European Aviation Safety Agency

Study on single-engined helicopter operations over a hostile environment

Data Analysis and Member States Assessment

ALG TRANSPORTATION INFRASTRUCTURE & LOGISTICS

in consortium with

SGI AVIATION

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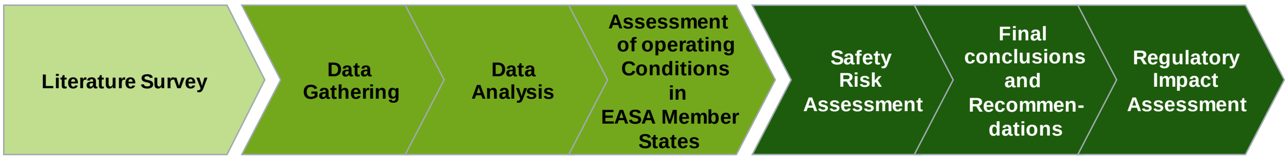
1 Introduction

The study on the single-engined helicopter operations over a hostile environment consists of the tasks included in the following scheme:



The first task of the study, the **Literature Survey**, was performed and the resulting report was approved by EASA. This task encompassed a survey and appraisal of the relevant, currently available publications pertinent to the scope of this study including reference documents, reports, general publications and databases on helicopter operations, as well as on helicopter operators, their fleets and aircraft usage and the associated accident and incident databases necessary for the subsequent tasks of the study.

The Literature Survey identified the official and unofficial databases from a multiplicity of sources necessary for the data gathering and analysis.

The second task of the study, the **Data Gathering**, was then conducted. The aim of the data gathering was to collect and collate extensive data about the usage of single-engined helicopters in all types of operations over hostile and non-hostile environments in EASA Member States from the different sources of information identified during the literature survey.

Our approach to the Data Gathering was to establish three “multisource” databases to be able to collect and collate the expected data. The three databases, their sources and the data obtained from them are depicted in the figure below.

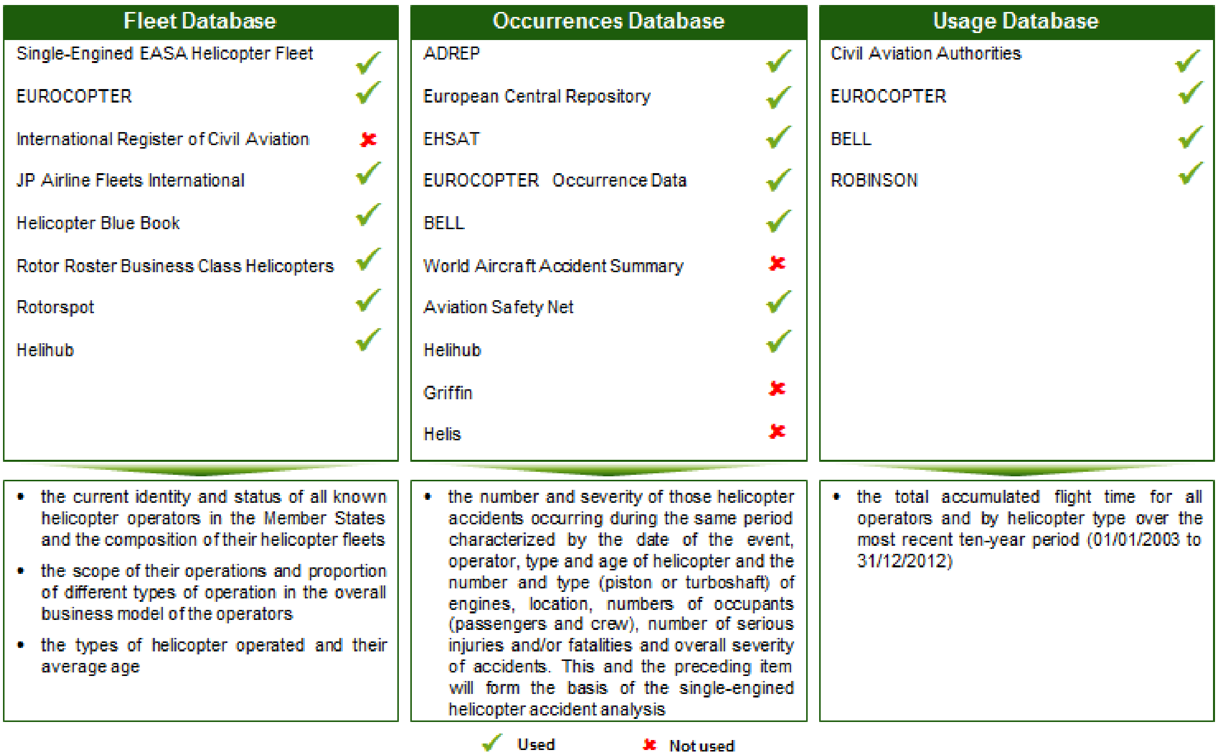


Figure 1: Fleet database building scheme

The Data Gathering process was particularly challenging and time-consuming, more than initially expected, and was strongly influenced by the general lack of information and standardization of the collected data. However these inconveniences did not prevent the study process and the subsequent data analysis of **accidents and serious incidents** in the most recent 10-year period (01/01/2003 to 31/12/2012), since the core of the single-engined helicopter accident analysis is based on the occurrence data and the usage of the helicopter fleet during the period.

Then, it should be noted that, although quite complete, the final occurrence database contains some information gaps as stated in the table below.

Missing data for Accidents and Serious Incidents (%)	Finding
0%	% of occurrences with unidentified date
1%	% of occurrences with unknown make, type or model
0,6% 0,04%)	% of helicopters with unknown year of manufacture without related official occurrence report (with related official occurrence report)
0,8% (0,6 %)	% of occurrences with undefined type of operation without related official occurrence report (with related official occurrence report)
0,6% (0,02 %)	% of occurrences with unspecified phase of flight without related official occurrence report (with related official occurrence report)

Table 1: Occurrence database gaps

After consolidating the database, the main purpose of this document is the development of **Data Analysis**. This task includes a comprehensive statistical approach in relation to fatality impact of accidents and serious incidents recorded during the 10-year period. The study encompasses differences on type of engines, on main types of operation of single-engined flights, on the hostility of the environment, and on other flight conditions. Furthermore, it has emphasized the analysis of engine-failure occurrences, especially over hostile environment and for commercial air transport operations.

To get a broader view of the main causes of the accidents and serious incidents studied, it has been executed a factor identification analysis of occurrences documented with report available according to Standard Problem Statements (SPS) and Human Factors Analysis and Classification System (HFACS) enforcing EHSAT methodology patterns.

Next part of the study includes the **Assessment of Operating Conditions in Member States**. The operating conditions are reviewed as allowed by EASA member states for commercial air transport of helicopters over hostile environment located outside a congested area. It focuses on the use of the variations that are allowed, but subject to a special approval, as per JAR-OPS 3.005(e) and the associated Appendix 1.

To that end, this section discusses the following:

1. Essence, evolution and implementation in member states of JAR-OPS 3.005(e).
2. Information from member states with respect to application of JAR-OPS 3.005(e).
3. An analysis of the results obtained per item 2 above.

In addition, this document gives an overview of existing and future technological improvements that offer added safety to helicopter operations and thereby can contribute in reducing the accident rate on flights, including those over a hostile environment.

All these aspects covered are the basis for the final phase of the project, which will develop the **Safety Risk Assessment** at the first stage, and then the definition of the final **Conclusions and Recommendations**, and then the Regulatory Impact Assessment in case of any proposal for Regulation modifications.

2 Executive Summary

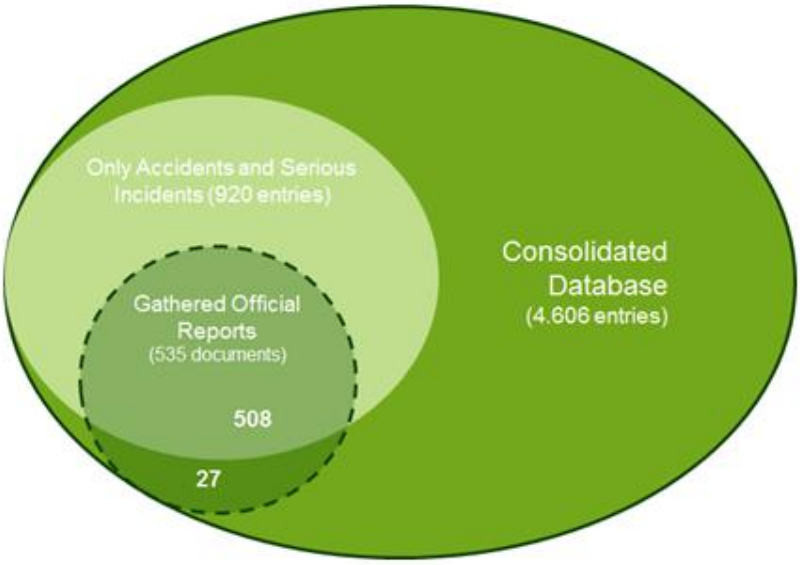
2.1 Data analysis

The data analysis seeks to identify and assess the causes and contributing factors (especially in the case of engines related events) of single-engined helicopter accidents and serious incidents in any type of operation (but especially in Commercial Air Transport operations), and in which type of environment (hostile and non-hostile) those accidents and serious incidents happened.

To this purpose, the following data has been studied:

- Type of occurrence: accident, serious incident, incident, unknown
- Type of engine: piston, turbine
- Injury level: fatal, serious, minor, none
- Damage level: destroyed, substantial, others
- Type of operation: Commercial Air Transport (CAT), Aerial Work (AW), General Aviation (AG) and others, including military, state, illegal and unknown
- Type of environment: hostile and non-hostile
- Flight conditions: VMC, IMC
- Phase of flight: standing & taxi, take-off, en-route & manoeuvring, approach & landing, unknown
- Year of helicopter manufacturing

As far as the environment is concerned, and considering that the different sources used did not usually contain the information on the environment (hostile or not) where the occurrence took place, it has been necessary to proceed with the analysis of the relevant occurrence reports when available. Indeed, reports publicly available from the Air Accident Investigation Boards concern 535 occurrences. A comprehensive analysis of 503 accidents and serious incidents included among the 920 accidents and serious incidents identified has been successfully developed. Despite the efforts of EASA, it was not possible to retrieve additional occurrence reports. The figure below illustrates the availability of such reports.



Occurrence database gaps

Despite the partial lack of information regarding the occurrences description, the type of environment and even the difficulties to collect the total Flight Hours accumulated by the European fleet of single-engined helicopters –expected to be available from the Civil Aviation Authorities–, it has been agreed with EASA to proceed with the study of accidents and serious incidents.

Then, the different analyses performed from the available information has been carried out with the final target of evaluating the suitability of the single-engined helicopters, both piston and turbine, for certain types of activities, especially Commercial Air Transport operations over hostile environment.

This part of the report is structured according to the following sections:

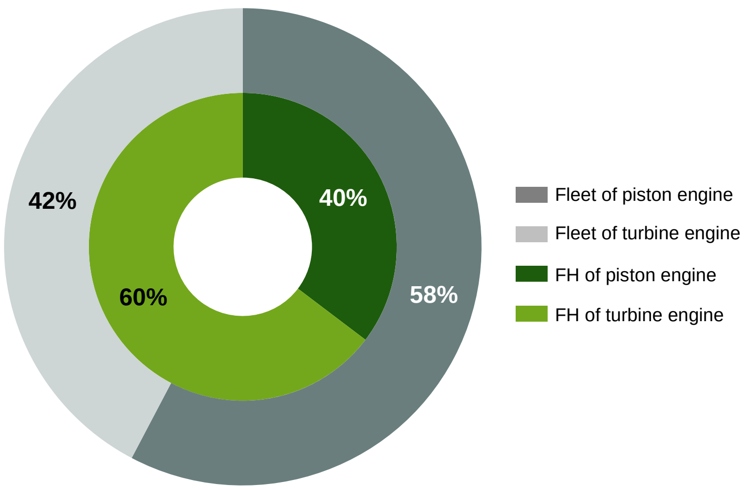
- General statistics analysis, presenting the registered events histogram and the European helicopter fleet and utilization
- Plain analysis of accidents and serious incidents, individually evaluating the relationship of accidents and serious incidents per type of engine, per type of operation, per type of environment, per operating conditions and per rotorcraft age.
- Multi-criteria analysis of accidents and serious incidents, providing an overview of the total occurrence trends by means of the analysis of combined parameters, including the hostile environment analysis and the engine related study.
- Factor identification of accidents and serious incidents, following both SPS and HFACS taxonomies in order to understand the main causes of the singe-engined helicopter accidents and serious incidents.

The **general statistics** analysis presents the histogram of registered events during the ten-year period of study (01/01/2003 to 31/12/2012), with a mean of accidents and serious incidents around 100 events, and a clear evidence of reporting increase in case of minor incidents over the last years, due to implementation of Regulation for the notification of occurrences.

This initial analysis also provides general ideas about helicopter occurrences in terms of fatality (19% of the accidents and serious incidents) and damage level (38% of destroyed aircraft), as well as general figures in terms of single-engined helicopter fleet and usage:

- There are more than 6.800 active single-engined helicopters in EASA Member States, with four countries concentrating almost 60% (UK, France, Italy and German) of the total fleet. Most common single-piston helicopters are the Robinson 44 and 22 (close to 1.500 and 1.000 aircraft respectively), while the most common single-turbine models are AS350 Ecureuil 1 and JetRanger series (close to 1.000 and 650 aircraft respectively).
- Collecting data on the total accumulated flight time has proven more challenging and difficult than initially expected, with OEMs and CAAs identified as the most appropriate sources of information for single-engined helicopter usage data. A double approach has been performed to solve the lack of available data and the standardization of the databases, correcting the usage rates of the CAAs with the manufacturers' records. Then, the total number of estimated Flight Hours for the 2003-2012 period, over all the EASA Member States, is around 9.900.000 FH (Flight Hours), 6.000.000 FH corresponding to turbine-engined helicopters and 3.990.000 FH to piston-engined helicopters.

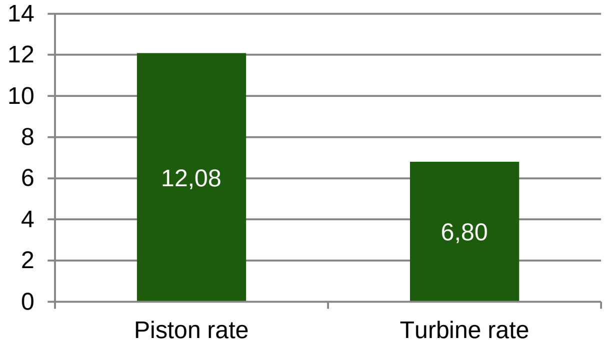
As shown in next figure, despite the fleet distribution by type of engine is relatively balanced (58% piston, 42% turbine), helicopters powered by turbine engines represent 60% of the total accumulated Flight Hours over the period of study.



Single-engined helicopter usage share versus fleet by engine type

The **plain analysis of accidents and serious incidents** allows identifying different behaviours according to different individual parameters.

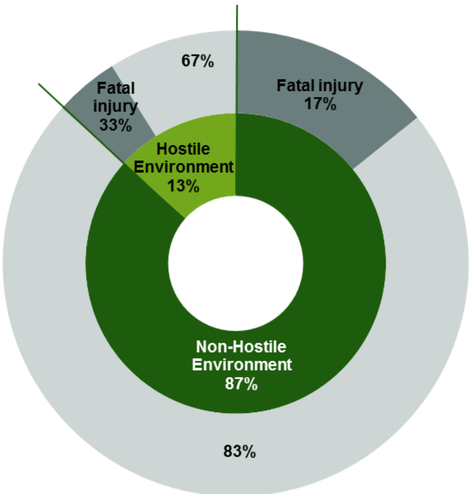
Regarding the type of engine, the absolute amount of occurrences is relatively balance, with piston helicopters having a slightly higher share of the total events. However, it should be noted that the relative number of these occurrences is very influenced by the type of engine when related to Flight Hours. Next figure shows that piston-engined rate of occurrences per 100.000 FH is 1,78 times that the turbine rate.



Accidents and serious incidents rate per 100.000 FH by engine type

Regarding the type of operation, it can be observed that CAT operations have a substantial minor absolute number of accidents and serious incidents comparing with AW and GA, but a substantial higher ratio of minor incidents by accidents and serious incidents. This last point could probably be due to a better monitoring of CAT operations versus other activities.

Regarding the type of environment, only 13% of the accidents and serious incidents occur in hostile environment, being this figure influenced for the specific regulations applied on helicopter operations for this type of environment. However, when comparing the level of fatal injury between hostile and non-hostile environment, results in a very different ratio, with only 17% of fatal occurrences in non-hostile environment, but almost double percentage for hostile environment, 33% of the total accidents and serious incidents. This strengthens the definition of hostile environment.



Accidents and serious incidents distribution and fatality share per type of environment

Regarding the phase of flight, only 45% of the accidents and serious incidents occur during the en route & manoeuvring phase, but accumulating 69% of the total fatal occurrences. Per Flight Hour, the behaviour during the different phases of the flight are similar in terms of fatality, around 1,50 occurrences per 100.000 FH, except for a higher ratio during en route piston operations (1,77).

Finally, the rotorcraft age analysis does not reveal any relevant conclusion, with similar behaviour regardless the age of the aircraft.

The **multi-criteria analysis** provides a better understanding of the single-engined helicopter events, thanks to a double or triple approach.

The hostile analysis introduces the environment within the type of engine and operations analyses, showing that piston and turbine engined helicopters have a similar rate of fatality in hostile environment (around 30% of the accidents and serious incidents), and a different behaviour when comparing non-hostile occurrences, with turbine helicopters having a fatality rate 50% higher than piston, but still both engine types below the hostile environment events.

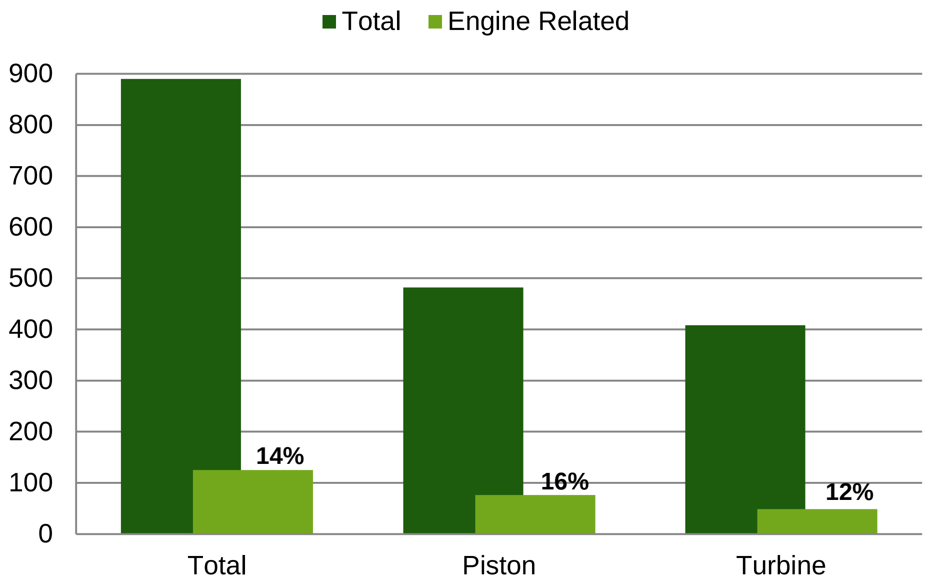
Type of operation	Piston-engined		Turbine-engined	
	Non-Hostile	Hostile	Non-Hostile	Hostile
Commercial Air Transport	**6 fatal occurrences over 26 total occurrences (23% of fatality)**	**0 / 2 (0%)**	**10 / 45 (22%)**	**5 / 19 (32%)**
Aerial Work	5 / 54 (9%)	3 / 11 (27%)	24 / 139 (17%)	18 / 58 (31%)
General Aviation	43 / 340 (13%)	7 / 22 (32%)	19 / 91 (21%)	4 / 10 (40%)
Total	**57 / 444 (13%)**	**12 / 38 (32%)**	**68 / 318 (21%)**	**29 / 90 (32%)**

Fatality comparison of accidents and serious incidents per type of engine and environment

This analysis for the different type of operations shows the intrinsic hazard of the hostile environment, as presented in the table, for both piston and turbine engines, except for CAT operations in hostile environment with piston-engined helicopters due to current regulation restrictions for such as this type of operations.

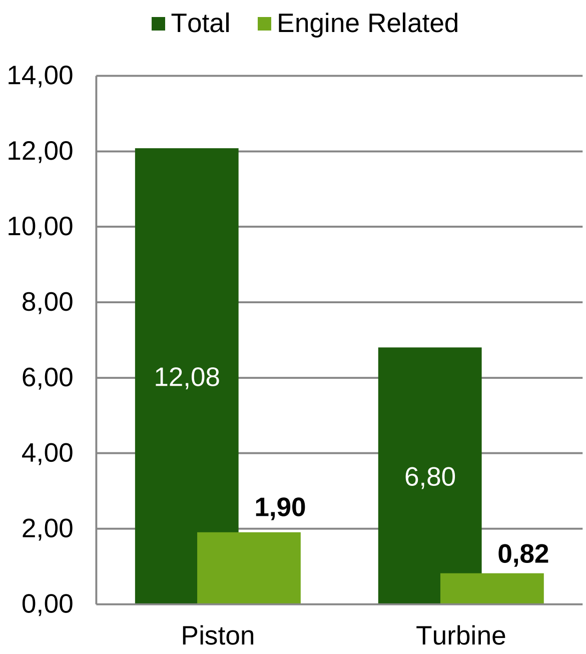
It must be also noted that when looking only at en route & manoeuvring accidents and serious incidents for CAT operations in hostile environment with turbine-engined helicopters, the fatality ratio raises up to a 62% (comparing with the global rate of 32%), but the low number of events (5 fatal over 8 in total) distorts the analysis.

The same problem appears when looking only at engine related occurrences. As shows below, this group of events represents the 14% of the total accidents and serious incidents, with similar results for both piston and turbine power plant, but slightly higher for piston-engined helicopters (16% versus 12%).



Engine related accidents and serious incidents per type of engine

The relative number of these engine related occurrences is very influenced by the type of engine when related to Flight Hours: the proportion shows an important difference between single engine accident rate for piston and turbine, with piston rate 2,33 times the turbine rate. As the next figure shows, the difference between piston and turbine rates is greater in engine related occurrences than respect to total occurrences per 100.000 FH.



Engine related accidents and serious incidents rate per 100.000 FH by engine type

The analysis of the engine related events shows a higher rate of fatality in hostile environment, around 43% both piston and turbine (comparing with the global 32%), but also in non-hostile environment. However, the small number of events do not allow to present clear conclusions due to the high level of dispersion when looking at the details, as shown in the next table by type of engine and type of operation.

Type of operation	Piston-engined		Turbine-engined	
	Non-Hostile	Hostile	Non-Hostile	Hostile
Commercial Air Transport	**0 fatal occurrences over 2 total occurrences (0% of fatality)**	**0 / 0 (-)**	**1 / 4 (25%)**	**1 / 3 (33%)**
Aerial Work	0 / 11 (0%)	0 / 2 (0%)	4 / 17 (22%)	3 / 7 (43%)
General Aviation	4 / 49 (8%)	2 / 3 (67%)	1 / 10 (10%)	0 / 0 (-)
Total	**6 / 71 (8%)**	**2 / 5 (40%)**	**9 / 39 (23%)**	**5 / 10 (50%)**

Fatality comparison of engine related accidents and serious incidents per type of engine and environment

Finally, the **factor identification** study involves the analysis of 503 occurrences through its available reports, allowing addressing the categorization of main causes of occurrences and the classification of main contributory factors using both Standard Problem Statements (SPS) and Human Factors Analysis and Classification System (HFACS) taxonomies.

According to SPS level 1 codes, the top 3 areas are Pilot judgment & actions (76% of occurrences have at least once code of this category), Safety Management (61%) and Ground Duties (37%). The HFACS taxonomy provides a complementary perspective. According to this criterion, the three main areas are Unsafe Acts - Errors (55%), Preconditions - Condition of Individuals (34%) and Supervision 19%.

Detailing level 2 categories, different patterns were observed for Commercial Air Transport, Aerial Work and General Aviation. While in Commercial Air Transport and General Aviation causes used to involve pilot responsibility, in the case of Air Transport the risk mission and the existence of obstacles around the accident environment contribute considerably in the occurrence damage.

	Commercial Air Transport	**Aerial Work**	**General Aviation**
SPS level 2 >25% of occurrences	Visibility/Weather External Environment Awareness Inadequate Pilot Experience Terrain/Obstacles Management Flight Profile Procedure Implementation Mission Planning Human Factors - Pilot's Decision	Human Factors - Pilot's Decision Management Pilot Intensive Flight Profile External Environment Awareness Mission Planning Terrain/Obstacles	Flight Profile Procedure Implementation Inadequate Pilot Experience Human Factors - Pilot's Decision
HFACS level 2 >10% of occurrences	Coordination/Communication/Planning Perceptual Errors Organizational Process Planned Inappropiate Operations Cognitive Factors Physical Environment Psycho-Behavioural Factors Judgement & Decision-Making Errors	Physical Environment Organizational Process Cognitive Factors Planned Inappropiate Operations Psycho-Behavioural Factors Skill-based Errors Coordination/Communication/Planning Judgement & Decision-Making Errors	Planned Inappropiate Operations Coordination/Communication/Planning Cognitive Factors Psycho-Behavioural Factors Skill-based Errors Judgement & Decision-Making Errors
	Causes related to errors due to both failures on procedural execute or pyscho-behavioral factors	Mission risk can result in pushing the helicopter and pilot towards the limits of their capabilities Existence of obstacles	Related to crew and pilot skill and non-proper procedure implementations

Most common SPS and HFACS level 2 categories per type of operation accidents and serious incidents

2.2 Assessment of operating conditions in Member States

The subject of this substudy, assessment of operating conditions allowed in EASA Member States, centres on the application of JAR-OPS 3.005(e) and its associated Appendix by Member States.

This requirement was introduced by the JAA in 1999 to provide a variation to the general requirement that commercial air transport operation of single-engined helicopters shall only be conducted along such routes or within such areas for which surfaces are available which permit a safe forced landing to be executed. This variation is in the form of an approval that may be issued by the state issuing the AOC and is subject to a series of conditions, one of which is that the engine must be a turbine engine and another that a Usage Monitoring System (UMS) is required. At the time, this requirement was at variance with ICAO standards. However, ICAO has since amended its standards such that 3.005(e) is now compatible with them.

In order to establish how Member States apply this provision, a number of Member States were approached. Initially, states were approached such as to cover one or two states from each geographical EASA region, but as the study progressed the targeting shifted to those states for which information became available that they were actually using this provision.

Eventually, the following states were identified as issuing approvals per 3.005(e), or using an alternative that has the same effect: Finland, France, Sweden and Switzerland.

Two other states confirmed that they do not issue approvals per 3.005(e) (the Netherlands and United Kingdom), whereas Austria indicates that although it has not issued approvals now, it would consider applications that are well-substantiated. Three more states that were approached (Germany, Hungary, Spain) did not respond and it is assumed that they do not issue approvals per 3.005(e) or apply equivalents. That assumption is supported by information gained form EASA on the basis of State Conversion Reports and information provided by Eurocopter.

The conditions under which the four states that issue approvals per 3.005(e) or allow alternatives differ significantly.

- France has added an extra condition on top of those in 3.005(e), which is that the exposure time over a hostile environment may not exceed half of the flight time with a maximum of 5 minutes.
- Finland issues such approvals even though a UMS is not necessarily in place.
- Sweden has not issued approvals, but allows operations under the provisions of 3.005(e) pending the development of a formal approval process.
- Switzerland does not follow JAR-OPS but has national requirements in place which replicate 3.005(e) but allows piston-engined helicopters in addition to turbine-engined.

As to the number of helicopters operating under the provision of 3.005(e) or equivalent, there are two states that stand out: France with just over 100 helicopters and Switzerland. For the latter, no number was provided as no such approvals are given. However, the number of single-engined helicopters operated by Swiss AOC holders is estimated at 120. Finland has issued approvals for 5 aircraft in total. For Sweden, no estimate could be established,

2.3 Technological improvements

An overview is provided of existing and future technological improvements that offer added safety to helicopter operations and thereby can contribute in reducing the accident rate on flights, including those over a hostile environment. The focus of the search process has been aimed at engine failure because, in single-engine helicopters, it is an extreme caution condition without any possible degraded operation.

It seems that hybrid engine models are the new line of research and innovation by manufacturers and operators. The aim of these initiatives is to provide extra power required on critical phases, such as take-off, hovering or emergency situation, with a second energy source. Main engine has a supplemental electric system to increase manoeuvrability of a single-engine helicopter, for example during an autorotation landing, which is performed by helicopters in the event of a main engine failure. Eurocopter and Turbomeca have implemented some prototypes.

Finally, systems that improve tracking and planning route phase can also increase the safety performance. The latest pilot-vehicle interfaces, as FADEC or VMED, can monitor numerous engine operating parameters and compactly display on a single screen, reducing pilot workload. Other actions to be implemented are the incorporation of cameras to record the motor operation (as a black box) and provide warnings in case of malfunction. Similarly, audio and tactile warming caution systems facilitate pilot's attention and reduce the time to respond to unexpected occurrences. All these systems have been further developed in the last section of this report.

3 General Statistics

This section of the report contains the general statistics which have been extracted and which, once combined with data related to single-engined helicopter usage for all operators and by helicopter type over the most recent ten-year period (01/01/2003 to 31/12/2012), will provide the occurrence rates.

3.1 Registered events histogram

3.1.1 Accidents and incidents evolution

The total registered events in the consolidated database from January 2003 to December 2012 have been split in accidents and serious incidents on one side, and then the rest of incident categories on the other side. This study only analyses in detail accidents and serious incidents, focusing on existing reports associated to those especial events.

The following histogram shows that the registered accidents and serious incidents count in the period analysed has been oscillating between 73 and 119 events, with a medium value of 92 events per year. However, the record of other type of incidents registered has significantly increased over the years, due to implementation of Regulation for the notification of occurrences.

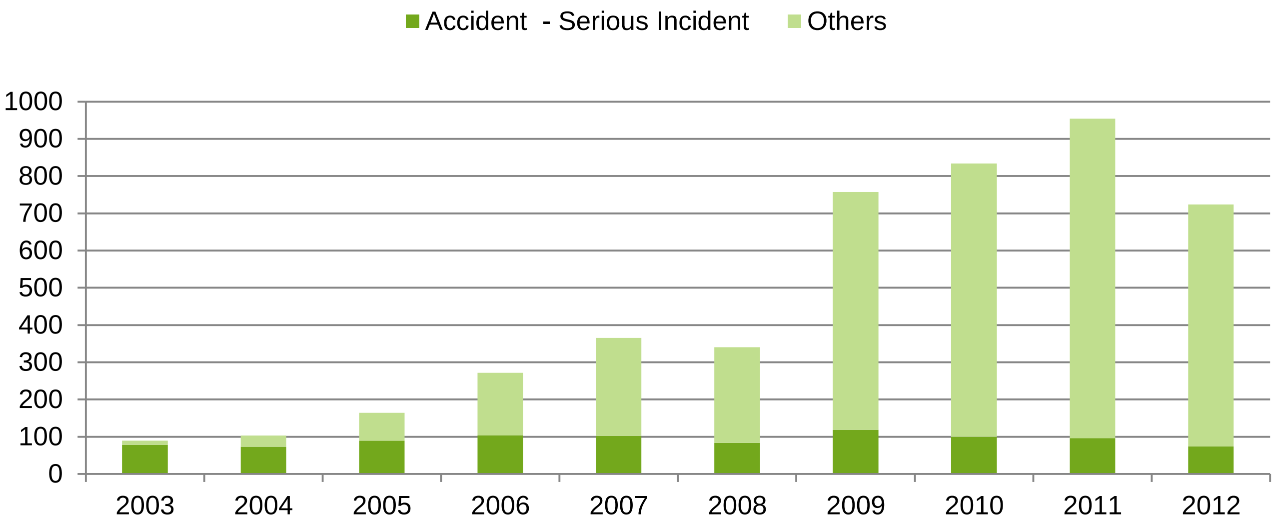


Figure 2: Registered events distribution per event type and year

3.1.2 Accidents and serious incidents by injury level

For accidents and serious incidents, the injuries of the database have been split in fatal and non-fatal events. Fatal events are those in which at least one of the helicopter occupants (crew or passengers) died because of the accident-related injuries within 30 days of the accident; it also includes fatalities in the ground. Non-fatal events, on the other hand, group those cases in which no life loses are counted, including the serious injuries, the minor injuries and the no-effect situations[1]. The annual evolution is shown in next figure.

[1] Injury taxonomy (fatal, serious and minor) according to ADREP 2000 standard as defined by ICAO and implemented in version 4.2.6 of ECCAIRS, Section: Severity, Id.451 Injury severity level.

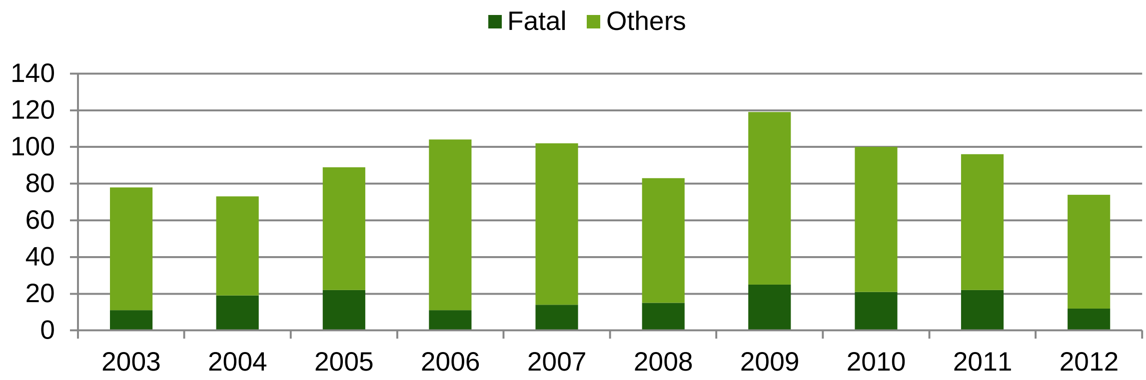


Figure 3: Accidents and serious incidents annual evolution per injury type

The relative distribution of the results by injury level for the whole period is shown in next figure. It can be therefore deduced that the 19% of the accidents and serious incidents of the database implied fatal injuries, while the non-fatal injury events account for the 81% of the cases.

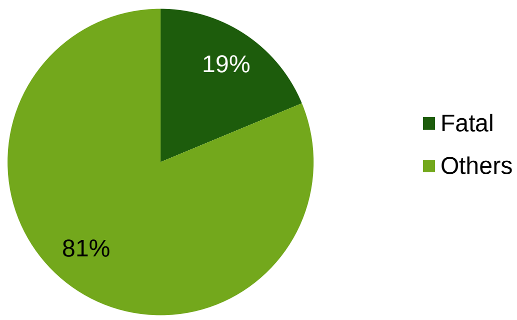


Figure 4: Accidents and serious incidents distribution per injury type

3.1.3 Accidents and serious incidents by damage level

The accidents and serious incidents have been classified in the database in three groups depending on the damage[2] they caused on the rotorcraft: destroyed, substantial damage, and others, which refer to minor and no-effect events. The annual evolution is shown in next figure.

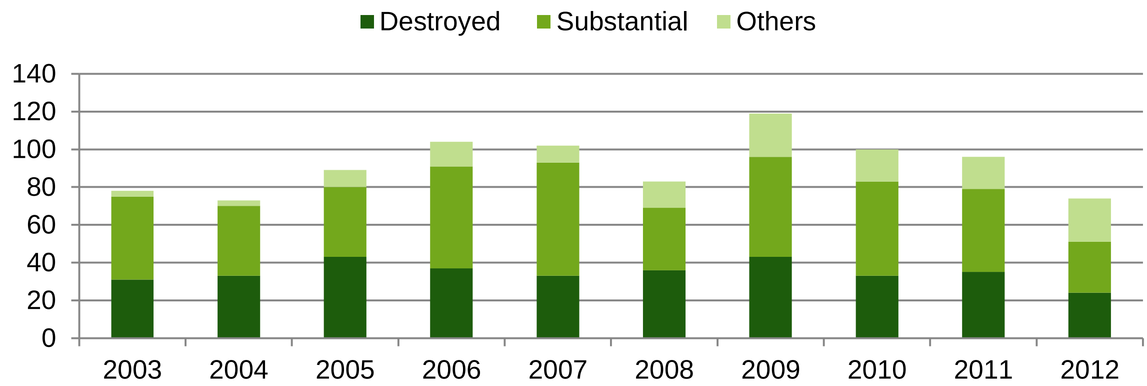


Figure 5: Accidents and serious incidents annual evolution per damage type

[2] Damage taxonomy (destroyed, substantial, minor, none, unknown) according to ADREP 2000 standard as defined by ICAO and implemented in version 4.2.8 of ECCAIRS, Section: Severity, Id.432 Damage severity level.

The relative distribution of the results for the whole period of time is shown next. It can hence be deduced that most of the helicopters become substantially damaged (48%), or completely destroyed (38%), after an accident or serious incident. The minor and no effect group only accounts for a 14% of the analysed cases.

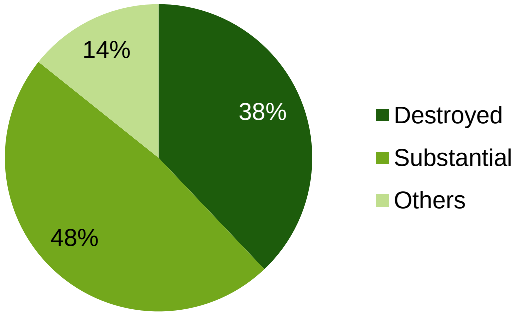


Figure 6: Accidents and serious incidents distribution per damage type

3.2 European helicopter fleet and utilization

Europe has one of the most important fleet of helicopters in the World, with a wide range of manufactures, models, types and air operators, covering a broad variety of activities and missions.

3.2.1 Helicopter fleet

Nowadays, there are more than 6.800 active single-engined helicopters in EASA Member States, with four countries concentrating almost 60% (UK, France, Italy and German) of the total fleet, and with three manufacturers concentrating 73% of the total fleet of single-engined helicopters in Europe: Robinson, Eurocopter and Bell. With regard to engine type, 82% of the turbine fleet was manufactured by either Eurocopter (Airbus Helicopters) or Bell, while 61% of the piston fleet was manufactured by Robinson.

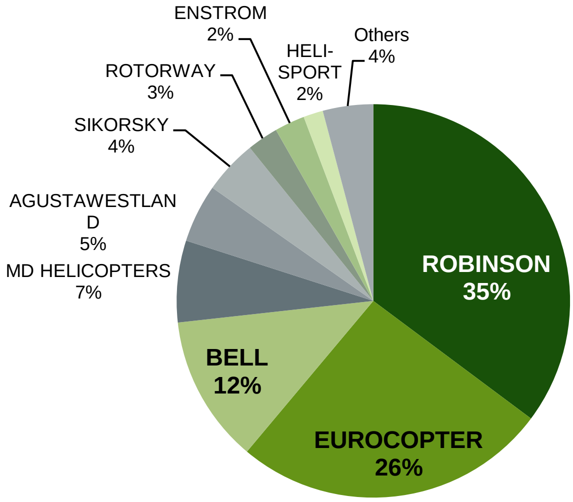


Figure 7: European helicopter fleet share by manufacturer

Then, the share of the single-engined fleet between turbine and piston in Europe is very similar, with a slight higher number of turbine craft operating in Europe. Most common single-piston helicopters are the Robinson 44 and 22 (close to 1.500 and 1.000 aircraft respectively), while the most common single-turbine models are AS350 Ecureuil 1 and JetRanger series (close to 1.000 and 650 aircraft respectively).

3.2.2 Flight hours estimation

Collecting data on the total accumulated flight time for all operators, type of operation and by helicopter model over the most recent ten-year period (01/01/2003 to 31/12/2012) has proven more challenging and difficult than initially expected by the Consortium.

The helicopter manufacturers and the Civil Aviation Authorities were identified during the previous stages of the study as the most appropriate sources of information for single-engined helicopter usage data. All the 31 CAAs were consulted, but only 22 CAAs responded positively to the enquiry, and only 13 CAAs[3] delivered information regarding usage data on their helicopter fleets, representing 28% of the total Single Engined Helicopter fleet in Europe. Additionally, data has been delivered in many different formats, depending on its data gathering and storage standards: some CAAs provided detailed data for each model per year, others for the whole period, and some data was even provided in an aggregated format.

Then, due to difficulties in obtaining this information from the CAAs despite repeated attempts and the lack of standardization of the databases, it was mutually agreed with EASA to estimate the total accumulated flight time for whole fleet of helicopters during the period of study based on the information made available by OEMs and some CAAs. As the nature of the data did not allow a direct merge and extrapolation of the Flight Hours, two different approaches have been followed to obtain the total flight time over all the EASA Member States: one approach with the CAA information, and a different one for the manufacturer data.

For the first approach, it has been analysed the information provided by the different CAAs, dismissing the non-consistent data in order to get a high quality figures and a homogeneous source for this calculation. According to this initial analysis, it has been used only the information of helicopter usage of the following selected countries:

- Switzerland on one side, due to the particular orography of this country.
- Bulgaria, Cyprus, Estonia, Finland, Hungary, Latvia, Lithuania, Luxembourg, Portugal and UK on the other side, while Denmark and Greece –together with some other specific records–, have not been included.

The compilation of total Flight Hours per family of helicopters over the 2003-2012 period, splitting between piston and turbine-engined aircraft, together with the accumulated fleet during the selected period, allows identifying the average annual flight time per helicopter type. These ratios are used to estimate the annual Flight Hours since 2003 to 2012 for the whole European fleet of single-engined helicopters.

To double check these calculations, the second approach has introduced the data provided by the main helicopter manufacturers, Eurocopter, Bell and Robinson. This perspective is again very heterogeneous, but a conscientious analysis allows an adequate interpretation of the available information, in order to facilitate the comparison with the results of the CAA study.

The convergence of both approaches has required a correction of the initial ratios of usage by helicopter provided by the CAAs analysis. The directionality of this correction is due to the fact that OEMs usually have better reliable information of helicopter utilization than CAAs, thanks to the maintenance programmes and the technical support provided to the operators.

In these terms, Eurocopter has provided aggregated annual Flight Hours by family of helicopters for its European fleet, Bell has provided global annual Flight Hours by helicopter type and an estimation of European share, and finally Robison has provided statistical usage of a fleet of near to 1.000 helicopters and annual distribution of Fight Hours by country and helicopter type.

With this information, and considering that near to 75% of the turbine fleet has been manufactured either by Eurocopter or by Bell, and that near to 60% of the piston fleet has been manufactured by Robinson, an extrapolation of the data provided by these three companies has been made to the rest of the helicopters in order to correct the usage ratios for the whole fleet.

Given all these assumptions, the total number of Flight Hours for the 2003-2012 period, over all the EASA Member States –which will be used in the following sections of the study– is around **9.900.000 FH (Flight Hours), 6.000.000 FH corresponding to turbine-engined helicopters and 3.990.000 FH to piston-engined helicopters**.

[3] Bulgaria, Cyprus, Denmark, Estonia, Finland, Greece, Hungary, Latvia, Lithuania, Luxembourg, Portugal, Switzerland, UK

As shown in next figure, despite the fleet distribution by type of engine is relatively balanced (58% piston, 42% turbine), helicopters powered by turbine engines represent 60% of the total accumulated Flight Hours over the period of study.

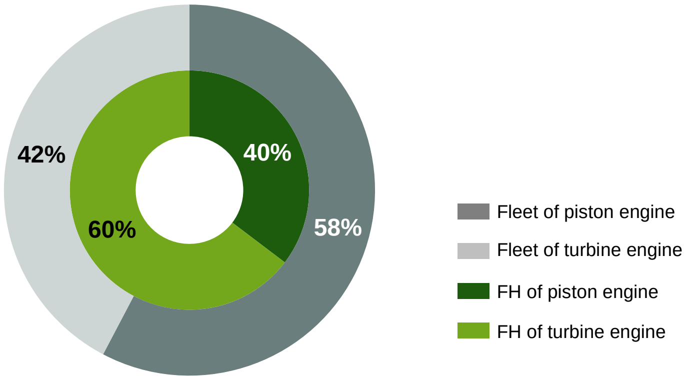


Figure 8: Single-engined helicopter usage share versus fleet by engine type

Complementarily to this study, an additional analysis has been calculated to estimate the split of aircraft utilization during the different phases of flight. For this analysis, it has been used the data provided by the CAAs of Cyprus, Finland, Latvia, Lithuania and Portugal in terms of flight cycles (or landings, depending on the source).

The average flight time per flight stage in these country is around 30 minutes (0,5 FH/flight). Using a typical flight profile make by three simple phases (take-off, en-route, landing), and assigning a normal operating time of 5 minutes for both take-off and landing phases, results an average en-route time of 20 minutes per flight (67% of the time). These figures will be used as a reference for the en-route analysis.

3.2.3 General industry information

Finally, it has also been estimated other general information regarding the helicopter sector as follows:

- Total active fleet of helicopters in 2012 around 7.600 rotorcrafts, including both single and twin engine helicopters.
- Total accumulated flight time for all operators in 2012 around 1.500.000 FH, almost ¾ corresponding to single helicopters and ¼ to twin helicopters.
- Total number of professional pilots in the range of 16.000-18.000 active pilots, under the assumptions of 2,5-3 pilots per single-engined helicopters in commercial duties, 4-5 pilots per twin-engined commercial helicopters, and 1-2 pilots per private helicopter, plus an additional 10%. It results over 2 pilots per helicopter.
- Total number of technical maintenance staff involved in the operation in the range of 5.000-7.000 people, under the assumptions of 1,6/2,4 man-hours per flight hour of a single/twin-engined helicopter on scheduled tasks, plus an additional 50% of man-hours for unplanned activities, with an estimated average rate of 265 FH/man per year. It results 0,75 man per helicopter.
- Total annual revenue of the commercial activity for the whole fleet in the Member States in 2012 estimated in a global amount of around 2.500 M€. This figure can oscillate due to the heterogeneous types of services provided, as well as the additional of other complementary revenues.

Other relevant parameters as the number of transported passengers, the number of services provided to customers, or even the usage of the helicopters by type of operation or by type of environment, are not able to be estimated due to the actual dispersion of information and lack of available data within the industry.

4 Plain analysis of accidents and serious incidents

This section presents the analysis of accidents and serious incidents in a direct approach by evaluating different parameters individually, in order to initially understand the behaviour of the single-engined fleet during last 10 years.

The parameter analysed are the following:

- Type of engine
- Type of operation
- Type of environment
- Flight conditions
- Age of the rotorcraft

4.1 Analysis per type of engine

The distribution of the accidents and serious incident per engine type shows that the proportion of piston engine helicopters and turbine engine helicopters involved in accidents and serious incidents is very similar, with a relatively stable evolution.

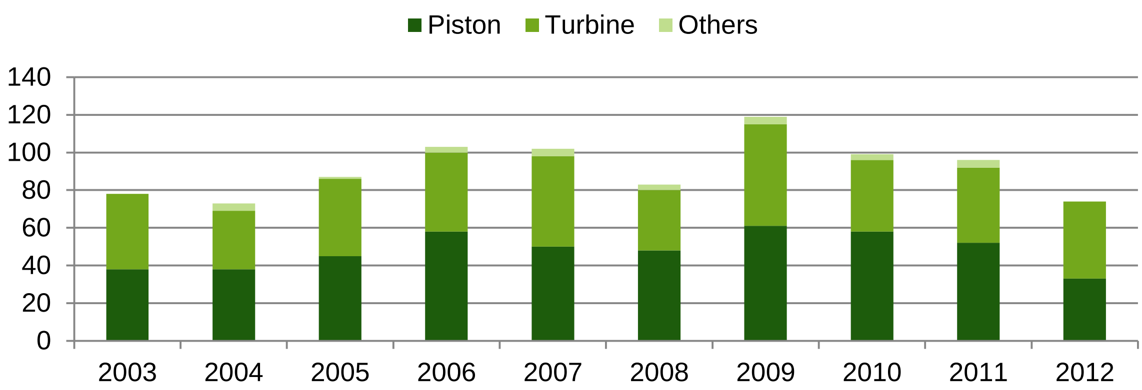


Figure 9: Accidents and serious incidents annual evolution per engine type

The relative distribution of the results for the whole period of time is shown in the next figure. In absolute figures, there are more accidents for piston than for turbine helicopters. Others category represents events not clearly identified or other type of engine.

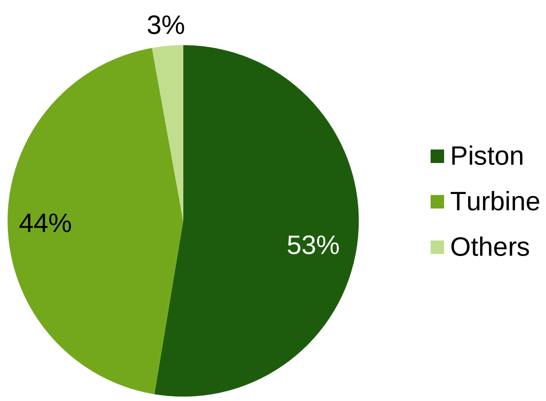


Figure 10: Accidents and serious incidents registered in the consolidated database distribution per engine type

In order to have a better understanding of this classification by type of engine, it is important also to analyse the number of accidents and serious incidents by fleet utilization. As depicted in the figure below, the relative number of these occurrences is very influenced by the type of engine: when related to Flight Hours, the proportion shows an important difference between single engine accident rate for piston and turbine, with piston rate 1,78 times the turbine rate.

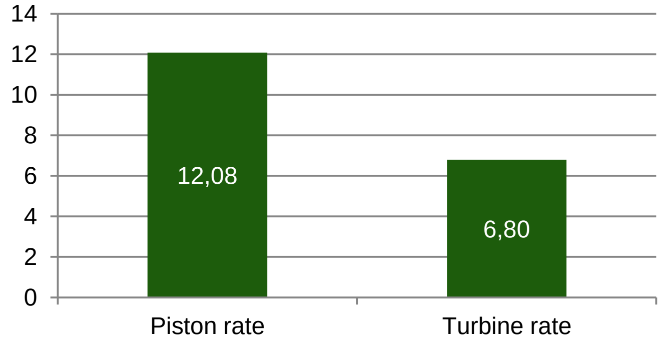


Figure 11: Accidents and serious incidents rate per 100.000 FH by engine type

4.1.1 Level of injury per type of engine

The accidents and serious incidents distribution per engine type and human injury level is shown next, split by fatal, serious and others (minor, none, unknown).

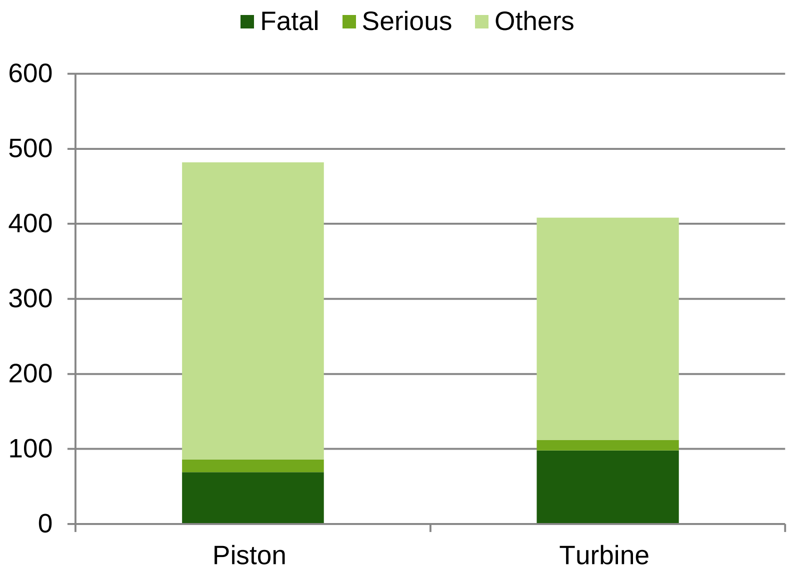


Figure 12: Accidents and serious incidents distribution per engine type and injury level. Absolute number of occurrences

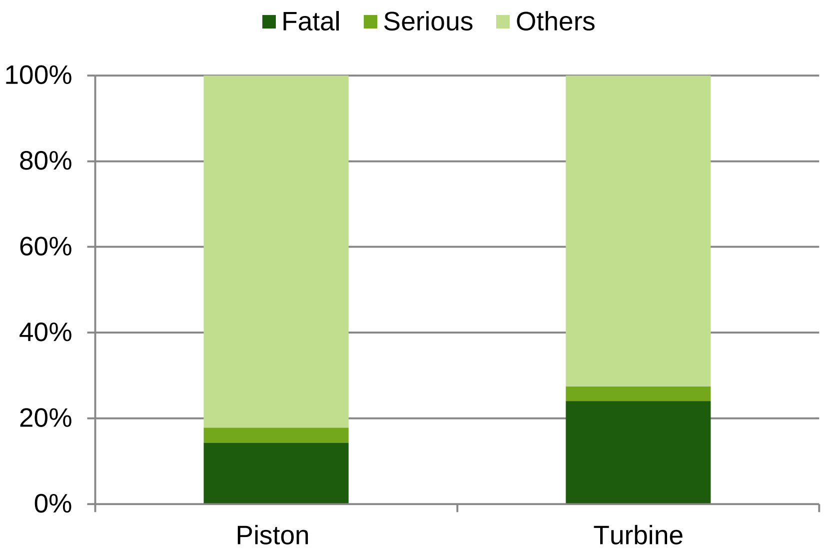


Figure 13: Accidents and serious incidents distribution per engine type and injury level. Relative number of occurrences

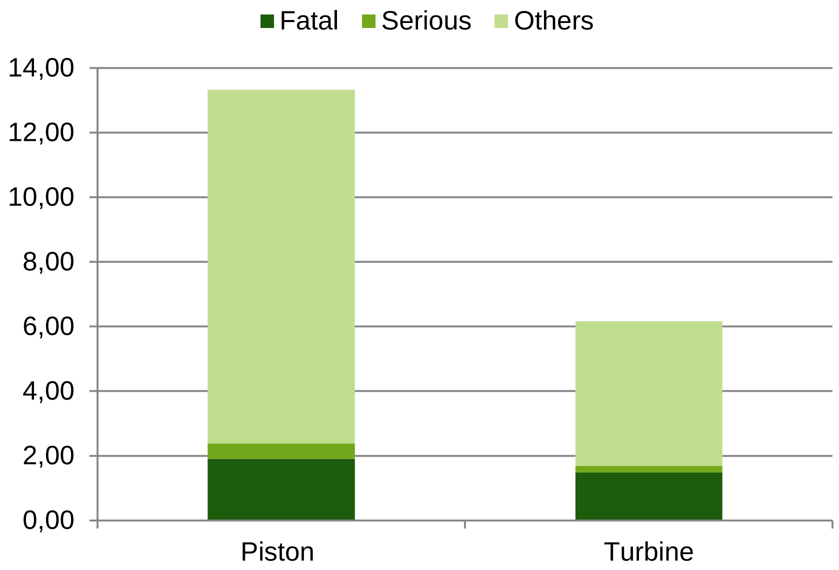


Figure 14: Accidents and serious incidents distribution per engine type and injury level. Occurrences per 100.000 FH

Results of the previous chart show that turbine-engined helicopter have a higher rate of fatal occurrences (24%) than piston-engined ones (14%). This situation shows the same results when analysing together fatal and serious events (27% versus 18%).

4.1.2 Level of damage per type of engine

On the other hand, the accidents and serious incidents per engine type and aircraft damage level are shown next, split by destroyed helicopter, substantial damage or other categories.

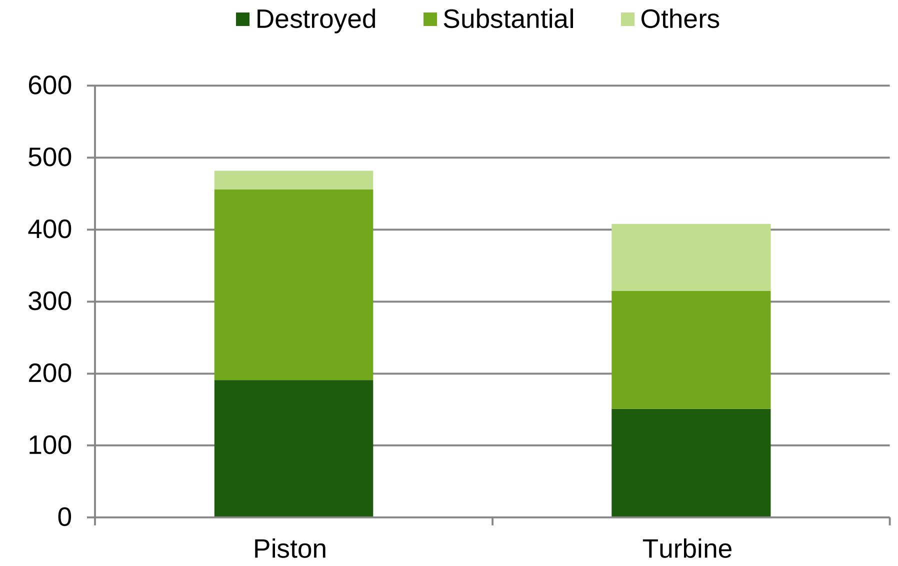


Figure 15: Accidents and serious incidents distribution per engine type and damage level. Absolute number of occurrences

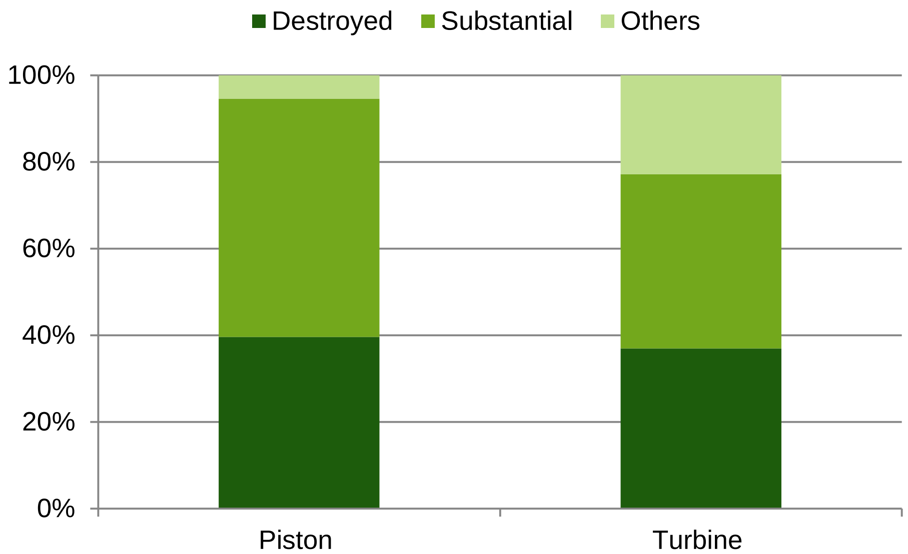


Figure 16: Accidents and serious incidents distribution per engine type and damage level. Relative number of occurrences

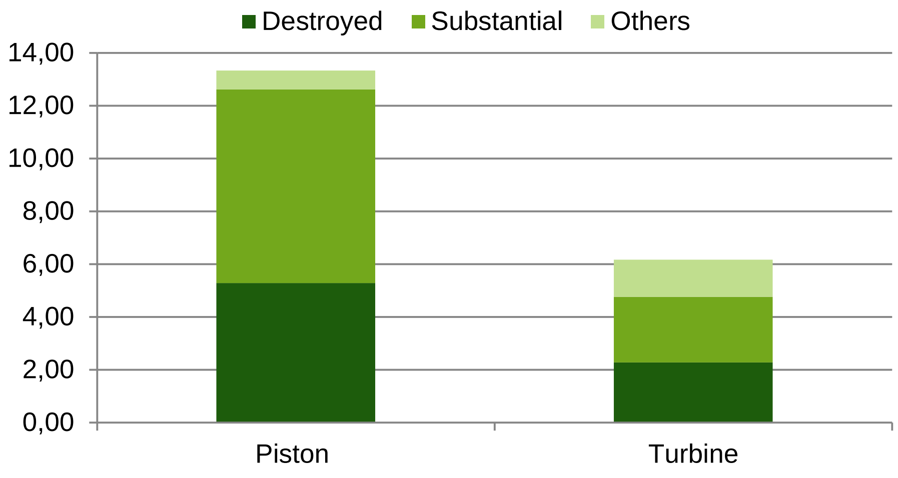


Figure 17: Accidents and serious incidents distribution per engine type and damage level. Occurrences per 100.000 FH

Results of the previous chart show that piston-engined helicopters suffer a higher rate of damage during the accidents and serious incidents (40% destroyed, and 55% more substantially damaged), than turbine-engined helicopters (37%, plus 40%, respectively).

4.2 Analysis per type of operation

Three main types of operation have been considered for the study:

- Commercial Air Transport (CAT): an aircraft operation involving the transport of passengers, cargo or mail for remuneration or hire.
- Aerial Work (AW): an aircraft operation in which an aircraft is used for specialised services such as agriculture, construction, photography, surveying, observation and patrol, search and rescue, aerial advertisement, etc.
- General Aviation (GA): an aircraft operation other than a commercial air transport operation or an aerial work operation (including private flight, basic flight training…).
- Others: the rest of operations regarding military, state, illegal and unknown flights

The following figure shows the evolution of the accidents and serious incidents per type of operation

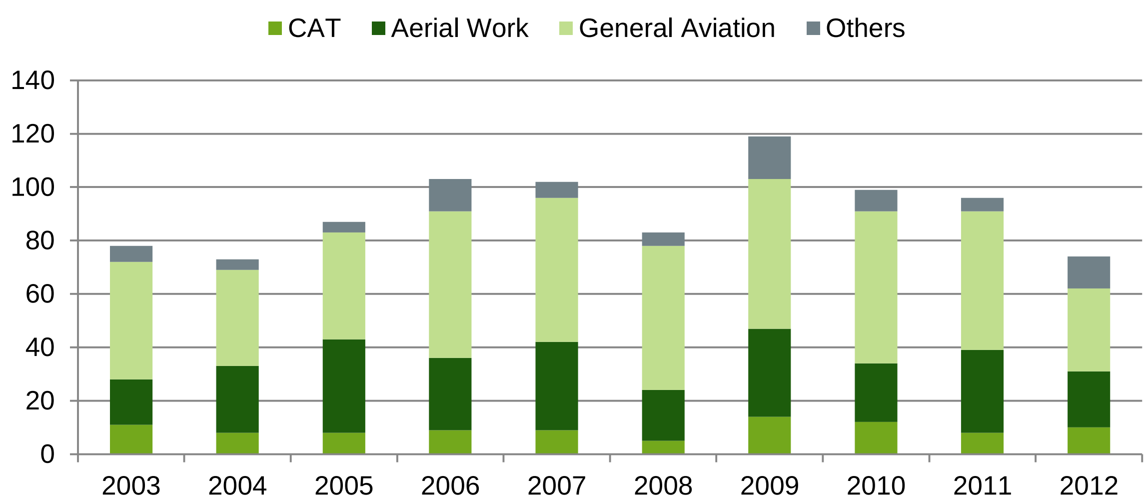


Figure 18: Accidents and serious incidents annual evolution per type of operation

The relative distribution per type of operation is shown in the next figure. It can be observed that most of the analysed accidents and serious incidents happen for general aviation (52%), followed by the aerial works (29%). The commercial air transport, on the other hand, only accounts for a 10% of the database.

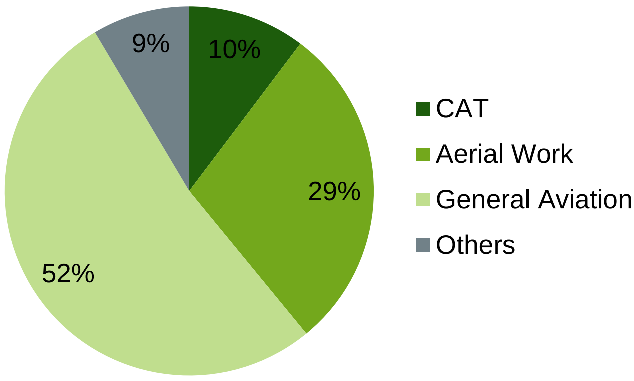


Figure 19: Accidents and serious incidents distribution per type of operation

In order to have a better understanding of this analysis, the next figure present the global scheme of events, including not only accidents and serious incidents but also minor incident and other events (mainly unknown).

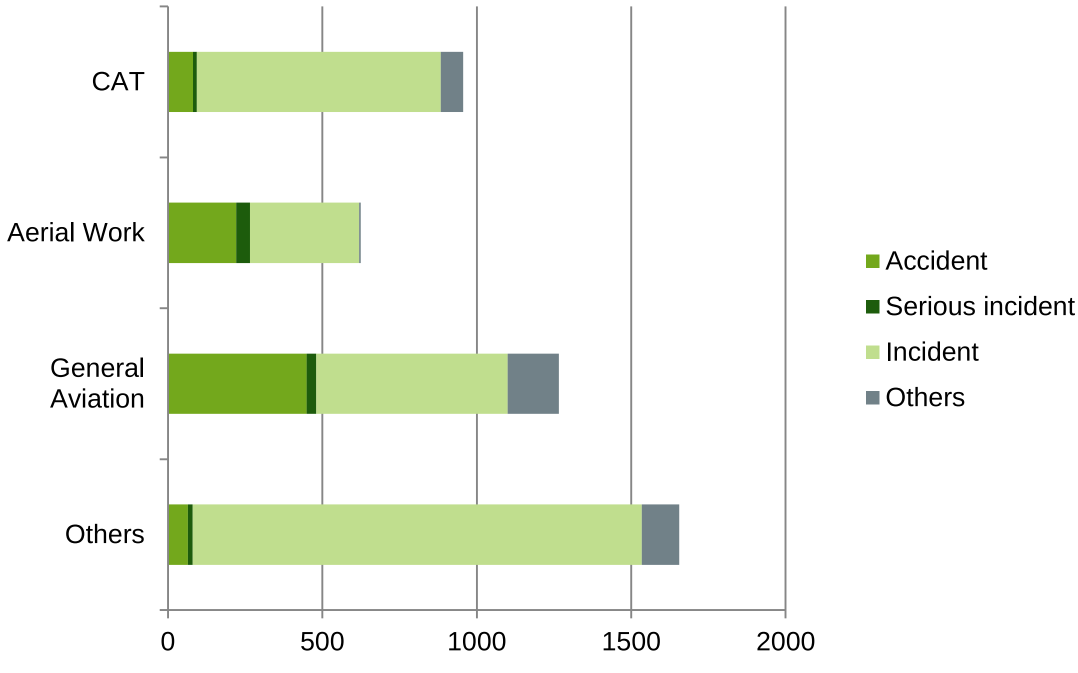


Figure 20: All events distribution per type of operation

Excluding “Others” events, this bar chart states the fact that most of the registered events correspond to general aviation, with CAT operations in second place.

However, it can also be observed that CAT category has a substantial higher ratio of minor incidents by accidents and serious incidents, comparing with AW and GA. This point confirms the fact that CAT operations are better reported than the rest of activities.

4.3 Analysis per type of environment

The type of environment makes reference to hostile and non-hostile environment. As defined in JAR OPS Part 3, a hostile environment means:

- An environment in which:
  - a safe forced landing cannot be accomplished because the surface is inadequate;
  - the helicopter occupants cannot be adequately protected from the elements;
  - search and rescue response/capability is not provided consistent with anticipated exposure; or
  - there is an unacceptable risk of endangering persons or property on the ground;
- In any case, the following areas are considered as hostile environment:
  - for overwater operations, the open sea areas north of 45N and south of 45S designated by the authority of the State concerned;
  - those parts of a congested area without adequate safe forced landing areas.

According to this description, accidents and serious incidents have been categorized and the evolution of this parameter is shown in the next figure.

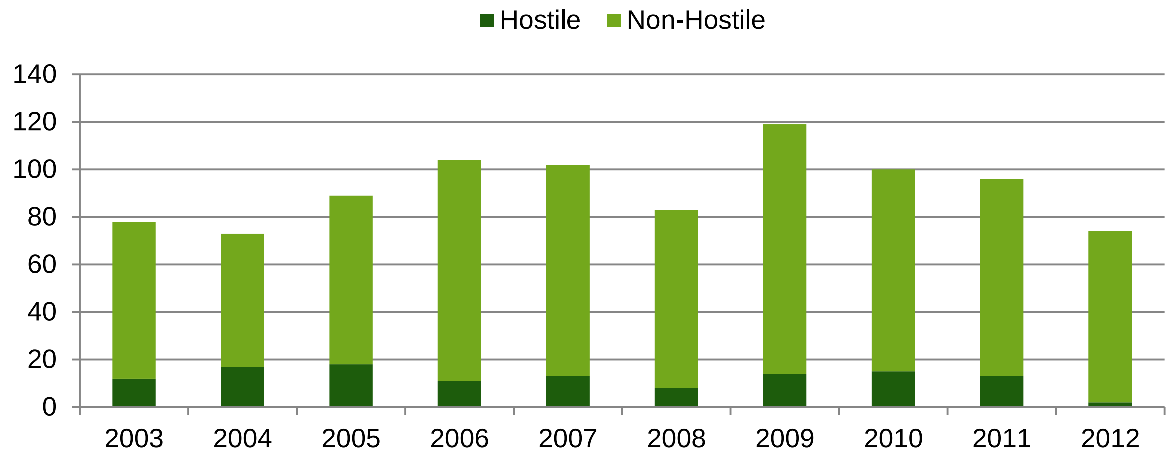


Figure 21: Accidents and serious incidents annual evolution per type of environment

On average, only 13% of the accidents and serious incidents occur in hostile environment, being this figure influenced for the specific regulations applied on helicopter operations for this type of environment. However, when comparing the level of fatal injury between hostile and non-hostile environment, results in a very different ratio, **with only 17% of fatal occurrences in non-hostile environment, but almost double percentage for hostile environment, 33% of the total accidents and serious incidents**.

Environment	Injury level		Total
	Fatal	Others	
Hostile	41	82	**123**
Non-Hostile	131	666	**797**
Total	172	748	**920**

Table 2: Accidents and serious incidents distribution and fatality per type of environment

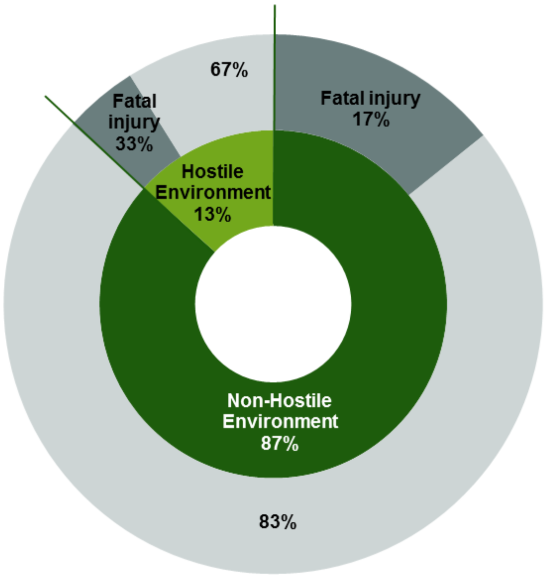


Figure 22: Accidents and serious incidents distribution and fatality share per type of environment

4.4 Analysis per flight conditions

This analysis includes both flight conditions (flight rules) and phases of flight.

4.4.1 Meteorological conditions

Helicopter is a mean of transport mainly associated to specific flight missions and conditions hardly impossible to develop with other type of aircraft. Due to its especial performance conditions, helicopters are basically operated under Visual Meteorological Conditions (VMC), and only a few rotorcrafts fly under Instrumental Meteorological Conditions (IMC). This is the main reason most of the accidents and serious incidents occur under visual conditions, as shown in the next figure.

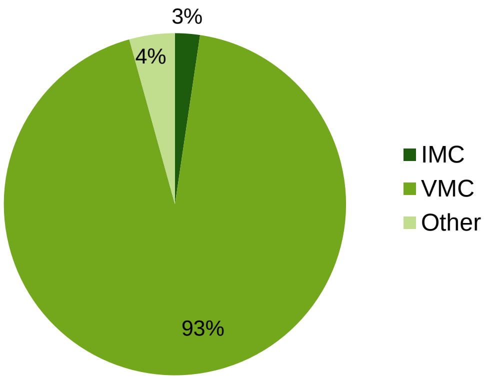


Figure 23: Accidents and serious incidents distribution per flight conditions

In this case, “Other” category only represents especial cases, while non-evaluated situations (more than 40% of the events) have not been considered for this analysis.

4.4.2 Phase of flight

Almost half (45%) of the accidents and serious incidents occur during the en route and manoeuvring phase of flight, while 30% of events had been recorded during approach and landing phase, 18% during take-off, and 8% during standing and taxing.

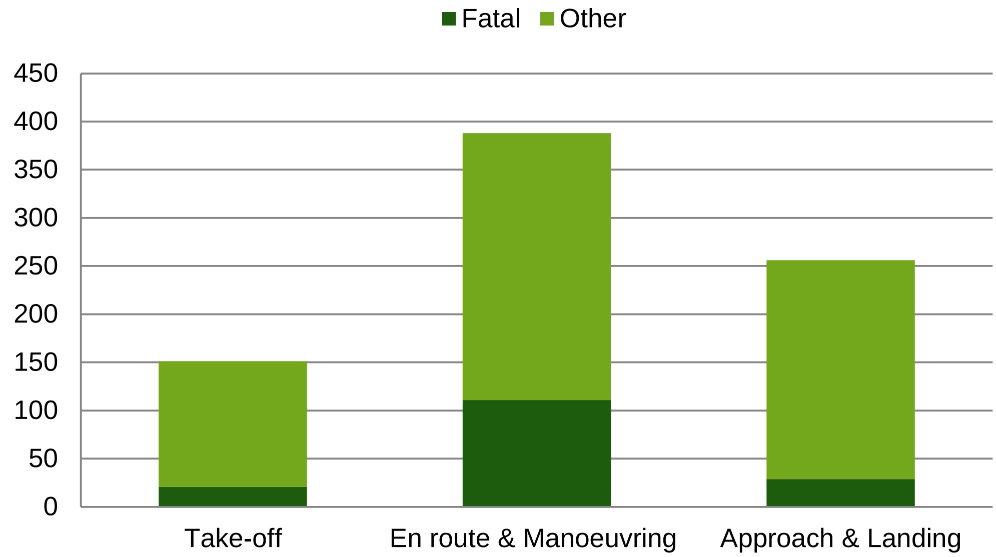


Figure 24: Accidents and serious incidents composition over the phase of flight

However the distribution of fatality within the different phases of flight is different, with en route and manoeuvring presenting a higher ratio comparing with take-off and approach & landing.

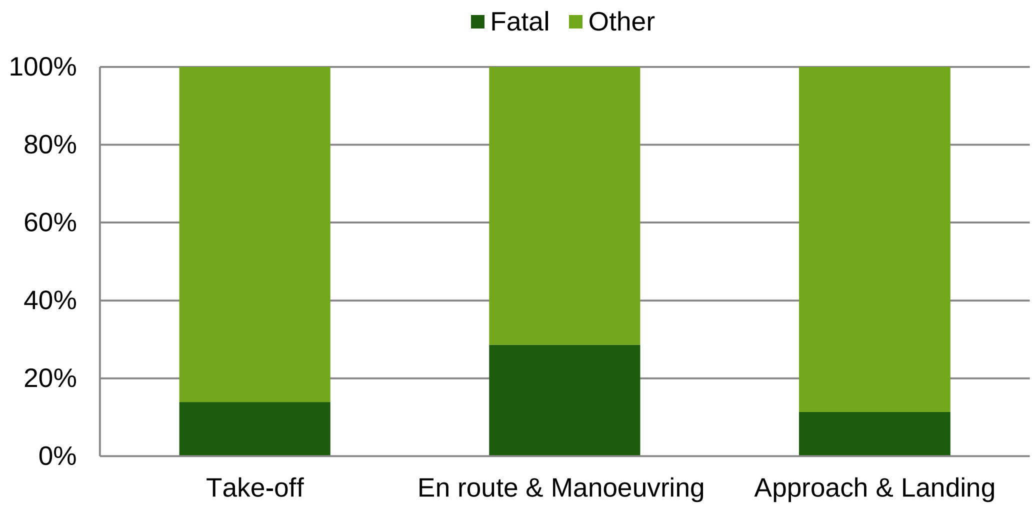


Figure 25: Fatal accidents and serious incidents rate per phase of flight

Then, when looking only at fatal occurrences, next figure, 69% of the fatal accidents and serious incidents occur during the en route and manoeuvring phases.

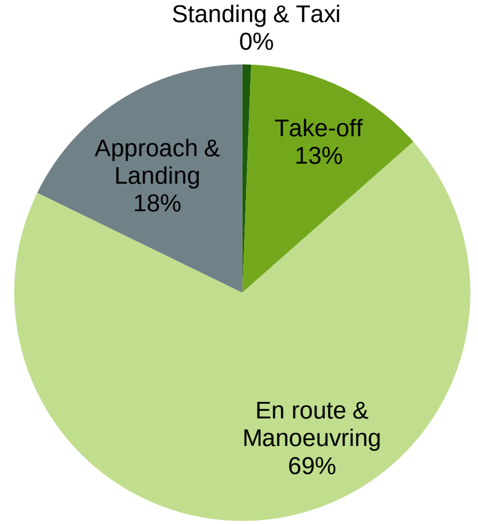


Figure 26: Fatal accidents and serious incidents distribution per phase of flight

Next bar charts present ratios of accidents and serious incidents per 100.000 FH during en route and manoeuvring by type of engine, and then (below) the other flight phases (Take-off and Approach & Landing).

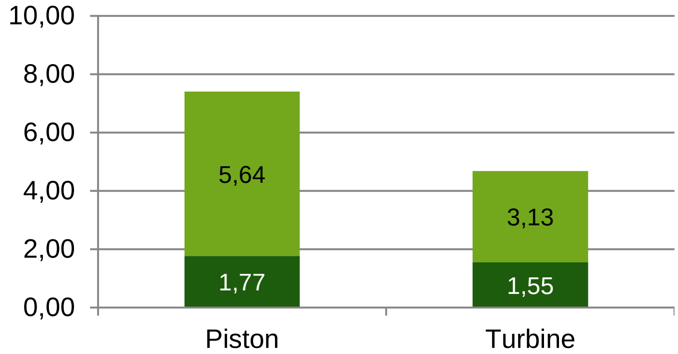


Figure 27: Accidents and serious incidents rate per 100.000 FH during En route & Manoeuvring by engine type

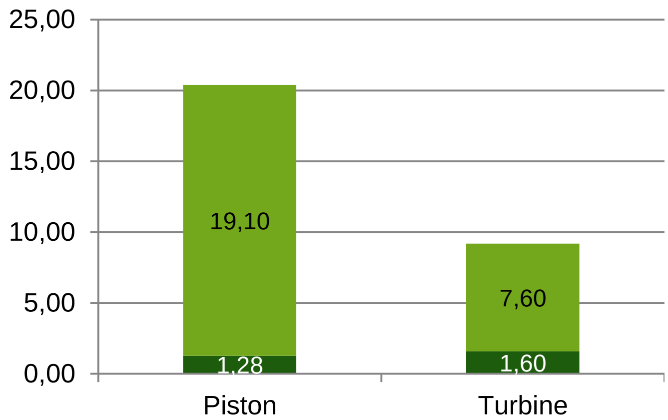


Figure 28: Accidents and serious incidents rate per 100.000 FH during Take-off and Approach & Landing by engine type

4.5 Analysis per rotorcraft age

The analysis of accidents and serious incidents per rotorcraft age has been performed according to 5-year groups up to 20 years, and the older aircraft. The following figure shows a heterogeneous evolution for each group, with non-standardized pattern for any of them.

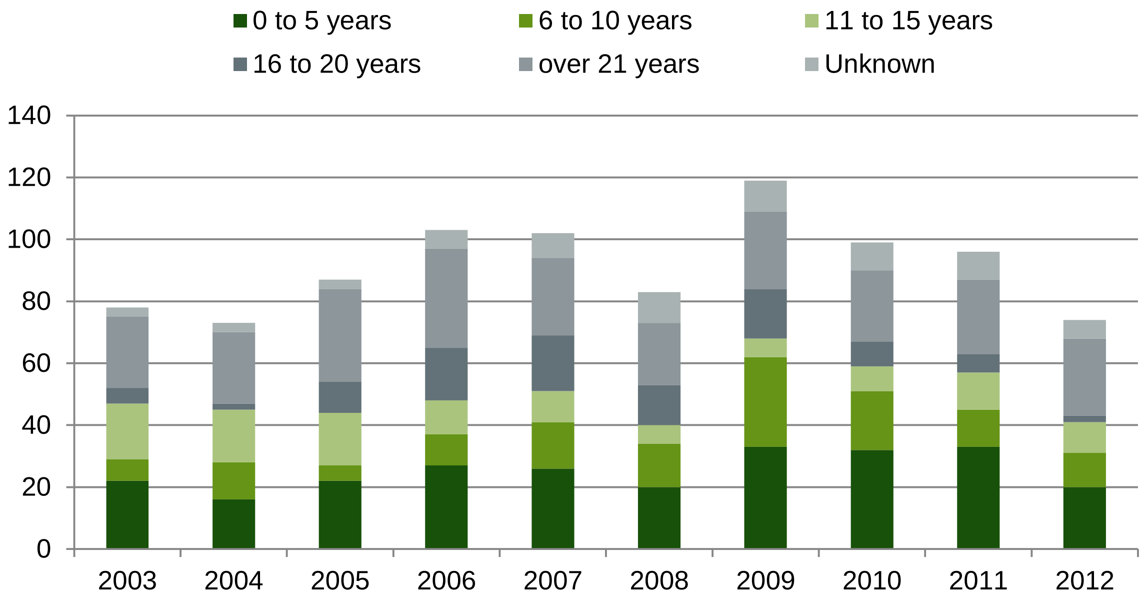


Figure 29: Accidents and serious incidents annual evolution per age group

The relative distribution of the results for the whole period of time is shown in the next figure.

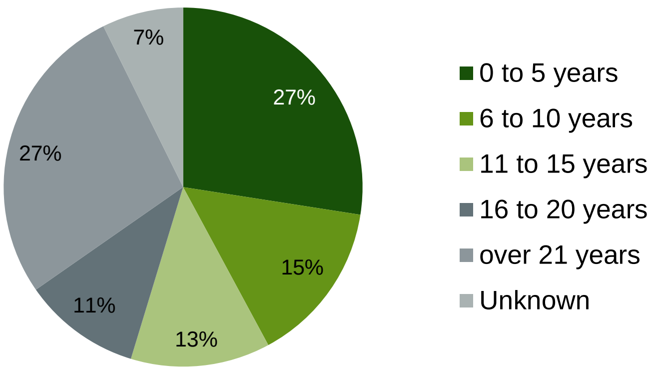


Figure 30: Accidents and serious incidents distribution per age group

The age of the helicopters at the date of the occurrence does not present significant conclusions. While helicopters from 0 to 5 years old have an important share of the total accidents and serious incidents, it is safe to say that new helicopters usually fly more often than the older ones. Additionally, helicopters older than 21 years also have an important contribution on the accidents and serious incidents, but this fact is influenced by issues like the use of this type of helicopter for high-risk aerial works (i.e. fire-fighting).

5 Multi-criteria analysis of accidents and serious incidents

This section aims to provide a better understanding of the accidents and serious incidents of single-engined helicopters, especially in hostile environment and under engine-related occurrences.

5.1 Hostile analysis by type of engine

When introducing the environment type in the analysis of the type of engine, following figure, the results show piston and turbine engined helicopters with a similar rate of fatality in hostile environment (over 32% of the total accidents and serious incidents respectively). At the same time, it can be observed a difference in the behaviour when comparing non-hostile occurrences, with turbine helicopters having a fatality rate higher than piston, but still both below the hostile environment events.

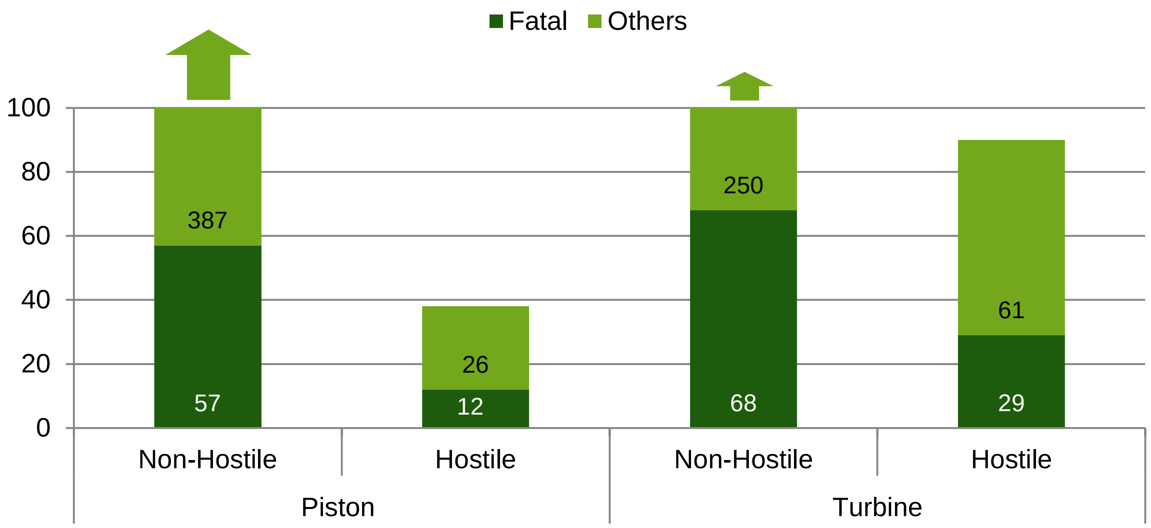


Figure 31: Accidents and serious incidents fatality share per type of engine and environment. Absolute number of occurrences

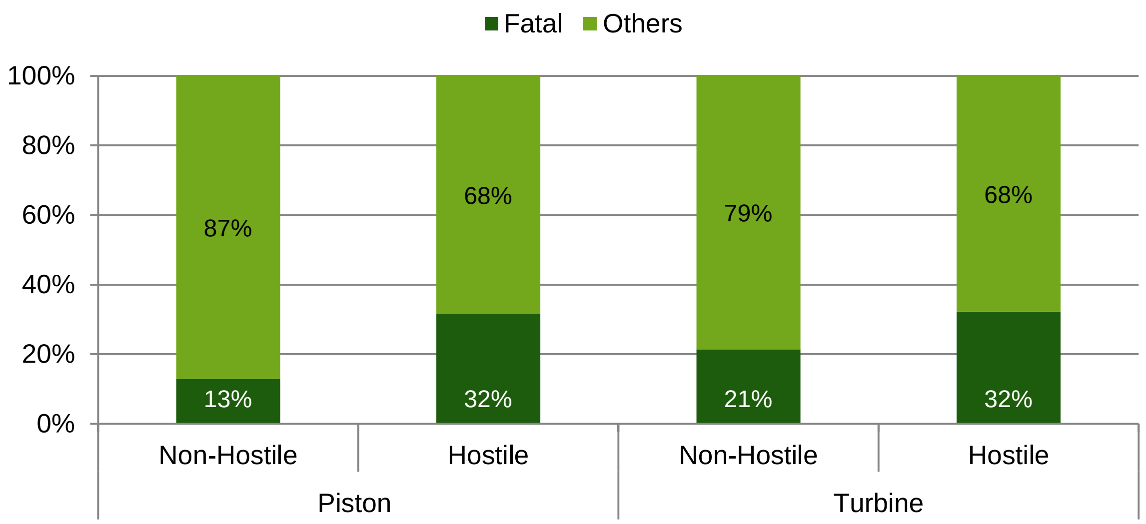


Figure 32: Accidents and serious incidents fatality share per type of engine and environment. Relative number of occurrences

5.2 Hostile analysis by type of operation

Three main types of operation have been analysed: Commercial Air Operations (CAT), Aerial Work and General Aviation. All these types present similar fatality rates, with hostile environment accidents and serious incidents at 30-35%, and non-hostile environment events at around 15-20%. Only CAT operations show a higher rate comparing with the other activities, when analysing non-hostile environment.

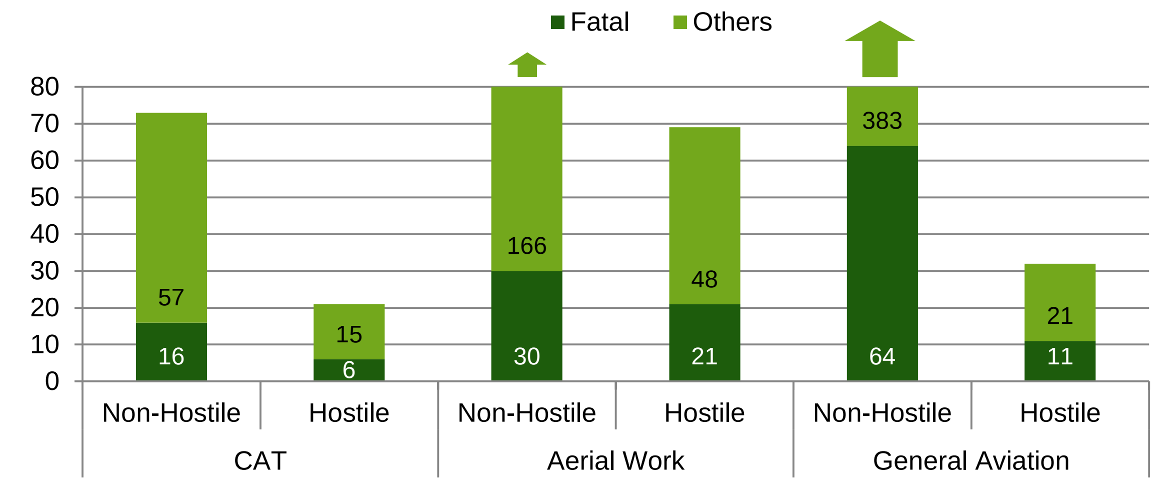


Figure 33: Accidents and serious incidents fatality share per type of operation and environment. Absolute number of occurrences

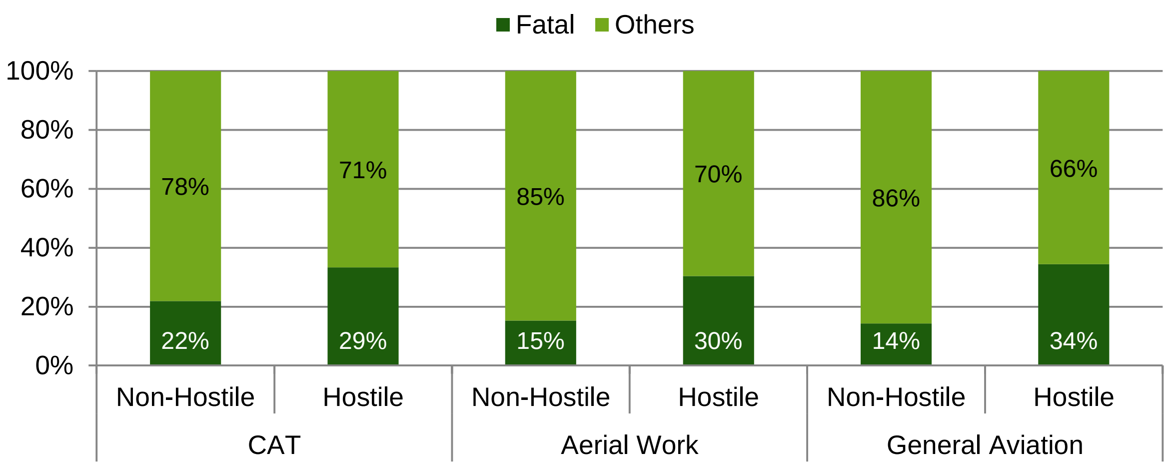


Figure 34: Accidents and serious incidents fatality share per type of operation and environment. Relative number of occurrences

5.3 Hostile analysis by type of engine and operation

The combination of both previous analyses in hostile environment, allows going a step forward in the study of accidents and serious incidents, thanks to the simultaneous analysis of these parameters:

- Type of engine
- Type of operation
- Type of environment
- Injure fatality

5.3.1 Commercial Air Transport

For Commercial Air Transport (CAT) operations, the analysis presents a 32% of fatal accidents and serious incidents for turbine-engined helicopters in hostile environment, almost double than the fatality ratio shows by non-hostile environment for both piston and turbine aircraft.

It is important to observe that there are not significant events in hostile environment with piston helicopters for Commercial Air Transport operations. Noteworthy those, according to standard JAR OPS Part 3, piston helicopters are not allowed to flight CAT operations in hostile environments.

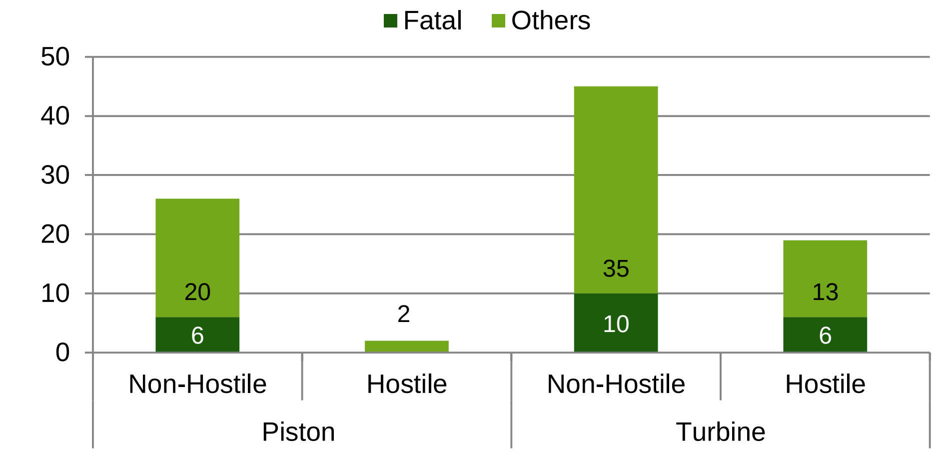


Figure 35: Accidents and serious incidents fatality share per type of engine and environment for CAT operations. Absolute number of occurrences

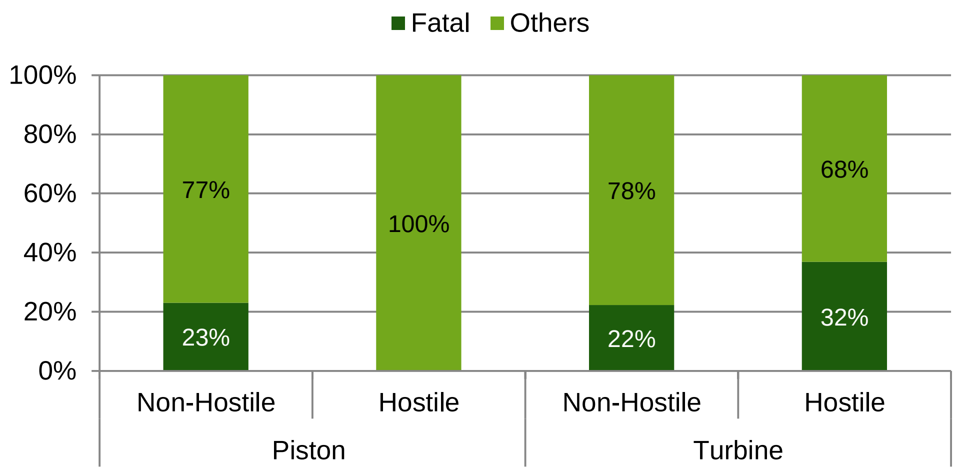


Figure 36: Accidents and serious incidents fatality share per type of engine and environment for CAT operations. Relative number of occurrences

<u>Commercial Air Transport – En route & Manoeuvring flight phase</u>

A detailed analysis of CAT operations during en route and manoeuvring flight phase shows a fatality rate of 62% for turbine engine helicopters over hostile environment. This fatality percentage corresponds to a total of 5 occurrences, see next charts[4].

[4] Group of occurrences addressed by CAT.POL.H.420 and JAR.OPS 3.005(e).

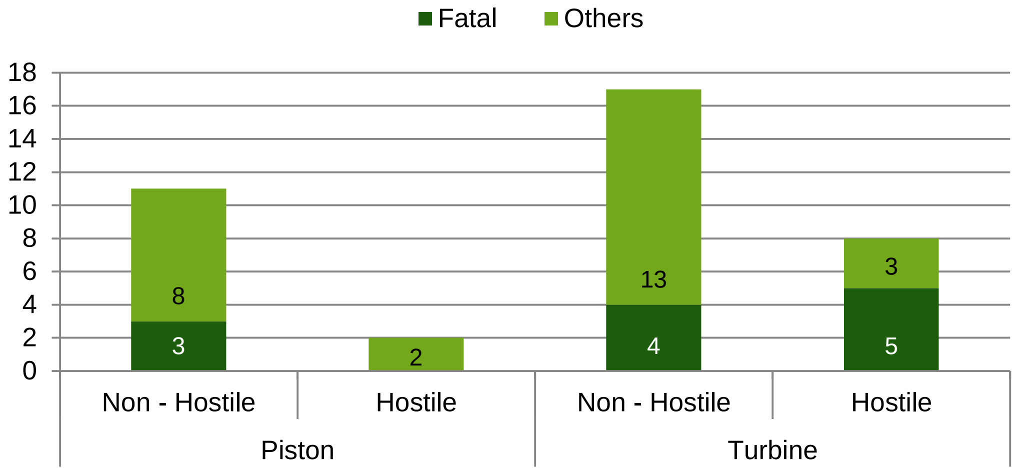


Figure 37: En route & manoeuvring accidents and serious incidents fatality share per type of engine and environment for CAT operations. Absolute number of occurrences

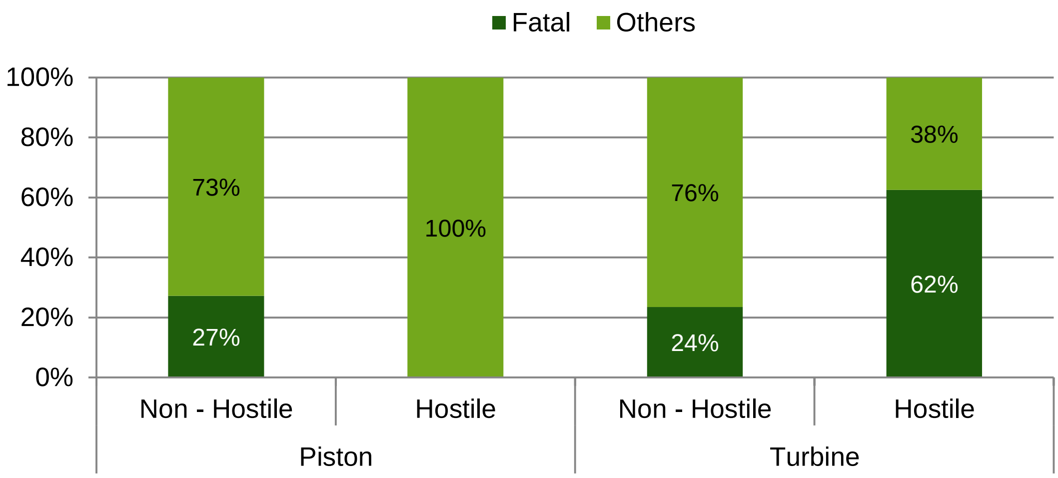


Figure 38: En route & manoeuvring accidents and serious incidents fatality share per type of engine and environment for CAT operations. Relative number of occurrences

It has been recorded 38 accidents and serious incidents of CAT operation during en route and manoeuvring phase, 8 of them occurred over hostile environment with fatality in 5.

The Appendix 2 includes a brief description of this 5 fatal occurrences and an evaluation of the impact of environment hostility. Most of the causes are due to a poor performance of procedures and bad weather conditions. In most cases the presence of a hostile environment does not affect the mortality because of the context of the impact limited the survival of passengers and crew.

5.3.2 Aerial Work and General Aviation

The next table represents the hostile environment analysis by type of engine and operation,

For Aerial Work (AW) operations, it shows the typical behaviour previously observed for the global database, with piston and turbine engined helicopters with a similar rate of fatality (around 30% of the total accidents and serious incidents) in hostile environment, then a lower rate for non-hostile operations, and finally a slightly unbalance situation per type of engine, with piston-engined rotorcraft showing a better ratio than the turbine ones.

For General Aviation (GA) operations, next table also shows the typical behaviour previously observed for the global database –as they represent the most important share of the events–, with piston and turbine engined helicopters with a similar rate of fatality (around 30-40% of their accidents and serious incidents) in hostile environment, then a lower rate for non-hostile operations (around 10-20%), and finally a slightly unbalance situation per type of engine, with piston-engined crafts showing a better ratio than turbine ones.

Type of operation	Piston-engined		Turbine-engined	
	Non-Hostile	Hostile	Non-Hostile	Hostile
Commercial Air Transport	6 fatal occurrences over 26 total occurrences (23% of fatality)	0 / 2 (0%)	10 / 45 (22%)	6 / 19 (32%)
Aerial Work	5 / 54 (9%)	3 / 11 (27%)	24 / 139 (17%)	18 / 58 (31%)
General Aviation	43 / 340 (13%)	7 / 22 (32%)	19 / 91 (21%)	4 / 10 (40%)
Total	**57 / 444 (13%)**	**12 / 38 (32%)**	**68 / 318 (21%)**	**30 / 90 (33%)**

Table 3: Fatality comparison of accidents and serious incidents per type of engine and environment

It is clear the intrinsic hazard of the hostile environment in this table for all the different types of operations, for both piston and turbine engined helicopters.

The next table represents the hostile environment analysis by type of engine and operation during en route and manoeuvring phase of flight. While fatalities on Aerial Work (AW) operations over hostile environment follows the general trend, around 30%, the fatality rate for General Aviation (GA) operations is notably higher (56% on piston engine and 75% on turbine engine).

Type of operation	Piston-engined		Turbine-engined	
	Non-Hostile	Hostile	Non-Hostile	Hostile
Commercial Air Transport	3 fatal occurrences over 11 total occurrences (27% of fatality)	0 / 2 (0%)	4 / 17 (24%)	5 / 8 (62%)
Aerial Work	5 / 40 (13%)	3 / 10 (30%)	18 / 69 (26%)	12 / 36 (33%)
General Aviation	28 / 114 (25%)	5 / 9 (56%)	11 / 29 (38%)	3 / 4 (75%)
Total	**37 / 174 (21%)**	**10 / 23 (43%)**	**41 / 136 (30%)**	**22 / 51 (43%)**

Table 4: Fatality comparison of en route & manoeuvring accidents and serious incidents per type of engine and environment

5.4 Engine related analysis by type of engine

Engine related[5] events are those accidents and serious incidents in which an engine related cause has been identified, like general power plant failure, engine component failure, engine oil starvation, etc. The next

[5] When there was not an available report, an occurrence is defined as engine related according to ADREP 2000 standard as defined by ICAO and implemented in version 4.2.6 of ECCAIRS, Section: Attribute values, Id.430, Occurrence category. When the occurrence report was available, causes had been analysed by expert judgment to define it as engine related.

figure shows this type of situation per type of engine, with **similar results for both piston and turbine power plant, but slightly higher for piston-engined helicopters** (16% versus 12%).

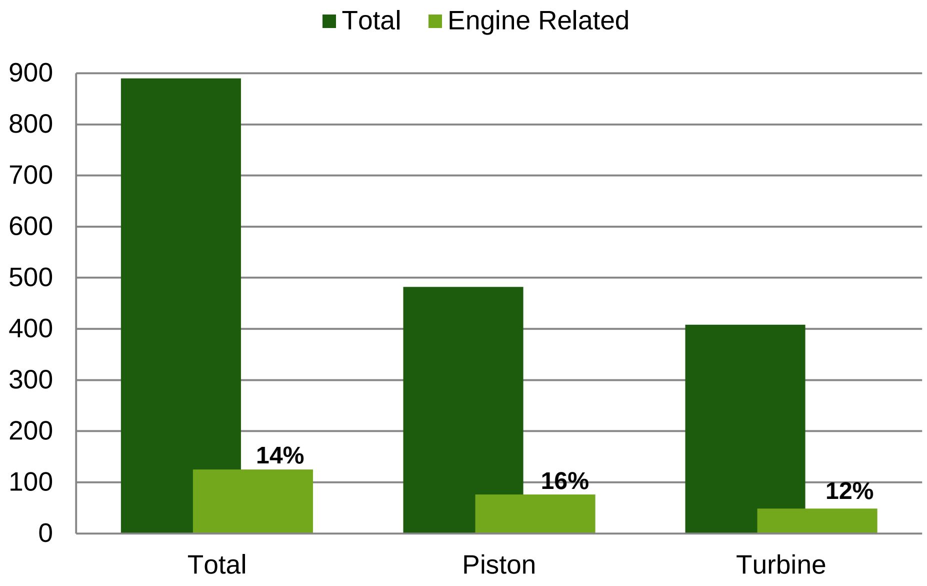


Figure 39: Engine related accidents and serious incidents per type of engine

The relative number of these engine related occurrences is very influenced by the type of engine when related to Flight Hours: the proportion shows an important difference between single engine accident rate for piston and turbine, with piston rate 2,33 times the turbine rate. As the figure shows, the difference between piston and turbine rates is greater in engine related occurrences than respect to total occurrences per 100.000 FH.

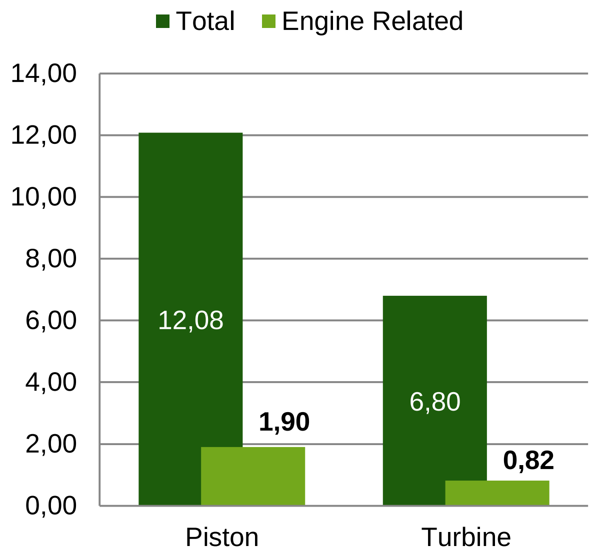


Figure 40: Engine related accidents and serious incidents rate per 100.000 FH by engine type

When also looking at the type of environment, the results of the analysis differ over the type of engine. As observed in the next figure composition, 20% of the engine related accidents and serious incidents with turbine engined helicopters involved occur in hostile environment, while only 7% in the case of piston helicopters (12% in average for the total events).

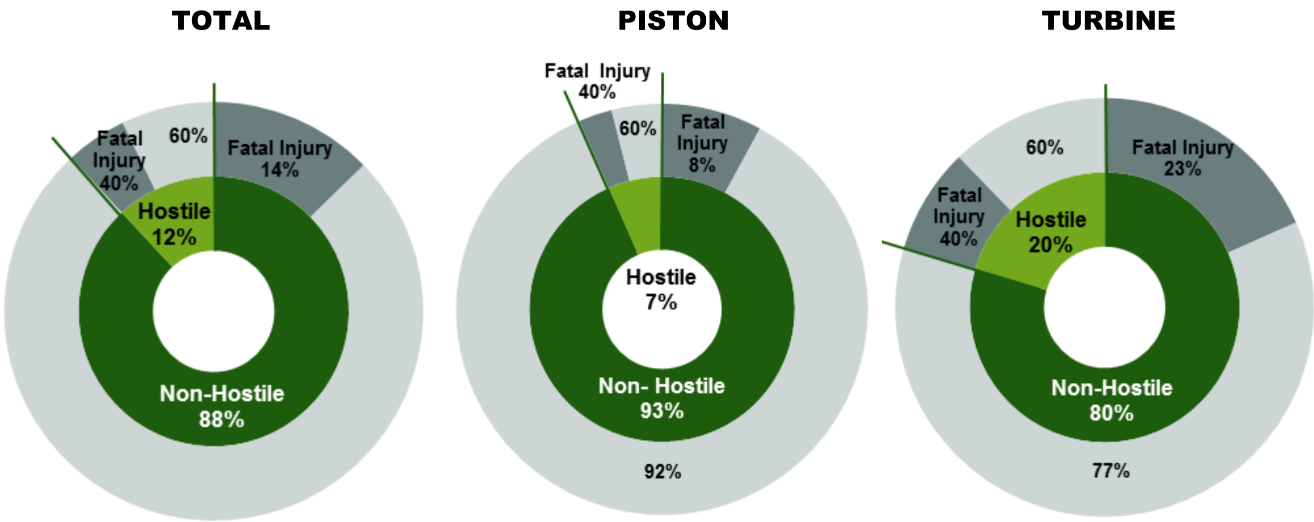


Figure 41: Engine related accidents and serious incidents distribution and fatality share per type of environment and engine

This figure above also shows the fatality rates for the different type of environment and engine. Comparing with the analysis performed in section 4.3 – Analysis per type of environment, the total figure shows similar behaviour for both engine related events and other events, with a 17-14% of fatal injury occurrences in non-hostile environment. The difference is more pronounced in the case of hostile environment (33% of total accidents and serious incidents over 47% of engine related occurrences).However, when looking to the type of engine, these ratios change significantly, with turbine helicopters presenting higher figures than piston helicopters in non-hostile environment:

- Non-hostile environment: 23% for turbine versus 8% for piston (x 2,9 times)
- Hostile environment: 40% for turbine versus 40% for piston

This analysis demonstrates a **significant higher fatality rate for engine related events of turbine versus piston engined helicopters**, both in hostile and non-hostile environment. However, <u>it should be noted that the number of engine related events evaluated are very small</u>.

5.5 Engine related analysis by type of engine and operations

This study has a similar approach to the hostile analysis by type of engine and operation previously done, by highlighting the engine related situations.

Then, this analysis of accidents and serious incidents is a combination of these simultaneous parameters:

- Type of engine
- Type of operation
- Type of environment
- Injure fatality

5.5.1 Commercial Air Transport

For Commercial Air Transport (CAT) operations, the number of relevant events is very small, so it is not possible to ensure the reliability of the results of this analysis.

Anyway, the following figure presents a 33% of fatal occurrences for turbine helicopters operating in hostile environment, 25% for turbine in non-hostile. No available date for piston helicopters in hostile environment and no fatal occurrences in non-hostile environment.

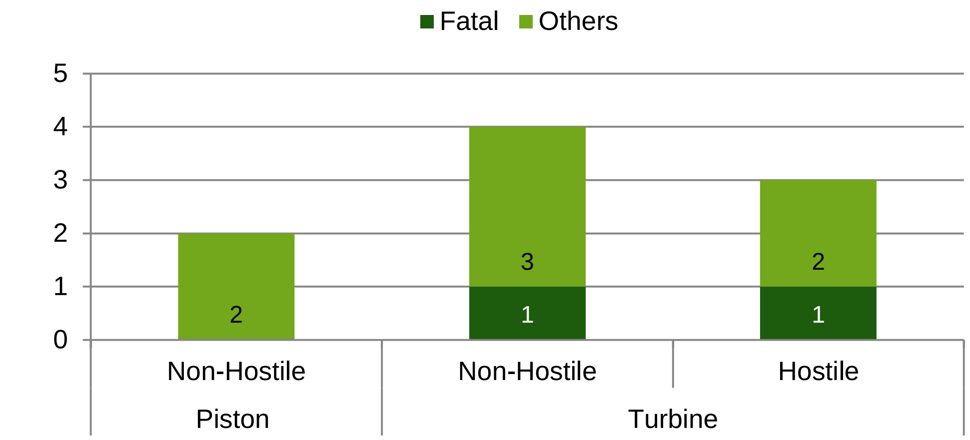


Figure 42: Engine related accidents and serious incidents fatality share per type of engine and environment for CAT operations. Absolute number of occurrences

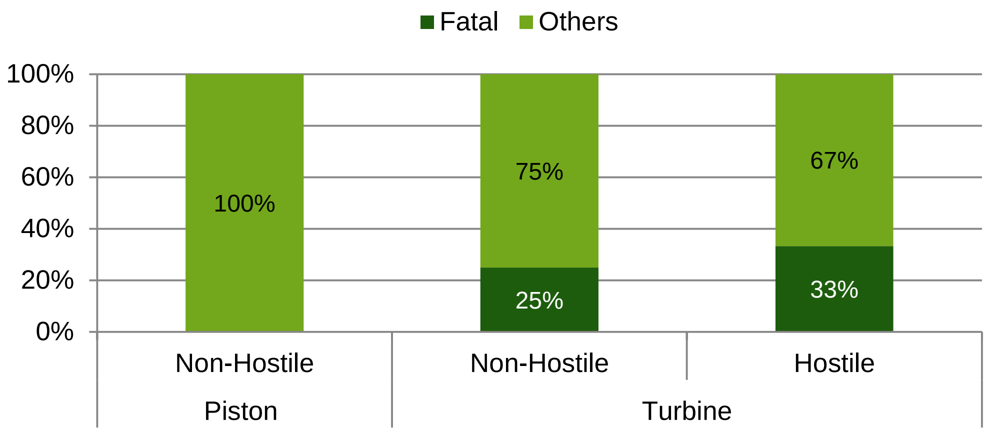


Figure 43: Engine related accidents and serious incidents fatality share per type of engine and environment for CAT operations. Relative number of occurrences

Commercial Air Transport – En route & Manoeuvring flight phase

As it is shown in next figures, 1 fatal occurrence for turbine helicopters operating in hostile environment occur during en route flight phase. The description of the event could be found on Appendix 2. The cause of the crash was due to engine failure and poor procedural response, the type of environment did not affect in the damage.

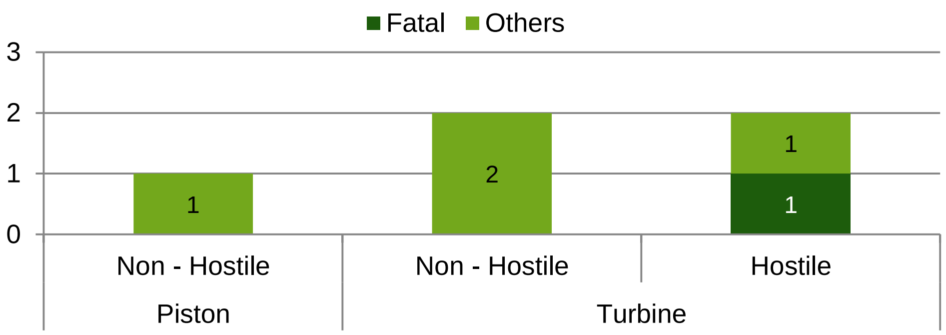


Figure 44: En route & manoeuvring engine related accidents and serious incidents fatality share per type of engine and environment for CAT operations. Absolute number of occurrences

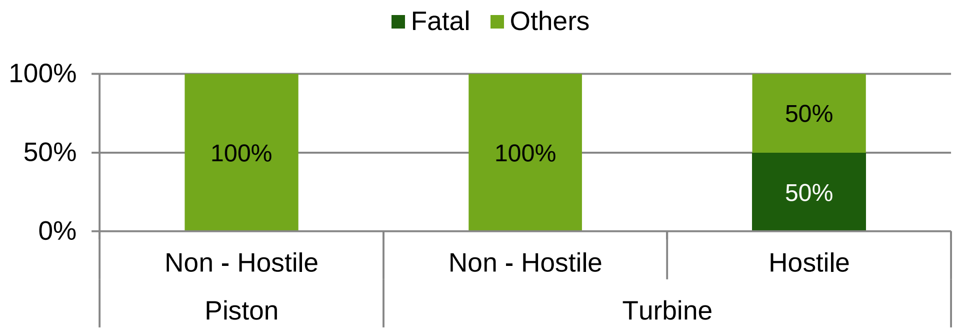


Figure 45: En route & manoeuvring engine related accidents and serious incidents fatality share per type of engine and environment for CAT operations. Relative number of occurrences

5.5.2 Aerial Work and General Aviation

The next table represents the engine related analysis by type of engine and operation.

For Aerial Work (AW) operations, the situation is different to CAT operations, with no fatal engine related accidents and serious incidents for piston helicopters, but a fatality ratio of 22% for turbine non-hostile operations and 43% for hostile environment.

For General Aviation (GA) operations, the behaviour changes, with almost no fatal events for turbine helicopters, but a fatality ratio of 8% for piston non-hostile operations and 67% for piston engined hostile environment. It is important to observe that the small number of events do not allow to present clear conclusions regarding engine related events, showing the different analysis a high level of dispersion.

Type of operation	Piston-engined		Turbine-engined	
	Non-Hostile	Hostile	Non-Hostile	Hostile
Commercial Air Transport	**0 fatal occurrences over 2 total occurrences (0% of fatality)**	**0 / 0 (-)**	**1 / 4 (25%)**	**1 / 3 (33%)**
Aerial Work	0 / 11 (0%)	0 / 2 (0%)	4 / 17 (22%)	3 / 7 (43%)
General Aviation	4 / 49 (8%)	2 / 3 (67%)	1 / 10 (10%)	0 / 0 (-)
Total	**6 / 71 (8%)**	**2 / 5 (40%)**	**9 / 39 (23%)**	**5 / 10 (50%)**

Table 5: Fatality comparison of engine related accidents and serious incidents per type of engine and environment

The next table represents the hostile environment and engine related analysis by type of engine and operation during en route and manoeuvring phase of flight. Again, it should be noted the small number of occurrences recorded throughout the 10 years studied. While fatalities on Aerial Work (AW) operations over hostile environment are concentrated in turbine-engined (36% in non-hostile environment and 40% in hostile environment), the fatality rate for General Aviation (GA) operations appears only in piston-engined (10% on non-hostile environment).

Type of operation	Piston-engined		Turbine-engined	
	Non-Hostile	Hostile	Non-Hostile	Hostile
Commercial Air Transport	0 fatal occurrences over 1 total occurrences (0% of fatality)	0 / 0 (-)	0 / 2 (0%)	1 / 2 (50%)
Aerial Work	0 / 10 (0%)	0 / 0 (-)	4 / 11 (36%)	2 / 5 (40%)
General Aviation	3 / 30 (10%)	0 / 1 (0%)	0 / 3 (0%)	0 / 0 (-)
Total	**4 / 45 (9%)**	**0 / 3 (0%)**	**6 / 21 (29%)**	**4 / 7 (57%)**

Figure 46: Fatality comparison of en route & manoeuvring engine related accidents and serious incidents per type of engine and environment

6 Factor identification of accidents and serious incidents

The factor identification analysis aims at identifying all factors, casual or contributory, that played a role in each occurrence. Factors and causes are coded according to Standard Problem Statements (SPS) and Human Factors Analysis and Classification System (HFACS) enforcing EHSAT methodology patterns. The code structure consists of three levels, but the discussion of the results in this report is mainly focused on the highest and medium levels (level 1, level 2).

Final factor identification database was composed by a 503 occurrences documented with a state report.

6.1 General factor analysis

6.1.1 General SPS analysis

As next figures present in relation with high level code (level 1), the area identified in almost 76% of the database occurrences is Pilot judgment & actions followed by Safety Management with 48%. The same trend is also observed in the majority of causes identified for Commercial Air Transport. However, the percentage of Pilot Judgment & Actions is more common and it is found in 86% of accidents. Another noteworthy aspect is seen in the causes Ground Duties and Pilot situation awareness which percentage are present in around 50% of CAT occurrences.

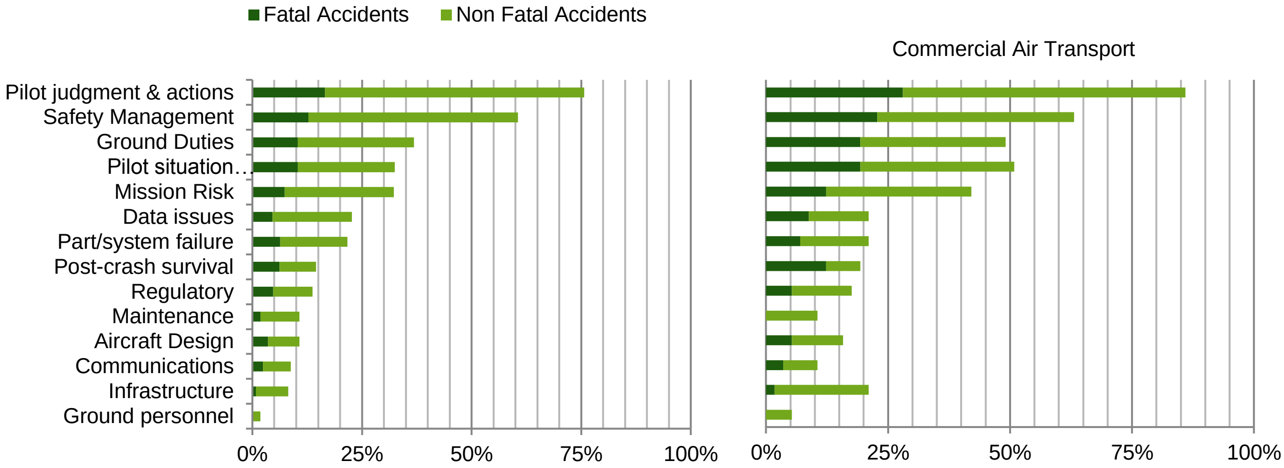


Figure 47: Percentage of TOTAL (left) and CAT (right) occurrences in which SPS category at level 1 was identified at least once

Analyzing the main causes of the second level, the percentages of occurrence are lower due to the greater number of existing codes. The most identified area is Human Factors - Pilots Decision (40%), followed by Inadequate Pilot Experience (38%), Mission planning (31%), Procedure Implementation (31%) and Flight Prolife (29%). The perceptual distribution in CAT category do not follow the same order, despite presenting higher percentage in the main cause Pilot judgment & actions (61%), Inadequate Pilot Experience cause is lower (30%). Note that most of them belong to level 1 area: "Pilot Judgments & actions".

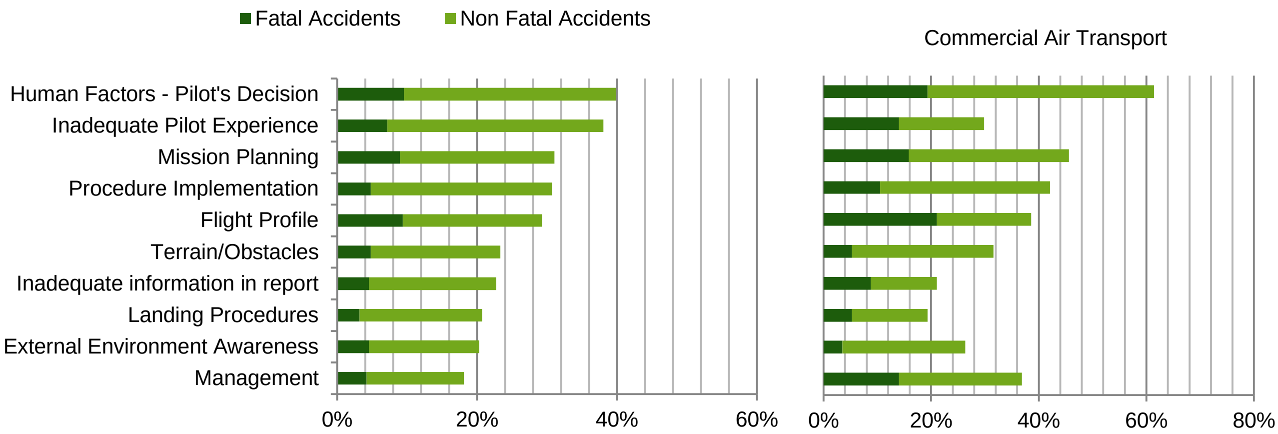


Figure 48: Percentage of TOTAL (left) and CAT (right) occurrences in which SPS category at level 2 was identified at least once

6.1.2 General HFACS analysis

As next figures present in relation with high level code (level 1), the main HFACS area identified is Unsafe Acts – Errors in the 55% of the occurrences followed by Preconditions – Condition of individuals (34%). The remaining areas are count in less than 20% of the occurrences.

In Commercial Air Transport, Unsafe Acts – Errors and Preconditions – Condition of individuals' causes are accounted in the 40% of the occurrences, Preconditions – Environmental Factors stands in third place with 26%.

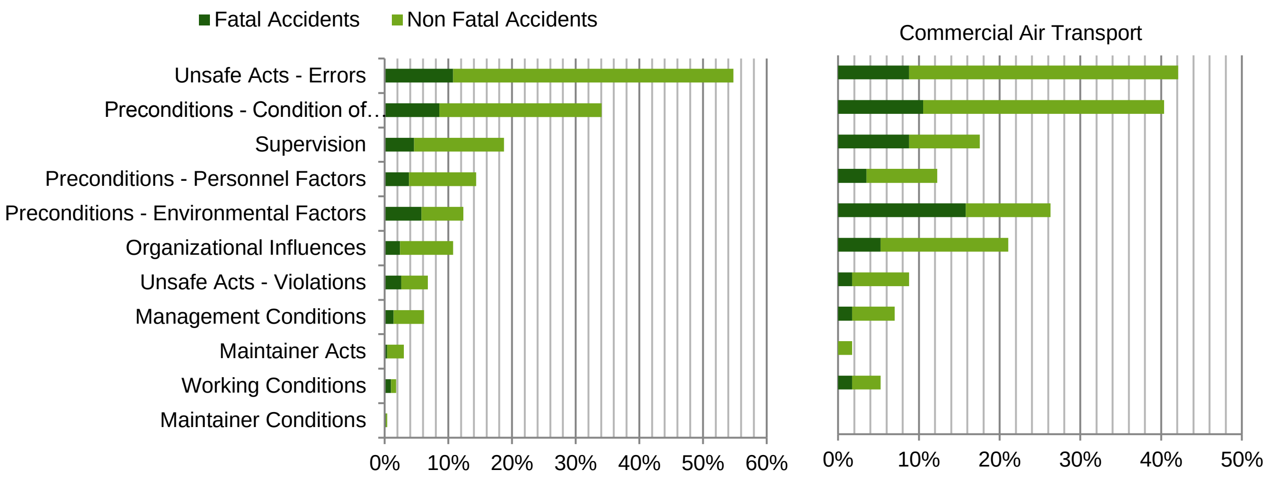


Figure 49: Percentage of TOTAL (left) and CAT (right) occurrences in which HFACS category at level 1 was identified at least once

Analysing the details of the causes of the second level, Judgement & Decision-Making Errors is the main cause recorded (35%). The second most identified area (26% of the accidents and serious incidents) is Skill-based Errors. The perceptual distribution in CAT presents notable differences. Judgement & Decision-Making Errors remains the main cause but In a fewer number of accidents issues related to Skill-based Errors influences were captured.

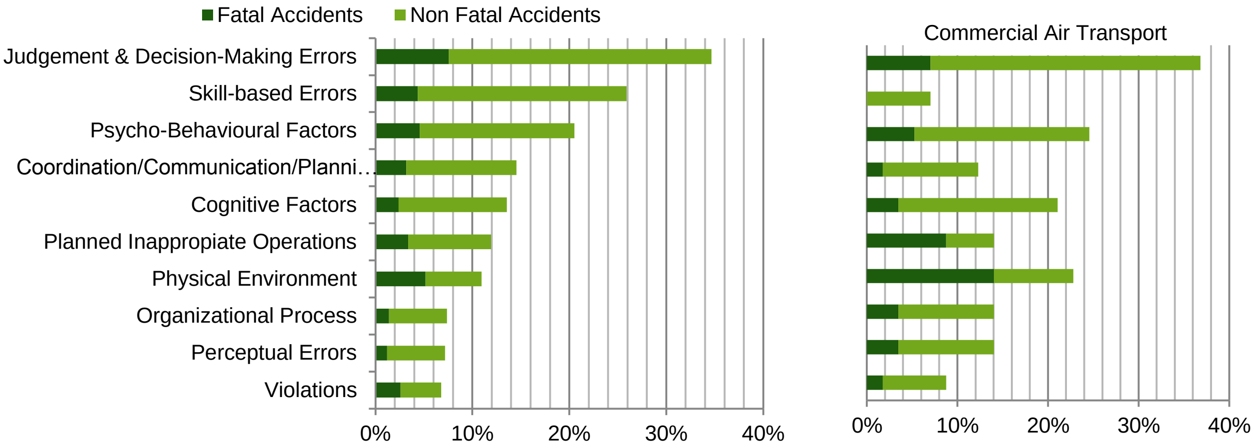


Figure 50: Percentage of TOTAL (left) and CAT (right) occurrences in which HFACS category at level 2 was identified at least once

6.2 Factor identification per type of operation

In order to detail the analysis in relation to the type of operation the following tables list the main causes of Commercial Air Transport (CAT), Aerial Work and General Aviation.

6.2.1 Commercial Air Transport

A total of 57 helicopter accidents in the database concern Commercial Air Transport operations. The most causes are related to errors in the cockpit due to both failures on procedural execute or pyscho-behavioral factors.

SPS - level 2	HFACS - level 2
Visibility/Weather	Coordination/Communication/Planning Factors
External Environment Awareness	Perceptual Errors
Inadequate Pilot Experie1nce	Organizational Process
Terrain/Obstacles	Planned Inappropriate Operations
Management	Cognitive Factors
Flight Profile	Physical Environment
Procedure Implementation	Psycho-Behavioral Factors
Mission Planning	Judgment & Decision-Making Errors
Human Factors - Pilot's Decision	

Table 6. Main SPS & HFACS level 2 codes in Commercial Air Transport

6.2.2 Aerial Work

A total of 137 helicopter accidents in the database concern Aerial Work operations. Using a helicopter for such purpose can result in pushing the helicopter and pilot towards the limits of their capabilities. These aspects and the existence of objects or obstacles that hinder the mission are often the principal causes of the accident.

SPS - level 2	HFACS - level 2
Human Factors - Pilot's Decision	Human Factors - Pilot's Decision
Management	Management
Flight Profile	Flight Profile
External Environment Awareness	External Environment Awareness
Mission Planning	Mission Planning
Terrain/Obstacles	Terrain/Obstacles

Table 7. Main SPS & HFACS level 2 codes in Aerial Work

6.2.3 General Aviation

A total of 280 helicopter accidents in the database concerned General Aviation operations. In the case of general aviation, the factors are related to crew and pilot skill and non-proper procedure implementations.

SPS - level 2	HFACS - level 2
Mission Planning	Planned Inappropriate Operations
Flight Profile	Coordination/Communication/Planning Factors
Procedure Implementation	Cognitive Factors
Human Factors - Pilot's Decision	Psycho-Behavioral Factors
Inadequate Pilot Experience	Skill-based Errors
	Judgment & Decision-Making Errors

Table 8. Main SPS & HFACS level 2 codes in General Aviation

7 Assessment of Operating Conditions

In this part of the study, the operating conditions are reviewed as allowed by EASA Member States for commercial air transport of helicopters over hostile environment located outside a congested area. It focuses on the use of the variations that are allowed, but subject to a special approval, as per JAR-OPS 3.005(e) and the associated Appendix 1.

7.1 Operating Conditions and JAR-OPS 3.005(e)

This section introduces the operating conditions allowed by EASA Member States, especially in terms of JAR-OPS 3.005(e) circumstances, and its implementation status.

7.1.1 Essence of JAR-OPS 3.005(e)

According JAR-OPS 3, commercial air transport operation of single-engined helicopters shall only be conducted along such routes or within such areas for which surfaces are available which permit a safe forced landing to be executed.

JAR-OPS 3 allows an exception to this rule, under the following conditions:

- the engine of the helicopter is a turbine engine;
- the operation is outside congested area (but over hostile environment);
- the maximum approved seating passenger capacity is six or less;
- the operator substantiates that helicopter limitations, or other justifiable considerations, preclude the use of the appropriate performance criteria (i.e. a risk assessment);
- the operator reports engine failures to the Type Certificate holder;
- prior approval is obtained from the state issuing the AOC;
- prior approval is obtained from the state of operations, if different from state issuing the AOC;
- the operator complies with a set of conditions for such operations;
- the operator has specific procedures in the Operations Manual for power failure during take-off and landing;
- the operator has implemented a Usage Monitoring System.

This exception is regulated in JAR-OPS 3.005(e) and Appendix 1 to JAR-OPS 3.005(e).

7.1.2 Evolution of JAR-OPS 3.005(e)

The provisions of JAR-OPS 3.005(e) and the associated Appendix were introduced in Change 1 of JAR-OPS 3, dated 1 February 1999. It was a result of JAA NPA-OPS-8, which itself, for the present subject, was preceded by discussions in the JAA Operations Committee in 1996 centring on allowing a deviation from the safe forced landing requirement for operations of helicopters in mountainous areas[6]. The intent was to continue to allow such operations which were conducted at the time in JAA Member States, even though not in compliance with the ICAO standard applicable at the time[7]. That standard required that performance class 3 operations only be conducted over such routes which permit a safe forced landing in case of engine failure. NPA-OPS-8 introduced a deviation to that standard provided a safety level is maintained, expressed in an engine failure rate better than $1*10^{-5}$ per flight hour.

It should be noted that ICAO Annex 6 has changed since[8] and now allows performance class 3 operations without the safe forced landing assurance when substantiated by a risk assessment.

[6] Notes of JAA Operations Committee Meeting OC 96/3, 96/6, 96/7

[7] Annex 6, Part III, Chapter 3: '3.1.2 Performance Class 3 helicopters shall only be operated in conditions of weather and light and over such routes and diversions therefrom, that permits a safe forced landing to be executed in the event of engine failure.'

[8] With Amendment 12, issued in 2007

In 2006, JAA issued NPA-OPS-38. With respect to 3.005(e) this NPA proposed a simplification for operators with respect to the set of conditions for the operations, particularly in the area of demonstrating that the safety level is maintained. The NPA resulted in amendment 5 of JAR-OPS 3. This is the latest and current amendment of JAR-OPS 3 and formed the basis for the regulations of Part-CAT of Implementing Rule Air Operations (Commission Regulation 965/2012).

The IEM to Appendix 1 explains the following about Appendix 1 to JAR-OPS 3.005(e):

> 1 The subject Appendix has been produced to allow a number of existing operations to continue. It is expected that the alleviation will be used only in the following circumstances:
>
> > 1.1 Mountain Operations; where present generation multi-engined aircraft cannot meet the requirement of Performance Class one or two at altitude.
> >
> > 1.2 Operations in Remote Areas; where existing operations are being conducted safely; and where alternative surface transportation will not provide the same level of safety as single-engined helicopters; and where, because of the low density of population, economic circumstances do not justify the replacement of single-engined by multi-engined helicopters (as in the case of remote arctic settlements).

In Part CAT, 3.005(e) has been transposed as CAT.POL.H.420. The text has essentially remained the same.

Sweden, supported by Switzerland, asked EASA in 2008 to remove the discrimination between turbine and piston engined helicopters and allow both on the basis that they have the same level of reliability[9].

Since, the EASA rulemaking programme contains a task for updating this paragraph, as follows:

> *RMT.0319/OPS.049 – Review of the Implementing Rules in order to set non-discriminatory requirements for operations over hostile environment and not allow only one technology (turbine engines).*

This task is currently in the pre-Terms of Reference stage and is scheduled to start in 2014.

7.1.3 Implementation of JAR-OPS 3.005(e) in Member States

JAR-OPS 3, being a JAA set of standards, is not automatically binding in all EASA Member States, but needs adoption in local regulations on a state-by-state basis. Many Member States have adopted JAR-OPS 3, but not all at the same amendment level. The latest amendment of JAR-OPS 3 is amendment 5, which was issued by the JAA on 1 July 2007.

On 10 October 2007, the JAA published the last version of the Mutual Recognition list. This list indicates JAA Member States which have been visited under the OPST programme and which have been found to have implemented JAR-OPS 3.

The consortium has approached a number of states to determine the status of implementation of JAR-OPS 3. In addition, the consortium specifically asked about whether or not the state issued approvals as per 3.005(e), by asking the following questions using a questionnaire:

- Does the member state allow single-engined helicopter operations over hostile environment outside congested areas;
- What specific continuing airworthiness conditions apply;
- What specific training and operational procedures apply to mitigate the consequences of the critical engine failure;
- Has the state transposed ICAO Annex 6 risk assessment conditions if not done via JAR-OPS 3;
- What risk mitigation strategies are in place for single engine helicopter operations over a hostile environment?
- Which technological improvements or legislative amendments would have a positive impact on flight safety regarding single engine helicopter operations over hostile environment;
- If an approval is issued, what proportion of helicopter operations is subject to that approval?

In addition, the consortium made telephone interviews with a number of state experts on helicopter operations.

[9] AGNA minutes 2nd meeting 2008.

7.1.4 Selection of States Canvassed

The technical proposal contained a selection of states to be canvassed. This selection was based on two determinants: (1) Representing a significant number of helicopters[10]; (2) Distribution over the various regions.

This resulted in the following proposed selection of states:

Area	States
Northern Europe	Finland or Sweden
Central Europe	Germany
Western Europe	France, the Netherlands and/or UK
Southern	Spain
Eastern	Hungary
EEA/EFTA State	Switzerland

Table 9: Proposed Selection of States

This list gives two regions where options were offered:

- for Northern Europe: Finland or Sweden. Initially, Finland was approached, not Sweden;
- for Western Europe: France, the Netherlands and/or UK. Initially, the Netherlands and the UK were approached, but not France.

As the study progressed, information was obtained from EASA on states that reportedly applied the provision of 3.005(e). That information is based on Standardization Inspection Reports and State Conversion Reports. In anticipation of the conversion from JAR-OPS 3 to Implementing Rule Air Operations (Commission Regulation 965/2012), EASA is canvassing Member States as to their current level of implementation of JAR-OPS 3. One of the questions is whether or not use is made of the provisions of JAR-OPS 3.005(e). The information supplied by EASA indicates that out of sixteen states so far canvassed ('EASA 16'), only two use that provision. These states are France and Sweden.

Another source (Eurocopter) indicates that two additional states, not belonging to the EASA 16 use this provision as well (Switzerland and Italy) plus one state that does belong to the EASA 16 list and for which the conversion report says it does not use this provision: Finland.

Switzerland was already in the list of states approached. France and Sweden were added, prompted by the information supplied by EASA. The information supplied by France and Switzerland indicate that they make a significant use of the provision of 3.005(e) (or equivalent), primarily for the Alpine regions. Austria, another Alpine state, however, reportedly does not use that provision. Hence, it was decided to include Austria as well to understand the differences.

Thus, eventually, the following states were approached:

States approached	
Austria	Netherlands
Finland	Spain
France	Sweden
Germany	Switzerland
Hungary	UK

Table 10: Approached States for the assessment

[10] In the technical proposal, it was determined that the following 12 states represent 90% of the helicopters registered in EASA Member States: Finland, France, Germany, Hungary, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom.

7.2 Information from Member States on JAR-OPS 3.005(e)

This section of the report contains the gathered results from the selected Member States with respect to the implementation of JAR-OPS 3 and, specific to 3.005(e), information on national variants, risk assessment, airworthiness conditions, training and operational procedures; SMS/SSP, and technological improvements.

7.2.1 Survey Return

The following table provides information on interviews held and return of questionnaires.

State	Information obtained
Austria	By interview
Finland	By questionnaire
France	By interview and questionnaire
Germany	None
Hungary	None
Netherlands	By questionnaire
Spain	None
Sweden	By interview and questionnaire
Switzerland	By questionnaire
UK	By questionnaire

Table 11: Interviews held and return of questionnaires

Out of ten states that were sent the questionnaire, six completed it. In addition, telephone interviews were held with three states. This is assumed to cover all the states for which there are indications that they apply 3.005(e), except Italy.

7.2.2 Implementation of JAR-OPS 3

Information on implementation on JAR-OPS 3 and national variants specific to 3.005(e) was obtained from three sources:

- The mutual recognition list, published by JAA in October 2007;
- Information supplied by EASA on JAR-OPS 3 amendment level for seventeen states[11];
- Information obtained directly from the states.

Results are in the following table.

State	Mutual recognition?	EASA info (amendment level and national variants)	Information obtained directly from states
Austria	No	5, with national variants	
Belgium	Yes	No info	

[11] Viz. Austria, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Lithuania, Luxembourg, Norway, Portugal, Slovak Rep., Spain, Sweden, Switzerland, United Kingdom. This information was based on an EASA internal document from Q4, 2011 base on information gathered rom Standardizatoin Inspection Reports at the time and therefore not necessarily fully accurate.

State	Mutual recognition?	EASA info (amendment level and national variants)	Information obtained directly from states
Bulgaria	No	No info	
Croatia	No	No info	
Cyprus	No	No info	
Czech rep.	Yes	No info	
Denmark	Yes	No info	
Estonia	No	5	
Finland	Yes	5	1. **Amendment level**: 5 has been fully implemented in level: JAR-OPS 3 amendment 5 implemented by aviation regulation OPS M3-14, latest amendment 29.3.2011. 2. **National variant**: Single-engine operations permitted with special approval. However usage monitoring system is not required (JAR-OPS 3 3.517(a)) due to "level playing field" with neighbouring countries. Also 3.540 b(2) is not required to be fulfilled. Helideck/elevated heliport operations not permitted.
France	No	2 or 3	1. **Amendment level**: 5 has been fully implemented by 'arrêté du 21 mars 2011 modifié', but with some flexibility provision, one of which relates to performance class 3 operations over non-congested hostile areas[12] 2. **National variant**: 'A possibility is implemented in French OPS 3: according to appendix 1 to 3.005(e) - §(b)(2), the flight over hostile environment outside congested area is allowed if limited in time as specified in (d) of appendix 1 to 3.005(e). Indeed, this paragraph specifies in (d)(2): when the cumulative flight time over hostile environments outside congested areas is less than half the total flight time of the leg, with no portion of flight over hostile areas exceeding 5 consecutive minutes, helicopters may operate in PC3 and be exempted from complying with OPS 3.240 (a) (5). For these operations, the operator shall comply with (a)(1) and (a)(2) of appendix 1 to OPS 3.517 (a) (meaning a risk assessment, implementation of a set of conditions and of a UMS).'
Germany	No	5, with national variants	
Greece	Yes	5, not officially transposed	
Hungary	No	1	

[12] http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000024027862, text of 3.005(e) reproduced in Appendix to this report.

State	Mutual recognition?	EASA info (amendment level and national variants)	Information obtained directly from states
Iceland	No	No info	
Ireland	Yes	No info	
Italy	No	5, with national variants	
Lithuania	No	5	
Luxembourg	No	5	
Malta	No	No info	
Netherlands	Yes	No info	Amendment 5 fully implemented
Norway	Yes	3	
Poland	Yes	No info	
Portugal	Yes	5	
Romania	Yes	No info	
Slovenia	No	No info	
Slowak Rep.	No	4	
Spain	No	5	
Sweden	Yes	4	1. **Amendment level**: 'JAR-OPS 3 amdt 4 is fully implemented. The intention has been to invoke a process for permit according to JAR-OPS 3.005 e) according to amdt 5 since the latest amd was deemed to be easier to interpret and understand. The project group consisting of operational and technical inspectors are in the process to finalize its work during this or next year.' 2. **National variant**: 'Apart from the implementation of JAR.OPS 3 Sweden has no national requirements in regard to single engine operations over hostile environment'
Switzerland	No	5, but no JAR-OPS AOC's	Switzerland did not implement the JAR-OPS 3 Performance Requirements. The requirements in JAR-OPS 3 could not be fulfilled. Up to this date the operations are performed under the Swiss law. As attachment see the 'Verordnung der UVEK über den Bereich von Helikoptern zur gewerbsmässigen Beförderung von Personen oder Gütern" (VJAR-OPS 3)
UK	Yes	3, but most operators use 5	The UK has introduced JAR OPS 3 as a voluntarily-adopted code. Almost all of the 50 UK commercial helicopter operators apply JAR OPS 3 AL 5. There are two operators remaining on national rules.

Table 12: Information on implementation on JAR-OPS 3 and national variants specific to 3.005(e) per Member State

7.2.3 Application of 3.005(e)

Information on whether states issue approvals per 3.005(e) was primarily obtained from the states itself. As discussed earlier, lead information was obtained from EASA based on the State Conversion Reports[13] and information from Eurocopter. In one case (Denmark), information is solely based on information from EASA.

The following table summarizes the information obtained directly from the states.

State	Has state issued 3.005(e) approvals?	If so, how many operators and helicopters?
Austria	No, but would consider well substantiated applications	
Denmark	Yes	Two operators, 13 helicopters in total
Finland	Yes	Two operators (out of three). Five helicopters in total.
France	Yes	1. Single engine helicopter operations are permitted over hostile environment in accordance with JAR OPS 3.005(e): - in the mountainous areas (i.e take-off and landing above 1500m) - in some remote areas (Mafate in la reunion Island, in the Antarctic area 2. Approval holders - 22 operators hold an approval to operate under 3.005(e) in compliance with the 50%, five minute rule - 15 operators hold an approval to operate under 3.005(e) (mountainous area or remote area). - 9 operators do not hold an approval (two of them operate only twin engine, some operate helicopters which are not eligible to the exposure time concept). Some of them hold the two types of approval. 3. Percentage of approval holders In terms of percentage, if we do not take into account the operators who operate only twin engine helicopter, we end up approximately with a percentage of **80% of CAT operators with the approval.** Regarding the number percentage of single-engine **helicopters** used for CAT to which this approval would apply (assuming all single-engined helicopters used for CAT is 100%), we have only nineteen helicopters out of 127 with **no** approval. In terms of percentage: **85% single engine helicopters are operated under 3.005(e).**’

[13] For the following states: Austria, Belgium, Czech Rep., Estonia, Finland, France, Iceland, Ireland, Luxembourg, Netherlands, Poland, Romania, Slovak Republic, Spain, Sweden, United Kingdom.

State	Has state issued 3.005(e) approvals?	If so, how many operators and helicopters?
Netherlands	1. 'No, the Netherlands is too small and therefore hostile areas are always close to a city or town' 2. 'In my opinion there is no safe single engine operation over hostile environment, but FDM is a very powerful tool'	
Sweden	Yes and no	Sweden has issued one approval, which is a dispensation for CAT with single engine to ice breakers in the Baltic sea. This dispensation will only be valid a short time longer and the reporter now wonders whether that approval actually was rightly issued under 3.005(e). *Consortium note: For the sake of this report, this approval is not taken into consideration.* 'The Swedish authority has declared for the operators that its position is that operations in the mountainous part of northern Sweden require permit according to 3.005 e). However, this position is disputed by the operators, and in some cases the operator has adhered to the UMS requirement and believe that this means that they are allowed for single engine operation over hostile environment' Pending development of their approval process, Sweden allows these operations.
Switzerland	Allows an alternative (JAR-OPS not implemented)	'Operations over hostile environment are permitted but not according JAR-OPS 3.005(e). No special requirements for flights over hostile environment in Switzerland'. The number of single-engined helicopters operated by Swiss AOC holders is estimated to be around 120. This includes turbine and piston-engined helicopters.
UK	No, by policy	

Table 13: Information on whether states issue approvals per 3.005(e) per applicable Member State

7.2.4 Specific Airworthiness Conditions

The question specific to specific airworthiness conditions was answered by states issuing 3.005(e) (or equivalent) approvals as follows:

Finland:

'No such conditions exist'.

France:

'The operators have to be in compliance with Part M sub part G of UE 2042/2003

To be approved under 3.005(e), the helicopter has to be eligible to the exposure time concept and thus has to be in compliance with the standard defined by the manufacturer (information notice for Eurocopter for example). This standard has to be maintained.

The manufacturer also provides the sudden in-service power loss rate, for some engine / helicopter families which has to be lower than 1 per 100 000 flight hours.

The preventive maintenance actions recommended by the helicopter or engine manufacturer (oil analysis, engine trend monitoring…) have to be done'.

Sweden:

'No specific mandatory conditions are in place since the permit process is not active yet. The operators who operate single engine hostile generally use helicopters with VMD.' (See section 6.2 for an explanation of VMD).

Switzerland:

'The operators have to fulfil the requirements of PART 145 and CAMO. Many operators operate newer types like Eurocopter AS50, EC120, Bell 429, A109 Da Vinci etc[14]. These machines are equipped with the newest technology to monitor the airframe, engine, gearbox etc. parameters.

It is a concern to keep the maintenance standard high. With that mitigation the chances of an engine failure is extremely unlikely'.

7.2.5 Specific Training and Operational Procedures

The question specific to specific training and operational procedures was answered by states issuing 3.005(e) (or equivalent) approvals as follows:

Finland:

'Normal JAR-OPS 3 training only applies'.

France:

'The training and checking is compliant with JAR OPS 3 (two Operator proficiency checks per year, one line check a year, recurrent training). The training and checking have to be adapted to the type of operations (and includes discussions, demonstration, use and practice of the technique to minimize the risks). When the operator holds an approval to operate single engine with exposure time, the training and checking shall focus on the procedures to be followed after an engine failure, the assessment of pilots knowledge and skills regarding selection of safe forced landing areas available along the route…

The operators have to put in place specific operational procedures when they operated under 3.005(e): for example in part C of the OPS manual, for regular routes, all available safe forced landing areas have to be identified. The procedures have to be optimized in order to minimize the exposure time'.

Sweden:

'Sweden has no mandatory training except the normal Proficiency Check-routine. Some operators have implemented routines to train and test autorotation and emergency techniques in hostile environment. This is performed during the Operational Proficiency Check.'

Switzerland:

'There is (besides the license proficiency check) no mandatory training required. No specific operational procedures are required.

The pilots are trained to choose a flight path when possible to perform a safe landing in case of an malfunction or an engine failure'.

7.2.6 ICAO Risk Assessment if not via JAR-OPS 3

There is one state in the survey that has not transposed JAR-OPS 3.005(e), which is Switzerland. It replied that the risk assessment for operation in hostile environments is left with the operators, who all have implemented an SMS.

The states that issue approvals and have a national variant, answered this question as follows:

[14] Although the questionnaire was specific to single-engined helicopters, the respondent also mentioned twin-engined helicopters.

Finland

'Risk assessment is not implemented'.

France

'JAR OPS 3 requirements are fully transposed'.

7.2.7 Risk Mitigation

The question with respect to risk mitigation was answered by states issuing 3.005(e) (or equivalent) approvals as follows:

Finland

'SMS not yet implemented'.

France:

'SMS is applicable in France since 01/01/2009. Operators are expected to conduct any additional training required to mitigate risks identified by their own risk assessment.

SSP: The single engine helicopter operations over hostile environment have to be dealt by the SMS of the operators.

Moreover, DGAC takes specific actions regarding helicopter operations safety: In 2012 a symposium on safety management for helicopter operators was organized. The main topics were: management systems, technological solutions to improve safety, how to collect and share safety information, feedback.[15]

It was also the occasion to provide the operators with a leaflet dealing with the redaction of sub Part C of the OPS manual. In the case of operations with single engine helicopter over hostile environment, sub part C has to point the safe forced landing areas available along the flight path.

In the context of the SSP, an initiative is currently in progress at DGAC in order to establish a portfolio of recommended safety practices derived from in service experience regarding helicopter operations. It is done through a thorough analysis of all available relevant information (European action plan, accident reports, EHEST analysis, SMS…). Then an assessment of actual helicopter operators' practices will be made against this portfolio.

A specific division called MALGH (mission aviation légère et helicoptères) which is the focal point for all the helicopter issues, was created at DGAC in order to facilitate as much as possible the communication with the operators'.

Sweden:

'The operators claim that they chose flight paths and altitude so that assured safe forced landing can be guaranteed.'

Switzerland:

'All companies in Switzerland have implemented an SMS'.

7.2.8 Technological Improvements and legislative amendments

The question with respect to which technological improvements or legislative amendments would have a positive impact on flight safety regarding single engine helicopter operations over hostile environment was answered as follows:

Finland:

'Implementation of HUMS/UMS requirement'.

France:

[15] More information (and the power point presentations) is available on: http://www.developpement-durable.gouv.fr/14-novembre-2012-Securite.html.

'As it is done for ETOPS, the eligibility of the helicopter types should be dealt with by EASA as an airworthiness activity (through the OSD process for instance). EASA should standardize the list of helicopters which are eligible to the exposure time concept (and also the list of Usage monitoring systems). In this context, not only events should be reported to the manufacturer, but also volume of activities performed in order to establish well founded statistics.

Regarding the implementation of UMS, it appears that it is very difficult for operators to perform an analysis of the data because they do not have any guidance from the engine or helicopter manufacturers. They only have guidance in case of an exceedance (subsequent maintenance actions should be done). Engine and helicopter manufacturers could be more involved on the exposure time issues'.

Sweden:

'The procedure for permitting operations according to CAT.POL.H.420 is deemed sufficient. Sweden plans to have application forms and a routine for permit in place when the opt-out period for 965/2012 is final.'

'Since the possibility to operate single engine in hostile environment was written the piston engine reliability has greatly improved. Many operators in Sweden has repeatedly demanded that the authority would grant them permit to operate piston single engine in hostile environment. So far this has not been possible since one requisite for the permit is that it is a turbine powered helicopter. It would be a good idea to perform a reliability study of piston engines in order to evaluate if they could be included in a permit procedure.'

7.2.9 Other Remarks by States

Finland:

'Finland has a long, safe, tradition with CAT operations on single engine helicopters. That should be able to continue. However, reasonable, but regulatory, mitigating measures (hardware/training) are acceptable for Finnish Transport Safety Agency.'

Sweden:

'It was Sweden's intention to implement a procedure for single engine hostile environment permit. However, since amdt. 4 was deemed very difficult to interpret, it was decided to use the requirements in amd 5 instead.

Since 965/2012 is now in force and Sweden will be fully compliant in the fall of 2014 procedures for this permit according to the new IR will be in place by that time.'

Switzerland:

'We do not see a problem in single engine helicopter operations over hostile environment. In most cases operational influences are far more dangerous. (Weather conditions, workload, operational pressure, human factors, training and coaching etc.). Out of that our perspective it is more important to keep a high standard in maintenance and training'.

'Based on our own experience, the current data and studies that are available we have the opinion that twin engine helicopters are not necessarily safer than single engine helicopters.

Accidents are mainly caused by human factors like bad pilot decision making (weather, routine, training, coaching etc.), inadequate mission planning, operational and mental pressure. The goal should be to keep the workload for the pilot as low as possible which can be done i.e. by choosing a "simple to operate" helicopter with a large power margin. Experiences made in Switzerland (especially in mountainous regions):

- Twin engine helicopters (even the light ones) do often not fulfil the performance requirements needed for a safe operation.'

United Kingdom:

'We support the purpose of the rule as explained in IEM to Appendix 1 to JAR-OPS 3.005(e). The UK has a well-developed industry offering provision of twin-engined helicopters and the criteria of the IEM allowing reduced safety margins do not apply.

7.3 Analysis of Member States on JAR-OPS 3.005(e)

This section provides an analysis of the information provided in previous chapter section.

7.3.1 JAR OPS implementation

Most 'major' states apply amdt. 5 of JAR-OPS 3. Exceptions include Norway, Sweden and Switzerland.

7.3.2 Alternatives/national variants to 3.005(e)

The following states apply national variants relative to JAR-OPS 3.005(e):

Finland: does not require UMS for 3.005(e) approvals.

France: applies criteria for cumulative and maximum flight time over hostile environment of less than half the leg flying time and five minutes maximum respectively.

Sweden: allows operations per 3.005(e) although not formally approved, pending the development of a formal approval process.

Switzerland says it has not implemented JAR-OPS 3 performance requirements and, hence, 3.005(e), but uses Swiss law. However, the latter seems to suggest that 3.005 (e) is followed for single-engined helicopters, with only one exception: it allows the use of <u>piston</u> engined helicopters in addition to turbine-engined.

7.3.3 Application of 3.005(e)

Application of 3.005(e) appears to concentrate in two regional areas:

- Alpine states: confirmed for France and Switzerland. Austria seems to apply a stricter regime, but does not exclude it. The remaining Alpine state, Italy, has not been verified.
- Nordic states: confirmed for Denmark and Finland. Sweden applies it *de facto* but not *de jure*.

The characteristics of these regions coincide with the two circumstances listed in IEM to Appendix 1 to JAR-OPS 3.005(e): mountain operations and operations in remote areas.

As to the number of helicopters operating under the provision of 3.005(e) or equivalent, there are two states that stand out: France with approximately 100 helicopters and Switzerland. For the latter, no number was provided as no such approvals are given. However, the number of single-engined helicopters operated by Swiss AOC holders is estimated at 120.

Finland has issued approvals for 5 aircraft in total. For Sweden no figures are available,

7.3.4 Airworthiness

For continuing airworthiness, no specific conditions are given other than those required by 3.005(e). Sweden reports that most operators use VMD (Vehicle Multifunction Display) on a voluntary basis.

Switzerland, in its response to the questionnaire, states that due to high maintenance standards, the chances of an engine failure are extremely unlikely. Actually, the In-Flight Shutdown rate target of 10^{-5} is considered remote, not extremely improbable or extremely remote.

7.3.5 Operational / training

For operational and training procedures, only one state that issues 3.005(e) approvals or equivalent (France) puts emphasis on operational procedures and training specific to safe forced landing areas and engine failure techniques.

7.3.6 SSP / SMS

Only one state mentioned emphasis in its SSP on helicopter operations (France), but this is not specific to the 3.005(e) condition. France however does expect relevant operators to include this in their SMS.

7.3.7 Technological improvements and legislative amendments

States have varied responses to the question which technological improvements or legislative amendments would have a positive impact on flight safety regarding single engine helicopter operations over hostile environment.

Finland proposes UMS, but this is actually already required by 3.005(e). France explains that for UMS to be functional, more guidance from the manufacturers would be needed.

Sweden and Switzerland would like to see the turbine engine requirement removed, so as to also allow piston engine operations under the provision of 3.005(e).

7.3.8 Notes on response, inconsistencies and compliance

Response: states that (reportedly) do not use 3.005(e) appear less inclined to participate in the survey.

Consistency of data:

- Finland, according to information based on the State Conversion Report, does not issue approvals per 3.005(e) but in direct information says it issued such for all single engine turbine helicopters on AOCs.
- France has a national variant for 3.005(e) but claims full transposition of JAR-OPS 3.
- s known to is
- According to the information based on the State Conversion Report, Sweden would have issued one approval per 3.005(e). This was confirmed in the telephone interview but then denied in the questionnaire.
- Switzerland: 'claims not to apply 3.005(e) but its legislation actually adopts it, albeit with the variation mentioned under 3.3 above'.
- UK has a policy not to issue approvals per 3.005(e) but does publish a form for applying for those.[16]

Compliance:

- It is noted that France issues the 3.005(e) approval to EC130 helicopters. This helicopter type has a Maximum Approved Passenger Seating Capacity (MAPSC) of 7, which is above the limit of 6 as given in Appendix 1(d) to JAR.OPS 3.005(e). This helicopter type was introduced after Change 1 of JAR-OPS 3 was issued. The IEM to Appendix 1 to JAR-OPS 3.005(e) explains that 'The subject Appendix has been produced to allow a number of existing operations to continue'. This IEM text did not prevent France from providing the specific approval to new operations. It should be noted however that the nature of a JAA IEM is Information and Explanatory Material only. When JAA would sincerely have intended to prevent new operations to be so approved, it would have included regulatory material in either Section 1 of JAR-OPS 3 or as an AMC in Section 2 and not an IEM. The EASA CAT.POL.H.420 requirement also does not give a restriction to new operations, but retains the limit of 6 MAPSC.

[16] See http://tinyurl.com/kqpwevk.

8 Technological improvements

This section gives an overview of technological improvements –currently available or under development– that offer added safety to helicopter operations and thereby can contribute in reducing the accident rate on flights, including those over a hostile environment.

The facts and factors that can trigger an occurrence include a wide range of causes and consequences, and they used to involve more than one single event. However, the statistics showed in the previous report determined that about 75% of accidents are primarily due to pilots' judgments and actions. This area encompasses human factors such as pilot decisions and procedure implementations but also problems with aircraft interface and crew resource management. Moreover, the causes associated with the risk of the mission and the pilot situation awareness, including the lack of meteorological conditions and positioning of obstacles, contribute to a third of the accidents analysed. According to these statistics, it is proposed to focus technological development on implementation of integrated information systems by advanced pilot-vehicle interfaces (PIV) that decrease pilot workload during en route phase and improve mission safety.

In addition, since the engine failure is a risky and very critical event in single-engine helicopters, considering alternative technology intended for reducing the impact of malfunction or engine stoppage is highly appropriate.

8.1 Engine related technology

8.1.1 Hybrid engines

The research and development efforts of manufacturers and operators are focus on increasing helicopter safety and performance for the benefit of costumers. A way to achieve this goal is incorporating hybrid engines, which for the single-engined helicopters is an important safety measure in case of engine failure.

It consists in combining a number of sources of energy adapted to the various phases of helicopter flight. For critical phases, such as take-off or hovering, or emergency situations as this study concerns, the additional energy required to power the helicopter is supplied by other sources such as electric systems. Engines will not have to be sized for the most extreme flight conditions and as a result, fuel consumption would fall.

Eurocopter is using a supplemental electric system to increase manoeuvrability of a single-engine helicopter during an autorotation landing, which is performed by helicopters in the event of a main engine failure. The demonstrator helicopter is a production version of single-engine AS350 equipped with and internal combustion engine and a supplementary electric motor. In the case of an engine failure, the electric motor provides power to the rotor, allowing a pilot to control the helicopter during the descent to a safe touchdown.

Eurocopter AS350 is one of the most successful helicopters with an excellent performance in hot conditions and very high altitudes. The AS350 hybrid demonstrator has a compact electric motor and lithium ion polymer battery installed in the centre area of the helicopter. Electronic controls enable precise deployment of power delivered by the electric motor during the period of autorotation. The monitoring and implementation possibilities in other series of single engine to ensure greater safety in case of engine failure should be evaluated by Eurocopter.

Same approach is being carried out by a part of **Safran Group of Turbomeca**. The company proposes hybrid model concepts related to thermodynamic and electric solutions to achieve a reduction in specific fuel consumption of 25%, greater reduction than it would be obtained by varying or optimizing the internal architecture of the motor. However, according to own company judgments, progress on hybrid propulsion will also depend on the gradual improvement in the power-to-weight ratio of electric storage systems.

Safran Groups is busy with shorter term research-and-development programs, notably developing demonstrators in a wide power range. One demonstrator, the Tech 600, is focused on the 600 to 900 shp[17] power range, while the Tech 800 is geared to the 1.000 to 2.000 shp. This full range of demonstrators would

[17] Shaft horsepower (shp) is the power delivered to the propeller shafts of an aircraft powered by a piston engine or a turbine engine, and the rotors of a helicopter.

cover the entire helicopter spectrum, from light single-engined turbine to models with 27,000 pound of MTOW, that is, helicopters greater than the size of the Eurocopter EC225.

Under all these considerations, it is noteworthy that hybrid propulsion is an important element of manufacturer's innovation to develop on next generation of helicopters inasmuch as it offers new opportunities for improvements in safety, along with the potential for reducing fuel consumption and emissions.

8.1.2 Monitoring engine operation

As part of innovation policy on operational flight safety, Eurocopter intends to equip with little cameras (as the model Alerts Vision 1000 System) light helicopters that includes single engined.

This camera constantly records high resolution images of the cockpit, as well as the aircraft's GP S position, acceleration and attitude. This data can then be used for flight debriefings as part of training sessions, where the flight path is displayed and used as a teaching aid. This data set could be analysed on the ground with specific software. Furthermore, because images are recorded together with sound in the cabin, cameras can also be used for investigative purposes, following incidents or accidents, just like a "black box" flight data recorder. Targeted toward the engine, it records the development of engine performance and can display in the pilot screens on real time. The knowledge of early failure or fire engine is fully documented decreasing the pilot reaction time.

8.2 Planning and tracking en route phases

In single engine helicopter operations there is not a degraded mode of flight when an engine failure occurs. In this situation, it is especially important that the pilot has a very good awareness of the condition, status and limitations of the power plant and related systems during all phases of the flight; but especially during en route to be aware of the obstacles and the environment hostile if it would be necessary performing an emergency landing or change the flight path.

This section presents the latest and most modern interfaces in use, some of new warming caution systems and other technology that currently increases planning, monitoring and, as a result, flight safety.

8.2.1 Pilot-Vehicle Interfaces (PIV)

To improve the pilot perception and awareness on the screens and consoles, some single-engine helicopters incorporate a Vehicle and Engine Multifunction Display (VEMD) and integrate instrumentation, which enable to see at a glance the main vehicle and engine parameters on a dual LCD screen. For instance, it is available in several Eurocopter's single-engine helicopter families. VEMD technology also supports technicians and pilots' training courses as a simulation tool, which provides the opportunity to acquire appropriate reflexes on ground and in-flight.

It could provide information about:

- Engine: oil pressure, oil temperature
- Fuel: quantity, flow and estimated remaining time to fly
- Ammeter and voltmeter and battery temperature
- Outside temperature
- Enhanced usage monitoring functions: IGE/OGE performance calculations, engine cycle counting, engine power check or over limits display
- Peripheral maintenance information
- Data downloading capability: software and connection wire as option.

An innovative element, which is part of VEMD, is the First-Limit Indicator (FLI). FLI considerably simplifies engine and torque monitoring. It process engine, aircraft and atmospheric parameters, computes the data and then automatically indicates to the pilot the first limit he will reach during a period of flight. The FLI encompasses three torque, true heading and gas generator rpm displays onto a single gauge. From the pilot's perspective, it is one needle to look at as opposed to the six for take-offs and landings in older models. Being relieved from extensive instrument scan without missing vital information, pilots can dedicate more of their attention to the mission.

Engine manufacturers like Turbomeca and Rolls Royce have been implementing electronic engine controller units to control all aspects of engine performance. The Full Authority Digital Engine Control (FADEC) system is a digital computer that allows the engine to perform at maximum safety and efficiency for a given condition. It works receiving multiple input variables of the current flight (density, throttle lever position, engine temperatures and pressures) that analyses 70 times per second to adapt fuel flow, stator vane or bleed valve position between other controls including engine starting and restarting. FADEC also allows to program engine limitations and to receive engine maintenance reports. Redundancy provided by multiple channels, automatic engine protection against out-of-tolerance operations, better system operations integration with engine and aircraft systems or its support on automatic engine emergency responses are some of its advantages.

8.2.2 Warming Caution Systems

Warning Caution and Advisory systems require a boost in the future development technology. Achieving a better use of audio and tactile systems could improve the pilot attention and lessen the impact of fatal occurrences both en route complicated operations and hostile environment situations.

Enhanced Ground Proximity Warning System (EGPWS) serves as an independent monitor of an aircraft's position relative to surrounding terrain. It is one of the most advanced and effective solutions. EGPWS uses aircraft inputs such as position, attitude, air speed and glideslope, which along with internal terrain, obstacles, and airport databases predict a potential conflict between the aircraft's flight path and terrain or an obstacle.

Engine Instrumentation and Crew Alert System (EICAS) Computers is supporting by EDCU (Astronautics' Engine Data Converter Unit), which digitizes engine and non-avionics sensor data. The EDCU convert all inputs into a digital format, condition the signals and perform any required filtering and data conversion computation. It may include logic implementation in software for generating alerts and advisory to the pilot based on a pre-defined logic. The alerts may be generated upon a parameter exceedance, out of range values and/or a combination of values from different sensors and/or state of input discretise.

A helicopter tactile Safe Flight's Exceedance Warning System includes a tactile warning device attached to the collective and pedal shaker. The collective shaker provides two noticeably different levels of warning: low-speed and high-speed shake, which it provides a more urgent alert as the limit is reached or exceeded. Safe Flight's Pedal Shaker warns the pilot when approaching the pedal limit. The Pedal Shaker enhances the pilot's situational awareness during out-of-ground-effect hover situations, high crosswind operations, or high-density altitude situations, where power required may exceed power available. The shaker activates at a predetermined limit, giving the pilot time to maintain control. These systems can improve performance, expand safety margins, and reduce your operating costs.

8.2.3 Other systems

Depending on the type of mission, it is necessary an appropriate obstacle recognition system to allow safe operation without hindering manoeuvrability.

In low altitude operations during en route phase, apart from urban and natural obstacles, some accidents and fatalities are caused by inadvertent wire strikes. Wire Strike Protection System (WSPS) consists of a roof-mounted cutter and one or more cutters mounted on the fuselage of a helicopter that break wires avoiding rotor and blades collisions. The Powerline Detector System (PDS) senses the electromagnetic fields surrounding power lines and uses audio and visual warning signals to alert the pilot. Other Radar Systems transmit radio frequency for detecting obstacles in the flight path or use eye-safe laser to give the pilot information about the surrounding environment.

Finally, still in development and without direct implementation examples, navigational aids are systems with a lot of potential in relation to monitoring and tracking the en route phase. ADS-B uses information from a position service, for instance GPS, to broadcast the aircraft's location, thereby making this information more timely and accurate than the information provided by the conventional radar system. EGNOSS technology would permit safer flight operations in low visibility conditions and would facilitate an easier upgrade path for helicopter and general aviation operations.

Although its application as a safety system is not focus on the context of the study, its widespread use on general operations deserves mention.

Appendix 1: Factor identification matrix

The next tables identified the relation between SPS and HFACS (level 1) counted in the total occurrence database. The first table contains the percentage of occurrences that show at least once both identified SPS and HAFC codes (503 occurrences). The second table shows the percentage in Commercial Air Transport operations (CAT - 58 occurrences), the third table includes CAT in hostile environment (20 occurrences) and the fourth table completes the analysis with CAT in hostile environment occurrences due to engine related causes (3 occurrences).

The combinations of codes with a greater percentage of the total occurrences (first table) and CAT operation (second table) are Pilot judgments & actions / Unsafe Acts – Errors (500/5000) by 48% and 41% respectively, and Pilot Judgments & actions / Precondition of Individuals (500/5300) at 30% and 38% respectively. The combination is consistent due to both refer to the responsibility of the pilot in flight.
First table also highlights the combination of codes 5000-HFACS Unsafe Acts - Errors and 5300-Precondition of Individuals with SPS 700-Pilot situation awareness, 200-Safety Management and 100-Ground and Duties. The same trend including 900-Mission Risk was observed in CAT operations.

Although the percentile distribution in CAT operations – Hostile environment (see third table) is more homogeneous, it also highlights the combinations with 500-Pilot Judgments & actions. The number of occurrences due to engine failure studied in CAT is too poor to make effective code combinations.

	HFACTS										
SPS	5000	5100	5200	5300	5400	5500	5600	600	6100	6200	6300
100	22%	4%	7%	14%	10%	10%	5%	1%	0%	1%	2%
200	37%	5%	6%	23%	10%	16%	9%	1%	0%	1%	3%
300	4%	1%	1%	2%	1%	1%	1%	3%	12%	0%	4%
400	4%	1%	1%	3%	2%	2%	1%	0%	0%	0%	0%
500	48%	6%	10%	30%	12%	15%	9%	1%	0%	1%	3%
600	6%	1%	1%	4%	5%	3%	2%	0%	0%	0%	1%
700	19%	4%	9%	15%	7%	7%	5%	1%	0%	1%	2%
800	8%	2%	3%	4%	2%	4%	3%	3%	0%	0%	3%
900	16%	2%	7%	12%	8%	8%	5%	0%	0%	0%	1%
1000	8%	1%	4%	6%	4%	14%	3%	0%	0%	0%	0%
1100	10%	3%	1%	8%	3%	4%	2%	1%	0%	0%	1%
1200	1%	0%	0%	0%	1%	0%	1%	0%	0%	0%	0%
1300	9%	2%	2%	5%	3%	3%	4%	1%	0%	0%	2%
1400	6%	1%	3%	3%	2%	2%	3%	1%	0%	0%	1%

Table 14. Factor matrix identification – Total accidents and serious incidents (503 occurrences)

	HFACTS										
SPS	5000	5100	5200	5300	5400	5500	5600	600	6100	6200	6300
100	17%	5%	17%	17%	9%	12%	12%	2%	0%	3%	5%
200	33%	7%	14%	24%	10%	17%	19%	0%	0%	5%	3%
300	2%	0%	3%	2%	0%	0%	2%	2%	10%	0%	3%
400	10%	2%	2%	7%	5%	5%	7%	0%	0%	2%	2%
500	41%	9%	22%	38%	12%	17%	21%	0%	0%	3%	3%
600	9%	0%	2%	5%	7%	3%	3%	0%	0%	2%	2%
700	24%	5%	21%	26%	7%	16%	17%	2%	0%	3%	5%
800	5%	2%	7%	3%	3%	3%	2%	2%	0%	0%	3%
900	17%	5%	14%	12%	9%	9%	10%	0%	0%	3%	2%
1000	9%	0%	14%	3%	5%	19%	7%	0%	0%	0%	0%
1100	5%	3%	7%	5%	2%	2%	3%	0%	0%	0%	0%
1200	3%	0%	0%	0%	2%	2%	3%	0%	0%	3%	2%
1300	12%	2%	5%	9%	3%	3%	10%	0%	0%	0%	0%
1400	5%	0%	9%	5%	0%	2%	5%	2%	0%	0%	2%

Table 15. Factor matrix identification – Commercial Air Transport related events (58 occurrences)

SPS	HFACTS										
	5000	5100	5200	5300	5400	5500	5600	600	6100	6200	6300
100	20%	5%	15%	20%	15%	20%	20%	5%	0%	10%	15%
200	25%	5%	10%	25%	15%	25%	25%	0%	0%	15%	10%
300	0%	0%	5%	0%	0%	0%	0%	5%	10%	0%	5%
400	15%	0%	0%	10%	15%	15%	15%	0%	0%	5%	5%
500	25%	5%	10%	30%	20%	25%	25%	0%	0%	10%	10%
600	15%	0%	5%	5%	15%	10%	10%	0%	0%	5%	5%
700	15%	0%	20%	20%	10%	25%	20%	5%	0%	10%	15%
800	0%	0%	5%	0%	5%	5%	5%	5%	0%	0%	5%
900	20%	0%	15%	15%	20%	20%	15%	0%	0%	10%	5%
1000	0%	0%	5%	0%	5%	10%	0%	0%	0%	0%	0%
1100	0%	5%	0%	10%	0%	5%	5%	0%	0%	0%	0%
1200	5%	0%	0%	0%	5%	5%	5%	0%	0%	10%	5%
1300	10%	0%	0%	0%	5%	5%	10%	0%	0%	0%	0%
1400	5%	0%	5%	0%	0%	0%	5%	5%	0%	0%	5%

Table 16. Factor matrix identification – Commercial Air Transport in hostile environment related events (20 occurrences)

SPS	HFACTS										
	5000	5100	5200	5300	5400	5500	5600	600	6100	6200	6300
100	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%
200	0%	0%	0%	0%	0%	33%	33%	0%	0%	0%	0%
300	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
400	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%
500	0%	0%	0%	0%	33%	33%	33%	0%	0%	0%	0%
600	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
700	0%	0%	0%	0%	0%	33%	33%	0%	0%	0%	0%
800	0%	0%	0%	0%	33%	33%	33%	0%	0%	0%	0%
900	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%
1000	0%	0%	0%	0%	33%	33%	0%	0%	0%	0%	0%
1100	0%	0%	0%	0%	0%	33%	33%	0%	0%	0%	0%
1200	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1300	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1400	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 17. Factor matrix identification – Commercial Air Transport in hostile environment engine related events (3 occurrences)

Appendix 2: Occurrences evaluation

Fatal accidents and serious incidents turbine-engined of Commercial Air Transport operation during en route and manoeuvring phase over hostile environment

A total of 5 accidents and serious incidents recorded within next conditions:

- Commercial Air Transport operation
- Turbine-engined helicopter
- En route & manoeuvring phase
- Hostile environment
- One or more fatalities

This section includes a brief description of the occurrences and the evaluation of the impact of environment hostility.

1) 8/06/2004, France

On 8 Junel 2004 the Eurocopter AS 350 BA flew a regular public passenger transport line between Nice and Monaco with four passengers. A few minutes after take-off, the helicopter was flying a cruise between 300ft and 500ft above the sea at an approximated distance of 1350m from the Cap Ferrat when, suddenly, it hit the water with a high vertical speed and almost without rolling. The occupants died in the crash (1 pilot, 4 passengers).

The centrifugal compressor of the turbine engine had a technical failure that caused engine stoppage, which triggered a jolt and yaw destabilization. Technical examinations showed that the destruction of the centrifugal compressor was due to pre-existing fatigue cracks on the blade 1 of front wheel and at least two light modules of the lid. Maintenance program was according to JAR OPS.145.

The pilot was surprised by the suddenness of the failure and did not detect anything before the warning signal. The action to be performed must be lower completely control collective to enter autorotation, however, the low speed of rotation and instability did not allow it. Moreover, poor experience of the pilot in emergency procedures contributed to the accident.

Evaluation: *The accident occurred while the helicopter was flying in a hostile environment over the sea; however, it did not contribute to the cause of the accident. The accident was caused by pre-existing fatigue cracks on centrifugal compressor along with a late reaction to identify engine failure.*

2) 14/04/2005, Switzerland

On 14 April 2005 the Bell 206 B helicopter, registration HB-XXN, took off from Zurich airport on a flight to Bergamo-Orio al Serio. At the time of the accident, the helicopter was flying at low altitude from the Gotthard Pass in the direction of Hospental, which appeared to be covered in cloud and it was snowing. The flight down the valley towards Hospental can only be explained by the fact that the pilot had tried to cross the Gotthard Pass but had had to abort this attempt because of unfavorable weather conditions.

The HB-XXN collided with a rock face, running from north to south, of the Pizzo della Valletta. The occupants died in the crash (1 pilot, 1 passenger). The impact angle of approximately 60° indicates that the aircraft was not flying parallel to the rock face when the collision did occur. The for-ward speed at the moment of the collision was considerable which indicates a sudden collision and not at the conclusion of a braking manoeuvre or while the helicopter was hovering.

From this it can be concluded that the pilot did not see the obstacle or saw it too late, making loss of visual references probable. The final direction of flight between the mountains, more or less across the valley, indicates that the pilot had lost orientation. The pilot's limited experience of mountain flying under demanding weather conditions and a too optimistic weather forecast for the visual flight route may have contributed to the origin of the accident.

***Evaluation:** The accident is attributable to the fact that the helicopter crashed with the terrain because the flight was continued even though adequate visual references were no longer available. It is concluded that the severity of the impact was not dependent of the type of environment.*

3) 10/05/2005, Norway

The commander was tasked by his employer Airlift to do an event flight[18] over the Oslo fjord for the company PS-Arrangements, with en Eurocopter AS350 registered as LN-OPY. He spent the evening before the flight watching a video of how Airlift had conducted a similar assignment previously.

On 10 April 2005, the en Eurocopter AS350, registered as LN-OPY, was prepared by the removing the doors and mounting a climbing rope, carabiners and climbing harnesses for fastening in the passengers. The manager of PS-arrangements took active control of how the flight should proceed. After the assignment over the Oslo fjord, the manager of PS-arrangements wanted to reward some of his assistants and it was decided to fly a short trip to Kolsås. Four of the passengers were fastened in by rope, and were seated on the floor with their legs outside the cabin. The manager was secured in the helicopter with a somewhat longer rope.

Making a right turn towards rising terrain, the commander misjudged the turn in relation to the helicopter's performance limitations and altitude over the terrain. Following an unexpected loss of altitude during the turn, the helicopter hit some treetops resulting in heavy vibrations. In the subsequent emergency landing, the helicopter rolled over onto its side and the manager of PS-arrangements fell out and was trapped under the helicopter. He later died of his injuries.

The investigation has revealed that, over time, a market has developed for event flights for passengers, which has not been particularly regulated by the Norwegian Civil Aviation Authority. In addition, Airlift did not have approved procedures covering this type of operation.

***Evaluation:** While flying with narrow safety margins, the accident was caused because of the commander misjudged the described turn in relation to the helicopter's performance limitations (6 passengers and commander on board) and altitude over the terrain in a hostile environment.*

The lack of approved procedure covering this kind of flights implies the non-existence of guidance, instruction or training in how the task should be carried out. The practical implementation of the assignment was very much influenced by the client's wishes. Under all these assumptions, although the hostility of the environment influenced the injuries of the accident, the main causes are the poor management of mission risk and inadequate passenger safety.

4) 30/06/2007, France

The flight of the Eurocopter AS 350 B, registration F-GGAR, took place between Nevers and the helipad of a hotel located in Sully-sur-Loire while the pilot carried four passengers who attended the Grand Prix of France, Formula 1 on 30 June 2007. A few minutes after take-off, the pilot deviated eastward of the most direct route and just flew over a wooded area about five kilometres.

At the time of the accident, the mass was still important. Passengers said that after a left turn, the helicopter slowed down while the pilot executed a turn in the opposite direction with a significant tilt. In this configuration, the helicopter could not be maintained at a constant altitude. Given its low altitude, the pilot was unable to rectify the situation. The helicopter hit the treetops and fell into the wood where it came to rest on the right flank. The pilot and two passengers died, two others are seriously injured.

The accident probably resulted from the sudden pilot's decision to make changes at low speeds, high angle and high mass. Given his limited experience, he has not been able to master these developments and lost control of the helicopter.

***Evaluation:** The accident occurred while the helicopter was flying in a hostile environment over a wooden area; however, the cause of the accident was a poor turning manoeuvre that could not be stabilized because of performance limitations at low altitude.*

[18] Event flight is not a defined expression in an aviation context. However, it could be described as a flight designed to give passenger a thrilling experience (low flying, jump out of the helicopter…).

5) 20/10/2010, France

On 28 October 2010, the pilots of the two helicopters operated by SAF HELICOPTERS perform a passenger and cargo flight from the ship Astrolabe to base Dumont d' Urville in Terre Adélie. These flights were developed in response to damage of ship's propeller, which forced to interrupt his progression in Dumont d' Urville. When they decided to make the flight the weather was good and the range of helicopters permitted to reach the destination.

The pilots of both helicopters take off with about fifteen minutes of difference. First pilot continued the flight at a low height, sometimes lower 200 ft to stay below the cloud layer. The pilot of the second helicopter, registered F-GJFJ, choose to fly through the cloud layer at first; then he decided to turn to also pass under the cloud at low speed and low height. The helicopter collided with the surface of the ice. The last trajectory points recorded indicated a height of about 30 feet. The pilot and three passengers died.

The accident was due to the decision to undertake the flight and continue despite adverse weather in a hostile environment that did not offer any possibility of change the flight path or action plan. This probably resulted on a loss of visual reference phenomenon of white day with dense fog.

The particular context of the mission, the lack of operational documentation for the operation in Terre Adélie and the lack of authority supervision of Part C of the SAF HELICOPTERS Operations Manual were contributed factors to the accident. The fact that the pilot took medication with sedative effect also contributed to the accident.

Evaluation: *The weather conditions did not allow the realization of a safe flight. The fatality is given to poor operations and risk management resulting in a severe accident. This was regardless of whether the hostility of environment on the day of the accident.*

Appendix 3: 3.005(e) text in French Regulations

Source:

Arrêté du 21 mars 2011 relatif aux conditions techniques d'exploitation d'hélicoptères par une entreprise de transport aérien public (OPS 3)

NOR: DEVA1108675A
Version consolidée au 24 août 2011

3.005(e)

Les dispositions particulières aux opérations d'hélicoptères au-dessus d'un environnement hostile situé hors zone habitée sont fixées par l'appendice 1 au paragraphe 3.005 (e).

Pour effectuer un vol conformément à ces dispositions, l'exploitant doit détenir une autorisation spécifique. Cette autorisation est dite "autorisation environnement hostile situé en zone hostile située hors zone habitée".

Cet appendice ne s'applique pas aux vols SMUH spéciaux effectués en accord avec les exigences de l'appendice 1 au paragraphe OPS 3.005 (d).

Appendice 1 au paragraphe OPS 3.005 (e)

Exploitation d'hélicoptères au-dessus d'un environnement hostile situé hors zone habitée

(a) Approbation.

L'exploitant qui souhaite effectuer des opérations conformément à cet appendice doit avoir l'autorisation préalable de l'Autorité et de l'Autorité de l'Etat dans lequel il a l'intention d'effectuer de telles opérations. Cette autorisation doit spécifier :

(1) Le type d'hélicoptère ;
(2) Le type d'opération.

(b) Application.

Cet appendice est applicable aux hélicoptères à turbine exploités au-dessus d'un environnement hostile hors zone habitée lorsque :

(1) Soit il a été prouvé que les limitations de l'hélicoptère, ou autres considérations justifiables, empêchent l'utilisation des critères de performances appropriés ;
(2) Soit le temps de survol de zones hostiles hors zones habitées est limité, comme spécifié par les sous-paragraphes (c) et (d) ci-après.

Les dispositions particulières des paragraphes (c) à (f) suivantes remplacent les dispositions générales de la présente annexe ;

(c) Allégement pour la classe de performances 2 ;

Les hélicoptères exploités en classe de performances 2 au-dessus d'une zone hostile non habitée et dont la configuration maximale approuvée en sièges passagers (CMASP/MAPSC) est inférieure ou égale à 9 sont exemptés du respect des exigences des paragraphes suivants de la sous-partie H de l'OPS 3:

(1) OPS 3.520 (a) (2);
(2) OPS 3.535 (a) (2);

(d) Allégement pour la classe de performances 3.

Les hélicoptères exploités en classe de performances 3 au-dessus d'une zone hostile non habitée et dont la configuration maximale approuvée en sièges passagers (CMASP/MAPSC) est inférieure ou égale à 6 sont exemptés du respect des exigences du paragraphe OPS 3.240 (a) (5) :

(1) Lorsqu'il a été montré que les limitations de l'hélicoptère, ou autres considérations justifiables, empêchent l'utilisation des critères de performances appropriés, à condition que l'exploitant se conforme aux sous-paragraphes (a) (2) (i) et (ii) de l'appendice 1 au paragraphe OPS 3.517 (a) ;
(2) (Ou lorsque le temps cumulé de survol de zones hostiles hors zones habitées est inférieur à la moitié de la durée totale du vol, par périodes ne dépassant pas 5 minutes consécutives, à condition que l'exploitant se conforme aux sous-paragraphes (a) (2) (i) et (ii) de l'appendice 1 au paragraphe OPS 3.517 (a) ;

(e) Exploitation.

Les procédures spécifiques à suivre en cas de panne de groupe motopropulseur au cours du décollage ou de l'atterrissage doivent être décrites dans le manuel d'exploitation ;

(f) Oxygène de subsistance pour les hélicoptères non pressurisés.

L'exploitation d'hélicoptères non pressurisés peut être effectuée à des altitudes supérieures à 10 000 ft sans système à bord pouvant stocker et dispenser l'oxygène de subsistance requis, à condition que l'altitude cabine n'excède pas 10 000 ft pendant une période supérieure à 30 minutes et n'excède jamais 13 000 ft.

Appendix 4: 3.005(e) text in Swiss Regulations

Source:

Verordnung des UVEKüber den Betrieb von Helikoptern zur gewerbsmässigenBeförderung von Personen oder Gütern (VJAR-OPS 3) vom 14. Oktober 2008 (Stand am 1. Januar 2013)

Anhang 2

Abweichungen von den Anhängen zu JAR-OPS 3,

Subpart B, 3.005

3. Einsatz von Helikoptern über Gelände mit schwierigen Umgebungsbedingungen ausserhalb besiedelter Gebiete, Anhang 1 zu JAR-OPS 3, Subpart B, 3.005(e)

Für den Einsatz von Helikoptern über Gelände mit schwierigen Umgebungsbedingungen ausserhalb besiedelter Gebiete gelten folgende Abweichungen von Anhang 1 zu JAR-OPS 3, Subpart B, 3.005(e):

3.1 In Abweichung von JAR-OPS 3, Subpart I, 3.540(a)(2) und JAR-OPS 3, Subpart I, 3.550(b) dürfen Gebiete mit schwierigen Umgebungsbedingungen ausserhalb von besiedeltem Gebiet mit Helikoptern der Kategorie B überflogen werden.

3.2 Alternativ zu Anhang 1 zu JAR-OPS 3, Subpart B, 3.005(e), Abschnitt (b) können in der Schweiz kolbengetriebene Helikopter verwendet werden.

3.3 In Abweichung von Anhang 1 zu JAR-OPS 3, Subpart B, 3.005(e), Abschnitt (f) ist die Sauerstoffregelung von Anhang 1 zu JAR-OPS 3, Subpart B, 3.005(f), Abschnitt (d)(12) massgebend.

TRANSPORTATION INFRASTRUCTURE & LOGISTICS

in consortium with

Aitor Martin

amartin@alg-global.com

www.alg-global.com

Fons Schaefers

fschaefers@sgiaviation.com

www.sgiaviation.com

BARCELONA
Tanger 98, 3ª planta
08018 Barcelona (Spain)
Tel: (+34) 93 430 4016
Fax: (+34) 93 363 0623
alg@alg-global.com