INCIDENT REPORTING IN OFFSHORE HELICOPTER TRANSPORTATION

Felipe A. C. Nascimento, f.a.c.nascimento@imperial.ac.uk, Imperial College London (UK)
Arnab Majumdar, a.majumdar@imperial.ac.uk, Imperial College London (UK)
Washington Y. Ochieng, w.ochieng@imperial.ac.uk, Imperial College London (UK)

Abstract

This paper builds on the lessons from accident investigations to analyse helicopter incidents in the British Mandatory Occurrence Reporting (MOR) scheme. From the results of the analysis, the paper highlights potentially severe shortcomings in a number of critical areas, and informs stakeholders in industry of specific initiatives to ensure that the right lessons are learned from past occurrences and how these could be used to inform future interventions.

1. INTRODUCTION

For over five decades, helicopters have provided essential support to offshore oil and gas exploration and production activities worldwide. To address unacceptably high accident rates in the initial years of operations [1], considerable investment has been made, mostly in the North Sea (NS) [2-3], an area of the world's second largest volume of offshore helicopter flights [4] undertaken under the attentive watch of coordinated stakeholders (e.g., regulators, petroleum companies and helicopter operators). Currently, the oil and gas industry drives safety requirements for helicopter operations worldwide [5-6] and the North Sea remains a test bed for the development of novel safety infrastructure and programmes that subsequently benefit the wider helicopter community, e.g. [7].

One programme of major importance to offshore helicopter operations in the North Sea is the Mandatory Occurrence Reporting (MOR) Scheme (NB: occurrences are incidents, serious incidents and accidents). Initiated in the UK in 1976, the scheme addresses the requirements set out by the European Parliament and International Civil Aviation Organisation (ICAO) whereby contracting states are required to establish a mandatory occurrence reporting system which facilitates the reporting, collection, storage, protection, analysis and dissemination of information on actual and potential safety deficiencies across the aviation industry [8]. Effective safety reporting systems form a fundamental building block of ICAO-mandated Safety Management Systems (SMS) [9-10].

The MOR Scheme has as the sole objective to prevent accidents and incidents and does not attribute blame or liability. Therefore, it has provisions to ensure confidentiality of the reporters, specified by the UK Civil Aviation Authority (CAA). The scheme applies to any aircraft operating under an air operator's certificate or with a certificate of airworthiness granted by the UK CAA. Voluntary reporting is also encouraged in non-obligatory circumstances [8]. Annually, over 14,000 mandatory occurrence reports are filed with a current total of over 200,000 entries, making it the world's most established scheme [11].

For many years, the contents of the MOR Scheme's database have been used in Probabilistic Safety Assessments (PSA) to inform the establishment of safety interventions in the offshore helicopter industry (e.g. [12]). The underlying premise for such use is that incidents are precursors to accidents. Therefore, by monitoring incidents and acting appropriately, accidents could be avoided.

This view stems from the work of Heinrich dating back to 1931 (and re-published more recently [13]), in which safety events of varying severity could be ordered in a pyramidal fashion according to their frequencies. The pyramid shows that numerous occurrences with fairly negligible consequences (the base of the pyramid) precede the much less frequent, but significantly more damaging accidents (at the top). Precisely, Heinrich observed that unreported incidents, reported incidents and accidents occurred at a 300:29:1 ratio (Figure 1).

The belief in pyramidal relationships across occurrence types has endured (e.g. [14]), despite some dispute over its validity [15-16]. The proportions involved have often been re-calibrated and new severity levels incorporated to reflect the practices of various industrial applications not covered by Heinrich's pioneering work. For example, the existence of a fourth severity level appears to have recently been acknowledged at the base of the pyramid of offshore helicopter operations, representing the many deviations in flight path and aircraft attitude routinely registered by Helicopter Flight Data Monitoring (HFDM) devices [17].

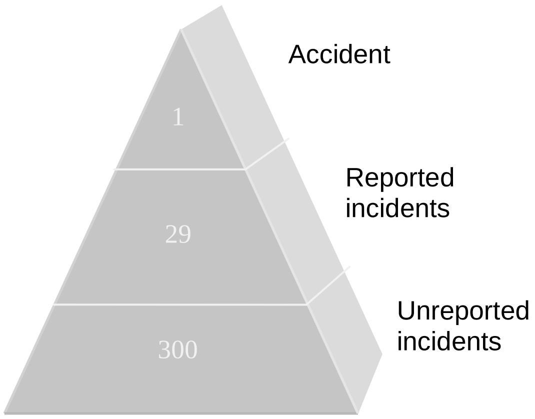

Figure 1: Heinrich's pyramid [13]

Occurrence data are also used for the establishment and monitoring of safety performance indicators in a number of hazardous industries. For example, the Norwegian offshore helicopter operators have employed statistical analysis of incidents to assess their levels of safety and define areas in need of priority attention. Additionally, the sheer number of incidents coupled with their severity has been regarded as a safety performance indicator on its own right [18]. However, previous attempts to use reported incidents in a robust quantitative manner have also been unsuccessful because of the uncertainty in the quality of the collected data, e.g. [19].

The importance of analysing safety occurrences is now a major topic of discussion, given the ongoing need to improve safety through lessons learnt from infrequent and high risk operations, such as nighttime offshore helicopter flying. This is particularly relevant as a number of countries plan for massive expansion of helicopter operations towards Polar regions [2], where darkness prevails for several months of the year and accurate knowledge of current safety shortcomings is needed to enable well-informed hazard predictions and implementation of appropriate interventions. Moreover, given the new performance based data grounded safety audits mandated by SMS regulations in aviation, data quality considerations have become very important in this domain [11].

Learning useful lessons from safety occurrences thus relies on the quality of the information input, stored and retrieved from such databases, as much as on the characteristics of the database [20]. In this respect, data quality assessment and assurance techniques, developed to address serious concerns related to the reliability, validity and representativeness of the data collected in several domains, might potentially apply to helicopter operations. Therefore, a review of data quality issues follows.

2. DATA QUALITY CONSIDERATIONS

Over the past decades, several industries (e.g., banking and consumer goods manufacturing [21-22]) have sought assurance that the information used for business-related decisions is of the best quality possible. This has led to treating information production by means of designed processes with a focus on data quality. Such processes often require the identification of relevant data quality dimensions (e.g., believability, completeness, timeliness and value-added) and the development of metrics with which to evaluate such dimensions (e.g., simple ratio, minimum and maximum operators, weighted averages) [23]. Exhaustive lists of quality dimensions and metrics can be found in [21-28].

The design of data production processes also requires the identification of the stakeholders involved, as they can both introduce biases and set out specific requirements to be met downstream or upstream for increased data quality. Stakeholders can be categorised as data collectors, data custodians or data consumers [26]. All have important roles to play in case low quality data is being produced, for example in the offshore helicopter industry. For instance, whilst pilots and maintenance engineers (i.e., data collectors) could bias the data collected by under-reporting human factors occurrences (thus compromising the 'value-added' dimension of data quality) [12, 14, 20], this could well be a result of insufficient guidance provided by data custodians (e.g., the MOR Scheme's database designers and operators) in relation to the types of occurrences to be reported, or that the data collectors are not sufficiently aware of the relevance of such events to data consumers (e.g., the CAA safety analysts). Indeed, previous research has identified that informing data collectors about the needs of downstream data consumers facilitates the generation of higher quality data [26]. This corroborates the need to educate professionals in the aviation sector as to what use is made of the occurrences reported, as well as about the issues associated with under-reporting or biased reporting of occurrences.

Some quality dimensions are more likely influenced by the acts of data consumers (e.g., under specification of requirements to data collectors and data custodians), whereas others depend more on the data custodians (e.g., the type of data input into the database due to the format of occurrence reporting forms), and finally on data collectors (e.g., sheer willingness to report). As a recurring topic in aviation which might also affect the offshore helicopter transportation, data collectors' reporting culture shall be discussed.

3. CRITICAL FACTORS FOR EFFECTIVE REPORTING OF OCCURRENCES

Many factors can influence the willingness to report safety occurrences. In the UK military for example [20], the time investment and effort associated with reporting occurrences, as well as fear of punishment, were found to be factors for under-reporting. Moreover, faulty information feedback mechanisms, leaving the reporter oblivious to the associated safety actions taken, were identified. Nevertheless, when reporting occurred, it was most often biased towards technical issues (e.g., faulty equipment) as guidance on what such occurrences consisted of, and event traceability (e.g., by recorded engine exceedances) were greater than with the less tenable human factors occurrences. From the over 4800 occurrence entries of 2007, only 65 were related to human factors.

In the USA, the reporting of occurrences in civil operations under the Aviation Safety Reporting System (ASRS) increased considerably after the operation of such database was transferred from the Federal Aviation Administration (FAA, a regulatory body with power to levy fines and revoke licenses) to the National Aeronautics and Space Administration (NASA, an independent body without such powers). Besides this suspicion on the dual role of the regulatory agency, fear of litigation and breaches of the scheme's confidentiality by magistrates were also speculated as factors for under-reporting [14].

Van der Schaaf et al. [29-30] explored why workers would still hesitate to disclose self-errors at a chemical processing plant renowned for its good safety culture. Besides some of the reasons mentioned above, they added that perceived uselessness (e.g., feeling that reports would not be acted upon by management anyway), accepted risk (i.e., understanding that some types of risk are inherent to the job), sense of personal immunity and a 'macho' attitude could be factors affecting the will to report.

'Perceived dread' [31-32] might also influence the reporting of incidents. It is an effect whereby reporters would tend to overestimate the frequencies of the factors that appeal to their fears, therefore potentially reporting such occurrences more often than the frequency with which they really happened.

According to the first edition of ICAO's Safety Management Manual (SMM, [33]) some of the factors for under-reporting of safety occurrences included embarrassment in front of peers, self-incrimination, fear of retaliation from employer for having spoken out and true sanctions, such as enforcement action by regulatory authorities. On the other hand, the principles of good reporting systems were listed:

- Trust, i.e. that the information disclosed won't be used against the reporter.
- Non-punitive; often achieved by the regulatory authority and top management assuring the confidentiality of the reporters.
- Inclusive reporting base; e.g., not only focused on capturing the flight crew's view, but also that from ground handlers.
- Independence; e.g., the operator of the database does not possess regulatory powers; or, in State-run databases, clear assurance is given that the information reported will be used only for safety purposes.
- Ease of reporting; e.g., as many tick off questions as possible.
- Acknowledgement; i.e. some call-back capability so that reporters know what resulted from their reports.
- Promotion; e.g., giving knowledge of the reporting scheme's existence by maximum exposure using a variety of communications media.
- Timely sharing the information reported with the aviation community.

In its second edition, the SMM ([34]) places greater responsibility on senior managers for fostering a safety culture in which sharp end workers (e.g., pilots and maintenance engineers) feel compelled and protected to report their genuine mistakes. Based on Reason's theories [35-36], such safety culture (and thus effective reporting systems) stem from five organizational traits:

- Effective sharing of information.
- Flexibility to reach the persons able to correct systemic faults directly.
- Positive learning environment.
- Clear accountabilities.
- Operators' willingness to report.

All such critical factors for effective reporting of occurrences could apparently apply to helicopter operations.

4. REPORTING CULTURE AND DATA QUALITY IN HELICOPTER OPERATIONS

In the helicopter industry, the quality of reported occurrences remains a serious concern raising important questions about the prospects of achieving the objective of the MOR Scheme across the wider, general aviation-dominated, rotary community. For example, in an analysis of 3481 helicopter occurrences reported under the British MOR Scheme between 1995 and 2004, Mitchell [37] identified that only 10% of the reports filed corresponded to private flights. However, such operations sustained 47% of all helicopter accidents in the same period. It was also noted that human factors issues were only causal to 17% of the reported occurrences, whereas they were attributed to 76% of the accidents. The opposite happened in relation to airworthiness failures, which corresponded to 68% of the MOR Scheme's dataset but to only 16% of the accidents.

The reasons for such discrepancies could include a lack of understanding of safety requirements and ad-hoc relationships between the smaller helicopter companies and their customers [37], both of which carry the potential to favour under-reporting (e.g., as listed in [12]) or biased reporting of occurrences.

In the USA, a public enquiry launched after a series of accidents involving helicopters used in Emergency Medical Services (EMS) also concluded that the scarcity of data severely impaired the analysts' full understanding of the issues involved [38]. Likewise, Fox [5] and the International Helicopter Safety Team (IHST) members of various regions [6, 39] found that the fundamental information needed for causal analysis of safety occurrences and the calculation of accident rates and safety targets (e.g., helicopter flying hours) are too infrequently logged in this domain.

Although it is generally expected that the offshore helicopter industry should be considerably less affected by the above influences, little is factually known in this domain about the data stored on official occurrences databases.

5. INCIDENTS AS PRECURSORS TO ACCIDENTS

Given the background in the previous sections, it interesting to investigate based on a specific operational scenario, if incidents can be trusted to be precursors to accidents. The scenario analysed is the North Sea's occurrences within the British MOR Scheme. The methodology used is designed to address the following objectives.

- Establishment of a framework for the analysis of occurrences for causes.
- Analysis of occurrences for causes.
- Establishment of a framework for the analysis of occurrences for phases of flight.
- Analysis of occurrences for phases of flight.
- Establishment of a methodology to estimate the flying hours of North Sea offshore helicopters according to lighting conditions (i.e., daytime and nighttime).
- Analysis of occurrences for lighting conditions.
- Confirmation of the findings by consultation (i.e., interviews) with experts in the field.

6. METHODOLOGY

With particular interest in causes, phases of flight and lighting conditions, the methodology starts by the sampling of occurrences at the MOR Scheme's database.

6.1. Sampling of occurrences

Occurrence data stored at the MOR Scheme's database are formed by objective information (e.g., date, time, location, route, speed, altitude, phase of flight) and a title and narrative sections open to the reporter's description of the event on their own words. Key phrases of the narratives are pick out using a key phrase lexicon developed by the UK CAA, which is an extended version of the Air Transport Association's specification 100 (ATA Spec 100) that incorporates human factors aspects. Subsequent searches on the database are done by means of such key phrases [8]. In this paper's case, the following search phrases were used: 'offshore', 'human factors', 'non human factors', 'day', 'night', 'twilight'.

The analysis timeframe was set to 1997 to 2010. This was deliberately chosen to reflect current practice as most of the aircraft models of today were incorporated during this period, and other were phased out before it [40].

6.2. Data processing needs

Because of the applicability of the MOR Scheme to all UK registered aircraft, the sampling strategy also retrieved accidents of overseas British aircraft (e.g., in offshore operations in China). Such occurrences were excluded from the analysis.

We additionally separated the occurrences into either accidents or incidents/serious incidents, which was fundamental to enable the investigation of the assumption that the latter are precursors to the former. In this respect, all accidents published by the UK Air Accident Investigation Board (AAIB, [41]) in the period of concern were gathered and analysed separately from the incidents and serious incidents retrieved from the search undertaken at the MOR Scheme's database.

Finally, the database does not differ between civil and military offshore operations, and this separation was undertaken by reading the title and narrative of each occurrence.

6.3. Analysis of occurrences for causes

Because of the frequently very brief narratives of the

MOR Scheme's occurrences, analysis of combinations of causal and contributory factors was most often impossible. Therefore, in order to enable comparisons of causes across accidents and incidents/serious incidents, causes were assigned only to the 'precipitating factor' (i.e., the factor which initiated the occurrence sequence and from which the occurrence became inevitable [5, 40, 42]).

Accidents and incidents (including serious incidents) were analysed independently by checking each accident against the incidents reported under the MOR Scheme on the 2 preceding years. This timeframe was chosen to reflect a period of time in which safety management practices were expected not to have changed considerably, and in which reasonable samples of incidents could be gathered for the analysis.

In order to achieve consistency with industrial practices and enable comparisons with other helicopter safety studies, the analysis framework for causes (attributed to precipitating factors) combined elements of [4, 43], expanded by Template Analysis [44-45] as prompted by the incident data. The analysis framework is shown in Appendix 1.

6.4. Analysis of occurrences for flight phases

Previous authors have employed various taxonomies to investigate the flight phases of helicopter safety occurrences, e.g. [43, 46-47]. The UK CAA's taxonomy of flight phases used in the MOR Scheme's database [8] was adopted, as follows:

- Parked
- Taxiing
- Takeoff
- Initial climb
- Climb
- Cruise
- Descent
- Holding
- Approach
- Landing
- Circuit
- Aerobatics
- Hover

During the statistical analysis, the flight phases were clustered in meaningful manners so that the minimum cell frequencies required by the tests could be achieved, as shown in the results section.

6.5. Methodology to estimate flight hours for each lighting conditions

Previous authors working on behalf of the International Association of Oil and Gas Producers (OGP) have estimated that the worldwide nighttime flying hours of offshore helicopters would correspond to 3% of the total hours [48]. However, differently from most regions of the world, this proportion should be considerably greater in the North Sea. This is mainly due to regular nighttime passenger ferrying operations during the winter months, an activity virtually only needed in high latitude locations, of which the North Sea has the greatest volume of operations (NB: nighttime passenger ferrying flights might also occur in Canada, USA (Alaska), Greenland, Russia, Chile and Argentina for example, but with considerably fewer flights).

Both in the North Sea and in other parts of the world nighttime offshore helicopter flying also occurs during emergency situations. This is the case with the medical evacuations ('medvac') of offshore workers in need of onshore treatment, and during the de-manning of installations in impending catastrophes (e.g., in pre-hurricane storms or gas leaks) [2].

6.5.1. Nighttime flying hours in regular passenger ferrying missions

Nascimento et al. [49] found that the flight schedule of British offshore helicopter operations was typically contained within the hours between 06:00 and 18:00 throughout the year. Assuming this is generally true, the periods of nighttime flying were determined by calculating the civil twilights for all days of the year using the astronomical almanac [50], and subtracting from the beginning and end hours of the flight schedule when there was an overlap. Figure 2 illustrates on a timeline some key daylight cycles calculated for the latitude of Aberdeen in 2010. This city was chosen because it is the main base for operations in the North Sea, concentrating over 60% of the total hours flown offshore in the UK [40]. The shaded and blue areas are the hours of darkness and the typical flying schedule, respectively.

6.5.2. Nighttime flying hours in medvac missions

The British and Norwegian North Sea scenarios are fairly similar in many respects [2, 51]. Therefore data available from operations in Norway were used for this estimation, as data from the UK were not publicly available.

Although medvac flights are stochastic in nature, the average number of such missions, observed for the 5-year period between 2003 and 2007 [1] was used as a typical representation of reality across the North Sea. We calculated the percentage of such flight hours in relation to the overall flight hours of the Norwegian sector (taken from [18]) during the same period. The assumption behind this is that, given that both the passenger ferrying and medvac flight hours are to some extent determined by the size of the offshore population, they are intrinsically related.

6.6. Confirmatory interviews with experts in the field

The methodological assumptions in this paper (specially in relation to flying hour calculations) were discussed with safety experts (including from the UK CAA) and active pilots flying from both Aberdeen and Blackpool, as well as from other non-British bases in the North Sea, as presented in [2, 49]. Additionally, the experts commented on the developing results and suggested ways of improving the shortcomings identified. This is presented on the results section.

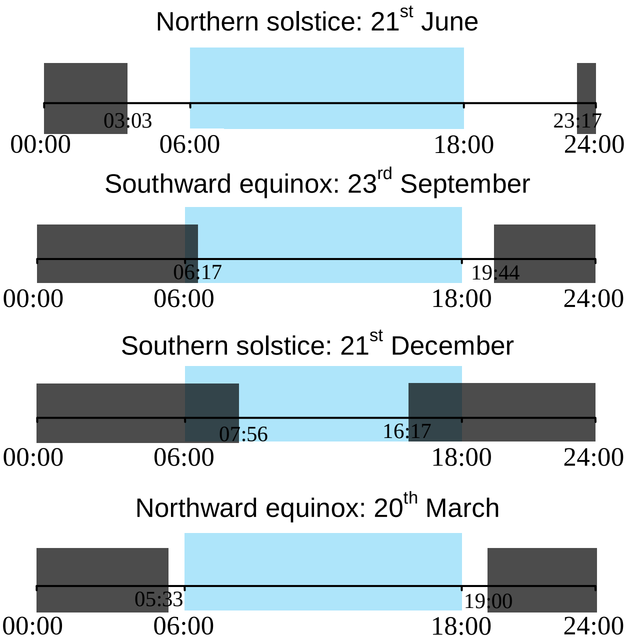

Figure 2 – Timelines showing the nighttime flights of a typical flight schedule of the UK NS

7. RESULTS

7.1. Analysis of occurrences for causes (i.e., precipitating factors) and flight phases

According to the AAIB, there were 10 accidents between 1997 and 2010, in which period a total of 789 incidents were reported under the MOR Scheme. Exploration of each one of the 10 accidents and the incident reports that preceded them by 2 years follows (NB: all percentages are in relation to the totality of reports issued during the 2 year period considered).

7.1.1. G-BMAL, 12 July 2001

Brief description: pilot manoeuvred the aircraft on the ground and inadvertently applied collective, lifting off and landing heavy tail first.

Precipitating factors (refer to Appendix 1)**:** operational failure, pilot-related, pilot procedure.

Phase of flight: taxiing.

Distribution of precipitating factors at the MOR Scheme's dataset (N=75): technical issues related to the aircraft were dominant, accounting for virtually 75% of the incidents reported. Operational failures corresponded to 25%, with pilot performance-related issues representing only 4% of the total incident reports. Figure 3 presents the incidents at the second level of our framework (see Appendix 1), where pilot-related occurrences are more visible. This was a typical distribution of reported occurrences throughout the whole analysis.

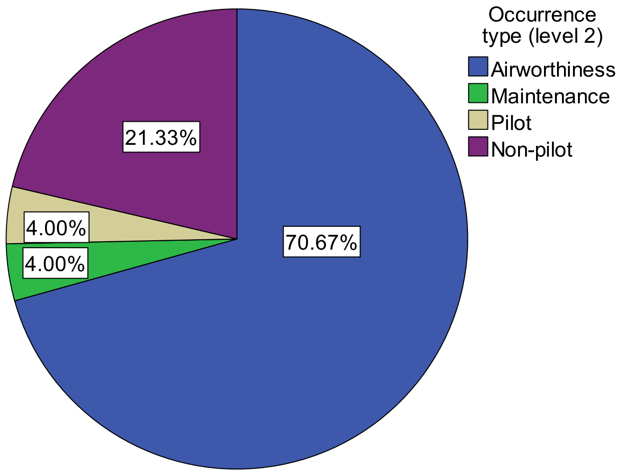

Figure 3 – Distribution of MOR Scheme's incidents at 2nd level of the classification framework

Distribution of phases of flight at the MOR Scheme's dataset (N=55, 66.7% completeness)**:** the cruise and approach phases received more reports (38.7% and 9.3%, respectively). The taxiing phase saw the lowest number of reports, with only 1 (1.3%).

7.1.2. G-BKZE, 10 November 2001

Brief description: in high winds, the ship lost steering control and the helicopter rolled over on deck.

Precipitating factors: operational failure, non-pilot-related, platform or ship procedure.

Phase of flight: parked.

Distribution of precipitating factors at the MOR Scheme's dataset (N=71): technical issues again dominated the distribution of reported incidents, reaching 77% of the totality. However, when precipitating factors are analysed at the most granular level of the analysis framework (i.e., the bottom categories of Appendix 1), 'platform or ship procedure' was second in frequency, with 15.5% of the reports (problems with 'engines' were first with 23.9%). Such occurrences related to inaccurate weather reports, excessive vessel movement and lack of prompt response from platform and ship personnel involved in air operations.

Distribution of phases of flight at the MOR Scheme's dataset (N=66, 91.5% completeness): the cruise and approach phases again received more reports (46.5% and 11.3%, respectively). The parked phase was ranked 3rd, with 9.9%.

7.1.3. G-BJVX, 12 July 2002

Brief description: catastrophic in-flight blade failure.

Precipitating factors: technical failure; airworthiness; main rotor, transmission, drive shafts.

Phase of flight: approach.

Distribution of precipitating factors at the MOR Scheme's dataset (N=87): technical issues were most frequent at approximately 83%, against operational issues at 17% of the incidents reported. Technical failures were mainly due to airworthiness problems, which accounted for just over 78% of the reports. Within this category, engine problems dominated (21.8%), followed by problems with main rotors, transmissions and drive shafts at 12.6%.

Distribution of phases of flight at the MOR Scheme's dataset (N=87, 100% completeness): the cruise-approach-parked pattern was repeated, with 48.3%, 12.6% and 10.3%, respectively.

7.1.4. G-CHCG, 03 March 2006

Brief description: lightning strike, causing damage to blades, instruments and servos.

Precipitating factors: operational failure, non pilot related, lightning strike.

Phase of flight: cruise.

Distribution of precipitating factors at the MOR Scheme's dataset (N=101): the split between technical and operational issues from the previous period remained (83% and 17%, respectively). This was dominated by airworthiness problems at the 2nd level of the framework (75%), of which engine problems dominated again (33.7%). On the 2 years preceding this accident, no single report was filed in relation to lightning strikes.

Distribution of phases of flight at the MOR Scheme's dataset (N=101, 100% completeness): the cruise-approach-parked pattern was again repeated, with 50.5%, 13.9% and 12.9%, respectively.

7.1.5. G-PUMI, 13 October 2006

Brief description: severe vibration led to a rejected takeoff from Aberdeen. One blade's spindle fractured.

Precipitating factors: technical failure; airworthiness; main rotor, transmission, drive shafts.

Phase of flight: takeoff.

Distribution of precipitating factors at the MOR Scheme's dataset (N=104): similar distribution as to the previous period, with slight corrections in the percentages of reports (technical: 82.7%; airworthiness: 76%; engine failure: 25%; main rotor/transmission/drive shafts: 11.5%).

Distribution of phases of flight at the MOR Scheme's dataset (N=104, 100% completeness): cruise was followed by the parked phase (49% and 12.5% respectively), and then the approach and climb at 9.6% each. Takeoff was only mentioned in 4.8% of the cases (5 reports).

7.1.6. G-BLUN, 27 December 2006

Brief description: the aircraft flew into the sea after breaking off an approach to the platform. No technical defects found and the aircraft manoeuvring seemed to be in response to control inputs.

Precipitating factors: operational failure, pilot-related, CFITW (i.e., controlled flight into terrain or water).

Phase of flight: approach.

Distribution of precipitating factors at the MOR Scheme's dataset (N=110): the distributions of technical, airworthiness, engine and main rotor / transmission / drive shafts were fairly similar to the previous period (79.1%, 70.9%, 22.7% and 11.8%, respectively). Pilot-related factor saw an increase from 10% prior to the previous accident to 12% before the G-BLUN's crash, mainly due to shortcomings in 'pilot procedure' (5.5% from overall bottom-level issues).

Distribution of phases of flight at the MOR Scheme's dataset (N=110, 100% completeness): once more, cruise was followed by the parked phase (50% and 12.7% respectively). The approach was next with 10.9% of the reports.

7.1.7. G-REDM, 22 February 2008

Brief description: lightning strike causing damage to main rotor blades.

Precipitating factors: operational failure, non pilot related, lightning strike.

Phase of flight: cruise.

Distribution of precipitating factors at the MOR Scheme's dataset (N=117): with slight variations, the previous tendencies remained (technical: 76.9%; airworthiness: 70.9%). The differences appear to be a more even split between engine and main rotors, transmission and drive shaft problems (17.9% and 12.8% respectively). A decrease of reported pilot-related issues (down to 7.7%) was also observed. There was a single report (.9%) concerning lightning strike in this period.

Distribution of phases of flight at the MOR Scheme's dataset (N=117, 100% completeness):

the cruise phase predominated, followed by the parked and approach phases (50.4%, 15.4% and 11.1%, respectively).

7.1.8. G-BKXD, 09 March 2008

Brief description: while manoeuvring to land on an offshore helideck, the tail fairing of the helicopter struck the guardrails of a deck mounted crane.

Precipitating factors: operational failure, pilot related, obstacle strike.

Phase of flight: approach.

Distribution of precipitating factors at the MOR Scheme's dataset (N=120): the majority of reports referred to technical faults (approximately 77%), leaving only 23% to comment on operational failures. At the second level of our framework (see Appendix 1), airworthiness failures still dominated (70%) whilst pilot-related factors accounted for 8.3% of the overall incidents. At the bottom level, pilot procedure received only 5 reports (4.2% of all reports).

Distribution of phases of flight at the MOR Scheme's dataset (N=120, 100% completeness): the previous pattern was kept with a slight change in percentages (49.2%, 15.8% and 10.8%, for the cruise, parked and approach phases, respectively).

7.1.9. G-REDU, 18 February 2009

Brief description: while on a nighttime approach to an offshore installation in reduced visibility, the aircraft inadvertently struck the surface of the sea.

Precipitating factors: operational failure, pilot related, CFITW.

Phase of flight: approach.

Distribution of precipitating factors at the MOR Scheme's dataset (N=116): at the upper level of the framework (Appendix 1), reports followed the numbers of the previous period (81% technical failures; 19% operational failures). At the second level, airworthiness failures still dominated (75.9%) whilst pilot-related factors accounted for 14.7% of the overall incidents. At the bottom level, pilot procedure received only 2 reports (1.7% of all reports), with no single mention to possible CFITWs.

Distribution of phases of flight at the MOR Scheme's dataset (N=116, 100% completeness): the previous pattern was again kept, however with some change in percentages (43.1%, 16.4% and 12.1%, for the cruise, parked and approach phases, respectively).

7.1.10. G-REDL, 01 April 2009

Brief description: catastrophic failure of the main rotor gearbox as a result of a fatigue fracture of a second stage planet gear in the epicyclical module.

Precipitating factors: technical failure, airworthiness; main rotor, transmission, drive shafts.

Phase of flight: cruise.

Distribution of precipitating factors at the MOR Scheme's dataset (N=114): approximately 81% of the reports referred to technical failures (leaving 19% to operational failures). Airworthiness failures collaborated to 74.6% the incidents reported at the second level of the framework, followed by operational non-pilot-related issues with just under 15%. At the bottom level, issues related to engines, hydraulics, and main rotor / transmission / drive shafts were dominant (with 22.8%, 12.3%, 11.4%, respectively).

Distribution of phases of flight at the MOR Scheme's dataset (N=114, 100% completeness): once more, the previous pattern was found, with 45.6%, 14.9% and 11.4% of the incidents attributed to the cruise, parked and approach phases, respectively.

7.1.11. Association between precipitating factors and flight phases

Because most of the accidents occurred in the approach phase (4 out of 10), 3 of which were caused by pilot-related factors, the association between flight phases and precipitating factors across all incidents reported at the MOR Scheme's database was explored, using a non-parametric test for categorical variable.

It is acknowledged that, given the low accident sample sizes, this higher incidence of pilot-related factors in the approach phase could have been a sheer random effect. However, the approach-and-landing phases have also been found significant factors for impaired pilot performance in worldwide offshore helicopter accidents [2].

To increase sample sizes as required by the statistical test, the phases of flight were grouped as follows:

- Ground manoeuvring: formed by the parked, taxiing and hover phases.
- Departure segment: encompassing the takeoff, initial climb and climb phases.
- Cruise: formed only by the cruise phase.
- Arrival segment: encompassing the approach, circuit, descent and landing phases.

A significant association was found between incidents' precipitating factors and the clustered flight phases, showing that pilot-related factors were reported significantly more frequently in the arrival segment of flight ($\chi^2(3)=8.556$, $p=.036$).

7.2. Analysis of occurrences for lighting conditions (daytime versus nighttime)

The study of offshore medvac missions in Norway (refer to section 6.5.2) revealed that such flights corresponded to 1.1% of the total flying hours of offshore helicopters in the Norwegian oil and gas industry, which we accepted as reasonably transferable to the British sector of the North Sea. This left the regular passenger ferrying services with 98.9% of the total flying hours. Assuming that the medvac missions have equal chances of occurring in daylight or at night, we accepted that .55% of the total offshore helicopter flying hours were employed in nighttime medvac sorties.

The study of the astronomical almanac (section 6.5.1) revealed that, on a typical year, 8% of the passenger ferrying missions should be undertaken during the nighttime, which corresponds to 7.91% of the total flying hours offshore. This said, the total nighttime flying hours of the British North Sea can be reasonably estimated as 7.91% + .55% = 8.46% of the total offshore helicopter flying hours.

In the period under study, there were 3 nighttime offshore helicopter accidents (G-BLUN, G-BKXD and G-REDU) out of a total of 10 accidents. All nighttime accidents had pilot performance as a precipitating factor (analysed at the 2nd level of the framework). This 30% proportion is greater than the expected in light of the estimated nighttime flying hours, greater by a factor of 3.5.

Although the sample sizes are extremely small for any statistical inferences in relation to accident causes, studies of offshore helicopter accidents with considerably bigger sample sizes (worldwide accidents) have found statistically significant results for increased pilot performance impairment risk during nighttime offshore helicopter operations [2, 48].

Concerning the 789 incidents reported at the MOR Scheme's database, 10.4% referred to nighttime operations, which is just slightly higher than the expected frequency.

Because of the indications that the nighttime is an important factor for impaired pilot performance in the offshore helicopter domain, the same non-parametric test as before was undertaken to check the association between lighting conditions (daytime and nighttime) and incidents' precipitating factors (pilot-related and non-pilot-related). However, the result was non-significant ($\chi^2(1)=.192$, $p=.809$). This means that pilot-related reports were not significantly more frequent amidst the nighttime reported incidents.

Because all 3 nighttime accidents happened in the approach phase, also tested was the association between flight phases and lighting conditions across the reported incidents by use of the same non-parametric test for categorical variable as before. Again, Although it is acknowledged that random effects might have occurred in such a small accident sample, the reader is reminded that the approach-and-landing phases have also been found a significant factor for nighttime accidents in worldwide offshore helicopter operations [2]. The same clustering of flight phases shown in section 7.1.11 was employed.

Once more, the test failed to show significance ($\chi^2(3)=1.795$, $p=.616$), meaning that the reports concerning issues during the nighttime arrival segment were not significantly more frequent than in any other clustered flight phase.

7.3. Interviews with experts in the field

Nascimento et al. [2, 49] reported the results of interviews of pilots based in various places, including the North Sea (Aberdeen and Blackpool in the UK, and Stavanger in Norway). In all three scenarios, the under-reporting of occurrences was identified as a factor for missed lessons and thus increased risk in nighttime offshore helicopter operations. During such studies, our nighttime flying hours estimation procedure was also evaluated in light of pilots' logged flying hours. Generally, our calculation reflected the hours that pilots had accrued throughout their careers in the North Sea. Nevertheless, more recently the authors undertook other projects with operators in Bergen (Norway), when it was found that nighttime medvac missions by offshore-based helicopters closely matched the estimations in this paper.

Pilots also mentioned their factors for under-reporting occurrences, all of which have been covered in section 3.

8. DISCUSSION

Between 1997 and 2010, there were seven operational accidents in the British sector of the North Sea against three accidents caused by technical malfunctions of the helicopter. However, regardless of the precipitating factors discovered, section 7.1 shows that the incidents reported under the MOR Scheme on the 2 years preceding the accidents could not have indicated the type of failure that was about to strike. An exception might have been the more consistent reporting of issues related to 'platform and ship procedures' prior to the accident of the G-BKZE (section 7.1.2). Nonetheless, the specific circumstance of the accident (loss of steering ability by the ship) was barely predictable before the onset of the accident and did not figure in any such incident reports.

Surprisingly similar to the findings across the whole British helicopter community [37], the occurrences reported are heavily biased towards technical failures (e.g., Figure 3), of which the issues related to limited engine performance still dominate. This shows that the decision of the regulators and operators in the North Sea to only employ twin engine aircraft in the offshore environment is indeed necessary, and might significantly contribute to the lower accident rates when compared to operations in the USA for example [4]. In this area, single engine helicopter operations are still dominant.

By being biased towards technical failures (specially engine and main rotor components), it comes with no surprise that it was the cruise phase of flight that consistently received the greatest numbers of reports. As the cruise is normally longer than any other flight phase, the opportunities for components' wear and tear signs appearing should also be greater.

By failing to show any credible precursor relationship between reported incidents and accidents, this study raises two fundamental arguments. In one hand, Heinrich's pyramid [13] might not be true and invalid in the offshore helicopter domain, or indeed invalid in any domain where operational and human factors aspects are dominant. This raises awareness for potential sudden failures in this domain, which require a new safety paradigm be embraced by safety regulators and managers. Given that accidents will strike in unexpected ways (i.e., with virtually no precursors), inventive ways of predicting (or reasoning over) possible failures will have to be devised (e.g., [2]). More than a good reporting culture, a generative safety culture will be necessary to avoid such accidents. This is particularly relevant in high risk, low frequency operations, e.g., nighttime flying offshore.

On the other hand, it might be that Heinrich's premises stand but were not met because there is a worrying under-reporting of the really relevant occurrences in the offshore helicopter domain. This requires a review of the MOR Scheme from the standpoint of data consumers, data custodians and data collectors.

On the analysis in this paper of the MOR Scheme's fundamental publication [8] (i.e., a data consumers' point of view), it appears that sufficient information is given to data collectors as to what should be reported, including in relation to human factors incidents. However, a few points for improvement are advised, especially to cover operations in degraded visual environments: because pilots are likely to suffer from decision-making impairment in such conditions [2], any doubt as to the sufficiency of the external visual cues for visually referenced flying should prompt the reporting of an incident, not only the cases which resulted in the minimum descent height (MDH) or other prescribed altitude being violated. Nonetheless, the generally fair guidance provided by data consumers (i.e., the UK CAA) does not mean that promotion is being assured, and the need for increased publicity should be addressed.

From a data custodian perspective, it appears that the data collection method still has room for improvement. For example, all the objective information regarding the flight (e.g., route, time, flight number) could be automatically input if the MOR form operated on computer systems integrated with the company's flight plans. Although such objective information was found to be of a generally good quality across the reports studied (e.g., good completeness of flight phase data, see section 7.1), integrating such systems would relieve the data collectors (e.g., pilots) from the burden of seeking and writing down this information, leaving them free to invest their time and effort on producing a quality narrative of the facts experienced.

In relation to data collectors, there seems still to be considerable scope for improvements in the reporting culture, especially in relation to operational and human factors related occurrences [2, 44, 49]. In light of the potential for sudden failures of such types, developing a good reporting culture is more so in need of priority intervention. We believe that this should be achieved through education (and re-education) of aviation professionals. Good airmanship should be taught as inextricably related to an open reporting attitude, which in turn has to be supported (and facilitated) by the regulators and management.

In spite of the results of the analysis in this paper, it is important to acknowledge that incident data collection remains extremely important for risk mitigation. Whereas the incidents were found of limited use as predictors of more serious safety events, they are very useful for the prediction of their severity, which is a composing term of risk (i.e., risk = frequency X severity). For example, even though engine issues were reported consistently more frequently during our analysis timeframe, because dual engine operations are mandatory over the North Sea, single engine failures can be expected to be of lesser severity. On the other hand, although main rotor components scored frequently (and by far) second in frequency, the severity of such events can be easily predicted as catastrophic.

On the way to a generative safety culture, it is also important not to rely solely on reported occurrences for knowledge of hazard factors. There are several systems at present with formidable data collection capability, e.g., HFDM, which can be used in creative ways. For example, with slight hardware modifications, HFDM could be coupled with routine recording of flights, in and out of the cockpit, for a complete picture of the dormant factors awaiting to combine in various harmful ways.

In all cases, the results are encouraging, as they show that the industry is eagering for such next steps towards a generative safety culture. Some such indications would be, for example, the significant association found between flight phases and incident causes (section 7.1.11) where it is known to have existed across past accidents [2]. Additionally, the number of reported occurrences has been raising since 2007, which should also encourage their use as safety (or reporting culture) performance indicators. Finally, there is a slight tendency to report more frequently nighttime occurrences (section 7.2), when the nighttime is a known factor for increased risk.

9. CONCLUSIONS

This paper has raised a number of safety concerns in relation to:

- Potential for sudden failures during offshore helicopter operations in a clear contradiction to classic incident-accident pyramidal relationships. This is especially the case at night and in relation to operational and human performance issues. Tackling sudden failures will require creative interventions from regulators, operators and aircraft manufacturers (e.g., enhanced autopilot technology towards auto-land).
- Potential flaws in the reporting culture of the offshore helicopter industry, which unexpectedly reflected the problems identified within the wider British helicopter community.
- The need to educate operators for enhanced recognition of subtle human factors-related occurrences and for improved understanding of the relevance of reporting apparently negligible events.
- The need to strengthen operators' trust in the reporting scheme on the way to a generative safety culture.
- The need to re-evaluate the occurrence reporting scheme in relation to guidance to reporters, ease of reporting and promotion, with a view to producing quality data for future use.
- The need to develop new ways of collecting data from routine operations which will not solely rely on the reporting of occurrences.

With respect to the North Sea offshore helicopter industry, it has been shown that there is the desire to attain a generative safety culture.

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Appendix 1 – Framework for the analysis of incident causes

Operational failures

Pilot-related

Non-pilot related

Operational failure analysis

- Dangerous goods
- Configuration management
- CFITW
- Tie down procedure
- External load procedure
- Obstacle strike
- Fuel management
- Miscellaneous pilot procedure
- Loose cargo
- Pilot incapacitation
- ATC
- Lightning
- Weather
- Passenger control
- Hostile fire
- Bird strike/FOD
- Platform or ship design and size issues
- Platform or ship procedure

Technical failures

Airworthiness failure

Maintenance failure

Failure part analysis

- Airframe
- Avionics fire/smoke
- Communications
- Electrical system
- Floatation system
- Hydraulics
- Landing gear
- Navigation
- Main rotor, transmission, drive shafts
- Engines
- Tail rotor
- Control malfunction
- Fuel system
- Automation malfunction
- Indicator malfunction
- Under slung load
- Ventilation
- Windscreen
- Unknown

Unknown or unavailable