A CASE STUDY USING THE HUMAN FACTORS ANALYSIS AND CLASSIFICATION SYSTEM FRAMEWORK

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Aircraft accidents are generally the end result of a number of latent conditions arising in the organizational and managerial sectors. These conditions frequently permit or even motivate the unsafe acts by the flight crew. The Human Factors Analysis and Classification System (HFACS) is a system safety tool for the investigation and analysis of underlying human causal factors in aircraft accidents. Using the HFACS framework, four researchers classified the human factors identified by the Brazilian Aeronautical Accidents Investigation and Prevention Center (CENIPA) during the investigation of a mishap (PR-AFA) that happened in Brazil in 2014. CENIPA argued that errors and violations by both pilots contributed to the accident. Results of this study indicate that inappropriate decision making by upper-level management had an adverse effect on the performance of the PR-AFA pilots. Most importantly, safety strategies to mitigate unsafe acts by crewmembers should receive significant attention from the highest managerial levels of the organization.

Approximatelly 80% of aircraft mishaps are associated with human errors (Wiegmann & Shappell, 2003). The terms human error and procedural violations may have limited value in preventing future accidents (Reason, 1997, 1998). These factors could indicate where the breakdown occurred, but provide no guidance as to why an accident occurred or how to prevent one from occurring in the future (ICAO, 2013; Reason, 1998; Wiegmann & Shappell, 2003). Several accident causation models have been developed to assist in mitigating human errors and violations. The Human Factors Analysis and Classification System (HFACS) describes four levels of failure (Li, Harris, & Yu, 2008; Wiegmann & Shappell, 2003) proposed in the Reason model (Reason, 1997, 1998). HFACS is a system safety tool that can be used within aviation sectors to systematically and effectively examine underlying human causal factors during the investigation of aircraft accidents. This tool facilitates the development of data-driven investment safety strategies to enhance aviation safety addressing areas where the benefits will be the highest.

A Cessna Citation CE-560XLS+, registered as PR-AFA, crashed in Brazil in August 2014, claiming the lives of seven people, including a Brazilian presidential candidate during the political campaign. The Brazilian Aeronautical Accidents and Prevention Center (CENIPA) thoroughly investigated this accident (CENIPA, 2014) in accordance with the ICAO Standards and Recommended Practices (SARPs) (ICAO, 2016). Weather conditions were below flight minimums at the destination airport. The crewmembers performed an instrument flight rules (IFR) procedure and missed approach with a profile different from the one prescribed in the aeronautical chart. In addition, CENIPA (2014) presented other human factors issues that could have contributed to the accident, such as fatigue, spatial disorientation, and poor team dynamics. Using the HFACS framework, the purpose of this case study was to analyze the human factors elements, including errors and violations, which may have contributed to the accident. Findings were expected to suggest new insights to mitigate the risk of aircraft accidents due to human factors.

The Human Factors Analysis and Classification System

Safety professionals have used organizational and systemic models during the investigation of aircraft accidents as well as the development of the ensuing mitigation strategies since the 1990s (Reason, 1997, 1998). Human factors models such as the "Swiss Cheese", also known as Reason's model (Reason, 1997; 1998), and the HFACS model (Wiegmann & Shappell, 2003) provide a better capture of the complexity of organizational and social-technical systems. Therefore, they enable safety professionals to have a greater understanding of the factors that may contribute to aircraft mishaps (Shappell et al., 2007). Reason's model, the most popular accident causation framework, describes the interactions between active failures by frontline personnel and latent conditions. According to Reason (1997, 1998), it is inadequate to attribute accidents to individual operator performance. Human errors and violations are the end result rather than the cause of mishaps, and just the starting point of the safety investigation process. Accident investigators must focus on events beyond the Unsafe Acts by pilots to latent preexisting conditions, which are usually induced by fallible decisions made on managerial levels.

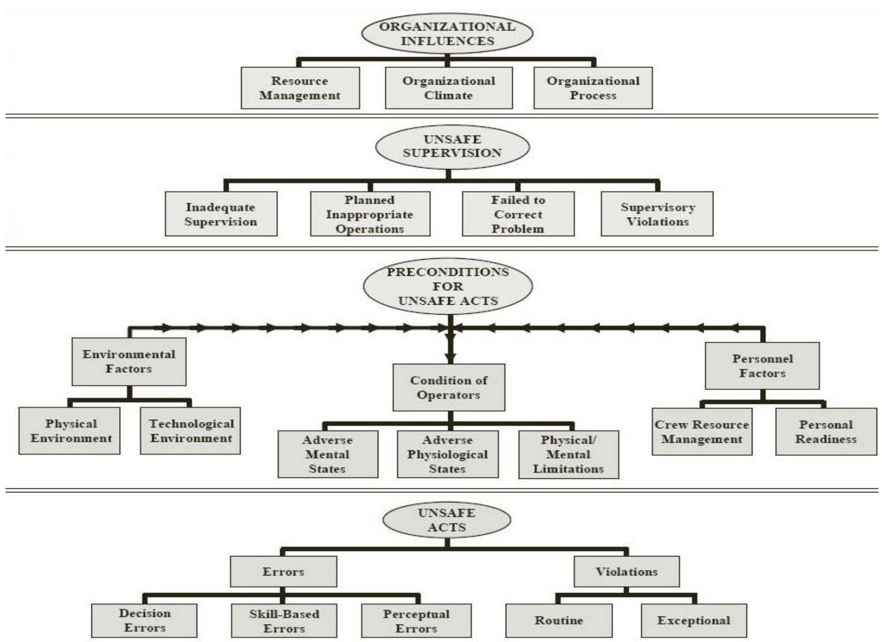

Figure 1. The HFACS Framework. Adapted from the "Human error approach to aviation accident analysis: The human factors analysis and classification system" by Wiegmannn, D. A., & Shappell., S. A. (2003). Burlington, VT: Ashgate Publishing Limited.

The HFACS framework was drawn upon the concept of latent conditions and active failures by Reason (1997). It bridges the gap between theory and pratice by providing safety professionals with a scientifically tested framework designed to investigate the active failures by operators. Additionally, it also encourages safety experts to investigate the latent conditions upstream in the organization (Shappell et al., 2007; Wiegmann & Shappell, 2003). The HFACS model succesfuly describes human errors at four levels: Unsafe Acts of Operators, Preconditions for Unsafe Acts, Unsafe Supervision, and Organizational Influences. The HFACS framework is presented diagrammatically in Figure 1.

Each lower level is impacted by the higher levels in the HFACS framework (Li et al., 2008). The HFACS model goes beyond the identification of unsafe acts by frontline employees, and provides a better understanding of the latent conditions that permited or even prompted Unsafe Acts by human operators. Human errors and violations are viewed as consequences of systemic failures, and are the starting point of an investigation process (Wiegmann & Shappell, 2003). The use of the HFACS framework during the investigation of mishaps facilitates the identification of the contributing factors to the accident, the elaboration of hypotheses, and the development of safety recommendations designed to mitigate latent conditions and Unsafe Acts, greatly improving aviation safety.

The PR-AFA Accident

The PR-AFA, a Cessna Citation CE-560XLS+, was on a non-scheduled flight from Santos Dumont Airport (SBRJ) bound for Santos Aerodrome (SBST), in Brazil, on August 13, 2014. At the time of the accident, the destination airport was operating under severe weather conditions with mist and rain significantly affecting both visibility and operational ceiling. The crewmembers informed the Aerodrome Flight Information Service (AFIS) their intention to perform a non-directional beacon (NDB) instrument flight rules (IFR) approach procedure to land on runway 35. However, they did not follow the profile of the Echo 1 IFR procedure. CENIPA raised the hypothesis that the captain used the aircraft flight management system (FMS) to intercept a direct approach to land at SBST, even though the aircraft manual warned the crew that the FMS visual approach mode must not be utilized in instrument meteorological conditions (IMC) as a substitute for IFR approaches. The pilots discontinued their approach, but did not follow the profile prescribed in the aeronautical chart. The PR-AFA crashed into the ground at a high negative pitch angle and at a high speed, killing two pilots and five passengers, including a well-known Brazilian politician who was campaigning for president. The mishap was thoroughly investigated by CENIPA (CENIPA, 2014).

In addition to the aforementioned factors, CENIPA (2014) posited in its final report that both pilots had not had the adequate and prescribed training while transitioning to the CE-560XLS+ (they were not qualified in that aircraft model). CENIPA (2014) also argued that other human factors issues could have contributed to this mishap. For example, at the time of the accident, there was a self and organizational pressure on the pilots relative to flight schedule due to the political campaign of a passenger. Analysis of the copilot's voice, speech, and tone indicated compatibility with fatigue and somnolence. Moreover, both pilots had difficulties in applying crew resource management concepts. CENIPA (2014) also postulated that the first officer operational capabilities (e.g., cockpit and operational routine management, provision of support as a pilot-not-flying [PNF], effectiveness in the execution of procedures) were inadequate. Those conditions degraded the crewmembers' aeronautical decision making process (ADM).

Following CENIPA (2014), the captain had previously utilized the FMS resources (visual mode) for making direct approaches and very likely used the FMS for reducing the time spent in the Echo 1 IFR procedure. Because the pilots did not follow the profile of the Echo 1 IFR procedure, and due to a tailwind, the crewmembers had difficulty in maintaining a stabilized approach. Thus, they had to perform a missed approach. Yet, after the missed approach the flight crew attempted to maintain visual meteorological conditions (VMC), despite the bad weather conditions. CENIPA (2014) also claimed that the inadequate training, the conflicting relationship and synergy between crewmembers, and the pilots' personal characteristics (e.g., captain authoritarian, first officer passive) hindered the dynamics of the crewmembers, and greatly increased their workload. Moreover, such conditions favored the onset of spatial disorientation of an incapacitating type during a high-risk flight-condition.

Methods

CENIPA is a Brazilian Air Force organization responsible for the investigation of aircraft accidents and incidents involving civil and Brazilian Air Force aircraft in Brazil, all in accordance with the ICAO SARPs. The final report of the PR-AFA, the unit of this case study, was available at the CENIPA website. Using both tabular and narrative data from the PR-AFA final report, each human causal factor was classified using the HFACS framework (Wiegmann & Shappel, 2003). One researcher, who had previous HFACS training and experience using the model during the investigation of aircraft mishaps, made the initial classification. After that, the remaining members of the research team, all with experience in aviation safety and human factors, reviewed potential classifications independently until all researchers reached an agreement. Considering the high inter-rater reliability found in previous studies using the HFACS model (Li et al., 2008; Shappell et al., 2007; Wiegmann & Shappell, 2003), consensus classification was deemed appropriate for the study.

Findings and Discussions

The current study presents an analysis of the accident involving the PR-AFA, a Cessna Citation CE-560XLS+, using the final report by CENIPA (2014) and the HFACS tool (Wiegmann & Shappell, 2003). The HFACS model provides safety investigators with an empirically tested framework that bridges the gap between theory and practice, and assists in identifying and classifying human errors and violations in aircraft mishaps. In addition, it helps safety professionals to focus on latent conditions, active failures, and their interrelationships (Wiegmann & Shappel, 2003). Most importantly, it permits the identification of the underlying causes of Unsafe Acts by crewmembers.

The analysis of this accident started with the level most closely tied to the mishap: Unsafe Acts of operators (Wiegmann & Shappell, 2003). In the first level, researchers agreed that the following actions by the crewmembers could be classified as:

1. Execution of the Echo 1 IFR procedure by the flight crew even though the weather was below the minimums for the procedure (Exceptional Violation);
2. Probable use of the aircraft FMS by the pilots to make a direct approach (Routine Violation);
3. Nonconformity with the profile established in the aeronautical chart during the procedure (Routine Violation) and ensuing missed approach (Exceptional Violation);
4. Attempt to maintain VMC during the missed approach (Decision Error); and
5. Inadequate response to spatial disorientation (Percpetual Error).

Latent conditions, arising in the managerial and/or organizational levels, such as failing to provide crews with proper training, are unavoidable components of the aviation system. They could combine with local triggering conditions and allow or even induce unsafe acts by frontline personel (Reason, 1997, 1998). Unsafe acts of crewmembers can reduce safety margins and lead to mishaps. However, it is paramount to investigate the second level of the HFACS framework, Preconditions for Unsafe Acts, in order to better prevent future accidents. For example, both pilots had not received the prescribed training to transition to the Citation CE-560XLS+ (Personal Readiness). Therefore, they did not have the adequate knowledge and skills to safely operate the aircraft, or the adequate experience for the complexity of the situation (Mental Limitations). In addition, such conditions reduced the pilots' situational awareness (SA) and demanded more cognitive efforts during the IFR procedure, especially the missed approach. The copilot's fatigue and somnolence were Adverse Physiological States that also reduced the crewmembers' SA, thus precluding their ADM process and the safe operation of the aircraft (CENIPA, 2014). In the final report, CENIPA argued that both pilots had difficulty in applying CRM concepts. Even more, they had an unfriendly relationship before the accident. Hence, this situation led to poor coordination, confusion, low SA, and inadequate ADM by both pilots (FAA, 2016). Moreover, these factors most likely contributed to the spatial disorientation of the flight crew. The researchers agreed that loss of SA, complacency, and overconfidence (Adverse Mental States) were factors that adversely influenced the pilots' performance and ADM. The operational environment, the deteriorating weather before and during the time of the accident, also had an adverse effect on the Unsafe Acts by the flight crew. First officer operational weaknesses as a crewmember (Mental Limitations) also was a precondition for the unsafe acts committed by the flight crew.

The Unsafe Supervision level of the HFACS framework connects Unsafe Acts by pilots to the level of the front-line supervisors. The role of front-line supervisors is to provide their personnel leadership, training, guidance, and the adequate tools to perform their jobs efficiently and safely (ICAO, 2013; Shappell et al., 2007). At the supervisory leadership level, researchers identified actions and inactions that had an adverse effect on the safety of the PR-AFA. For instance, both pilots were neither provided with nor required to undergo the adequate and prescribed training before operating the aircraft. Leadership also failed to provide proper CRM training for both crewmembers. Middle management failed to identify and correct risky behaviors by the captain (e.g., inappropriate use of the aircraft FMS; poor CRM skills), by the first officer (e.g., lack of aptitude and skills to act as a crewmember), and the unfriendly relationship of the crewmembers. Additionally, front-line supervisor(s) failed to provide adequate rest in order to mitigate fatigue (Inadequate Supervision). The fourth level of the framework describes the contributions of fallible decisions in upper-levels of management that have a negative effect on the lower levels of the model. Corporate-level decision-making for organization resources, including monetary and human resource management (e.g., inadequate CRM training), played a role in this accident (Resource Management). A poor safety culture (Reason, 1997, 1998), and ill-defined safety policies (ICAO, 2013) contributed to the mishap (Organizational Climate). Finally, organizational pressures due to the presidential campaign (e.g., time; schedule), and inadequate safety programs to mitigate safety hazards were latent conditions that allowed and prompted unsafe acts by the crewmembers (Organizational Process).

Conclusion

Human errors and violations in aviation are elusive and complex to investigate. The accident involving the PR-AFA was analyzed using the HFACS framework. This analysis, demonstrated that actions and inactions at the highest organizational levels can promulgate throughout lower levels. Moreover, those actions and inactions could allow or even motivate Unsafe Acts by crewmembers on the aircraft flight deck. Furthermore, it indicated that the HFACS framework could provide accurate information that should be used for the development, implementation, and the quantifiable assessment of effective safety intervention and mitigation strategies addressing the highest organizational levels. The most cost-effective strategies with the greatest improvement in safety should target these areas (Li et al., 2008; Reason, 1997, 1998; Shappel et al., 2007; Wiegmann & Shappell, 2003).

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