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Review of U.S. Army Unmanned Aerial Systems Accident Reports: Analysis of Human Error Contributions

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14. ABSTRACT

Unmanned aerial systems (UAS) accident reports occurring between 1 October 2010 (FY11) and 30 September 2015 (FY15) were reviewed for human-error trends. The following common themes were identified within the report narratives: poor planning, fueling errors, and maintenance errors. Personnel data, including hours slept, hours worked, and hours flown prior to the accident, were also reviewed to evaluate if fatigue due to sleep or long shifts may have played a causal role. However, none were identified as significantly contributing to the possible cause of the accident. The role of human error in UAS mishaps is discussed and recommendations have been put forth to assist in future identification of causes of mishaps.

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Introduction

The success of unmanned aerial systems (UAS) operations relies upon a variety of factors, including, but not limited to, the functionality of the overall system, the human operator monitoring and contributing to the flight, and the weather conditions and environment the flight is occurring within. The human contribution to UAS accidents and mishaps is oftentimes not thoroughly examined, therefore limiting the ability to make recommendations for improving operations. The purpose of the present project was to review U.S. Army UAS accident reports to identify the degree of human error involved in the accidents reported, and to quantify potential contributing factors, such as fatigue, as cited or included within report documents. The information presented was obtained through a request to use the U.S. Army Combat Readiness Center's Risk Management Information System (RMIS).

Background

The use of UAS within the Army has seen a rapid increase over the past 16 years since first using them in combat operations in 2001 (U.S. Army UAS Center of Excellence, 2010). The increase in their use within the Army has been attributed to the following three capabilities they provide: (1) reduction of risks (e.g., explosives) to Soldiers; (2) reduction in workload experienced by Soldiers operating the UAS; and (3) opportunities for extended range missions (U.S. Army UAS Center of Excellence, 2010). UAS are comprised of various systems, to include the unmanned aircraft, payload, human element, weapons systems platform, display, communication architecture, life cycle logistics, and supported Soldiers. The role of the human element within the UAS operating scheme can be crucial in determining the success of a mission and can impact the likelihood of an accident or mishap. In fact, previous examinations of UAS mishaps including Air Force, Army, and Navy/Marines identified human factors as a causal factor in approximately 60% of the reviewed mishaps (Tvaryanas, Thompson, & Constable, 2006). However, no recent review of U.S. Army UAS accidents, specific to the role of the human element, has been conducted. Through a review of U.S. Army UAS accidents occurring between FY 2010 and 2015, the objective of the present study was to quantify the extent to which the human element contributes to the mishaps reviewed.

The present study reviewed Class A, B, C, and D UAS accident reports to examine the presence of human error identified within the report and characterize the potential operational stressors (e.g., fatigue, shift work) involved. The U. S. Army Combat Readiness Center (2015) defines Class A mishaps as "An Army accident in which the resulting total cost of property damage is $2,000,000 or more; an Army aircraft or missile is destroyed, missing, or abandoned; or an injury and/or occupational illness results in a fatality or permanent total disability. Note that unmanned aircraft systems (UAS) accidents are classified based on the cost to repair or replace the UAS. A destroyed, missing, or abandoned UAS will not constitute a Class A accident unless replacement or repair cost exceeds $2,000,000 or more." Class B mishaps are defined as "An Army accident in which the resulting total cost of property damage is $500,000 or more, but less than $2,000,000; an injury and/or occupational illness results in permanent partial disability, or when 3 or more personnel are hospitalized as inpatients as the result of a single occurrence." Class C mishaps are defined as "An Army accident in which the resulting total cost of property damage is $50,000 or more, but less than $500,000; a nonfatal injury or occupational illness that causes 1 or more days away from work or training beyond the day or shift on which it occurred or disability at any time (that does not meet the definition of Class A or B and is a lost time case).” Class D is defined as “An Army accident in which the resulting in total cost of property damage is $2,000 or more, but less than $50,000; a nonfatal injury or illness resulting in restricted work, transfer to another job, medical treatment greater than first aid, needle stick injuries and cuts from sharps that are contaminated from another person’s blood or other potentially infectious material, medical removal under medical surveillance requirements of an OSHA [Occupational Safety and Health Administration] standard, occupational hearing loss, or a work-related tuberculosis case”.

Human factors issues in UAS operation have been identified as including, but not limited to, the number of aircraft a single operator can divide attention between and effectively control, maintaining operator performance by mitigating fatigue and vigilance decrement, complex crew coordination systems, and degraded operator situational awareness (Goodrich & Cummings, 2013). Degraded operator situational awareness has been identified as a possible causal factor in one review of Air Force UAS accidents, where situation awareness errors associated with perception of the environment accounted for 57% of human-error-related accidents (Tvaryanas & Thompson, 2008). Examining which of these stressors/human factors issues are most currently impacting operational effectiveness and health as reported in accident reports aids in prioritizing these stressors for future research lines.

The present study reviewed UAS accident reports to further examine accidents where the human element was identified as a contributing factor. In compiling the accident reports, the investigators decompose the role of the human element by identifying the “system” inadequacies that contributed to the error. Here the “systems” are broken down into the following categories: support, standards, training, leader, and individual. Support refers to whether the individual had support (e.g., personnel, equipment/materiel, supplies, services/facilities) available to perform the task. Standards refer to whether or not standards/procedures exist for the task and if they are clear and practical. Training refers to whether the individual received training on how to perform the task, and if it was complete and sufficient. Leader refers to whether the leader(s) enforced standards. Lastly, individual refers to whether the individual knew and was trained on the standards, as well as whether the individual elected to not follow the standard. For each accident where human error is considered a contributing factor, these five systems are examined to identify whether any contributed to the error that occurred and have been included in our analyses to identify any prevalent trends related to operational stressors. In addition to examining the system inadequacies identified by the accident reviewers, we also examined the narratives of the accident reports where the human element was identified as a contributing factor to identify common themes.

Method and Materials

Data source

All U.S. Army Class A, B, C, and D UAS accident reports from 1 October 2010 (FY11) to 30 September 2015 (FY15) were included in this study. A total of 288 accident reports were retrieved from the U.S. Army Combat Readiness Center’s RMIS and reviewed. Report elements reviewed included information such as a description of the accident (written summary and categories such as environment, time of day, etc.), aircraft type, classification of the accident, accident findings, and personnel information (e.g., rank, gender, hours slept). The extracted report elements did not include any personally identifiable information.

Procedure

The accidents retrieved were first screened for those classified as human error being a contributing factor. The narratives of the identified accidents with human error as a contributing factor were then examined for personnel factors potentially contributing to the accident. The narratives of these were also examined to identify any common themes. Extracted data elements included the following: identified human error failures (individual, support, standards, training, and leader), time of day of accident, accident classification, primary aircraft, personnel demographics, hours slept, hours worked, and hours flown.

Statistical Analysis Approach

Statistical analyses were performed using the statistical software package IBM SPSS Statistics Release 19.0.0. Frequencies and descriptive statistics were calculated for the extracted data elements. Narrative descriptions provided in the reports were reviewed for trends.

Results

Of the 288 total reports retrieved, 69 (24%) cases were identified in the reports as having been attributed to human error. Of these 69 cases, 11 (16%) were Class A, 19 (27%) Class B, 35 51%) Class C, and 4 (6%) Class D (see Table 1 for total costs associated with each classification). With respect to system type, the majority of accidents were reported with the RQ-7B Shadow with 50 (73%) accidents reported (see Table 2 for the remaining system types and breakdown by classification). The majority of the accidents were reported as occurring during the day, with 54 (78.3%) reported as daytime, 2 (2.9%) dawn, 1 (1.4%) dusk, and 12 (17.4%) at nighttime.

Table 1. Total Cost by Classification.

	Frequency – Class A	**Frequency – Class B**	**Frequency – Class C**	**Frequency – Class D**
N	11 (16%)	19 (27%)	35 (51%)	4 (6%)
Total Cost	$50,671,003	$14,970,179	$7,544,915	$173,114

Table 2. Airframe frequencies by classification.

Airframe	Frequency Total	Frequency – Class A	Frequency – Class B	Frequency – Class C	Frequency – Class D	Accident Rate per 10,000 hours
MQ-1B	2	1	0	1	0	0.14
MQ-1C	9	6	1	2	0	0.59
MQ-5B	7	2	0	5	0	1.28
PTDS	1	1	0	0	0	*
RQ-7B	50	1	18	27	4	1.19

* Hours are not available for PTDS.

With respect to determination of human error source responsible for the human error identified within the accident report table 3 provides a breakdown of each system type and their frequencies with regards to playing no role, suspected to have played a role, and definitely played a role.

Table 3. Human Error Source

Error Source	None	Suspected	Definite
Individual	5 (7.2%)	30 (43.5%)	34 (49.3%)
Support	46 (66.7%)	11 (15.9%)	12 (17.4%)
Standards	53 (76.8%)	15 (21.7%)	1 (1.4%)
Training	41 (59.4%)	27 (39.1%)	1 (1.4%)
Leader	34 (49.3%)	28 (40.6%)	7 (10.1%)

Note. Each row contains all 69 accidents, as accidents could be classified as multiple error sources having played a role.

The narratives of the accident reports were also examined by the researchers for any common themes. Three common themes stood out. These were related to poor mission planning and lack of situational/spatial awareness that often resulted in controlled flight into terrain (13 accidents), fueling errors by improper techniques (7 accidents), and a variety of maintenance errors (10 accidents). The remainder of the accidents had a variety of differing causes that did not group into a common cause, such as midair collision with another aircraft or proceeding to land in bad weather, which were identified as “Not Defined” (39 accidents). Table 4 reports the frequency of these common themes within each of the human error sources as identified by the accident reviewers. As shown in the table, individual error was identified as a source of error as suspected or definite in a majority of the accidents, including the Not Defined group (36 of 39 accidents). Further noteworthy, individual error was identified as a suspected or definite causal factor in 12 of the 13 accidents that fit into poor planning, all 7 of the fueling accidents, and 9 of the 10 maintenance accidents.

Table 4. Frequencies Based on Source of Human Error

Human error source	**Presence**	**Poor Planning**	**Fueling Error**	**Maintenance Error**	**Not Defined**
Individual					
	None	1 (1.45%)	0 (0%)	1 (1.45%)	3 (4.35%)
	Suspected	2 (2.90%)	4 (5.80%)	5 (7.25%)	19 (27.54%)
	Definite	10 (14.49%)	3 (4.35%)	4 (5.80%)	17 (24.64%)
Support					
	None	13 (18.84%)	1 (1.45%)	1 (1.45%)	31 (44.93%)
	Suspected	0 (0%)	3 (4.35%)	6 (8.70%)	2 (2.90%)
	Definite	0 (0%)	3 (4.35%)	3 (4.35%)	6 (8.70%)
Standards					
	None	12 (17.39%)	7 (10.14%)	9 (13.04%)	25 (36.23%)
	Suspected	1 (1.45%)	0 (0%)	1 (1.45%)	13 (18.84%)
	Definite	0 (0%)	0 (0%)	0 (0%)	1 (1.45%)
Training					
	None	6 (8.70%)	6 (8.70%)	8 (11.59%)	21 (30.43%)
	Suspected	6 (8.70%)	1 (1.45%)	2 (2.90%)	18 (26.09%)
	Definite	1(1.45%)	0 (0%)	0 (0%)	0 (0%)
Leader					
	None	6 (8.70%)	5 (7.25%)	10 (14.49%)	13(18.84%)
	Suspected	5 (7.25%)	2 (2.90%)	0 (0%)	21 (30.43%)
	Definite	2 (2.90%)	0 (0%)	0 (0%)	5 (7.25%)

Note. Each human error source contains all 69 accidents, as accidents could be classified as multiple sources having played a role.

The four identified common accident themes were also examined in relation to variables including accident classification, aircraft type, and location of accident with frequency information reported in Table 5. Noteworthy is that 11 of the 13 poor planning accidents were Class A and B accidents, which resulted in significant financial loss. The planning errors were largely related to altitude separation from terrain in mountainous areas of Afghanistan, which is in line with where the majority of Army operations were occurring during the timeframe under investigation.

Table 5. Frequency Table of Accident Themes.

Variable		**Poor Planning**	**Fueling Error**	**Maintenance Error**	**Not Defined**
Classification					
	A	2 (2.90%)	0 (0%)	1(1.45%)	8 (11.59%)
	B	9 (13.04%)	1(1.45%)	3 (4.35%)	6 (8.70%)
	C	2 (2.90%)	6 (8.70%)	6 (8.70%)	21 (30.43%)
	D	0 (0%)	0 (0%)	0 (0%)	4 (5.80%)
Aircraft Type					
	MQ-1B	1 (1.45%)	0 (0%)	1 (1.45%)	7 (8.70%)
	MQ-1C	0 (0%)	0 (0%)	2 (2.90%)	0 (0%)
	MQ-5B	1 (1.45%)	0 (0%)	0 (0%)	6 (8.70%)
	PTDS	0 (0%)	0 (0%)	0 (0%)	1 (1.45%)
	RQ-7B	11 (15.94%)	7 (8.70%)	7 (8.70%)	25 (36.23%)
Location					
	Afghanistan	10 (14.49%)	4 (5.80%)	6 (8.70%)	26 (37.68%)
	Iraq	1 (1.45%)	2 (2.90%)	0 (0%)	3 (4.35%)
	Training	2 (2.90%)	1(1.45%)	4 (5.80%)	10 (14.49%)

The possible impact of fatigue in relation to the human errors accidents was examined by looking at the following variables within the data: hours slept in the previous 24 hours, hours worked in the previous 24 hours, and hours flown in the previous 24 hours. These were examined by parsing out the average hours reported slept by personnel involved in the accident by the source of human error (see table 6). As shown in the table, the majority of personnel reported approximately 8 hours of sleep during the 24 hours prior to the incident.

The only possibly noteworthy finding is under the human error source of "Standards" with a definite presence of human error. Here, an average of 6.33 hours was reported, however, upon further inspection, it was identified that this number was the average of three personnel involved in one incident. Thus, while it appears noteworthy no significant conclusions can be made from this data point.

Table 6. Hours slept in 24 hours prior to incident.

Human error source	**Presence**	**Mean**	**SD**	**Median**
Individual				
	None	8.10	0.32	8.0
	Suspected	7.98	0.94	8.0
	Definite	8.20	1.56	8.0
Support				
	None	7.97	1.19	8.0
	Suspected	8.00	0.78	8.0
	Definite	9.10	1.56	8.5
Standards				
	None	8.24	1.29	8.0
	Suspected	7.97	0.85	8.0
	Definite	6.33*	2.10	7.0
Training				
	None	7.85	1.26	8.0
	Suspected	8.32	1.18	8.0
	Definite	8.50	0.71	8.5
Leader				
	None	8.06	0.98	8.0
	Suspected	8.20	1.41	8.0
	Definite	7.79	1.05	8.0

Note. SD = Standard Deviation
*Average of the three personnel involved in one incident

Table 7 presents the number of hours reported worked in the 24 hours prior to the incident. The number of hours reported having worked are all well within a normal working day (e.g., less than 9 hours).

Table 7. Hours Worked in 24 Hours Prior to Incident

Human error source	**Presence**	**Mean**	**SD**	**Median**
Individual				
	None	8.43	3.36	6.00
	Suspected	6.88	2.87	7.00
	Definite	6.42	3.95	6.00
Support				
	None	6.84	3.32	7.00
	Suspected	6.64	3.82	6.00
	Definite	6.50	4.30	7.00
Standards				
	None	6.47	3.73	6.00
	Suspected	7.47	2.99	7.00
	Definite	6.00	1.73	7.00
Training				
	None	6.63	3.74	6.00
	Suspected	6.96	3.29	7.00
	Definite	6.00*	0.00	6.00
Leader				
	None	7.30	3.44	7.00
	Suspected	6.22	3.42	6.00
	Definite	7.36	3.67	8.00

*Only one observation.

Table 8 reports the number of hours flown in the 24 hours prior to the incident. The only standout numbers present are reports of no hours flown prior to the incident. However, these are both from only a few individuals that were involved in the particular accident reported. Thus it is difficult to identify any potential trend within the data that may point to a possible causal role in the accident.

Table 8. Hours Flown in 24 Hours Prior to Incident.

Human error source	**Presence**	**Mean**	***SD***	**Median**
Individual				
	None	3.20	2.62	4.50
	Suspected	1.31	2.33	0.50
	Definite	1.41	1.91	1.00
Support				
	None	1.65	2.28	1.00
	Suspected	1.75	2.60	0.50
	Definite	0.67	0.50	1.00
Standards				
	None	1.72	2.43	1.00
	Suspected	1.43	1.83	1.00
	Definite	0.00*	0.00	0.00
Training				
	None	1.51	2.36	1.00
	Suspected	1.69	2.12	1.00
	Definite	0.00**	0.00	0.00
Leader				
	None	1.37	2.45	0.00
	Suspected	1.36	1.93	1.00
	Definite	2.64	2.37	2.50

*n=3
**n=2

Discussion

Of the 288 mishaps included in the analysis, the bulk (219) were deemed to be not due to human-factors errors. This is a relatively high number as a previous Air Force study (Tvaryanas & Thompson, 2008) has shown that human factors typically cause 50-60% of their UAS mishaps. This discrepancy is almost certainly due to the nature of the systems involved; Army systems in the main are smaller and less mature in their development cycle. The RQ-7B Shadow in particular showed a very high level of technical failure, especially in the power plant and control avionics. These issues are being addressed in the iterative process of system development and thus the human factors mishaps are likely to represent a higher proportion of the total as the systems mature in upcoming years.

Of particular interest to the authors were the following three areas of persistent failure involving the humans in this particular loop: poor situational awareness, basic fueling errors, and maintenance errors. These three areas of persistent failure stood out as they are all potentially relatively simple to fix. The situational awareness issue leading to planning flights at altitudes or positions where the UAS would either lose link or simply fly into a mountain might be solvable by either an automatic warning in the flight planning software or closer terrain study before flight. Refueling is a fundamental to powered flight and if either a human cross-check were conducted or again an automatic software warning were implemented then this simple error might be avoided. The system could probably be programmed to simply not take off with less than full fuel unless specific action were taken, fail safe rather than unsafe. Maintenance is a more complex issue with availability of technicians and supervision a real issue in deployed formations, this failure is likely one that could only be overcome with a combination of training and increased supervision/sign-off of maintenance tasks.

One other finding of interest was one that has plagued aviation for many years; that of taking off with the pitot cover still on the probe. This happened on four occasions in this mishap series and although only representing 1.4% of the mishaps, they are clearly preventable in all cases simply by someone following a checklist with a subsequent visual inspection. This lack of supervision/cross-checking was something of a theme in the human factors mishaps and may be a result of time-pressured units operating in theater (where most occurred) with low levels of manning and high workload. In this they would have much in common with deployed aviation units, and the only remediation in that circumstance is systematic examination of the whole UAS deployment process on operations. Indeed, the majority (approximately 93%) of the human-error accidents indicated individual error as being either a suspected or definite source of the accident cause. The definition used by the accident investigators in determining the contribution of the individual as an error source is "whether the individual knew and was trained on the standards, as well as whether the individual elected to not follow the standard." While the report narratives did not provide full detail regarding low levels of manning or high workloads experienced, the attribution to the individual that the investigators assigned suggests that some of these factors may have been at play. Further inquiry into UAS operations is needed to fully identify the problematic areas and remedial steps.

Conclusions and Recommendations

A number of conclusions can be drawn from the data presented in this study regarding both the continuing threats to unmanned aviation and the need for adjustments to the level of detailed information that should be included in the investigation of mishaps and the subsequent report.

Given that the main focus of the current study was to examine the human factors involved in reported the UAS accidents, the most apparent result from the study was the lack of human factors related information included within these accident reports. While information was mostly provided for the amount of hours worked, slept, and flown with the past 24 hours, further details that would assist in understanding the role of the human in the accident were frequently missing. More detailed information regarding the nature of the task the individual was involved in prior to the occurrence of the accident may assist in shedding some light on the role of the human in the accident that took place. Additionally, capturing more detailed scheduling information, such as what shift rotation (e.g., nights/days) the individuals were on leading up to the incident or if a change in shift rotation (e.g., shifted from nights to days or vice versa) occurred prior to the incident would assist in identifying possible operational stressors related to fatigue and shiftwork.

The main conclusion to be drawn regards the reporting of UAS mishaps. Unmanned aerial systems will become ubiquitous on the future battlefield. The current rate of incidents and accidents is high and if maintained will become a serious resource drain. There have been many previous instances where careful examination of mishap data has led to trend or fault identification and remedial action has been put in place. Unfortunately the data recorded for UAS mishaps including total loss is rather inconsistent, thus proper analysis is difficult. In particular, the examined accident reports do not include full detailed information, or include sparse information, on the UAS operators. Previous studies have noted boredom, inattention, and inability to maintain situational awareness as potential factors in UAS mishaps (Cummings, Mastracchio, Thornburg, & Mkrtchyan, 2013; Tvaryanas & Thompson, 2008), which coupled with long shifts and fatigue, could result in an increase in accidents. However, without adequate reporting of operator characteristics at the time of the accident, it is impossible to determine what additional factors may have been at play when the accident occurred.

Limitations and Future Studies

The findings in this report are limited given that certain elements from reports were extracted rather than examining the full investigation results. Additionally, this report is limited to the data that was available from database. Certain elements of accident report are not published onto the database system due to classification or security level of the information.

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