Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Executive summary

Helicopter safety: everybody's concern

Problem area
The long-term helicopter accident rates on a worldwide basis have remained unacceptably high and trends have not shown significant improvement during the last 20 years. In late 2005, the International Helicopter Safety Team (IHST) was launched as a government and industry cooperative effort with the goal to reduce the worldwide civil helicopter accident rates by 80% in the year 2016. According to an extensive IHST analysis, groups most likely to have helicopter accidents are general aviation pilots, trainees and small operators. Their accident rate is higher than the rate for more prominent mission types such as emergency medical services, law enforcement and tour operators.

Description of work
The basic principle adopted by IHST is to improve helicopter safety by complementing regulatory actions by voluntarily encouraging and committing to cost-effective safety enhancements. The process is directly linked to the analysis results of real accident data, which results are used as a basis to develop safety-enhancing material addressing the highest rating safety issues. In Europe, the European Helicopter Safety Team (EHEST) has adopted the IHST objective.

Results and conclusions
Helicopter safety cannot be improved by developing tools and disseminating information alone. In the end, it will be up to the various individuals and organisations to apply those solutions for the benefit of the helicopter community.

Applicability
The article has been published to spread the word to the helicopter community.

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The long-term helicopter accident rates on a worldwide basis have remained unacceptably high and trends have not shown significant improvement during the last 20 years. In late 2005, the International Helicopter Safety Team (IHST) was launched as a government and industry cooperative effort with the goal to reduce the worldwide civil helicopter accident rates by 80% in the year 2016 (1). According to an extensive IHST analysis, groups most likely to have helicopter accidents are general aviation pilots, trainees and small operators. Their accident rate is higher than the rate for more prominent mission types such as emergency medical services, law enforcement and tour operators.

The basic principle adopted by IHST is to improve helicopter safety by complementing regulatory actions by voluntarily encouraging and committing to cost-effective safety enhancements. The process is directly linked to the analysis results of real accident data, which results are used as a basis to develop safety-enhancing material addressing the highest rating safety issues. In Europe, the European Helicopter Safety Team (EHEST) has adopted the IHST objective.

EHEST: a safety improvement partnership

The European Helicopter Safety Team took off in 2006 as the helicopter component of the European Strategic Safety Initiative, ESSI (2), and as the European branch of

Fig. 1: "Dangerous operations": The long-term helicopter accident rates on a worldwide basis have remained unacceptably high and trends have not shown significant improvement (Photograph: S. Burigana/ Elilombarda)

the International Helicopter Safety Team, IHST. EHEST is committed to the IHST objective with emphasis on improving European safety.

EHEST brings together European helicopter manufacturers, operators, authorities, helicopter and pilots associations, research institutes, universities, accident investigation boards and some military operators (totalling around 130 participants from 50 organisations). EHEST addresses the broad spectrum of European helicopter operations, from Commercial Air Transport to General Aviation, and also includes flight training activities.

EHEST itself is the strategic and decision-making body and within its structure, two main working groups have been created to deal with different steps in the process:

- The European Helicopter Safety Analysis Team (EHSAT) analyses helicopter accident investigation reports and identifies suggestions for safety enhancements, called Intervention Recommendations (IRs); EHSAT will also be involved in the measuring of results and effectiveness of safety improvements developed within the initiative;
- The European Helicopter Safety Implementation Team (EHSIT) uses the results from the EHSAT accident analyses and their IRs to develop safety enhancement strategies and action plans.

Communication is also an important part of the safety initiative, as this can raise awareness and can contribute to improve safety by making available and sharing good practices. The EHEST-wide Communication Working Group has defined a process to efficiently communicate with the helicopter community, especially General Aviation and small operators. The Group addresses the global helicopter community through publications in professional journals and linking to international forums such as the Forum of the American Helicopter Society (AHS) and the European Rotorcraft Forum (ERF).

EHSAT: analysing helicopter accidents

The EHSAT accident analysis aims at identifying all factors, causal or contributory, that played a role in the accident. In order to tackle the variety of languages in the accident reports and account for regional characteristics, regional teams have been formed in various countries like France, Germany, United Kingdom, Italy, Spain, Switzerland, Norway, Sweden, Finland, Ireland, Hungary and the Netherlands. The countries covered by the regional teams account for more than 90% of the helicopters registered in Europe. In order not to interfere with ongoing accident investigations and to ensure the data analysed are to the same ICAO Annex 13 standard, only those accidents where a final investigation report is available, are analysed.

The first step is the collection of factual information on the accident, such as occurrence date, state of occurrence, helicopter registration, helicopter make and model, type of operation, phase of flight, meteorological conditions, the flight crew's flight experience as well as damage and injury level. Next, the team identifies all the factors that played a role in the accident, using standardised taxonomies to ease accident aggregation and statistical analysis. Two complementary taxonomies are used, the Standard Problem Statements (SPS) and Human Factors Analysis and Classification System (HFACS) by Wiegmann and Shappell (3).

Fig. 2: The EHEST-wide Communication Working Group has defined a process to efficiently communicate with the helicopter community, especially General Aviation and small operators (Photograph: J.P. Brasseler/ Eurocopter)

Standard Problem Statement

The Standard Problem Statements (SPS) taxonomy has over 400 codes in a three-level structure. The first level features the following 14 categories:

- 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

The second and third levels go into more detail. A single causal factor identified in the accident can be coded using multiple SPSs. E.g. when one of the causal factors was a pilot lacking proficiency for a certain type of operation, this can be coded as "inadequate pilot experience" and additionally as "inadequate supervision"; and maybe even as "customer/company pressure", depending on the narrative in the accident report.

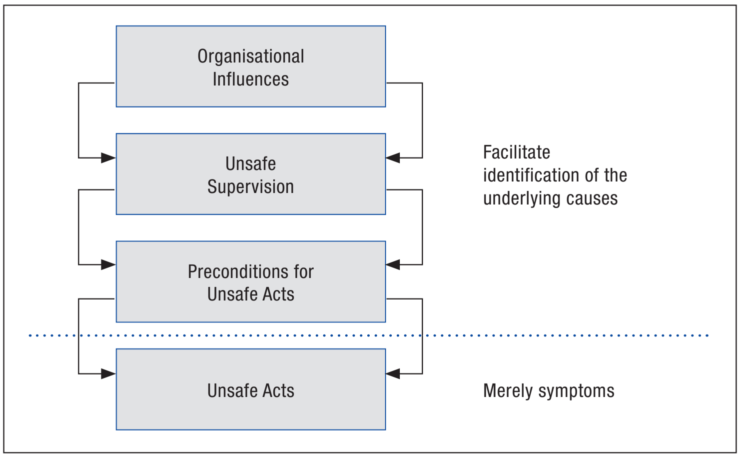


Fig. 3: HFACS Model Structure (5)

Human Factors Analysis and Classification System

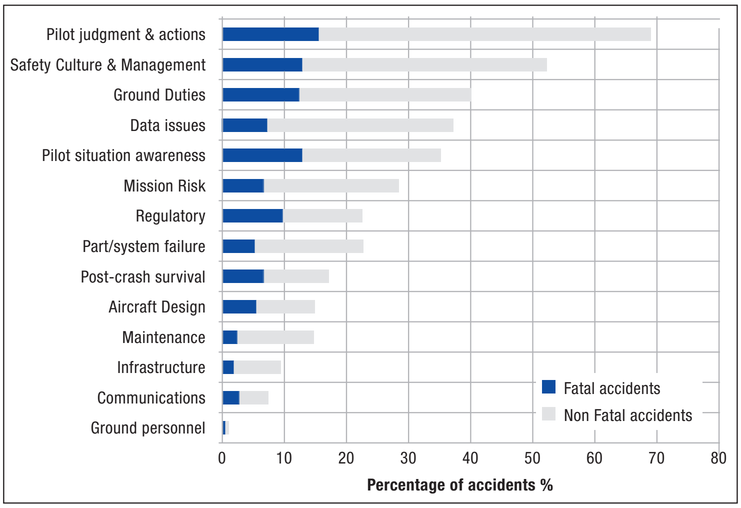
In order to address human factors in a structured manner, EHSAT also uses the Human Factors Analysis and Classification System (HFACS). HFACS allows describing and analysing human errors in four levels (Fig. 3):

1. Organisational Influences
2. Unsafe Supervision
3. Preconditions for unsafe Acts and
4. Unsafe Acts of Operators (e.g. flight crew, maintainers, air traffic controllers etc.)

Only focusing on unsafe acts (the "lower" levels) would be like focusing on merely symptoms without looking at the disease that caused them (the "higher" levels). HFACS divides each level into a series of causal factors. HFACS contains over 170 codes in the four main areas. In addition to providing more detail on human factors, it also encourages the analysis to not only identify the human error at an operator level, but also to search for underlying management and organisational factors.

For maintenance related human factors, the HFACS Maintenance Extension (HFACS ME) was introduced. Developed by the US Naval Safety Center, this is an additional coding system adapted for maintenance. The system features the following main categories: Maintainer acts, Maintainer conditions, Working conditions, and Management conditions.

Fig. 4: Standard Problem Statement (SPS) Analysis Results: Percentage of accidents where SPS has been identified at least once in the accident dataset 2000-2005, based on Van Hijum M et al. (2010)



Accident Analysis Result

Analysis results for the timeframe 2000-2005 were published in October 2010 in the Final Report – "EHEST Analysis of 2000-2005 European Helicopter Accidents" (4), available on the EHEST website. Results are based on the analysis of 311 European helicopter accidents. The scope of the data set is accidents that occurred within an EASA Members State where a final investigation report from the Accident Investigation Board (AIB) had been issued. Of the accidents analysed, 140 accidents (45%) involve General Aviation operations; 103 accidents (33%) involve Aerial Work operations; 59 (19%) were Commercial Air Transport operations; and 9 (3%) involved State Flights. Most accidents analysed by the EHSAT occurred during the en-route phase of flight.

For the accidents in the dataset more than 1,800 Standard Problem Statements have been recorded, with the top three SPS categories at level 1 being (Fig. 4):

- "Pilot judgement and actions", identified in almost 70% of the accidents; this includes issues like pilot decision making, unsafe flight profile, and procedure implementation;
- "Safety culture and management" identified in more than 50% of the accidents; with issues like Safety Management System, training and pilot experience;
- "Ground duties", identified in 40% of the accidents, including mission planning and helicopter pre- and post- flight duties.

The lower SPS levels provided insight into why "pilot judgement and actions" figures were the highest amongst the top three accident factors. E.g. when a helicopter is being used for aerial work, this can result in pushing the helicopter and pilot towards the limits of their capabilities, and operating close to terrain or obstacles. Therefore, aerial work is highly prone to accidents related to the mentioned category. The use of the HFACS taxonomy provided a complementary perspective on human factors. In most accidents, unsafe acts or preconditions of unsafe acts were identified. In fewer accidents supervisory or organisational influences were found. For the SPS as well as for the HFACS taxonomies, different patterns were observed for various types of operation (see Table 1). These patterns provide an understanding of a 'typical' accident scenario.

The accident analysis teams were also tasked to develop suggestions for safety enhancements, the so-called Intervention Recommendations (IRs), for all identified safety issues. Most recommendations fall into the following categories:

- Flight Operations and Safety Management/Culture
- Training/Instructional and
- Regulatory/Standards/Guidelines

EHSIT: developing safety-enhancing products
The EHSIT defined a process to aggregate, consolidate, and prioritise the intervention recommendations produced by the EHSAT and to develop suitable and effective safety enhancement action plans. To address the top IR-categories identified by the EHSAT, the EHSIT has launched Specialist Teams (STs) focussing on specific topics:

- ST Operations and SMS, focussing on risk management, Safety Management System (SMS) and Standard Operating Procedures (SOPs);
- ST Training, developing safety leaflets and videos;
- ST Regulation, identifying potential areas for rulemaking;
- ST Maintenance, developing a maintenance toolkit (in co-operation with IHST);
- ST Technology, developing a tool linking the results of the EHSAT analysis to technological developments.

All safety products developed by the teams are selected because of their potential to resolve the identified top safety issues, thereby also taking into account economic and other considerations. The following products have been developed or are under development, all of which are published on the EHEST website.

Standard Operating Procedures
Standard Operating Procedures (SOPs) are being prepared for Helicopter Emergency Medical Service (HEMS) operations. Several more SOPs are being considered.

Safety Leaflets
Four training leaflets have been published, regarding

- Safety Considerations (addressing important subjects such as Vortex Ring State, Loss of Tail-Rotor Effectiveness, dynamic and static rollover and loss of visual references)
- Helicopter Airmanship
- Off Airfield Landing Site Operations and
- (Single Pilot) Decision Making

Other leaflets regarding Risk Assessment in Training and Autorotation, Weather Anticipation and Passenger Management are under development.

Videos
Videos on Flying in the Degraded Visual Environment (DVE) and on Helicopter Passengers Management have been published. A video on Helicopter Mission Preparation Including Off-Airfield Landing is under development.

Guides
Development of a Helicopter Flight Instructor Guide that addresses Threat and Error Management is planned for 2013.

Tools and toolkits
A Helicopter Maintenance Toolkit has been published. This toolkit enables operators to assess their existing maintenance activities against guidelines for maintenance procedures, quality assurance, training and competence assurance, record keeping, HUMS, maintenance support equipment and fuel systems. The toolkit shows best practices used by many operators throughout the world.

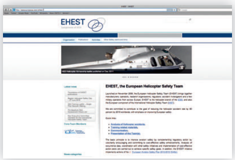
A Pre-flight Risk Assessment Tool has recently been published, and the same team also published a Safety Management Manual (SMM) and toolkit. The manual was developed to comply with the Annex III to the future EU regulation on Air Operations, to be published end of 2012. It aims at assisting 'complex operators' (a regulatory concept defined in the AMC) with little experience of running an SMS.

Technology matrix
The ST Technology has been created to assess the potential of technologies to mitigate safety issues. Technology is not high on the list of highest-ranking SPSs, as it is merely the lack of technology that may have led to an

Type of operation	Top issues SPS	Top issues HFACS
Commercial Air Transport	- Pilot decision making - Pilot in command, self-induced pressure - Inadequate oversight by the Authority	- Inattention - Decision-making during operation - Channelized attention
Aerial Work	- Mission involving flying near hazards, obstacles, wires - Mission requires low/slow flight - Pilot decision making	- Risk assessment during operation - Mission planning - Channelized attention
General Aviation	- Pilot decision making - Mission planning - Pilot misjudged own limitations/capabilities	- Risk assessment during operation - Overconfidence - Mission planning

Table 1: Top safety issues (at the lowest taxonomy level) per type of operation

Fig. 5: Various training (safety) leaflets published by EHEST



For more information, visit:
››› **http://easa.europa.eu/essi/ehest/**

accident. Technology however provides a variety of solutions that can (directly or indirectly) address the identified safety issues and that can contribute to prevent different types of accidents or to increase survivability. Technology can be a powerful means to improve safety, as it can bring solutions to known safety problems, including those of operational nature.

Rotorcraft technological developments have not been as fast as, for instance, fixed wing jet fighter developments. Current technologies are focussing on 3rd generation rotorcraft versus 5th generation fighter aircraft. Technologies that may have been in use on fixed wing aircraft for many years, are transferred to rotorcraft at a (much) later date. And only few technologies have been developed specifically for rotorcraft. Fig. 6 shows a miniature Voice/Flight Data Recorder (standard “Coke” can size).

The ST Technology consists of a range of stakeholders, with various expertise and backgrounds. The main goal of the team is to list technologies and link them with incident/accident causes and contributing factors. The team developed a tool that contains a listing of technological developments (technology database) and a technology-safety matrix providing rows with technologies and columns with the top 20 (level 2) SPS items as revealed by the EHSAT analysis of more than 300 accidents.

The process consists of two steps:

- The technology database is filled with relevant technologies for the period 2006 till present; the basic selection criteria for the technologies are: new (emerging) technologies, existing technologies not yet used on helicopters and existing technologies used on large helicopters, but not yet on small helicopters;
- The listed technologies are scored against each of the SPS items; this process involves two rating elements, the results of which are automatically summed and colour-coded: impact (how well can the technology mitigate the specific SPS) and usability (can the technology be utilised for a specific SPS and against what relative cost), each on a scale from 0 to 5.

The results can be used in three ways:

- Which technology best addresses a specific safety problem. By scanning the coloured cells, one can

Fig. 7: The EHSIT aggregates, consolidates, and prioritises the EHSAT suggestions for safety enhancements and defines safety strategies and action plans (Photograph: A. Pecchi/ Eurocopter)

easily identify those technologies that are rated highest, that are the specific technologies with the highest potential in mitigating certain safety issues. These technologies can then be promoted to make them more widely available.
- Where can (additional) safety benefits be expected from a technology. New technologies are predominantly aimed at a specific goal. By rating this technology against the top SPS items, it can become clear that the technology also can be used to mitigate other safety issues. For instance, a certain sensor that aims at mitigating visibility/weather-related problems may turn out also to be useful to mitigate unsafe flight profiles or to aid landing procedures.
- Which safety problems are not (sufficiently) addressed by technology. Safety issues lacking (sufficiently promising) technological mitigation means, stand out as a result of the colours used. Manufacturers, research organisations and alike can address these specific safety issues, thereby creating new incentives and justification to perform research and to develop technologies.

Fig. 6: Miniature Voice/Flight Data Recorder (Photograph: Cassidian)

Based on the limited number of technologies that have been listed and scored so far, a few promising technologies stand out already:

- Predictive ground collision avoidance using digital terrain referenced navigation, bringing improved situational awareness to the pilot and reducing the workload;
- Flight data monitoring for light helicopters (Helicopter Operations Monitoring Program, HOMP); during flight, predefined events are recorded, thereby helping to set priorities on training and maximising awareness of potential dangers;
- Synthetic vision system (vision augmentation); the system will bring improved situational awareness to the pilot through a 3D-terrain with obstacles rendering on a head-up or helmet-mounted display.

Concluding Remarks

The European Helicopter Safety Team (EHEST) started its work in 2006 as the helicopter component of the European Strategic Safety Initiative (ESSI) and the European branch of the International Helicopter Safety Team (IHST). The team is committed to the IHST objective to reduce the helicopter accident rate by 80 percent by 2016 worldwide, with emphasis on improving European safety. Within EHEST, the European Helicopter Safety Analysis Team (EHSAT) analyses accident investigation reports. The analysis aims at identifying all factors, causal or contributory, that played a role in the accident, and identifying suggestions for safety enhancements. The European Helicopter Safety Implementation Team (EHSIT) aggregates, consolidates, and prioritises the EHSAT suggestions for safety enhancements and defines safety strategies and action plans. For this, the EHSIT has launched Specialist Teams that develop various safety products. All products are selected because of their potential to resolve the identified top safety issues and are published on the EHEST website.

Helicopter safety cannot be improved by developing tools and disseminating information alone. In the end, it will be up to the various individuals and organisations to apply those solutions for the benefit of the helicopter community.

NLR

The National Aerospace Laboratory (NLR) is the main knowledge enterprise for aerospace technology in the Netherlands. NLR carries out commissions for government and corporations, both nationally and internationally, and for civil and military aviation. The overarching objective is to render aviation safer and more sustainable and efficient. In this way, NLR has been making essential contributions to the competitive and innovative capacities of Dutch government and industry for more than 90 years.

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