European Aviation Safety Agency

Study on single-engined helicopter operations over a hostile environment

Final Conclusions and Recommendations

ALG TRANSPORTATION INFRASTRUCTURE & LOGISTICS

in consortium with

SGI AVIATION

16st June 2014

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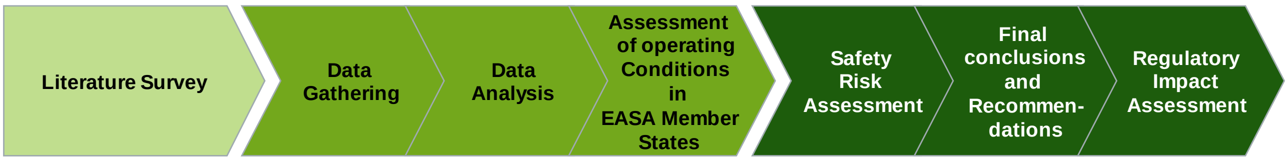
1 Introduction

The aim of the single-engined helicopter study was to provide an operational factual picture of the suitability and safety of single engine helicopters for Commercial Air Transport operations over hostile environment; clarifying whether or not and under which conditions this type of operations can be conducted.

In order to achieve this objective, the main actions developed have been the following:

- Collecting data on the use of single-engined helicopters in the EASA Member States for all types of operation for the last 10 years;
- Studies of the utilization of single-engine helicopters in all types of operations and in all types of environment in the EASA member states for the last 10 years;
- Analysis of accidents and incidents of single-engine helicopters in all types of operations and under all types of environment in the EASA member States in the last 10 years;
- A Safety Risk Assessment on the utilization of single-engine helicopters for Commercial Air Transport (CAT) operations over a hostile environment in the EASA member States.

Even though the main objective of the Study is to assess the concept of CAT operations over hostile environment, it is understood that a wider scope needs to be considered in the analysis to encompass all types of operations. Thus, the study has consisted of the following tasks:



This report, Final Conclusions and Recommendations, addresses the conclusions and most important items of each chapter in the project.

The data collection revealed the importance and usefulness of numerous official and independent sources. With further treatment of data, an extensive and accurate database of occurrences, fleet and usage was created. From it, a statistical analysis of fatalities was performed considering different types of engines, operations and environments.

In addition, the Consortium studied the application of JAR OPS 3.005(e) and relevant Appendices by the EASA member states. Along with studying the safety risk assessment of CAT operations –mainly focusing on engine-related occurrences-, it was possible to analyse the greatest factors of concern in the sector and propose mitigation measures.

All these approaches have allowed us to gain an understanding the industry, the causes of the accidents rates registered during the ten-year period and the key points of improvement.

The set of final recommendations evaluates the implementation and alleviation of JAR-OPS 3.005 (e) and relevant Appendices for each type of engine, its temporary nature, and the application particularities of each country. Furthermore, it exposes the mitigation measures for both piston and turbine powered single-engined helicopters proposed after the safety risk assessment analysis, including both reactive and proactive measures. Some of these proposed measures include the use of flight data monitoring and analysis systems, new technologies concerning hybrid engines and advisory caution and warning systems or the supervision of maintenance procedures and training programs.

Finally, to present additional considerations regarding the single-engined helicopter operations and a much more comprehensive view of the sector, Appendix 1 includes an extensive reflection on five operative areas: safety culture, reporting culture, pilot decision-making, pilot training and policies and aerial work operations. It discusses some controversial issues among different agents involved in single-engined operations (pilots, passengers, OEMs, operators or authorities) and sets up complementary recommendations to improve safety, decrease the rate of accidents and serious incidents and avoid passenger and crew fatalities.

2 Executive Summary

After the comprehensive analysis developed in the previous tasks of the project, the Final Conclusions and Recommendations seek to identify the most relevant points of single-engined helicopter study, with particular interest in Commercial Air Transport operations over hostile environment, to propose a set of recommendations that could improve operational safety.

This report is structured according to the following sections:

- The Final **Conclusions** highlight the most important issues of previous task: Literature Survey, Data Gathering, Data analysis, Assessment of Operating Conditions in EASA Member States and Safety Risk Assessment. It collects the final occurrence, fleet and usage databases composition as well as the statistical results of fatality rates according to type of engines, type of operations and type of environment. It also shows the most remarkable differences on how each country applies JAR-Ops 3.005(e) conditions. Finally, the conclusions on the Safety Risk Assessment summarizes the process of identifying hazards before properly defining mitigation measures, some of which are based on the most recently technologic improvements implemented in this field.

- The Final **Recommendations** suggest measures to improve the suitability of single-engined helicopters for Commercial Air Transport operations according to all previous analysis, especially the Safety Risk Assessment.

First recommendations are referred to **JAR-OPS 3.005(e) approvals**. JAR-OPS 3.005(e) and the successor rule, CAT.POL.H.420, allow an exception to the rule for Commercial Air Transport operation of turbine single-engined helicopters to be conducted only along such routes or within such areas for which surfaces are available which permit a safe forced landing. The safety level to be maintained in these operations is expressed as an engine failure rate being better than $1x10^{-5}$ per flight hour.

The results of this study indicate that, whereas the rate for turbine-engined helicopters is significantly better at $0,82x10^{-5}$ per flight hour, the rate for piston-engined at $1,90x10^{-5}$ per flight hour is a factor of 2,33 higher and higher than the limit of $1x10^{-5}$ per flight hour.

It is therefore **recommended to**:

- **retain the alleviation**, but **not to expand it to piston-engined helicopters**; and
- take the adequate steps to **ensure that all states apply the same standards in the same manner**, ultimately when Implementing Rule 965/2012 takes effect on 28 October 2014, as a number of EASA member States appear to vary with the JAR-OPS standards.
- The assess of limitation in seat capacity according to the Maximum Operational Passenger Seating Configuration (MOPSC) have concluded the recommendation to **retain the limit of 6 passengers**.

Then, the assess of limitation in seat capacity according to the Maximum Operational Passenger Seating Configuration (**MOPSC**) have concluded the **recommendation to retain the limit of 6 passengers**.

And finally, last section involves the **mitigation measures** as a result of safety risk assessment analysis. Reactive and proactive measures have been proposed for each risk category, for both piston and turbine powered single-engined helicopters.

Part / System Failures of the Power plant and issues with maintenance management could be proactively mitigated by a broader use of Health Usage Monitoring Systems (HUMS). Adopting hybrid techniques to support loss of power has been proposed as a reactive mitigation measure for Part / System Failures of the Power plant. Potential issues related to inadequate pilot experience, Pilot Situational Awareness and pilot judgment and actions could potentially be mitigated proactively by implementing good cueing and intuitive warning systems. As a reactive measure for situations related to judgment and actions, the operators could be encouraged to implement Flight Data Monitoring equipment on-board. Additional, training on Full Flight Simulators (FFS) could increase pilots' awareness of the limited options for a favourable forced landing in case of low level operations and/or operation in the vicinity of obstacles.

Next table summarize the proposed measures for each factor category regarding the type of engine.

	Engine type(s)	SPS assignment	Reactive measure	Proactive Measure
1	Piston / turbine	**8020**: Part / system failure – Power plant	Hybrid techniques to support loss of power	• HUMS* onboard coupled with maintenance procedures
2	Piston / turbine	**500**: Pilot judgment and actions	Flight data monitoring and analysis	• RADAR altimeter onboard coupled with Audio / tactile warning system • EICAS* / EGPWS* onboard
3	Piston / turbine	**3010**: Maintenance – maintenance management	Adjustment of maintenance intervals	• HUMS* onboard coupled with maintenance procedures
4	Turbine	**7020**: Pilot SA – environment awareness	Flight data monitoring and analysis	• RADAR altimeter onboard coupled with Audio / tactile warning system • EICAS* / EGPWS* onboard
5	Piston	**2090**: Safety management – inadequate pilot experience	Flight data monitoring and analysis	• Additional training on Full Flight Simulators • Training on uncomplicated training helicopters with typical flying characteristics

* EICAS: Engine Indicating and Crew Alert System; HUMS: Health & Usage Monitoring systems; EGPWS: Enhanced Ground Proximity Warning System

Summary of specific mitigation measures

3 Final conclusions

3.1 Literature Survey conclusions

The Literature Survey phase has allowed understanding the position of single-engined helicopter operations within the current aviation industry, highlighting an operational factual picture on the suitability and safety of single-engined helicopters for Commercial Air Transport operations over a hostile environment. However, a wider scope was considered in the analysis to encompass all types of operations (*i.e.* not only CAT), which recognizes the fact that helicopters used for CAT operations will also be used for other types of operations conducted by the same operator.

The first task developed consisted of understanding the regulatory background. Helicopter operations over a hostile environment located outside a congested area must be conducted in accordance with the requirements contained in JAR-OPS Part 3, except for the variations contained in CAT.POL.H.420 and therefore helicopter operations over a non-congested hostile environment without a safe forced-landing capability with turbine engine helicopters may be able to be conducted in some EASA Member States, although this transposition does not reflect the variations allowed by some Member States.

The majority of the research encompassed a survey and appraisal of reference documents, reports, general publications and databases on helicopter operations; as well as of the helicopter operators, their fleets and aircraft, and the associated accident and incident databases necessary for the subsequent tasks of the study. The cross-matrix below, Table 1, serves to summarize the results of the survey. It shows the types of information against the various types of sources for this information, as well as their level of suitability.

	Sources of Information									
	Authorities			Industry				Others		
Type of information	EASA	CAAs	EHEST	Helicopter Operators	Manufacturers	Associations	Pilot Unions	Multi-client consulting. reports	Independent initiatives	Universities
Operational Occurrences	Medium		Medium		Medium	High		Medium	High	
Safety & Research Reports	Medium	Medium	Medium		Medium	Medium		Medium	Medium	Medium
Fleet and operator information	Medium	High			Medium			High	Medium	
Usage data		High			Medium					
Design-related Occurrences					Medium					
Reliability Reports					Medium					

Legend:

(green)	**High Suitability: The information provided by the source is considered complete and reliable**
(orange)	**Medium Suitability:** The information provided by the source is complete and reliable but only covering a specific area
(red)	**Low Suitability**: Not completely reliable and not completely exhaustive
(white)	No information available

Table 1: Level of suitability in information provided by each sources of information

After assessing the information available from authorities (EASA, CAAs, EHEST), operators, manufacturers, associations, pilot unions, independent initiatives and universities; the consortium concluded that no single source could provide the completeness and quality of necessary data to produce a meaningful analysis. It was proposed to combine all credible and available data into a single occurrences database and to adopt a

"multi source" approach to data collection, both for safety occurrences and for identifying the operators and their fleets.

- Occurrence databases: The official data repositories, ADREP, was consulted. It contains the most comprehensive collection of worldwide accidents and ECCAIRS, which, in turn, contains fewer accidents but many more incidents, focusing mainly on Europe. However, both suffer from a great quantity of incomplete data relating mainly to aircraft identification. Simultaneously, the unofficial sources consulted have been: the Helihub database, with 2.500 worldwide occurrences dates mainly from 2009 and includes significant numbers of incidents as well as accidents; and the Aviation Safety Net "Wikibase", with relatively little missing information and with the largest number of accidents occurred on a worldwide basis.
- Operator, Fleet and Usage data: Potential reference sources included the EASA Operator and Fleet Database, EUROCOPTER Fleet Database, International Register of Civil Aviation (IRCA), JP Airline Fleets International, Helicopter Blue Book, Rotor Roster Business Class Helicopters, Rotorspot and Helihub.

3.2 Data Gathering conclusions

The Data Gathering task has developed an exhaustive and detailed procedure for the treatment, merging, and polishing of the data obtained from each of the sources identified in the first stage of the project, in relation to occurrences and fleet data. After the data collection, it was necessary to develop a complex process to standardize inputs, filter duplicates and fill in the gaps. In addition, all accident reports publicly available from the Air Accident Investigation Boards have been downloaded and crosschecked.

The final **occurrences database** outcome encompasses:

- **4.606 occurrences,** of which **920 are accidents and serious incidents**.
- **535 official reports,** of which **508 are accidents and serious incidents**.
- Excel file collect database.

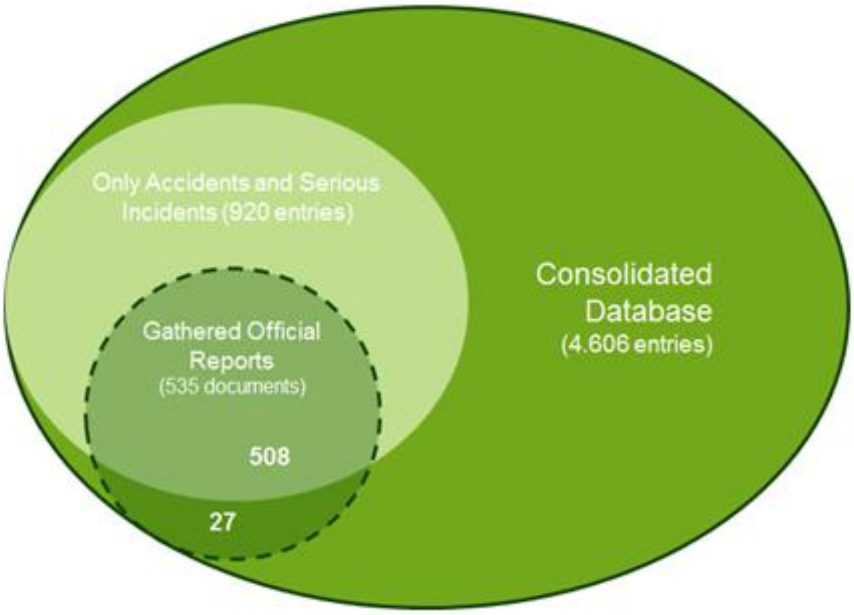


Figure 1: Occurrence database gaps

The information gaps are summarized in Table 2. It should be noted that the number of gaps decreases in the case of accidents and serious incidents when compared with the total occurrence database. This is due to the fact that accident and serious incidents are better registered and published than minor accidents.

Whole Data Base	Accidents and Serious Incidents (%)	Finding
0,04%	**0%**	% of occurrences with unidentified date
16%	**1%**	% of occurrences with unknown make, type or model
25%	**0,6% (0,04%)**	% of helicopters with unknown year of manufacture and <u>without</u> related official occurrence report (<u>with</u> related official occurrence report)
36%	**0,8% (0,6%)**	% of occurrences with undefined type of operation and <u>without</u> related official occurrence report (<u>with</u> related official occurrence report)
20%	**0,6% (0,02%)**	% of occurrences with unspecified phase of flight and <u>without</u> related official occurrence report (<u>with</u> related official occurrence report)

Table 2: Occurrences database gaps

The final **fleet database** outcome encompasses:

- Total single-engined fleet composed of **6.880 helicopters**.
- Four EASA countries concentrate almost **60% (UK, France, Italy and German)** of the total single-engined fleet.
- Three manufacturers, **Robinson, Eurocopter and Bell,** concentrate **73%** of the total single-engined fleet.
- Very similar share of single-engined fleet between piston (3.970 helicopters) and turbine (2.910 helicoters) in Europe, with slight higher number of piston craft (58% vs 42% respectively):
    - Most common **single-piston** helicopters are the Robinson 44 and 22 (close to 1.435 and 987 aircraft, respectively registered in database),
    - Most common **single-turbine** models are the AS350 Ecureuil 1 and JetRanger series (close to 1969 and 645 aircraft, respectively registered in database).
    - General consideration: 75% of the turbine fleet has been manufactured either by Eurocopter or by Bell, and approximately 60% of the piston fleet has been manufactured by Robinson.

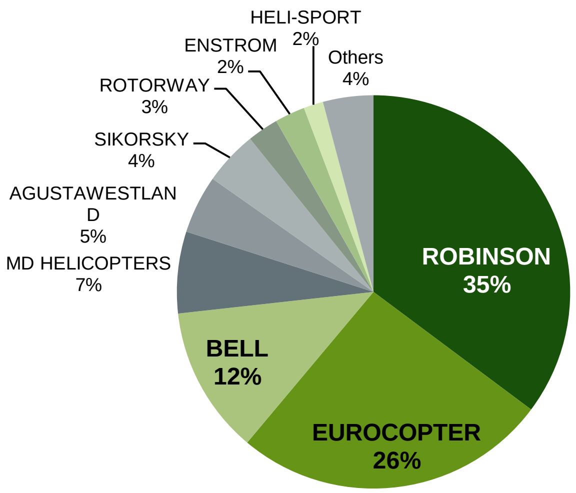


Figure 2: European helicopter fleet share by manufacturer

The collection of **usage data** has proved more challenging and difficult part. It involves flight hours, cycles and other usage information considered relevant for the aim of study. To obtain these data, two sources were consulted: the Civil Aviation Authorities (CAA) and manufacturers (OEMs).

i. Civil Aviation Authorities: All of the 31 CAAs were consulted, but only 22 CAAs responded positively to the enquiry, and only 13 CAAs[1] delivered information regarding usage data on their helicopter fleets, representing 28% of the total Single-engined Helicopter fleet in Europe. Dismissing the non-consistent data, only the information of the following selected countries was used:

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

   The compilation of total Flight Hours per helicopter family over the 2003-2012 period, splitting between piston and turbine-engined aircraft, together with the accumulated fleet during the same period, allowed the average annual flight time per helicopter type to be identified.

ii. Helicopter manufacturers: An adequate interpretation of the available information from Eurocopter, Bell and Robinson facilitated the comparison with the results of the CAA study.

Due to difficulties in obtaining this information from the CAAs, it was agreed to estimate the total accumulated flight time for whole fleet of helicopters during the period of study over all EASA Members:

- A total number of Flight Hours of around **9.990.000 FH (Flight Hours)**
- **6.000.000 FH** corresponding to **turbine-engined** helicopters (60% of total FH)
- **3.990.000 FH** corresponding to **piston-engined** helicopters (40% of total FH)

Finally, the main difficulties encountered by the Consortium during the development of Data Gathering are summarized below:

- Lack of information and standardization of the collected occurrences data which increased treatment and polishing time and schedule.
- Only 55% of accidents and serious incidents registered on the whole database (508 of 920 occurrences) have official reports documented and available.
- Heterogeneous information in reports between countries: different content, extension and detail.
- Lack of processed data on fleets and usage (FH) by the CAAs.
- The fact that some data required was unprocessed, or not recorded, produced many difficulties in CAA responses and availability.

3.3 Data Analysis conclusions

The Data Analysis seeks to identify and assess the causes and contributing factors, especially in the cases of: engine-related events, single-engined helicopter accidents and serious incidents in any type of operation; and, especially in Commercial Air Transport operations, and in which type of environment (hostile and non-hostile) those accidents and serious incidents occurred.

General Statistics analysis conclusions during the ten-year period of study (01/01/2003 to 31/12/2012):

- The histogram of the 4.606 events registered shows an **annual average of 100 accidents and serious incidents**, and **clear evidence of an increase in the reporting of minor incidents** over the last few years, due to implementation of Regulation for the notification of occurrences.
- A general scenario defines a **19% of fatality** in accidents and serious incidents (920 occurrences).
- A general scenario of helicopter events defines, in terms of helicopter damage, a **38% of destroyed** aircraft and 48% with substantial damage.

Plain analysis of accidents and serious incidents (a total of 920 occurrences) has stated conclusions related to individual parameters:

i. Differentiated according to **type of engine**:

   - Although the absolute amount of occurrences is relatively balanced between each type of engine (482 piston , 408 turbine, 30 occurrences not defined) , the piston-engined accidents and serious incidents rate per 100.000FH is 1,78 times bigger than that of turbine-engined

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

aircraft (12,08 piston-engined accidents and serious incident per 100.000FH vs. 6,80 turbine-engined accidents and serious incident per 100.000FH).
- Turbine-engined helicopters have a higher rate of fatal occurrences (24%) than piston-engined ones (14%).
- Piston-engined helicopters suffer a higher rate of damage (40% of piston aircraft destroyed), than turbine-engined ones (37% of turbine aircraft destroyed).

ii. According to **the type of operation**, Commercial Air Transport (CAT) operations have a substantially lower absolute number of accidents and serious incidents if compared with Aerial Work (AW) and General Aviation (GA) operations, but have a substantially higher ratio of minor incidents because of the higher reporting obligations in CAT operations.

iii. Regarding **environment hostility**:

- Only 13% of the accidents and serious incidents occur in a hostile environment (123 of 920 occurrences) due to the specific regulations applied on helicopter operations in this type of environment.
- However, 17% of fatal occurrences occur in non-hostile environments (131 fatalities of 797 occurrences) but almost double the percentage in hostile environments: 33% (41 fatalities of 123 occurrences).

iv. In relation to **flight conditions** and phases of flight:

- 45% of the 920 accidents and serious incidents occur during the en-route & manoeuvring phase, accumulating 69% of the total fatal occurrences.
- Per Flight Hour, it showed a similar behaviour regardless the flight phase 1,28 piston fatal occurrences per 100.000FH during take-off and approach & landing phases, 1,60 turbine fatal occurrences per 100.000FH during take-off and approach & landing phases, and 1,55 turbine fatal occurrences per 100.000FH during en-route phase.
- Only Piston operations during en-route phase present a higher ratio: 1,77 of fatal piston occurrences during en-route phase per 100.000FH.

v. The distribution of **helicopter age** does not present significant differences.

A multi-criteria analysis has allowed relating the influence of different parameters on the fatality study: hostility of environment, type of engine and type of operation.

Table 3 summarizes the absolute and relative fatality values per type of environment, engine and operation.

- Piston and turbine-engined helicopters have a similar rate of fatality in hostile environments (around 30% of the accidents and serious incidents), but have a different rate for non-hostile occurrences.
- The intrinsic hazard of the hostile environment for both piston and turbine engines in AW and GA should be noted, with higher percentages than in the case of non-hostile environments.
- In **CAT operations**, turbine-engined presents a 32% fatality rate over hostile environment. However, the regulation’s restriction on piston-engined aircraft shows zero ratio of fatality and only 2 occurrences registered over hostile environment.
- Looking only at **en route & manoeuvring** accidents and serious incidents for CAT operations in hostile environment with turbine-engined helicopters, the fatality ratio rises to 62% (comparing with the global rate of 32%), but the low number of events (5 fatal over 8 in total) distorts the analysis.

Type of operation	Piston-engined		Turbine-engined	
	Non-Hostile	Hostile	Non-Hostile	Hostile
Commercial Air Transport	**6 fatal occurrences over a total of 26 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%)**

Note: A total of 890 valid occurrences filed under piston and turbine have been recorded

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

Engine-related occurrences are defined as engine-related according to ADREP 2000 standard, as stated by ICAO and implemented in version 4.2.6 of ECCAIRS, Section: Attribute values, Id.430, Occurrence category. For those cases where the occurrence report was available, the causes had been analyzed by expert judgment to define it as engine-related.

This group of occurrences represents 14% of the total accidents and serious incidents (125 engine-related cases over 920 occurrences): 16% in piston-engined versus 12% in turbine-engined. Moreover, the relative number of occurrences per 100.000FH is very influenced by the type of engine.

Table 4 summarizes the absolute and relative engine-related fatality values per type of environment, engine and operation.

- The piston engine related accidents and serious incidents rate per 100.000FH is 2,33 times higher than the turbine rate (1,90 piston engine related accidents and serious incident per 100.000FH vs. 0,82 turbine engine related accidents and serious incident per 100.000FH).
- 20% of turbine engine related accidents and serious incidents occurred over hostile environment (10 of 49 turbine engine related occurrences), while only 7% in the case of piston helicopters (5 of 76 piston engine related occurrences); which means a 12% in average for the total events.
- It should be noted that the number of engine-related events evaluated is very small (125 occurrences).
- In **CAT operations,** 33% of fatal occurrences for turbine helicopters operating in hostile environment, 25% for turbine in non-hostile.
- Only 1 fatal occurrence for turbine helicopters operating in hostile environment occurs during en route flight phase and CAT operation.
- As for AW and GA operations, the situation is different than in CAT operations. Again, it should be noted that there is a small number of events recorded in the analyses that includes filters of various parameters.

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%)**

Note: A total of 125 occurrences filed under piston and turbine have been recorded

Table 4: Fatality comparison of engine related accidents and serious incidents per type of engine and environment

A comprehensive analysis of 503 accidents and serious incidents with recorded and published reports included among the 920 accidents and serious incidents identified has been successfully developed. This has allowed the consultant to address the categorization of the main causes of occurrences and the classification of the main contributory factors, using both Standard Problem Statements (SPS) and Human Factors Analysis and Classification System (HFACS) taxonomies.

Top 3 level 1 SPS categories (% of occurrences that have at least one code of this category):

- Pilot judgment & actions (76%)
- Safety Management (61%)
- Ground Duties (37%)

Top 3 level 1 HFACS categories (% of occurrences that have at least one code of this category):

- Unsafe Acts - Errors (55%)
- Preconditions - Condition of Individuals (34%)
- Supervision (19%)

In detailing level 2 categories, the Consultant observed different patterns depending on the type of operation. Figure 3 summarizes the context:

- CAT: Causes related to errors due to failures on procedural executions or psycho-behavioural factors.
- Aerial Work: Causes related to mission risk and the existence of obstacles, which can result in pushing the helicopter and pilot towards the limits of their capabilities.
- General Aviation: Related to failures to implement the correct procedures by crew and pilots.

Focusing only on CAT accidents and serious incidents, a total of 58 occurrences were properly analysed, the most important categories of which were:

i. Top 3 level 1 SPS categories in CAT operations (% of occurrences that have at least one code of this category):
   - Pilot judgment & actions (86%)
   - Safety Management (63%)
   - Pilot situation awareness (53%)
ii. Top 3 level 1 HFACS categories in CAT operations (% of occurrences that have at least one code of this category):
   - Unsafe Acts - Errors (42%)
   - Preconditions - Condition of Individuals (40%)
   - Supervision (18%)

	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

Figure 3: Most common SPS and HFACS level 2 categories per type of operation accidents and serious incidents

3.4 Operation Conditions in EASA Member States conclusions

The following states were successfully surveyed for the purpose of the operational assessment analysis:

- Austria
- Finland
- France
- Netherlands
- Sweden
- Switzerland
- United Kingdom

Summarizing the application differences of JAR OPS 3.005(e):

- Two states have a policy of not applying JAR-OPS 3.005(e): The Netherlands and the United Kingdom.
- One state has no such policy but has not issued 3.005(e) approvals: Austria.
- Three states issue 3.005(e) approvals: Finland, France and Sweden.
- One state has not implemented 3.005(e) but allows such operations: Switzerland.

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 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.

Thus, 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 for 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. No figures are available in the case of Sweden,

Regarding conditions for 3.005(e) approvals:

i. **Airworthiness**
For retaining airworthiness, no specific conditions are given, other than those required by 3.005(e). Sweden reports that most operators use VEMD (Vehicle and Engine Multifunction Display) on a voluntary basis.
ii. **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.
iii. **SSP / SMS**
Only one state placed emphasis on 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.

3.5 Technological Improvement conclusions

The comprehensive overview of the technological improvements underway and under-development has been conclusive to reinforce the different final recommendations to improve safety in case of engine failure, a risky and very critical event in single-engined helicopters, and in planning and tracking en route flight phase.

- New lines of research on OEMs highlight the incorporation of **hybrid engines,** which combine an electric system to create a supplementary power in critical phases such as take-off, loitering or/and autorotation landings in case of engine failure. Eurocopter has developed an AS350 hybrid demonstrator, while Turbomeca has proposed a thermodynamic and electric hybrid engine solution.
- As part of innovation policy on operational flight safety, Eurocopter intends to equip aircraft with little **cameras** which constantly record high-resolution images of the cockpit. Such measure could be used for investigating the causes of accidents and for documenting flight conditions.

In order to improve pilot-awareness conditions and to decrease exposure times in case of engine failure and pilot workload, a series of powerful sources have been provided to achieve safe operations.

- Pilot Vehicle Interfaces allow joining many factors and indicators of helicopter and engine conditions with a set of automatic engine emergency responses. The **Vehicle and Engine Multifunction Display (VEMD),** available in several Eurocopter's single-engined families, enables the quick monitoring of the main vehicle and engine parameters. It includes a **First-Limit Indicator (FLI)** which simplifies engine and torque monitoring. **Full Authority Digital Engine Control (FADEC)** system is a digital computer that: allows the engine to perform at maximum safety and efficiency, programming engine limitations and allows receiving engine maintenance reports.
- Warning Caution and Advisory systems could improve the pilot attention and lessen the impact of fatal occurrences both under complicated operations en route and in hostile environment situations.

Enhanced **Ground Proximity Warning System (EGPWS)**, Engine Instrumentation and Engine Indicating and **Crew Alert System (EICAS)** and Safe Flight's Exceedance Warning System are examples of current available technology.

- An appropriate obstacle recognition system to allow safe operation without hindering manoeuvrability. It is referring to Wire Strike Protection System (WSPS), Powerline Detector System (PDS) or Radar Systems.
- Navigational aids could also be systems with a lot of potential, in relation to monitoring and tracking the en route phase.

3.6 Safety Risk Assessment conclusions

In order to support a potential revision of EASA requirements regarding single-engined helicopter CAT operations over hostile environment, the Safety Risk Assessment methodology has focused on identifying, quantifying and mitigating hazards which are specific to single-engined helicopter operations. Furthermore, in order to discriminate between single- and multi-engine helicopter hazards, only engine-related failures, which directly or indirectly contributed to the final outcome of the event, have been used for further analysis. Besides the engine itself, several other parts of a single-engined helicopter have been identified as design-specific and could potentially result in more severe outcomes in the event of encountering problems. For example, engine air intake, engine driveshaft or belt, the fuel system and the Pilot-Vehicle Interface (PVI) are non-redundant parts of a single-engined helicopter. For this reason, safety events, which could be traced back to failures in one or several of these systems, have been considered as engine-related and subjected to further analysis.

In order to compare safety performance of piston and turbine single-engined helicopters, the estimated total Flight Hours per engine type have been used to determine relative occurrence rates of engine-related hazards per 100.000 FH. Analysis of original occurrence reports yielded a total of 56 confirmed engine-related accidents and serious incidents based on the available reports. The "engine-related accidents and serious incidents" bracket (56) is relatively small relative to the total number of occurrences in the database (4.606). This is due to the fact that not all low impact engine-related events get reported. In order to account for potential inaccuracies of low-number statistics, a qualitative approach has been used for assessing potential severity of a particular failure mode. The actual reported severity of events and their respective estimated severity for both hostile and non-hostile environments has been compared and used as one of the inputs for a priority list of risk mitigation measures.

From the 56 identified accidents and serious incidents, the piston-engined helicopter occurrence rate is more than twice as high as that of the turbine engine: 0,80 vs 0,40 occurrences per 100.000 FH. The majority of these events for both engine types have occurred over non-hostile environments. For further analysis, the events have been broken down by SPS Level 1 category.

Table 5 presents the SPS Level 1 categories for both piston- and turbine-engined helicopters, sorted by frequency of occurrence.

	Piston		Turbine	
Rank by frequency	**SPS Level 1 code**	**Occurrence rate per 100.000 FH**	**SPS Level 1 code**	**Occurrence rate per 100.000 FH**
1	800 (Part/system failure)	0,75	800 (Part/system failure)	0,33
2	500 (Pilot judgment & actions)	0,38	500 (Pilot judgment and actions)	0,20
3	300 (Maintenance)	0,38	300 (Maintenance)	0,15
4	200 (Safety management);	0,28	700 (Pilot situation awareness)	0,15

Table 5: Most frequent SPS Level 1 categories for piston and turbine engine helicopters

In order to provide a comprehensive list of mitigation measures for the identified failure modes, piston- and turbine-engined helicopter occurrences have been reviewed separately. Within the top four most frequent

SPS Level 1 categories, a further break-down has been made by SPS Level 2 categories. Since multiple SPS Level 1 and Level 2 codes can be assigned to a single event, in order to isolate the dominant (engine-related) contributing factor, the events have been assigned to one of the clusters, presented in Table 6.

Cluster	Definition	Examples from database
Design	Factors which are specific to the design and prescribed maintenance schedules and procedures of single-engined helicopters	Gear failure due to fatigue.
Maintenance	Possible flaws which occurred during maintenance, use of wrong parts, early signs of imminent failure missed by maintenance personnel or not reported by ground personnel or pilot	Wrong type of drive belt installed; Cylinder clearances adjusted incorrectly.
Inadequate handling of engine failure	In case of engine failure, incorrect employment of standard procedures, pilot situation awareness	Wrong ignition switch selection
Environment	Environmental factors[2], which contributed to an event	Carburettor icing, compressor blade failure due to ingestion of ice/snow, whiteout, turbulence
Pilot induced	Potential errors in piloting techniques, operation outside of the prescribed flight envelope	Accidental engine shutdown by switch error
Flight preparation	Factors which are missed by pilot or ground personnel during routine pre-flight checks	Insufficient fuel
No Fault Found	In case of engine-failure, detailed investigation revealed no probable cause of the event	Intermittent loss of power during flight
Fuel pollution	Contamination of fuel, leading to a failure	Fuel polluted with a polymer
Other	Any and all other factors contributing to an accident / incident	Irregular poorly performed maintenance, pilot not licensed to fly at night

Table 6: Definition of clusters per dominant contributing factor

A review of the combination of the actual and estimated severity of the event, its assignment to a particular cluster and the relative frequency of the associated SPS Level 2 codes, has made it possible to isolate a shortlist of hazards to be counteracted by proposed mitigation measures.

[2] *Physical Environment* is a *factor "in a mishap if environmental phenomena such as weather, climate, whiteout or brown out conditions affect the actions of individuals and result in human error or an unsafe situation."*
Technological Environment is a factor "in a mishap when cockpit / vehicle / control station / workspace design factors or automation affect the actions of individuals and result in human error or an unsafe situation."
Related to maintenance situations: inadequate natural light, inadequate artificial lighting, dusk/nighttime, high noise levels, housekeeping/cleanliness, and hazardous/toxic substances. For instance, a maintenance worker who is working at night does not see a tool he left behind or an operator working on a pitching deck falls from a ladder

4 Recommendations

This section includes the final recommendations about the suitability of single-engined helicopters for Commercial Air Transport operations and it is based on all previous analysis, especially the Safety Risk Assessment.

4.1 JAR-OPS 3.005(e) approvals

JAR-OPS 3.005(e) and the successor rule, CAT.POL.H.420, allow an exception to the rule for Commercial Air Transport operation of single-engined helicopters to be conducted only along such routes or within such areas for which surfaces are available which permit a safe forced landing, under the following conditions:

- the engine of the helicopter is a turbine engine;
- the operation is outside a congested area (but over a hostile environment);
- the maximum approved seating passenger capacity (MAPSC) 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 the 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.

The 3.005(e) rule was conceived assuming a safety level could be maintained, expressed as an engine failure rate being better than $1x10^{-5}$ per flight hour.

The results of this study indicate that indeed the engine failure rate is better than that. However, there is a significant difference between piston engine and turbine engine helicopters. Whereas the rate for turbine-engined helicopters is significantly better at $0{,}82x10^{-5}$ per flight hour; the rate for piston-engined at $1{,}90x10^{-5}$ per flight hour is a factor of 2,33 higher and higher than the limit of $1x10^{-5}$ per flight hour.

It is therefore **recommended to**:

– **retain the alleviation**, but **not to expand it to piston-engined helicopters**; and
– take the adequate steps to **ensure that all states apply the same standards in the same manner**, ultimately when Implementing Rule 965/2012 takes effect on 28 October 2014, as a number of EASA member States appear to vary with the JAR-OPS standards.

According to an IEM published by the JAA[3] the 3.005(e) alleviation was intended only to allow a number of existing operations to continue and thus, not to allow new operations. The question therefore can be raised whether continuation of this rule is justified. It must however be appreciated that the rule itself, which has a higher level, does not contain this restriction. The incident occurrence rate of $0{,}82x10^{-5}$ per flight hour supports a **permanent nature** for this alleviation possibility, at least for turbine helicopters.

4.2 MAPSC versus MOPSC

With respect to seat capacity, the 3.005(e) alleviation established that the Maximum Approved Passenger Seating Configuration (MAPSC) was limited to 6 passengers –excluding crew seats– according to the standard seat capacity of single-engined helicopters at that time existing operations (excluding old models). Nowadays, there is transposition of the rule with certain important changes, as the new criteria have moved from Maximum Approved Passenger Seating Configuration (MAPSC) to Maximum Operational Passenger Seating Configuration (MOPSC). This means that taking as a baseline the MAPSC established during the certification process conducted for the Type Certificate (TC), Supplemental Type Certificate (STC) or change to any of them, as relevant to the individual aircraft, the MOPSC may establish a –more flexible– equal or

[3] IEM to Appendix 1 to JAR-OPS 3.005(e)

lower number of seats, depending on the operational purposes and constraints, and specified in the operations manual for an individual aircraft.

Simultaneously, and looking in perspective at the market, it can be observed that since the introduction of the original alleviation only one single-engined turbine helicopter –Eurocopter EC-130– has been designed with a MAPSC of 7 passengers. However, this high density configuration is just an optional cabin layout for this specific helicopter, and at the same time it is perfectly compatible with the modification of the alleviation approach from MAPSC to MOPSC.

Therefore, it is recommended not to change the current restriction and **maintain the limit in 6 passengers** (MOPSC). If new generations of single-engined helicopters were to be designed to allocate 7 or more passengers in a regular basis, the question that could be raised is what limit would be safe –it could be 7, 8, 9 or even 10–, and then a **deeper analysis involving all the stakeholders should be performed**, in order to try not to be discriminative to one or more helicopter types, as it could be today the existing regulation.

4.3 Mitigation measures

The analysis of actual occurrence reports has shown that in some instances the pilots had received cues of impending failure prior to the actual event such as a different engine sound, rough running engine, delayed clutch engagement etc. These had either been ignored or classified as unlikely to affect the operation. Changes in behaviour of the engine, drive train or other critical components (noise and vibrations) within the limitations of the flight manual could indicate slight differences in normal performance with an unknown status.

Considering the general flight conditions for helicopters, it is reasonable to assume that there would be a suitable landing area within a few minutes' flight after signs of potential impending failure had been noticed by the pilot. Precautionary landings are not popular within the pilot community as they require a lot of subsequent administration and reporting. Another aspect is embedded in pilot culture: pilots prefer to solve a problem at home rather than land in a field. Moreover, company level issues regarding planning and costs of precautionary landings would not encourage conducting a landing when it is not deemed absolutely necessary. It should therefore be encouraged that, in case of doubt regarding the status of the helicopter, a precautionary landing is conducted. Member state CAAs could facilitate this by decreasing the administrative burden for pilots and allowing them to land and have a quick check before continuing en-route. Operator companies could also be encouraged to stimulate such decisions of their pilots. CAAs could encourage this by rewarding companies for every precautionary landing. For example, safety credits could be assigned for these practices and published by the CAA in a list of safe operators. These could be used by operators to demonstrate their safety policy to the customers.

Table 7 summarizes proposed risk mitigation measures for both piston and turbine-powered single-engined helicopters. In most cases it has been possible to assign a mitigation measure to a particular SPS Level 2 category. In some cases however, no principal SPS Level 2 code could be identified based on its occurrence rate, therefore the whole SPS Level 1 500 category (Pilot judgment and actions) has been assigned a mitigation measure.

	Engine type(s)	SPS assignment	Reactive measure	Proactive Measure
1	Piston / turbine	**8020**: Part / system failure – Power plant	Hybrid techniques to support loss of power	• HUMS onboard coupled with maintenance procedures
2	Piston / turbine	**500**: Pilot judgment and actions	Flight data monitoring and analysis	• RADAR altimeter onboard coupled with Audio / tactile warning system • EICAS / EGPWS[4] onboard

[4] The use of EGPWS could also provide increased local (geographic) situational awareness. Predefined routes and altitudes based on usage of EGPWS could ensure minimum safe relative altitude and enhance the ability to reach safe forced landing areas.

	Engine type(s)	SPS assignment	Reactive measure	Proactive Measure
3	Piston / turbine	**3010**: Maintenance – maintenance management	Adjustment of maintenance intervals	• HUMS onboard coupled with maintenance procedures
4	Turbine	**7020**: Pilot SA – environment awareness	Flight data monitoring and analysis	• RADAR altimeter onboard coupled with Audio / tactile warning system • EICAS / EGPWS onboard
5	Piston	**2090**: Safety management – inadequate pilot experience	Flight data monitoring and analysis	• Additional training on Full Flight Simulators • Training on uncomplicated training helicopters with typical flying characteristics

Table 7: Summary of specific mitigation measures

Analysis has shown that Part / System Failures of the Power plant (SPS Level 2 8020) and issues with maintenance management (SPS Level 2 3010) could be proactively mitigated by a broader use of Health Usage Monitoring Systems (HUMS). Closer monitoring of wear of critical components could reduce the chance of fatigue failures if maintenance intervals were adjusted accordingly. It has been rather difficult to estimate the residual severity, should this measure be adopted. Additional research into effects of broad-scale implementation of HUMS on maintenance planning and safety is advised. Adopting hybrid techniques to support loss of power has been proposed as a reactive mitigation measure for Part / System Failures of the Power plant. Electrical backup power to drive the rotor in case of loss of engine power, as demonstrated by EC, could provide valuable time for the pilot to maintain control of the helicopter and concentrate on safe landing options.

Potential issues related to inadequate pilot experience (SPS Level 2 2090), Pilot Situational Awareness (SPS Level 2 7020) and pilot judgment and actions (SPS Level 1 500) could potentially be mitigated proactively by implementing good cueing and intuitive warning systems. EICAS systems could support better Situational Awareness and assist in proper decision-making as well as a reduction of response time. A simple but effective mitigation for unintended loss of altitude could be a radar altimeter with adjustable altitude selector for (audio) warning. Moreover, besides altitude information, more advanced systems like EGPWS would provide a complete view of the flight path of the helicopter in relation to the surrounding terrain. As a reactive measure for situations related to judgment and actions (SPS Level 1 500), the operators could be encouraged to implement Flight Data Monitoring equipment on-board. Reviewing information stored on quick access renderers would yield valuable insights into potential causes of failure and reveal issues such as disobedience of prescribed flight rules. Besides technical aids, additional training on Full Flight Simulators (FFS) could increase pilots' awareness of the limited options for a favourable forced landing in case of low level operations and/or operation in the vicinity of obstacles. There are different or unconventional methods of taking evasive action that could be reinforced by FFS practises[5]. However, limited availability of simulators for single-engined helicopter class is a disadvantage, since flight technical aspects cannot easily be trained.

[5] For instance, training in autorotations is normally carried out within a speed bracket as prescribed by the OEM in the flight manual. Zero speed autorotations are not as safe as autorotations with (safe) forward speed, but could be a better option in certain conditions. These are never trained for in normal operation as damage or injury are not unlikely. It could be compared to a landing on water with a passenger jet. These options have a low success rate, but could reduce the severity of consequences in certain conditions significantly (eg, Hudson River)

Appendix 1: Additional considerations regarding the single-engined helicopter study

In the past 20 years, the helicopter sector has experienced significant growth, increasing the number of operations and agents involved. These agents include pilots, instructors and training schools, operators, maintenance companies and regulatory experts.

The versatility of this aircraft and the huge range of operations that can be carried out in remote areas and using small airfields has allowed the rise of small and medium-sized companies. These take advantage of the set of operations that they can offer to their clients with few financial and human resources.

The high accident rate that has been occurring over the past 20 years has resulted in some detailed analyses of the sector. The first work carried out in these terms was guided by EHEST group, who published the first study on accident analysis for helicopters in 2010, in order to understand the problems and formulate measures to address them. However it is necessary to safeguard the whole sector, reducing accident and incidents, so that industry can carry out operations within acceptable parameters of safety.

The study of single-engined helicopter operations over a hostile environment is a further step in achieving this purpose. This appendix covers other aspects than Commercial Air Transport operation regarding the general utilization of single-engined helicopters.

Safety culture

The helicopter sector has a widespread impression related to Commercial Air Transport operations, which are considered simple activities compared to the complexity of flights that single-engined helicopters can perform, for instance in Aerial Work operations. CAT operations are often programmed for pilots with little experience because no special skills are required. However, the take-off, en route and landing skills of external load carrying or fire fighting practice usually demand higher levels of ability and experience.

Within the CAT operations, "taxi" flights are unscheduled flights that pilots conduct on non-established routes. In fact, the client can suggest the path and the best flight options for a quick and comfortable trip. One of the features of these flights is that the operators "sell" a flight giving the customer the idea that the helicopter will go "where" and "when" they want. This places extra pressure on the pilot, who does not know the landing area because the passenger can propose on improvised landings, probably in a remote area without ensuring that regulatory conditions apply. Furthermore, in general, departure and landing operations in heliports lack supervision and control, a fact that also affects the safety of pilots and crew.

As mentioned previously, the human and financial resources of medium sized companies in the sector are smaller, which, added to the low profit margin of these operations, brings the viability of these operators into question. In these cases there may be a degradation of pilots' and maintenance technicians' work, which leads to bad practices and errors. This context leaves safety guarantees in second place.

Another problematic practice is the abuse of loopholes, again for the motive of reducing costs. It is not uncommon that operators take some liberties in the implementation of regulations, acting to the limits, and reducing the safety margin. It is recommended to reinforce the dissemination and knowledge of the responsibilities of each collective (pilots, maintenance organizations and operators), to clarify the right implementation of different practices related to assessing the safety of flights.

In the end, achieving the desired safety level means a good implementation of procedures.

An important point to take into account relates to the operational benefits that can be offered by redundant technology systems in single-engined helicopters. As well, the reinforcement of passive measures should be emphasised. A simple action that would significantly improve the protection of the crew in a crash is the use of helmets. The flight helmet greatly minimizes injuries in case of accident, also in the increasingly frequent bird strikes.

Regarding design and structural configurations, anti-crash reinforcement of the front of the cabin would be desirable, since impact can often completely destroy the aircraft due to the fragility of the materials it is built from, seriously affecting the crew and passengers. This is a passive type of measure that can reduce injury.

Recommendations

- Promote efficient implementation of Safety Management Systems (SMS), not just formally but also including even commercial departments.
- Promote safe flight marketing campaigns.
- Avoid the common recent trend of using cheap resources to save money, including maintenance practices.
- Correctly define the responsibility of each agent in regulation to avoiding loopholes and ambiguous personal interpretations in regulatory implementations that could compromise the safety of passengers and crews.
- Strengthen supervision and control of operations in small and remote heliports.
- Increase awareness through safety seminars combined with the preparation of guides and manuals on best practices.
- Promote and continue the development of the Safety EHEST Leaflets as well as increasing their dissemination.
- Improve the availability of weather forecast information.
- Compulsory use of helmets for the crew to reduce injury.
- It is proposed to conduct a more extensive evaluation of the benefits of implementing safer systems on single-engined helicopters versus redundant systems with greater complexity and failure probability.
- Incorporate anti-crash reinforcement of the front of the cockpit

Reporting culture

Promoting safety culture also involves the creation of an easy process for reporting incidents, which will avoid accidents. There is still much to be done by the CAAs in the homogenization of reports, both in content and detail, in order to understand the causes and problems of different occurrences. Since the language of publication of the reports varies depending on the country, incorporating summaries in English or promoting publication in a single language would be very useful to improve understanding by all Member States.

In relation to the recording of the "flight time" of helicopters, certain practices have been detected that can have negative effects on maintenance procedures and, therefore, on safety in flight. There is evidence that some operators are recording the flight hours in line with engine manufacturers' guidelines, which differ from ICAO[8] and EASA EU[9] regulations. Both authorities define helicopter flight time as the total time from the moment the helicopter's rotor blades start turning until the moment the helicopter's rotor blades are stopped. However, Turbomeca indicates in its maintenance manual of Arriel 2B, referring to the programme of inspections based on flight hours, that flight hours should be counted as the time recorded from the moment the wheels (or skids) leave the ground until the time when the wheels (or skids) touch the ground. It also states that this standard is used in the engine logbook and, more generally, it is being applied to all official logbooks for all types of helicopters. This is causing the spread of an incorrect method of recording flight hours in helicopters, since it reduces the number of hours actually recorded. In the medium to long term, it will affect the maintenance schedule of helicopters very significantly.

Recommendations

- Simplify and automate the reporting of occurrences, not only accidents and serious incidents but also minor incidents, under conditions of anonymity.
- Encourage the homogenization of contents and format for reports in all EASA Members States.
- Incorporate an English summary of accident reports to facilitate reading and understanding.
- CAAs should be briefed about the incorrect interpretation and recording of flight hours by operators following the guidelines issued by some engine OEMs.
- Remind operators, by letter, of the right way to record flight hours in helicopters as set out in the regulations as well as the importance of carrying out maintenance procedures.

[8] ICAO Annex 6, Chapter 1 Section 1.

[9] According to Regulation (EU) No 1178/2011 of the Commission 3/11/2011. It defines technical requirements and administrative procedures related to flight personnel in civil aviation under Regulation (EC) No 216 / 2008 of the European Parliament and of the Council. FCL.010 Definitions, Flight time.

Pilot decision making

The skills required in piloting helicopters are complex, much higher than in an airplane due to automation being less common. Single-engined helicopters are more maneuverable aircraft, with faster response, and more versatile. Piloting requires direct and constant pilot action which can result in an extreme pilot workload.

A specific constraint of CAT operations is that, unlike commercial airplane flights, the pilot is literally next to the customer, there is no physical separation between crew and customer or passenger. This implies an extra pilot workload. Speaking directly with passengers while he is carrying out different tasks can create synergies that do not occur in other types of operations. These synergies can influence forgetfulness or attitudes that are not understood by the external customers, even exerting very direct pressure in their haste for their requirements to be met or to fly over the desired areas. It is not unusual for a client to tell the pilot: "That other pilot landed on this site, so why not you?"

This unique condition may predispose that pilot to "attend" to customer requests, giving an "extra" excitement to the flight. Pilots are also greatly influenced by the fact of wanting to maintain their employment. If the customer is satisfied, there will be more chances to maintain employment. That situation could explain flight accidents in unnecessarily low altitude, high speeds or quasi-acrobatic manoeuvres, with passengers on board. Also impacts due to low visibility. All these conditions mean that a part of the flight is performed within the zone of the H/V diagram which is not permitted, with a high associated risk that is generally not required in CAT operations. It should be noted that these factors may be masked in the subsequent reporting tasks.

Definitively, authorities should promote initiatives to prevent "excessive motivation to succeed".

Decision-making by the pilot creates a possible cause of human error. Operators must be forced to strictly enforce standard operational procedures. SOPs mark guidelines for correct performance of actions in each case and they are defined according to the conditions and needs of each helicopter and operation. Damage can be alleviated by tracking each specific procedure.

Recommendations

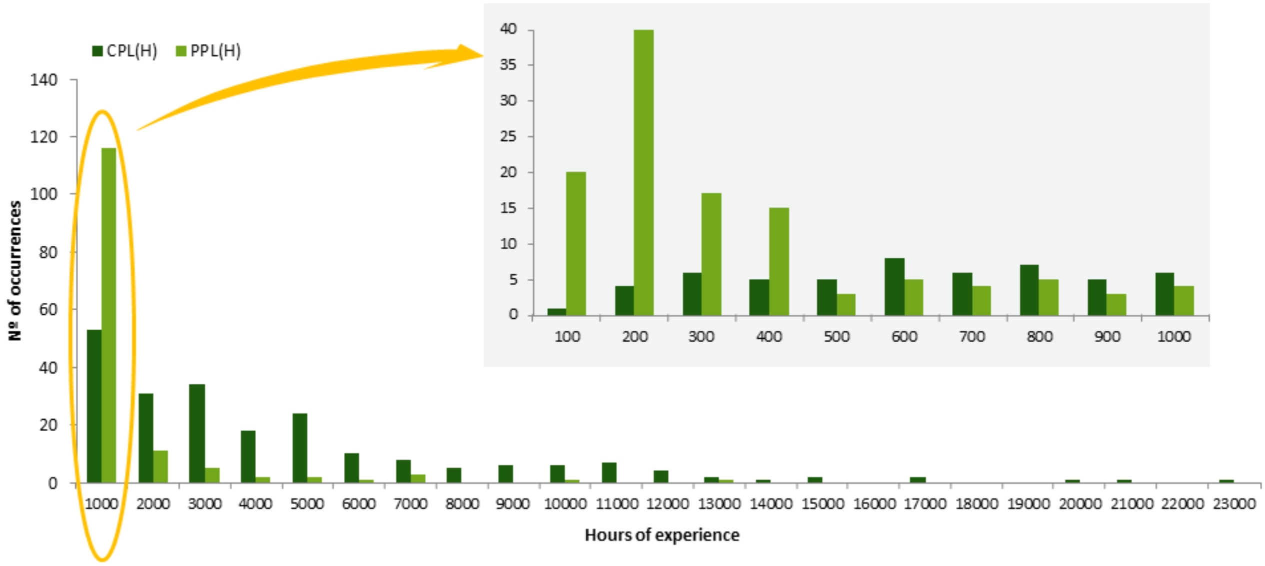
- Establish and promote strict compliance with SOPs.
- Define guidelines of standard procedures.
- Real implementation of passenger safety briefings.
- Planning conducted prior to a flight in a low stress context to define a safe strategy for the flight.
- Reduction of exposure time in the hostile area.
- Reinforce maintenance procedures such as daily-checks and pre-flight checks by operator companies.
- Control bad practices in maintenance and crew procedures.
- Establish a minimum flight altitude in hostile areas () to ensure time for proper selection autorotation and landing zone.
- In departure and approach phases, establish SOPs to avoid completely hostile and congested areas until reaching 2.000 feet AGL.
- Implement a realistic FTL and FDTL to avoid pilot fatigue.

Pilot training and policies

The helicopter is a complex aircraft. Given the great manoeuvrability of single-engined helicopters, piloting requires direct and permanent pilot actions, especially in those without automatic pilot mechanisms, which refer to mainly small and medium sized helicopters.

All this means that, although a pilot may learn to conduct standard flights and more complex aerial works, single-engined operations require intense pilot attention and effective decision-making in extreme conditions. CAT operations have an added component to demand high levels of pilot skill because they fly with passengers. Pilots have to be constantly manipulating flight controls, both hands and feet, which generates a high demand on the pilot in terms of coordination and response actions.

The pilot experience is an indicator of the acquisition of required pilot skills. Based on a detailed analysis of the information available from pilots in collected reports, an elevated rate of accidents and serious incidents has been noticed among pilots with less than 500 hours of experience in helicopters—excluding training occurrences. 47% of occurrences where information on pilot experience is available (169 occurrences of 358 reports with detailed pilot flight hours in helicopters) involved pilots with less than 1.000 hours of experience; and specifically 116 of them had less than 500 hours. The next figure also highlights a higher rate of accidents and serious incidents in helicopters controlled by private pilots with less than 400 hours of experience.



Accidents and serious incidents by hour of experience in helicopters

<u>Recommendations</u>

- Standardization of training programmes.
- Reinforce both theoretical knowledge and skills training practices.
- Improvement of training programmes, including compulsory subjects such as Loss of Tail rotor Effectiveness (LTE), Ground Resonance, PIO-ODP[10], flight in degraded visibility conditions, etc.
- Develop training programmes related to emergency decision and management risk skills in the case of critical and stressful situations.
- Inclusion of SPO operators in training courses of an introduction to the different Aerial Work SOPs.
- Conduct periodical briefings by the NAA on Flight Safety and SOPs. These could be regularly held in flying clubs and private airfields where training schools also fly.
- Implement pedagogy and psychology seminaries in the instructor group.

Aerial Work operations

Other recommendations are directly related to Aerial Work operations, which have similarities to CAT operations because they involve the transport of the client to the workplace. However, Aerial Work practices have important differences as they simultaneously involve a flight and the specific task. The Aerial Work is the reason for the client's payments, and the client could be on board and giving directions to the pilots. This usually occurs during photography tasks, monitoring wires or filming documentaries.

This feature represents a higher workload and additional pressure for the pilot. Pilots and companies are dependent on customer satisfaction with the performance of the work. The priority is given to the performance of work for which the helicopter has been hired; the safety of the flight takes a back seat.

Some AW jobs require huge expertise and experience from the pilot because they are highly sensitive due to geography and/or high altitudes as well as the need to maximize cargo (external loads, wildfires, construction, etc). Getting high flying experience requires an important investment of time and money, which is not always invested. Ground personnel are directly involved with the flight safety. They should also receive flight safety training appropriate as well as establishing specific SOPs to each type of work.

[10] PIO: Pilot-Induced Oscillation; ODP: Obstacle Departure Procedures

In relation to flight performance conditions, most parts of Aerial Work operations are developed over remote areas with few operational tools. The reason for using a helicopter instead of a plane, with a cost three times greater for the same load capacity, is precisely its ability to hover and perform at low altitude and speed. It is necessary to implement higher proactive and passive protection measures for pilots and crew.

Aerial Works Recommendations

- Reduce the exposure time in the not-permitted zone of the H/V diagram.
- Reinforce the importance of giving priority to establishing Safety in comparison with Mission Objectives.
- Detail SOPs for each type of operation and promote compliance.
- The ground personnel should undergo appropriate flight safety training to avoid improvisations.
- Detail specific ground personnel SOPs.
- Establish appropriate PPEs which must include flight helmet, proper shoes and fire retardant work clothes.
- Implement a realistic FTL and FDTL to avoid extreme pilot fatigue in these complex operations.
- Establish remote infrastructure according to a minimum level of safety and comfort for the operation and crew.
- Protect the legal side of pilot operations from commercial pressures.

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