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A causal factors analysis of aircraft incidents due to radar limitations: The Norway case study

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ABSTRACT

Provision of seamless, safe and effective surveillance services to airspace users requires high performance surveillance sensor coverage in the whole airspace. Limitations in the surveillance system will lead to an inability to provide the required surveillance services to the users. This may result in aircraft incident and accident occurrences. In this paper a case study is developed for the Norwegian airspace, based on five years of safety reports, to identify causal factors of incidents/accidents due to radar system limitations. This is conducted with a safety data analysis from Avinor – Norway's Air Navigation Service Provider (ANSP) and structured communication with Surveillance/ATM safety experts from Avinor. The case study shows that, 76 out of 124 occurrences within the five years in the Norwegian airspace/airport were related to the surveillance function, and 34 out of the 76 occurrences were due to limitations in the radar systems. The analysis identified that the highest contributing causal factors of the occurrences due to radar system limitations were limited surveillance coverage, followed by the lack of situational awareness for flight crew/controllers and unsynchronised surveillance information between flight crew and controllers.

1. Introduction

Air transport is amongst the fastest growing means of transportation due to a number of factors, including increasing globalization and freedom of movement of people and goods within and between regions. According to EUROCONTROL's 20 years traffic forecast, there will be 14.4 million Instrument Flight Rules (IFR) movements in Europe in the year 2035, 1.5 times more than in 2012. The growth is estimated to average at 1.8% annually (EUROCONTROL, 2013). However, the current Communication, Navigation, and Surveillance (CNS) systems that support Air Traffic Management (ATM), and in particular Air Traffic Control (ATC), are at their operational limits and, therefore, cannot readily accommodate the increasing air traffic. This is particularly acute in the provision of ATC services in low altitude, remote and oceanic areas.

Limitations in the radar systems include unavailability of services in oceanic and remote areas, limited services during extreme weather conditions and outdated equipment without spare parts (ICAO, 2000). The impact of the limitations can be seen in the occurrence of incidents and accidents that involve casualties. For example, there is a 13% probability of a fatality in a terrain-incursion accident in Alaska for an air taxi pilot due to a limited surveillance service as a result of difficulties in siting radar in the area (Butterworth-Hayes, 2012).

The term ***system limitation*** in this paper refers to insufficient capability or inadequacy of a system to perform in the different phases of operation with the required performance in terms of accuracy, integrity, continuity and availability (Surveillance and Conflict Resolution Systems Panel, 2004) which could lead to incidents or accidents. The limitations identified in the radar systems might be due to particular functional requirements overlooked during the system design phase, e.g. extreme cases such as coverage in remote areas, the need for high-performance situational awareness for flight crew and controllers, degraded visual conditions during extreme weather (Herrera et al., 2009), especially for Visual Flight Rules (VFR) flights and requirements to meet future air traffic volumes. Today there is no single surveillance system that satisfies the Required Surveillance Performance (RSP)

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(Surveillance and Conflict Resolution Systems Panel, 2004) required for future traffic volumes without jeopardising safety.

The impacts of the limitations manifest in the occurrence of incidents and accidents. The ICAO defines these two types of occurrences (ICAO, 2001) as:

- An ***accident*** is "an occurrence associated with the operation of an aircraft, which takes place between the times that any persons board the aircraft with the intention of flight and that all such persons have disembarked, in which any person suffers death or serious injury, or in which the aircraft receives substantial damage";
- An ***incident*** is "an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation. Such incidents and accidents are reported by ANSPs to civil aviation regulators".

In order to analyse the manifestation of the impact of radar limitations in the real world, a case study using safety data is developed in this paper. The case study considers the Norwegian airspace. This research is conducted with a literature review of the current surveillance systems, safety data collection and analysis from Avinor – Norway's Air Navigation Service Provider (ANSP), and structured communication with Surveillance/ATM Safety experts from Avinor. Five years of safety reports from Avinor are examined to identify incident occurrences due to limitations in the radar systems. The causes of the occurrences are then further analysed to identify the contributing causal factors. All of the safety reports considered in this paper involve aircraft incidents in radar airspace.

In Section 1, the research background is introduced. Section 2 describes the specific surveillance situation in the Norwegian airspace. Section 3 begins by describing the required data for the research, followed by a detailed description of the analysis and subsequent results. The next section discusses the findings in Section 4 and assimilates the results with the aim of the research in Section 1. Finally, the last section concludes the work.

2. Norwegian airspace

Norway has a large oceanic area with a length of coastline of 25,148 km (Avinor, 2012). Aviation links the country together by having very good airport coverage. Apart from large airports in urban areas such as Oslo, there are also many small airports in less populated areas. In addition, the country has a relatively large offshore industry, whereby 13% of domestic flights are linked to the oil and gas sector. This does not include 550,000 helicopter flight movements yearly to/from the rigs (Avinor, 2012). Furthermore, Norway has harsh climatic conditions. Taking into account these factors, realizing full surveillance coverage for the Norwegian airspace solely with radar is a challenge.

The Norwegian ANSP operates 46 airports in Norway, with 12 of these in cooperation with the armed forces. Their operations also include air traffic control towers, control centres and technical infrastructure for aircraft navigation and surveillance. Fig. 1 shows the radar locations maintained by the ANSP. Most of Norway's airspace has redundant radar coverage. Table 1 presents Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) aircraft movements for all the 46 airports in Norway for the period 2008 to 2012. The trend indicates a gradual increase from 2009 to 2012 after a significant drop from 2008 to 2009.

3. Safety data analysis

This analysis involves a step-by-step approach to identify the causal factors of occurrences due to the limitations in the radar system. The steps are described as follows:

Step 1 The reports of occurrences involving aircraft in the radar airspace are extracted from the database.
Step 2 The occurrences due to ATM supporting functions, which include navigation, surveillance and communication systems are reported as 'insufficient separation', 'lack of, or reduced ability to provide ATM Services', and 'inability to provide Air Traffic Services (ATS)'. The occurrences under these categories are identified.
Step 3 Narratives of all the reports identified in Step 2 are analysed to identify the specific ATM supporting function that contributed to the particular occurrence.
Step 4 Causal factors of occurrences associated with surveillance function are categorized into three categories, based on the narratives: 'Contextual Environment', 'Human Error' and 'System Limitation'.
Step 5 Percentages of occurrences for the three categories in Step 4 are measured.
Step 6 A questionnaire is developed and used with the ANSP experts to identify the underlying causes of all the occurrences under 'System Limitation' category.
Step 7 The narratives of the occurrences under 'System Limitation' category, are analysed further to identify the specific causal factors of the occurrences.
Step 8 The causal factors' grouping phrases are developed to bring together similar reported causal factors using different sentences in the safety reports by different investigators.
Step 9 The number of occurrences for each causal factor identified in the safety reports are measured and mapped to the corresponding grouping phrase developed in Step 8.

After reviewing the safety reports from various ANSPs and regulators, it was found that data from the Norwegian ANSP, Avinor, was best suited for this analysis due to its completeness and organised structure. In addition, structured communication with SMEs from EUROCONTROL indicated that, based on their working experience with the European countries on safety issues, the Norwegian ANSP has an excellent reputation for reporting of safety occurrences. All the safety reports are stored in the MESYS database, which contains original reports and the findings of investigations. This reporting system complies with the EUROCONTROL Safety and Regulatory Requirements (ESARR 2) (EUROCONTROL, 2009). Based on these facts, the organisation was evaluated as a reliable source of reporting and five years (2008–2012) of incident data were gathered accordingly.

The key requirements for the data are:

- a detailed explanation of the causal factors of the events;
- sufficient reporting duration (to meet the analysis objective) and
- a consistent quality of reporting.

The next sub-section provides detailed results of each step in the analyses.

4. Results

A descriptive statistical analysis (Table 2) of the five years of safety data shows that with the exception of 2010 and 2011, with the same level of incidents, the number of incidents has been increasing significantly. However, the number of accidents decreased significantly from 2010 to 2011 (from 9 accidents to 3 accidents) despite the increase in air traffic. The accident figure