118 East Columbia River Way
Bingen, WA 98605 USA
tel: +1.509.493.8600
insitu.com

Evolution of Mishap Prevention: Application of Human Factors Evaluation Techniques for Unmanned Aircraft Systems (UAS)

Elise Lagerstrom, Ph.D. Insitu Inc., Human Factors Mishap Investigator

Elise Lagerstrom (PhD, AEP) is a mishap investigator in the Aviation Safety department at Insitu. Her responsibilities include conducting mishap instigations, providing human factors support to Aviation Safety and Procedures, and conducting human factors analysis on new and existing products and programs. She graduated from Embry-Riddle Aeronautical University in 2013 with a B.S. in Human Factors Psychology. In 2018, she graduated from Colorado State University with a PhD in Environmental Health and Safety, with a specialty in ergonomics. She has multiple peer reviewed publications on the analysis of injury/fatality data in various industries and the development of targeted safety interventions.

Main Points

1. The Aviation Safety team at Insitu uses both proactive and reactive evaluation techniques to improve overall product quality and usability. Recently, methods such as focus groups and interviews, a year-round focus on hazard reporting from all employees, and use of the Human Factors Analysis and Classification System (HFACS) in mishap investigations and near-misses have resulted in actionable and functional recommendations.

2. The most common recommendations generated by these prevention programs center on curriculum/training of pilots and maintainers, pilot experience, gaps between system capabilities and desired functionality, and system documentation.

3. As a result of dispositioning recommendations to the responsible teams, findings from the programs and methods mentioned in this study have been used to:

    a. Correct documentation gaps and errors

    b. Change autopilot logic for improved integration with manned aviation

    c. Improve maintenance procedures and documentation

    d. Modify the pilot curriculum

    e. Change the user interface to improve pilot situation awareness and monitoring of aircraft function

Introduction

The evolving root cause of aviation mishaps has been well documented; with technological development, materials and processes become more reliable, leading to decreased material failures and increased relative prevalence of mishaps due to human error (International Civil Aviation Orgnaization, 1984). Statistics on the substantial role of human factors to aviation mishaps was first published back in 1993; however, this distribution still holds true today with the latest statistics indicating 70-80% of aviation mishaps are attributed to human error (Wiegmann & Shappell, 2001). In manned aviation, the focus of safety and mishap prevention has appropriately shifted to address the human-machine interface (HMI) and usability with advances in technology, such as the glass cockpit, augmented reality, and improved training simulations. However, in unmanned aviation, it could be argued that we lag behind, with a focus on perfecting the airframe, autopilot logic, and performance characteristics to meet varying operational demand. While these advances are essential to safe operations, there is a warped and inappropriate feel that the role of the pilot and safety of the system are somehow less important because of the lack of physical human presence within the aircraft. This attitude is detrimental not only to the development of systems, but also to attempts to integrate unmanned aircraft system (UAS)/remotely piloted aircraft system (RPAS) into airspace with manned platforms.

Insitu is a company focused on UAS, however, we believe that in order to be safe and successful aviators, we need to refocus on the pilot. In the last year, we have integrated human factors evaluation techniques and programs, both proactive and reactive, to anticipate the shift in the root cause of mishaps in UAS from material to human-related causes.

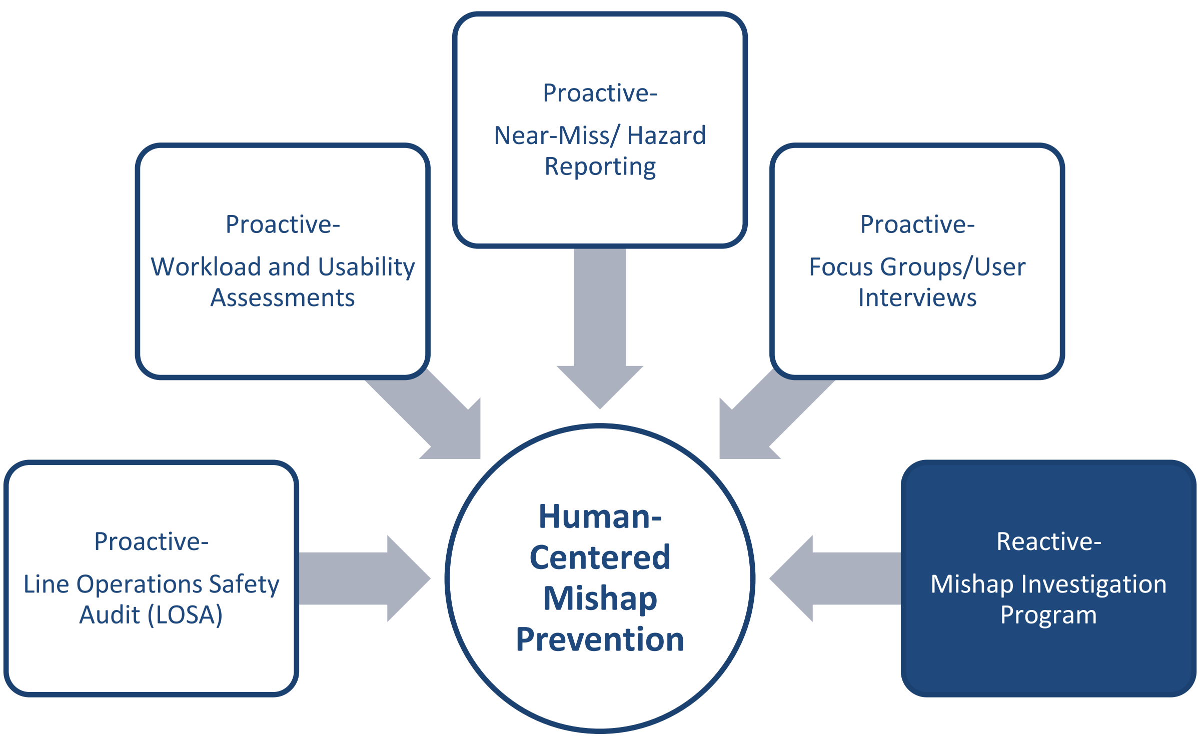

Figure 1: Human-Centered Mishap Prevention

Proactive Mishap Prevention Programs

One of the ways we are working to anticipate and prevent future mishaps is by moving to proactive forms of mishap prevention. In order to do this, we have implemented several initiatives with the goal of identifying and tracking threats before they result in mishaps. Four of these initiatives include: a line operations safety audit (LOSA) program with specific focus on UAS, pilot workload and usability assessments, tracking of active and latent conditions using the Human Factors Analysis and Classification System (HFACS) for near miss events, and the use of focus groups and user interviews with pilots and maintenance personnel. Each of these methods has provided different and valuable recommendations that can be pushed upstream to design and engineering teams, as well as downstream, to the end users.

Line Operations Safety Audit (LOSA)

According to the FAA Advisory Circular on Line Operations Safety Audit (LOSA), "A LOSA is a formal process that requires expert and highly trained observers to ride the jumpseat during regularly scheduled flights to collect safety-related data on environmental conditions, operational complexity, and flight crew performance. Confidential data collection and non-jeopardy assurance for pilots are fundamental to the process" (Federal Aviation Administration, 2006). In order for successful LOSA program implementation to occur, there must be support throughout the initiating organization.

The objectives of implementing a LOSA program are as follows:

- To obtain feedback from pilots so that system improvements can be made;
- To obtain baseline data on crew workload and threat management for comparison if and when changes are made to the system;
- To heighten safety and procedural awareness; and
- To reduce the incidence and cost of human error related mishaps by identifying unsafe conditions prior to mishap occurrence.

At Insitu, successful implementation of the LOSA program is reliant on cooperation and assistance from pilots, training, curriculum development, deployed operations, management, and safety teams. The Aviation Safety department at Insitu serves as the facilitators of the LOSA program and created training materials for pilots, observation forms, as well as methods of data management and dissemination of results. The LOSA forms that were created were designed for specific application to UAS. In addition, the LOSA observation forms that were developed are specific to pilot and maintainer actions.

The LOSA observation form for UAS pilots was designed to capture human error and areas for improvement during normal flight operations with specific emphasis on items that are known to specifically threaten the safety of UAS operations. The LOSA observation form for pilots consists of the following sections: demographic and flight data collection, a written narrative evaluation, behavioral assessment standards evaluation, error identification and management worksheet, and a self-assessment form which is completed by the pilot who was observed. The forms are divided and completed during each phase of flight in order to distinguish between the unique threats seen during each period.

The LOSA observation form for maintainers is designed to capture human error and areas for improvement during normal maintenance tasks. In contrast to the LOSA observation form for pilots, which makes observations during each phase of flight, the LOSA observation form for maintainers will assess maintainer actions and behaviors during pre-flight checks, post-flight checks, and regularly scheduled maintenance procedures (such as 50hr engine inspection).

The LOSA program at Insitu is still in the development phase. The data collection forms, methods, and training materials have been created, but they are still being piloted locally. We are still working to scale and deploy the program to remote sites to achieve one of the defining features of LOSA, which is that audits are completed by peers during actual missions. Before the end state can be achieved, awareness training must be completed with all pilots involved in the program and more extensive training must be provided to pilots who wish to serve as program auditors. Before conducting this training, we are working to trial the data collection forms and methods during training and simulation flights. These trials, while not providing "true" LOSA observations, have helped to identify deficiencies within the methods and we have been able to receive feedback from operational personnel on not only the methods, but how to best implement the program.

Workload and Usability Assessments

Periodically, workload and usability assessments are completed on the user interface. The purpose of the evaluations is to measuring pilot workload and subjective usability during various operational tasks. Usually, these tasks and scenarios are designed to verify specific aspects of the user interface for compliance with standards while simultaneously providing feedback which helps improve the human-machine interface to meet future operational needs and expand system capabilities.

Limitations of the workload analysis are due to sample size and that the evaluations have thus far been conducted during simulated flight. While there are benefits to conducting the evaluations in a simulated environment (the main benefit being elimination of mishap risk due to divided attention), the simulated environment does not perfectly mirror the stresses of a live flight or mission scenario.

As a result of the workload and usability assessments we have received both qualitative and quantitative feedback from operational personnel that has been translated into actionable recommendations for software development.

HFACS for Near Miss/Hazard Reporting

Insitu has a robust Near Miss/Hazard Reporting System which receives Hazard Reports (HAZREPs) from multiple different sources. These HAZREPs are categorized, triaged, and dispositioned at a formal review board. During the triage and review process, the identified hazards are screened for elements related to human factors and/or human error. If there is a human component to the identified hazard, the HFACS system (Shappell & Wiegmann, 2000) is used to tag and categorize the identified hazard or near-miss.

The HAZREP program is beneficial in that we are able to identify hazards before they result in mishaps; and, when paired with the HFACS system, we are able to identify which barriers prevented the hazard from resulting in a mishap. Using this database, successful mitigations can be tracked and a major strength of the program is that it provides an avenue to solicit field knowledge, circumstances, and expert opinions on a recommended path forward for operational concerns.

There have been numerous instances of maintenance errors and near-miss reports being used to create system and procedural change at Insitu. Through use of the HAZREP program, these errors, near-misses, and prevention ideas are evaluated, tracked, and implemented.

For example, the HRB received multiple HAZREPs documenting the hazard of not being able to communicate between the ground crew and the GCS at a site. There was concern that the inability to communicate would cause an inadvertent launch or could result in personnel injury. As a result of the Hazard Review Process, a new radio system with headsets for the ground crew was implemented at the site.

Currently, the most prevalent condition reported using the hazard identification program is the identification of procedural guidance or publications which create an unsafe situation. This type of hazard is commonly identified by either deployed personnel or the training department. One of the most challenging aspects of managing the hazard reporting program is encouraging the reporting of problems or deficiencies without creating an environment where the team responsible for fixing the deficiency feels they are to "blame". This is a fine balance and is contingent on the cultural maturity of the organization. One of the points that is emphasized to reinforce the positive aspects of the program and ensure that the organization is united in trying to accomplish a common goal is to emphasize the point that every time a hazard is reported using this system it is an opportunity to intervene in a condition that had the potential to result in a mishap. Therefore, by reporting hazards, personnel are ensuring a safe work environment for themselves, as well as contributing to an overall organizational mission of reducing the mishap rate.

Focus Groups/User Interviews

As a part of failure review boards spurred by clusters of a specific type of failure, focus groups and user interviews have been used to obtain information from pilots and operational personnel. The best recommendations and discussion thus far have developed out of using a focus group type session where questions are posed to groups of operational personnel rather than one-on-one interviews. Using a focus group as a forum, insight is obtained from multiple operational sites at once and comparison and contrast of the challenges under different conditions is easily obtained. While a standard list of questions is usually followed, when open discussion between operational personnel is facilitated it has been possible to identify similarities (as well as differences) between the failures and challenges occurring at different operational locations or using different product configurations. This information has been invaluable for gathering information on experience and training of personnel, flight operations, and desired software improvements.

Most recently, multiple focus groups were conducted over a period of several weeks to gather information on failures and challenges related to AV recoveries. The targeted focus group participants were pilots and maintainers who had just returned from a deployment. During these interviews, we learned the importance of team composition and the desired skill level of pilots. One of the major topics of discussion was the gap between the idealized (and trained) aircraft recovery schema versus how the UAS pilots were actually expected to interact with airspace and other aviators. Based on the information provided, changes were made to the software which allows for greater manipulation of the approach corridor, and allows the AV to perform more similarly to manned aircraft in controlled airspace. With this expanded functionality, there was also the suggestion for expanded training, to improve the pilots' ability and comfort in operating alongside manned aircraft.

Mishap Investigation/ Reactive Mishap Prevention

While it is still early in the development and implementation of these proactive initiatives, the process to track and complete recommendations stemming from the investigation of mishaps is well established. Investigations are conducted for all mishaps reported to Insitu Aviation Safety which meet a defined criteria. During the investigations, all evidence that was received is reviewed. This evidence is analyzed for material, environmental, and human-related failures. Assignment of a single type (material, environmental, or human) of failure is often not possible, as the mishaps are due to a combination of conditions which all aligned to create the circumstances in which the mishap occurred. Therefore, the investigator must determine the role and contribution of each type of contributing factor.

At Insitu, since 2009, material failures are identified as the primary cause of mishaps more prevalently than human or environmental causes. However, if Insitu follows a similar path to manned aviation, as aircraft become more (mechanically) reliable, the total number of mishaps will decrease, but the percentage of mishaps caused by human factors will increase.

To aid in the investigation, the Human Factors Analysis and Classification System (HFACS) (Shappell & Wiegmann, 2000) is utilized to categorize casual and/or contributory conditions which were identified. The purpose of the identification and categorization of these factors is to identify trends and also to guide the development of recommendations and mitigations. This information is stored within the database and queried monthly to identify trends and push the latest information out to users and development groups.

In anticipation of the transition from primarily machine related causes to human error mishaps, the causal and contributory factors for mishaps attributed to human error are tracked and further categorized. Failure to follow checklists and procedures, as well as inadequate risk assessment, are the leading contributory human factors in mishaps attributed to human error. In addition, at the organizational level, providing inadequate procedural guidance and publications to sites has been identified as a contributing factor to many mishaps attributed to human error.

Figure 1: Human-Centered Mishap Prevention

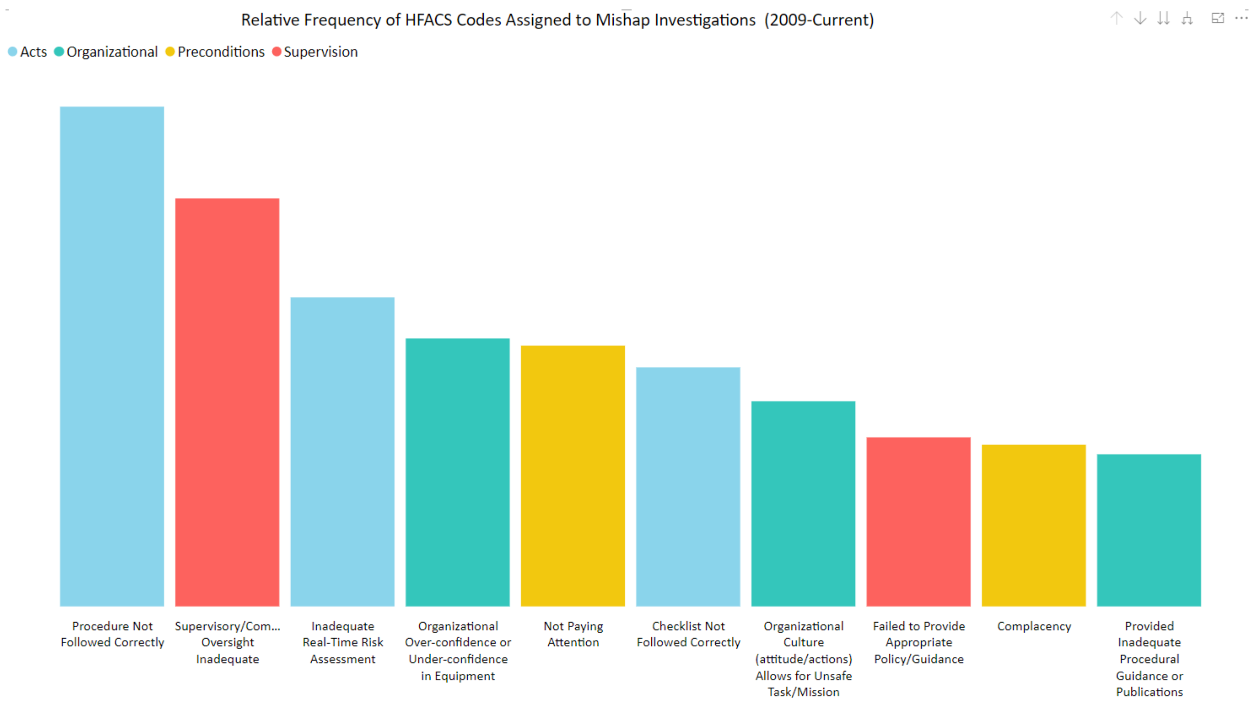

Figure 2: Relative Frequency of HFACS Codes Assigned to Mishap Investigations

Conclusion

As a result of the findings from mishap investigations and the proactive mishap prevention programs described above, recommendations are developed and distributed to accountable departments throughout the company. These recommendations have resulted in changes to the design of the software, autopilot logic, publication updates and changes, training curriculum development, and even improvements to the infrastructure surrounding deployed locations.

One of the complex challenges we identified and anticipate for the future is the interaction between manned and unmanned aircraft. In order to safely and successfully provide an environment where both manned aircraft and UAS coexist, changes will need to be made to regulations, technology, training, and culture. As regulations are currently under development across the globe, we are using feedback from controlled encounters to predict and proactively address some of the potential operational challenges. For example, UAS pilots come from a variety of backgrounds and may not have experience in manned aviation. In order to decrease risk and increase the probability of successful interactions, we are working on ways to develop the curriculum to increase the relative skill level of UAS pilots to make them more than operators, but aviators. In addition, the need for education is two-sided. Comparative to manned aviation, every aircraft has operating limitations. In order to operate cooperatively, we need to develop communication channels and inform air traffic control and other users within the area of operations on our performance capabilities and limitations.

As time progresses, we will work to improve and mature these programs; building the fundamental structure of a Safety Management System (SMS). One of the greatest challenges is the process to effectively and efficiently bridge the gap between operational personnel and design activities. To be effective, the process to take the feedback and lessons learned and efficiently distribute this knowledge back to areas which can execute change should be scheduled, solidified, and formalized.

In looking to the prevention of future mishaps, the past is anything but irrelevant; however, future safety lies not only in correcting mistakes from the past and preventing reoccurrence, but also in the anticipation of future challenges and threats.

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