Taking Control: An HFACS Analysis of Loss of Control in Helicopter EMS Flights

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ABSTRACT

Loss of control (LOC) accounts for approximately 40% of fatal accidents in general aviation and roughly half of all aviation fatalities. Within Helicopter Emergency Medical Services (HEMS), LOC is an increasingly pressing issue contributing to fatal accidents. This analysis aims to explore the causal factors which contribute to LOC within HEMS. HEMS accidents occurring between the years 2014-2019 were pulled from the National Transportation Safety Board (NTSB) accident database. Inclusion of FAR Part 91 and Part 135 accident flights resulted in a total of 26 accidents. Causal factors contributing to each accident were then coded using the Human Factors Analysis and Classification System (HFACS). Analyses to obtain frequencies were completed using IBM SPSS. Of the 26 accidents that occurred between the years of 2014-2019, the cause of 53.8% of accidents was LOC. For accidents occurring due to LOC, 38.9% of those were a result of inadvertent flight into instrument meteorological conditions (IMC) and were attributed to skill-based errors (45.5%). Additionally, 57% of accidents caused by LOC resulted in fatalities. The continued threat of LOC within HEMS presents a need for closer examination of causal factors within accidents that occur as a result of LOC. Fatal accidents in HEMS are largely the result of LOC following inadvertent flight into IMC despite new rulings implemented by the Federal Aviation Administration (FAA) to improve safety in HEMS operations. Preliminary results of an HFACS analysis indicate that skill-based errors are the largest contributors to these accidents, prompting further examination of the factors contributing to these errors. Applications of simulation based training which focuses on high psychological fidelity as well as virtual reality training systems present potential solutions for addressing errors which contribute to LOC in HEMS operations.

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Dr. Albert J. Boquet is a Professor of Human Factors and Behavioral Neurobiology at Embry Riddle Aeronautical University. Prior to joining Embry-Riddle, he served as a principal investigator for the Federal Aviation Administration's Civil Aerospace Medical Institute in Oklahoma City, Oklahoma. His work at the FAA included research on topics such as shiftwork and fatigue among Air Traffic Controllers and human error in aviation accidents. His work in safety and accident investigation included programs such as General Aviation, Helicopter Emergency Services, Air Tour and Air Taxi, in addition to larger commercial operations. He has over 150 publications, presentations, and training series on topics relating to systems safety, human error in complex systems, fatigue, and fatigue management, system performance in healthcare, and the health consequences of stress. He has conducted training for system safety, error management, and fatigue and shiftwork management across multiple industries, including aviation, oil and gas, healthcare, chemical and materials processing.

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INTRODUCTION

On December 10, 2015, at 7:03 pm local time, a helicopter operating as an air ambulance flight departed from a hospital in Porterville, California with the intent to transport a patient to another hospital in Bakersfield, California. On board at the time were the pilot, the patient, and a flight nurse and paramedic. The flight began normally as the helicopter departed under visual flight rules (VFR) in night visual meteorological conditions (VMC). While airports near the flight's point of origin and destination reported VMC around the time of the flight, there were no recorded weather observation stations located along the route. During the course of the flight, the accident pilot encountered an area of fog or rain resulting in reduced visibility and attempted a course reversal; however, the pilot likely became spatially disoriented, due in part to weather and unlit, hilly terrain, and subsequently lost control of the aircraft, ultimately impacting terrain and leading to fatal outcomes for everyone on board. The following NTSB investigation revealed that a contributing factor to the accident was the pilot's lack of recent experience with nighttime operations. The HEMS operator that the accident flight was operating under used two Bell 407 helicopters. One of the helicopters had an advanced instrument display system and the other used analog instruments. The accident pilot had primarily flown using analog instruments and, while certified to fly under instrument flight rules (IFR), the pilot had only 11.2 hours of flight experience in the accident helicopter, with only 2 of those hours being in nighttime conditions and only .3 of those nighttime hours occurring within four months of the accident. The accident pilot had also previously expressed concerns with flying at night around terrain without the use of night vision goggles (NVGs). The pilot had not yet completed company training for use of NVGs. This lack of nighttime experience with an unfamiliar instrument system could have increased the pilot's likelihood of becoming spatially disoriented and subsequently losing control of the aircraft.

This accident demonstrates the risk that HEMS pilots and crew undertake as part of their role in the healthcare system in the United States; however, it also highlights the complex nature of HEMS operations as a part of both aviation and healthcare. In order to balance the importance of providing care to critically ill patients as well as the inherent risk of helicopter operations, it is as imperative as ever that HEMS crews are able to sufficiently assess risk, make decisions that maintain the safety of both patients and the crew, and handle the unique challenges presented by HEMS operations and the environments within which they operate.

HEMS

In 1972, an operation called Flight for Life, based in Denver, Colorado, became the first civilian, hospital-based HEMS program. From this point, the HEMS industry has grown steadily and operates to transport critically ill patients from hospital to hospital as well as from the scene of accidents (Taylor et al., 2010). Within the United States, there are approximately 1,515 operating medical helicopters (Widmeier, 2014) which transport over 400,000 patients each year (Huber, 2018). Part of the reason for the growth of the HEMS industry stems from the concept of the "Golden Hour," which refers to the importance of administering treatment within the first hour from the time of injury and the increased likelihood of achieving a positive outcome if treatment is administered within that time frame. It has since been recognized that there is no longer a dramatic drop in survivability outside of the golden hour; however, there is no denying that faster is better when it comes to administering care to critically injured patients, and helicopters are a faster mode of transportation than ground transport (ambulances), particularly in rural areas. This may not be the case for more urban areas in which ground transport may be faster.

Despite the benefit of HEMS, it has become apparent that these operations come with a higher level of risk than other types of operations. With the growth of the industry, HEMS operations have also seen a rise in overall accident rates.

HEMS operators experienced fatal accident rates higher than those of all other aviation operation types in the period between 1997 and 2001 (Baker, 2006). More recently, 2008 was a record year for fatal accidents in the HEMS industry with 21 fatalities of pilots, medical personnel, and patients. The fatality rate for HEMS crews during that year was 164 deaths/100,000 workers, which was a higher fatality rate than all other recognized hazardous professions (Blumen, 2009). While the accident rate has remained somewhat stable over the past several years, the HEMS industry has not seen the decrease in accident rates that new rulings and interventions have sought to accomplish. Accident rates and fatalities for LOC accidents between 2014 and 2019 can be seen in Figure 1.

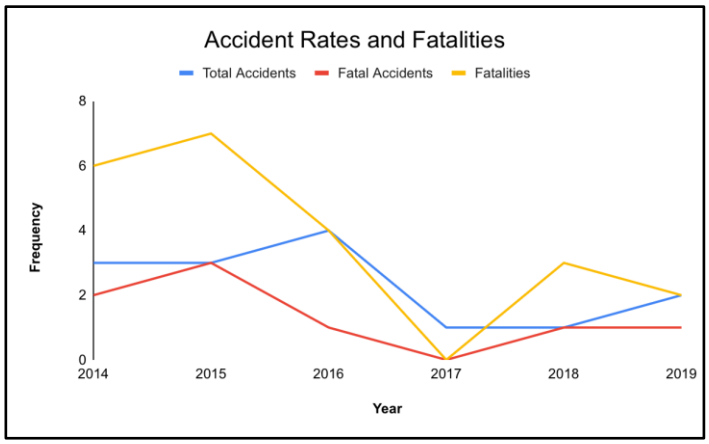

Figure 1. HEMS LOC Accident Rates and Fatalities

In a safety report published by the NTSB in 2009, six accidents that occurred in 2008 were utilized to demonstrate safety issues upon which they based recommendations. Among those recommendations were the following:

- Development of criteria for scenario-based helicopter emergency medical services (HEMS) pilot training that includes inadvertent flight into IMC and hazards unique to HEMS operations and determine how frequently this training is required to ensure proficiency.
- Require HEMS pilots to undergo periodic FAA-approved scenario-based simulator training, including training that makes use of simulators or flight training devices.
- Require HEMS operators to implement safety management system programs that include risk management practices.
- Require HEMS operators to install night vision imaging systems and require pilots to be trained for use in night operations.
- Require medical helicopters to be equipped with autopilots and that the pilots be trained to use the autopilot if a second pilot is not available (Blumen, 2009).

In 2014, the FAA also published new rulings to improve safety for HEMS operations. The rulings include increasing weather minimums, requirement of HEMS flights to be carried out under part 135 rules when medical crew, not only a patient, are on board, preflight risk analyses and safety briefings for medical personnel, the establishment of operations controls centers (OCCs) to aid with flight planning and weather assessment, and installation of helicopter terrain awareness and warning system (HTAWS). In addition, HEMS pilots are required to hold instrument ratings and be able to maneuver the aircraft to safety if they encounter IMC (FAA, 2014).

Despite the recommendations by the NTSB and rule changes by the FAA, the same threats to crews and patients stubbornly persist. In fact, a review of HEMS accidents reveals that, like other aviation platforms, LOC with subsequent ground impact is a persistent threat. Furthermore, while recognition of the need to understand LOC is prevalent in other aviation platforms, it remains understudied in the HEMS industry. Given this, the current investigation will seek to understand LOC in the HEMS community by selecting those accidents identified by the NTSB as occurring due to LOC and applying the Human Factors Analysis and Classification System to understand the underlying human error associated with these accidents.

LOC

LOC has been identified as the leading cause of fatal accidents in general aviation. The two most common causes of fatal accidents are loss of control (LOC) at 40% and controlled flight into terrain (CFIT), which accounts for an additional 14% (Kirkendoll et al., 2020). Additionally, LOC also accounts for roughly half of all aviation fatalities (Jacobson, 2010). While accident rates have decreased since the 1940s, those rates have remained relatively stable since about 2000, prompting many organizations within aviation to focus efforts and resources towards developing strategies to lessen the likelihood that pilots will lose control and suffer fatal outcomes. One such strategy was a joint effort by the FAA and the NTSB in which the two organizations formed the General Aviation Joint Steering Committee (GAJSC) which was tasked with identifying leading causes of accidents in GA and corresponding mitigation strategies (Wright, 2020). While many of the strategies that were formulated by this group may prove to be effective if implemented, a closer look at the causal factors leading to LOC may provide greater insights for future mitigation strategies. Our approach to this problem is discussed later in this paper.

LOC in HEMS

HEMS operations present unique challenges not faced by other helicopter operations or fixed wing operations. HEMS pilots are regularly required to land in unestablished landing zones due to the nature of missions such as transporting patients from the scene of a motor vehicle collision (MVC) where helicopters must land on whatever location can be made available. Conditions at these landing sites may lead to LOC through "dust-ups" or brown outs which may result in loss of control. Another unique challenge to HEMS operations can be the pressure to accept flights due to the condition of the patient. HEMS pilots may feel more pressure to accept flights in degraded environmental conditions if the patient's condition is critical. These degraded environmental conditions, particularly inadvertent IMC, can also be conducive to loss of control in flight and can result in fatal crashes.

This investigation seeks to highlight the prevalence of LOC in HEMS operations and the human factors associated with these accidents and identify potential training solutions aimed at addressing these risks. Specifically, we examine accidents occurring since rulings issued by the FAA in 2014 that were intended to implement safer practices for HEMS operations and reduce the occurrence of accidents. By examining the types of errors that precede these accidents, we aim to determine if there are common trends in these accidents and identify potential training or process safety interventions targeted to address LOC in HEMS. In this investigation, the Human Factors Analysis and Classification System is used to classify the unsafe acts and preconditions for those errors which contribute to HEMS accidents.

HFACS

The Human Factors Analysis and Classification System (HFACS), depicted in Figure 2, was created by Drs. Douglas Wiegmann and Scott Shappell. This framework is based on Reason's swiss cheese model of human error and classifies human error into four tiers: Unsafe Acts, Preconditions for Unsafe Acts, Supervisory Factors, and Organizational Influences (Wiegmann & Shappell, 2000). The HFACS framework classifies errors into active failures, which are covered under the Unsafe Acts tier, and latent failures, which are covered under the remaining tiers. The use of HFACS in this application facilitates the identification of the types of errors which contribute to LOC in HEMS accidents. Identification of these errors also aids in directing the formulation of data driven interventions which can target specific problems within HEMS operations.

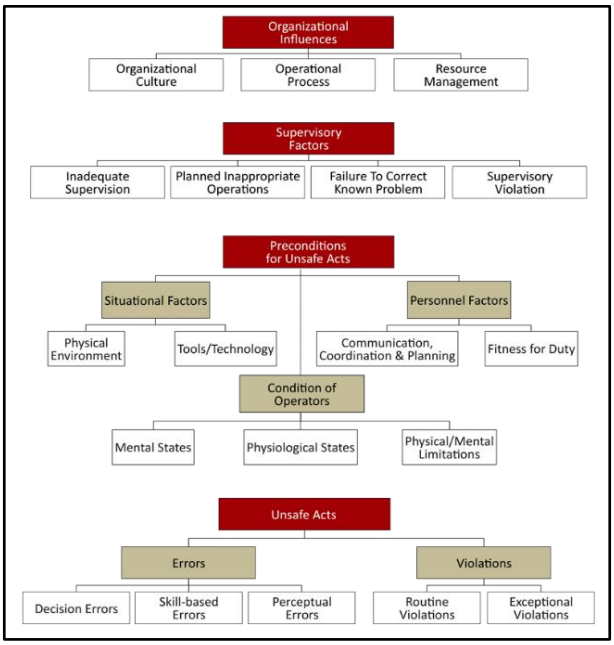

Figure 2. The HFACS Framework

This paper focuses primarily on the Unsafe Acts and Preconditions for Unsafe Acts tiers due to lack of accident data provided to address the Supervisory Factors and Organizational Influences tiers. The Unsafe Acts tier is divided into errors and violations. Errors are further broken down into decision errors, skill based errors, and perceptual errors. Decision errors tend to be based on erroneous decisions which may be made due to lack of information or misunderstanding of a situation. Skill based errors involve problems with "stick and rudder" skills and perceptual errors involve problems stemming from things like spatial disorientation or any factor which causes a pilot to misperceive the surrounding environment. Violations are broken down into routine violations (those which occur regularly with little to no consequence) and exceptional violations (serious violations of rules or regulations which typically result in disciplinary action). The Preconditions for Unsafe Acts tier is broken down into situational factors, personnel factors, and condition of operators. Errors stemming from situational factors may involve the physical environment, such as lighting, weather, or terrain as well as errors stemming from the use of tools and technology such as equipment design and issues with automation. Under personnel factors, issues with communication, coordination, and planning may stem from lack of communication between pilot, crew members, and/or ATC and ground personnel. Errors involving fitness for duty may be related to factors such as insufficient sleep, overexertion while off duty, or self-medication. Under condition of operators, adverse mental states can include things like distraction, complacency, and mental fatigue. Physiological states can include things like physical fatigue, medical illness, and hypoxia. Physical and mental limitations can include things like individual visual limitations, inadequate experience for a situation, and incompatible physical capabilities.

METHODS

Data. HEMS accidents occurring in the years 2014-2019 were obtained from the NTSB database. Search criteria involved examining all helicopter accidents within this time frame to ensure that all accidents were accounted for as the NTSB database does not contain a HEMS specific search option within the list of available operations. Inclusion of FAR Part 91 and Part 31 accident flights yielded a final 26 accident reports to be examined. Accident reports containing insufficient detail to determine accident cause were excluded from the analysis.

Causal Factor Classification Using HFACS. The cause for each accident was determined by examining the NTSB classification of the defining event for each report as well as the summary and factual information. Each accident was analyzed and consensus coded using the Human Factors Analysis and Classification System (HFACS). All coding was completed by a team of four HFACS certified coders. Tabular and narrative data were obtained from final NTSB

reports with each coder independently classifying the human causal factors. Only those factors identified by the NTSB as causal factors were included in the analyses. Upon completion of the independent analyses, the coders reconciled any inconsistencies in the classifications by consensus.

Data Analyses. Frequency counts and percentages were calculated using the Statistical Package for the Social Sciences (SPSS) developed by IBM. For the purposes of this investigation, only the bottom 2 tiers of HFACS (unsafe acts and pre-conditions for unsafe acts) were included in the analyses due to the lack of supervisory and organization data included in the NTSB reports.

RESULTS

Of the 26 HEMS accidents that occurred between the years 2014 and 2019, 53.8% of accidents were determined to be the result of loss of control of the aircraft, which can be seen in Figure 3. Controlled flight into terrain and hard landing accounted for 11.5% of accidents each. The remaining 23% of accidents were attributed to causes other than human error including, fuel starvation, separation of parts from the aircraft, and fire/smoke, among other causes. Additionally, LOC accounted for 80% of fatal HEMS accidents that occurred within this time period. This large proportion of fatalities occurring in LOC accidents is indicated by the red bar for LOC in Figure 4.

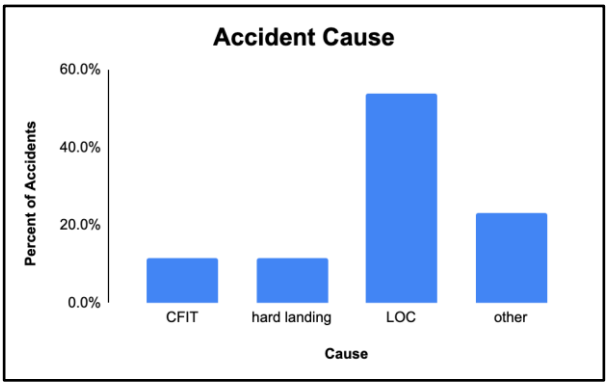

Figure 3. Accident Cause

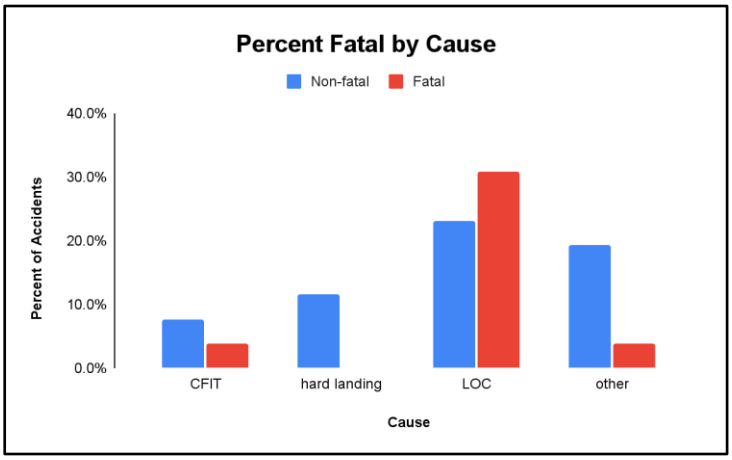

Figure 4. Percent of Fatal Accidents by Cause

Of the 44 active and latent failures identified within LOC accidents using the HFACS framework, 40.9% of codes fell within the Unsafe Acts tier and 56.8% of codes fell within the Preconditions for Unsafe Acts tier, which can be seen in Figure 5. The remaining 2.3% were under the Supervisory Factors tier and consisted of a single codable instance. Among the Unsafe Acts, 44.4% of errors were skill based, whereas 22.2% of errors were decision based and 22.2%

were perceptual errors and 11.1% were violations. Preconditions for Unsafe Acts saw 64% of codes attributed to environmental factors, with 16% attributed to adverse mental states, and 12% to communication, coordination, and planning (CCP), as seen in Figure 6.

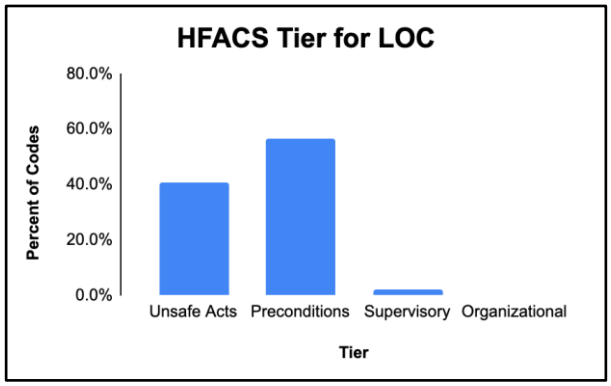

Figure 5. HFACS Tiers for LOC

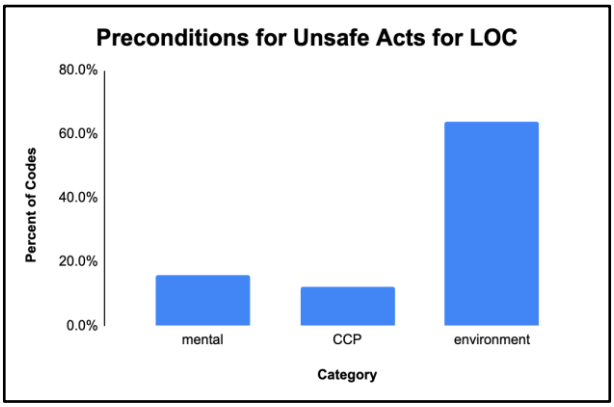

Figure 6. Preconditions for Unsafe Acts for LOC

Although the majority of errors for all LOC accidents were skill based, fatalities were much more likely to occur when decision errors are present given that 42.9% of decision errors were associated with fatal accidents compared to 28.6% of skill based errors associated with fatalities (Figure 7).

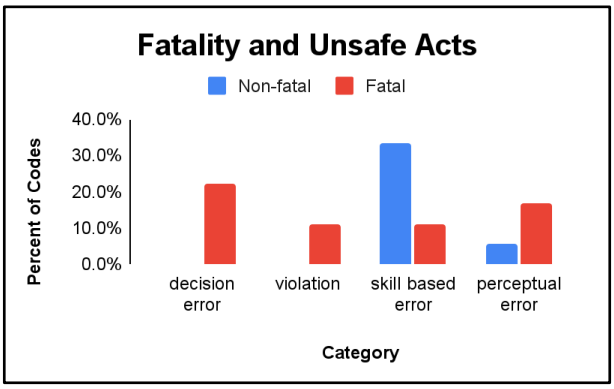

Figure 7. Fatality and Unsafe Acts

In order to better understand the nature of the unsafe acts, nano codes were derived for both errors and violations. Poor technique/airmanship was by far the greatest contributor to skill-based errors at 27.8%. These accidents largely involved collisions with objects and hard landings. Not surprisingly, spatial disorientation was the most common perceptual error, being associated with 22.2% of the codes, with all of these resulting from VFR flight into IMC. Inappropriate maneuver/procedure, a decision error, accounted for 16.7% of codes. Decisions, both intentional (violation) and unintentional, leading to flight into adverse weather accounted for 16.7% of Unsafe Acts nano codes. All codes (perceptual and decision) involving flight into IMC accounted for 38.9% of nano codes within the Unsafe Acts tier.

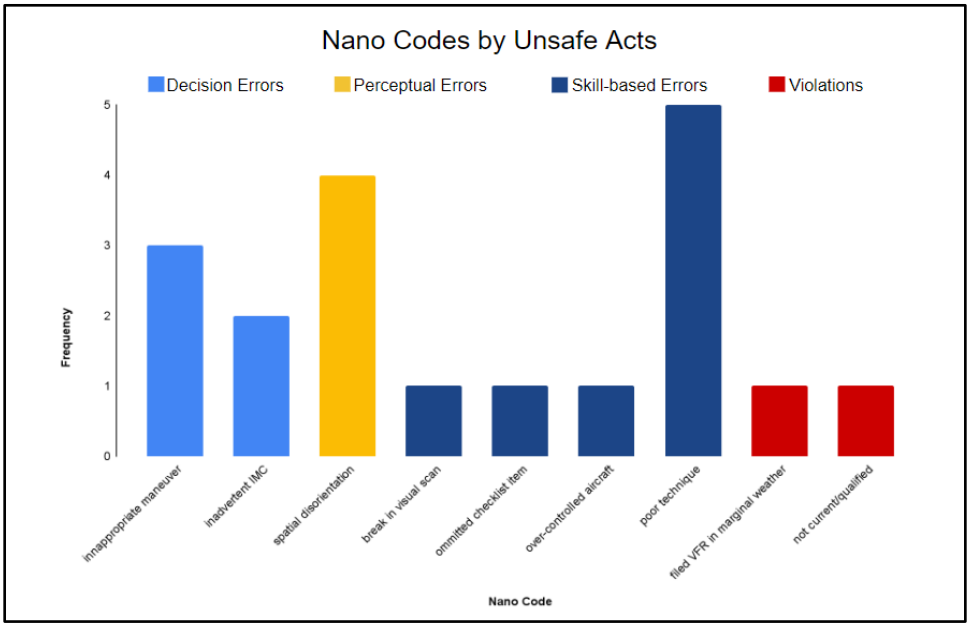

Figure 8. Nano Codes by Unsafe Acts

DISCUSSION

HEMS operations have grown steadily over the last few decades, and while accidents rates have decreased overall since the start of these operations, the trend in recent years does not demonstrate the continued decrease in those rates that HEMS operators and organizations like the FAA and the NTSB have hoped to see. Additionally, HEMS remains one of the most dangerous occupations and comes at a high cost to operators, air medical crews, and the patients they transport despite recommendations and rulings put out by the FAA and the NTSB aimed to decrease the number of HEMS accidents. The problem remains that medical helicopters have been, and still are, crashing for the same reasons for decades and previous mitigation strategies have yet to result in the desired drop in accident rates. As it stands, LOC is the leading cause of accidents in HEMS operations, and accidents occurring due to LOC are more likely than any other cause to result in fatality. Additionally, many of these accidents are happening due to flight into degraded conditions, or flying VFR into IMC. By taking a deeper dive into accidents occurring because of LOC, we are able to identify the causal factors contributing to these accidents and provide training recommendations based on the types of errors contributing to those accidents.

Results of an HFACS analysis of HEMS accidents which occurred due to LOC indicate that errors are primarily skill based; however, examination of fatal LOC accidents indicates that fatalities are more likely to occur when decision errors or violations (intentional decisions to violate rules) are made. Research has shown that degraded conditions, particularly dark night and IMC remain the largest threat to HEMS operations; however, pilots continue to make decisions that lead to fatal accidents in these conditions. Decision errors in these accidents occurred due to pressure to complete missions, lack of knowledge regarding weather information, and decisions to knowingly fly into night IMC. Contributing factors to some accidents occurring in night IMC included lack of recent experience in those conditions, which may contribute to decisions made by HEMS pilots in these circumstances. Therefore, our first

recommendation for mitigation strategies focuses on aiding and training pilots with making decisions preceding and during flights. Also of importance is ensuring that HEMS pilots are equipped to manage situations, such as flying into adverse weather, which could potentially lead to LOC. Since most errors identified were skill-based, additional recommendations address these types of errors and behaviors as well. The majority of skill-based errors were attributed to poor technique/airmanship and these accidents typically resulted in hard landings or collision with objects. While these accidents were not typically fatal, they still present instances of unnecessary risk and cost to HEMS operators.

In pursuit of solutions to this problem, one study discusses the potential role of surprise in pilots' ability to recover from upsets and other in-flight surprises which can lead to loss of control. A study by Kochan, et al. (2005) found that surprise events of more than one type (flight upset) could produce a situation with an undesirable outcome, such as LOC, and that pilot responses to these events could be improved by cognitive flexibility training, adaptive expertise training, and metacognitive training. In other words, training should encourage pilots to be flexible in their responses to surprises rather than formulaic, reinforce new responses acquired through expert training, and teach pilots to reflect on their own mental processes when responding to surprise events. Training that emphasizes these aspects of performance may be crucial for HEMS pilots who conduct inadvertent flight into IMC or experience degraded conditions or difficulty maneuvering around obstacles due to improvised landing zones. Additionally, training pilots to reflect on their mindset in surprise scenarios may also lend itself to enhanced decision-making in situations in which HEMS pilots experience pressure to complete missions due to patient condition. While it is important for simulation-based training to focus on the physical actions associated with HEMS flights, this training may be enhanced by prompting HEMS pilots to actively reflect on their own mindset while experiencing a simulated event in order to facilitate more accurate decision making conditions.

Rogers, et al. (2007) explored the effects of simulation-based training for upset recovery. This study aimed to determine if adequate training could be accomplished using low fidelity, low-cost simulators. The authors conducted this training by having an experimental group complete 10 hours of classroom training and 10 hours of simulation-based recovery upset instruction. A control group received no training of either kind. All participants were flight tested in an aerobatic E33C Beech Bonanza. Testing involved having participants close their eyes while the safety pilot induced one of four randomly ordered upsets. Upset recovery was considered successful if participants returned the aircraft to straight and level flight without assistance. The results of the study indicated a strong relationship between the low fidelity simulator training and control responses during flight testing. This type of low fidelity simulator training may present similar benefits to HEMS pilots training for inadvertent encounters with IMC. One point of emphasis for low fidelity simulator training should be on the psychological aspect of training scenarios. By increasing psychological fidelity of simulator training, HEMS operators can increase the likelihood that pilots will be engaged in the same mental processes that they would be during real missions. It is no secret that HEMS pilots experience unique stressors due to time pressures and patient condition. By implementing simulator training that replicated the mental stress HEMS pilots experience during the "go, no go" decision process and the flights themselves, HEMS pilots may be able to more accurately answer the question "what would I do in this situation?" Would that pilot let their knowledge of patient condition affect their evaluation of the risk associated with accepting a flight? Often, emphasis is placed on having high-fidelity simulators which involve movement and making the experience feel as real as possible; however, given that these options are usually more expensive and less attainable for smaller operations, turning the focus to creating simulation-based training geared towards higher psychological fidelity through the use of low physical fidelity simulators may provide a useful tool for addressing LOC in HEMS pilots. Given that fatal accidents, particularly those involving flight into IMC, are typically the result of decision errors, this shift in focus may allow training to target the stress and difficult decisions pilots may encounter in these situations without the need for simulators which come at a much higher cost, making this an attainable training solution for a greater number of HEMS operations.

In particular, computer-based virtual reality training systems (VRTS) may suit training needs for HEMS operators and pilots. A study by Clifford (2020) investigated the use of immersive virtual reality training for Air Attack Supervisors (AAS) who operate as copilots and aid in directing helicopters and fixed wing aircraft during aerial wildfire fighting operations. The three core abilities that the authors aimed to target through the use of this training were situational awareness, effective communication, and decision making in high risk environments; all essential skills for HEMS pilots and crew as well. Results indicated that psychological fidelity is more important for effective training than physical fidelity and that situational awareness was enhanced with the use of immersive displays, such as head mounted displays (HMDs) and cylindrical projection displays (CPDs) in training. Participants reported greater confidence in their abilities after training with the VRTS than they reported following a low fidelity simulation training

session. Additionally, participants experienced similar stress levels during the VTRS condition and a real world training scenario. These results indicate that immersive virtual reality training may present a viable training option to increase readiness for decision making in stressful environments and situations such as those encountered by HEMS pilots arriving at non-established landing zones as well as pilots who find themselves in degraded visual conditions. Both types of immersive displays used in this study may also lead to enhanced training for spatial disorientation encountered by pilots and allow them to more closely experience the stressors they might encounter on real world missions. The study also indicated that a CPD may enhance users' sense of presence with regard to interactions with a copilot; however, all HEMS flights analyzed as a part of our investigation were conducted by a single pilot. Despite the lack of copilot in these cases, pilot interactions with medical crew are similarly critical and may be enhanced through the use of CPDs in virtual reality training systems. Clifford also discusses the benefits of CPDs for expert users who require additional stimuli to remain engaged; however, since CPDs require more space, HMDs present a better option for users completing training at home or from bases where space is limited.

A simulation based training solution for HEMS, based on the recommendations outlined above, should focus on skill based errors as well as decision based errors (and violations). CPDs and HMDs present virtual reality training systems that are likely to increase psychological fidelity, which would more accurately simulate stress levels that HEMS pilots would experience during real missions as well as provide a more dynamic simulated training experience that would allow training for all crew members simultaneously (with the use of CPDs). This training should prompt HEMS pilots and crew to reflect on their own mindset during these scenarios and promote flexible responses to emergency situations. While it is important to address "stick and rudder" skills, training solutions that demonstrate higher psychological fidelity are more likely to address errors which precede fatal accidents while still fulfilling training needs for scenarios involving spatial disorientation. While the suggestion of simulation based training for HEMS operations is certainly not a new idea, fatal HEMS accidents are happening for the same reasons they have been for years, indicating that a change is still needed. Based on analysis of the errors which contribute to fatal accidents, the proposed simulation training elements may be a step in the right direction.

CONCLUSION

One of the most common causes of accidents in general aviation is loss of control of the aircraft and this trend is also present in HEMS. HEMS operations remain one of the most dangerous occupations with significant risk falling on HEMS pilots and crew and the patients they transport. And despite several rulings issued by the NTSB and the FAA which aimed to mitigate risk in these operations and reduce the number of accidents, there has not been a satisfactory drop in accident and fatality rates. An HFACS analysis of HEMS accidents occurring due to LOC since the most recent rulings issued by the FAA in 2014 shows that HEMS accidents in general are often due to skill based errors, whereas fatal HEMS accidents are primarily due to decision errors. Perceptual and decision errors culminating in LOC after flying into degraded weather conditions accounted for a large portion of identified errors. While degraded visual and weather conditions have long been cited as the greatest dangers to HEMS and other operations within aviation, efforts to solve this problem have yet to show widespread success within HEMS. The use of lower cost but high psychology fidelity simulation presents a training solution which may address the types of errors most prevalent in both fatal and non-fatal HEMS accidents. In particular, the use of virtual reality simulation training systems provides an immersive training experience which may enhance pilots' readiness for decision making in high stress environments as well as potentially provide pilots with some experience with spatial disorientation prior to flight in an actual aircraft. Head mounted virtual reality displays and cylindrical projection displays are two viable options that warrant further exploration for HEMS training applications. Historically, the problem with simulation has been cost. Virtual reality training solutions may also prove to be a more affordable option for HEMS operators as consumer based applications for gaming become more popular and more prevalent. Whichever virtual reality training method is used, emphasis should remain on maintaining high psychological fidelity in order to address errors through an immersive experience.

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