Nuisance Alerts in Operational ATC Environments: Classification and Frequencies

Ferne Friedman-Berg, Ph.D. and Kenneth Allendoerfer
Federal Aviation Administration, Atlantic City International Airport, NJ, USA

Shantanu Pai
Engility Corporation, Egg Harbor Township, NJ, USA

Nuisance alerts can cause many problems in operational settings. They are distracting and can lead to desensitization. In Air Traffic Control (ATC), there has been much anecdotal evidence regarding the high rate of nuisance alerts in facilities, but there have been few formal studies to evaluate this problem. In this study, we measured the rate of nuisance alerts in en route and terminal ATC facilities. After calculating the average duration of alerts, the percentage of alerts that receive a controller response, and the timing of responses to these alerts, we estimate that 62% of Conflict Alerts (CAs) and 91% of Minimum Safe Altitude Warnings (MSAWs) in en route, and 44% of CAs and 61% of MSAWs in terminal are unnecessary. Using human factors principles, we make recommendations for improving the accuracy and utility of ATC alerts.

NUISANCE ALERTS

Alerts are intended to cause people to stop what they are doing and attend to a potential hazard. However, some alerts fail to provide useful information and can create their own human factors problems. These are known as *nuisance alerts* (Sanquist, Thurman, & Mahy, 2005). Nuisance alerts are troubling because the person receiving the alert must devote attention to deciding if the alert is valid and whether action is necessary (Sarter, 2005). There is also a resumption lag after any interruption, defined as the time it takes to gather one's thoughts and resume the task at hand (Altmann & Trafton, 2002). If the alert has identified a real potential hazard, the resumption lag is simply a necessary cost. If the alert is a nuisance and does not lead to action, however, the resumption lag reduces performance for no benefit.

Most importantly, nuisance alerts can desensitize people toward the alert and lead to slower responses to real alerts. Research has shown that when people experience frequent false or low-urgency alerts, they tend to respond less quickly and less accurately to real and high-urgency alerts (Getty, Swets, Pickett, & Gonthier, 1995). When there is a high incidence of nuisance alerts, people may suppress the alert before determining its actual status or may no longer treat the alert as mandatory. In both cases, overall alarm compliance decreases (Meyer, 2001; Parasuraman & Hancock, 1999). They also may stop responding to every alert (Xiao, Seagull, Nieves-Khouw, Barczak, & Perkins, 2004).

Audible alerts seem especially prone to being nuisances. They can be effective at drawing attention and can serve as an interruption cue that allows users to preattentively process alerts (Sarter, 2005). People also demonstrate a reduction in reaction time when an auditory signal accompanies a visual alert (Stokes & Wickens, 1988). However, these benefits are diminished when a system has a high rate of irrelevant or uninformative alerts. Audible alerts have also historically been the source of many complaints from air traffic controllers (FAA, 2006). Frequent and irrelevant auditory interruptions can disrupt visual task performance (Jones, 1999; Watson, Sanderson, & Anderson, 2000), which could be a serious problem in a highly visual domain like Air Traffic Control (ATC).

When a failure to respond to a hazard could lead to a negative outcome, alert systems are typically designed to minimize misses. According to Signal Detection Theory (SDT), systems designed to minimize misses will often experience correspondingly more false alarms. For this reason, domains like ATC where the cost of a miss is extremely high are especially susceptible to the negative human factors effects of nuisance alerts.

Nuisance Alert Categories in Air Traffic Control

Two types of alerts occur in ATC. In a Conflict Alert (CA), the system projects that two aircraft are closer than or soon will be closer than separation minima allow. In a Minimum Safe Altitude Warning (MSAW), the system projects that one aircraft soon will be closer to a physical obstruction (e.g., terrain, buildings) than is considered safe. The presentation methods for CAs and MSAWs vary among ATC systems, and incorporate combinations of flashing, color, text, and sound.

The primary purpose of CAs and MSAWs is to draw controllers' attention to situations that they may have overlooked or misinterpreted. The sequence of events in a *model alert situation* is as follows:

1. The controller, busy with many operational tasks, is unaware that a potentially hazardous situation is developing. Alternatively, the controller may be aware of the situation but may underestimate its severity or urgency.
2. The situation reaches a critical point and the alert activates.
3. The alert focuses the controller's attention on the situation.
4. The controller decides how to respond, takes the necessary actions, and the pilot responds appropriately.
5. The situation is resolved, and the alert deactivates.

However, only a small portion of real-world ATC alert situations follow this model. Most of the remaining alerts can

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be considered some form of nuisance alert, and fall into one or more of the following seven categories:

1. **No Action Necessary** – An alert activates for a situation where no Operational Error (OE) would actually occur, even if no action were taken. Such cases would be categorized as false alarms in SDT.

2. **Already Addressing It** – An alert activates for a situation that the controller is already working to resolve, but the resolution has not completely played out. For example, a controller detects a potential low altitude hazard, formulates a plan, begins to communicate with the pilot, and then the MSAW activates. The MSAW is valid in the sense that a potentially hazardous situation exists, but it is also a nuisance in that the controller already knew about the situation, and no action is required beyond what the controller is already doing. If an alert literally activates while the controller is taking action (e.g., communicating with the pilot), it can be distracting and cause delay or error in the completion of the communication (Ahlstrom, 2003).

3. **Somebody Else's Problem** – An alert activates in a location or for an aircraft that has no operational impact on the sector in question. Even though SDT would consider this to be a hit, from the perspective of the unaffected controller it is a nuisance. Flashing, loud audible alerts and potentially having to acknowledge or silence the alert can distract controllers who are not affected by a situation.

4. **Obnoxious** – An alert is more salient (e.g., brighter or louder) or lasts longer than necessary to draw attention. If an alert draws the controller's attention within 5 seconds but lasts for 10 seconds, controllers may regard the alert as a nuisance. This category also includes cases where the perceived urgency of the alert does not match the actual urgency of the situation.

5. **Using Other Types of Separation** – An alert activates for a potential conflict where the controller is using a type of separation other than radar separation, such as visual or diverging courses separation. Current ATC automation systems cannot determine when controllers are applying these types of separation.

6. **Repeat** – An alert activates a second time after a controller has already taken action or decided that no action is necessary. This often occurs with borderline alert situations. For example, due to noise in the radar data, an alert may activate for a few radar updates. The controller may act on the alert or may suppress it. If the controller does not suppress it, the alert might reactivate later.

7. **Surveillance or Tracking Error** – The terms "nuisance alert" and "false alert" are not interchangeable in ATC. Occasionally, errors in surveillance or tracking can cause the automation system to depict a target where none exists or two targets for one aircraft. In ATC, a false alert is one that occurs between one real target and one false one. These are false alarms in traditional SDT, and they are also nuisances because they draw attention but require no action by the controller.

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In this project, we quantify the extent of the nuisance alert problem in ATC. We developed methods for identifying nuisance alerts and applied these methods to field recordings.

METHOD

We collected these data from automation and communication recordings at ATC facilities. We selected facilities to include a range of facility sizes, terrain, traffic volumes, automation systems, and configurations.

Across both en route and terminal facilities, the initial data sample included 36,705 CAs and 11,744 MSAWS. It was not feasible to analyze all of these alerts in detail, so we selected a subset of sectors and time periods. We selected at least one primary CA and one primary MSAW sector-period from each facility (see Allendoerfer, Friedman-Berg, & Pai, 2007, for details). The total number of sector-periods requested from a single facility ranged from three to eight. In the requested sector-periods in en route, there were 299 CAs and 83 MSAWs. In terminal there were 1274 CAs and 394 MSAWs.

For these analyses, we determined when a controller action occurred relative to the activation of an alert by synchronizing the automation and voice recording data.

RESULTS

Analysis of Alert Durations

To determine whether a specific alert was a nuisance, we reviewed each alert in detail to determine how long the alert lasted and how controllers responded to the alert, if at all.

The duration of an alert is suggestive of its usefulness. Alerts that deactivate quickly indicate borderline alert conditions or could result from surveillance or tracking error. Such alerts provide no useful information and can create distraction and increase workload for controllers. Other short-duration alerts occur when the system detects a maneuver shortly after an alert activation. For example, a controller might recognize a potential conflict situation and issue a turn to the aircraft. However, time is needed for the pilot to implement the instruction, for the aircraft to respond, and for the tracker to detect the turn. An alert in this instance would be a nuisance because the controller resolved the situation before it activated and the alert provided no new information.

How long does an alert need to last before we can consider it not a nuisance? Research has shown that controller and pilot communications about maneuvers last 10.8 seconds on average, and traffic advisories 10.9 seconds (Cardosi & Boole, 1991). In addition, research indicates that the time required for an aircraft in the landing configuration to level off and start a climb is 10-12 seconds (Rogers, 1999). Therefore, at least 20 seconds are necessary for a controller to recognize an alert, formulate a response, communicate it to the pilot, and for the pilot and aircraft to respond.

We considered alerts lasting less than 20 seconds that did not result in OEs to be nuisances, because they deactivated before a controller response could have taken effect. Aircraft positions update every 12 seconds in en route, based on the update rate of long range radars, and every 4.8 seconds in terminal, based on the update rate of short range radars. Using the 20-second criterion and being conservative, we considered alerts lasting only one update in en route or one, two, or three updates in terminal to be nuisance alerts.

We calculated the alert duration for 653 alerts. To simplify the analysis, we divided durations into five categories based on how long the alert lasted. Table 1 shows the percentage of alerts in each category.

Table 1. Frequency Distribution of Alert Durations

Duration			CA		MSAW	
Updates	ARTCC	TRACON	ARTCC	TRACON	ARTCC	TRACON
1	10-12s	0-5s	31%	1%	7%	0%
2 or 3	13-36s	6-15s	34%	35%	39%	53%
4 or 5	37-60s	16-25s	14%	19%	10%	13%
6 or 7	61-84s	26-35s	6%	12%	7%	9%
> 7	>84s	>35s	15%	33%	37%	24%
		Total (n)	299	226	83	45

There were many short-duration alerts in both en route and terminal. In en route Air Route Traffic Control Centers (ARTCCs), 31% of the CAs lasted only one update (≤12 s). In Terminal Radar Approach Controls ((TRACONs), 36% of the CAs lasted one, two, or three updates (≤15 s), and 53% of MSAWs lasted one, two, or three updates. In these cases, there was not enough time between the activation and deactivation for a controller response to have had an effect. These short-duration alerts ended because situations resolved without controller action or due to controller action taken before the alert activated. For MSAWs in en route, only 7% lasted one update and, therefore, only a small percentage would be considered nuisances by this criterion.

There were also many alerts with durations longer than seven updates. We suspect that controllers delayed issuing control instructions when they concluded that a situation did not warrant immediate action or when they wished to let a situation play out before committing to changing the flight path of an aircraft. In addition, military flights frequently fly so close to other military flights or to the ground that they remain in alert status for a large portion of the flight. These flights contributed to the relatively large number of long-duration alerts. Although these alerts may be valid, they are nuisances in that they last longer than necessary and they occur long before any controller action is required.

Analysis of Controller Responses

For each alert, we determined whether the controller made a response to at least one of the aircraft involved. We defined a response as a communication that attempted to address a conflict or low altitude situation. To count as a response, a communication had to be relevant to the situation and the action taken. Because alerts can involve multiple aircraft and controllers can issue multiple commands to a single aircraft, a single alert may have received multiple responses.

These analyses are based on the percentage of alerts that received a controller response and the timing of those responses. The data include all alerts involved in CAs or MSAWs for which we obtained communication data. In en route, controllers responded to CAs 38% of the time; in terminal, 56% of the time. En route controllers responded to 9% of the MSAWs whereas terminal controllers responded to 39%. This leaves substantial portions of both alert types that received no response.

The reasons why a controller may not have responded to an alert include the following.

- An alert may occur while one or both aircraft are in a special status, such as military aircraft in Special Use Airspace, training flights with pre-coordinated actions, or helicopter flights with previously arranged flight paths (*Categories 1, 2, 3, and 5*). For CAs, 52% of the aircraft in en route and 43% in terminal were in one of these categories. For MSAWs, 85% of the aircraft in en route and 13% in terminal were in one of these special categories. In these cases, no response *was* the appropriate response. However, controllers still had to attend to and make decisions about these alerts. These are true nuisance alerts.
- The controller may assess a situation and determine that no response is necessary (*Categories 1, 2, 3, 5, and 6*). For CAs, this may occur when one aircraft is under Visual Flight Rules, because only the aircraft under control can receive a response. For MSAWs, this may occur when controllers become familiar with local obstructions and can quickly determine an aircraft's proximity to it.
- An alert may occur while an aircraft is on a previous sector's frequency or after a pilot changes to the next sector's frequency (*Categories 1 and 3)*.
- A controller may not have seen or heard an alert.

We excluded alerts that received no response from further analysis. When controllers do respond to potentially hazardous situations, the data show that controllers most often respond *before* the CA or MSAW activates. For the 394 aircraft involved in a CA and the 56 aircraft involved in an MSAW that received a response, 67% and 68% received responses before the alert activated. This indicates that controllers are continually searching for hazardous situations and proactively taking action, rather than waiting for automation to tell them when action is necessary. It is also strong evidence that most CAs and MSAWs notify controllers about situations of which they are already aware. At best, these alerts are redundant and create additional workload for controllers who must ignore or suppress them. At worst, they distract controllers at critical moments, increase alert desensitization, and decrease trust in the automation.

For responses that occurred *after* an alert activated and were the first responses made toward the affected aircraft, the median time from CA activation to the controller response was longer than a minute. For *control instructions,* where a controller asks a pilot to change altitude, heading, etc.,

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the median response time was approximately 88 s. For *traffic advisories*, where controllers warn aircraft that they may violate separation standards, the median response time was approximately 78 s.

These long gaps suggest that controllers wait to see how a situation develops before taking action. This does not mean that such alerts are unnecessary, because they do lead to action. However, the delays suggest that controllers do not consider most CAs to be situations requiring immediate attention. They may also be an indication of *cry wolf* syndrome (Breznitz, 1983). Further analysis is necessary to determine what situational factors prompt action from the controllers, such as the aircraft reaching some threshold.

For MSAWS, controllers also take time (38 s), before beginning to issue *control instructions* for responses that a) begin after the alert, and b) are the first response toward that aircraft. This suggests that they wait for low altitude situations to develop before instructing a pilot to climb or turn. However, controllers responding to MSAWs wait less than half as long before issuing control instructions as they do when responding to CAs (38 s versus 88 s). Additionally, controllers begin issuing low altitude *traffic advisories* almost immediately (3 s or 4 s) after an MSAW activates. Such immediate advisories are not as typical for CAs. This suggests that controllers regard most MSAW situations to be more urgent than most CAs. When low altitude alerts occur, controllers seem to consider this to be an urgent event requiring immediate attention.

Analysis of Operational Errors

We coordinated with the FAA Civil Aerospace Medical Institute (CAMI) to search the OE Database. We requested any information on OEs that occurred in the facilities during the time periods included in our alert sample. Out of 1573 CAs and 478 MSAWs examined, none resulted in an OE or deviation. This provided converging evidence that those alerts where controllers did not respond were nuisance alerts, given that no action was taken and no errors occurred.

CONCLUSIONS AND RECOMMENDATIONS

If a controller makes no response to an alert and the situation does not develop into an OE, we can conclude that the situation resolved itself and that the alert was some form of nuisance alert.

The results indicate that controllers experience a large number of nuisance CAs and MSAWs. The number of nuisance alerts is the most serious human factors issue facing ATC alerting systems. Nuisance alerts create workload and distractions and can lead to desensitization and poorer overall performance.

Determining whether an alert was a nuisance is a difficult task, after the fact, with limited data. In the moments after an alert activates, we do not know whether a controller considered it to be a nuisance. We also could not sort the data into the seven nuisance alert categories. Although we could make reasonable inferences as to whether and why an alert was a nuisance, we could not do so in all cases. To answer such questions, we would need to conduct a human-in-the-loop simulation where we could stop the simulation and ask controllers why they did or did not respond to an alert. We cannot know what a controller knew about the traffic at the time an alert activated. An alert that might be a nuisance to one controller might be a necessary warning to another. We also cannot know if the automation or the voice tapes failed to record some of the actions taken by controllers. At best, we can estimate the nuisance alert rate based on what the controllers did or did not do when the alert activated.

Of the alerts examined in en route, our best estimate is that 62% of the CAs and 91% of the MSAWs were nuisance alerts. Of the alerts examined in terminal, we estimate that 44% of the CAs and 61% of the MSAWs were nuisance alerts. They were nuisances in that no additional action from the controller was necessary after the alert to prevent the situation from developing into an OE. Of the aircraft in en route and terminal involved with CAs and MSAWs that received a controller response, 67% and 68% received the response *before* the alert activated. Although not entirely nuisances, these alerts can be considered redundant or unnecessary. Taking action prior to an alert is strong evidence that most CAs and MSAWs notify controllers about situations of which they are already aware. Furthermore, of the alerts we examined, 31% of CAs in en route, 36% of CAs in terminal, and 53% of MSAWs in terminal lasted for such short durations that controllers took action to address the situation prior to the alert activation or the alert situation resolved itself without action. Taken together with the estimated nuisance alert rate, we estimate that as many as 87% of CAs in en route, 81% of CAs in terminal, 97% of MSAWs in en route, and 87% of MSAWs in terminal did not provide useful information beyond what the controllers already knew and were not necessary to maintain safety.

Though our analysis did not tell us what effect such a large number of nuisance alerts may have on controller performance, the human factors literature from other domains is clear: Professionals do not respond as well to genuine alerts in environments where many nuisance or low-priority alerts occur. The high number of nuisance alerts decreases controller trust in the automation systems and desensitizes controllers. When controllers become desensitized, they are more likely to overlook genuinely hazardous situations because they become accustomed to treating most as nuisances.

Research in other domains has shown that if the reliability rate of an alert is lower than 70%, professionals would perform better, overall, if they ignored the alert entirely and relied on their own detection and decision-making abilities (Wickens & Dixon, 2005). With more than 80% of the alerts examined here being nuisances, the reliability of ATC safety alerts would need to be improved dramatically before we can conclude that they significantly help controllers maintain safety.

There are a number of improvements that could be made to the human factors attributes of ATC safety alerts. First, the FAA should develop alert algorithms and presentations that

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are specifically intended to reduce the number or human factors impact of nuisance alerts. Automation systems should also allow alerts to reactivate when a CA or MSAW lasts longer or becomes more urgent than a set of predetermined criteria. Field facilities should periodically determine where and under what circumstances nuisance alerts occur so as to build and improve suppression zones and MSAW grids. The FAA should develop prototype alarms that incorporate gradations of urgency or likelihood and evaluate these prototypes through human factors testing. Lastly, the FAA should conduct further analyses of controller and pilot response times to alerts to develop more precise parameters for use in safety alert algorithms.

Identifying nuisance alerts by listening to voice recordings and analyzing controller responses does not tell us why nuisance alerts occurred. What factors led the algorithms to conclude that an alert was needed to maintain safety when, in fact, it was not? What information could safety alert algorithms have considered that would have led to a different conclusion? Answers to these questions are necessary to help developers to select new information to include in algorithms and to incorporate better, more accurate alert parameters.

Lastly, one major source of nuisance alerts is that the automation systems are not aware of every action that controllers take or plan to take. If algorithms could incorporate information about aircraft intent, they might not issue as many nuisance alerts. En route systems incorporate some of this functionality already, including information such as routes and interim altitudes, but current terminal systems either lack this functionality or controllers do not commonly use it. Steps should be taken to ensure that future terminal automation systems incorporate some of this functionality.

REFERENCES

Ahlstrom, V. (2003). An initial survey of National Airspace System auditory alarm issues in terminal Air Traffic Control (DOT/FAA/CT-TN03/10).

Allendoerfer, K., Friedman-Berg, F., & Pai, S. (2007). *Human factors analysis of safety alerts in air traffic control* (DOT/FAA/TC-07/22).

Altmann, E. M., & Trafton, J. G. (2002). Memory for goals: An activation-based model. *Cognitive Science*, *26*, 39-83.

Breznitz, S. (1983). *Cry wolf: The Psychology of False Alarms*. Hillsdale, NJ.

Cardosi, K., & Boole, P. W. (1991). *Analysis of pilot response time to time-critical Air Traffic Control calls* (NTIS No. DOT/FAA/RD-91/20).

Federal Aviation Administration. (2006). Adjustable volume for the TRACON, Case File No. ATO0T-STARS-1021. Internal system configuration management communications between a field site and the FAA Standard Terminal Automation Replacement System (STARS) program, initiated February 1, 2006.

Getty, D. J., Swets, J. A., Pickett, R. M., & Gonthier, D. (1995). System operator response to warnings of danger: A laboratory investigation of the effects of the predictive value of a warning on human response time. *Journal of Experimental Psychology: Applied*, *1*, 19-33.

Jones, D. M. (1999). The 1997 BPS Broadbent Lecture: The cognitive psychology of auditory distraction. *British Journal of Psychology, 90,* 167-187.

Meyer, J. (2001). Effects of warning validity and proximity on responses to warnings. *Human Factors, 43*, 563–572.

Parasuraman, R., &. Hancock, P. A. (1999). Designing automated warning systems: A signal detection and Bayesian analysis. In M. W. Scerbo & M. Mouloua (Eds.), *Automation technology and human performance: Current research and trends* (pp. 63-67). Mahwah, NJ: Erlbaum.

Rogers, R. (1999). *Flight test results of the controlled flight into terrain avoidance maneuver in fly-by-wire transports*. Report of the Air Line Pilots Association. Airworthiness Performance Evaluation and Certification Committee.

Sanquist, T. F., Thurman, D. A., & Mahy, H. A. (2005). The human element in homeland security systems: Application issues and research needs. *Proceedings of the HFES 49th Annual Meeting*, 913-917.

Sarter, N. B. (2005). Graded and multimodal interruption cueing in support of preattentive reference and attention management. *Proceedings of the HFES 49th Annual Meeting,* 478-47.

Stokes, A., & Wickens, C. (1988). Aviation displays. In E. L. Wiener & D. C. Nagel (Eds.), *Human factors in aviation* (pp. 387–431).

Watson, M., Sanderson, P., & Anderson, J. (2000). Designing auditory displays for team environments. *Proceedings of the 5th Australian Aviation Psychology Symposium (AAvPA)*,

Wickens, C. D., & Dixon, S. R. (2005). *The benefits of imperfect diagnostic automation: A synthesis of the literature* (Technical Report AHFD-05-01/MAAD-05-1).

Xiao, Y., Seagull, F. J., Nieves-Khouw, F., Barczak, N., & Perkins, S. (2004). Organizational historical analysis of the failure to respond to alarm problem. *IEEE Transactions on Systems, Man, and Cybernetics. Part A: Systems and Humans*, *34*, 772-778.

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