The Impacts of Systematic False Alarms on Air Traffic Controllers' Situation Awareness

Ousmane Diack, James Blundell & Wen-Chin Li

Safety and Accident Investigation Centre, Cranfield University

SUMMARY

The safety net, made of a set of alarms, is considered the final Air Traffic Management (ATM) protection to prevent an accident. The prevalence and causes of false Short-term Conflict Alerts (STCA), an alarm intended to represent one of the final safety barriers, was investigated based on the occurrence of 315 STCA events generated by a Western African Upper Airspace ATM system over an 11-month time period. Based on subject matter expert review, 313 STCA events (99.9%) were classified as false alarms. False STCA were caused by a combination of technical (aircraft position sensor fusion misalignment) and human attributes within the system. Furthermore, a survey with 26 ATCOs on the cognitive and behaviour effects elicited by the experience of false STCAs revealed that 73.08% of ATCOs experienced increased workload. Whilst 38.46% reported a reduction in situation awareness. Results of the analysis of the retrieved data on the STCA suggest that implementing efficient system integration of different sensors and reducing human error will reduce workload, and improve ATCO's situation awareness and overall ATM system efficiency.

KEYWORDS

Air Traffic Controller, Air Traffic Management, False Alert, Situation Awareness

Introduction

Air Traffic Controllers (ATCOs) provide services to aircraft by allocating them speed, altitude, and trajectory requirements in a high-pressure environment that demands strategic planning and rapid decision-making. To assist the ATCOs, automation is implemented to generate alarms that advise on potential conflicts (Ruskin et al., 2021). Alarms help the ATCO manage their workload and situation awareness by offering predictive guidance and solutions for potential conflicts between aircraft. Among the different alerts experienced by ATCOs, the Short-Term Conflict Alert (STCA) represents the last line of defence within the Air Traffic Management System (ATM) system in preventing accidents; Triggered when a breach of vertical and lateral minimum spacing between two aircraft occurs whilst a short time window for air traffic controllers to react and prevent a collision is available (Kearney et al., 2016a).

According to Rovira & Parasuraman (2010), it is unlikely for automation to be 100% reliable. For example, an ATM system can exhibit missed alarms - that are potentially hazardous - or false alarms that are considered more acceptable. False alarms can be classified into two categories: 1) true false alarms that are not justified, and; 2) nuisances that are correct according to system configuration but remain persistent despite controllers' actions as automation has not identified the controllers' resolution (Wickens et al., 2009). Therefore, for the ATCO to be efficient, they need to possess a good understanding of an alarm's intended function and its reliability in order to demonstrate a desirable level of trust in the automation (Ruskin et al., 2021). According to Rein et al (2013), a 67%

reliability in automation is associated with performance gains. Whilst overreliance can lead to reductions in accurate and timely responses to alerts (Ruskin et al., 2021) due to a startle and surprise reaction when the ATCO's expectation of the automation's capability is challenged (Landman et al., 2017). Conversely, consider an ATM system where false STCA alarms occur frequently and have the same auditory alert signal as other system alarms (MSAW or APW). Such a case might result in a "cry wolf" effect (Breznitz, 2013) resulting in a situation where system alerts are disregarded – also known as automation disuse (Walker et al., 2023) - and ATCOs' situational awareness becomes compromised.

The false alerts are a cause of nuisance and distractions that can increase workload and diminish situation awareness and performance (Friedman-Berg et al., 2008). In the current study of Western African upper airspace, 315 STCA have been recorded over a period of 11 months from an ATM system which consists of over 11 alarms, among which flight plan conflict probe, route adherence monitoring and cleared level adherence monitoring are used by ATCOs to anticipate on potential conflicts. Despite all these alerts working accurately, the unique nature of the STCA representing the last safety barrier within a complex and dynamic system makes an examination of its reliability upon ATCO workload and situation awareness worthwhile.

Aircraft positioning on ATM System

The ATM displays the positions of air traffic on a 2-D map and calculates flight path using a combination of Secondary Surveillance Radar (SSR) /Automatic Dependent Surveillance-Broadcast (ADS-B) based sensors. The ADS-B benefits from a position update every 1s whilst the radar mode S varies between 5 to 12s (ICAO, 2008). However, whilst the combination provides enhanced positioning the ATM system needs to compute the information to give a single output. The fusion of sensors is designed to improve accuracy (Thales, 2010).

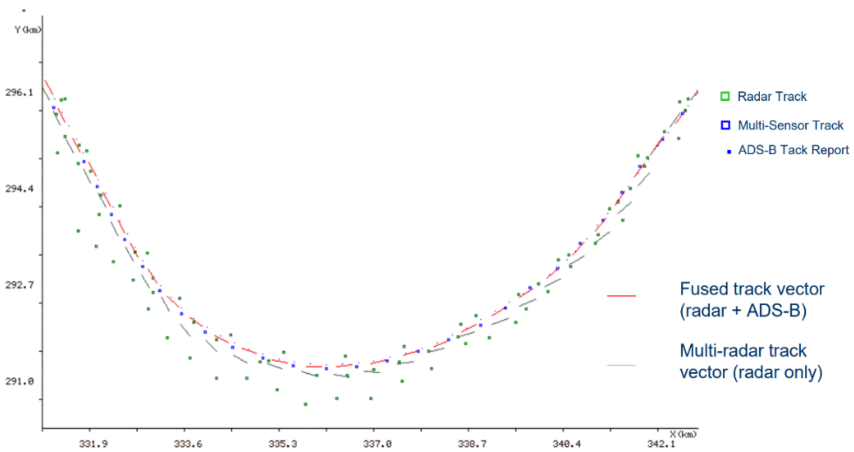

Figure 1: Example of SSR radar / ADS-B signal fusion (from Thales, 2010)

Short-Term Conflict Alert (STCA)

Coupling the positional data provided by the sensors with an existing flight data record (FDR), known as a flight plan, the system predicts future trajectories of multiple flights that have the potential to cause conflicts. The system allows authorised users to set minimum acceptable safety tolerance values for various warnings - such as STCA, APW and MSAW. The configuration of different system alerts is communicated to the ATCO via different audio and visual alert signals. Whereby, the alerts are differentiated by sound frequency depending on the urgency of the alert and visual representation on the display via the colouration of the aircraft track and its corresponding electronic strip. Consequentially, the multimodal nature that information is presented is designed to mitigate against potential cognitive tunnelling effects (Wickens & Alexander, 2009), to provoke an immediate shifting of attention to the alert, preserving an ATCO's ability to respond to a STCA. STCA is intended to represent one of the final barriers in the prevention of accidents within the ATM system. Three cases where a SCTA has been triggered is shown below in Figure 1 to illustrate the features and functionality of the alert which an ATCO may encounter. Example A represents a true alarm scenario, whilst examples B and C represent two false alarm scenarios.

- Case of actual, true, STCA: U-P is steady at Flight level (FL) 210 and R-45 crosses FL 206 climbing to 310 with a longitudinal distance of less than 5NM and vertical separation of 400 ft resulting in an actual STCA (see Figure 2A).
- Case of false alarm triggered by a terminated track: B-26E exiting the airspace at FL370 and R-11Z entering at FL360. After coordinating B-26E, as traffic approaches the exit point, ATCO has terminated the B-26E flight data record, as R-11Z is entering the airspace at F360 (see Figure 2B). Despite the 1000 ft between traffic, the system generates an STCA. Investigation revealed that ATCOs are aware of this induced STCA.
- Case of false alarm triggered by dual track sensor failure: The traffic T-YD crossing FL147 descending FL40 has two labels both referring to the same position (see Figure 2C for more detail). The ADS-B track is coloured in green and the SSR track in black, the system then analyses this situation as if it were two different traffic at the same flight level with no distance, hence the STCA alarm.

A B C

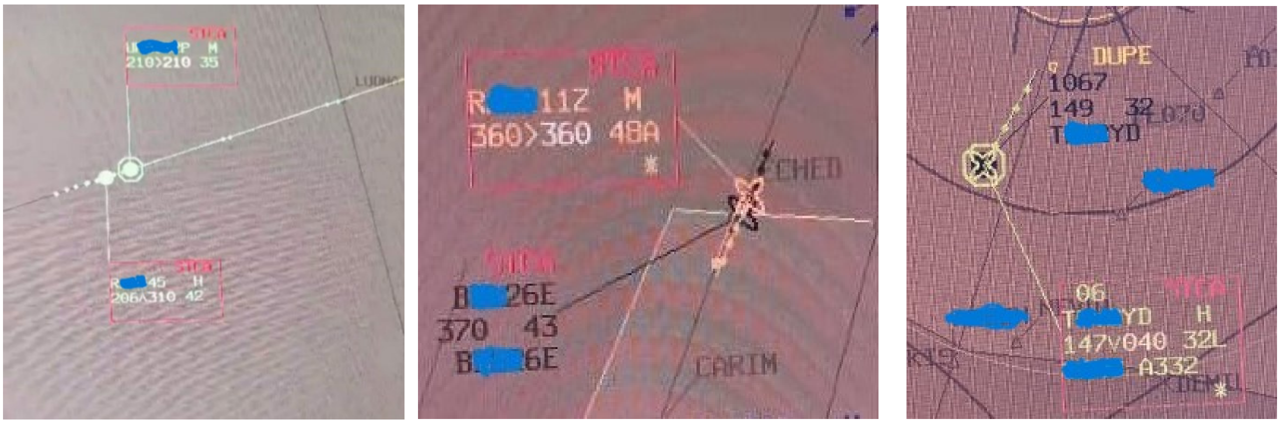

Figure 1: STCA features and functionality. A) True STCA, B) false alarm due to terminated flight track, and C) false alarm due to single aircraft dual track occurrence. (Source-ATM system)

Research Objective

Despite the importance of STCA as an accident protection measure within the ATM system, internal reports by ATCOs have highlighted that false alarms are occurring too frequently, specifically of the STCA, an investigation was conducted to analyse the data on the rate and causes of false STCA. This research is based on an analysis of 315 STCA alarms that occurred in a Western African Upper Airspace from January to November 2023. Furthermore, the impact of the false STCA upon ATCOs was conducted via a survey.

Methodology

STCA False Alarm Frequency and Causes

The data retrieved from the events journal on Safety Nets of the ATM system from January to November 2023 recorded 315 STCA alarm events that occurred within the west -African Upper Airspace. For each occurrence data is provided about the call-sign of each involved aircraft, their respective flight levels, minimum lateral distance, positions, speed and rate of climb/descent among others.

Each STCA event was investigated and validated by 3 domain experts: (2 ATCO with more than 20 years of experience and an ATCO with six years of experience). Validation of each STCA event was determined by checking how many aircraft were involved – true STCA events require two or more aircraft – and if the vertical and lateral distances between aircraft were below the minimum separation tolerance.

STCA Impact on ATCO Survey

To establish the impact of the false STCA events upon ATCOs a survey was conducted on a total of 26 ATCOs (5 female (19.23%) / 19 male (80.76%)). Eleven ATCOs (42.3%) had over 15 years of experience, 10 ATCOs (38.4%) had between 5 to 15 years of experience, and 5 ATCOs (19.2%) had less than 5 years of experience.

The survey was administered through Google Forms. Participants were asked to answer the following questions related to their familiarity with the alarms. In addition, participants provided feedback on whether they believed false STCAs impacted their workload (yes / no), situation awareness (yes / no), or had no cognitive effect (yes / no). Finally, a question was included that required participant to report their usual behavioural response to the false STCAs (inhibit / acknowledge).

Results

STCA False Alarm Frequency and Causes

Of the 315 instances of STCA Alerts, 57 cases involved two aircraft (18%), 229 cases were triggered by only one aircraft (73%), and 29 cases had no aircraft involved (9%).

The investigators examined the vertical and lateral separations involving the 57 cases involving two aircraft and revealed that only 2 events (4%) matched the defined values for an STCA (Table 1). None of the occurrences of the STCA resulted in an actual incident as far as regulation is concerned. However, the current data demonstrate a 99.99% false STCA rate existing in the current ATM system (313 out of 315).

Table 1: STCA accuracy analysis

STCA Total	315
STCA involving 0 aircraft	29
STCA involving 1 aircraft	229
STCA involving 2 aircraft	57
A/C less than 1000 ft	5
Total valid STCA	2
STCA false alarm rate	99.99%

The results show that 258 (81.90%) occurrences were caused by the system viewing dual track positions, the system compares a coupled track with its own shadow (229 cases) or because of the proximity of false position of two shadows (29 cases) the system issues a false STCA.

Out of the 57 occurrences involving two aircraft, 55(17.40%) have sufficient vertical or lateral separation, however due to system configuration the algorithm issues a false STCA.

ATCO cognition and behaviour responses to False STCA

Survey results are presented in Figure 3. In terms of cognitive responses to false STCAs the survey revealed that ATCOs 73.08% found their workload to be significantly increased, 38.46% reported a negative impact on SA, whilst 11.54 % described experiencing no effect. Behavioural responses showed that 73.08 % of ATCOs reported analysing the alarm report before acknowledging it, while 26.92 % simply inhibited the alarms due to their high frequency.

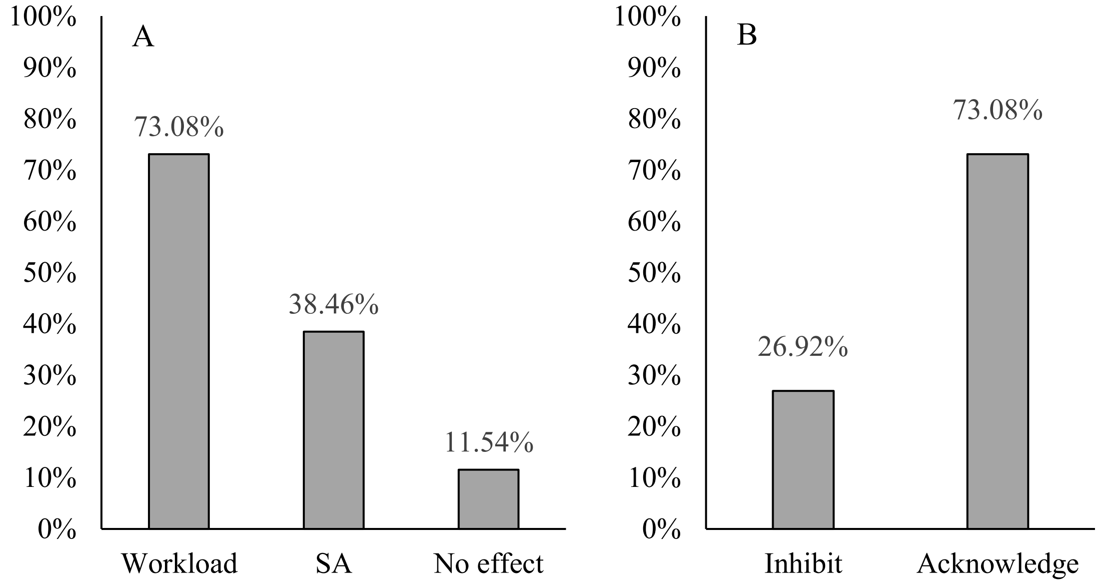

Figure 3: ATCO cognitive (panel A) and behaviour (panel B) responses to false STCA events.

Discussion

The current study investigated the rate and causes of false STCA in Western African Upper Airspace over a period of 11-months. Furthermore, ATCO cognitive and behavioural responses to the false STCA was examined via a survey.

A total of 315 STCA events were occurred of the 11-month time window. Crucially, 313 of these events (99.99%) were categorised as false STCA by subject matter experts. The leading cause of the 313 reported false STCAs was determined to be from "dual tracks" appearing for a single aircraft arising from the system's misalignment of ADS-B and SSR signals (81.90% of the cases). Conversely, the next leading cause originated from ATCOs themselves, whereby they manually terminating a flight data record (FDR) of a controlled aircraft just prior to the aircraft exiting their airspace boundary (17.40% of the cases). It is most likely this practice is employed by ATCOs to self-manage workload as it reduces the number of active traffic under their jurisdiction.

The majority of ATCOs (73.08%) reported an increase in workload when a sudden failure of automation is encountered, specifically during high levels of traffic where STCA events often occur. Fewer ATCOs reported a reduction in situation awareness (38.46%). This is important as situation awareness is influenced by past experiences and informs automation expectations prior to making a decision (Endsley, 2016). Likewise, an increase in workload could originate from the multiple "reframing" steps (Klein et al., 2007; Landman et al., 2017) that are required to reacquire situation awareness; The first step being the acknowledgement that a STCA event has occurred, with the second step involving the evaluation and comprehension of the alert's accuracy and authenticity.

Whilst the number of false STCA in the current study is high. It is also important to note that there was an absence of incidents, which could be partially explained by the anticipation attitude of ATCOs. In complex and dynamic environments, such as air traffic control, anticipatory thinking(Klein et al., 2007) allows ATCOs to maintain situation awareness in the event of a false STCA (Wickens, Rice, Keller, Hughes, et al., 2009). With the use of more accurate alerts (Flight Plan Conflict Probe) that enable projection of remote conflicts.

Missed alarm as suggested by (Endsley, 2016) tends to be very hazardous in underload and overload situations, as such the ATM system algorithm is designed to issue a false alarm rather than miss it. According to Wickens, et al. (2009) performance is worse under missed alarms compared to false alarms, with inaccurate alarms leading to human error in the air traffic control environment (Imbert et al., 2014). Despite a salient alerting system, a working memory load induced by the multiplicity of tasks can lead to inattentional blindness (Fougnie & Marois, 2007) and the misperception of safety-related events occurring in the visual field.

To address the high rate of false STCA in the ATM system:

- Actions must be taken to effectively integrate and synchronize ADS-B and radar signals.
- Instruct ATCO to not terminate coupled track before it exits the airspace boundary.
- ATM system, algorithms should be enhanced to have a more efficient pattern analysis.

Prospects of building ATM systems with the inclusion of modern tools such as machine learning (Ndichu et al., 2021) to limit the rate of false alarms should be explored, as exposure to many alarms can provoke unnecessary workload and impact safety (Ruskin & Hueske-Kraus, 2015). Beyond fixing the high rate of false alarms it is essential to consider implementing semantic-based alarms to improve ATCOs' perception and understanding of dynamic situations for conflict detection and resolution, in its current state it is not a human-centric design of alert (Kearney et al., 2016b).

Conclusion

The investigation of the occurrence and cause of safety-critical false alarms within an ATM system was found to emanate from distinct technical and human system origins. Technical contributors formed the leading cause of false alarms (81.90%), and were due to the ATM system's aircraft positioning algorithm. Human contribution to false alarms (accounting for 17.40% of false alarms) took the form of voluntary practices adopted by ATCOs in their interactions with the ATM system.

The high rate of false alarms that exhibit a system locus is likely to be a source of increased ATCO workload and reduced SA. Furthermore, false alarms undermine the perceived reliability of the system, resulting in the dismissal of alerts signals. In fact, in the current system over a quarter of ATCOs reporting using this behaviour. The investigation also revealed that ATCOs remained in control of the situation, as no incident was recorded involving a false or missed alert. It is possible that other, more reliable, alarm signals are used to offset existing system deficiencies. Allowing ATCOs to safely manage planned flight trajectories and remain in the loop in order to predict potential conflicts.

Nonetheless, the rate of false STCA is a nuisance that can cause increased workload, as such it should be addressed as a latent failure within the system that can lead to an incident in the future.

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