PROBABLE CAUSAL FACTORS IN UAV ACCIDENTS BASED ON HUMAN FACTOR ANALYSIS AND CLASSIFICATION SYSTEM

Muhammad Asim*, DR Nadeem Ehsan, Khalid Rafique*****
*, **, *** Center for Advanced Studies in Engineering, Islamabad , Pakistan

Keywords: UAV, Human Factor, Accident

Abstract

Human errors are responsible for 67.57% of accidents in one hundred years of aviation history (1905-2005). UAV technology was developed to eliminate human limitations and reduce chances of human factor in accidents. However, this experiment proved to be questionable, as the statistics show higher number of accidents involving human errors in unmanned systems. The aim of study is to determine causal factors in UAV accidents. A sample of 56 US Army UAV accidents was collected. The study revealed that human factor was involved in 18 (32%) accidents. It is recommended that man machine interface in UAV technology may improve further to avoid such cases. The ability of UAV crew to adjust in different scenario may be enhanced through extensive training.

1. Introduction

The history of aircraft accidents is as old as aircraft itself. A quick glance through the annals of aviation history reveals a fairly large number of accidents since man has started to fly. According to the statistics of Aircraft Crashes Record Office Geneva Switzerland, a total of **121,870** people have lost their lives in **17,369** accidents in one hundred years of aviation history (1905-2005) [5]. The principal causes of these accidents were classified as human error, technical failure, weather and sabotage. Human errors are responsible for 67.57% of these accidents, which is significantly large compared to other causes of accidents as shown in figure 1.

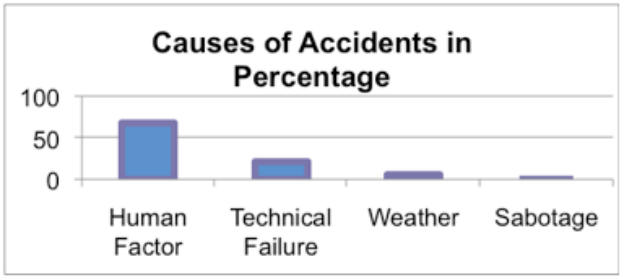

Fig. 1. Aircraft crash accident causes in percentage

Boeing Aircraft Company also attributed flight crew error to be a major cause (**55%**) of accidents in **183** airline accidents between 1996 to 2005 shown in figure 2.

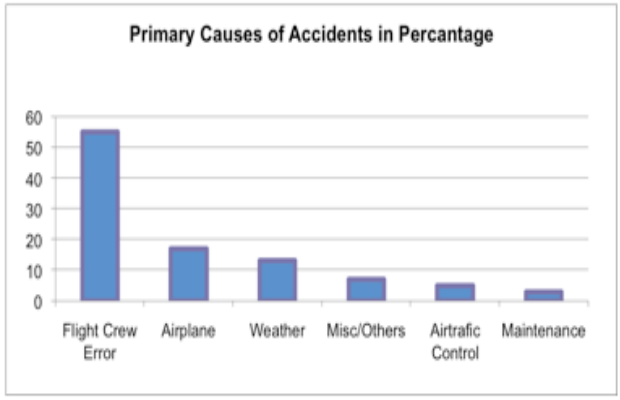

Fig. 2. Causes of airline accidents 1996-2005

Statistics show that most aircraft accidents and incidents have occurred due to human errors. Aircraft occurrence investigation agencies around the world estimate that 70 to 90 percent of accidents are due to non-adherence of procedures lack of training, bad decision-making and incorrect actions of personal involved in maintenance, operations or design of aircraft. (NTSB, 2000).

The fruits of technological development lead to the design and manufacturing of Unmanned Aerial Vehicle (UAV), which offers considerable advantages over manned aircraft. The concept of eliminating human's physical and mental limitations gave birth to unmanned technology. It was assumed that the lesser involvement of man would reduce the chances of failure due to human error. However, this supposition proved to be questionable as the statistics show a higher number of accidents in unmanned systems due to human error, compared to manned aircraft. Most of the UAV accidents occurred during the takeoff and landing phases of the flights, which involve human input to the unmanned system. The statistics of UAV accidents (as reported by Adams, 2005) involving these two critical phases of flights are given in table 1.

UAV	YEAR	NO OF ACCIDENT	LANDINGS	TAKEOFF
Pioneer	1968-2002	239	68%	10%
Hunter	1995-2003	32	47%	20%
Predator	1994-2004	15	13	N/A

Table 1. UAV accident statistics for critical phases of flight

UAV is controlled and operated from the ground by means of telecommunication linkages. It also flies autonomously with the help of autopilot. These distinct features reduce on-board situational awareness and rapid decision-making within the UAV. The introduction of autopilot in the system induces complacency in the pilots and they become casual in performing the tasks. Many UAV accidents occurred due to these reasons. Therefore, knowledge of human factors is vital to improve the system safety and reliability. The study is aimed to examine UAV accidents and analyze them for human causal factors through application of Human Factor Analysis and Classification System (HFACS).

2. Research Design

The research is aimed to investigate the causal relationship between human factor and UAV accidents. The outcome variable in this relationship is **UAV accidents**; therefore it is taken as **dependent variable**. There are various independent variables, which can be responsible for UAV accidents such as human factor, material failure, environment effects and design flaws. However the scope of this research is limited to human causal factors only, therefore **human factor** is selected as **independent variable**. Several other factors like workload, fatigue, situational awareness, crew co-ordination, training and ergonomics design can effect the dependent variable, therefore, are chosen as **extraneous variables**. A cross sectional study design is chosen to investigate research objectives. A sample of 56 UAV accidents was taken from US army accident database. The empirical model of variable is shown in figure 3.

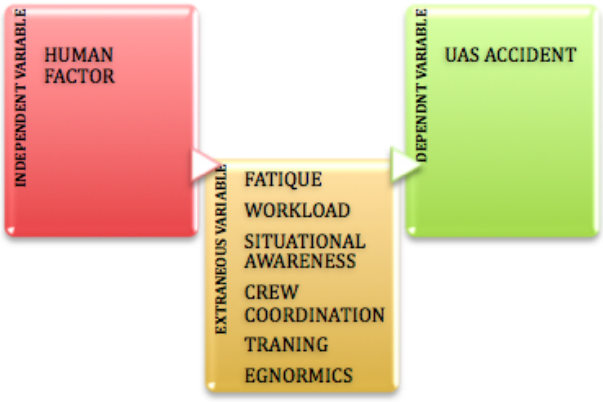

Fig. 3. Set of variables showing relationship between UAV accident and human factor

2.1 Hypothesis

The concept of eliminating human's physical and mental limitations gave birth to unmanned technology. It was assumed that the lesser involvement of man would reduce the chances of failure due to human error. For the purpose of this study **it is assumed that human casual factor is not a major contributor in UAV accidents**. Analyzing the sample of UAV accident is going to test the validity.

3. Human Factor Analysis and Classification System (HFACS)

Wiegmann and Shappell (2003) developed the Human Factors Analysis and Classification System (HFACS). It is a general framework of human error originally developed and tested within U.S. military for investigating and analyzing human elements in aviation accidents. The model is based on Reason's (1990) accident model. The framework has four levels of human errors namely, organizational influences, unsafe Supervision, precondition for unsafe acts and unsafe act. These four levels are further subdivided into 17 categories. The framework is extremely helpful in identification of human causal elements in accidents [13]. The HFACS framework is shown in Figure 4.

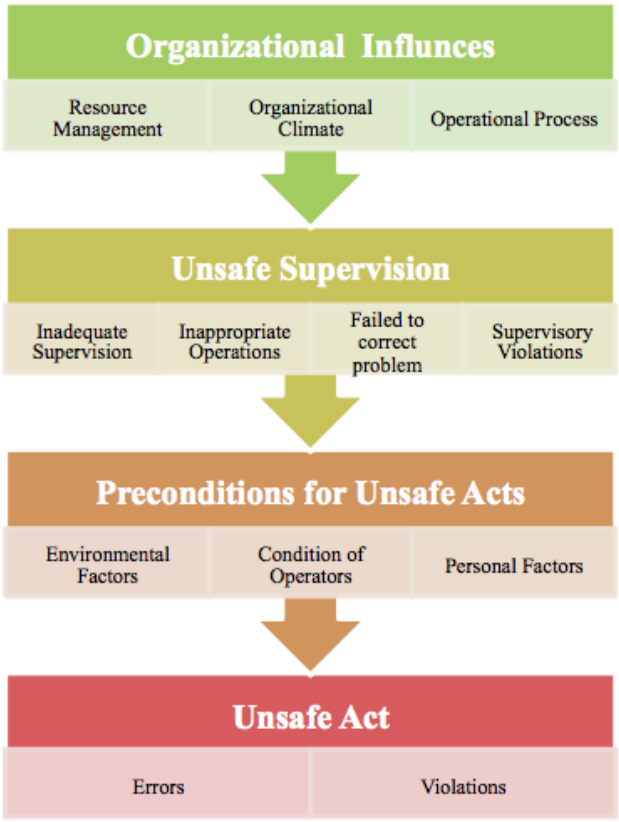

Fig. 4. HFACS framework

4. Findings

The sample of 56 UAV accidents for the period 1995-2005 is taken from U.S Army accident database[8]. These accidents are summarized under material failure, environment, human error or combination of any two failures as shown in figure 5. Material failure was responsible for 32 % accidents. Human factor was present in 11 % accidents, however if combination of error are added, human factor was present in 32 % of the accident, which is significantly large. 30 % of the accidents were categorized as undermined.

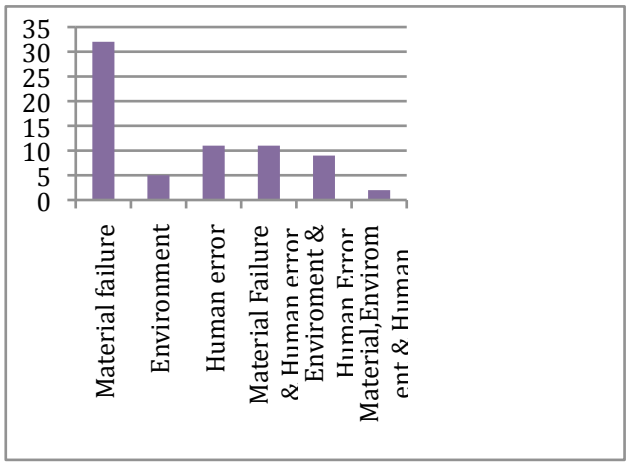

Fig. 5. Graphical representation of causal factors in percentage

5. Discussion

The accidents involving human factor (18 in no, 32%) is analyzed through Human Factor Analysis and Classification System. These 18 accidents were further divided into four levels and 17 categories of HFACS framework and represented in table 2 below. "Unsafe Acts" were present in 11 accidents, which is 20 % of all 56 accidents. Decision errors were present in 6 and violations were present in 4 accidents involving unsafe acts. Unsafe Supervision was prevalent in 16 %, organizational influences were present in 14 % and pre conditions for unsafe act were found in 2 % of all 56 accidents.

HFACS Category	Frequency of occurrence	Accident	% based on 56 Accident	% of 18 human error Accident
Unsafe acts	**16**	**11**	**20**	**61**
Skill-based errors	4	4	7	22
Decision errors	6	6	11	33
Perceptual errors	3	3	5	17
Violations	3	2	4	11
Pre Conditions for unsafe Act	**1**	**1**	**2**	**6**
Crew resource management	1	1	2	6
Unsafe supervision	**11**	**9**	**16**	**50**
Inadequate Supervision	6	6	11	33
Failed to correct known problem	3	3	5	17
Supervisory Violations	2	2	4	11
Organizational Influences	**8**	**8**	**14**	**44**
Organizational process	8	8	14	44

When 18 accidents related to human causal factors are considered out of sample of 56 then unsafe act was prevalent in 61 % accidents, organizational influences were present in 44 % accidents, unsafe supervision was present in 50 % accidents and pre conditions for unsafe acts was only present in 6 % accidents. As the accidents are shared in more then one category therefore sum of these percentages would show more then 100 % value.

5.1 Unsafe Act

The "Unsafe act" level is divided into four subcategories namely, skill based errors, decision errors, perceptual errors and violations. Decision based errors were found in 33% of unsafe acts, whereas 22 % accidents involved skill based errors. Perceptual errors and violations were identified in 17% and 11 % accidents respectively. The trend showed alarming findings that decision based errors were more in number as compared to rest of the sub categories. Though the data represent sufficient knowledge of errors, however the reason of particular error cannot be found through this framework. The answers to questions, like, why the pilot made decision errors, violations or perceptual errors cannot be isolated. In authors opinion the skill based errors are related to training and pilots ability to acquire, decision based errors are linked with pilots ability to respond quickly and accurately, perceptual errors are related to pilots environmental and mental state and violations are related to casual behavior or inadequate knowledge. The unsafe act categories may further be classified as shown in figure 6 for in-depth knowledge of rationale for unsafe acts.

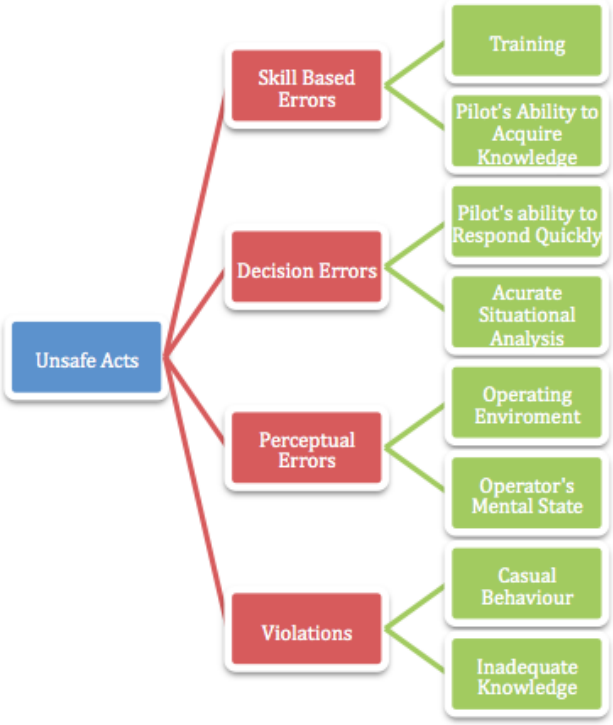

Fig. 6. Modified framework for unsafe acts

5.2 Preconditions for unsafe Act

Precondition for unsafe act is further classified into personal factors, environmental factors and operator's condition. It is found only in one accident where poor coordination exists between trainee and trainer. The share of this category is 2% of all 56 accidents and 6 % of 18 accidents involving human errors. This category involves deep understanding of external and internal factors associated with operators, their operating environment and conditions to establish the causation between accidents and preconditions for unsafe acts.

Fig. 7. Framework for precondition for unsafe acts

5.3 Unsafe Supervision

Unsafe supervision is classified into inadequate supervision, inappropriate operation, failed to correct problem and supervisory violations. Inadequate supervision was found in 11% of total 56 accidents and 33 % of 18 accidents. Supervisory violations were present in 4 % of 56 accidents and 11% of 18 accidents. The supervisory lapses for failed to correct known problems were prevalent in 5% of all 56 accidents and 17 % of 18 accidents. Probable reasons, which could have caused supervisory lapses, are displayed in unsafe supervision framework shown in figure 8.

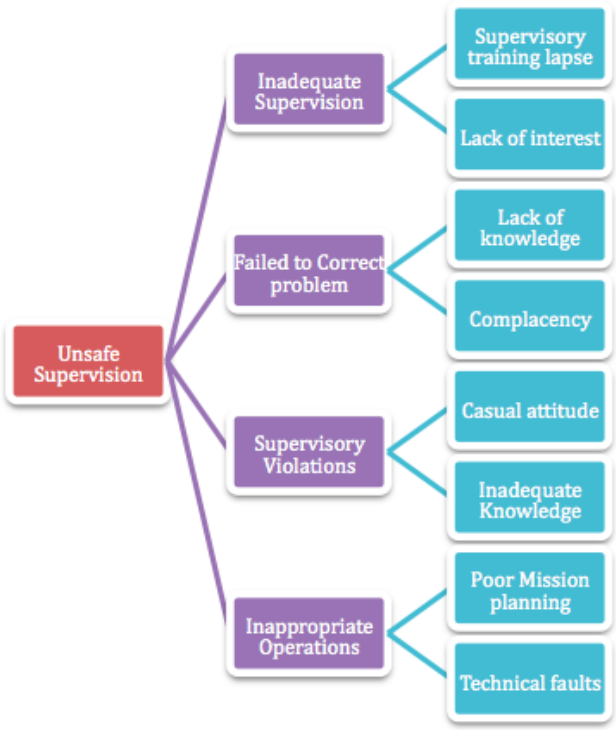

Fig. 8. Unsafe supervision framework

5.4 Organizational Influences

This level is subdivided into organizational climate, resource management and operational process. The sample data shows problem in organizational process, which make up to 14 % of 56 accidents and 44% of 18 accidents. Organizational influences have a trickle down effect on unsafe acts, preconditions for unsafe acts and unsafe supervision. The organizational culture dictates the importance on safety and improvements of human related aspects. Accidents related to human factors can be avoided if serious attention is paid toward organizational climate and culture, efficient resource management and process improvements.

To eliminate human causal factors from accidents a model is presented in figure 9. The model can be applied after identification of the problems through HFACS. The solution to problem of every level is recommended which may reduce the accidents involving human errors if not eradicate them completely.

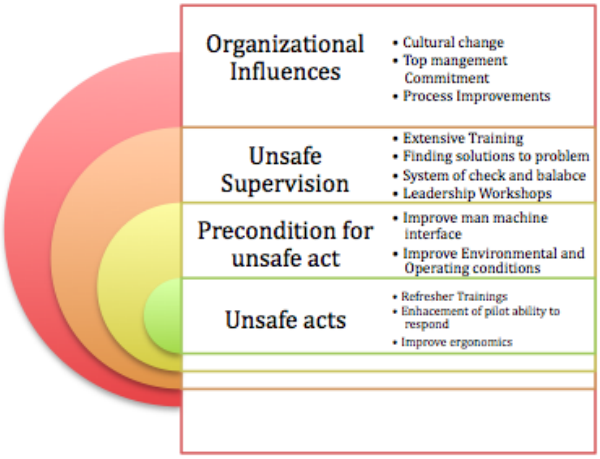

Fig.9. Proposed model of improvement

6. Conclusion

The study revealed that human factor is responsible for 32 % accidents in a sample of 56 UAV accidents. This percentage may increase by increasing the sample size. A positive correlation is established between accidents and human causal factors therefore study hypothesis proved to be wrong. Human Factor Analysis and Classification System is very helpful in determination and categorization of human errors, however, certain modification in the HFACS framework is suggested to get the in-depth causation of human failures. A model is presented to eliminate or reduce the human related accidents in UAVs.

7. Contact Author Email Address

a007pk@yahoo.com

References

[1] Daniel J. Garland, John A. Wise, V. David Hopkin, 1999, *Handbook of Aviation Human Factors*, Lawrence Erlbaum Associates, New Jersey London.

[2] Earl l. Weiner, David C. Nagel, 1988, *Human Factor in Aviation,* Academic Press Limited, London.

[3] Nancy J. Cooke, Heather L.Pringle, 1994, *Human factor of Remotely Piloted Vehicle,* Eduardo Sales, Newyork.

[4] Sharma S, Rattan N, SJoshi VV, 2002, *' Human Factors in Unmanned Aerial Vehicle operations in India: A Preliminary Report'*, 50th International Congress of Aviation and Space Medicine, Sydney.

[5] *Aviation Crash Statistic,* Available at: http:// www.baaa-acro.com/Statistics.html.

[6] *Aviation Accidents and Incidents*, Available at: http:// www.wekipedia.com.

[7] Peter Donaldson, 2008 ' US DoD Publishes UV Road MAP', *Unmanned Vehicle,* Vol 13, No 1, pp.4.

[8] Department of the Army (1994a). Accident reporting and records. Washington, DC. Army Regulation 385-40.

[9] Department of the Army (1994b). Army accident investigation and reporting. Washington, DC. Army Pamphlet 385-40.

[10] DoD (2001). *Unmanned aerial vehicles roadmap*, 2000- 2025. Office of the Secretary of Defense, Department of Defense, Washington, DC, April 2001.

[11] Manning, S.D., Rash, C.E., LeDuc, P.A, Noback, R.K., and McKeon, J. (2004). *The role of human causal factors in U.S. Army unmanned aerial vehicle accidents*. U.S. Army Aeromedical Research Laboratory Report # 2004-11.

[12] Gawron, V.J. (1998). *Human factors issues in the development, evaluation, and operation of uninhabited aerial vehicles*. AUVSI '98: Proceedings of the Association for Unmanned Vehicle Systems International, Huntsville, AL, 431-8.

[13] Shappell, S.A. and Wiegmann, D.A. (2000). *Human factors analysis and classification system - HFACS.* Department of Transportation, Federal Administration: Washington, DC. DOT/FAA/AM-00/7.

[14] Strikenet (2001). *VTUAV P1 accident investigation board report.* Downloaded from URL http://www.strikenet.js.mil/pao/vtUAV_crash_in-vest_news_release.html.

[15] Wiegmann, D.A. and Shappell, S.A. (2003). *A human error approach to aviation accident analysis: The Human Factors Analysis and Classification System*. Burlington, VT: Ashgate.

Copyright Statement