilot collision avoidance - visual": challenged 11 times, failed in 4 cases (36%) and worked or was not needed in 7 cases (64% success).
- Performance of the basic barrier "Providence": challenged 4 times and worked in all cases (100% success).

5.2. Performance of first barrier "Tactical Conflict Prevention"

The figure below shows the distribution of the failure scenarios for the first barrier.

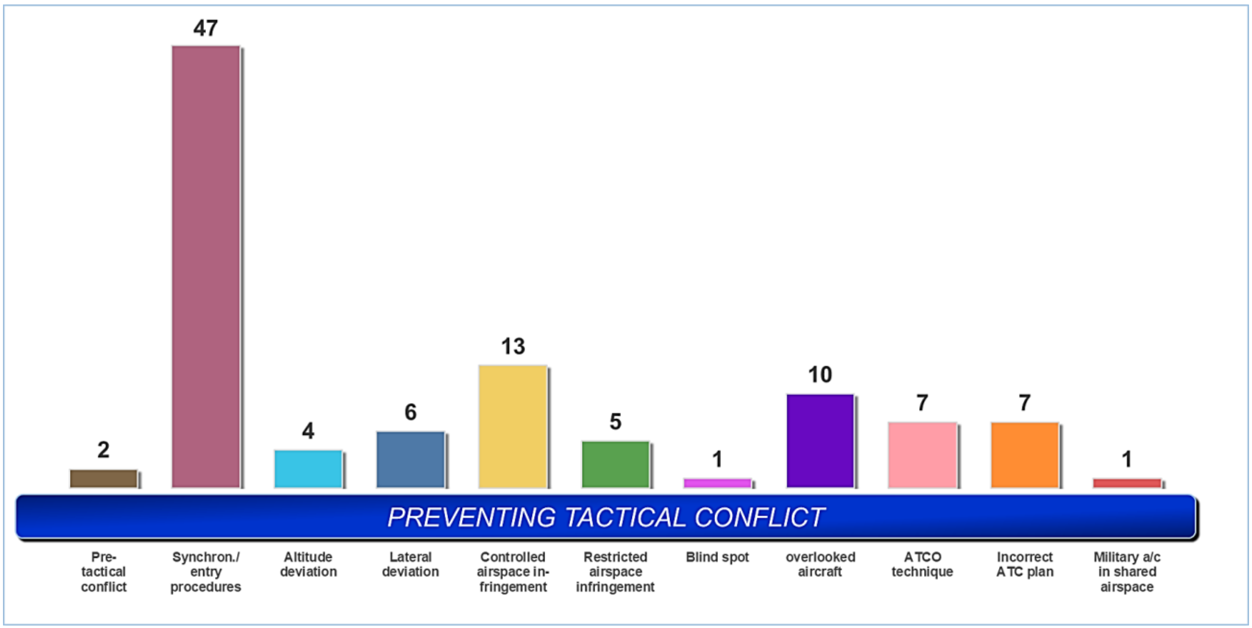

Figure 5-2: Separation minima infringement scenarios and initiators

The SAFMAP analysis helped identify the following initiating factors that played a role in the 2022 occurrence data sample:

- In 47 incidents (46% of the data sample) the conflict was generated by "ATC tactical planning and traffic synchronisation". Associated with almost half of the events in the data sample, this initiator's share remains consistent with 2021's 52%.
- In 13 incidents (13% of the data sample) the conflict was generated by "Controlled airspace infringement", approximately doubling in share from 7% in 2021.
- In 10 incidents (10% of the data sample) the conflict was generated by "Overlooked aircraft" – increasing from 8% in 2021.
- In 7 incidents (7% of the data sample) the conflict was generated by "Incorrect ATCO techniques" – similarly to 2021 (6%). However, this factor also contributed to 36% of the traffic synchronization events.
- In 7 incidents (7% of the data sample) the conflict was generated by "Incorrect ATCO plan" – rising again after a drop to 1% in 2021. Additionally, this factor also contributed to 13% of the traffic synchronization events.
- In 6 incidents (6% of the data sample) the conflict was generated by "Lateral deviation" – nearly halving from 10% in 2021.
- In 5 incidents (5% of the data sample) the conflict was generated by "Restricted airspace infringement" – considerably rising from 1% in 2021.

- In 4 incidents (4% of the data sample) the conflict was generated by “Altitude deviation” – halving from 2021.
- In 2 incidents (2% of the data sample) the conflict was generated by Pre-tactical planning” – none in the previous year.
- In 1 incident (1% of the data sample) the conflict was generated by Blind spot” – the same as the previous year.
- In 1 incident (1% of the data sample) the conflict was generated by “Military aircraft in shared airspace” – none in 2021.

NB: One event involved both lateral and altitude deviations.

5.3. Barriers' resilience per initiator

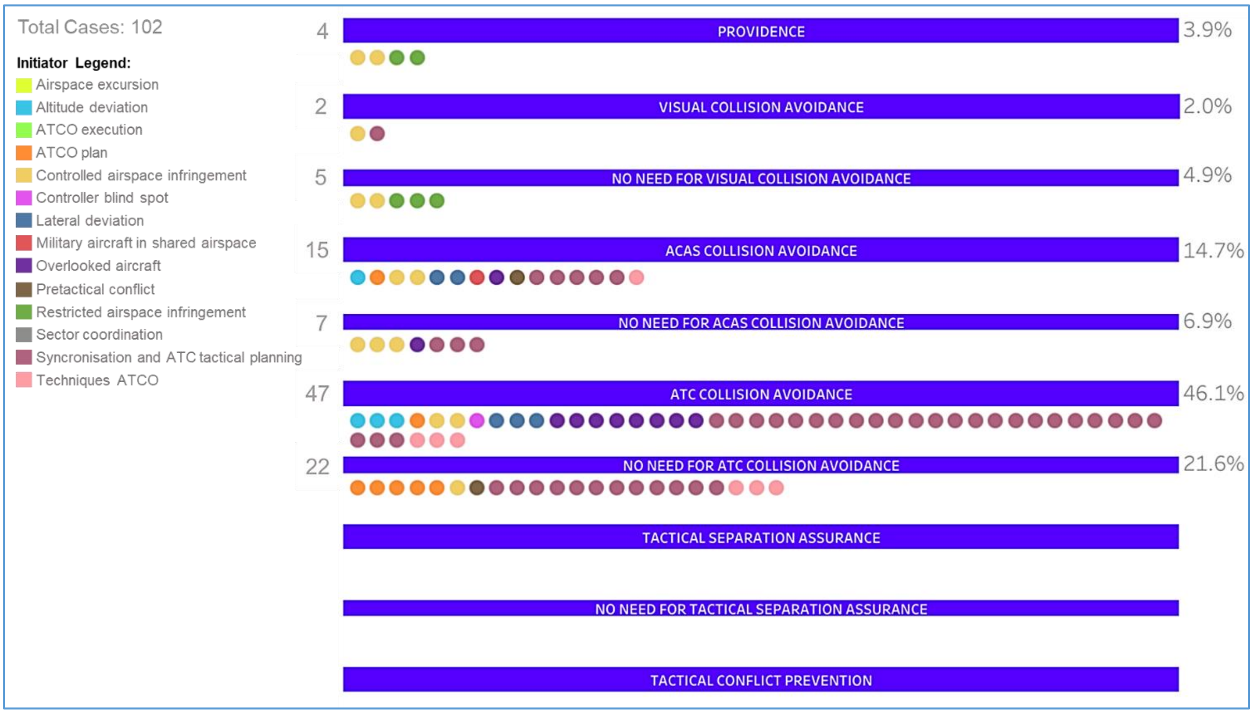

Figure 5-3: Barrier resilience per initiator

Figure 5-3 illustrates the distribution of incidents that were stopped by a barrier and those that crossed it, as well as the resilience of the barriers to the different initiators. The following can be concluded regarding the barrier effectiveness:

- The majority of events were stopped at the "ATC collision avoidance" barrier – 68%.
- 21% of all incidents were stopped at the "Pilot collision avoidance – ACAS" barrier.
- 7% were stopped by "Pilot collision avoidance – visual".
- 4% of all incidents reached the last barrier "Providence", increasing from 1% in 2021.
- The initiators with the highest safety criticality were "Controlled airspace infringement" and "Restricted airspace infringement", each responsible for nearly half of all events that reached the last two barriers (45%) and each seeing an important share increase from the previous year.
- The entirety of "Restricted airspace infringement" events was stopped at the last two barriers, making this initiator the most critical to safety in 2022. The ACAS barrier was unavailable in all of these events. The only "Restricted airspace infringement" in 2021 was also of relatively high criticality, reaching the technical barrier "No need for visual collision avoidance".
- The largest initiator, "ATC tactical planning and traffic synchronisation" has a slightly reduced safety criticality from the previous year, with the big majority (81%) of its events having been stopped at the "ATC collision avoidance" barrier.

5.4. ATC tactical planning and traffic synchronisation incidents

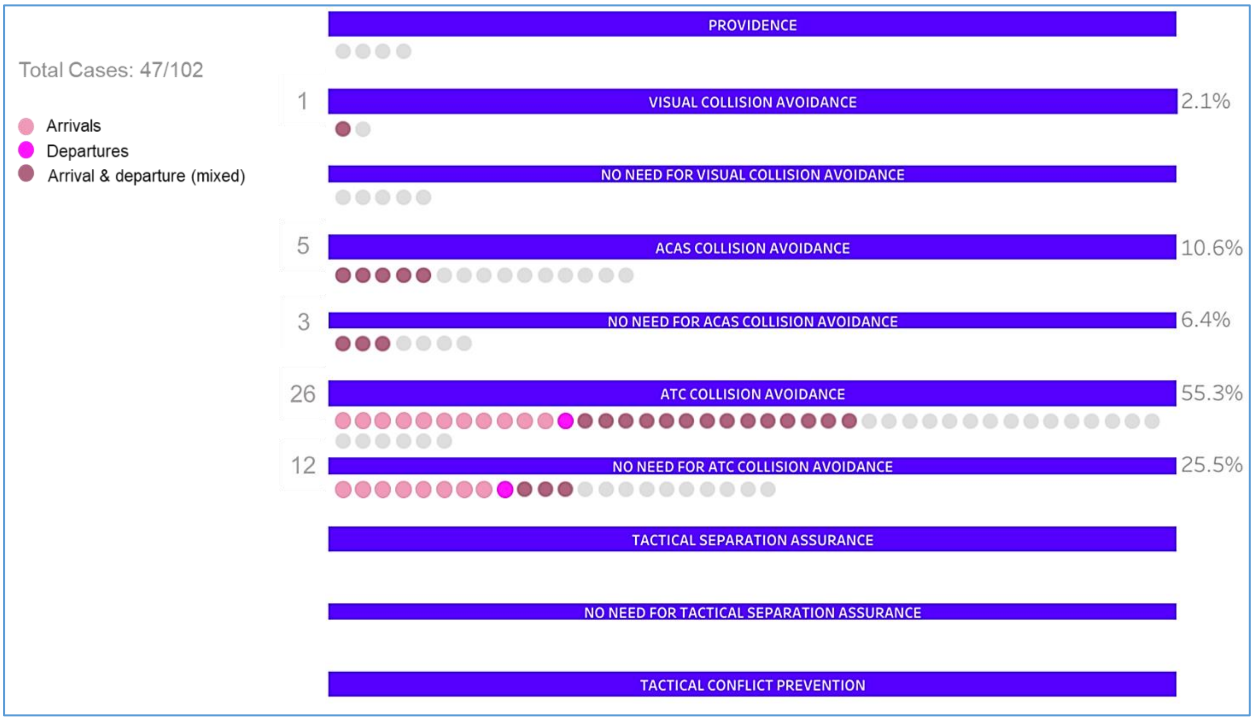

Figure 5-4: Incorrect ATC traffic synchronisation / entry procedures

Figure 5-4 provides insight into the largest TMA/CTR incident initiator in 2022: incorrect traffic synchronisation by ATC. The following was identified:

- 81% of incorrect traffic synchronisation events were stopped at the “ATC collision avoidance barrier”.
- There was a marked increase in the need for active ATC collision avoidance action – in 55% of 2022 events compared to 32% of 2021 events.
- More than half (55%) of events involved inadequate synchronisation between a departing and an arriving aircraft; 40% - between successive arriving aircraft; and 4% - between successive departing aircraft.
- The largest contributory factors were:
  - Inadequate ATCO controlling techniques, including vectoring, speed management and rate of change management (all) – 36%.
  - Incorrect interception of final approach (arrivals) – 19%.
  - Go-around conflict with departing aircraft (mixed) – 19% .
  - Inappropriate ATCO plan (mixed; arrivals) – 13%.
  - Inadequate ATC coordination (mixed) – 11%.

- The contributory factors to events of higher safety criticality, passing the "ATC collision avoidance" barrier, are "go-around conflict", "inadequate ATCO controlling techniques" and "inadequate ATCO plan".
- In 40% of incorrect traffic synchronisation incidents, ATC detected the separation minima infringement late (in 26% with the aid of STCA).
- In 11% of incidents ATC did not detect the potential separation minima infringement.
- In 17% there was insufficient time for separation assurance by ATC.
- 51% of incorrect traffic synchronisation incidents occurred during sequencing for final approach.
- 19% of conflicts involved poor ATC teamwork.
- 11% of conflicts occurred during ATCO on-the-job training.

In view of the above it is suggested to monitor the risk associated with "Synchronisation of successive arriving to land and of arriving to land and departing aircraft".

5.5. Controlled Airspace Infringement

Figure 5-5: Controlled airspace infringement incidents

Figure 5-5 provides insight into the controlled airspace infringement incidents. The following was identified:

- Controlled airspace infringements are characterised by high safety criticality.
- They account for 45% of all events that reached the last two barriers.
- 77% of conflicts passed all ATC barriers. Half of those (38%) were impossible to detect for ATC, as they involved transponder non-equipped Remotely Piloted Aircraft Systems (RPAS), and reached the last two barriers.
- 23% of separation minima infringements were detected late (2/3rds of which after STCA). 15% were not detected by ATC despite the availability of system support.
- In 23% of conflicts, there was insufficient time for ATC collision avoidance.
- 62% of the controlled airspace infringement incidents involved VFR flights.
- 31% involved non-commercial flights.
- In the incidents involving RPAS (38%), visual collision avoidance was not available in 20% (1 out of 5)

Due to their high safety criticality in the 2022 sample, it is suggested to retain "Controlled Airspace Infringements" as a safety priority.

5.6. Restricted Airspace Infringement

Figure 5-6: Restricted airspace infringement incidents

Figure 5-6 provides insight into the initiating factors of restricted airspace infringement incidents. The following was identified:

- All restricted airspace infringement events were stopped at the "Providence" and "Pilot collision avoidance – visual" barriers, thus are of very high safety criticality.
- Two out of 5 of these events were stopped by "Providence", accounting for half of all events reaching this barrier in the data sample.
- In 3 out of 5 incidents, the need for ATC collision avoidance was undetectable.
- In all incidents, ACAS barrier was not available.
- In the incident initiated by inadequate communication, after misleading R/T phraseology by the FISO, there were no other barriers left but "Providence".

Due to their high safety criticality in 2022's enroute and TMA/CTR data samples, it is suggested to treat "Restricted airspace infringements" as a safety priority.

5.7. *Contextual factor analysis – TMA/CTR*

This section presents the results of the analysis of the typical contextual factors, for which information was available in the description of the occurrences of separation minima infringements in TMA/CTR airspace included in the 2022 data sample. The following contextual factors were selected for their significance: occurrence during sequencing for final approach, VFR flight involved, non-commercial flight involved, inadequate ATC teamwork, occurrence during missed approach/go-around, ACAS unavailability, and ATCO on-the-job training.

5.7.1. *Incidents during sequencing for final approach*

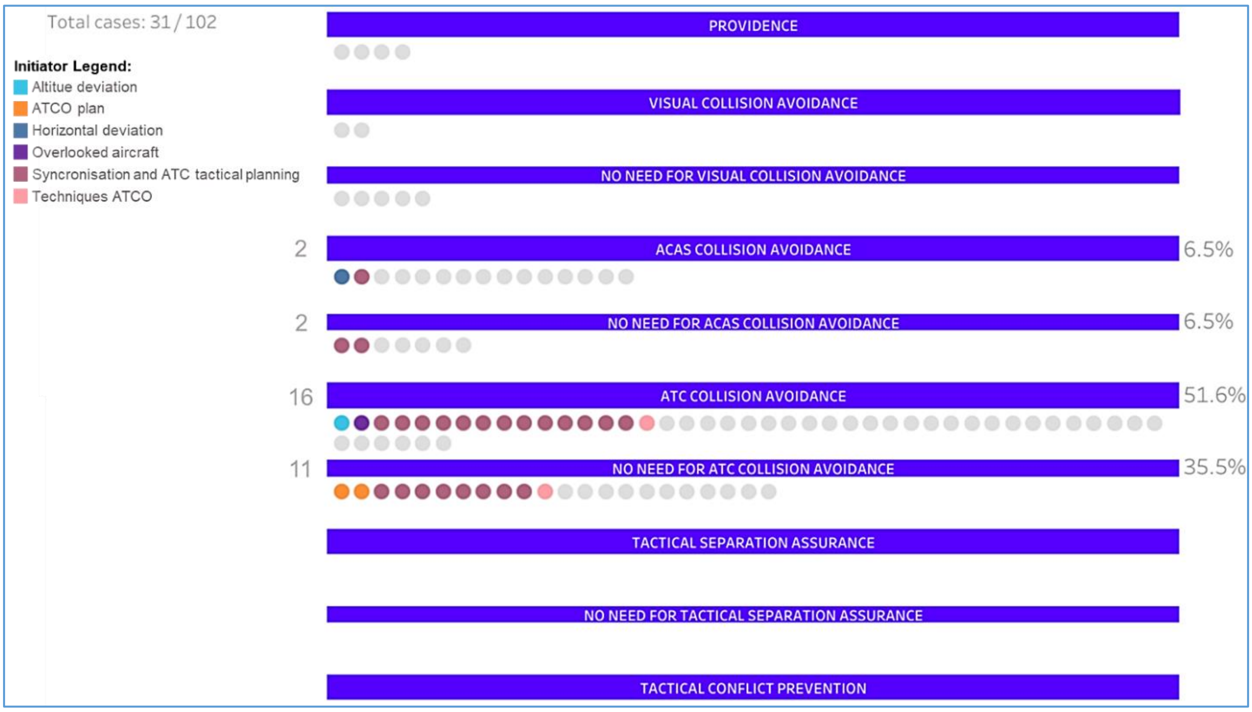

Figure 5-7: During sequencing for final approach

Figure 5-7 illustrates the incidents that occurred during sequencing for final approach. The following can be noted:

- The incidents which occurred during sequencing for final approach account for 30% of 2022's data sample (31 cases).
- Most (87%) events were stopped at the "ATC collision avoidance" barrier and the remaining 13% were stopped at "Pilot collision avoidance – ACAS".
- 77% of incidents were initiated by incorrect "ATC tactical planning and traffic synchronisation" (accounting for half of that entire initiator).
- In 42% ATCO detected the separation conflict late (35% with STCA).
- In 19% ATCO did not assure separation due to inadequate controlling techniques.
- In 16% ATCO did not assure separation due to inadequate decision/goals.

- In approximately half of all incidents during sequencing for final approach, ATC detected the conflict too late to prevent separation infringement but in time to issue successful collision avoidance instruction.
- 16% involved VFR flights.
- 10% occurred during high ATC workload.
- 10% factored ATCO OJT.

The above findings support the suggestion made in section 5.4 to monitor the risk associated with synchronisation of successive arriving to land aircraft.

5.7.2. *Visual Flight Rules (VFR) flights involved*

Figure 5-8: VFR flights involved

Figure 5-8 depicts the incidents in which VFR flight took part. The following can be noted:

- Incidents involving VFR flights account for 22% of the analysed sample (almost double from 12% in 2021)
- VFR flights were involved in 72% of all airspace infringement incidents.
- ATC barriers stopped 55% of all cases, vastly improving from 30% in the previous year. Even so, incidents involving VFR flights remain of high safety criticality.
- In 32% of events, ATC did not assure separation due to flawed decision/goals.
- In 23%, ATC did not detect the separation conflict.
- In 27%, ATC detected the conflict late (18% with STCA).
- In 27%, ATC detected the conflict too late to prevent separation infringement but in time to issue successful collision avoidance instruction.
- 55% involved non-commercial flights.
- 23% occurred during sequencing for final approach.
- In 18%, ACAS was unavailable.

In view of the above it is suggested to monitor the risk associated with VFR/IFR incidents in TMA/CTR airspace.

5.7.3. Non-commercial flights involved

Figure 5-9: Non-commercial flights involved

Figure 5-9 illustrates the incidents associated with reported non-commercial flight involvement. The following can be noted:

- ❑ 19% of analysed sample included non-commercial flight participation.
- ❑ 39% of all airspace infringement events involved non-commercial flights.
- ❑ 37% of incidents with non-commercial flight participation passed all ATC barriers.
- ❑ In 21% of the events, ATC did not detect the conflicts.
- ❑ In 32% ATC detected the conflict late (almost always after STCA).
- ❑ In 16% ATC did not assure separation due to inadequate decision/goals.
- ❑ In 37% ATC detected the conflict too late to prevent separation infringement but in time to issue successful collision avoidance instruction.
- ❑ In 63% the flight was conducted according to the VFR
- ❑ 16% occurred during high ATCO workload.
- ❑ 16% factored inadequate ATC teamwork.
- ❑ In 16% ACAS barrier was unavailable.
- ❑ In 10% ATC collision avoidance was unavailable.

In view of the above it is suggested to monitor the risk associated with non-commercial flights in TMA/CTR airspace.

5.7.4. *Inadequate ATC teamwork*

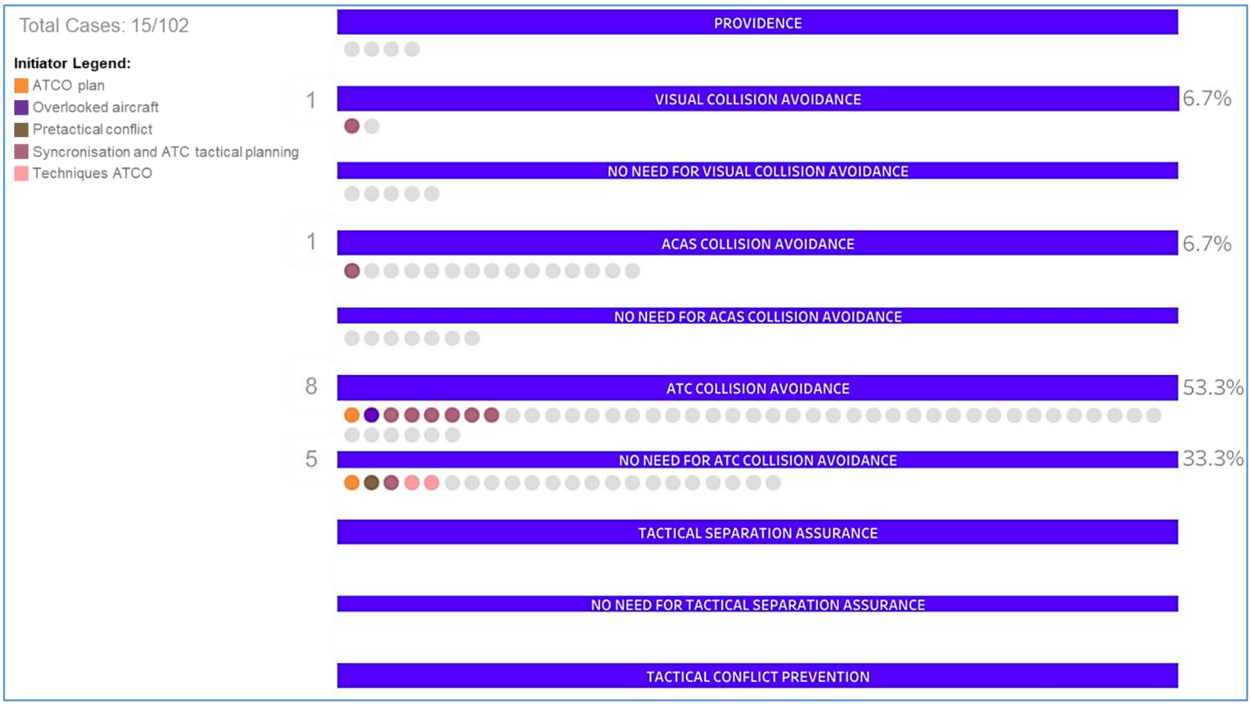

Figure 5-10: Incidents involving poor ATC teamwork

Figure 5-10 showcases the incidents involving inadequate ATC teamwork. The following can be noted:

- Events involving inadequate ATC teamwork make up 15% of the analysed sample.
- 13% (2) of these events passed all ATC barriers.
- The majority of incidents (60%) involving inadequate ATC teamwork were initiated by inappropriate "ATC tactical planning and traffic synchronisation", including the higher safety criticality incidents.
- In 13%, ATC did not assure separation due to not detecting the conflict.
- In 40% ATC detected the conflict late (27% after STCA).
- In 20% ATC detected the conflict timely, but did not act on time to assure separation.
- In 40% of events ATC detected the conflict too late to prevent separation infringement but in time to issue successful collision avoidance instruction.
- 27% involved a missed approach/go-around conflict.
- 20% included ATC clearing aircraft on a direct route.
- 20% involved non-commercial flights.
- 13% factored handover-takeover of operational ATC position.
- 13% occurred during sequencing for final approach.

In view of the above it is suggested to monitor the risk associated with inadequate ATC teamwork.

5.7.5. *Airborne Collision Avoidance System (ACAS) not available*

Figure 5-11: ACAS unavailable

Figure 5-11 illustrates the incidents associated with reported ACAS unavailability. The following can be noted:

- The ACAS barrier was unavailable in 11% of the studied sample (up from 8% in the previous year).
- The unavailability of the barrier can be explained by the lack of equipped transponders in 55% of the events (drone participation in 45%).
- Logically, cases in which ACAS is not available are of high safety criticality. This factor group encompasses 100% of the events that reached the last two barriers, seeing a very significant increase from 43% in 2021 (and then they only reached the technical barrier "No need for visual collision avoidance").
- All restricted airspace infringements fall into this category, and 38% of controlled airspace infringements.
- In the majority (72%) of these events, the ATC collision avoidance barrier was also unavailable.
- In 45%, the ATC tactical separation assurance barrier was also unavailable.
- In 27%, the pilot visual collision avoidance barrier was also unavailable.
- 36% of the incidents involved VFR flights.
- 27% involved non-commercial flights.

Due to their high safety criticality in the 2022 sample, it is suggested to retain "Flight without transponder or with dysfunctional one" as a safety priority.

6. RUNWAY INCURSION INCIDENTS - SUMMARY ANALYSIS

6.1. Overall barrier performance – runway incursion

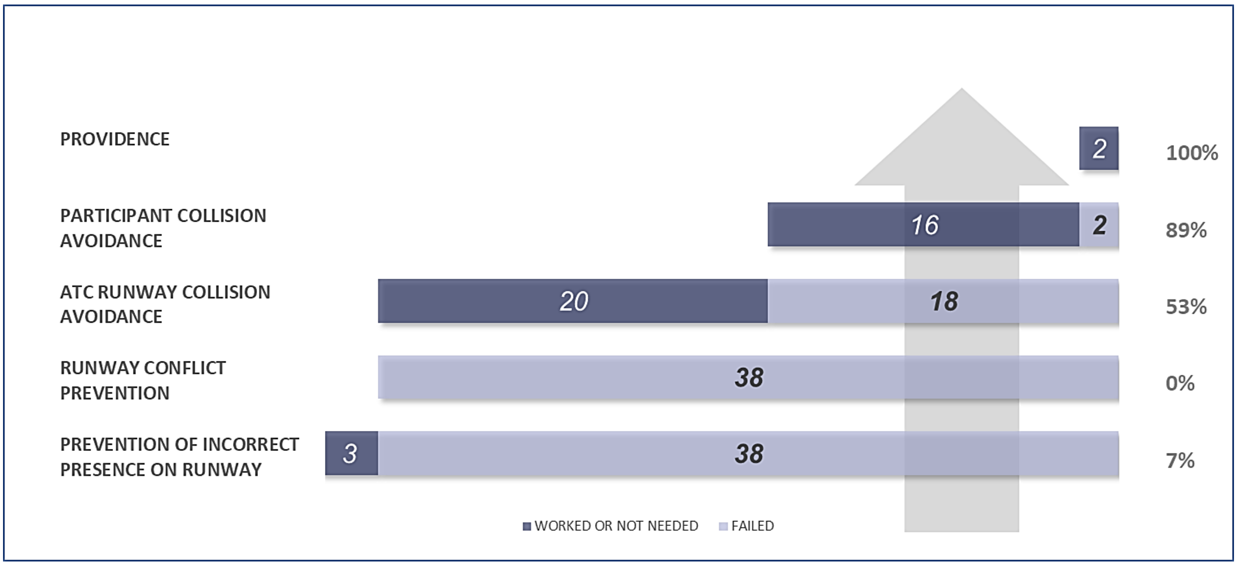

Figure 6-1: Overall barrier performance

- Performance of the basic barrier "Prevention of Incorrect Presence on Runway": challenged 41 times, failed in 38 cases (93%) and succeeded in 3 cases (7% success). The presence of the 3 cases in the sample is because they were reported as severity A or B incidents by the ANSPs. The high degree of this barrier failure is not a surprise, due to the high severity (A and B) of the events included in the analysed data sample. In order to obtain more reliable information about the barrier strength, incidents of lower severity (e.g. C, D and E) should be analysed, too.
- Performance of the basic barrier "Runway Conflict Prevention": challenged 38 times, failed in all cases.
- Performance of the basic barrier "ATC Runway Collision Avoidance": challenged 38 times, failed in 18 cases (47%) and worked or was not needed in 20 cases (53% success).
- Performance of the basic barrier "Conflict Participant Runway Collision Avoidance": challenged 18 times, failed in 2 cases (11%) and worked or was not needed in 16 cases (89% success).
- Performance of the basic barrier "Providence": challenged 2 times and worked in all cases (100% success).

6.2. *Performance of the first barrier "Prevention of Incorrect Presence on RWY"*

The figure below shows the distribution of the scenarios of incorrect presence on the runway protected area differentiated by initiating factor.

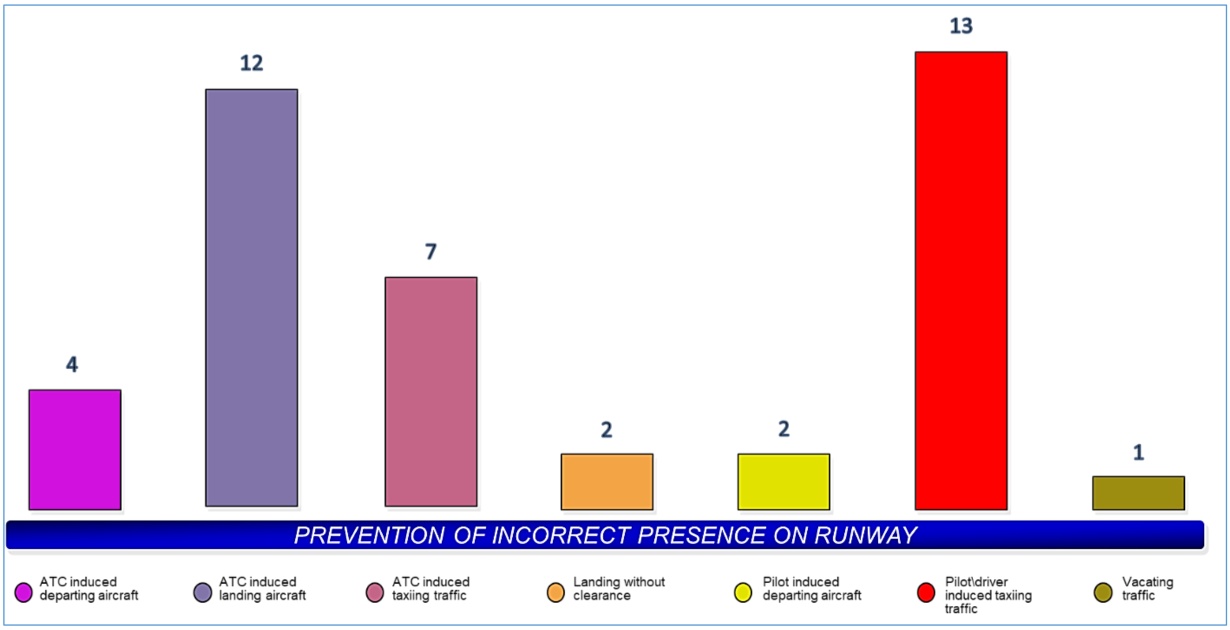

Figure 6-2: Runway incursion scenarios and initiators

The SAFMAP analysis helped identify the following initiating factors that played a role in the 2022 occurrence data sample:

- In 13 incidents (32% of the data sample) the incorrect presence on runway was caused by "Pilot/driver induced incorrect entry of taxiing traffic onto the runway protected area", an increase from around 22% in the previous three years.
- In 12 incidents (29% of the data sample) the runway incursion/runway spacing minimum infringement was caused by an "ATC induced incorrect presence of landing aircraft", decreasing from 47% in 2021.
- In 7 incidents (17%) the incorrect presence on runway occurred due to "ATC induced incorrect entry of taxiing traffic onto the runway protected area" - almost tripling its share from 2021 (6%).
- In 4 incidents (10% of the data sample) the initiator was "ATC induced incorrect presence of departing aircraft", similarly to 2021 (8% of its data sample).
- In 2 incidents the runway incursion was caused by "Aircraft landing without clearance" – 5% of the data sample, almost three times less than in the previous two years.
- In 2 incidents (5%), the runway incursion was due to "Pilot induced incorrect presence of departing aircraft on the runway protected area" (1 incident, 3% in 2021).

The notable difference in the distribution of the events by initiator to the 2021's sample, is that:

- "Pilot/driver induced incorrect entry of taxiing traffic onto the runway protected area" events have increased and overtaken "ATC induced incorrect presence of landing aircraft on the runway protected area" events (which was the main initiator in 2021),
- "ATC induced incorrect entry of taxiing traffic onto the runway protected area" events have nearly tripled, and
- "Landing without clearance" events have fallen to almost a third from 2021.

It is worth noting that ATC induced events of incorrect presence on the runway protected area (of taxiing traffic, landing and departing aircraft) made up more than half of all incidents – 23 out of 41 events, or 56% of the data sample.

6.3. Barriers' resilience per initiator

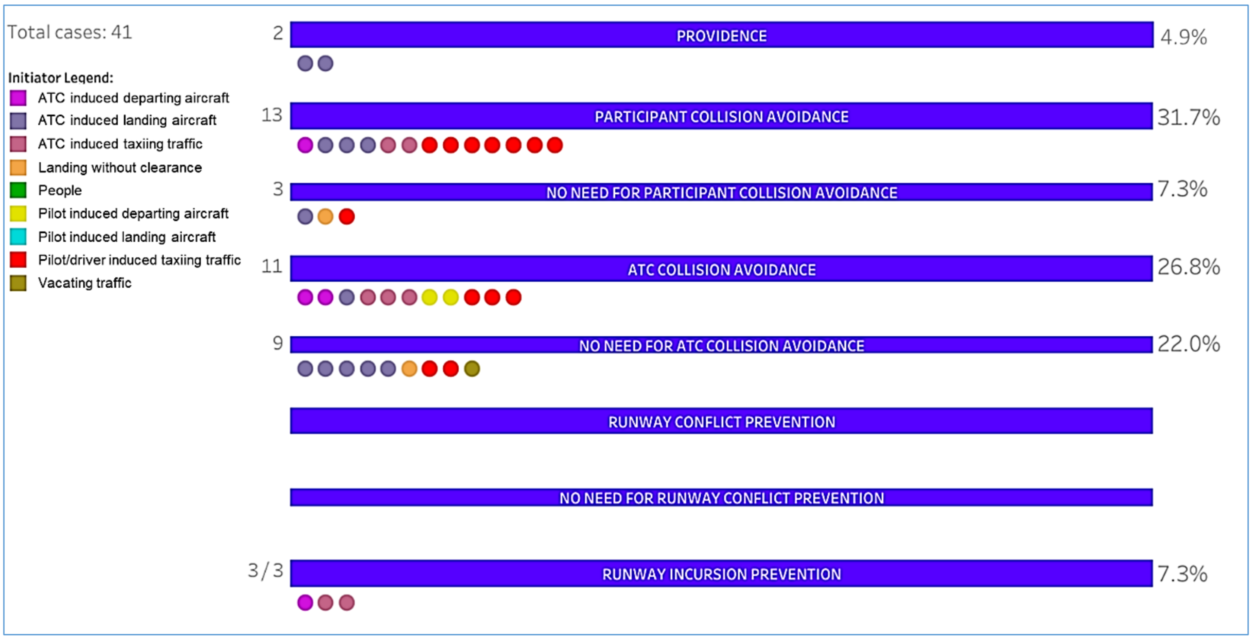

Figure 6-3: Barrier resilience per initiator

Figure 6-3 illustrates the distribution of incidents that were stopped by a barrier and those that crossed it, as well as the resilience of the barriers to the different initiators. The following can be concluded regarding the barrier effectiveness:

- 44% of the events crossed all ATC runway collision prevention barriers – resulting in a decline in barrier effectiveness and increase in event criticality compared to the previous year (28%).
- The "ATC runway collision avoidance" barrier stopped nearly half of the hazardous events, (49% of all events, with "No need for ATC collision avoidance at 22%).
- No event was stopped at the "Runway conflict prevention" barrier in 2022 – a drop from 17% in 2021.
- 27% of the incidents were resolved without ATCO or conflict participant proactive intervention (these events were stopped by the 'technical barriers' "No need for ATC collision avoidance" and "No need for participant collision avoidance"), down from 39% in 2021.

The trend established by the previous two years' data samples with regard to the safety criticality of the various initiators was broken in 2022. The following can be noted regarding the runway incursion initiators:

- The most critical events in last year's sample are those of "ATC induced incorrect presence of landing aircraft".
- The second in terms of criticality initiator is "Pilot/driver induced incorrect entry of taxiing traffic onto the runway protected area".
- "ATC induced incorrect entry of taxiing traffic onto the runway protected area" and "ATC induced incorrect presence of departing aircraft on the runway protected area" events have a nearly identical distribution across the barriers.

6.4. Pilot/driver induced taxiing traffic events

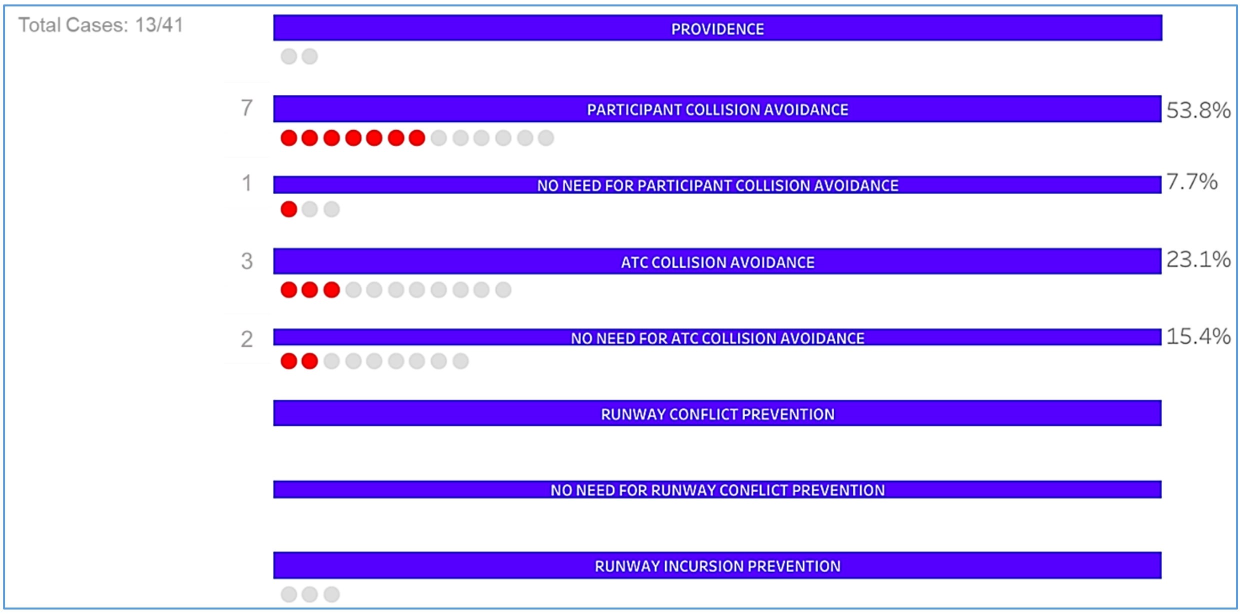

Figure 6-4: Incorrect RWY entry caused by pilot/driver

Figure 6-4 provides insight into the incidents of incorrect entry of taxiing traffic onto the runway protected area induced by pilot/driver. The following was identified:

- 62% of these events reached and were stopped at the “Participant collision avoidance” barrier.
- The higher criticality events involved omitted lack of clearance or incorrect clearance execution (each of these initiating factors accounting for 21% of the events (3 out of 13). This finding is consistent with previous years.
- 54% could have been prevented by stop bars.
- 54% involved non-commercial flights.
- 21% included conditional clearance.

Due to the share and high safety criticality of the events involving incorrect entry of taxiing aircraft or vehicles onto the runway protected area, it is suggested to monitor the safety risk associated with events involving “Pilot/driver induced incorrect entry onto the runway protected area”.

6.5. ATC induced landing aircraft events

Figure 6-5: Incorrect presence of landing aircraft induced by ATC

Figure 6-5 provides insight into the causal factors of the incidents of "ATC induced incorrect presence of landing aircraft". The following was identified:

- The safety criticality of this type of event has spiked during 2022 compared to previous years.
- 66% of events were due to insufficient aircraft spacing; half of them were only stopped at the "Participant collision avoidance" barrier.
- 33% were caused by incorrect/late ATC clearance; half of these were only stopped at the "Providence" barrier, thus are of higher safety criticality.
- In 1/4th of events, ATC did not detect the conflict and issued landing clearance despite the correct presence of another aircraft/traffic on the runway, including the 2 incidents that reached the "Providence" barrier.
- In 17%, non-commercial flights were involved.
- In 17%, vehicles were involved.
- 17% occurred during high ATC workload.

6.6. *ATC not detecting the potential runway conflict*

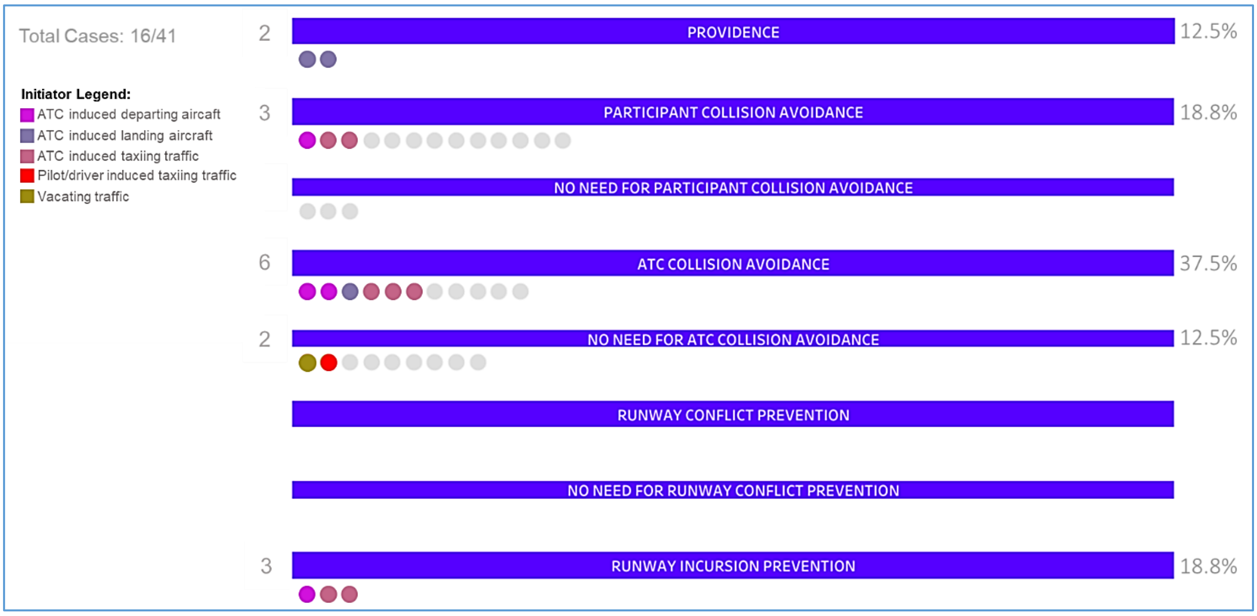

Figure 6-6: Non-detection of potential RWY conflict by ATC

Figure 6-6 showcases the events in which ATC did not detect the potential runway conflict. The following can be noted:

- The incidents in which ATC did not detect the potential runway conflict account for 39% of the analysed sample.
- 31% of the events passed all ATC barriers, comprising all incidents that reached the last barrier "Providence".
- The largest initiator was "ATC induced incorrect entry of taxiing traffic onto the runway protected area", making up almost half (44%) of these events.
- In 25% of these conflicts, ATC issued take-off clearance despite the correct presence of another aircraft/traffic on the runway (i.e. the "ATC induced departing aircraft" initiator).
- In 19% of these conflicts, ATC issued landing clearance despite the correct presence of another aircraft/traffic on the runway (or "ATC induced landing aircraft").
- In 13%, ATC issued landing clearance despite the incorrect presence of another aircraft/traffic on the runway.
- 31% factored incorrect use of runway occupancy memory aids.
- 31% involved vehicles.
- 25% factored a runway crossing.
- 19% involved non-commercial flights.

Due to the significant share and high safety criticality of the events associated with ATC not detecting the runway conflict, it is suggested to keep "Controller detecting the potential runway conflict" as a safety priority in 2023.

6.7. Contextual factor analysis – runway incursion

This section presents the results of the analysis of the typical contextual factors, for which information was available in the description of the occurrences of incorrect presence on the runway included in the 2022 data sample. The following contextual factors were selected for their significance: non-commercial flight involved, stop bars being able to prevent the conflict, and vehicle participating in the scenario.

6.7.1. Non-commercial flight involved

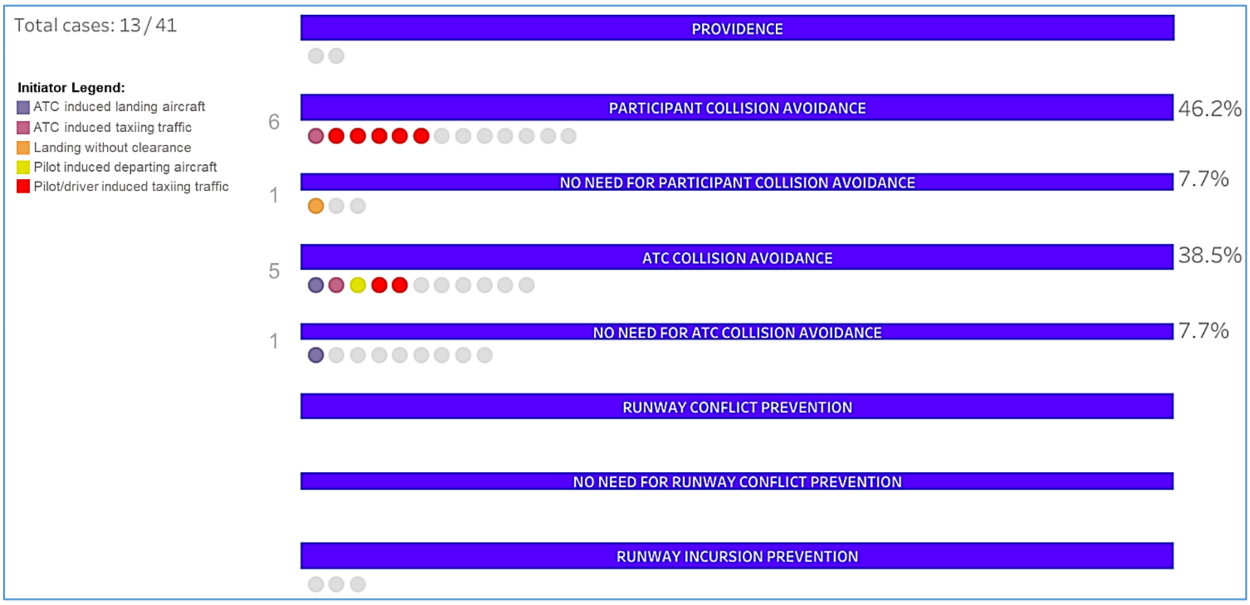

Figure 6-7: Non-commercial flight involved

Figure 6-7 illustrates the incidents associated with reported non-commercial flight involvement. The following can be noted:

- The incidents which involved non-commercial flight account for 32% of 2022's data sample (the same as in the previous year's sample).
- Comparably to 2021, 54% of them were stopped at the "Participant collision avoidance" barrier, thus these events including this contextual factor remain of high safety criticality.
- "Incorrect entry of taxiing traffic onto the runway protected area induced by pilot/driver" is the largest initiator for events involving non-commercial flights.
- 38% were preventable by stop bars.
- In 23% of cases, ATC did not detect the potential runway conflict when issuing clearance.
- 15% involved vehicles.
- In 15% runway occupancy memory aids were incorrectly used by ATC.

It is therefore suggested to continue monitoring the safety risk associated with events involving incorrect presence of non-commercial flight aircraft on the runway protected area.

6.7.2. Conflicts that could have been prevented by stop bars

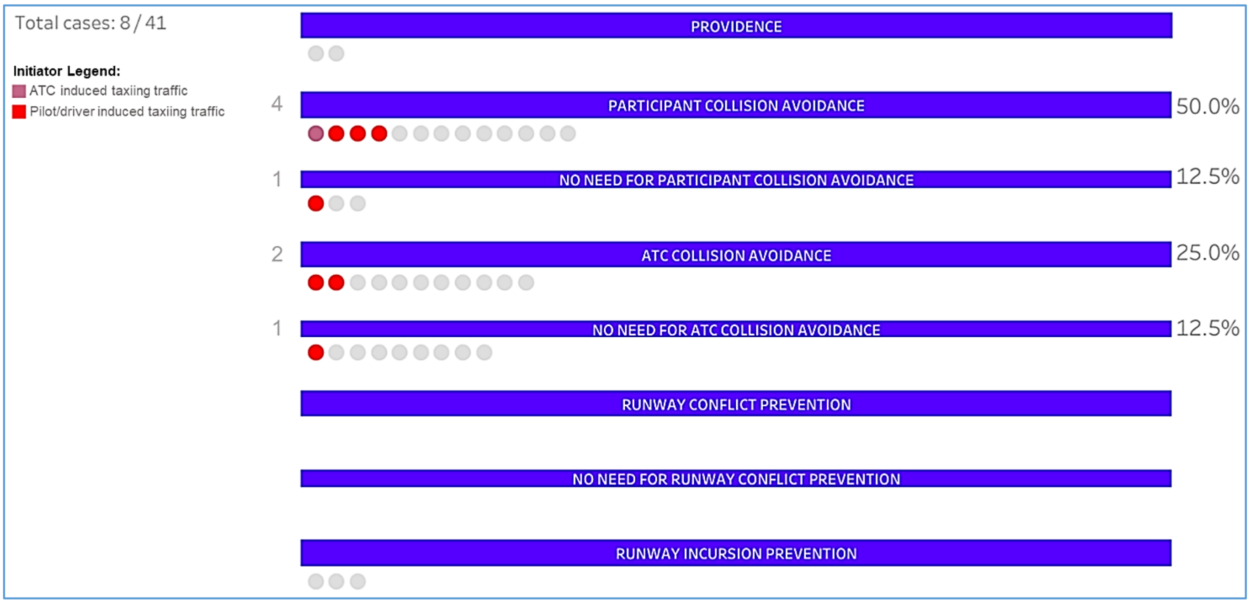

Figure 6-8: Incidents preventable by stop bars

Figure 6-8 showcases the incidents which could have been prevented by stop bars. The following can be noted:

- 20% of all events in the analysed sample could have been prevented by stop bars if installed at all runway holding points and used 24 hours – double from the previous year.
- 63% of these events are of high safety criticality (up from 50% in 2021), accounting for 28% of all events that passed all ATC barriers.
- The same event initiators were present as in 2021.
- 63% involved non-commercial flights and 25% involved vehicles.
- In 25% technical issues were being experienced with the (A)SMGCS and ATC did not detect the potential runway conflict before issuing clearance.

Further to the conclusions of this and the previous years' data sample analyses, it is suggested to continue monitoring the risk associated to events that "could have been prevented by stop bars".

6.7.3. Events with vehicle participation

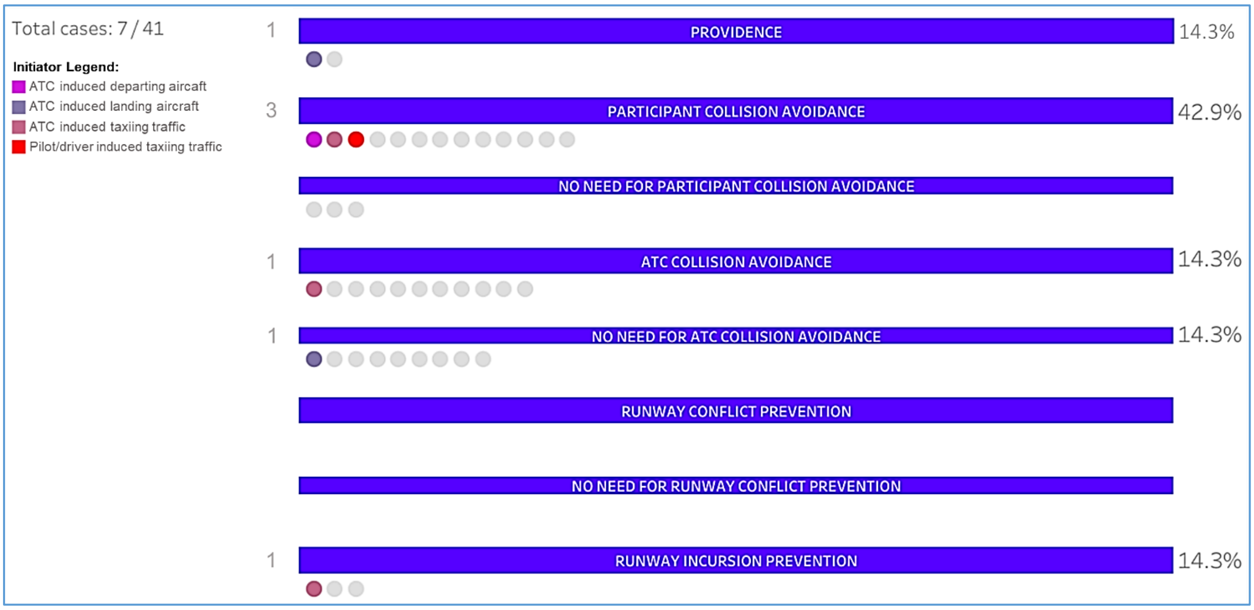

Figure 6-9: Incidents involving vehicles

Figure 6-9 illustrates the incidents associated with reported vehicle involvement. The following can be noted:

- Events involving vehicles make up 17% of analysed sample (down from 25% in 2021).
- Such events are of high safety criticality: 57% reached the last two barriers, accounting for 22% of all 2022 events that reached them.
- Almost all (86%) were events in which the incorrect presence on the runway was induced by ATC.
- In most (71%), ATC did not detect that issuing a clearance would create a runway conflict (usually a landing or take-off clearance to aircraft while a vehicle was already cleared on the runway).
- In 29%, ATC operational position handover/takeover was a contributing factor.
- 29% could have been prevented by stop bars.
- In 29%, ATCO did not use runway occupancy memory aids correctly.
- 29% involved non-commercial flights.

Due to the share and safety criticality of the events involving vehicles, it is suggested to continue monitoring the safety risk associated with events involving "Incorrect presence of vehicles on the runway protected area".