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Short-term consequences of radio communications blackout on the U.S. National Airspace System

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ABSTRACT

Loss of Air Traffic Control (ATC) radio communication is considered a high consequence failure due to the potential increase in mid-air collision risk. An analysis was conducted to determine how quickly collision risk would increase after a full ATC communications failure, or blackout, to determine requirements for backup communication systems. The analysis was conducted for the enroute high-altitude environment and also for terminal area operations in the New York City region. Communication failure simulations were run every 15 minutes using 7 days of ETMS data for the entire U.S. airspace, and using 5 days of PDARS data for New York City region. Conflict rates were observed to increase beyond the baseline level within 1 minute of the simulated communication failure and to have increased by at least a factor of 4 within 5 minutes of the communication failure indicating the requirement for immediate backup ATC communications.

1. Introduction

The air–ground communication system is considered to be one of the most critical technical elements in the Air Traffic Control system. Loss of communication renders the controller unable to issue commands to aircraft. The failure of the communication for an individual aircraft is managed by means of standard procedures where the aircraft continues on its assigned clearance while other aircraft are vectored away from the expected route. A large-scale communication failure, or blackout, is significantly more critical and the only mitigation from conflicting trajectories is the onboard Traffic Collision Avoidance System (TCAS).

This study investigates the rate at which the collision risk would increase in the event of a large-scale ATC communications failure. The results will provide insight into the speed at which back up communications systems must come on-line to ensure that safe separation between aircraft is maintained.

Mid-air collisions are rare but often catastrophic in modern Air Traffic Control systems. Worldwide, the number of mid-air collisions for airlines has decreased from one per year in the 1970s to four per decade in the 1980s and 1990s, with just two mid-air collisions in the 2000–2009 time period [4]. The reduction in mid-air collisions is thought, in part, to be the result of the introduction of the Traffic Collision Avoidance System (TCAS), which has contributed to the decrease in mid-air collisions despite increased traffic levels. TCAS II was mandated in the U.S. in 1993 (Federal Aviation Regulation FAR 121.356) and stating in 2003 the International Civil Aviation Organization (ICAO) mandated world wide use for passenger capacity of more than 30 (extended to more than 19 passengers in 2005). Studies conducted for Eurocontrol concluded that the current probability of a mid-air collision in the European airspace is equivalent to one every 3 years, and this probability will be reduced by a factor of 4 with the implementation of TCAS II version 7.1 [1]. Even with the TCAS backup, the loss of ATC communications is a significant event with the potential to increase collision risk. In addition, if ATC communication is lost due to intentional denial of service (jamming), it is possible that TCAS signals will also be jammed, resulting in a more significant increase in collision risk.

2. Description of the analysis approach

The general approach used in this study was to simulate communications failure with actual traffic scenarios observed in operational radar data from the Enhanced Traffic Management System (ETMS) and Performance Data Analysis and Reporting System (PDARS). Communications failure was simulated by extrapolating the velocity vectors of each aircraft at the time of assumed communication failure. This is a simple approximation of the current lost communication procedure for No Radio (NORDO) aircraft. Federal Aviation Regulation FAR 91.185 [2] states that under VFR conditions each pilot should continue the flight and land as soon as practicable, and under IFR conditions pilots shall continue the

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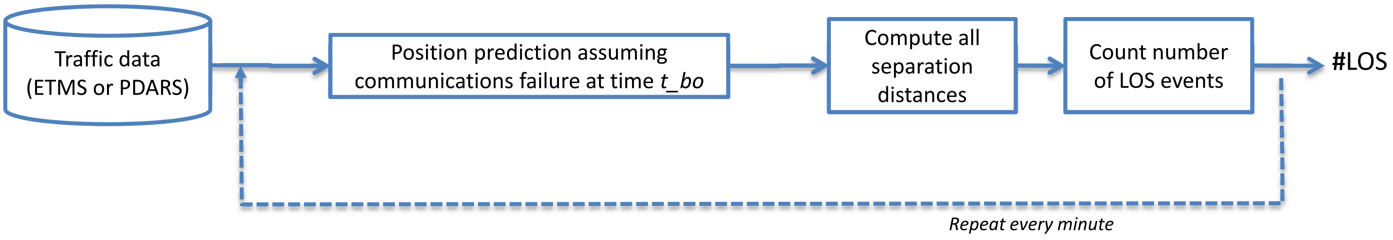

Fig. 1. Analysis approach.

flight according to the route assigned in the last ATC clearance or the route filed in the flight plan. Therefore the assumption of constant velocity vectors is acceptable since the regulation does not mandate any immediate course change as soon as the radio failure is detected (such as descend to a given flight level). Moreover, it may take some time for the pilots to realize that they have lost communications since there is no real-time monitoring for availability. For example, in the mid-air collision of GLO 1907 and N600XL on September 29th, 2006 over Brazil in which TCAS was unavailable due to technical failure [10], the ATC had been trying to contact pilots of the Embraer Legacy business jet during 30 minutes before the collision and also the aircraft had been trying to call ATC in 19 unsuccessful attempts during the last 9 minutes before the collision; the course was not modified during that time. Maybe the most extreme example of continuous flight without communication was Northwest 188 on October 21st, 2009, in which pilots were distracted by their laptop computers and did not communicate with ATC for about 1 h 17″ while they cruised past their destination [11].

It should be noted that the assumption of constant velocity vectors will overestimate the number of expected conflicts because this simple extrapolation does not take into account previously issued clearances (which are not observable in the data set), but should give a reasonable representation of how quickly potential conflicts emerge in the uncontrolled blackout environment. It is difficult to evaluate how many near-conflicts are being avoided by communications between air traffic controllers and pilots. Some research into Enhanced Traffic Management System (ETMS) has focused on synchronizing actual data with flight plans, in order to evaluate if deviations from the initial flight plan were implemented to avoid potential loss of separation [7]. In the proposed approach, a communications blackout is simulated by extrapolating position. Future positions are computed under failure condition by assuming constant velocity vectors, and then separation distance is monitored.

The analysis is based on tracking the number of events of Loss of Separation (LOS) as a function of time after the simulated communication failure. The number of loss of separation events is used as a surrogate for risk, although other mitigations such as TCAS would of course prevent the majority of mid-air collisions from occurring. Minimum separation distance was the parameter used in the analysis. In accordance with the current minimum separation standards in radar conditions, a value of 5 miles and 1000 ft was used as the separation criterion in the enroute airspace analysis and 3 miles and 1000 ft was used in terminal area airspace analysis. Minimum separation distance is the most important parameter used in air traffic control safety analysis. This parameter was also used in [6] to obtain separation times at Initial Approach Fix (IAF) for different types of aircraft, using Advanced Continuous Descent Approach (ACDA) or conventional approach procedure.

To define the baseline of apparent LOS events that will be used to compare with simulated conditions, the number of loss of separation events is first evaluated in actual conditions. Note that some apparent LOS events are expected in the baseline conditions due to VFR aircraft operating with visual separation procedures which have no specific minimum separation criteria. The analysis then evaluated the progression of the number of LOS events after communication failure compared with the baseline level. Simulations of communications failure were executed for different days of the week and at different times of the day in order to examine if the consequences were sensitive to initial conditions. The approach is summarized in Fig. 1.

Two data sources have been used to evaluate the consequence of communication failure in both the high-altitude enroute environment and terminal area environment. For the high-altitude enroute environment one week (9/21/09–9/27/09) of Enhanced Traffic Management System (ETMS) data was analyzed. In order to avoid ambiguity with enroute vs terminal separation standards, only the ETMS data above 7000 ft MSL was used which resulted in 377,174 flight tracks. For the terminal area environment, Performance Data Analysis and Reporting System (PDARS) data was collected in the New York Terminal Radar Approach Control (TRACON) for 5 days in 2008 (2/5/08, 3/19/08, 3/31/08, 6/23/08, 7/23/08). During this period, there were a total of 39,567 flights.

The ETMS dataset includes information about all aircraft following Instrument Flight Rules (IFR) in the National Airspace System (NAS) and a few flights in other territories (mostly flight tracks reported by U.S. Airlines) as well as aircraft following Visual Flight Rules (VFR) but receiving ATC radar services. Information outside the U.S. and Canada is not reliable for detailed analysis and was eliminated for this study. The information in the ETMS database includes the 4D trajectory of every aircraft nominally at 1 minute intervals based on the position as tracked by radar systems or reported by onboard positioning systems. The trajectories are stored in terms of latitude, longitude and MSL altitude, with a resolution of one minute in latitude and longitude, 100 ft in altitude.

It is well documented that altitude data in ETMS is sometimes inconsistent [8] and the database occasionally includes rapid altitude changes which are not physically realizable by current aircraft. The noisy altitude date appears to be related to switching between altitude data sources and default altitude assumptions when source data is not available. Because the trajectory predication algorithm is sensitive to these altitude errors, it was necessary to filter ETMS data. A procedure was developed to filter ETMS altitude data [13] that was able to correct 99.7% of the flights affected by noise. The filtering is performed in such a way that altitude erroneous data, when detected, are corrected by interpolation with neighboring points, while preserving the original clean altitude data (see Fig. 2).

ETMS data is valid for the analysis of enroute flights due to the large separation standards in enroute airspace (5 miles, 1000 ft). However, ETMS does not provide enough resolution for the analysis of aircraft traffic in the terminal area where the minimum lateral separation standards reduce to 3 miles and the aircraft are more likely to be maneuvering for approach or departure. Therefore the terminal area analysis was based on radar data from Performance Data Analysis and Reporting System (PDARS). PDARS trajectories are based on terminal radar data, with a nominal sampling period of 4 seconds in the terminal area (in contrast with one minute in the ETMS dataset) and more accurate altitude data [3].

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