NM Top 5 Safety Priorities
Safety Functions Map Analysis
of European A and B severity safety incidents
2023 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 2024 within the context of Network Manager Safety Prioritisation Process. The analysis is based on 2023 incident data sample built by the occurrence data provided by European ANSPs.

This analysis also provides information regarding to 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 of severity A or B. Therefore, the information in the sample is 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 suggested to be retained as safety priorities:

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

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

- **"High workload".**
- **"Non-commercial/non-scheduled flights".**
- **"VFR/IFR conflicts in TMA/CTR airspace".**
- **"Synchronisation of successive arriving to land and of arriving to land and departing aircraft".**
- **"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 **26 Air Navigation Service Providers** (see Figure 2-1).

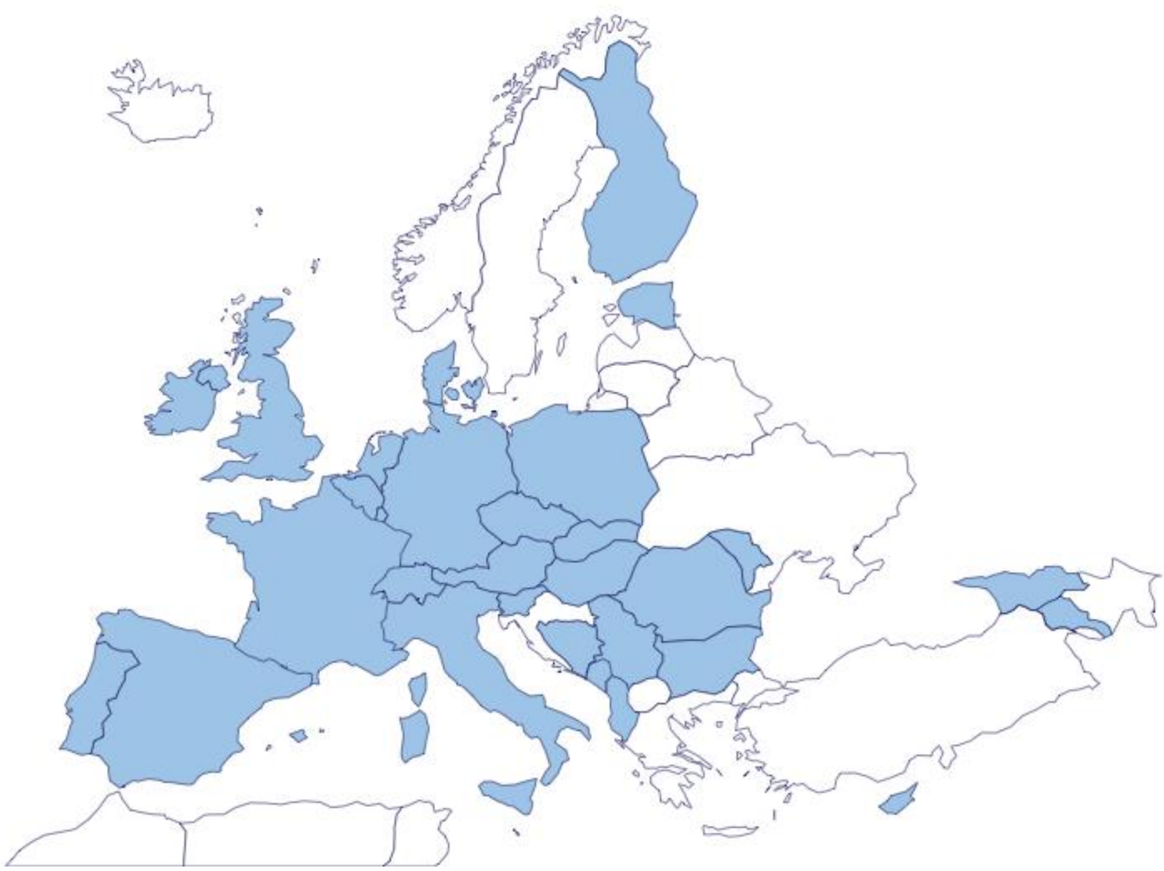

Figure 2-1: Participating ANSPs

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, **254 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:

- **98 separation minima infringements in the en-route phase of flight**, 9 of which have been classified as severity A and 89 as severity B incidents – see the on-line dashboard here.
- **101 TMA/CTR related separation minima infringements**, 11 of which have been classified as severity A and 90 as severity B incidents – see the on-line dashboard here.
- **55 runway incursions**, 3 of which have been classified as severity A, 52 as severity B incidents – see the on-line dashboard here.

Figure 2-2: Analysed data sample

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 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 functions 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.

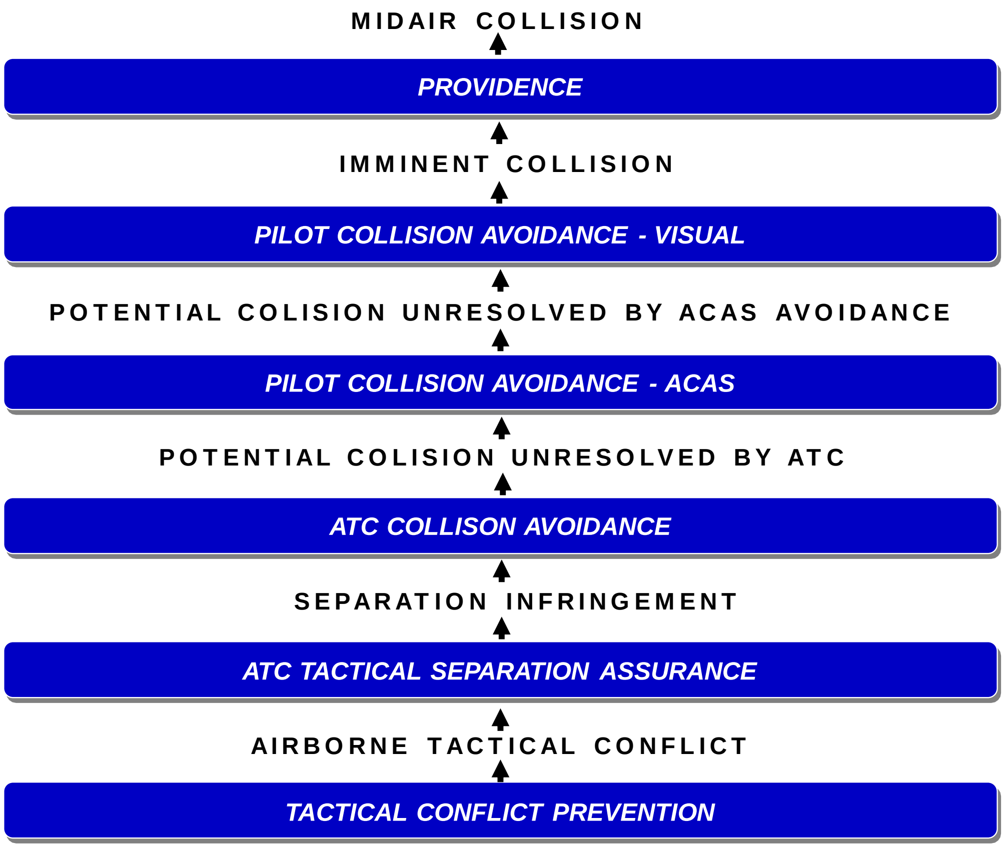

Figure 3-1: SAFMAP basic safety functions

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 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 4 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.

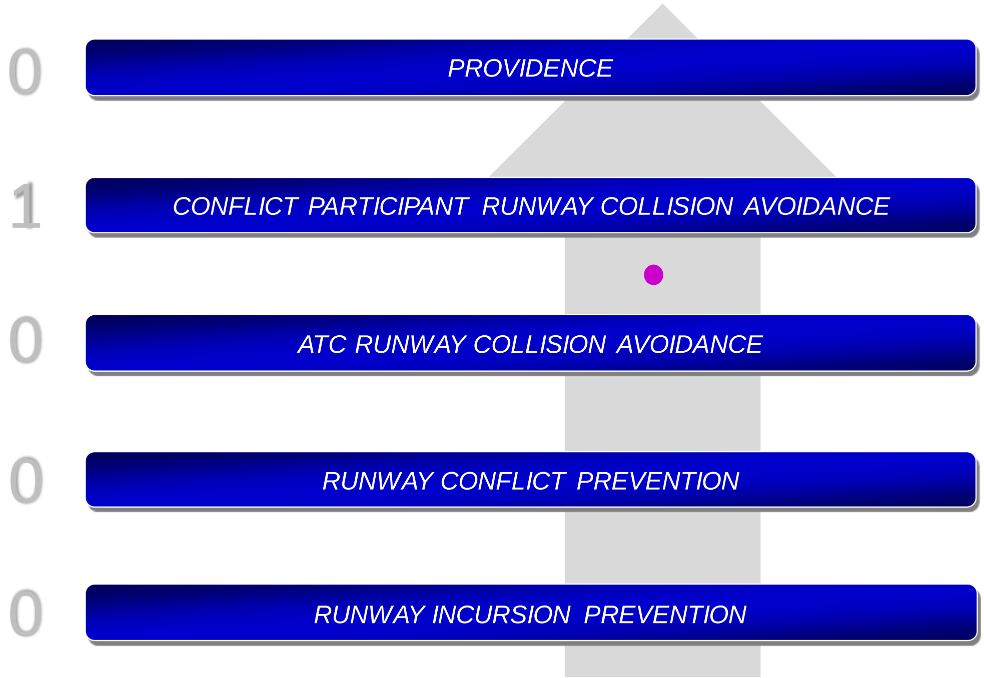

Figure 3-2: Incident data presentation example

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*

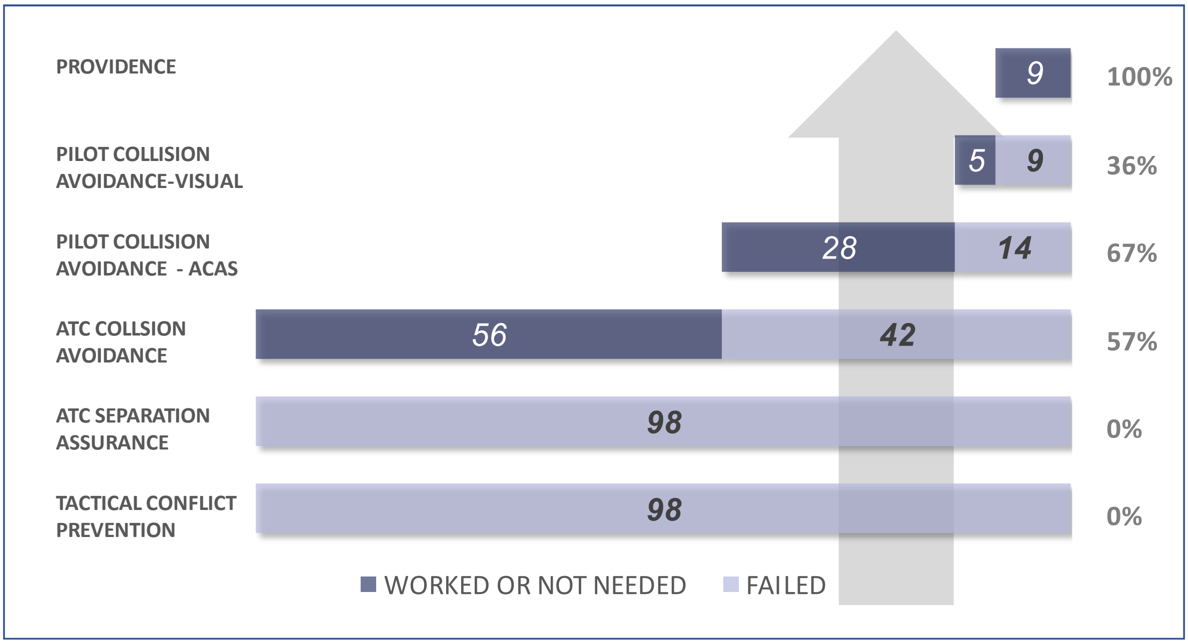

Figure 4-1: Overall barrier performance

- Performance of the Basic Barrier "Tactical conflict prevention": challenged 98 times, failed in 98 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 98 times, failed in 98 cases.
- Performance of the basic barrier "ATC collision avoidance": challenged 98 times, failed in 42 cases (43%) and worked or was not needed in 56 cases (57% success). In 28 cases this barrier was not needed.
- Performance of the basic barrier "Pilot collision avoidance - ACAS": challenged 42 times, failed in 14 cases (33%) and worked or was not needed in 28 cases (67% success). In 7 cases this barrier was not needed.
- Performance of the basic barrier "Visual collision avoidance": challenged 14 times, failed in 9 cases (64%) and worked or was not needed in 5 cases (36% success). In 8 of the incidents where this basic barrier failed the initiator was restricted airspace infringement. The 9th one was caused by pre-tactical deconfliction procedures failure and involved a military formation. In 3 cases this barrier was not needed.
- Performance of the basic barrier "Providence": challenged 9 times, worked or was not needed in all 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.

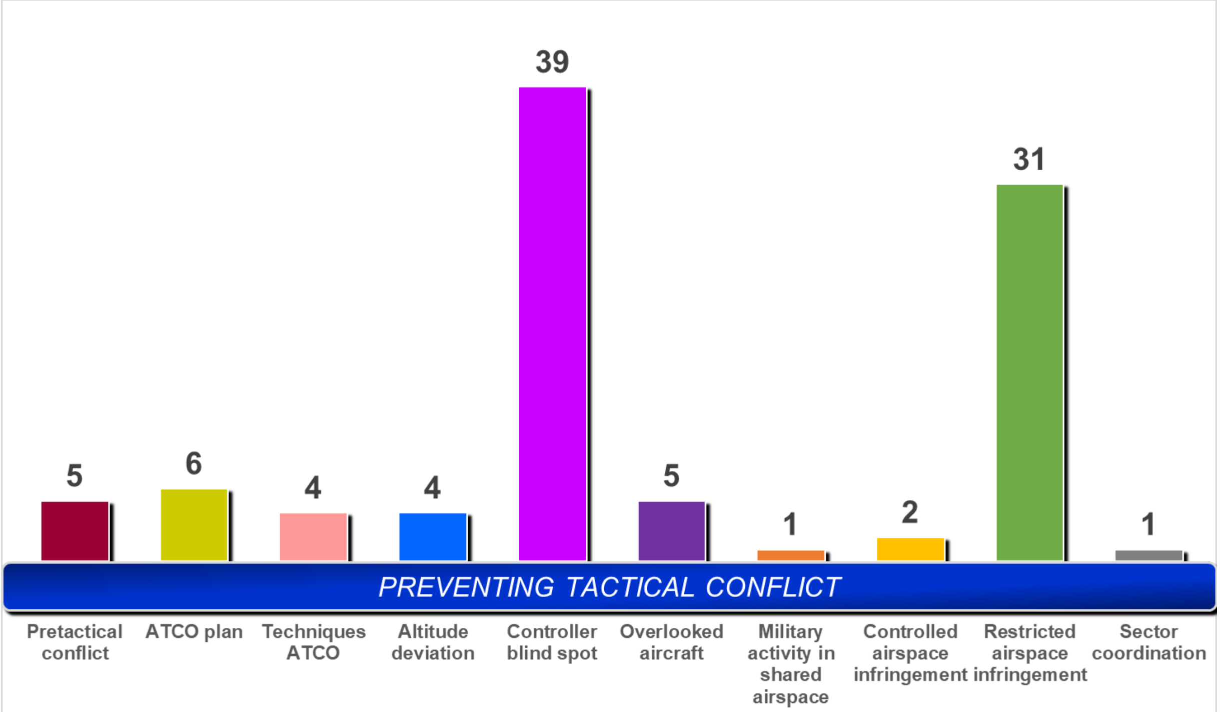

Figure 4-2: Barrier performance – Tactical conflict prevention

Performance of the basic barrier "Tactical Conflict Prevention" – failed in all 98 analysed events:

- In 39 incidents (40% 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 31 incidents (32% of the data sample) the conflict was generated by "Restricted airspace infringement".
- In 6 incidents (6% of the data sample) the conflict was generated by "Incorrect ATCO plan".
- In 5 incidents (5% of the data sample) the pre-tactical conflict was not prevented by the "ATC tactical planning" function.
- In 5 incidents (5% of the data sample) the conflict was generated by "ATCO overlooking an aircraft" while clearing or instructing another one which was not proximate.
- In 4 incidents (4% of the data sample) the conflict was generated by "Inadequate ATCO controlling technique".
- In 4 incidents (4% of the data sample) the conflict was generated by "Altitude deviation".
- In 2 incidents (2% of the data sample) the conflict was generated by "Controlled airspace infringement".
- In 1 incident (1% of the data sample) the conflict was generated by "Military flights in shared airspace".
- In 1 incident (1% of the data sample) the conflict was generated by incorrect inter-unit coordination.

It is worth noting that:

- Overlooking a conflicting aircraft (“Blind spot” and “ATCO overlooking an aircraft”) accounts for 45% of the events included in the 2023 en-route incident sample.
- The occurrences in the en-route sample are concentrated in two groups (“overlooking a conflicting aircraft” and “restricted airspace infringement”), accounting for ¾ of all events.

4.3. *Barriers' resilience per initiator*

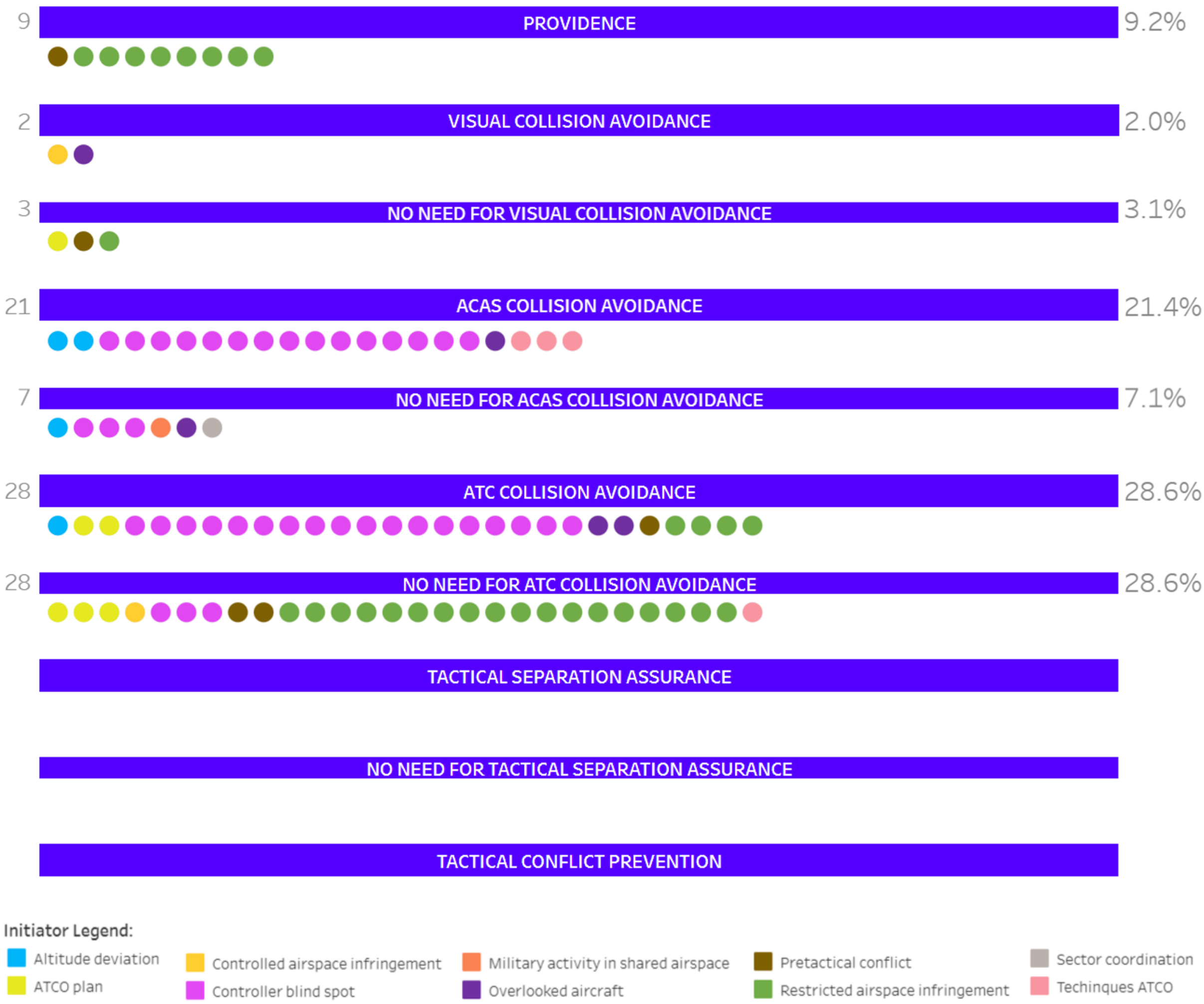

Figure 4-3: Barriers' resilience to initiators

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

- ❑ "Restricted airspace infringement represents almost a third of the incidents in the sample, and it also accounted for 8 out of 9 events that were stopped by the "Providence" barrier, the rest being stopped at the ATC Collison Avoidance barrier.
- ❑ The initiators causing the incident that was stopped at the "Pilot collision avoidance- Visual" barrier are "Controlled Airspace infringement" and "Overlooked Aircraft".
- ❑ 38% (15 events) of the blind spot incidents were stopped by the "Pilot collision avoidance – ACAS" barrier.

4.4. *"Blind Spot" events*

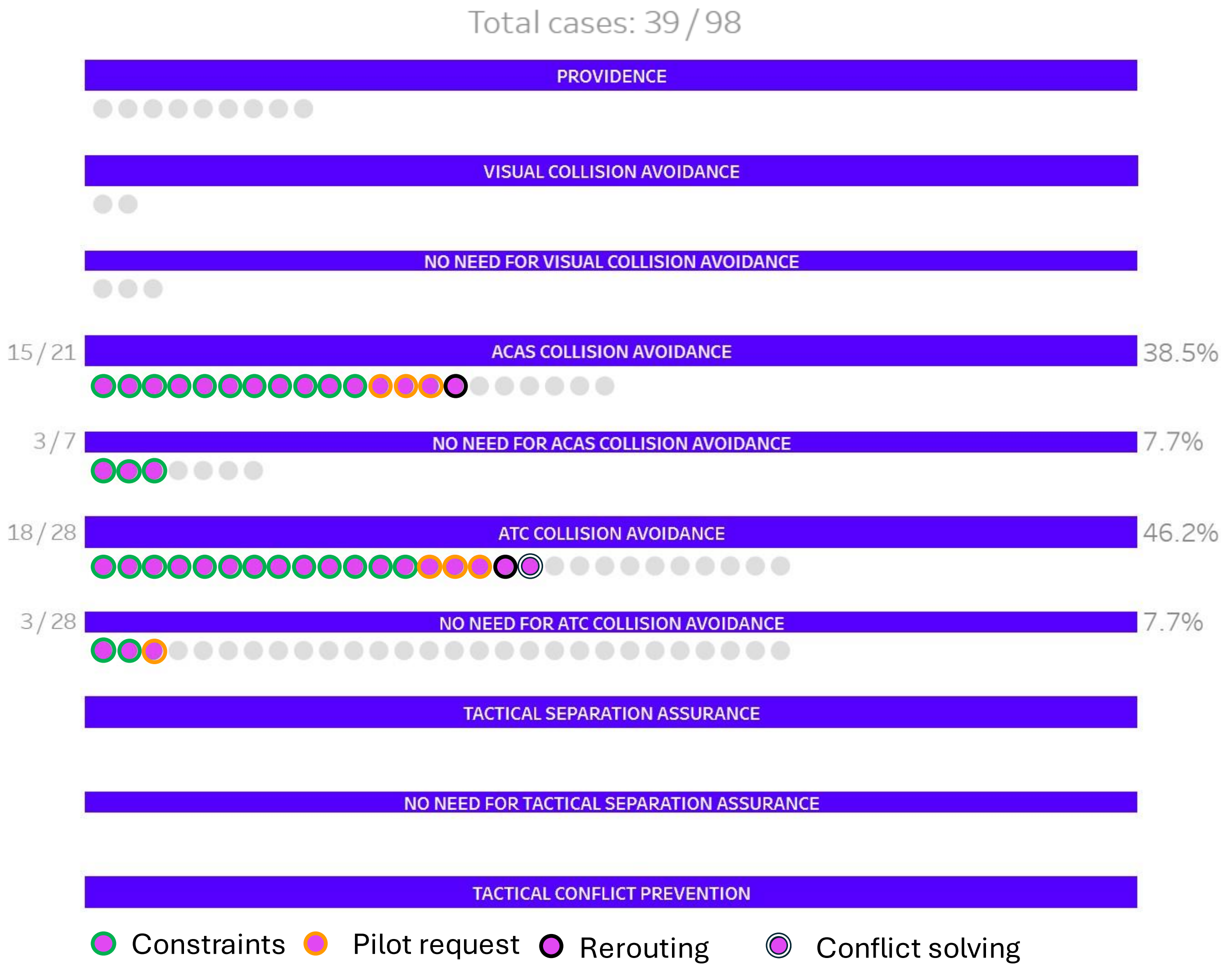

Figure 4-4: Blind spot events

Figure 4-4 provides insight into the specific initiators of the blind spot incidents. The following was identified:

- Almost half of the occurrences (18 out of 39) were stopped at the ACAS barrier (i.e. all controller-reliant barriers have been breached). This was the most frequent scenario.
- Almost ¾ of the occurrences (29 out of 39) were caused by issuing an instruction in order to meet standing sector exit constraint or filed FL in the FPL route.
- In 7 out of 39 events the conflicting clearance was issued after a pilot request to climb or descend.
- In two incidents the conflicting clearance involved a change in the horizontal flight profile (direct routing).
- In one event the conflicting clearance was issued in order to solve another conflict.

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 as a safety priority "Controller Blind Spot".

4.5. Restricted airspace infringement events

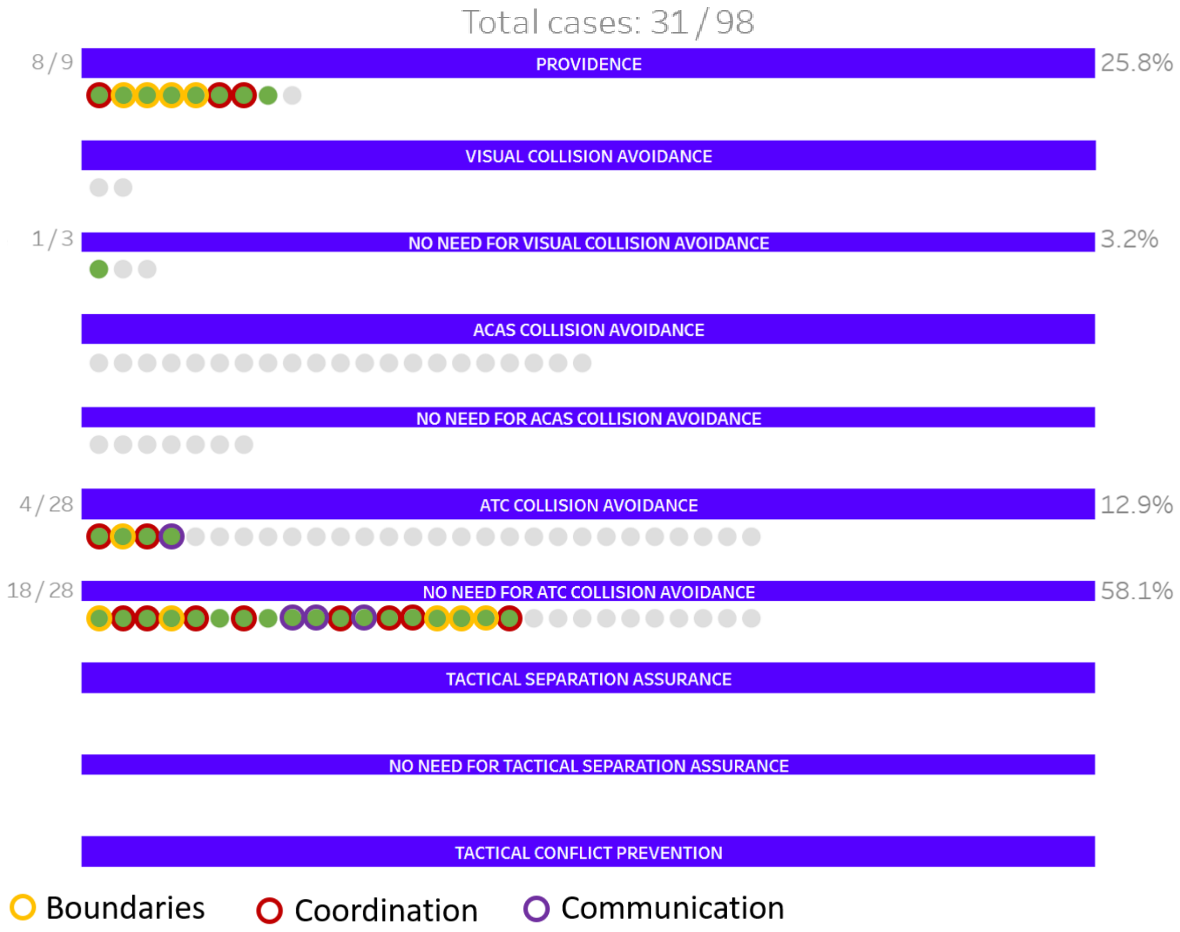

Figure 4-5: Restricted airspace infringement events

Figure 4-5 provides insight into the specific initiators of the restricted airspace infringement incidents. The following was identified:

- The restricted airspace infringement incidents are the events of highest safety criticality in the analysed 2023 en-route incident data sample.
- Restricted airspace infringement was the second most common initiator in the 2023 en-route sample.
- 9 out of 31 of these events passed the "ACAS collision avoidance" barrier and 8 were stopped at the final barrier, "Providence".
- In 10 of the events the underlying reason of the infringement was the fact that an ATCO was unaware of the lateral, vertical or time boundaries of the area being infringed.
- In 13 of the events improper coordination was identified as a contributing factor.
- In 4 of the events inadequate pilot-controller communication was identified as a contributing factor. In all these cases the communication was via CPDLC.

Considering the criticality of the "Restricted airspace infringement" incidents, it is suggested to retain it as a safety priority.

4.6. 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 2023 en-route data sample. Several contextual factors were selected for their significance, including: high workload, and on-the-job training,

4.6.1. High workload

Figure 4-6: Restricted airspace infringement events

Figure 4-6shows events where high workload was reported. The following was identified:

- High workload was reported in almost 20% of the events in the sample (18 out of 98).
- Two thirds (12 out of 18) of the incidents with reported high workload originated from a blind spot event.
- More than half (10 out of 18) of the events penetrated all ATC-based barriers.

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

4.6.2. Tracks in unconcerned colour

Figure 4-7: Tracks in unconcerned colour

Figure 4-7 shows events where the participating aircraft's tracks and labels were in "unconcerned" colour making them harder to recognize as a risk factor. The following was identified:

- In most cases the event initiator was "blind spot" (8 out of 11) or "overlooked aircraft" (2 out of 11).

Considering the prominence of the incidents associated with tracks in unconcerned colour, it is suggested that this factor is noted in the report.

4.6.3. *Flights without a transponder or with a dysfunctional one*

Figure 4-8: Flights without a transponder or with a dysfunctional one

Figure 4-8 shows events involving flights without a transponder or with a dysfunctional one. The following was identified:

- Most of the events (9 out of 11) were initiated by restricted airspace infringement. Almost all of these (8 out of 9) penetrated all barriers up to "providence". It should be noted that the use of restricted airspace often, by design and according to procedures, involves flying objects without transponders.
- Two events (unrelated to airspace infringement) involved military aircraft. One of these penetrated all barriers up to "providence".

Considering the significance of the incidents associated with flights without a transponder or with a dysfunctional one, it is suggested to retain "Flight without a transponder or with a dysfunctional one" as a safety priority.

4.6.4. *Incidents involving use of CPDLC*

Figure 4-9: Incidents involving use of CPDLC

The 2023 sample contains 7 events where CPDLC was identified as a factor. The following was identified:

- In 4 cases the poor CPDLC communication led to restricted airspace infringement.
- Only one event penetrated the “ATC collision avoidance” barrier.

Considering that CPDLC is a relatively newly implemented technology, it is suggested that this factor is noted in this report.

4.6.5. *Incidents involving non-commercial/non-scheduled flights*

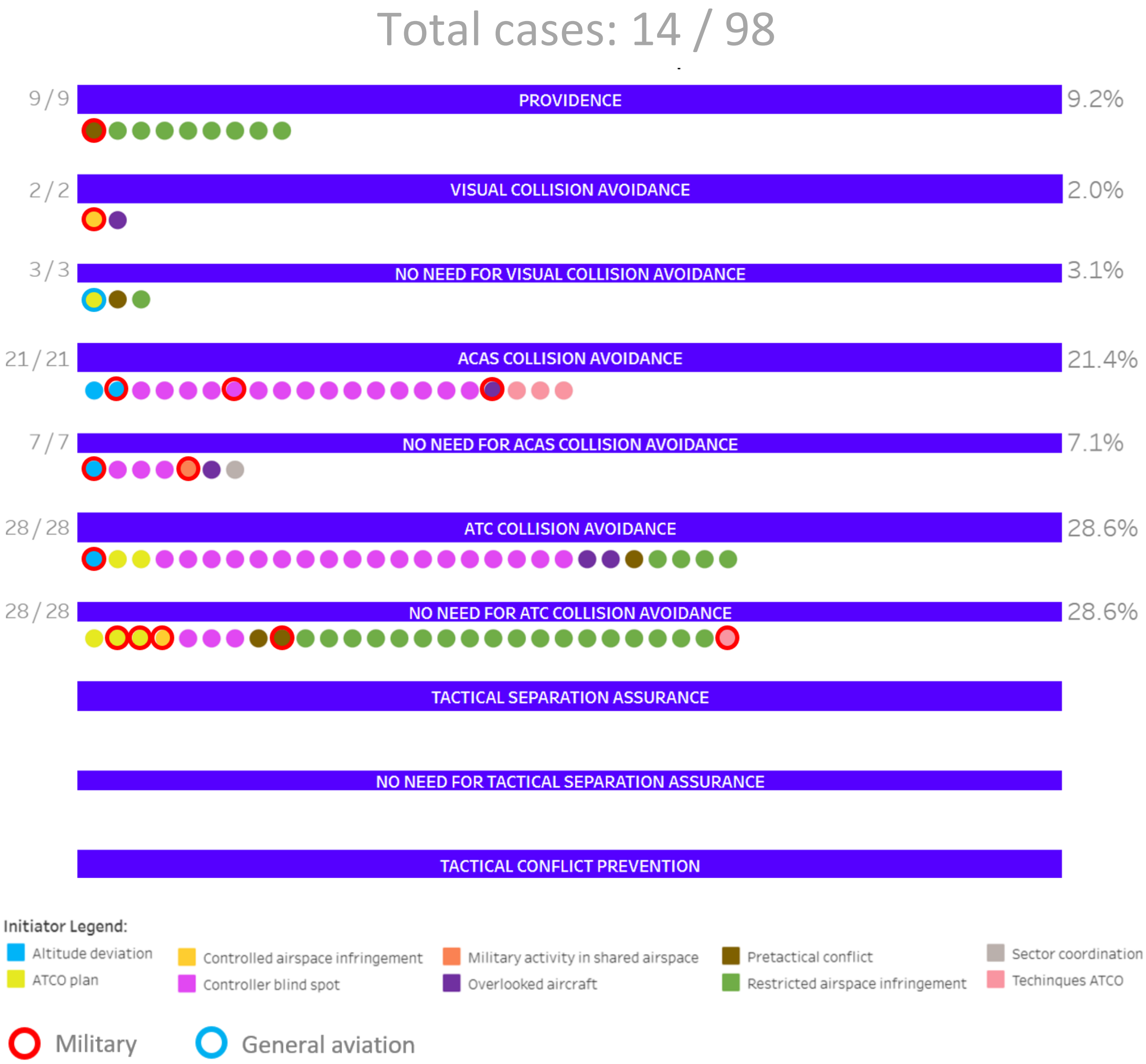

Figure 4-10: Incidents involving non-commercial/non-scheduled flights

The 2023 sample contains 14 events where non-commercial/non-scheduled flights were involved. The following was identified:

- Most cases (13 out of 14) involved military aircraft and 1 involved general aviation aircraft
- 8 events penetrated the “ATC collision avoidance” barrier.
- The events were spread over 8 groups of initiators, excluding the “Restricted airspace infringement” initiator and including only 1 “Blind spot” event.
- “Altitude deviation” and “ATCO plan” were the most common initiators (3 events each)
- “Controlled airspace infringement” and “Pre-tactical conflict” were identified as initiators in 2 events each (4 events in total).

Considering the significance of the incidents associated with non-commercial/non-scheduled flights, it is suggested that this factor is monitored for the risk associated with it.

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

5.1. *Overall barrier performance – TMA/CTR*

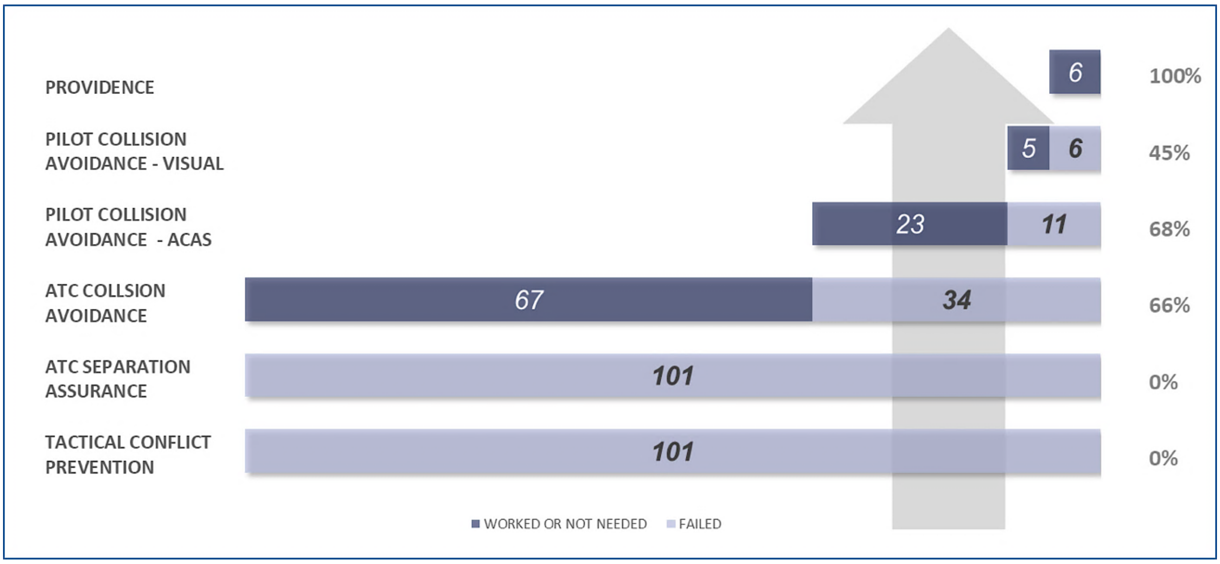

Figure 5-1: Overall barrier performance

- Performance of the basic barrier "Tactical conflict prevention": challenged 101 times, failed in all 101 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 101 times, failed in all 101 cases. 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 collision avoidance": challenged 101 times, failed in 34 cases (34%) and worked or was not needed in 67 cases (66% success).
- Performance of the basic barrier "Pilot collision avoidance - ACAS": challenged 34 times, failed in 11 cases (32%) and worked or was not needed in 23 cases (68% success). In all 11 events 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 6 cases (55%) and worked or was not needed in 5 cases (45% success).
- Performance of the basic barrier "Providence": challenged 6 times, worked or was not needed 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.

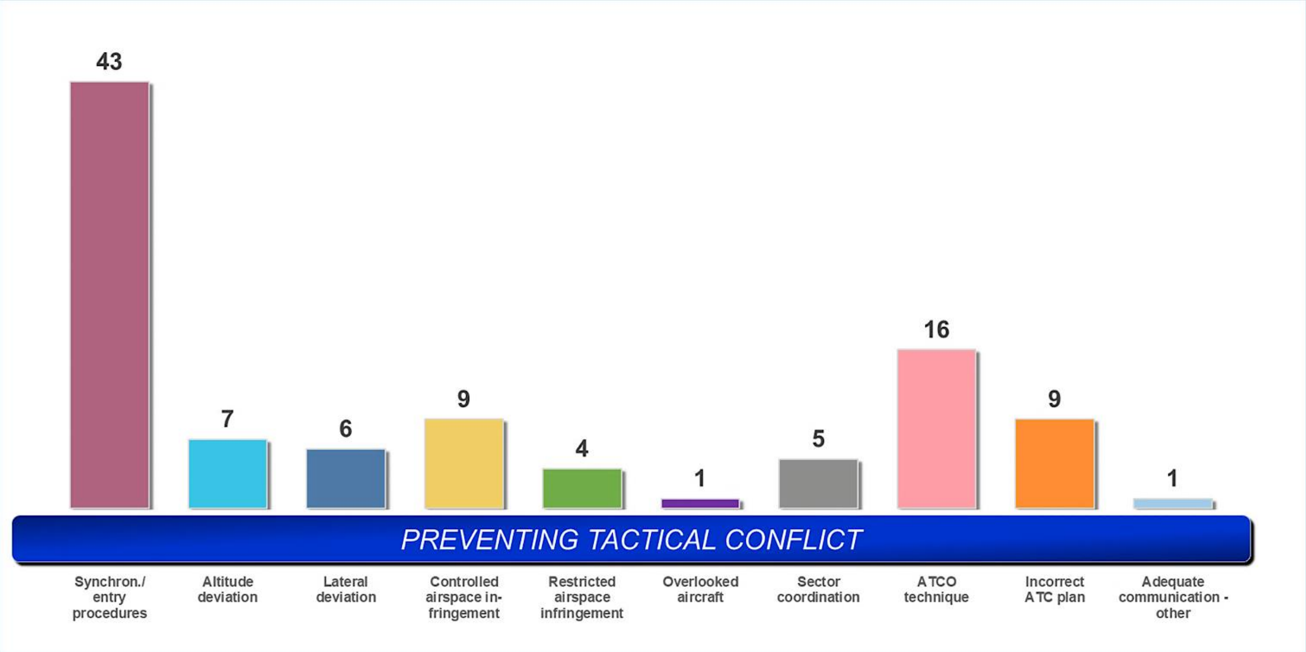

Figure 5-2: Separation minima infringement scenarios and initiators

The SAFMAP analysis helped identify the following initiating factors that played a role in the 2023 occurrence data sample:

- ❑ In 43 incidents (43% of the data sample) the conflict was generated by "ATC tactical planning and traffic synchronisation". This initiator's share remains consistent with 2022's 46%.
- ❑ In 16 incidents (16% of the data sample) the conflict was generated by "Incorrect ATCO techniques. This factor also contributed to 28% of the traffic synchronization events, adding up to an overall share of 28% in the analysed data sample.
- ❑ In 9 incidents (9% of the data sample) the conflict was generated by "Incorrect ATCO plan". This factor also contributed to 12% of the traffic synchronization events, adding up to an overall share of 14% in the analysed data sample.
- ❑ In 9 incidents (9% of the data sample) the conflict was generated by "Controlled airspace infringement".
- ❑ In 7 incidents (7% of the data sample) the conflict was generated by "Altitude deviation".
- ❑ In 6 incidents (6% of the data sample) the conflict was generated by "Lateral deviation".
- ❑ In 5 incidents (5% of the data sample) the conflict was generated by "Sector coordination".
- ❑ In 4 incidents (4% of the data sample) the conflict was generated by "Restricted airspace infringement".
- ❑ In 1 incident (1% of the data sample) the conflict was generated by "Overlooked aircraft".
- ❑ In 1 incident (1% of the data sample) the conflict was generated by "Inadequate communication – other".

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 share of events stopped at each basic barrier in 2023 has largely remained the same as in 2022.
- The majority of events were stopped at the "ATC collision avoidance" barrier – 68% – same as in the previous year.
- 23% of all incidents were stopped at the "Pilot collision avoidance – ACAS" barrier.
- 5% of all incidents were stopped by "Pilot collision avoidance – visual", none requiring pilot visual collision avoidance action.
- 6% of incidents reached the last barrier "Providence".
- The initiators with the highest safety criticality remain the same from the previous year: "Controlled airspace infringement" – responsible for 55% of all events in the data sample that reached the last two barriers – and "Restricted airspace infringement" – 27%. The ATC barriers could not prevent and resolve three quarters of airspace infringement conflicts.
- The largest initiator, "ATC tactical planning and traffic synchronisation" has remained largely the same in terms of safety criticality from the previous year.
- "Incorrect ATCO technique" events saw somewhat increased safety criticality (compared to previous years) with 31% having been stopped by the "Pilot Collision Avoidance – ACAS" barrier. "Incorrect ATCO plan" events show the same trend, 1/3rd being stopped by the "Pilot Collision Avoidance – ACAS" barrier.

- “Altitude deviation” conflicts show a similar distribution across the barriers to the previous year, with 29% (2 events) reaching “Pilot collision avoidance – ACAS” barrier.
- “Sector coordination” conflicts were among the lower safety criticality events in the sample, all stopped by the “ATC collision avoidance” basic barrier.
- The only “Overlooked aircraft” event was stopped by “ATC collision avoidance”.
- The only event of “Inadequate communication – other” was also stopped by “ATC collision avoidance”.

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 2023: incorrect traffic synchronisation by ATC. The following was identified:

- 81% of incorrect traffic synchronisation events were stopped at the "ATC collision avoidance barrier".
- 19% were stopped at the "Pilot collision avoidance – ACAS" barrier.
- 2% (1 event) reached the "Pilot collision avoidance – Visual" barrier.
- Half (51%) of events involved inadequate synchronisation between successive arriving aircraft; 28% between a departing and an arriving aircraft; 12% - between successive departing aircraft; and 9% involved inadequate TMA tactical planning.
- The largest contributory factors were:
    - incorrect interception of final approach (arrivals) – 33%
    - inadequate ATCO controlling techniques, including vectoring, speed management and rate of change management (all) – 28%
    - go-around conflict with departing aircraft (mixed) – 16%
- In 37% of incorrect traffic synchronisation incidents, ATCO did not assure tactical separation due to inadequate controlling techniques (2nd basic barrier failure).
- In 28% of incorrect traffic synchronisation incidents, ATCO did not assure tactical separation due to flawed decision/goals.
- In 14%, ATC detected the separation minima infringement late (in half of those with the aid of STCA).

- In 9%, there was insufficient time for separation assurance by ATC.
- In 28%, ATC detected the conflict too late to prevent separation infringement but in time to issue successful collision avoidance instruction.
- 51% of incorrect traffic synchronisation incidents occurred during sequencing for final approach.
- In 16% of this group of incidents, a flown missed approach/go-around was a contributing factor.
- In 12%, wake vortex was an issue.
- 12% involved non-commercial flights.
- 12% occurred during controller on-the-job training.
- 12% occurred during high ATC workload.
- 12% occurred after controller position handover/takeover.

In view of the above findings, 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*

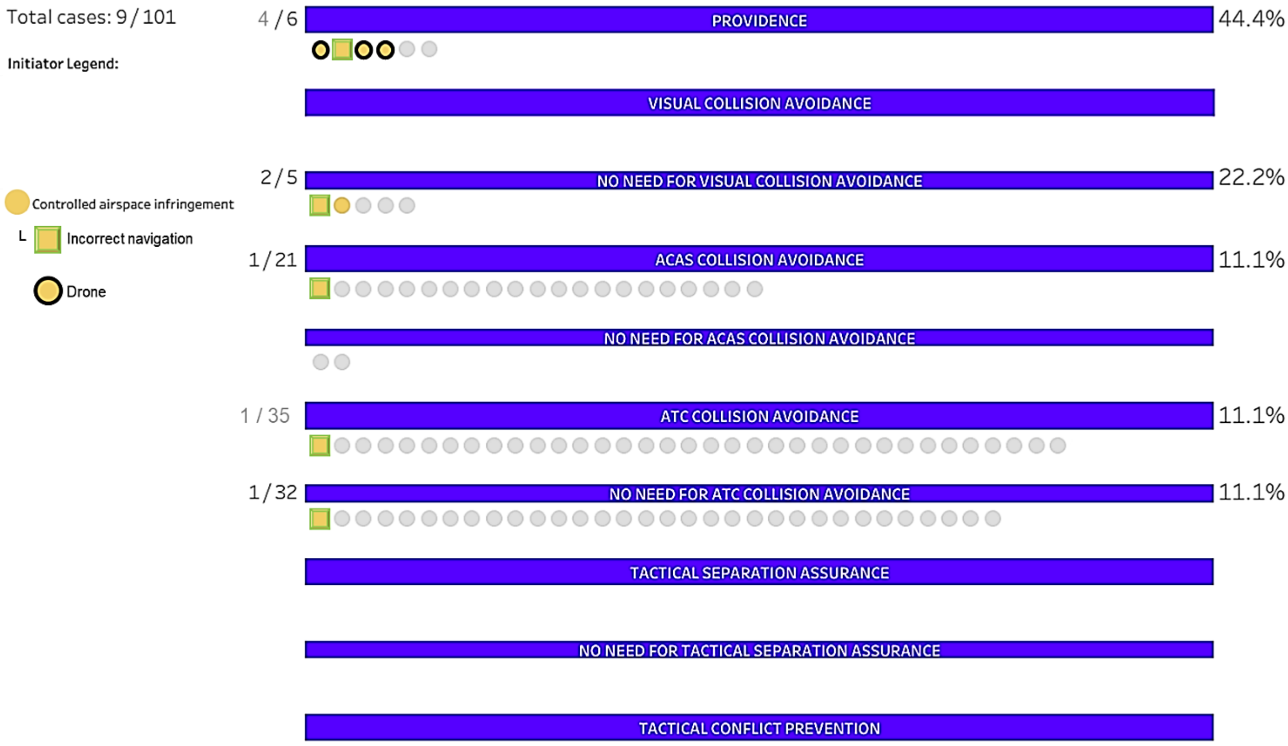

Figure 5-5: Controlled airspace infringement incidents

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

- ❑ Controlled airspace infringements are characterised by high safety criticality.
- ❑ 67% of controlled airspace infringement incidents reached the last two barriers, comprising over half (55%) of all events in the sample that did so.
- ❑ They account for 67% of all events in the sample were only stopped by Providence (3 drones and a paraplane).
- ❑ 55% of controlled airspace infringements were due to incorrect flight navigation and 33% were caused by drones.
- ❑ In the majority of events (66%), the conflict was undetectable and ATC tactical separation assurance and collision avoidance were unavailable.
- ❑ In 78% of the events, the aircraft infringing CAS were not transponder equipped and ACAS collision avoidance was unavailable.
- ❑ In 33%, visual collision avoidance was unavailable.
- ❑ 66% involved non-commercial flights.
- ❑ 44% involved VFR flights.

Due to their high safety criticality in the 2023 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:

- There were few events but with high safety criticality: 75% of restricted airspace infringement events were stopped by the last two barriers, and they account for 27% of all events in the sample that reached the last two barriers.
- In 3 out of the 4 events (75%) separation assurance was not ATCO responsibility, and in the remaining 1 event, the conflict was undetectable (active shooting range area).
- In all cases ATC and ACAS collision avoidance were unavailable.
- Half of restricted airspace infringement incidents involved aircraft not equipped with a transponder.
- Half occurred during controller on-the-job training.
- Half involved non-commercial flights.

Due to their high safety criticality in 2023's enroute and TMA/CTR data samples, it is suggested to retain "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 2023 data sample. Several contextual factors were selected for their significance, including: occurrence during sequencing for final approach, non-commercial flight involved, VFR flight involved, ACAS unavailability, ATCO on-the-job training and ATCO position handover/takeover.

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 35% of 2023's data sample.
- Most (74%) events were stopped at the "ATC collision avoidance" barrier and the remaining 26% were stopped at "Pilot collision avoidance – ACAS".
- 63% of incidents during sequencing for final approach were initiated by incorrect "ATC tactical planning and traffic synchronisation" (accounting for half of that entire initiator).
- In 31% ATCO did not assure separation due to flawed decision/goals.
- In 29% ATCO did not assure separation due to inadequate controlling techniques.

- In 17% 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.
- In 14% ATCO detected the separation conflict late (9% with STCA).
- 16% involved VFR flights.
- 14% occurred during ATCO on-the-job training.
- 14% occurred while an aircraft was cleared on heading/direct.
- In 11% wake vortex was an issue.
- 9% involved non-commercial flights.

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. *Non-commercial flights involved*

Figure 5-8: Non-commercial flights involved

Figure 5-8 illustrates the incidents associated with reported non-commercial flight involvement. The following can be noted:

- 23% of the analysed sample included non-commercial flight participation.
- 62% of all airspace infringement events involved non-commercial flights.
- 43% of incidents with non-commercial flight participation passed all ATC barriers.
- Incidents involving non-commercial flights account for just over half (55%) of all events in the sample that reached the last two barriers.
- In 22% of events with non-commercial flight involvement, ATC detected the conflict late (in half after STCA).
- In 22%, ATC did not assure separation due to flawed decision/goals.
- In 13%, ATC did not assure separation due to inadequate controlling techniques.
- In 26%, even though ATC did not prevent separation minima infringement, ATCO's actions were sufficient to prevent a collision.
- In 57%, the flight was conducted according to the VFR.
- In 39%, ACAS was unavailable.
- In 22%, ATC collision avoidance was unavailable.
- In 18% of cases, aircraft were not equipped with a transponder.

- In 13%, ATC tactical separation assurance was unavailable.
- 17% occurred after controller position handover/takeover.
- In 13%, flying a missed approach/go-around was contributing factor.
- 13% occurred during ATC on-the-job training.
- 13% occurred during high ATCO workload or overload.
- 13% occurred during sequencing for final approach.

It is suggested to keep monitoring the risk associated with non-commercial flights due to their considerable share in the analysed data sample and high safety criticality.

5.7.3. ACAS barrier not available

Figure 5-9: ACAS unavailable

Figure 5-9 illustrates the incidents associated with reported ACAS unavailability. The following can be noted:

- The ACAS barrier was unavailable in 14% of the studied sample. The unavailability of the barrier can be largely explained by the lack of equipped transponders in 64% of the events, including drone participation in 21%.
- Logically, events in which ACAS is not available could be of high safety criticality. This factor group encompasses 100% of events that reached the last two barriers in the 2023 data sample, same as in the previous year.
- All restricted airspace infringements fall into this category, and most (78%) of controlled airspace infringements.
- In the majority (71%) of these events, ATC collision avoidance was also unavailable.
- In half of the events, ATC tactical separation assurance was unavailable.
- In 29%, pilot visual collision avoidance was unavailable.
- 64% involved non-commercial flights.
- 36% involved VFR flights.
- 21% occurred during ATC on-the-job training.
- 14% occurred after controller position handover/takeover.

Due to the safety criticality and risk associated with events involving flights without a transponder, it is suggested to retain "Flights without a transponder or with a dysfunctional one" as a safety priority.

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

Figure 5-10: VFR flights involved

Figure 5-10 depicts the incidents in which VFR flight took part. The following can be noted:

- Incidents involving VFR flights account for 13% of the analysed sample.
- ATC barriers stopped 54% of all cases, as in the previous year. Even so, incidents involving VFR flights remain of relatively high safety criticality.
- VFR flights were involved in 44% of all controlled airspace infringement incidents.
- All VFR flight were non-commercial flights.
- In 23% of conflicts involving VFR flights, ATC detected the conflict late (with STCA).
- In 23%, ATC did not assure separation due to flawed decision/goals.
- In 15%, ATC did not assure separation due to inadequate controlling techniques.
- 30% occurred after controller position handover/takeover.
- In 38%, ACAS was unavailable.
- In 15%, transponders were not equipped on aircraft.
- In 15%, ATC collision avoidance was unavailable.
- 15% occurred during sequencing for final approach.

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

5.7.5. Controller On-the-Job Training

Figure 5-11: ATCO OJT

Figure 5-11 depicts the incidents which took place during ATCO on-the-job training. The following can be noted:

- Incidents which occurred during ATCO on-the-job training account for 11% of the analysed sample.
- 27% of these incidents passed through the "ATC collision avoidance" barrier.
- Nearly half of incidents (5 out of 11) were initiated by "inadequate ATC tactical planning and traffic synchronisation".
- In 36% of incidents (4 out of 11), ATC did not assure tactical separation due to inadequate controlling techniques.
- In 18%, ATC did not assure tactical separation due to flawed ATCO decision/goals.
- In 73% of incidents, although separation minima infringement was not prevented, ATCO's actions were sufficient to prevent a collision.
- 45% occurred during sequencing for final approach.
- 36% occurred after controller position handover/takeover.
- 27% involved non-commercial flights.
- In 27%, ACAS collision avoidance was not available.
- 18% occurred during high ATC workload.
- 18% included conflicting climb/descent flight trajectories.

- 18% occurred while aircraft were cleared on heading/direct

Also considering the number and prominence of en-route incidents that occurred during OJT, it is suggested that this factor is noted in the report.

6. RUNWAY INCURSION INCIDENTS - SUMMARY ANALYSIS

6.1. *Overall barrier performance – runway incursion*

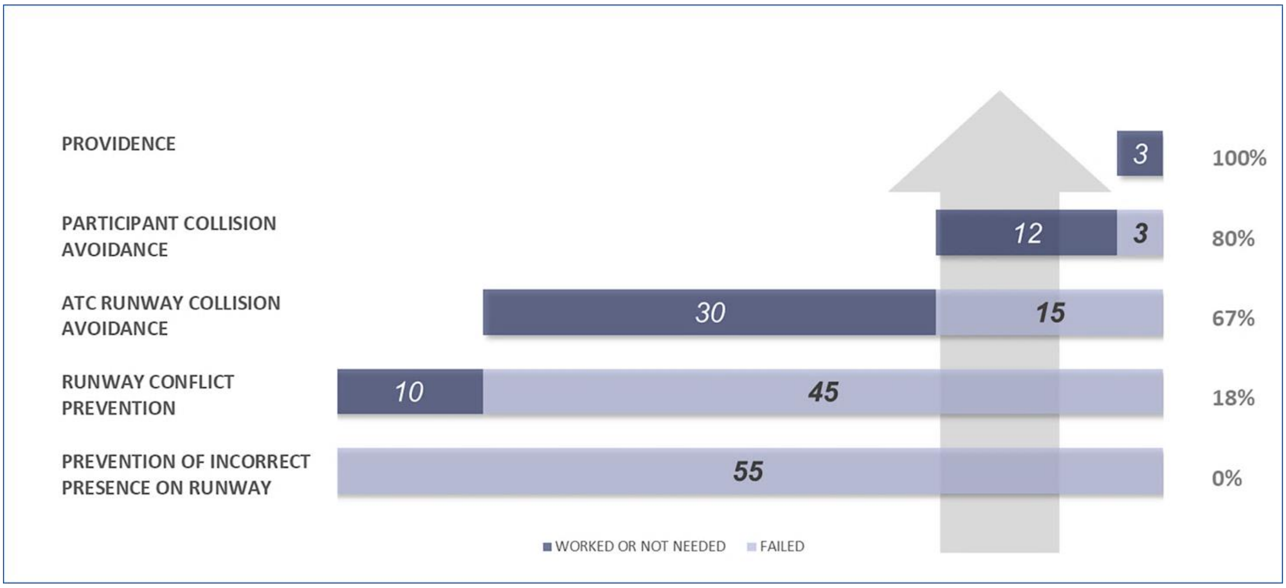

Figure 6-1: Overall barrier performance

- Performance of the basic barrier "Prevention of Incorrect Presence on Runway": challenged 55 times, failed in all 55 cases. This high degree of failure is not a surprise, due to the high severity (A and B) of the events included in the analysed data sample.
- Performance of the basic barrier "Runway Conflict Prevention": challenged 55 times, failed in 45 cases (82%) and worked or was not needed in 10 cases (18% success).
- Performance of the basic barrier "ATC Runway Collision Avoidance": challenged 45 times, failed in 15 cases (37%) and worked or was not needed in 30 cases (67% success).
- Performance of the basic barrier "Conflict Participant Runway Collision Avoidance": challenged 15 times, failed in 3 cases (20%) and worked or was not needed in 12 cases (80% success).
- Performance of the basic barrier "Providence": challenged 3 times and worked or was not needed 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.

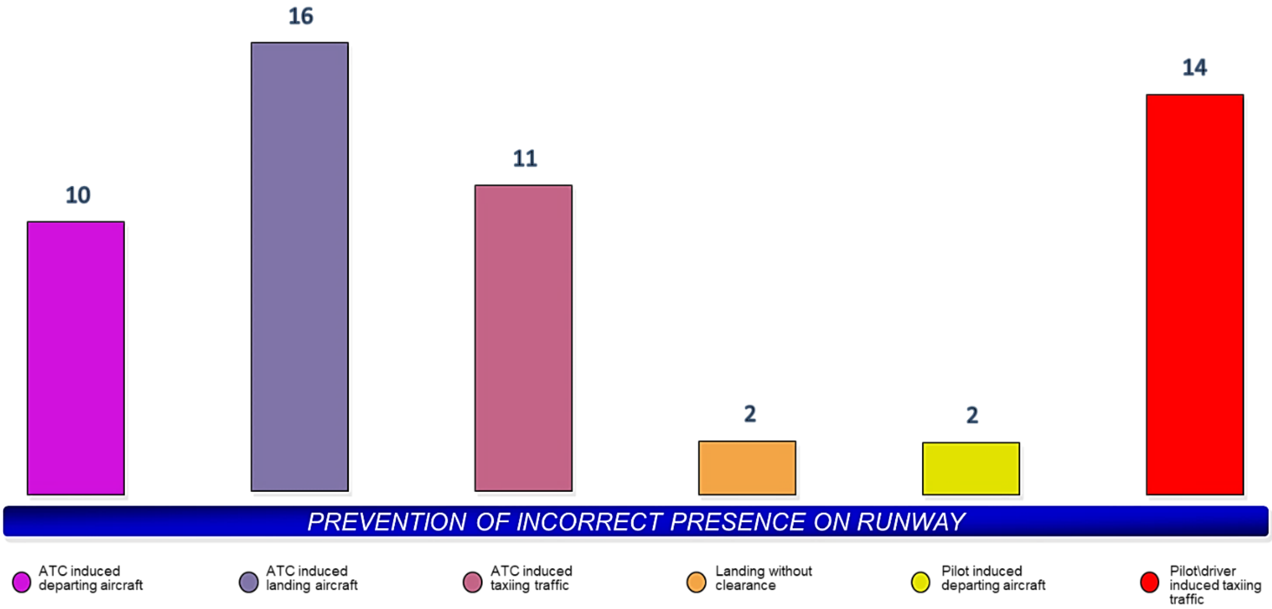

Figure 6-2: Runway incursion scenarios and initiators

The SAFMAP analysis helped identify the following initiating factors that played a role in the 2023 occurrence data sample:

- In 16 incidents (29% of the data sample) the runway incursion/separation infringement was caused by "ATC induced incorrect presence of landing aircraft", retaining the same share as in the previous year.
- In 14 incidents (25% of the data sample) the incorrect presence on the runway was caused by "Pilot/driver induced incorrect entry of taxiing traffic".
- In 11 incidents (20%) the incorrect presence on the runway occurred due to "ATC induced incorrect entry of taxiing traffic".
- In 10 incidents (18% of the data sample) the initiator was "ATC induced incorrect presence of departing aircraft".
- In 2 incidents (4%), the runway incursion was caused by "Aircraft landing without clearance".
- In 2 incidents (4%), the runway incursion was due to "Pilot induced incorrect presence of departing aircraft".

6.3. Barriers' resilience per initiator

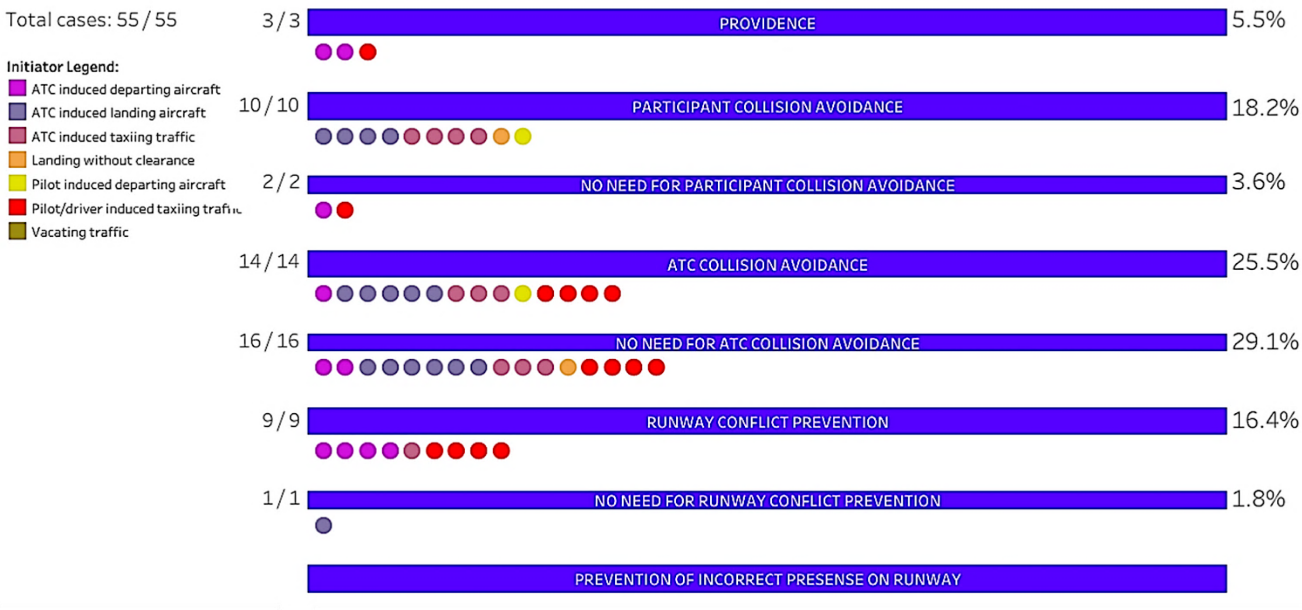

Figure 6-3: Barrier resilience per initiator

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. Similarity to 2021 barrier effectiveness can be observed across most barriers. The following can be concluded regarding the barrier effectiveness:

- 27% of the events crossed all ATC runway collision prevention barriers (44% in 2022 and 28% in 2021).
- The ATC runway collision avoidance barrier stopped just over half of the hazardous events: 55% of all events, with "No need for ATC collision avoidance" at 29%.
- 18% of events were stopped at the Runway conflict prevention barrier this year (0 in 2022 and same barrier effectiveness in 2021).
- 22% of conflicts were stopped by Participant collision avoidance (39% in 2022, and 20% in 2021).
- 29% of conflicts were resolved without ATCO proactive intervention (stopped by the 'technical barrier' - No need for ATC collision avoidance.
- 3 events (5%) crossed all ATM barriers and were stopped at the Providence barrier.
- 67% of the events in the 2023 data sample have been induced by ATC.
- ATC induced departing aircraft events had the highest safety criticality of all events in 2023, comprising 2 of the 3 conflicts only stopped by Providence. The other initiators of high criticality events are ATC induced taxiing traffic and ATC induced landing aircraft – both with a 27% share of all events that reached the last two barriers – and Pilot/driver induced taxiing traffic with a 13% share of all events reaching the last two barriers and 1 event stopped by Providence.
- Only 14% (2 events) of the incidents initiated by Pilot/driver induced incorrect entry of taxiing traffic passed all ATC barriers (62% in 2022).

6.4. ATC induced landing aircraft events

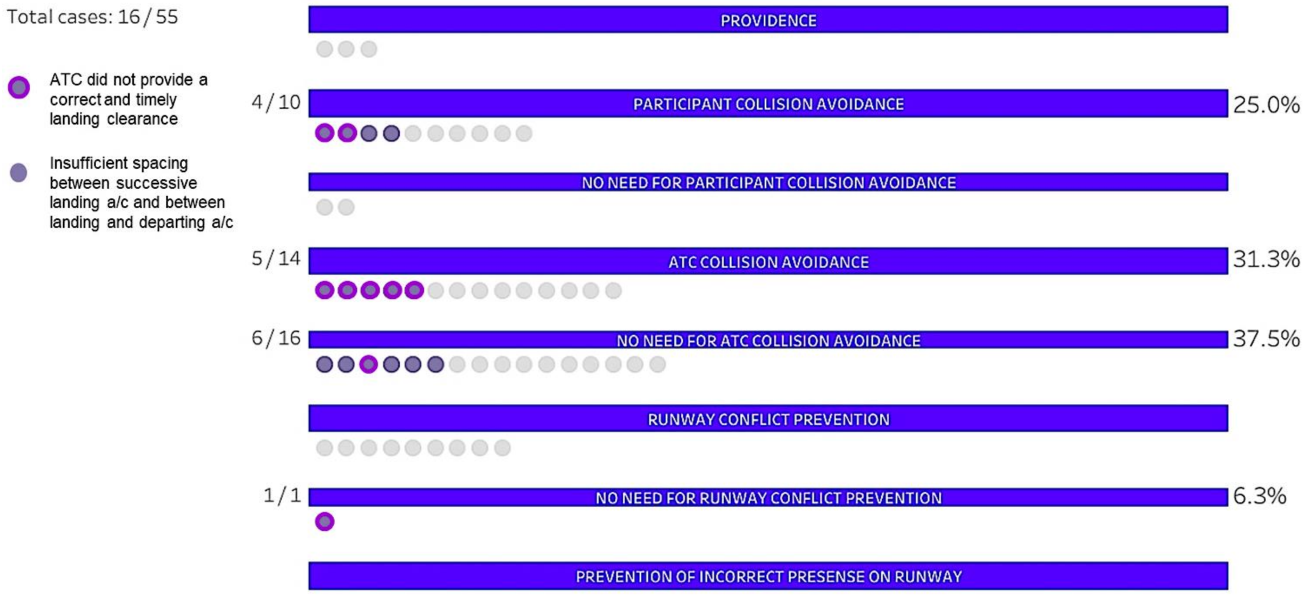

Figure 6-4: Incorrect presence of landing aircraft induced by ATC

Figure 6-4 provides insight into the causal factors of the incidents of “ATC induced incorrect presence of landing aircraft”. The following was identified:

- This is the largest initiator in 2023’s data sample accounting for 29% of the analysed data sample (16 events).
- 25% of incidents initiated by ATC induced incorrect presence of landing aircraft on the runway crossed all ATC barriers and they make up 27% of all events in the sample stopped at the last two barriers.
- The majority (69%) of this group of incidents were stopped at the ATC collision avoidance barrier, with over half of those (38%) not requiring ATC action.
- 56% were caused by incorrect/late ATC clearance and 44% were due to insufficient aircraft spacing.
- In 6 out of 16 events (38%), ATC did not detect the conflict and issued landing clearance despite the correct presence of another aircraft/traffic on the runway.
- In 5 out of 16 events (31%), SMGCS was available but not used or alert ignored.
- In 4 out of 16 events (25%), non-commercial flights were involved.
- 4 out of 16 events (17%) occurred during controller on-the-job training.

6.5. Pilot/driver induced taxiing traffic events

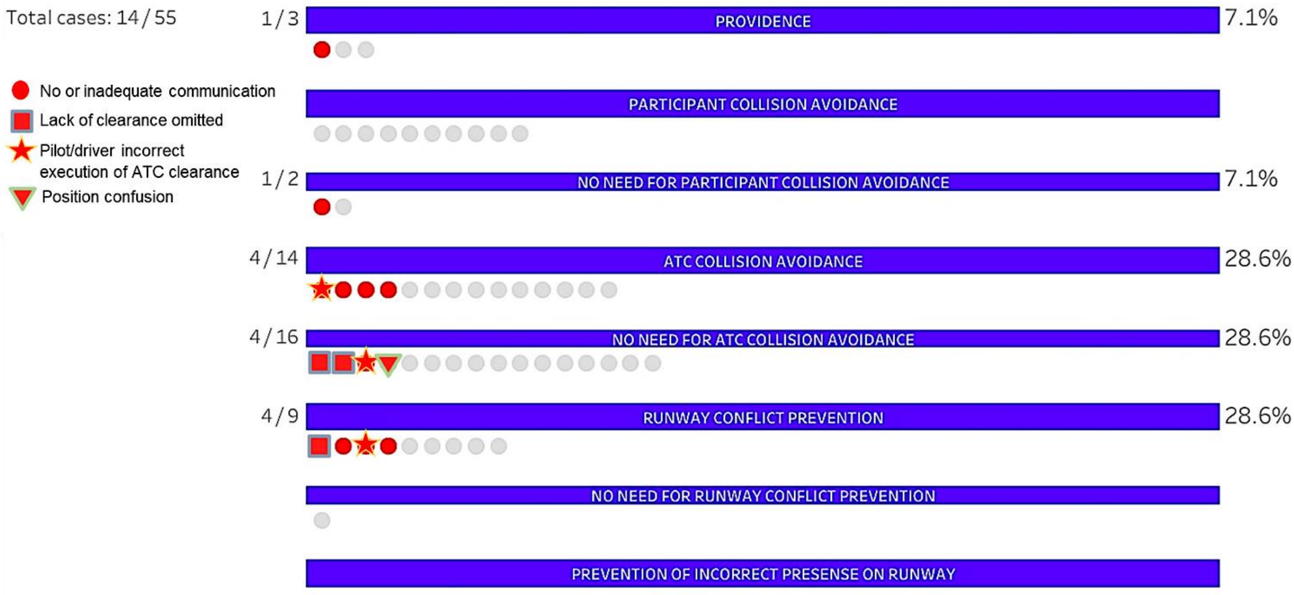

Figure 6-5: Incorrect RWY entry caused by pilot/driver

Figure 6-5 provides insight into the incidents of incorrect entry of taxiing traffic onto the runway protected area induced by pilot/driver. The following was identified:

- 2nd largest initiator in 2023's data sample accounting for 25% of the analysed data sample (14 events).
- 14% of events initiated by pilot/driver induced incorrect entry of taxiing traffic onto the runway passed all ATC collision avoidance barriers, accounting for 13% of the share of all high criticality events in the sample that did so, and comprise 1 of the 3 events stopped only by Providence.
- 57% of pilot/driver induced taxiing traffic events were stopped by ATC collision avoidance, with half of those not requiring any controller collision prevention action.
- Half of this group of events were caused by lack of or inadequate communication – and unlike previous years - these were the higher safety criticality events.
- 21% of the events involved omitted lack of RWY clearance, another 21% involved incorrect clearance execution, and 7% (1 event) was due to position confusion.
- 10 out of 14 incidents (71%) could have been prevented by stop bars.
- 5 out of 14 incidents (36%) involved non-commercial flights.
- 4 out of 14 cases (29%) involved non-use of English language.
- 4 out of 14 events (29%) occurred during Single Person Operation in the Tower.
- In 4 out of 14 events (29%), ATC did not detect the potential runway conflict.
- In 3 out of 14 events (21%), vehicles were involved.

6.6. ATC induced taxiing traffic events

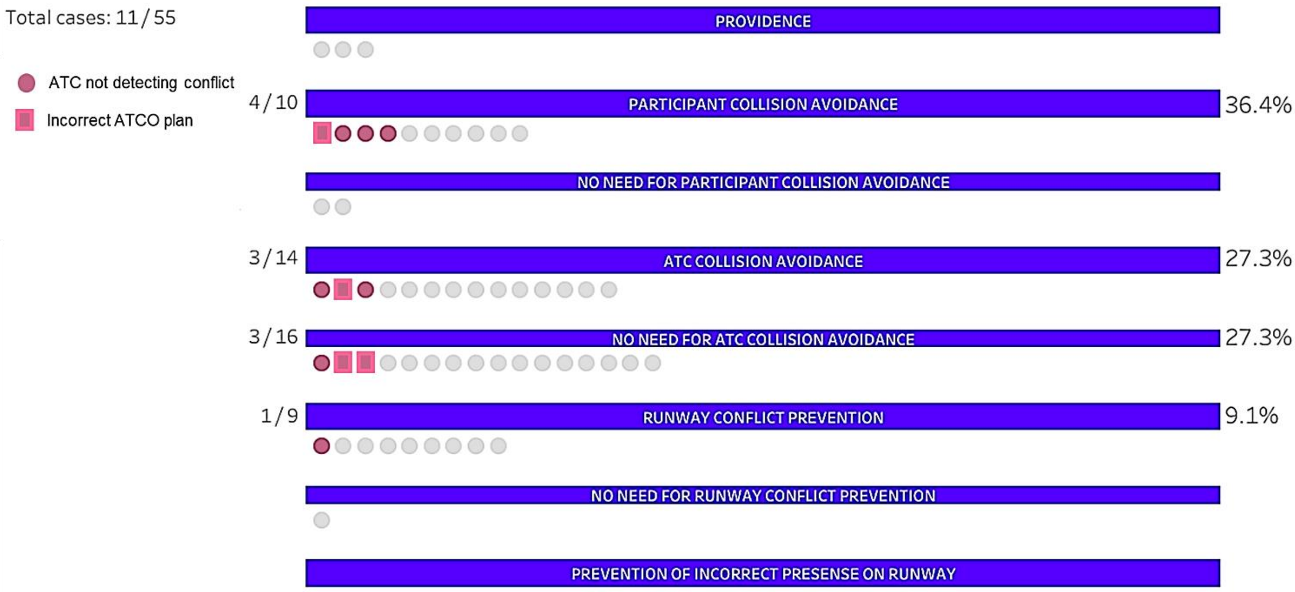

Figure 6-6: Incorrect presence of taxiing traffic induced by ATC

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

- 3rd largest initiator in 2023's data sample accounting for 20% of the analysed incidents (11 events).
- 36% of these events were of high safety criticality, requiring Participant collision avoidance action, and accounting for 27% of the events in the data sample that passed all ATC barriers.
- Just over half (55%) of these events were prevented at the ATC collision avoidance barrier, with half of them not requiring ATCO collision avoidance action.
- 64% of incidents were due to no conflict detection by ATC and the remaining 36% were caused by incorrect ATCO plan.
- In 9 out of 11 events (82%), ATC did not detect the potential runway conflict (2nd basic barrier failure).
- In 5 out of 11 events (45%), non-commercial flight were involved.
- 4 out of 11 events (36%) occurred after ATCO position handover/takeover.
- In 2 out of 11 events (18%), runway configuration change was a factor.
- In 2 out of 11 events (18%), local language was used.
- In 2 out of 11 events (18%), there was pressure to get the aircraft airborne.
- In 2 out of 11 events (18%), SMGCS was available but not used or the alert was ignored.

6.7. ATC induced departing aircraft events

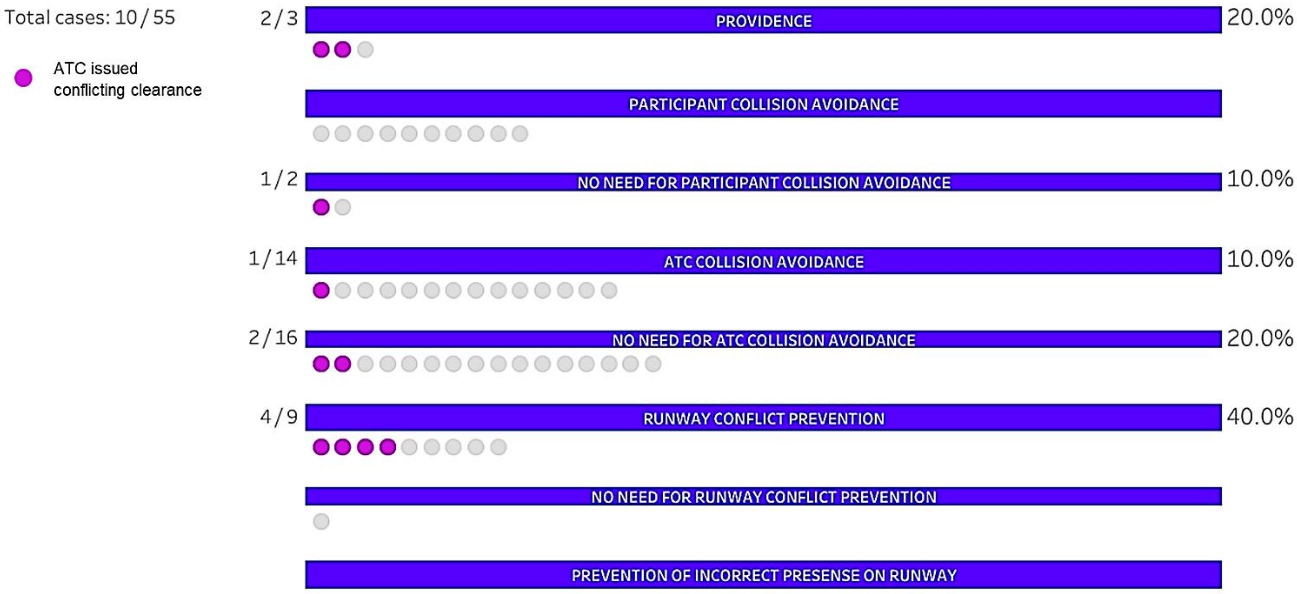

Figure 6-7: Incorrect presence of departing aircraft induced by ATC

Figure 6-7 provides insight into the causal factors of the incidents of "ATC induced incorrect presence of departing aircraft". The following was identified:

- Significant initiator in 2023's data sample accounting for 18% of the analysed incidents (10 events) and 2/3rds of the events stopped only by Providence.
- 30% of the ATC induced departing aircraft conflicts passed all ATC barriers, comprising 20% of all events in the sample that reached the last two barriers.
- In all ATC induced departing aircraft incidents, ATCO did not detect the potential runway conflict and issued take-off clearance after a runway already was (or was about to be) correctly occupied.
- In 3 out of 10 events (30%), runway occupancy memory aids were used incorrectly.
- 2 out of 10 cases (20%) involved non-commercial transport flights.
- 2 out of 10 cases (20%) involved vehicles.
- In 2 out of 10 events (20%), ATCOs had high workload.
- 2 out of 10 events (20%) occurred during Single Person Operation in the Tower.

6.8. ATC not detecting the potential runway conflict

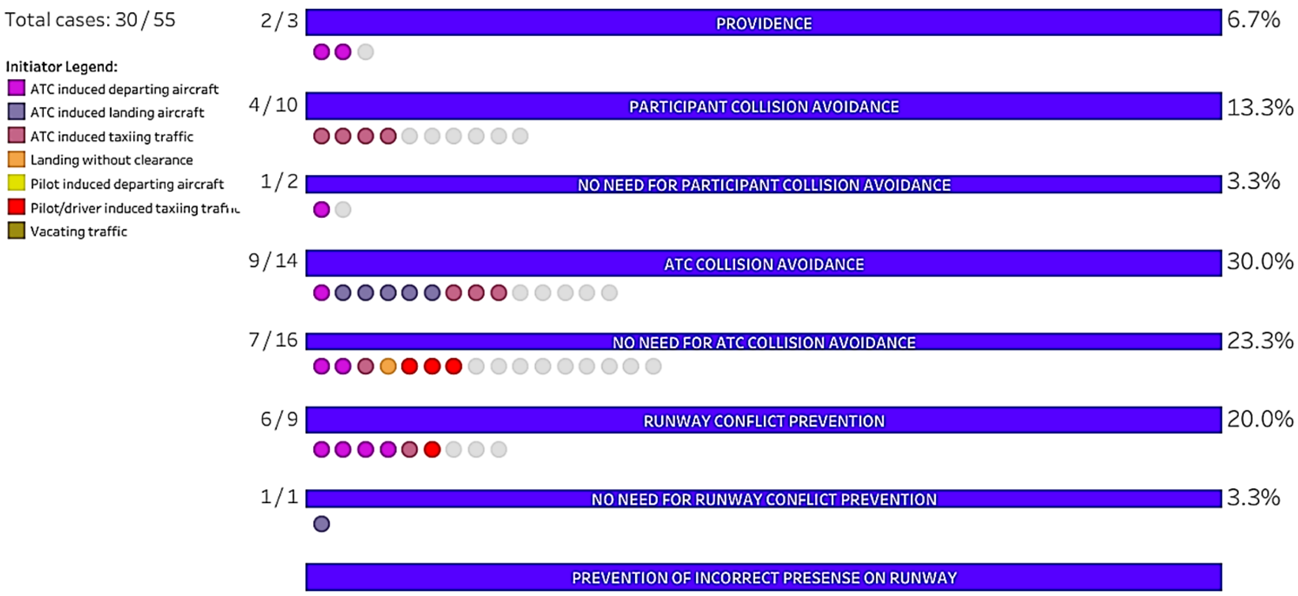

Figure 6-8: Non-detection of potential RWY conflict by ATC

Figure 6-8 showcases the events where ATC issued a conflicting runway clearance after not detecting the potential runway conflict. The following can be noted:

- The incidents in which ATC issued a conflicting runway clearance after not detecting the potential runway conflict account for 55% of the analysed sample.
- 23% of the events passed all ATC barriers, comprising 2 of the 3 incidents that reached the last barrier "Providence".
- The largest initiator was "ATC induced incorrect presence of departing aircraft onto the runway protected area", making up 1/3rd of all events, followed by "ATC induced incorrect entry of taxiing traffic onto the runway protected area (30% of events).
- In 33% of events involving non-detection of potential runway conflict by ATC, ATC gave take-off clearance after correct presence on the runway (this is the ATC induced departing aircraft initiator).
- In 20%, ATC gave landing clearance after correct presence on the runway (this is the ATC induced landing aircraft initiator).
- In 7%, ATC gave landing clearance after incorrect presence on the runway.
- 33% involved non-commercial flights.
- 23% involved ATC incorrectly using runway occupancy memory aids.
- 20% occurred during controller position handover/takeover.
- 17% involved vehicles.
- 17% could have been prevented by stop bars.
- 13% occurred during Single Person Operation in the Tower.

- In 13%, the view from the Tower was constrained.
- In 13%, SMGCS were available but not used or the alerts were ignored.
- In 13%, SMGCS were experiencing technical issues.

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

6.9. *Contextual factor analysis – runway incursion*

This section presents the results of the analysis of the significant contextual factors reported in the description of the occurrences of incorrect presence on the runway included in the 2023 data sample. The contextual factors selected for their significance include: non-commercial flight involved and stop bars being able to prevent the conflict.

6.9.1. *Non-commercial flight involved*

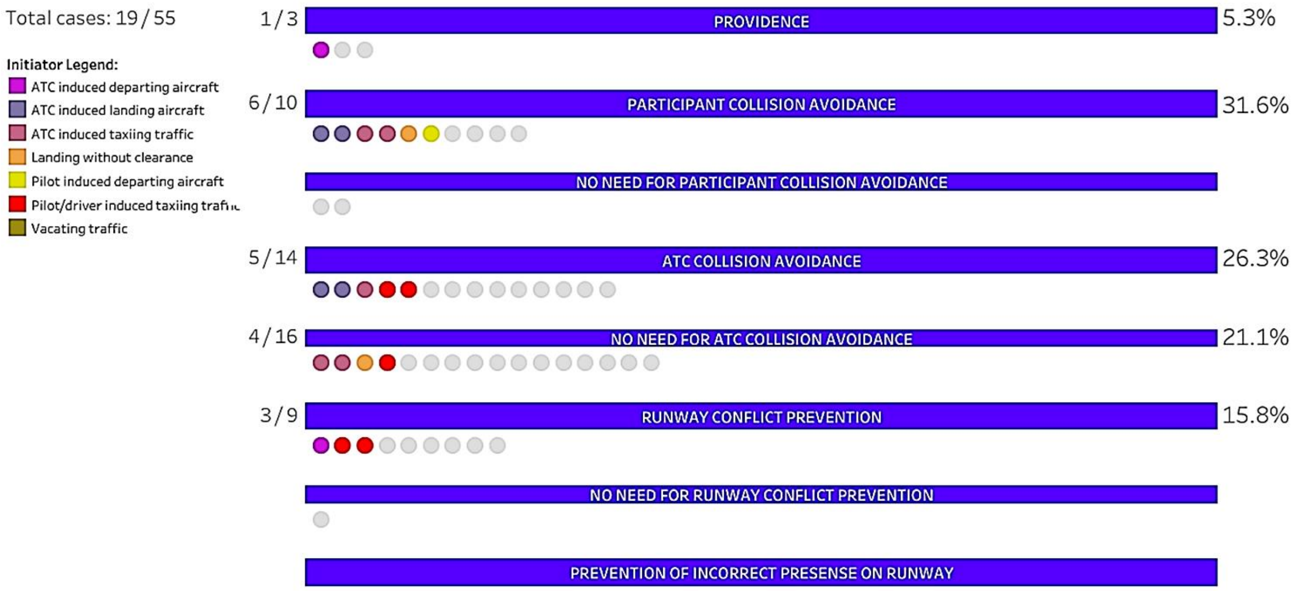

Figure 6-9: Non-commercial flight involved

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

- The incidents which involved non-commercial flight account for 35% of 2023's data sample (the same as in the previous year's sample).
- 37% (7 out of 19) of incidents involving non-commercial flights reached the last two barriers.
- This group of events account for roughly half of all events in the sample that passed all ATC barriers.
- All initiators other than "Pilot/driver induced incorrect entry of taxiing traffic" reached the last two barriers.
- Pilot/driver induced incorrect entry of taxiing traffic events have dropped in terms of both numbers and safety criticality from the previous year, when they were the largest and most safety-critical initiator for events involving non-commercial flights.
- In 53% (10 out of 19), ATC did not detect the potential runway conflict when issuing runway clearance.
- 21% (4 out of 19) occurred during Single Person Operation in the Tower.
- 16% (3 out of 19) were preventable by stop bars.

- In 16% (3 out of 19), the view from the Tower was constrained.
- In 16% (3 out of 19), SMGCS was not available.

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.

6.9.2. *Conflicts that could have been prevented by stop bars*

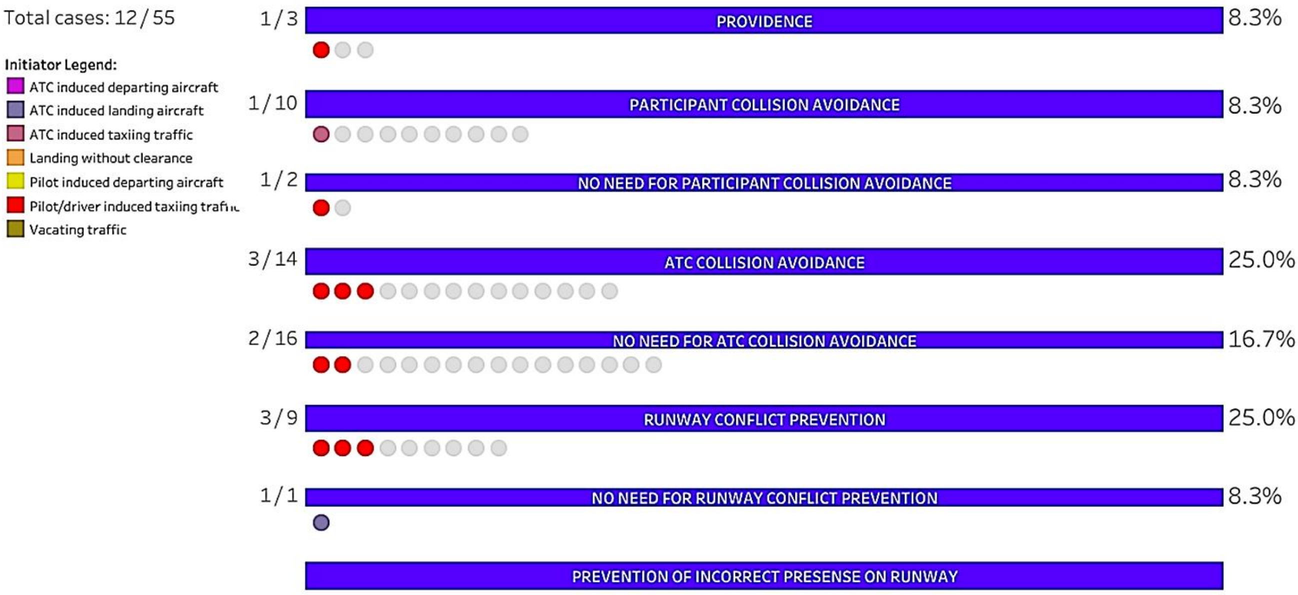

Figure 6-10: Incidents preventable by stop bars

Figure 6-10 showcases the incidents which could have been prevented by stop bars. The following can be noted:

- 22% 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 – the same as in the previous year.
- 82% of these events were initiated by Pilot/driver induced incorrect entry of taxiing traffic.
- 25% passed all ATC barriers, making up 20% of all events in the sample that did so, therefore events that could have been prevented by stop bars are exhibiting the potential for high safety criticality.
- In 5 out of 12 events (42%), not using the English language was an issue.
- In 5 out of 12 events (42%), ATC did not detect the runway conflict before issuing clearance.
- 3 out of 12 events (25%) involved non-commercial flights.
- 3 out of 12 events (25%) occurred during Single Person Operation in the Tower.
- In 2 out of 12 events (17), the view from the Tower was constrained.
- In 2 out of 12 events (17%), runway occupancy memory aids were used incorrectly.
- In 2 out of 12 events (17%), SMGCS was available but not used or the alert was ignored.
- In 2 out of 12 events (17%), SMGCS was not installed.

It is therefore suggested to continue monitoring the safety risk associated with events involving incorrect presence on the runway protected area that could have been prevented by stop bars.