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**Human factors in helicopter accidents: results from the analysis performed
by the European Helicopter Safety Analysis Team within the IHST**

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Abstract

The European Helicopter Safety Team (EHEST) is the European branch of the International Helicopter Safety Team (IHST) and the rotorcraft component of the European Strategic Safety Initiative (ESSI). In 2008, the European Helicopter Safety Analysis Team (EHSAT) of the EHEST has analysed 186 helicopter accidents reported by the Accident Investigation Boards (AIBs) within timeframe 2000-2005 and State of occurrence located in Europe. EHSAT analyses are based on a standard method adapted by the Joint Helicopter Safety Analysis Team (JSAT), the analysis team of IHST, from the US Commercial Aviation Safety Team (CAST). The European team has included HFACS to enrich the analysis of human factors involved in the accidents. The paper presents this European helicopter safety initiative and focuses on human performance related analysis results. It concludes by presenting the benefits of using HFACS in addition to the Standard Problem Statements (SPS) analysis taxonomy by the JSAT.

EHEST: The European component of the International Helicopter Safety Team (IHST)

IHST was established after the first International Helicopter Safety Symposium (IHSS) held in Montreal in September 2005. IHST is a combined government and industry effort to reduce the helicopter accident rates (both civil accidents and noncombat military mishaps) by 80% within 10 years in the US and worldwide. See <http://www.ihst.org/>.

The IHST is led by representatives of the American Helicopter Society International, Helicopter Association International, the Federal Aviation Administration (FAA), Transport Canada, the European Aviation Safety Agency (EASA), and several industry partners. IHST has established regional teams in the US, Europe, Canada, India, Brazil, and Australia and is seeking to create new groups in the Middle East, Far East, Commonwealth of Independent States (CIS) and South Asia.

IHST has two types of working groups: the Joint Helicopter Safety Team (JHSAT) and the Joint Helicopter Safety Implementation Team (JHSIT). JHSAT reanalyses helicopter accidents and produces suggestions for safety improvement called intervention recommendations. The JHSIT revisits these intervention recommendations, produces safety enhancement action plans, and monitors action plan implementation and progress towards fixed objectives. Action plans may address both the regulators and the industry. The European Helicopter Safety Analysis Team (EHSAT) is the analysis team of the EHEST and the European JHSAT, and the European Helicopter Safety Implementation Team (EHSIT) is the implementation team of the EHEST and the European JHSIT.

EHEST: The helicopter component of the European Strategic Safety Initiative (ESSI)

EHEST brings together helicopter manufacturers, operators, regulators, helicopter and pilots associations, research organisations, accident investigators, general aviation and a few military operators from across Europe [Ref 1-6].

analysis is accomplished by a team analysing what happened and why (the chain of events), and what should be done differently (interventions) to prevent similar events in the future.

The analysis methodology features five steps:

1. Collect General Information

Several accident identification elements are collected for classification and analysis purposes such as occurrence date, state of occurrence, aircraft registration, helicopter make and model, operation type, aircraft damage, injury level, number of fatalities, phase of flight, meteorological conditions, and flight crew flight experience. EHSAT has introduced the ICAO ADREP 2000 taxonomy to collect this information, with the purpose of standardisation and of allowing exchange of information with the ECCAIRS¹ system.

2. Describe and Analyse the Accident

The analysis aims at identifying all factors that played a role in the accident. The underlying assumption is that accidents are the result of a chain of events that could have been prevented by altering or eliminating one or more of the “links” in the chain. Instead of focusing on an accident’s “primary cause”, the process focuses on identifying and removing one or more links in the accident causal chain, which can initiate hours, days or even weeks before the accident.

An event is defined as a decision, action or failure that contributed to or led to an occurrence. Events and conditions are presented in chronological order, and analysed one by one. The method requires analysing what happened and why. The teams can first use ‘free text’ to describe the accident. ‘What happened’ provides factual description, using or summarising statements from the accident report, whilst identification of ‘why’ certain things happened is based on the analysis provided in the accident report or on aspects identified by the analysis team based on expert judgement.

3. Assign standardised codes to the factors

The next step in the methodology is to translate the free text in step 2 into standardised codes. The use of standardised codes support accident aggregation and statistical analysis. EHSAT uses two models to assign codes: Standard Problem Statements and HFACS codes.

The **Standard Problem Statements** (SPS) taxonomy inherited from IHST/US JHSAT has over 400 codes in 14 different areas. The structure consists of three levels: the first level identifies the main area of the SPS, and the second and third levels go into more detail. Level 1 categories are: Ground duties; Safety Management; Maintenance; Infrastructure; Pilot Judgement and actions; Communications; Pilot situation awareness; Part/system failure; Mission Risk; Post-crash survival; Data issues; Ground personnel; Regulatory; and Aircraft Design. A single factor identified in the accident can be coded using more than one SPS. Figure 2 presents an example of the translation of the analysis into a three-level SPS code.

Analysis /Why/Contributing factors	SPS nr.	level 1	level 2	level 3
The commander inadvertently entered IMC and probably became spatially disoriented	701005	Pilot situation awareness	Visibility/Weather	Inadvertent entry into IMC

Figure 2 - Example of Standard Problem Statement

¹ ECCAIRS stands for European Coordination Centre for Accident and Incident Reporting Systems. The mission of ECCAIRS is to assist National and European transport entities in collecting, sharing and analysing their safety information in order to improve public transport safety. The ECCAIRS Reporting System is composed of various applications forming together a suite of products allowing organisations to create, maintain and deploy a repository of accident and incident reports. ECCAIRS is used by many national aviation authorities and accident investigation boards in Europe, but also worldwide.

Because of the ambitious goal setting of 80% reduction in accident rates, where it can be predicted that many of the identified factors will lie within the human factors domain, EHSAT decided to include a second model and taxonomy in the analysis phase to better address these human factors: **The Human Factors Analysis and Classification System (HFACS)**. HFACS was originally developed by from Reason’s concept of latent and active failures [Ref. 7]. The HFACS model describes human error at four levels: organisational influences, unsafe supervision, preconditions for unsafe acts and the unsafe acts of operators (e.g. flight crew, maintainers, air traffic controllers etc.). See Figure 3.

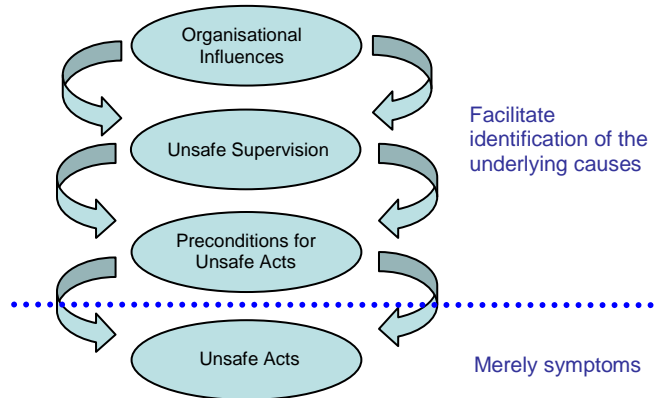


Figure 3 - HFACS model structure

The classification system contains over 170 codes in these four main areas. An example of HFACS coding in the EHSAT analysis is provided below in Figure 4.

Analysis /Why/Contributing factors	HFACS nr.	level 1	level 2	level 3
The commander inadvertently entered IMC and probably became spatially disoriented	5305100	Preconditions - Condition of Individuals	Perceptual Factors	Spatial Disorientation 3 Incapacitating
	5001040	Unsafe Acts - Errors	Skill-based Errors	Overcontrol/Under control
	5501030	Supervision	Inadequate Supervision	Local Training Issue / Programs
	5603020	Organizational Influences	Organizational Process	Program and Policy Risk Assessment

Figure 4 - Example of application of HFACS code

Additionally, a special HFACS Maintenance Extension (HFACS ME) was introduced to code maintenance related human factors. HFACS ME is the coding system for maintenance personnel and organisations developed by the US Naval Safety Center. The system features the following main categories (from local to remote): Maintainer Acts, Maintainer Conditions, Working Conditions, and Management Conditions.

4. Produce Intervention Recommendations

The next analysis step consists of identifying Intervention Recommendations (IRs) for all the factors identified in the previous steps. IRs are aimed at preventing factors, directly or more remotely involved, from reoccurring. One or several Intervention Recommendations (IRs) can be formulated for each SPS or HFACS. IRs are freely generated and formatted in free text, using the diverse expertise and supporting creativity in the analysis team. A special support table was created to invite the analysis teams to go through all flight phases and to target

various aspects within the IRs such as regulations, design and other technical factors (e.g., weight and balance), certification, operations; procedures, staffing, qualification, licensing and training, weather, winds, turbulence and other environment factors, working environment factors, workload, fatigue, attitudes, national, regional, company and professional culture and other human factors, production, commercial and market factors, management, Safety Management Systems (SMS) and safety culture, and accident investigation aspects. Finally, the IRs are categorised to allow consolidation of results. Figure 5 presents an example of an Intervention Recommendation.

Intervention recommendation (free text)	Intervention recommendation (coded on Category level)
All periodic base check flying tests carried out by the Operator should include the pilot's capability to fly by sole reference to flight instruments.	Training/Instructional
Regulations should address the hazards of flight in a Degraded Visual Environment (DVE).	Regulatory

Figure 5 - Example of Intervention Recommendations

5. Score Standard Problem Statements and Intervention Recommendations

To assist the implementation team, and ultimately the industry and authorities, to determine the best course of action, all the coded factors in step 3 are scored on Validity and Importance and the IRs identified in step 4 on Ability and Usage. Validity is dependent on the level, quality and credibility of data and information available in the event report: factors associated with hypothetical events not supported by documented evidence in the accident reports are scored low on validity. Importance is the measure of the identified factor importance in the event's chain of causal factors. Ability is the measure of how well an IR can mitigate an event's problem or contributing factor, assuming it performed exactly as intended. Usage is the measure of how confident we are that this intervention will be utilised and will perform as expected given this particular accident scenario.

6. Handover to the EHSIT

Accident analyses provided by the regional teams are aggregated at European level. Then, analysis results and IRs are passed on to the implementation team, the EHSIT. Economic and other considerations are introduced in the EHSIT process to decide on best course of action and develop suitable safety enhancement action plans (these fall outside the scope of this paper).

Preliminary EHSAT results

Preliminary results concern accidents occurring in 2000–2005 in EASA Member States where a final report from an AIB was available. Only the accidents analysed up to 30 Sep 08 are addressed in this paper. Results encompass accidents from the 9 regional teams. A total of 186 accidents form the dataset. It is estimated that this number covers some 58% of the accident reports available and some 25% of the estimated total number of helicopter accidents within this timeframe.

The analysis teams were asked to identify, using both SPS and HFACS taxonomies, as many factors in an accident as they felt were justified.

Using the JSAT Standard Problem Statements (SPS)

For the 186 accidents in the dataset, a total of 1067 Standard Problem Statement counts were identified. The area that was identified in most accidents in the dataset is Pilot Judgment & Actions. This includes factors related to pilot decision making, unsafe flight profile, procedure implementation, Crew Resource Management and human factors such as diverted attention, perceptual judgment errors and aero medical factors. The second most identified area is Safety Culture & Management. This includes Safety Management Systems, training, pilot disregard of known safety risk, self-induced pressure and pilot experience. The third area

is Pilot Situation Awareness. This covers in-flight factors such as reduced visibility and external obstacle or hazard awareness. See Figure 6.

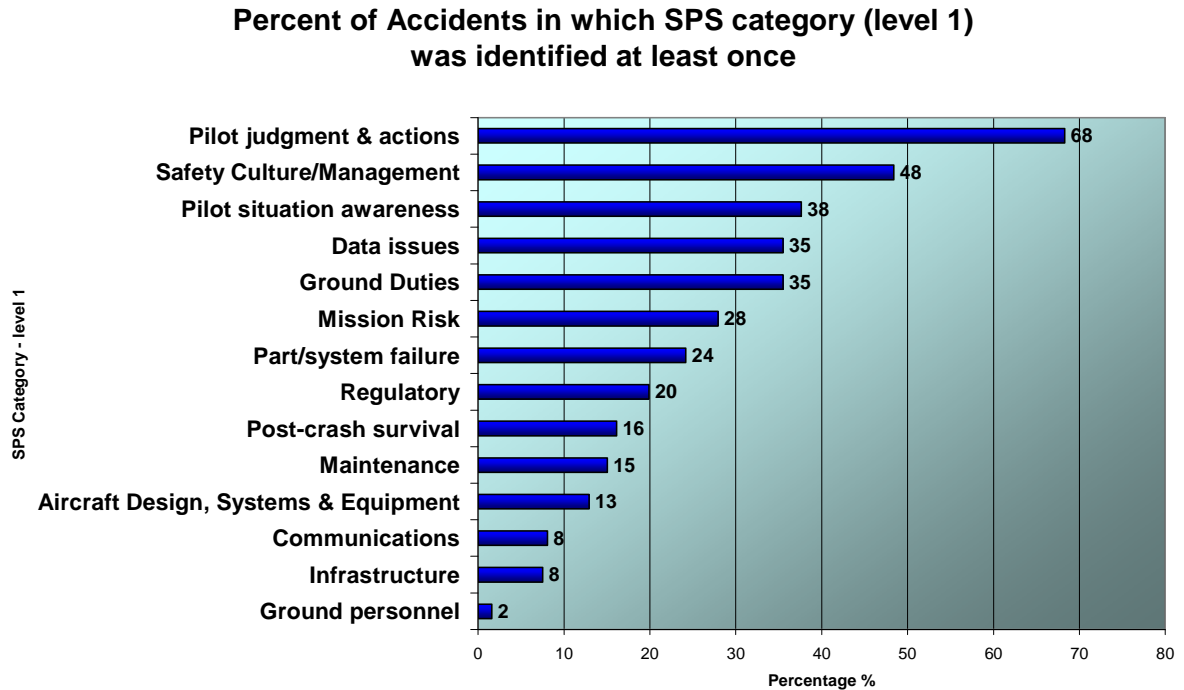


Figure 6 - Standard Problem Statement results on highest level in percentage of accidents in dataset

The area Data Issues is a specific area to code factors related to the lack of availability of information in the accident report. It was found by the teams that in 35% of the analysed accident reports there was insufficient information available to fully analyse and understand the accident. One of the reasons for insufficient information being available is the absence of FDR capability in many helicopters². In addition, some accidents were not investigated in detail. Since this is a special area not dealing with actual issues in the accident event sequence, this area will be left out of the results that follow.

The area Ground Duties, identified in 35% of the accidents, includes factors such as mission planning and aircraft pre and post flight duties. The US JHSAT completed a first analysis report in September 2007. A total of 197 accidents from the year 2000 were analysed. When comparing the European data with the US results on a high level (SPS level 1), it was calculated that the correlation of the results was high (0.89), see Figure 7. The top five of the level 1 areas are similar for both the US and the EHSAT analysis, but the order differs slightly. Similarities and differences will be investigated at a later stage.

Level 1 Standard Problem Statements only provide information on a general level. To better understand what kind of factors played a role in the accident data set one must look at a deeper level in the taxonomy. Looking at the level 2 Standard Problem Statements, it becomes clearer that the main factors identified involve issues in the human factors domain. Pilot's decision making, mission planning and external environment awareness are the three most identified factors, identified in respectively 31, 29 and 25 % of the accidents in the data set. See Figure 8.

² It is worth noticing that EASA has launched a research project on this subject in 2008.

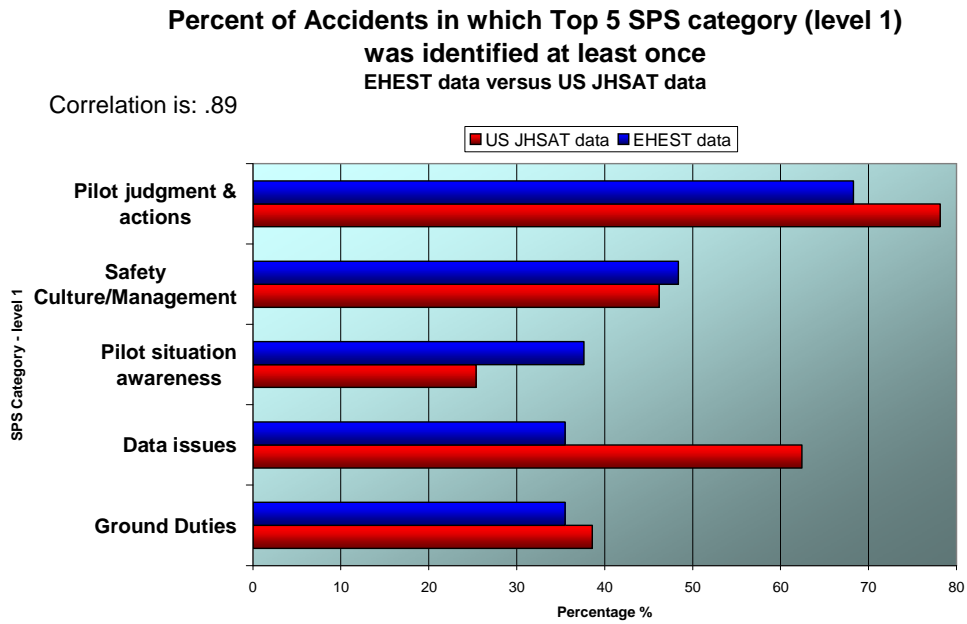


Figure 7 - EHSAT results on 1st level SPS in percentage of accidents compared with US JHSAT results

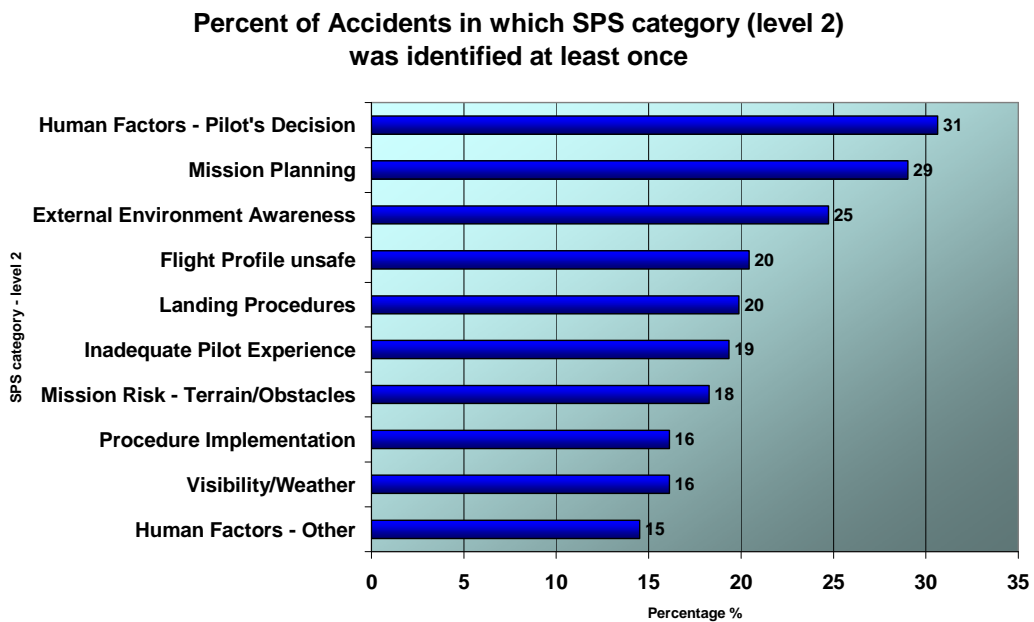


Figure 8 - Top 10 Standard Problem Statement results on 2nd level SPS in percentage of accidents

Because most of the identified factors lie within the human factors domain, EHSAT adopted a second model and taxonomy for factor identification: HFACS. Results are presented below.

Using HFACS

For the 186 accidents in the data set a total of 445 HFACS factor counts were identified. In 76% of the accidents, at least one HFACS factor was identified. In most accidents unsafe acts or preconditions for unsafe acts were identified, see Figure 9. In fewer accidents issues related to supervision or organisational influences were captured. *The possibility of identifying those factors is however very much depending on the depth of the accident investigation performed:* if the accident investigator did not look into managerial or organisational aspects related to the accident, the EHSAT analysis team couldn't assign factors in those areas.

Unsafe Acts

For the lowest level in the model, the unsafe acts, 84% of the identified factors concerned errors: activities that failed to achieve their intended outcome. Most errors were identified as being judgment & decision making errors, such as poorly executed procedures, improper choices, or misinterpretation of information. These errors represent conscious and goal-intended behaviour. Skill-based errors on the other hand are errors that occur with little or no conscious thought, such as inadvertent operation of switches and forgotten items in a checklist. These errors were identified in 28% of the errors. Finally, perceptual errors are related to a degraded sensory input.

Violations, wilful disregard of rules and regulations, were identified in 16% of the unsafe acts.

Preconditions for Unsafe Acts

Only focussing on unsafe acts, however, is "like focussing on a patient's symptoms without understanding the underlying disease state that caused it." [Ref.2]. Therefore, one must look deeper into preconditions to identify why the unsafe acts took place. 60% of the identified preconditions related to the condition of the individual. These conditions include overconfidence, channelised attention, 'press-on-it-is', inattention, distraction, misperception of operational condition, and excessive motivation. Personnel factors mostly concerned mission planning. Also cross-monitoring performance and mission briefing were mentioned. For the Environmental factors, restricted vision by meteorological conditions, brownout/whiteout and windblast were identified.

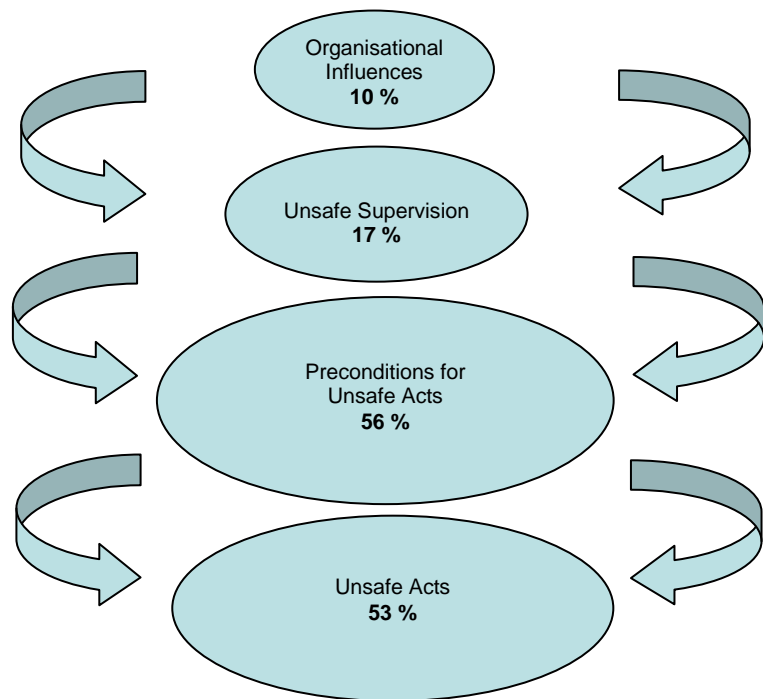


Figure 9 - Percentage of Accidents where HFACS level was identified at least once

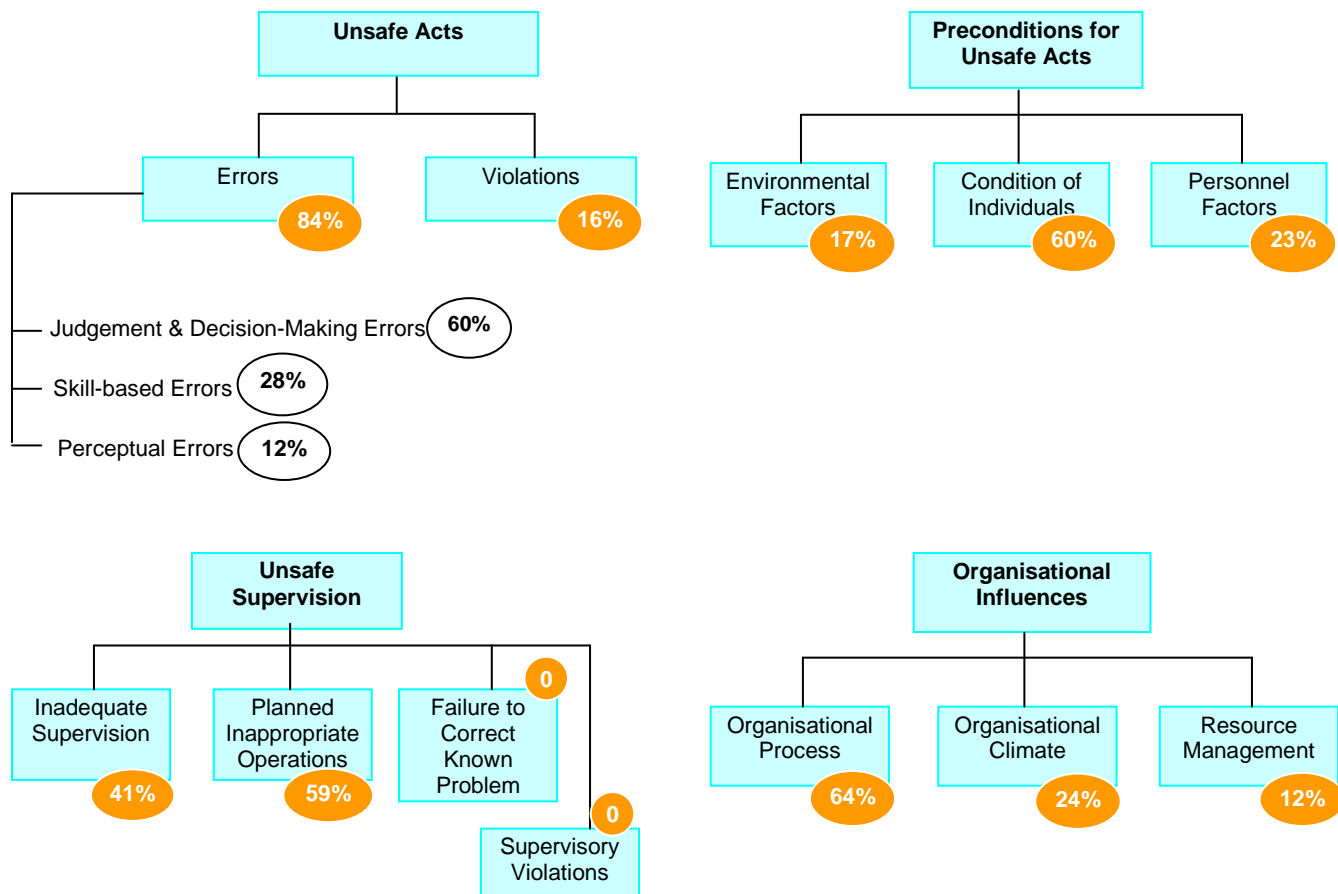


Figure 10 - HFACS results

Unsafe Supervision

In 17% of the accidents, latent failures on middle management level were identified. Under Planned Inappropriate Operations the factors limited total and recent experience and formal risk assessment, in case a supervisor does not adequately evaluate mission risks or risk assessment programs are inadequate, were identified. In addition, cases were identified under Inadequate Supervision relating to inadequate leadership/supervision or oversight and lack of policy or guidance.

Organisational Influences

In 10% of the accidents latent failures on the higher management level or organisational level were identified. Items identified under Organisational Process included issues related to procedural guidelines and publications, and doctrine. Under Organisational Climate organisational values/culture and organisational structure were identified.

Analysis per Type of Operation

The results presented so far were consolidated for all types of operations. Especially on a detailed level it is interesting to see if differences can be observed for the different types of operation. Table 1 to 3 present example results of the top issues identified for Commercial Air Transport, Aerial Work and General Aviation operations. The issues are presented on the lowest level of the used taxonomies.

The data in the table provides the reader an understanding of a 'typical' accident scenario for the different types of operation. Some differences and similarities between the three can be observed. These will be investigated in more detail at a later stage.

Top issues – Commercial Air Transport	
Top issues Standard Problem Statements	Top issues HFACS
Pilot decision making	Brownout/whiteout
Pilot-in-Command self induced pressure	Decision-making during operation
Pilot's flight profile unsafe for conditions	Communication critical information
Reduced visibility – whiteout, brownout	Pressing
Pilot inexperienced with area and/or mission	Risk assessment – during operation
Pilot experience leads to inadequate planning regarding weather/wind	Procedural error
Selection of inappropriate landing site	Excessive motivation to succeed
Management disregard of known safety risk	Mission planning
Inadequate consideration of aircraft operational limits	Inattention
Failure to enforce company SOPs	Limited recent experience
	Procedural guidelines/publications

*Table 1 - Top issues for Helicopter Commercial Air Transport operations
(Excluding factors related to Data Issues)*

Top issues – Aerial Work	
Top issues Standard Problem Statements	Top issues HFACS
Mission involves flying near hazards, obstacles, wires	Risk assessment - during operation
Pilot decision making	Channelised attention
Mission requires low/slow flight	Mission planning
Low flight near wires	Decision-making during operation
Inadequate consideration of obstacles	Error due to misperception
Diverted attention, distraction	Inattention
Risk management inadequate	Misperception of Operational Condition
Inadequate response to loss of tail rotor effectiveness	Excessive motivation to succeed
Inadequate training on avoidance, recognition and recovery of vortex ting state or LTE	Fatigue – Physiological/Mental
	Windblast
	Overconfidence
	Limited total experience

*Table 2 - Top issues for Helicopter Aerial Work operations
(Excluding factors related to Data Issues)*

Top issues – General Aviation	
Top issues Standard Problem Statements	Top issues HFACS
Pilot decision making	Risk assessment - during operation
Mission planning –other	Overconfidence
Inadequate consideration of weather/wind	Vision restricted by meteorological conditions
Pilot inexperienced	Procedural error
Pilot control/handling deficiencies	Mission planning
Pilot misjudged own limitations/capabilities	Decision-making during operation
External environment awareness – Other	Overcontrol/Undercontrol
Disregard of known safety risk	Violation – Lack of discipline

Failed to recognise cues to terminate current course of action or manoeuvre	Inadvertent Operation Error due to misperception Channelised attention Get-Home-Itis/Get-There-Itis Misperception of operational condition
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*Table 3 - Top issues for Helicopter General Aviation operations
(Excluding factors related to Data Issues)*

HFACS and SPS complement each other well: SPS codes are technically more adapted to helicopter operations while HFACS adds a valuable, theory-driven HF analysis system. As shown in Tables 1-3, the real benefit comes from *jointly* considering SPS and HFACS results in a single shell. When used in combination, HFACS and SPS provide a basis for richer analyses and recommendations.

The distribution of HFACS results per layer can be compared to other studies using the same taxonomy. When reviewing HFACS studies on Commercial Air Transport and General Aviation operations [Ref. 8-10] the preliminary EHSAT results show some differences with respect to a relatively lower frequency of skill based errors as part of the unsafe acts and relatively lower frequency of environmental conditions within the preconditions.

These differences can be partly due to a reporting bias. Human Factors can only be addressed as far as they were reported in the accident investigation report. This concerns especially the managerial and organisational issues. It is therefore suggested to the AIBs to report in the investigation reports these factors remote in time and space from the accident scene. Recommendations targeting the remote layers can help to prevent reoccurrence not only of the accident investigated but also of a whole set of potential accidents in which such factors can play a role.

Benefits of using HFACS

Why did EHSAT decide to use HFACS in the first place and what are the benefits?

Human Factors must be addressed in order to meet the IHST objective of achieving an 80% reduction in helicopter accident rates by 2016. HFACS address HF in a more detailed and structured manner. The system is well documented and has been used with success in other studies. It is based on a well known theoretical framework [Ref. 7-10]³, and the analysis instructions are clear and easy to apply.

HFACS invites us to think in depth about the psychological status of the crew, such as overconfidence. It leads to a better understanding of the events chain by helping to fill the gaps in the accident report. Also, there is no SPS code for pilot disorientation. This is regularly quoted as a proven or probable cause of numerous helicopter accidents and is available in well defined codes within HFACS.

HFACS encourages not only the identification of human errors at operational level but also the investigation of underlying management and organisational factors. HFACS also distinguishes between errors and violations, i.e. between unintentional and willful deviations. The prevention and management of errors and violations require different interventions.

The SPS list contains no codes appropriate to HF issues related to maintenance policy, planning, supervision or the conduct of maintenance. The HFACS codes allow much more detailed analysis of maintenance HF issues.

HFACS allows for the formulation of detailed and accurate recommendations in areas such as training and safety culture because it invites us to go deeper in the analysis.

³ See also <http://www.hfacs.com/>.

Using HFACS also helps pointing out key aspects regarding man-machine interaction useful for future technical developments and procedural improvements. The SPS taxonomy contains only 8 codes which can be used to identify piloting and aircraft interface issues. The EHSAT analysis has proved that this list is inadequate to identify all appropriate causal factors involving HF in helicopter accidents. The HFACS codes, while not perfect, allow much more detailed analysis of pilot-aircraft interaction issues. Benefits are expected for human engineering aspects such as crew systems design, pilot-aircraft interface, maintainer interfaces and accessibility, and ground support, and also for training and operations improvements.

Acknowledgements

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Acronyms

ADREP – the ICAO Accident / Incident Data Reporting System
CAST - Commercial Aviation Safety Team (U.S.)
EASA - European Aviation Safety Agency
ECCAIRS - European Coordination Centre for Accident and Incident Reporting Systems
EGAST - European General Aviation Safety Team
EHEST - European Helicopter Safety Team
EHSAT - European Helicopter Safety Analysis Team (part of EHEST)
EHSIT - European Helicopter Safety Implementation Team (part of EHEST)
ESSI - European Strategic Safety Initiative
HFACS - Human Factors Analysis and Classification System
ICAO - International Civil Aviation Organisation
IHST - International Helicopter Safety Team
IR - Intervention Recommendation (IHST methodology)
JHSAT - Joint Helicopter Safety Analysis Team (IHST)
JHSIT - Joint Helicopter Safety Implementation Team (IHST)
SMS - Safety Management System
SPS - Standard Problem Statement (IHST methodology)