European Aviation Safety Agency

Study on single-engined helicopter operations over a hostile environment

Final Report

in consortium with

16th June 2014

in consortium with

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1 Acknowledgements

The consortium formed by Advanced Logistics Group and SGI Aviation offers our sincere thanks to all those who made possible the performance and completion of this study "Study on single- engined helicopter operations over hostile environment", initiated and led by the European Safety Agency, to whom we are grateful for the opportunity and the confidence shown in us.

In the first place, we acknowledge the contribution made by the external experts Jaume Bosch (ALG) and Eric van de Pasch (SGI) who provided dedication and support in their respective areas of expertise, offering their critical knowledge of the industry and invaluable experience acquired over many years in the helicopter field.

We also wish to publicly express our gratitude to the Civil Aviation Authorities who have responded to all our requests providing statistical data and assessments on the particularities of the sector in their areas of influence.

Similarly, we would like to give special thanks to the manufacturers and operators of single-engine helicopters, who have shared their own data and indices, taking an impartial and open attitude in the conducting of the various analyses.

Last but not least, we wish to recognise the involvement of all those independent initiatives (partnerships, multi-consulting reports, universities and publications among others) that directly or indirectly have helped to consolidate the databases, adding value and weight to the project results.

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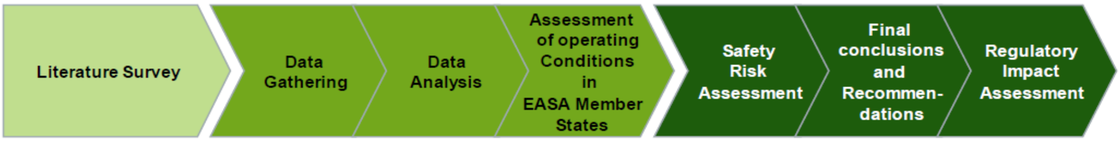
2 Executive Summary

In Europe there is an on-going discussion among helicopter manufacturers, commercial operators and regulatory oversight bodies regarding the relevance of the number (single or multi) as well as the types of engines (piston or turbine) and their suitability for certain types of operations. The discussion focuses in particular on single-engined helicopters that are used in Commercial Air Transport (CAT) operations over a hostile environment, which are regulated by JAR OPS 3.005(e) standard and its relevant Appendices

EASA has decided to review the whole concept of single-engined helicopter operations, with an emphasis on whether or not single-engined helicopter operations over a hostile environment should be allowed, and if so, to what extent, based on a full and objective safety risk assessment for commercial air transport operations that takes into account the impact by each type of operation. Since single-engined helicopters usually perform in a range of different operational fields – such as aerial works and general aviation practices - the impact of each type of operation needs to be taken into account with the aim of clarifying if and under which conditions CAT operations can be conducted.

Under this approach, an operational factual picture has been provided on the safety of single-engined helicopter operations; collecting data on usage in addition to an analysis of accidents and incidents involving single-engine helicopters in EASA Member States over the last 10 years. The study consists of the following tasks:



The literature survey comprised an appraisal of relevant, currently available publications and databases, including information sources from authorities, operators, manufacturers and many other independent initiatives. As well it includes an assessment of the suitability of the information sources, adopting a “multi source” approach to the data gathering process.

In the data gathering task, an exhaustive and detailed procedure was developed for the treatment, merging, and polishing of the data. The Occurrences Database encompasses 4.606 occurrences, of which 920 are accidents and serious incidents. The Fleet Database includes a total single-engined fleet composed of more than 6.800 helicopters. The final Usage Database defines around 9.990.000 FH for single-engined helicopters over the ten year period of the study; regarding the type of engine, 6.000.000 FH are turbine-engined helicopters (60% of total FH) and 3.990.000 FH are piston-engined helicopters (40% of total FH).

The data analysis sought 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, particularly in Commercial Air Transport operations, and in the type of environment (hostile and non-hostile) in which those accidents and serious incidents occurred. Regarding the type of engine, although the absolute number of occurrences is quite evenly balanced between the two types of engine (482 piston, 408 turbine, 30 occurrences not defined), the accident and serious incident rate per 100.000FH for piston engines is 1,74 times greater than that for turbine-engined aircraft (12,08 piston-engined accidents and serious incidents per 100,000 FH vs. 6,80 turbine-engined accidents and serious incidents per 100,000 FH). Focusing only on CAT operations, turbine-engined aircraft register a 32% fatality rate over hostile environment; while due to the regulatory restrictions on piston-engined aircraft, a zero ratio of piston fatalities, and only 2 occurrences, have been recorded over hostile environment.

In addition, the Consortium studied the application of JAR OPS 3.005(e) and relevant Appendices by EASA member states on single-engined helicopters in CAT operations over a hostile environment. Seven states were surveyed to analyse their particular national variants in implementation of the standard: differences between each region were taken into account as well as different levels of airworthiness, training and SSP-SMS conditions. Application of 3.005(e) appears to be concentrated in two regional areas: Alpine States & Nordic States, whose characteristics coincide with the two circumstances listed in IEM to Appendix 1 to JAR-OPS 3.005(e): mountain operations and operations in remote areas

Along with studying the safety risk assessment of CAT operations – mainly focused on engine related occurrences - it was possible to analyse the greatest factors of concern in the sector and propose reactive and proactive mitigation measures, for both piston and turbine powered single-engined helicopters. Power plant failures 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 also proposed as a reactive mitigation measure. Potential issues related to inadequate pilot experience, Pilot Situational Awareness and pilot judgment 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.

All these approaches have made it possible to understand the industry, the causes of the accident rates registered and the key points of safety improvements. Furthermore, they have provided the basis to evaluate and propose recommendations on the implementation and alleviation of JAR-OPS 3.005 (e) and relevant Appendices for each type of engine and the application particularities of each country.

JAR-OPS 3.005(e) and the rule which succeeds it, 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 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**.

With respect to the Maximum Approved Passenger Seating Configuration (MAPSC) limitation of 6, it is appreciated that since introduction of the 3.005(e) alleviation possibility, only one single-engined turbine helicopter type has been introduced with an MAPSC of 7. Given the overall safety occurrence rate of 0,82 x10-5 per flight hour, consideration could be given to extending this restriction to 7, or even 8 or 9. However there are many conditioning factors involved in ensuring safety in the case of extending this limit, so it is recommended to **retain the limit of 6 passengers**.

Finally, a number of EASA member states appear to vary in their practices with regard to JAR-OPS standards. It is recommended that steps are taken 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..

3 Background

The rules should always ensure safety, with a balance of judgment and reason, assuming that the only (almost) 100% safe aircraft is the one not flying. Historically in aviation the level of acceptable risk is scaled in such a way that the transport passenger is guaranteed a minimum risk whilst maximum risk is allowed for the private visual pilot (VFR). Aerial work stands in between and needs to be legislated as such with intermediate rules. The most important differences with CAT is the irregularity of flights, the diversity of operating environments, the operations in unprepared areas, so much so that analyzing aerial work with a similar optic as CAT might be misleading. It is obvious that the risk level inherent to the type of flight, the environment and the improvisation is greater. This controversy is international (the same debate exists in the USA) and there have always been parties with interest in supporting each side, it being a very sensitive question as it relates to safety and economics. The aim of this study has to be to determine if it is really a matter of greater safety versus higher cost or if that relationship does not exist. It is not yet 100% proven and 100% clear whether more engines equals to greater levels of safety since there are scenarios for which level of safety is decreased by adding engine (additional parts, weight etc..) and only one scenario (albeit-important one, engine failure) for which safety is increased.

The increase in cost (acquisition cost, operational cost, and maintenance cost) is rather obvious and often the industry has difficulties to cope with.

This study should assess all elements for and against safety in the balance and determine whether or not a twin engine helicopter is safer than a single engined helicopter, in which cases, in what type of service, operated by what kind of company, etc.. In so doing, legislation can be put forward with contribution of real value for safety, appropriate to the state of the art of current and future technology, avoiding at the same time to burden the industry with unnecessary additional costs.

The current JAR-OPS 3 (which covers only CAT operations) since its inception, has been demanding a level of performance class 1 for all helicopters involved in Commercial Air Transport Operations (with some special alleviation based on risk assessment in helicopter performance for specific cases such as mountain area operational altitude, remote areas, with limitation to 6 passengers). This requirement, basically translating as a requirement to have multi-engine helicopters for this type of operations has assumed a serious cost and issue for the CAT sector. It has been observed that interpretation and implementation of JAR-OPS 3 may have varied between EASA Member States leading to different practices on how such operations are conducted.

At the moment there is no pan-European regulation for the other sectors such as aerial work, training, General Aviation etc (the non CAT sectors); each EASA Member State has derived its own national regulations to manage the safety of non CAT operations.

This situation has meant variations of interpretation of current international recommendations by the different EASA Member States and hence for EASA a lack of visibility in national laws regarding aerial work (often low altitude) and private operations over hostile environment.

It has been a long time coming for such a European regulation to come out; the upcoming Implementing Rule – Air Operations (IR-OPS) will precisely intend to set up a regulation for each type of operations: CAT operations, Commercial operations other than CAT, operations requiring special approval etc..

An important point to be noted at this stage is the fact that contrary to ICAO and JAR recommended Standards and practices or requirements, EASA rules will be legally binding rules.

In the international context where IHSAT has set up the goal of reducing by 80% the helicopter accidents by 2016, EASA has joined in the effort by commanding various safety studies to be performed, additional to its annual safety reviews, by different organisations such as OGP and the European component of the IHSAT, namely EHSAT. The latter is proving to be the reference in terms of accident analysis in Europe.

It is also in the context of the NPA 2009-02 (Notice of Proposed Amendment) final stages that EASA requires a third independent party's educated recommendations on the safety of single engine helicopter operations over a hostile environment.

The Consortium is fully aware of the context described above and will take into account for the study mandated by EASA.

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4 Aims and Objective

EASA requires an independent third party to perform an exhaustive study on the utilization of single engine helicopters for all types of operations in the EASA member States (including also EEA/EFTA States: Iceland, Lichtenstein, Norway and Switzerland). The study is threefold:

1. Study of utilization of single engine helicopters in all types of operations in all types of environment in the EASA member states;
2. Analysis of accidents and incidents of single engine helicopters in all types of operations and all types of environment in the EASA member States in the last 10 years;
3. Safety Risk assessment on utilisation of single engine helicopters for commercial air transport operations over a hostile environment in the EASA member States.

The third aspect of the study could lead to a recommendation for changing the current regulation on the subject; as such and if it is deemed necessary, EASA will require as well a regulatory impact assessment of the proposed rulemaking action.

Even though the main objective of this study is to assess the concept of Commercial Air Transport (CAT)[1] single engine helicopter operations over hostile environment, it is understood that a wider scope needs to be considered in the analysis to encompass all types of operations (ie not only CAT) given the fact that usually the helicopters used for CAT operations will also be used for other types of operations within the same operator. The impact from each type of operation needs to be taken into account when carrying the risk assessment for the CAT operations.

The aim of this study is to provide EASA with an operational factual picture on the suitability and safety of single engine helicopters for commercial air transport operations over a hostile environment; clarifying if and under which conditions this type of operations can be conducted.

[1]Commercial air transport (CAT) operation' means an aircraft operation to transport passengers, cargo or mail for remuneration or other valuable consideration.

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5 Literature Review

It has been conducted a literature review and appraisal on the relevant, currently available publications pertinent to the scope of this study. This includes reference documents, report, general publications and databases on helicopter operations, as well as on the helicopter operators, their fleets and aircraft usage and the associated accident and incident databases necessary for the subsequent tasks of the study.

5.1 Regulatory framework

The JAR OPS 3 Amendment 5 from 1st July 2007 prescribes the requirements applicable to the operation of any civil helicopter for the purpose of commercial air transportation by any operator until ultimately 28 October 2014, when the opt-out provisions of Commission Regulation (EU) n° 965/2012 (Air Operations) that entered into force from 28 October 2012 will expire.

Requirements of JAR OPS 3 have been transposed into Annex IV (Part CAT) Commercial Air Transport Operations, Subpart C Aircraft Performance and Operating Limitations, Section 2 Helicopters of EU Regulation n° 965/2012.

This regulation applies to EASA member states, which are European Union Member States and EEA/EFTA[2] States (Iceland, Liechtenstein, Norway and Switzerland).

5.1.1 Definitions

Before introducing the above-mentioned regulations, it is relevant to recall the definition of the following terms in the regulations:

- Performance Class
- Hostile Environment
- Congested area

Performance Class

A code of performance requirements has been developed for helicopter operations:

- **Operation in performance class 1**: means an operation that, in the event of failure of the critical engine, the helicopter is able to land within the rejected take-off distance available or safely continue the flight to an appropriate landing area, depending on when the failure occurs.
- **Operation in performance class 2**: means an operation that, in the event of failure of the critical engine, performance is available to enable the helicopter to safely continue the flight, except when the failure occurs early during the take-off manoeuvre or late in the landing manoeuvre, in which cases a forced landing may be required.
- **Operation in performance class 3:** means an operation that, in the event of an engine failure at any time during the flight, a forced landing may be required in a multi-engined helicopter and will be required in a single-engined helicopter

A single-engined helicopter is, therefore by definition, required to be operated in Performance Class 3

Hostile environment

Hostile environment means an environment in which:

a) a safe forced landing cannot be accomplished because the surface is inadequate;

b) the helicopter occupants cannot be adequately protected from the elements;

c) search and rescue response/capability is not provided consistent with anticipated exposure; or

d) there is an unacceptable risk of endangering persons or property on the ground;

[2] EEA /EFTA – European Economic Area/European Free Trade Association

e) in any case, the following areas are considered as hostile environment:

1. for overwater operations, the open sea areas north of 45N and south of 45S designated by the authority of the State concerned;
2. those parts of a congested area without adequate safe forced landing areas;

Congested area means in relation to a city, town or settlement, any area which is substantially used for residential, commercial or recreational purposes;

5.1.2 Regulatory requirements in EASA member states

The regulatory requirements states that performance Class 3 operations shall only be conducted in a non-hostile environment.

In case of a critical engine failure, performance class 3 operations over hostile environment will lead to a situation where either a safe forced landing cannot be assured - with a very high likelihood of injuries/fatalities – or, after a successful forced landing, survival of the occupants cannot be guaranteed – resulting in a very high likelihood of injuries/fatalities.

However, according to the provisions of article CAT.POL.H.420, helicopter operations over a non-congested hostile environment without a safe forced landing capability with turbine-powered helicopters may be conducted provided that:

a) Maximum Operational Passenger Seating Configuration (MOPSC) is six or less;

b) The operator has been granted an approval by the competent authority, following a safety risk assessment performed by the operator specifying the type of helicopter and type of operations;

c) If operations in another Member State, endorsement by the competent authority of the Member State where the operation will take place;

d) The operator shall only conduct these operations in the areas and under the conditions specified in the approval;

e) The operator shall not conduct these operations under a HEMS approval;

f) The operator substantiates that helicopter limitations, or other justifiable considerations, preclude the use of the appropriate performance criteria; and

g) Engine failure risk mitigation measures have been implemented:

   a. Attain and maintain the helicopter/engine modification standard defined by the manufacturer;
   b. Conduct the preventive maintenance actions recommended by the helicopter or engine manufacturer;
   c. include take-off and landing procedures in the operations manual, where they do not already exist in the AFM;
   d. Specify training for flight crew; and
   e. Provide a system for reporting to the manufacturer loss of power, engine shutdown or engine failure events;
   f. Implement a usage monitoring system (UMS).
   g. General Performance Class 3 limitations are fulfilled (operations are forbidden out of sight of the surface; or at night; or when the ceiling is less than 600 ft.; or when the visibility is less than 800 m),

The provisions of CAT.POL.H.420 are not implemented yet in EASA Member States. Indeed the requirements from Appendix 1 to JAR-OPS 3.005(e) still apply. But these requirements, which are aligned with those of CAT.POL.H.420 are differently transposed and implemented by Member States.

5.2 Helicopter industry

5.2.1 Helicopters Manufacturers

The helicopter industry has had a historical wide catalogue of players, most of them no longer existing, or having merged or changed names to establish new brands and strategies.

The most representative players nowadays are Eurocopter, Agusta Westland, Bell, McDonnell-Douglas, and Sikorsky, accounting for the turbine helicopters manufacturers, and Robinson as the major player in the single piston helicopter industry.

The following table has a brief description for all of the major and minor civil airframe manufacturers of all type of helicopters, and details changes on ownership over the time and indicates if at least one of their models is certified by EASA.

Manufacturer	Based in	Description	Owner	At least one (1) helicopter model with EASA type certificate
Aerospatiale	France: Toulouse	Historical French aerospace manufacturer, merging the state owned companies Sud Aviation, Nord Aviation, and SÉREB. The activity of the company went from the military and civilian aircraft and rotorcraft division, to rocket and satellite matters. Some of the models, prior to the merging into Eurocopter (EADS) are still in service.	Company merged into Eurocopter group.	Yes
Agusta Westland	Italy / United Kingdom.	Resulting from the merger of Agusta and Westland, this manufacturer has historically built some models collaborating with Bell. Currently it has some production in Russia, after an agreement with Russian Helicopters.	Since May 26th 2004, AgustaWestland has been completely owned by Finmeccanica (Italy).	Yes
Alpi Aviation	Italy	Recreational airplanes manufacturer, born from a group of amateurs. They are currently manufacturing a light helicopter emphasizing in its visual design, and latest technologies in its field		No
Avicopter	China	Helicopter division of the Chinese aircraft manufacturer AVIC.	Owned 69 per cent by AVIC (state) and 31 per cent by Tianjin municipal government.	No
Bell	USA: Fort Worth, Texas	Founded in 1935, it started to develop helicopters six years later, and became one of the better known helicopter manufacturers. Has a close relation with Agusta Westland and its developments in Europe.	Textron, from 1960 until now.	Yes
Boeing	USA: Chicago, Illinois	Mostly known by its airplane division, Boeing is the main manufacturer of the tandem rotor helicopters. It also developed the V-22 Osprey in conjunction with Bell.	Share holders.	No

Manufacturer	Based in	Description	Owner	At least one (1) helicopter model with EASA type certificate
Brantly International	USA: Vernon, Texas	Designer of the B-1 and B-2 models, its only model in production is manufactured in China.	Privately held company. In 2009 all activities were handed over to the Chinese company Qingdao Haili Helicopters Co. Ltd.	Yes
Enstrom Helicopter	USA: Menominee, Michigan	Producing three models either with piston or turbine engines, Enstrom has more than 50 years of history.	Privately owned company	Yes
Eurocopter	France: Marignane	Resulting from the merger of Daimler-Benz Aerospace, and the helicopter division of Aerospatiale, Eurocopter is the main European manufacturer.	EADS	Yes
Hélicoptères Guimbal S.A.	Les Milles, France, Europe	Founded by a former Eurocopter engineer, it produced a piston two-seater helicopter that is currently an EASA type certificate holder		Yes
Hiller Aircraft Corporation		Widely used as utility helicopters, the Hiller Aircraft Corporation has been developing models since 1942. However manufacturing seems to be interrupted. Plans to restart seem to have stalled back in 1995 when the Hiller family bought back the company from Rogerson-Hiller.		No
Hughes Helicopters	USA: Culver City, CA and Mesa, AZ	Started as the helicopter division from Hughes Aircraft, produced own and licenced models, before being acquired by McDonnell Douglas.	McDonnell-Douglas	No
Kaman Aerospace	USA: Connecticut	Founded in 1945, still active in the civil and military helicopter market.	Shareholders in the stock market.	Yes
Kamov	Russia: Moscow	Building helicopters since 1929, it developed several unconventional models, and merged with Mil in 2006.	Oboronprom, amongst others.	Yes (Restricted)
Kawasaki Aerospace	Japan	Manufacturer of several models under licence from Boeing, and Agusta Westland.	Kawasaki	No
Kazan Helicopters	Russian Federation: Kazan city	Producer of Mil models for more than 50 years.		No
Marenco Swisshelicopter	Switzerland	Helicopter division of the engineering company MARENCO		No
McDonnell Douglas	USA: St. Louis, Missouri	Helicopter division of the historical airplane company, it is a result of the acquisition of Hughes Helicopters. Well known by its NOTAR models, and widely used in the United States.	Patriarch Partners, LLC, an investment fund	Yes
Messerschmitt-Bölkow-Blohm	Germany	Well known manufacture, in a Europe-wide used helicopter, the BO 105. It is currently part of Eurocopter.	Merged into DASA, which merged in Eurocopter.	No
Mil	Russia: Moscow	Historical company, a quarter of all the helicopters worldwide are from its manufacture, or designs.	Shareholders with Oboronprom being the largest one by far.	No
Mitsubishi	Japan	It currently has a light utility model only sold in the Japanese market.	Mitsubishi	No

Manufacturer	Based in	Description	Owner	At least one (1) helicopter model with EASA type certificate
NHIndustries		Established by Agusta, Eurocopter and Stork Fokker Aerospace, was responsible for the development of the NH90 helicopter.	Agusta, Eurocopter and Stork Fokker Aerospace.	No
PZL Swidnik	Poland	Currently part of the Italian manufacturer AgustaWestland, has developed some models under soviet licence. Its medium helicopter is widely used in Europe.	AgustaWestland	Yes
Qingdao Haili Helicopters Co. Ltd	China	Holder of the license to manufacture the B-2B helicopter in China.		No
Quest Helicopters	Dubai	UAE's helicopter company, with little information about its current developments.	Quest Investments	No
Robinson Helicopter Company	USA: Torrance, California	Main piston helicopter OEM, producing three models used worldwide, known for its frequent use in instruction.	Frank Robinson	Yes
Rotorway International	USA: Chandler, Arizona	Third largest American helicopter company, currently developing north American and south African markets, has intention to develop its own engine manufacturing company.	Owned by senior management.	No
Russian Helicopters Joined Stock Company	Russia	Sole current Russian helicopter manufacturer, it shares the experience of historical companies as Kazan, MIL and Kamov, and has also agreements with Agusta Westland to build some of its models.	Partnership between Kazan, MIL, Kamov and others.	No
Schweizer	USA: Horseheads, New York	Mainly producing light, utility and training helicopters, this brand has had models that lasted for more than 50 years. It is currently owned and maintained by Sikorsky.	Sikorsky Aircraft Corporation	Yes
Sikorsky	USA: Stratford, Connecticut	Founded in 1923, initiated its activity in the rotorcraft industry in the 1940s. From then, Sikorsky has been one of the major players both in the civilian and military helicopter market.	United Technologies Corporation	Yes
Sud Aviation	France	Sud Aviation, founder of Aerospatiale, was a French state-owned aircraft manufacturer. Some of its designs are still in service, with maintenance provided by EADS group.	Eurocopter	Yes

Table 1: Helicopter manufacturers

5.2.2 Helicopters certified in EASA member states

As stated in the table above, a significant number of manufacturers have helicopter models currently holding an EASA type certificate[3]. These models, in the date of the study account for 102 European and 39 foreign, and are available in the following websites:

- European rotorcraft: http://www.easa.europa.eu/certification/docs/products/Rotorcraft_EUR.pdf
- Foreign rotorcraft: http://www.easa.europa.eu/certification/docs/products/Rotorcraft_non-EUR.pdf

It must be noted that the major part of the fleet in this states accounts for a few of this models, and brands, and though while analysing the data there must be an important consideration on which of the models certified, are actually flying or available in the territories.

It is also remarkable that the European helicopters with EASA type certificate are Agusta Westland, Eurocopter (and merged manufacturers), Guimbal, Mecaer (A licence for MD in Europe), and PZL-Swidnik.

The non-European manufacturers holding EASA type certificates for their helicopters models are Bell, Brantly, Enstrom, Erickson, MacDonnell-Douglas, Philippine Aerospace Development (a Bolkow licenced product), Robinson, Schweizer and Sikorsky.

According to the current type certificate holders, overviewing the fleets present in Europe, and in the basis of this study, the key manufacturers approached for a solid information channel have been:

- Eurocopter
- Bell
- Agusta Westland
- Sikorsky
- Robinson (key manufacturer of smaller mainly piston-powered aircraft

On the other hand, the engine manufacturers have to be studied separately. There are currently five manufacturers controlling the major part of the industry. These OEMs, some product of merging historical companies, are: Turbomeca, Rolls-Royce/Allison, Honeywell/Lycoming, Pratt & Whitney Canada, and General Electric.

5.2.3 Helicopters operated in EASA member states

According to our first rough estimations, EASA member states counts around 7,500 helicopters. Four countries concentrate almost 60% of the total fleet of helicopters in Europe

Country	% Helicopter fleet
France:	19 %
United Kingdom	16 %
Germany	12 %
Italy	11 %
TOTAL	59 %

Table 2: Distribution of Helicopter Fleet in Europe

The 7,500helicopters in EASA member states are divided in the approximate proportions:

- Single turbine 31% (most common type AS350 Ecureuil 1 followed by JetRanger series)
- Twin turbine 32% (most common type EC135)
- Single piston 37% (over two thirds of them Robinson 22/44)

[3] Including type certificate (including restricted type certificates) issued by an EASA member state prior to the transfer to EASA type-certification of aircraft and components activities

According the EHEST Final Report 2010 (Analysis of 2000-2005 European Helicopter Accidents), the fleet of helicopters in Europe is split in three different profiles of operators:

- Small operators (1 to 2 helicopters) → around 30% of whole helicopter fleet in Europe
- Medium operators (3 to 20 helicopters) → around 37% of whole helicopter fleet in Europe
- Large operators (more than 20 helicopters) → around 33% of whole helicopter fleet in Europe

The large operators have divisions for all types of activities (offshore, Search and Rescue, patrol…) and have the appropriate organisation to support their activities (training department, quality assurance,..). The small operators are generally specialised (sightseeing, crop spraying, flight training…). These small operators do not have the resources and means that a large operator may have.

A fourth type of operators is the public services operators with large fleet and only one type of service (Police, Transit, SAR…) (mainly included in 33% of whole helicopter fleet in Europe).

5.3 Information Sources

5.3.1 Authorities

5.3.1.1 EASA

The European Aviation Safety Agency (EASA) is an agency of the European Union established in 2002 by a regulation of the European parliament and the Council in order to ensure a high and uniform level of safety in civil aviation, by the implementation of common safety rules and measures. It became operational in September 2003.

The Agency promotes the highest common standards of safety and environmental protection in civil aviation in Europe and worldwide. The European Aviation Safety Agency (EASA) is the centrepiece of the European Union’s strategy for aviation safety. The Agency develops common safety and environmental rules at a European level. Also, it monitors the implementation of standards through inspections in the Member States and provides technical expertise, training and research.

EASA has taken over the responsibilities of the former Joint Aviation Authorities (JAA) system which ceased on 30 June 2009. However, it is not a successor agency in legal terms since it functions directly under EU statute. The main difference between EASA and the JAA is that EASA is Regulatory Authority which uses NAAs to implement its Regulations whereas the JAA relied upon the participating NAAs to apply its harmonised codes without having any force of law at source.

The agency's responsibilities include:

- Expert advice to the EU for drafting new legislation;
- Implementing and monitoring safety rules, including inspections in the Member States;
- Type-certification of aircraft and components, as well as the approval of organisations involved in the design, manufacture and maintenance of aeronautical products;
- Authorization of third-country (non EU) operators;
- Safety analysis and research

The type formation available in EASA for the purpose of this study is detailed in the table below:

Type of Information	Support	Documented in
Operational Occurrences ☒	1. Accident/Incident Data Reporting (ADREP) 2. European Central Repository (ECR)	Section 5.4.1- Table 25, Table 26
Safety&Research Reports ☒	Various publications	Section 5.5.1
Fleet and operator information ☒	Operator and fleet database	Section 0 - Table 35: EASA Operator and Fleet Data
Usage data ☐	-	-
Design Related Occurrences ☒	Internal Occurrence Reporting System (IORS)	Section 5.4.3 - Table 43: Internal Occurrence Reporting System (IORS)
Reliability Reports ☐	-	-

Table 3: EASA Type of Information

5.3.1.2 Civil Aviation Authorities (CAA)

Each EASA member state possesses its Civil Aviation Authority which is given responsibility for determining and administering the regulatory regime which is in place to ensure that aircraft can be operated safely. In all there are 31 Civil Aviation Authorities with this responsibility.

As responsible for the delivery of aircraft registrations, each CAA maintains a database of aircraft national registers. Also, CAAs are responsible for collecting data related to the usage of aircraft reported by helicopter operators. Indeed it is required to operators to make available to the related CAA, the hours flown for each helicopter operated during the previous calendar year.

The information that may be obtained from the CAAs for the purpose of this study is detailed in the table below:

Type of Information	Support	Documented in
Operational Occurrences ☐	-	-
Safety&Research Reports ☒	Various publications	Section 5.6.2, Section 5.6.3
Fleet and operator information ☒	International Register of Civil Aviation (IRCA)	Section 5.4.2 - Table 37
Usage data ☒	International Register of Civil Aviation (IRCA)	Section 5.4.2 - Table 37
Design Related Occurrences ☐	-	-
Reliability Reports ☐	-	-

Table 4: NCAA Type of Information

As far as research and safety reports are concerned, the most active are the northern states, as well as the United Kingdom, very active in helicopter transport to offshore locations, and though having large units that study the field.

It has been considered relevant to survey non-European authorities, such as the American and Australian, having an extended helicopter use, even if the whole operational concept for single-engined helicopters is defined otherwise. However the studies have methodologies and accident approaches that have been considered relevant, even if most of the data will not be comparable with the current study outputs

Sections 5.6.2 and 5.6.3 address the reports published by different Civil Aviation Authorities worldwide in relation of the scope of this study.

5.3.1.3 European Helicopter Safety Team (EHEST)

Launched on November 2006, the European Helicopter Safety Team (EHEST) brings together manufacturers, operators, research organisations, regulators, accident investigators and a few military operators from across Europe. EHEST is the helicopter branch of the ESSI, an aviation safety partnership between EASA, other regulators, and the industry. The three pillars of ESSI are EHEST, as well as the Commercial Aviation and the General Aviation safety teams.

It is also the European component of the International Helicopter Safety Team (IHST).

Committed to contribute to the goal of reducing the helicopter accident rate by 80 per cent by 2016 worldwide, with emphasis on improving European safety, the basic principle of EHEST is to improve aviation safety by complementing regulatory action by voluntarily encouraging and committing to cost-effective safety enhancements. Analysis of occurrence data, coordination with other safety initiatives and implementation of cost-effective action plans are carried out to achieve specific safety goals. In addition, the EHEST initiative implements actions of the European Aviation Safety Plan 2012-2015 (EASP).

The information obtained from EHEST for the purpose of this study is detailed in the table below:

Type of Information		Support	Documented in
Operational Occurrences	☒	European Helicopter Safety Analysis Team (EHSAT)	Section 5.4.1- Table 27
Safety&Research Reports	☒	Various publications	Section 5.6.1
Fleet and operator information	☐	-	-
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 5: EHEST Type of Information

5.3.2 Manufacturers

With the support of the European Helicopter Association (EHA), the Consortium established contacts with the following key airframe and engine manufacturers:

- Eurocopter
- Bell
- Turbomeca
- Sikorsky
- Robinson (key manufacturer of smaller mainly piston-powered aircraft)

Unfortunately, EHA could not provide contacts for the other key players of the Original Equipment Manufacturer (OEM) industry:

- Airframe: Augusta Westland, Boeing, McDonnell-Douglas Helicopters (ex Hughes),
- Engine: Rolls-Royce/Allison, Honeywell/Lycoming, Pratt & Whitney Canada and General Electric.

The Consortium took the initiative to contact Augusta, but unfortunately no reply has been received yet.

At the time of this report only the following manufacturers showed willingness to contribute in this study

- Eurocopter
- Bell
- Turbomeca
- Robinson

Sikorsky is still considering our request of kind contribution to the study.

The Consortium intends to contact again OEMs once EASA releases the agreed mandate requesting the contribution of OEM through the provision relevant information to the purpose of this study.

According to our discussions with the above-mentioned manufacturers, it appears some differences between the databases of airframe manufacturers and power plant manufacturers.

- Airframe manufacturers keep track of every accident and serious incident. This information is either provided from authorities, reported to the manufacturer by the operators or by its extensive network of field engineers or simply collected by the manufacturer thanks to its active monitoring of fleet events
- Engine manufacturers records any reported accident or incident of their engine fleets. The added value with regard airframe manufacturer databases is that most probably it will contain more information related to incidents without catastrophic consequences. Indeed such engine incidents are not always reported. For example an engine failure ended in an autorotation without consequences, would not normally be reported either to the authorities or to the airframe builder. However, thanks to its network of repair stations, engine manufacturers are able to collect this information.
- In addition, engine manufacturers do not have extensive information about accidents and incidents without direct or indirect engine failure.

OEMS are willing to deliver aggregated data and statistics based on the queries that the Consortium will define. But the data stored in their databases would be redacted and therefore not be accessible for each single occurrence. OEMs will not provide access to their occurrence databases.

In addition to managing the above-mentioned databases, OEMs develops their own safety studies, parallel to and complementary with the ones from the national authorities.

5.3.2.1 Eurocopter

Eurocopter is a European manufacturer, resulting from the merge of various historical brands. It currently has the widest offering in single engine helicopters among all manufacturers, as well as the major fleet share of operators in Europe.

The Eurocopter group was created in 1992 with the merger between the helicopter divisions of Aerospatiale-matra (France) and DaimlerChrysler Aerospace (Germany).

The group is now a subsidiary owned 100% by EADS (European Aeronautic Defence and Space Company), one of the three largest aerospace groups in the world.

A meeting with Eurocopter was held at Eurocopter's facilities in order to expose the project, to identify the relevant information that could be shared and establish an information flow between the manufacturer and the consortium. The type formation that Eurocopter is aiming to share for the purpose of this study is detailed in the table below:

Type of Information	Support	Documented in
Operational Occurrences ☒	Eurocopter Operational Occurrence database	Section 5.4.1 - Table 28
Safety&Research Reports ☐	-	-
Fleet and operator information ☒	Eurocopter fleet database	Section 5.4.2 - Table 36
Usage data ☒	Eurocopter fleet database	Section 5.4.2 - Table 36
Design Related Occurrences ☒	To be obtained through IORS	Section 5.4.3 - Table 43
Reliability Reports ☒	Reliability Reports	Not yet available – Will be provided after signature of a Non-Disclosure Agreement by both parties

Table 6: EUROCOPTER Type of Information

5.3.2.2 Robinson

Robinson is an American helicopter company founded in 1973 by Frank Robinson to design and manufacture a light, inexpensive helicopter for general aviation markets. The Company is currently the world's leading manufacturer of civil helicopters, and has a network of more than 400 service centers.

Robinson manufactures three models of helicopter: two piston engine models, the R22, and R44, and a turbine engine variant the R66, all designed as a cheap and effective alternative to its competitors. Over the years Robinson has produced over 10.000 helicopters, from which almost a half have been R22, its most successful model.

Robinson does not maintain its own records of accidents or incidents. Instead Robinson relies on public databases such as NTSB accident reports and the FAA's SDR database. Also, Robinson does not maintain a record of ownership of the helicopters manufactured. As stated in the table below, the information provided by Robinson relates to Safety & Research Reports.

Type of Information		Support	Documented in
Operational Occurrences	☐		
Safety&Research Reports	☒	Study on R44 & R44 II engine power loss rates	Section 5.6.5
Fleet and operator information	☐		
Usage data	☐		
Design Related Occurrences	☐		
Reliability Reports	☐		

Table 7: Robinson Type of Information

5.3.2.3 Turbomeca

Turbomeca specialises in the design, production, sale and support of low- to medium-power gas turbines for helicopters. Including its joint programs with other manufacturers, Turbomeca is today the world's leading provider of helicopter engines, offering a full range of services close to customers, wherever they may operate.

The company also develops and markets turbo-jet engines for fixed-wing aircraft. Turbomeca also has one subsidiary: Microturbo, a specialist in turbo-reactors for missiles.

Turbomeca turbines power civil, parapublic and defence helicopters for all the leading helicopter manufacturers.

A conference call was organised with Turbomeca in order to expose the project, to identify the relevant information that could be shared and establish an information flow between the manufacturer and the consortium.

In the teleconference, Turbomeca pointed out that as part of its duties as a holder of the Engine Type Certificate, it is mandatory to report all design related occurrences to EASA.

The type formation that Turbomeca is aiming to share for the purpose of this study is detailed in the table below:

Type of Information		Support	Documented in
Operational Occurrences	☒	Turbomeca database	Section 5.4.1- Table 29
Safety&Research Reports	☐	-	-
Fleet and operator information	☐	-	-
Usage data	☐	-	-
Design Related Occurrences	☒	To be obtained through IORS	Section 5.4.3 - Table 43
Reliability Reports	☒	Reliability Reports	Not yet available – Will be provided after signature of a Non-Disclosure Agreement by both parties

Table 8: TURBOMECA Type of Information

5.3.2.4 Bell

A major American helicopter company founded in 1935, has been a reference in the helicopter industry since the beginning. Bell was the first company to obtain certification for a commercial helicopter, and has delivered over 35.000 aircraft to customers.

In Europe, most of its models have been developed jointly with Agusta.

Communication with Bell has been established through e-mails. Bell expressed its willingness to contribute to this study and a Non-Disclosure Agreement has been signed between both parties. At the time of this report, only safety related reports have been made available. The table below details the information already available and the information that is expected to be provided by Bell.

Type of Information		Support	Documented in
Operational Occurrences	☒	To be determined	Not yet available
Safety&Research Reports	☒	Various publications	Section 5.6.4
Fleet and operator information	☐	-	-
Usage data	☒	To be determined	Not yet available
Design Related Occurrences	☒	To be determined	Not yet available
Reliability Reports	☒	Reliability Reports	Not yet available

Table 9: BELL Type of Information

5.3.3 Helicopter Operators and Fleets

Large operators (more than 20 helicopters single or multi engine) concentrate around 33% of whole helicopter fleet in Europe. The most relevant large operators operating single engine helicopters are sampled in the table below:

Country	Details
Portugal	Heliportugal LDA = HPL Cascais-Tires
	Aerodromo Municipal de Cascais, Hangar 3/7 S Domingos de Rana, Tires P-2785-632, Portugal Tel: +351 214447230 Fax: +351 214448067 Email: info@heliportugal.pt
	F: 1982 Emps: 78 Head: Pedro Silveira ICAO: HELIPORTUGAL Web: www.heliportugal.pt
Spain	**INAER Helicopteros = UV (Member of Grupo INAER) Alicante**
	Partida de la Almaina 92, Mutxamel, Alicante E-03110, Spain Tel: +34 965663835 Fax: +34 965665924 Email: info@inaer.com
	F: 1983 Emps: 250 Head: Luis San Valero IATA: 662 ICAO: HELISURESTE Web: www.inaer.es

Country	Details
Ireland	**Executive Helicopters Ireland (Executive Helicopters Maintenance) Galway**
	Hangar A, Galway Airport, Carnmore Co Galway, Ireland Tel: +353 91783300 Fax: +353 91755588 Email: info@executive-helicopters.com
	F: 1998 Emps: 10 Head: Chris Shiel Web: www.executive-helicopters.com Provides: Air Charter Services , Maintenance & Training
France	**Heli-Union = HLU Toussus-le-Noble**
	4 Avenue De la Porte-de-Sevres, Paris F-75015, France Tel: +33 153780818 Fax: +33 139258485 Email: marketing@heli-union.com
	F: n/a Emps: n/a Head: Jean-Christophe Schmitt Web: www.heli-union.com
Italy	**Heliwest**
	Localita Tagliata North 314, Frazione San Marzanotto, Asti I-14100, Italy Tel: +39 0141595985 Fax: +39 0141595995 Email: heliwest@heliwest.it
	F: n/a Emps: n/a Head: Luciano Villani Web: www.heliwest.it
Norway	**Airlift Norway = ALI (Subs. of Helicopter Transportation Group) Forde**
	Forde Lufthavn, Bygstad N-6977, Norway Tel: +47 57718100 Fax: +47 57718101 Email: firmapost@airlift.no
	F: 1986 Emps: 86 Head: Kjell Paulseth Web: www.airlift.no
Belgium	**Heli Service Belgium NV Halle-Heliport**
	Gaasbeeksesteenweg 140, Halle B-1500, Belgium Tel: +32 23612121 Fax: +32 23602770 Email: ops@hsb.be
	F: n/a Emps: n/a Head: Bernard Slegten Web: www.hsb.be
	Heli Holland BV = HHE Emmer-Helipad
	Postbus 16, Kanaal B ZZ 3, Emmen NL-7881NB, Netherlands Tel: +31 591351251 Fax: n/a Email: info@heliholland.nl
	F: 1976 Emps: 5 Head: Rene Haring Web: www.heliholland.nl
Switzerland	**Air Glaciers = AGV Sion**
	Aeroport Civil, Case Postale 27, Sion CH-1951, Switzerland Tel: +41 273291415 Fax: n/a Email: info@air-glaciers.ch F: 1965 Emps: 120 Head: Bruno Bagnoud ICAO: AIR GLACIERS Web: www.air-glaciers.ch
Austria	**Heli Austria GmbH St Johann Im Pongau-Heliport**
	5600 St Johann im Pongau, Salzburg A-5310, Austria Tel: +43 64624200 Fax: +43 6462420042 Email: fly@heli-tirol.at
	F: n/a Emps: n/a Head: Rolf Knaus Web: www.heli-austria.at
Czech Republic	**DSA AS Hradec Kralove**
	Bratri Stefanu 101, Hradec Kralove CZ-500 03, Czech Republic Tel: +420 495407407 Fax: +420 495407407 Email: office@dsa.cz
	F: n/a Emps: n/a Head: Tomas Suchanek Web: www.dsa.cz
Sweden	**Osterman Helicopter Gothenburg-Saeve**
	Save Flygplatsvag 38, Gothenburg S-42373, Sweden Tel: +46 31926000 Fax: n/a Email: info@ohab.se
	F: 1950 Emps: 20 Head: Chris Hagberg Web: www.ostermanaero.se

The Consortium is liaising with Grupo INAER, one of the major large operators for the provision of relevant information for this study. At the time of this report, INAER could not have made available any pertinent information.

5.3.4 Associations

A large number of associations exist for the helicopter sector, at industry and user/operational level. The most relevant for the purpose of this study are addressed in this section.

5.3.4.1 European Helicopter Association

The mission of the EHA is to speak as the voice for the European Rotorcraft industry at the European institutions and elsewhere, including to the general public; representing and promoting the best interests of all sectors as an economically important, safe and sustainable industry essential to the success of European and National economies.

Despite EHA is not a source of information itself for the purpose of this study, it has been supporting the Consortium to establish contacts with the following airframe and engine manufacturers:

- Eurocopter
- Bell
- Turbomeca
- Sikorsky
- Robinson (key manufacturer of smaller mainly piston-powered aircraft)

5.3.4.2 Oil and Gas Producers

The International Association of Oil & Gas Producers (OGP) encompasses the world's leading private and state-owned oil & gas companies, their national and regional associations, and major upstream contractors and suppliers.

In the OGP the members share its best practices to achieve improvements in health, safety, the environment, security, social responsibility, engineering and operations

The OGP itself publishes data, studies, guidelines and assessment about safety performance and operations.

The table below highlights the type of information that has been collected from OGP from internet (http://www.ogp.org.uk).

Type of Information		Support	Documented in
Operational Occurrences	☐	-	-
Safety&Research Reports	☒	Various publications	Section 5.6.5
Fleet and operator information	☐	-	-
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 10: OGP Type of Information

Through its Aviation Sub-Committee, OGP conducts research into rotary and fixed wing aircraft safety and produces industry guides for heliport design, helicopter operating standards and the auditing of chartered flight operations. The Consortium has been put in touch with the Chairman of the Aviation Sub-Committee to enable a dialogue to take place to explore possible contributions to this study.

5.3.4.3 Flight Safety Foundation (FSF)

The Flight Safety Foundation was formed in 1947 to pursue the continuous improvement of global aviation safety. The Foundation meets this objective through research, auditing, education, advocacy and publishing.

The Foundation's effectiveness in bridging cultural and political differences in the common cause of safety has earned worldwide respect.

Today, membership includes more than 1,200 organizations and individuals in 150 countries. The Foundation is based in Alexandria, Virginia, U.S., has a regional office in Melbourne, Australia, and is affiliated with associate organizations in Japan, Russia, Southeast Europe, Taiwan, China and West Africa.

The table below highlights the type of information that has been collected from FSF through internet (http://flightsafety.org) and AV-DATA.

AV-DATA is a single source for aviation regulatory and compliance data and provides immediate access to relevant information from the complex range of domestic and international aviation authorities and agencies.

AV-DATA contains critical information from the FAA and other US agencies and is the only aviation product that includes worldwide information from other authorities such as EASA, JAA, ICAO and UKCAA. AV-DATA includes quick access to Flight Safety Foundation (FSF) reports.

The table below highlights the type of information obtained from FSF.

Type of Information		Support	Documented in
Operational Occurrences	☒	Aviation Safety Net	Section 5.4.1- Table 31
Safety&Research Reports	☒	Various publications	Section 5.6.7
Fleet and operator information	☐	-	-
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 11: FSF Type of Information

In addition to these researches, the Consortium took the initiative to contact FSF to explore further contribution to this study, but at the time of this report, no answer was received yet.

5.3.4.4 International Helicopter Safety Team (IHST)

The IHST was created to lead a government and industry cooperative effort to address the unacceptably high long-term helicopter accident rates. The IHST chose to pursue the goal of reducing the worldwide civil and military helicopter accident rates by 80% in 10 years by adopting the methods that have been used by the Commercial Aviation Safety Team (CAST) to substantially reduce the worldwide fatal accident rate in the commercial air carrier community.

The process used by CAST was directly linked to real accident data, used a broad spectrum of industry experts to analyse it and included objective success measurements to ensure that the actions taken were having the desired effect.

Accordingly, the IHST chartered the Joint Helicopter Safety Analysis Team (JHSAT) to adapt the CAST process to analyse helicopter accident data and to offer recommendations for reducing the accident rate.

The IHST also chartered the Joint Helicopter Safety Implementation Team (JHSIT) to assess the JHSATs' recommendations and to develop detailed implementation plans for the safety enhancements deemed to have the greatest potential benefit. Industry helicopter safety experts representing operators, airframe and engine manufacturers, and regulators comprise both the JHSAT and the JHSIT.

The table below highlights the type of information that can be obtained:

Type of Information		Support	Documented in
Operational Occurrences	☐	-	-
Safety&Research Reports	☒	Various publications	Section 5.6.8
Fleet and operator information	☐	-	-
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 12: IHST Type of Information

In addition to these researches, the Consortium took the initiative to contact IHST to explore further contribution to this study, but at the time of this report, no answer has been received yet

5.3.4.5 Other Associations

During the literature survey, some additional active helicopter associations were identified. Their websites were checked but not relevant information could be obtained. For some of the cases, these associations were also contacted but no reply has been received at the time of this report.

5.3.4.5.1 Helicopter Association of Canada (HAC)

The Helicopter Association of Canada, is a very active organisation within the helicopter world. Traditionally, Canada has been one of the reference countries in helicopter flights, and its operators along with its associations and authorities are considered worldwide. The HAC has the objective of ensuring the financial viability of the Canadian Civil Helicopter Industry, educating its members about issues important to the industry, promoting the enhancement of flight safety, developing the utilisation as a mean of transport, and exchanging best practices among members.

5.3.4.5.2 British Helicopter Association (BHA)

The BHA is the non-profit trade organisation that represents the UK's civil helicopter industry to government departments and international bodies. Its main aim is to promote the safe, efficient and environmentally responsible operation of rotorcraft throughout the UK. We have approached the BHA with a view to establishing a dialogue on the study issues and are currently awaiting receipt of a copy of their Yearbook

5.3.4.5.3 General Aviation Manufacturers Associations (GAMA)

International trade association representing over 80 leading manufacturers of general aviation airplanes, rotorcraft and its components.

Through its public information and education programs, GAMA promotes better understanding of general aviation and the important role it plays in economic growth and in serving the transportation needs of communities, companies and individuals worldwide.

5.3.4.5.4 Helicopter Association International (HAI)

For more than 60 years, HAI has provided support and services to its members and to the international helicopter community. Headquartered in Alexandria, Virginia, HAI members safely fly more than 5,000 helicopters some 2.3 million hours each year. Governed by a Board of Directors elected from the membership, with daily operations conducted by a dedicated professional staff.

5.3.5 European Cockpit Association

The European Cockpit Association (ECA) was created in 1991 and is the representative body of European pilots at European Union (EU) level. It represents over 38,000 European pilots from the National pilot Associations in 37 European states.

The European Cockpit Association represents the collective interests of its Member Associations at European level, striving for the highest levels of aviation safety and fostering social rights and quality employment for pilots in Europe.

The European Cockpit Association and in particular its Helicopter Working Group were considered a potential source of information. However no significant information has been provided yet.

5.3.6 Multi-client Consulting Reports

Among the extensive number of consultancy companies offering services related to helicopter safety, four firms have been identified as possible source of relevant information for the purpose of this study. Strictly in the context of the EASA study these organisations are consultancy and publishing companies specialising in the types of data required

5.3.6.1 ASCEND

Ascend is a global online information company, offering also a Valuations and Appraisals, and Consulting solutions across the entire aerospace industry. Their deliveries include detailed accident reports, analysis of safety trends, and recommending on air safety improvements.

It is currently owned by FlightGlobal (part of Reed Business Information), and claims to be the world's leader in multi-platform business information

Among its clients, it can be found the ICAO, FAA and UK CAA, as well as global insurers.

The table below highlights the type of information that can be obtained:

Type of Information		Support	Documented in
Operational Occurrences	☒	World Aircraft Accident Summary (WAAS)	Section 5.4.1 - Table 30
Safety&Research Reports	☐	-	-
Fleet and operator information	☒	HELICAS Database	-
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 13: ASCEND Type of Information

5.3.6.2 AV-DATA

AV-DATA is a single source for aviation regulatory and compliance data and provides immediate access to relevant information from the complex range of domestic and international aviation authorities and agencies.

AV-DATA contains critical information from the FAA and other US agencies and is the only aviation product that includes worldwide information from other authorities such as EASA, JAA, ICAO and UKCAA. AV-DATA includes quick access to Flight Safety Foundation (FSF) reports.

The table below highlights the type of information that can be obtained:

Type of Information		Support	Documented in
Operational Occurrences	☐	-	-
Safety&Research Reports	☒	FSF Publications	Section 5.6.7
Fleet and operator information	☐	-	-
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 14: AV-DATA Type of Information

5.3.6.3 FlightGlobal - JP Airlines Fleets International

FlightGlobal is an online news and information website related to the aviation and aerospace industries, providing different levels of service depending on the clients' needs. Its databases include information about airlines, routes, aircraft, and many sources of news. For the particular case of this study, FlightGlobal publishes a yearly book, with 46 editions at present, providing information about commercial operators, including its registered fleets, and main details.

The table below highlights the type of information that can be obtained:

Type of Information		Support	Documented in
Operational Occurrences	☐	-	-
Safety&Research Reports	☐	-	-
Fleet and operator information	☒	JP Airline Fleets International	Section 5.4.2 - Table 38
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 15: AV-DATA Type of Information

5.3.6.4 Helivalue$

Helivalue$ has over 25 years of experience publicating The Official Helicopter Blue Book, giving the historical records of helicopter transactions, as well as a detailed specification sheet for a wide number of different models and brands.

The table below highlights the type of information that can be obtained:

Type of Information		Support	Documented in
Operational Occurrences	☐	-	-
Safety&Research Reports	☐	-	-
Fleet and operator information	☒	The official helicopter Blue Book	Section 5.4.2 - Table 39
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 16: Helivalue$ Type of Information

5.3.6.5 Forecast International

Forecast International is a consultancy company, providing market intelligence, forecasting, and research services. Founded in 1973, the company evaluates data, and generates forecasts, offering accurate historic information as well as personalised reports. Its "Business Class" helicopter fleet report appears to be the most comprehensive and readiliy accessible means of identifying the main operators across the range of helicopters classes and models.

Type of Information		Support	Documented in
Operational Occurrences	☐	-	-
Safety&Research Reports	☐	-	-
Fleet and operator information	☒	Rotor Roster Business Class Helicopters	Section 5.4.2 - Table 40
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 17: Forecast International Type of Information

5.3.7 Independent Initiatives

A number of potential data sources both for accident data and for that relating to the worldwide helicopter fleet have been identified and analysed to determine its suitability for use in this study. This sections addresses these potential data sources:

5.3.7.1 Rotorspot

Developed mainly by an aeronautical engineer, and former spotter, Rotorspot is a website that gives access to a registration database built over the years. The database starting first with the Netherlands, then Belgium and Luxembourg, has been expanded to encompass the whole European territory and worldwide data.

The table below highlights the type of information that can be obtained:

Type of Information		Support	Documented in
Operational Occurrences	☐	-	-
Safety&Research Reports	☐	-	-
Fleet and operator information	☒	Rotorspot database	Section 5.4.2 - Table 41
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 18: ROTORSPOT Type of Information

5.3.7.2 Helihub

HeliHub.com is wholly owned by Jeremy Parkin, and is independent of all helicopter manufacturers, suppliers, operators, sales companies, or media organisations. It has been created to provide helicopter information, trying to overcome the US and European industry focus, and offering information and news in a worldwide basis.

The table below highlights the type of information that can be obtained:

Type of Information		Support	Documented in
Operational Occurrences	☒	Helihub database	Section 5.4.1 - Table 32
Safety&Research Reports	☐	-	-
Fleet and operator information	☒	Helihub database	Section 5.4.2 - Table 42
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 19: HELIHUB Type of Information

5.3.7.3 Griffin Helicopters

Griffin Helicopters is an online accident, news, and general information resource site, owned and developed by Gary Spender, with several pilots and experts collaborating in its content. The website is UK based, but has worldwide information in some fields, and some tools for the use of pilots.

The table below highlights the type of information that can be obtained:

Type of Information	Support	Documented in
Operational Occurrences ☒	Griffin Database	Section 5.4.1 - Table 33
Safety&Research Reports ☐	-	-
Fleet and operator information ☐	-	-
Usage data ☐	-	-
Design Related Occurrences ☐	-	-
Reliability Reports ☐	-	-

Table 20: GRIFFIN Type of Information

5.3.7.4 Helicopter Safety.org

Helicoptersafety.org is a website created by two pilots with an instructing background concerned about general aviation helicopter accidents in the UK. The organization was, at first, created to organize safety evenings to promote helicopter safety around the UK, and derived in a website providing as much information about helicopter safety in the UK as possible.

In the web there are some statistics from accident information extracted from a similar concept website, the Griffin Helicopter database.

The table below highlights the type of information that can be obtained:

Type of Information	Support	Documented in
Operational Occurrences ☒	Griffin Database	Section 5.4.1 - Table 33
Safety&Research Reports ☒	Website based	Section 5.6.10
Fleet and operator information ☐	-	-
Usage data ☐	-	-
Design Related Occurrences ☐	-	-
Reliability Reports ☐	-	-

Table 21: Helicopter Safety Type of Information

5.3.7.5 Helis

Maintained by a single person, the site belongs and is created by several pilots, experts, and helicopter amateurs. The website includes various historical informations, as well as an accident database, and some general information about the helicopter industry as shown in the table below:

Type of Information		Support	Documented in
Operational Occurrences	☒	Helis database	Section 5.4.1 - Table 34
Safety&Research Reports	☐	-	-
Fleet and operator information	☐	-	-
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 22: HELIS Type of Information

5.3.8 Universities

5.3.8.1 Nationaal Lucht- en Ruimtevaartlaboratorium (NLR)

The NLR is the aerospace knowledge enterprise in the Netherlands. It carries out studies about safety, environment, efficiency in all the fields of aviation.

The table below highlights the type of information that can be obtained:

Type of Information		Support	Documented in
Operational Occurrences	☐	-	-
Safety&Research Reports	☒	Various Publications	Section 5.6.9
Fleet and operator information	☐	-	-
Usage data	☐	-	-
Design Related Occurrences	☐	-	-
Reliability Reports	☐	-	-

Table 23: Nationaal Lucht- en Ruimtevaartlaboratorium (NLR) Type of information

5.3.8.2 Cranfield

Cranfield University, located in the UK, is a leading aeronautical post-graduate school. The College of Aeronautics, part of the University's Faculty of Engineering, is a centre of excellence for education, training and research into aviation safety, including the areas of safety analysis, accident investigation and the effects of human factors in aviation generally.

We have approached the head of the air transport department with a view to determining exactly what information may be made available to assist with the study.

The table below highlights the type of information that is expected to be obtained:

Type of Information		Support	Documented in
Operational Occurrences	☐	-	-
Safety&Research Reports	☒	Not yet available	Not yet available
Fleet and operator information	☐	-	-
Usage data	☐	-	-
Design Related Occurrences	☒	Not yet available	Not yet available
Reliability Reports	☐	-	-

Table 24: Cranfield Type of information

5.4 Databases

The collection of comprehensive data from a variety of official and unofficial databases is a key element of the Study's analytical content. In our initial reviews we have concluded that there is a wide variety of data sources of differing quality, particularly those relating to accident and incident data and helicopters operators and their fleets and usage. It is our opinion that the most comprehensive and complete of these are not necessarily the official sources.

To date we have not examined helicopter operator and fleet databases in any detail, but we have spent some time reviewing four of the most significant occurrence databases.

These are: the official ADREP and ECCAIR "data repositories" and the unofficial Aviation Safety Net "Wikibase" and Helihub database.

There is little commonality among any of these: ADREP appears to contain the most comprehensive collection of worldwide accidents while ECCAIR contains fewer accidents but many more incidents focussed mainly on Europe. However, both suffer from a great deal of incomplete data relating mainly to the identification of aircraft (registrations, make and model). There is also a small but significant amount of errors (mis-identification of aircraft types and models). In our experience much of the incomplete and incorrect data can readily be inserted or replaced by cross-referencing with other data sources. However, and in view of the size of this task, we would not propose to undertake this task until each data sources was reduced to entries relevant to the Study, i.e to occurrences from 2003 to 2012 and occurring within EASA member states and/or the EASA-registered helicopters.

The Helihub database of some 2,500 worldwide occurrences dates mainly from 2009 and includes significant numbers of incidents as well as accidents. Overall the most complete accident database is that in the Aviation Safety Net "Wikibase", with relatively little absent information and the largest number of accidents included on a worldwide basis.

We have not yet examined the ASCEND WAAS but given its focus on larger turbine powered aircraft consider it will not add greatly to the numbers of occurrences but should provide a reliable source for missing data.

Regarding helicopter operators and fleets, as we mentioned we have not yet examined the potential sources in any detail but consider the Forecast International fleet and operator database is likely to provide the main data sources, supplemented by several other sources mentioned below.

The fact that no information is available from Helicopter Operators nor Pilot Unions is not critical for the purpose of the study since the combination of all the other identified databases provides the necessary information coverage to conduct this study.

5.4.1 Operational Occurrences

Accident/Incident Data Reporting (ADREP)	
Description	The Accident/Incident Data Reporting (ADREP) system is operated and maintained by ICAO. All aircraft accidents which involve aircraft of a maximum certificated take-off mass of over 2 250 kg are reported by the States to ICAO. ADREP also gathers information on aircraft incidents considered important for safety and accident prevention. The ADREP system receives stores and provides States with occurrence data that will assist them in validating safety. In this context, the term 'occurrence' includes both accidents and incidents. The ADREP system operates using a software platform developed by the European Union (EU) - the European Co-ordination Centre for Aviation Incident Reporting System (ECCAIRS).
Appraisal / Limitations	ADREP covers period 1970-2012 and contains global accidents and serious Incidents – mainly Commercial Air Transport but a lot of data on European Products. Not every accident is in the database – especially for General Aviation
Mitigation / Complementary	To be combined with the Accident/incident Investigation authorities
Suitability for the study	Medium

Table 25: Accident/Incident Data Reporting (ADREP)

European Central Repository	
Description	European occurrence database, compiling the information provided by of the national aviation authorities and accident investigators of the EASA Member States. The data is stored and accessed using the same Taxonomy based system as ADREP. The European Central Repository operates using the system the European Co-ordination Centre for Aviation Incident Reporting System (ECCAIRS).
Appraisal / Limitations	The data extracted from ECCAIR contains some 18,500 records covering an estimated 13,650 accidents and incidents with a strong focus on Europe. Over 1,200 records relate to fixed wing aircraft. There are also a significant number of military occurrences. A substantial amount of information is absent, notably aircraft registration, make and model. Operator identities are not available Data available mainly from 2005 onward. Only occurrences inside EASA states, or from EASA states operators. No regular incidents. Narratives and operator names available.
Mitigation / Complementary	Need to be completed with another databases such ADREP for the period 2001-2005
Suitability for the study	Medium

Table 26: European Central Repository

EHSAT, the European Helicopter Safety Analysis Team (in EHEST)	
Description	The European Helicopter Safety Analysis Team (EHSAT) is the analysis component of the European Helicopter Safety Team (EHEST). From its Terms: EHEST is a voluntary partnership bringing together manufacturers, operators, research organisations, regulators, pilots' associations, accident investigators and other aviation groups from across Europe aimed at improving helicopter safety It is also open to European military operators. The EHSAT brings the Analysis Tool, a database of helicopter accidents and serious incidents, in the European countries.
Appraisal / Limitations	It is a voluntary initiative for EHEST, not all EASA MS countries were involved in the work so not all countries are covered. The majority of the data is from 2000-2005, since the study was commenced in 2006 and has now moved from an analysis to an implementation phase. Some countries have continued to add further data since 2006, but this is limited.
Mitigation / Complementary	Complete with other accident databases.
Suitability for the study	Medium

Table 27: EHSAT, the European Helicopter Safety Analysis Team (in EHEST)

EUROCOPTER Operational Occurrence Database	
Description	EUROCOPTER keep track of every accident and serious incident. This information is either provided by authorities, reported to the manufacturer by the operators or by its extensive network of field engineers or simply collected by the manufacturer thanks to its active monitoring of fleet events. The data stored in its databases would be redacted and therefore not be accessible for each single occurrence. We will only have access to the requested statistics and aggregated data.
Appraisal / Limitations	Not yet accessed. Prior to provide any information, a non-disclosure agreement must be signed (NDA) between EUROCOPTER and the Consortium, protecting the manufacturer's confidential data. However it has been explained that: Data is in an internal format, different from ICAO ADREP Taxonomy. All the data accessed is limited to Eurocopter models, Engine incidents data may not be complete, as most are not reported to the airframe manufacturer The information needed is all available in the EUROCOPTER database.Willing to deliver requested statistics and aggregated data, not having access to occurrence database The

	necessary information will be extracted and treated (redacted) by EUROCOPTER before delivery for the study, providing access to the aggregate results but not to the raw data.
Mitigation / Complementary	Engine incidents to be completed with engine manufacturer information.
Suitability for the study	High

Table 28: Eurocopter Operational Occurrence Database

Turbomeca Operational Occurrence Database	
Description	TURBOMECA records any reported accident or incident involving its engines. But TURBOMECA does not have extensive information about accidents and incidents without direct or indirect engine failure. The data stored in their databases would be redacted and therefore not be accessible for each single occurrence. We will only have access to the requested statistics and aggregated data.
Appraisal / Limitations	Not yet accessed. Prior to provide any information being provided, a non-disclosure agreement must be signed (NDA) between TURBOMECA and the Consortium, protecting the manufacturer's confidential data Limited to Turbomeca engines. The added value with regard airframe manufacturer databases is that most probably it will contain more information related to incidents without catastrophic consequences. Indeed such engine incidents are not always reported. For example an engine failure ended in an autorotation without consequences, would not normally be reported, For example an engine failure ended in an autorotation without consequences, would not normally be reported either to the authorities or to the airframe builder. However, thanks to its network of repair stations, engine manufacturers are able to collect this information. Willing to deliver aggregated data, not having access to each single occurrence.
Mitigation / Complementary	To be completed with other manufacturers data, and compared with airframe manufacturers information
Suitability for the study	High

Table 29: Turbomeca

World Aircraft Accident Summary (WAAS)	
Description	World Aircraft Accident Summary (WAAS) includes detailed descriptions for 8,000 accidents involving larger fixed wing aircraft and helicopter.
Appraisal / Limitations	We have not yet accessed this data but understand after enquiry that it contains only turbine-engined occurrences - civil and military – mainly accidents plus some more significant incidents. There is worldwide coverage and the data is largely complete but somewhat limited in scope. ASCEND claims there are 8,000 accidents in total, but not sure over what period, but this figure includes fixed wing aircraft
Mitigation / Complementary	Limited to Turbine occurrences – mainly accidents
Suitability for the study	Medium – possible additional source of turbine-powered aircraft accident data

Table 30: World Aircraft Accident Summary Occurrence Data Base

Aviation Safety Net	
Description	Private independent initiative, supported by the Flight Safety Foundation, covering accidents and safety issues. Most of its information is based on official sources such as regulatory authorities and safety boards as well as more informal sources and press reports. It also contains statistics from its database, and industry news with interest from the safety point of view. The database is in wiki format, edited by its users but well-moderated, and contains 11538 worldwide occurrences involving helicopters from 1932 to the present. http://aviation-safety.net/index.php
Appraisal /	Provides an extensive list of occurrences going back many years. This includes worldwide civil

Limitations	and military accidents and incidents
Mitigation / Complementary	To be considered along with other occurrence databases.
Suitability for the study	High – useful to substantiate missing information from some of the more official sources

Table 31: Aviation Safety Net Occurrence Data Base

Helihub	
Description	Helihub compiles and presents information regarding the helicopter industry. It contains an accident database, as well as a classified news and reports extensive file. http://helihub.com/
Appraisal / Limitations	Many of the accidents not supported by accurate, official, information, often redirecting to newspaper articles. Not all registers are fully up to date and has very limited coverage prior to 2009. Contains an extensive list and data of some 2,500 occurrences. This includes civil and military accidents and incidents – some apparently not reported elsewhere.
Mitigation / Complementary	To be compared and complemented with other occurrence databases.
Suitability for the study	Medium – useful to substantiate missing information from some of the more official sources

Table 32: Helihub

Griffin Helicopters	
Description	Primary database of accidents based on findings. Other resources to be used in the helicopter operation area. http://www.griffin-helicopters.co.uk/
Appraisal / Limitations	Low level information, based on news and internet findings.
Mitigation / Complementary	To supplement other occurrence databases
Suitability for the study	Low

Table 33: Griffin Helicopters

Helis	
Description	Primary database of accidents based on findings. Historical records, and articles. http://www.helis.com
Appraisal / Limitations	Low level information, based on news and internet findings.
Mitigation / Complementary	To supplement other occurrence databases
Suitability for the study	Low

Table 34: Helis Helicopters

5.4.2 Operator, Fleet and Usage Data

EASA Operator and Fleet Database	
Description	EASA also manages a worldwide fleet database containing aircraft registration, make, model series, serial number, year built and engine details of some 10,800 single engine helicopter. We understand that multi-engines type data is also potentially available.
Appraisal / Limitations	Not all the fields are fully populated and there is no operator data
Mitigation / Complementary	To be considered along with other operator and fleet databases.
Suitability for the study	Medium – potentially useful to cross-reference with other sources.

Table 35: EASA Operator and Fleet Data

EUROCOPTER Fleet database	
Description	In addition to the occurrence database, EUROCOPTER also maintains a database with usage data of its fleet.
Appraisal / Limitations	Not yet accessed. Prior to provide any information being provided, a non-disclosure agreement (NDA) must be signed between EUROCOPTER and the Consortium, protecting the manufacturer's confidential data. However it was explained that EUROCOPTER is regularly informed of usage of the fleet by the operators. When this information is not provided, usage is calculated through extrapolated assumptions.
Mitigation / Complementary	To be considered along with other usage databases
Suitability for the study	High

Table 36: EUROCOPTER Operator and Fleet Data

International Register of Civil Aviation (IRCA)	
Description	The International Register of Civil Aircraft collects information on over 86 national aircraft registers including 27 EASA Member States plus the USA and Canada on a single database. The aim of IRCA is to provide with an international database comprising of harmonized and substantial information on national aircraft fleets, in order to ease data access and exchange worldwide. All the information in IRCA is official, since it is directly provided by National Civil Aviation Authorities, assuring the complete veracity of the data. The original register's data is also enhanced with the addition of generic technical information such as: Airworthiness information Aircraft technical information Engine and propeller information
Appraisal / Limitations	It has been estimated that IRCA includes some 24,000 helicopters of the main helicopter makes. However the data does not lend itself to detailed analysis. The Civil Aviation Authorities of Bulgaria, Hungary, Romania and Slovenia have not provided any data to IRCA. Also, some Civil Aviation Authorities do not provide all the expected information.
Mitigation / Complementary	The Consortium will endeavour to contact the NCAA for which data is missing. For this purpose, the Consortium expects to receive from EASA a mandate requesting the contribution of CAA through the provision of national register and helicopter usage databases.
Suitability for the study	Medium

Table 37: International Register Of Civil Aviation (IRCA)

JP Airline Fleets International	
Description	Yearly reference book providing information for most of the known commercial aircraft operators. Covering over 6.000 operators, and 50.000 aircraft, the major commercial helicopter operators are listed in its pages. We estimate provisionally that some 11,500 mainly turbine-powered helicopters used in a variety of roles are included It contains information about each registered member of the included fleets, as well as some specifications and configuration data as indicated below
Appraisal / Limitations	Previous years editions are also available. Crucially JP Fleets identifies the main civilian commercial operators and their fleets. However, with some exceptions it excludes privately-owned aircraft and those under 2.0 tonnes and 2.8 tonnes maximum weight, for single and twin-engined aircraft respectively. This automatically excludes significant numbers of smaller and predominantly piston-engined helicopters.
Mitigation / Complementary	To be complemented with IRCA and National Registers information and other unofficial sources such as Rotorspot and Forecast Internationals “Business Class” helicopter fleet report
Suitability for the study	Low

The data in JP Airline Fleets is presented as follows:

Helijet Aviation (Yorkshire Helicopters Ltd dba) **Leeds/Bradford**
Leeds Heliport, Harrogate Road, Leeds West Yorkshire LS19 7XS, UK Tel: +44 1132500588 Fax: +44 1132508161 Email: info@helijet.co.uk SITA: n/a
F: 1996 Emps: 8 Head: Mike Thorpe Web: www.helijet.co.uk

☐	G-RAMI	Bell 206B JetRanger III	2955	N1080N	0380	1096	1	RR 250-C20B	1451	Utility	4032DF
300	registration	type of aircraft	cn/fn	exreg	mfd	del		powered by	mtow kg	configuration	hexcode name/fin/specialities/remarks

Figure 1: JP Airline Fleets information example

As shown in previous figure, the data presented for each operator includes some general and contact information, as well as the description of each model operated, including registration, age, powering, or configuration.

Table 38: JP Airline Fleets International

Helicopter Blue Book	
Description	The Official Helicopter Blue Book is a publication containing helicopter extensive specification sheets, as well as historical selling values. Its values vary every short period, adapting to the current market prices, while its specification sheets are precise and updated for almost every model
Appraisal / Limitations	No Russian or Polish helicopters
Mitigation / Complementary	Find data by other means (spec sheets, brochures)
Suitability for the study	Medium

Table 39: Helicopter Blue Book

Rotor Roster Business Class Helicopters	
Description	Database including 30,365 turbine and piston powered helicopters registered worldwide, with serial number and owner. Spreadsheet format.
Appraisal / Limitations	Not yet accessed but recommended by Robinson. Indeed Robinson does not maintain a record of ownership of the helicopters manufactured. The publicly available database "Rotor Roster", or civil registers are used when this information is needed.
Mitigation / Complementary	-
Suitability for the study	High

Table 40: Rotor Roster Business Class Helicopters

Rotorspot	
Description	Dutch database of current and historical worldwide rotorcraft registers. Most of this registers include production lists, and it is presented in a search-friendly interface The historical database currently contains 137.600 civil rotorcraft registrations, for 80.150 rotorcraft. http://www.rotorspot.nl/
Appraisal / Limitations	Rotorspot.com has more-or-less worldwide coverage of some 42,000 currently registered helicopters. However information is limited to registration, make and model and serial number.
Mitigation / Complementary	-
Suitability for the study	Medium

The database is a simple three column sheet, presenting each registration number, model and production number. This registers combined with information from the operators will provide a good picture of the fleets operating in each country.

The current registration data is presented as follows:

Registration	Make & model	Constructors no
F-BGOS	Bell 47D1	609
F-BGXR	Bell 47D1	158
F-BGXY	Bell 47G > 47G-2	690

Figure 2: Rotorspot registration example

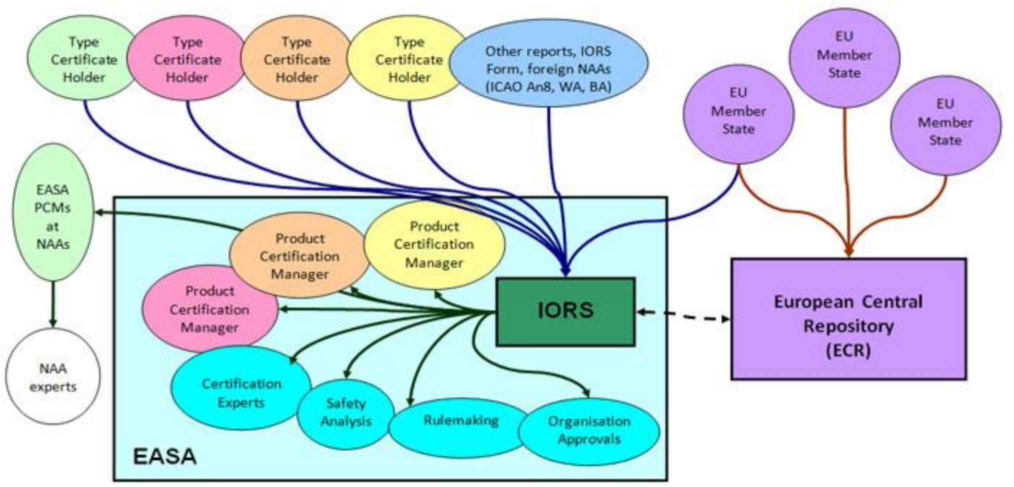
The history section additionally contains the previous and subsequent registration history of each aircraft plus the eventual fate of non-current aircraft

Table 41: Rotorspot

Helihub	
Description	Helihub compiles and presents information regarding the helicopter industry. It contains an updated register database with data limited to register number, type, and owner. http://helihub.com
Appraisal / Limitations	Not all registers are fully up to date.
Mitigation / Complementary	To be compared and complemented with other databases
Suitability for the study	Medium – mainly for accident and incident occurrences post 2008

Table 42: Helihub

5.4.3 Design Related Occurrences

<table>
<tr><th colspan="2">EASA
Internal Occurrence Reporting System (IORS)</th></tr>
<tr><td>Description</td><td>The Internal Occurrence Reporting System (IORS) is the system that the Agency uses to process and store in a central database using the ECCAIRS 5 format all safety related occurrences thus design related ones reported to EASA
The Internal Occurrence Reporting System at a glance. Please note that the inter-organisation reporting flows are not depicted on the picture below:


IORS – ECR relationship: IORS may have access to the ECR by virtue of article 19 of Commission Regulation (EU) No 996/2010. In the future IORS may be required to integrate occurrences into the ECR</td></tr>
<tr><td>Appraisal / Limitations</td><td>Possibility to share the certain portion of data related to engines of single-engined helicopters to be explored.
It is expected from this database to collect airworthiness related occurrences, in particular for those reported by engine OEMs causing an incident.
However the operational data related to the type of operation, location etc. would not generally be available.</td></tr>
<tr><td>Mitigation / Complementary</td><td>Statistics with engine OEMs</td></tr>
<tr><td>Suitability for the study</td><td>To be confirmed after appraisal, in particular for data prior to the implementation of IORS</td></tr>
</table>

Table 43: Internal Occurrence Reporting System (IORS)

5.5 Publications

This section addresses all those published reports and analyses found that are pertinent to the scope of this study and summarizes the already identified safety hazards and the mitigations in place or proposed

The publications surveyed that explicitly reported the subject concerning this study are four:

- ***Measuring safety in single and twin-engine helicopters***, published in 1991 – See section 5.8
- ***Measuring Risk in Single and Twin-engine helicopters***, published in 1992 – See section 5.6
- ***Argumentaire monomoteur***, published in 2009 – See section 5.11
- ***Single engine helicopter operations: an OEM view on flight safety, mission performance, environmental and economic constraints***, EUROCOPTER, presented in 2010

The first two publications are a result from the same study, presenting minor redaction differences, but with the same core data.

It is remarkable that none of this studies are investigating only the single-engine area, but comparing the performances and data of both single and twin-engine helicopters. As a matter of fact, helicopter flight has high accident rates compared to other means of transport, and those studies are generally stating that most of these accidents are not due to the helicopter characteristics, but to the inherent danger of operating helicopters.

Even though, two of these reports are more than 20 years old, and during this time helicopter technology has been improving along with the growth of the helicopter popularity in passenger transport, so the information, data and conclusions must be reviewed and updated.

The EUROCOPTER study, even if it is more recent, is OEM-oriented, and has a clear orientation in emphasizing that single engine helicopters have results comparable to multi engine rotorcraft.

On the other hand, EASA publishes its Annual Safety review, where in the 2011 edition it identifies the system component failure of the power plant as the sixth highest contributing factor in helicopter accidents. However, it is not detailed the cause of the failure.

Other reports and studies, do not have a clear aim to single-engine safety and operations investigation, but where mentioned, still do not identify the single-engine specification as a safety issue prior to other accident causes such as human error.

5.5.1 EASA

As part of its duties to promote the highest common standards of safety and environmental protection in civil aviation in Europe and worldwide, the Agency has been issuing a certain number of publications since its establishment.

- **Annual safety review**, published on an annual basis since 2005 - These documents are published by EASA to inform the public of the general safety level in the field of civil aviation. It also offers an overview of aviation safety measures taken in the different EASA Directorates Reports are available at http://www.easa.europa.eu/communications/general-publications.php

  Provides trends and statistics only

- ***Risk Assessment for European Public Transport Operations using Single Engine Turbine Aircraft at Night and in Instrument Meteorological Conditions,*** published by QinetiQ with date of 15 October 2007 for EASA under contract nºEASA-2006-C46 – The objective of the report is to conduct a full and objective risk assessment for SE-IMC operations in the European Context before introducing SE-IMC operations

Additionally, since 2007, EASA organises the annual EASA Rotorcraft Symposium, defined as a regular forum for the worldwide rotorcraft community, where topics of common interest in the rotary wings world are presented and discussed, aiming at updating participants, and getting their feedback on industry and authority initiatives concerning operational, design, manufacturing and regulatory matters with the common scope of fostering safety.

These symposiums have a wide variety of participants, and the presentations of each annual event can be found in the following links:

- **EASA Rotorcraft Workshop:** http://www.easa.europa.eu/events/events.php?startdate=05-12-2007&page=EASA_Rotorcraft_Workshop
- **Second EASA Rotorcraft Symposium:** http://www.easa.europa.eu/events/events.php?startdate=04-12-2008&page=Second_EASA_Rotorcraft_Symposium
- **Third EASA Rotorcraft Symposium:** http://www.easa.europa.eu/events/events.php?startdate=02-12-2009&page=Third_EASA_Rotorcraft_Symposium
- **Fourth EASA Rotorcraft Symposium:** http://www.easa.europa.eu/events/events.php?startdate=08-12-2010&page=4th_EASA_Rotorcraft_Symposium

- **Fifth EASA Rotorcraft Symposium:** http://www.easa.europa.eu/events/events.php?startdate=07-12-2011&page=5th_Rotorcraft_Symposium
- **Sixth EASA Rotorcraft Symposium:** http://www.easa.europa.eu/events/events.php?startdate=05-12-2012&page=6th_Rotorcraft_Symposium

Most of the presentations are only supported by slides, without further explanations, probably given during the conferences and the round of questions, and giving only some figures. The following have been found relevant for the purpose of the study:

- **Single Engine Argument**, Union Française de l'Helicoptère, presented in 2008. Supports the use of single-engine helicopters.
- **Rotorcraft Safety in Europe: Analysis Results by the European Helicopter Safety Team (EHEST) and Paths for Improvement**, presented in 2008
- **Flight Data Monitoring of Small Helicopters**, presented in 2008
- **Helicopter Flight in Degraded Visual Conditions**, UK CAA, presented in 2008
- **Helicopter Performance a historical perspective**, presented in 2010
- **Single engine helicopter operations: an OEM view on flight safety, mission performance, environmental and economic constraints**, EUROCOPTER, presented in 2010
- **Review and Analysis of UK and European Part 27 Helicopter Incident and Accident Data**, presented in 2012

5.6 Other reports are available at:

http://www.easa.europa.eu/rulemaking/docs/research/Single%20Engine%20Operations%20in%20IMC%20and%20at%20Night%20Risk%20Assessment%20Issue%202.pdf

5.6.1 EHEST

EHEST, from the results of its safety studies, publishes the following reports:

- ***EHEST analysis of 2000-2005 European Helicopter Accidents***, published in 2010. Safety report with the aim of improving aviation safety by analysing occurrence data, and implementing a cost-effective action plan. http://easa.europa.eu/essi/ehest/wp-content/uploads/2010/10/EHEST-Brochure.pdf
- ***Helicopter airmanship, Methods to Improve Helicopter Pilots Safety,*** published in 2011. After the EHEST review of helicopter accidents 2000 to 2005 revealed 140 general aviation helicopter accidents in Europe identifying airmanship related issues. This guide of best practices is addressed to improve this statistics. http://easa.europa.eu/essi/ehest/wp-content/uploads/2011/12/HE2_leaflet_helicopter_airmanship_v1.pdf

5.6.2 Civil Aviation Authorities from EASA Member State

As far as research and safety reports are concerned, the most active are the northern states (refer to 5.10.1 for details), as well as the United Kingdom, very active in helicopter transport to offshore locations, and though having large units that study the field.

The UK CAA publishes a wide selection of reports, leaflets and regulations, being one of the most active countries concerning helicopter flight safety. The following have been considered:

- ***Helicopter Flight in Degraded Visual Conditions,*** published in 2007, http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=2887
- ***Intelligent Management of Helicopter Vibration Health Monitoring Data***, published in 2012, http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=5040
- ***Review of Helicopter Offshore Safety & Survival***, published in 1995, http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=138

- ***Helicopter Operations Over a Hostile Environment,*** published in 2012, http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=5304
- ***Helicopter Airmanship,*** published in 2011, http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=1171

5.6.3 NTSB & FAA

It has been considered relevant to survey non-European authorities, such as the American and Australian, having an extended helicopter use, even if the whole operational concept for single-engined helicopters is defined otherwise. However the studies have methodologies and accident approaches that have been considered relevant, even if most of the data will not be comparable with the current study outputs

From the NTSB reports and presentations, the following have been kept for the concerns of this study:

- ***Human factors in helicopter accidents***, presented in the Fifth International Helicopter Safety Symposium 2011. www.ntsb.gov/doclib/speeches/sumwalt/Sumwalt_110911.pdf
- ***ROBINSON HELICOPTER Co. R22 loss of main rotor control accidents***. Published in 1996. www.rotorshop.com/sir9603.pdf

The FAA has published many safety reports, but this particular and updated study has been chosen for its singularity:

- ***Safety Study of Wire Strike Devices Installed on Civil and Military Helicopters***, published in 2008. www.tc.faa.gov/its/worldpac/techrpt/ar0825.pdf

5.6.4 BELL

Bell has some online publications that fit the requirements of this study:

- **The history of helicopter safety, published in 2005,** www.bellhelicopter.com/MungoBlobs/815/470/HelicopterSafetyHistory.pdf
- **Safety article published in Heliprops,** www.bellhelicopter.com/MungoBlobs/107/29/Vol%2020%20number%203%20-En.pdf

In addition, Bell sent some other reports directly to the Consortium:

- ***Measuring Risk in Single and Twin-engine helicopters***, Roy G. Fox, published in 1992
- ***Civil Rotorcraft Risks***, Roy G. Fox, published in 2002
- A supplementary report to “The history of helicopter safety” updating the data up to 2010.

5.6.5 ROBINSON

Robinson provided a report concerning engine failure in the R44 model. The report analyses statistical data registered in Robinson’s database:

- ***R44 and R44 II Engine Power Loss Rates – Engineering Report,*** published in 2007.

5.6.6 OGP

The OGP publishes many reports regarding transport to oil production facilities. The following have been selected, in the interest of the study:

- ***Aviation transport accident statistics***, published in March 2010. Provides information on aviation accident statistics for use in QRA. http://www.ogp.org.uk/pubs/434-11.pdf
- ***Safety performance of helicopter operations in the oil & gas industry***, published yearly from 2002 to 2009. Report based on submissions from operators worldwide, presenting the safety performance of helicopters involved in exploration & production. http://www.ogp.org.uk/publications/safety-committee/safety-performance-of-helicopter-operations/
- ***Aircraft management guidelines***, published in 2008, updated in 2011. Guidelines to provide a ready reference for the management of aviation. http://www.ogp.org.uk/pubs/390.pdf

5.6.7 Flight Safety Foundation

FSF has been publishing safety reports and studies related to helicopters. Among its most relevant publications within the scope of this study it is worth to mention.

- ***Measuring safety in single and twin-engine helicopters,*** Roy G. Fox, published in 1991 www.flightsafety.org/fsd/fsd_aug91.pdf
- ***For helicopter pilots, Managing stress is part of flying safely,*** Joel S. Harris, published in 1995, http://flightsafety.org/hs/hs_jan_feb95.pdf
- ***Most Fatal U.S. Commercial Helicopter Accidents Occur in Instrument Meteorological Conditions, FSF.FSD.01.03***, published in 2003.
- ***Use Of Night Vision Goggles Increases In Civilian Helicopter Operations, FSF.HS.11.04***, published in 2004
- ***Changes Expand U.S. Helicopter Operations Under Instrument Flight Rules, FSF.HS.11.95,*** published in 1995
- ***Typical Helicopter Accidents Profiled, HS.19.3,*** published in 1993
- ***Poll of Helicopter Operators Yields Data On Flight Operations and Fleets, HS.19.5,*** published in 1993
- ***Satellite-based Navigation Promises to Enhance Helicopter Utility in IFR Conditions, HS.20.06.1*** published in 1994
- ***Fatal Turbine-helicopter Accidents Provide Clues to Safer Operations, HS.21.02.1*** published in 1995
- ***Every Helicopter Pilot Must Be Prepared for Inadvertent Entry into Instrument Meteorological Conditions, HS.22.02.1*** published in 1996
- ***Engine-power Loss Was Most Frequent Category of U.S. Agricultural-helicopter Accidents, 1989-1995, HS.23.05.1*** published in 1997
- ***Helmets with Visors Protect Helicopter Crews, Reduce Injuries, HS.23.05.1,*** published in 1997
- ***Reports Show Pilot Error as the Major Cause of Helicopter Accidents in U.S. On-demand Operations, HS.24.06.1***, published in 1998
- ***Engine, Transmission Failures Lead Causes of Accidents in U.S. Helicopter Logging Operations, HS.25.5,*** published in 1999
- ***Data Show 50 U.S.-Registered Helicopters Involved In Wire-Strike Accidents From 1996 Through 2000, FSF.HS.07.02,*** published in 2002
- ***Unusual Attitudes: Helicopters and Instrument Flight, HS.19.1,*** published in 1993
- ***NTSB Investigates Loss-of-control Accidents Among Lightweight Helicopters, HS.23.06.1***, published in 1997
- ***Data Show Same U.S. Fatal-accident Rate for Single-turbine and Twin-turbine Helicopters, HS.25.01,*** published in 1999
- ***Records Show 27 U.S.-registered Helicopters Involved in Mid-air Collisions During 1990s, HS.26.4,*** published in 2000

5.6.8 IHST

The IHST has published various reports and compendiums mainly focused in the US market. However, for the potential use in this study by extrapolating the results, the following have been considered relevant:

- ***US JHSAT Compendium –Volume I, The U.S. JHSAT Baseline of Helicopter Accident Analysis ,*** (CY2000, CY2001, CY2006), published in August 2011. http://www.ihst.org/portals/54/US_JSHAT_Compendium_Report1.pdf

US JHSAT Compendium –Volume II, The U.S. JHSAT Baseline of Helicopter Accident Analysis , (CY2000, CY2001, CY2006), published in July 2011.
http://www.ihst.org/portals/54/US_JSHAT_Compendium_Report2.pdf

5.6.9 NLR

Most of the publications of the NLR are investigation reports, and technical studies. For the aim of the study, the following one has been considered appropriate to be taken in to account:

- ***European Helicopter Safety Team (EHEST): Mapping Safety Issues with Technological Solutions,*** Stevens, J.M.G.F.; Vreeken, J.; Masson, M.A., published in 2011.

  http://reports.nlr.nl:8080/xmlui/handle/10921/468

Other reports are found in:http://reports.nlr.nl:8080/xmlui/

5.6.10 Helicopter Safety.org

Website containing a comprehensive UK helicopter accident database, and the results of a study carried out in early 2008 to support the figures being discussed at the safety evenings.

The site also contains links to freely available safety material and information on venues and dates of helicopter safety evenings organised by some volunteers around the UK.

Classifies and studies the Griffin Helicopters database, using each individual report to build statistics. It also has a library of external reports in the subject.

http://www.helicoptersafety.org/

5.6.11 Others

Other entities not listed in the chapters above have published interesting documents in the terms of the study. The following are the ones considered most relevant:

5.6.11.1 SINTEF

SINTEF is the largest independent research organisation in Scandinavia, its most known and up to date studies are the Helicopter Safety Studies (HSS). This studies, although centred in the North Sea transportation, and then twin-engined focused, have been selected:

- ***Helicopter Safety Study 3***, published in 2010,

  www.norskoljeoggass.no/PageFiles/6353/100610sintefa15753helicoptersafetystudy3hss-3mainreport-100610071828-phpapp02.pdf?epslanguage=no

- ***HSS-2***, published in 1999,

  www.sintef.no/upload/Teknologi_og_samfunn/Sikkerhet%20og%20p%C3%A5litelighet/Rapporter/STF38%20A99423.pdf

5.6.11.2 Union française de l'helicoptère

In order to justify the permission or not to fly over hostile areas, the Union Française de l'Helicoptère has published a study in 2009 concerning this field:

- ***Argumentaire monomoteur***, published in 2009,

  http://www.helicomontagne.fr/PDF/Monomoteur.pdf

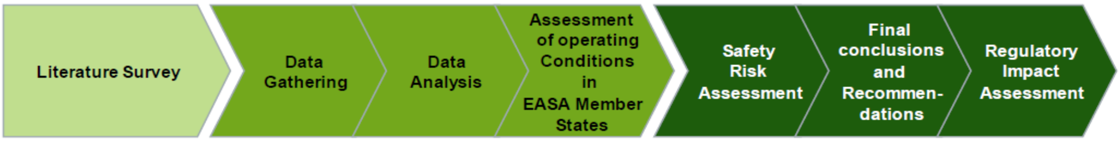
6 Methodology

This section describes the methodology that the Consortium will adopt to undertake the necessary tasks to successfully achieve the Study on single-engined helicopter operations over a hostile environment.

The main tasks to be carried out chronologically as required by the EASA tender specifications are the following:

1. Literature survey
2. Data gathering and data analysis
3. Risk assessment, final conclusions and recommendations

With regard to the above main tasks, the consortium will split the above tasks as follows:



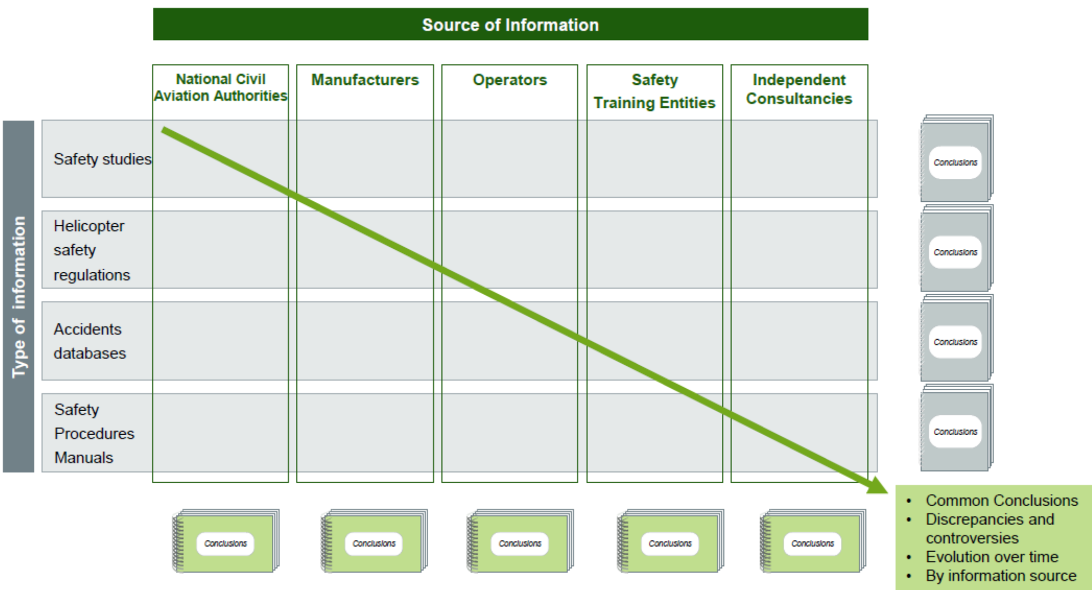
6.1 Literature Survey

The first aspect of this study will consist in conducting a literature survey and appraisal on the relevant and currently available publications; publications on helicopter operations, helicopter accidents and incidents. These could take various forms, such as research reports, databases, etc. For this task, the consortium proposes to take a matrix approach looking at the types of information to survey across the various types of sources for this information.

This approach will enable the consortium to summarise the already identified safety hazards, mitigations in place or proposed, additional potential risks and information gaps by type of information surveyed and also by source of information.

The matrix analysis will allow for common issues, conclusions and current recommendations to be highlighted and also for discrepancies and controversies to be put forward by source of information.

The diagram below proposes a pictorial representation of this approach.



6.2 Data Gathering

Our approach to the data gathering and analysis methodology to be adopted will need to reflect the availability of data from a multiplicity of sources – some official, some provided by EASA (ADREP, EHEST data), some other provided on a commercial basis and others from more freely available but not necessarily authoritative sources. Many of these are available on-line but others may require the payment of subscription or one-off data fees.

In a preliminary investigation we have already identified some 10,800 recorded helicopter accidents over 70 years, some 3,600 of them fatal. In the 10 years 2002 to 2011, the respective numbers are 3,870, 1,750 fatal. Total fatalities in this period were close to 3,500. EASA Member States contributed 2,110 of the total, 630 of them fatal, with Germany, the UK and Switzerland contributing around half the totals. Further research into additional data sources will no doubt reveal additional occurrences.

As with all data sources there will be errors and inconsistencies and a lack of completeness. For this reason we will initially cast our net wide to identify and capture the maximum relevant data on the worldwide helicopter market (manufacturers, types and numbers delivered taking account of the number and type of engines fitted), the operation of helicopters (operators and fleets and hours flown by type of operation. and accident and serious incident data).

The data will then be "drilled-down" into, to more closely identify those areas of particular interest to the study – civilian aircraft operations and occurrences in the 31 EASA Member States. While all civilian operations will be considered, it may not be practical in all instances to examine their operations in any detail. Private owners may not always be identifiable for data protection reasons and business operators' activity data may not be readily available.

However, while these two groups form a significant proportion of the operators population, they will be less significant in terms of fleet numbers and hours flown as commercial operators and others engaged "hire-and-reward flying" will in general have larger fleets and greater annual utilisation of the helicopters. The analysis will, of course include the significant numbers of aircraft operations by governmental (and quasi-governmental) organisations (Public Services) such as police, search and rescue, civilian training (including for the military). Purely military operations will, however, be excluded from further consideration.

Another factor to be considered is that the helicopter industry is a changing on and operators are subject to commercial events such as name changes, bankruptcies, start-ups and mergers. The manufacturing side is also complex with the additional aspect of licence production of several models across the Globe. The various helicopter types and their model designations will need to be rationalised for the purposes of The Study before being categorised by their propulsion systems and any particular role versions.

As specified in the Invitation to Tender, the data task will be divided into a series of sub-tasks, starting with the data gathering.

Using identified and available published and online information, the Consortium will collect and collate extensive data about the usage of single-engined and multi engine helicopters in all types of operations over hostile and non-hostile environment in EASA Member States.

- This will include the current identity and status of all known helicopter operators in the Member States and the composition of their helicopter fleets,
- the scope of their operations and proportion of different types of operation in the overall business model of the operators,
- the types of helicopter operated and their average age,
- the total accumulated flight time for all operators and by helicopter type over the most recent ten-year period,
- the number and severity of those helicopter accidents occurring during the same period characterised by the date of the event, operator, type and age of helicopter and the number and type (piston or turboshaft) of engines, location, numbers of occupants (passengers and crew), number of serious injuries and/or fatalities and overall severity of accidents. This and the preceding item will form the basis of the single-engined helicopter accident analysis described below in Task 2b,
- the current and past numbers of professional pilots and maintenance staff involved in the operations (full and part-time),

- the total numbers of transported passengers,
- the total number of flights operated on services provided to customers,
- the identification of operating environment (hostile or non-hostile) and,
- total annual revenue for at least the last three years.

Where possible operator and operating data will be based on reliable published information from authoritative sources, including World Aircraft Accident Statistics (WAAS – published for the UK CAA by Ascend), the Aviation Safety Net Accident "Wikibase" – produced under the auspices of the Flight Safety Foundation, The helicopter operators own published data and the various European and National Helicopter Associations Yearbooks, National Civil Aviation Authorities aircraft operating statistics, the Civil Aircraft Registers for EASA states.

Where such data is not readily available we will endeavour to contact the particular operators to obtain any missing information. In particular we expect to experience some difficulties in obtaining hours flown by operator and type of operations. In some instances informed estimates of operations may need to be made based on realistic typical rates of utilisation or analysis of fuel consumption.

It is also noted that the number and composition of the operators and their helicopter fleets will have changed significantly due to merger, start-up and failures over the study period and to the extent that the affected operators may have experienced accidents and serious incidents in the recent past, they too will need to be considered.

EASA holds relevant database regarding operators, or/and accidents and serious incidents that could be made available for the purpose of this study provided an appropriate confidentiality agreements being established on the use of data. In the EASA data base there is a selection of accidents and serious incidents in the ADREP database. However, the data helicopter accidents and serious incidents in the ADREP database is unlikely to contain all accidents and serious incidents relevant to the study

Also the data gathered for the EHEST study could be also be made available provided an appropriate confidentiality agreements being established on the use of data.

6.3 Data Analysis

This will focus on single-engined and multi engined helicopter operations and accidents7

Using all of the above data as appropriate the Consortium will perform a detailed analysis of accidents and serious incidents in the most recent ten year period, shown compared to the accumulated flight hours of single-engined helicopter types in EASA Member States for the same period.

The analysis will identify and assess the causes and contributing factors (especially of engines) of single-engined helicopter accidents and serious incidents in any class of operation, depending on which environment (hostile or non-hostile) those events happened as well as the consequences avoided or not in multi-engined helicopter accidents and incidents thanks to the multiple powerplant.

For the purpose of the data analysis, the Consortium will proceed as follows:

1. Retrieve data on accidents and serious incidents:

The following sources will be used, as a minimum, to retrieve data on accidents and serious incidents:

- ICAO Annex 13 accident investigation bodies of the 31 EASA member States: Accident and serious incident investigation reports on all helicopter accidents in the period 2001 – current;
- ECCAIRS database: occurrence reports on all relevant helicopter accidents in the period 2001 – current. Access to the ECCAIRS database will be obtained via various channels, including, if need be, a request for information under Article 3(1) of Commission Regulation 1330/2007. Where it is believed that member states have data that is not shared with other member states, and thus cannot be obtained under Article 3(1), attempts will be made to get such information direct from that state, via the Commission or via EASA;
- EASA Internal Occurrence Reporting System: occurrence reports on all relevant helicopter accidents in the period 2001 – current in the database. Access will be obtained via EASA channels.

Data that will be obtained will include all information that is available in the relevant report or database, including, where available:

- number of engines7
- type of engine (piston, turbine),
- number of maximum certified passengers seats and.or actual passenger seats,
- year of manufacture of helicopter,
- type of operation (classified in commercial air transport, aerial work, training flight, private flight),
- flight conditions (VFR, IFR, VFR in IMC, day or night),
- phase of flight (hovering, take-off, en-route, manoeuvring, approach, landing, low-level flights etc.),
- terrain/obstacle suitability (onshore, offshore, mountainous, overwater, congested),
- environment (hostile or non-hostile),
- other details found relevant to the study.

In addition, the probability of a critical engine failure during the 10 year period will be derived from the data collected focussing on those occurrences identified as such

Other sources may be used such as the data from the International Helicopter Safety Team (IHST) and the European Helicopter Safety Team (EHEST).

2. Categorise into type of occurrence (based on ADREP taxonomy);

The occurrences will be split into Occurrence Categories as defined in ICAO ADREP Taxonomy8 and then the main causes of accidents and serious incidents (if known) will be categorised using the Human Factors Analysis Classification System (HFACS) and Standard Problem Statements (SPS) as it is given in EHEST Analysis of 2000-2005 European Helicopter Accidents).

3. Determine for each occurrence causes and contributing factors;

For each occurrence, the probable cause or causes and contributing factor shall be determined form the data, with a focus on engines.

4. Determine for each occurrence the environment;

For each occurrence, the environment and location will be determined and classified into either hostile or non-hostile using the definition of EASA Opinion 04/2011.

5. Classify each cause and the main contributory factors;

For each occurrence, the cause or causes and the main contributory factors will be classified using the HFACS methodology9 and the SPS methodology as developed by the US Joint Helicopter Safety Analysis Team (JHSAT) and IHST.

6. Analysis.

All data will be collated in a database to allow analyses. Analyses will be made for all data points listed above. Thus, occurrence rates will be presented e.g. per type of engine, per helicopter age, per type of operation, etc. Other data points may be included in the database, and be analysed, when in the course of the study these are recognized as potentially of importance. Specifically, engine failure causes and failure rates will be included in the analysis.

6.4 Assessment of operating conditions allowed by EASA Member States

Following the data gathering and accident and serious incident analysis, the Consortium will elaborate and perform an assessment regarding conditions under which such operations are allowed in EASA Member States.

This assessment will address the following points:

- has the Member State fully implemented JAR-OPS 3 performance requirements?
- are single-engined helicopter operations permitted over hostile environment outside congested areas in accordance with JAR-OPS 3.005 (e)?
- if JAR-OPS 3 requirements are not fully transposed, how are the risk assessment conditions stated in ICAO Annex 6 Part III for operations over a hostile environment embedded in national legislation for the different types of operations?
- which specific continuing airworthiness conditions are applied to increase reliability of engines (maintenance programme, Airworthiness Directive (AD) status, Health and Usage Monitoring System (HUMS)
- which training and operational procedures to mitigate the consequences of the critical engine failure are applied?

The analysis will take into account new helicopter technology forecasted for the next 10 years that may allow reducing the accident and incident rate

The Consortium will proceed as follows:

1. Select representative member states

The EHEST study lists the following member states as representing 90% of the helicopter registered in Europe: Finland, France, Germany, Hungary, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom.

The consortium proposes to select the following states for the subsequent tasks: Northern Europe: Finland or Sweden; Central Europe: Germany Western Europe: France, the Netherlands and/or UK Southern: Spain Eastern: Hungary EEA/EFTA State: Switzerland

2. Retrieve data on regulatory system implemented in these member states;

3. More specific, retrieve whether a member state allows single-engined helicopter operations over hostile environment outside congested areas;

4. Determine how ICAO Annex 6 risk assessment conditions are transposed if not via JAR-OPS 3;

5. Determine specific continuing airworthiness conditions;

6. Determine specific training and operational procedures to mitigate the consequences of the critical engine failure;

For tasks 2 to 6 above, the following methods will be used to retrieve data: Interviews with selected member state NAA helicopter experts, possibly supported by a questionnaire. In which the following will be determined:

- Full or partial implementation of JAR-OPS 3. If partial, which parts are not implemented and when these deviations apply to helicopter performance and operating limitations, what other means of compliance with Annex 6, Part III are in place;
- Application of the provision of JAR-OPS 3.005(e) and Appendix;
- Which mandatory and voluntary continuing airworthiness conditions are in place to increase engine reliability;

- Which mandatory and voluntary training and operational procedures are in place related to critical engine failures. Consultation of the JAR-OPS 3 mutual recognition list; Consultation of the State Safety Programmes of these member states.

7. Determine technological improvements that may allow reducing the accident and incident rate.

Interviews with major helicopter, engine and parts original manufacturers will be held for his task.

Operators may be also consulted to obtain relevant advice on the last technology already available in the market or future technology in development (i.e night vision goggles, wire detectors, ADS-B, EGNOS, GNSS bases systems replacing TCAS and GPWS,...)

6.5 Safety Risk Assessment

On the basis of the results obtained under tasks 1 to 4, the Consortium will conduct a safety risk assessment in support to the decision if, and under which conditions, commercial air transport operations10 can be conducted over a hostile environment and the impact this might have on such operations;

The Consortium will proceed as follows: Hazard identification Risk assessment Risk mitigation

Hazard identification

The consortium will determine the hazards that exist to single-engined helicopter operations by means of a combination of reactive, proactive and predictive methods. Thus, not only will the data as collected under 4.2. be used, but also will experts be consulted to estimate the effects of hazards that have not yet manifested itself but can be anticipated. Subject to discussion with EASA, this element may be extended to other types of operation than commercial air transport to satisfy the outset of the study as defined in the first paragraph of section 2.1 of the invitation to tender.

Risk assessment

Subsequently, for each of the hazards thus identified, a risk assessment will be done to evaluate the seriousness of the consequences of the hazards occurring. This assessment includes at least the following elements: Likelihood of the event; Possible consequences (in terms of loss of lives and personal injury, both to helicopter occupants and on the ground, as well as damage);

So far, no common safety risk assessment methodology has been established in Europe.

Risk mitigation

Next, measures will be proposed to mitigate the risks identified above. These measures will normally be restricted to the helicopter operations itself (e.g. improved reliability monitoring; regulating circumstances of flight; route restrictions; contingency measures, etc.). However, for some risks, the only mitigation measure may be a ban of operations. In that case, alternative means of operations will be explored and assessed for safety hazards and risks and a comparison will be made.

6.6 Final conclusions and recommendations

Based on the safety risk assessment previously performed, the Consortium will make final reasoned conclusions and recommendations about the suitability of single-engined helicopters for commercial air transport operations and possible changes to the rule(s) contained in the Annexes to the Air Operations regulations11. These conclusions will be factual and concise. The Recommendations will define both the proposed measure and the recipient

The conclusions will determine if any rulemaking action is necessary and will allow to justify the need for rulemaking on the specific subject. In the case of positive answer, shall define the main guidelines (priority and scope) of the future regulation. In other terms, these conclusions will be used as Preliminary Regulatory Impact Assessments. This assessment is developed at the initial stage of the rulemaking process. To this purpose, the Consortium will use the relevant Agency procedure, as current at the time of the study12.

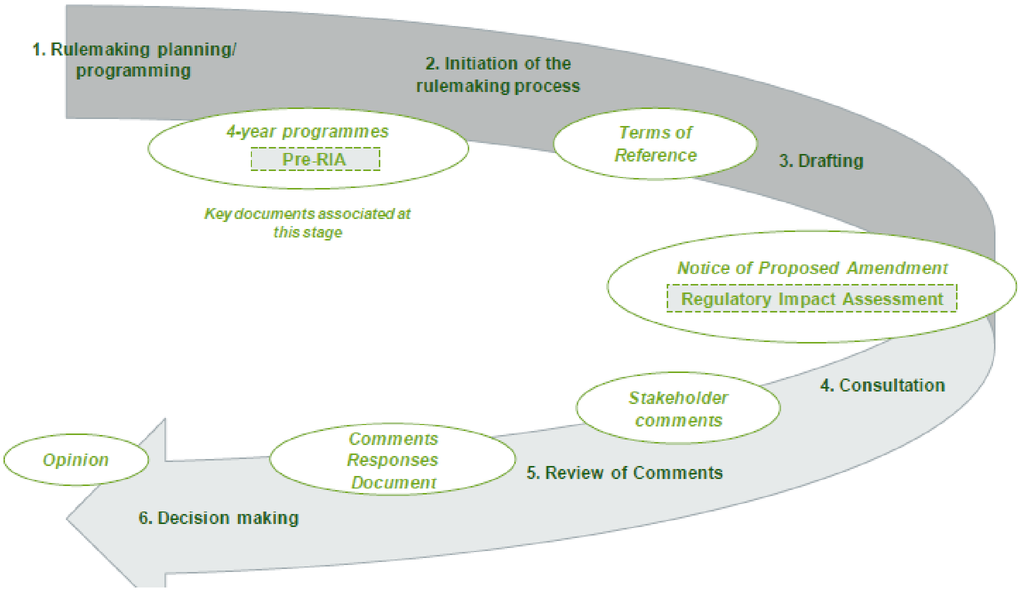
6.7 Regulatory Impact Assessment

One of the tasks assigned to the EASA is the drafting of aviation safety legislation and the provision of technical advice to the European Commission and to the Member States.

The rulemaking procedure adopted by the EASA includes:

- The establishment of preliminary regulatory impact assessments,
- A regulatory impact assessment (RIA) to accompany every Notice to Proposed Amendment.
- Regular evaluations of the impact of the rules (ex-post evaluations)

The following diagram illustrates the rule making procedures, detailing the 6 main processes and the main inputs/outputs of each process in terms of documents. It highlights the place of RIA within the whole rulemaking procedure.



The purpose of RIA is to support the rulemaking programmes so that regulatory amendment take into account the safety, economic, social and environmental impacts. Indeed, the Regulatory Impact Assessments consists of a detailed analysis to study several options through the assessment of the impacts in terms of safety, economic, social and environment

Subject to confirmation by the Agency, the Consortium may be required to perform the relevant Regulatory Impact Assessment of the rulemaking action proposed as part of the conclusions of the study

For the Regulatory Impact Assessment (RIA), the Consortium will use the relevant Agency procedure, as current at the time of the study13.That procedure provides an excellent basis for compiling the RIA.

A key element for any RIA is the determination of viable options. To make such a list, it is important to understand the issues that surround the subject at hand. Such understanding will be obtained from various sources, including regulators and industry stakeholders. The RIA will contain a section relating to process and consultation which will describe how it was developed. For each proposed regulatory change, an assessment will be done in the six assessment areas (safety, social, economic, environmental, proportionality and regulatory coordination/harmonisation).

Improvements in safety or environmental issues may be evaluated in terms of either a reduction in the frequency of occurrence of the unsafe condition or a reduction in the severity, or both. The data collected in the earlier phases of the study will provide the basis.

The Consortium has access to other aviation databases such as those related to fleet developments, economic growth, etc., including those maintained by Seabury (www.seaburygroup.com), a market leader on aviation market analyses. Seabury is associated with SGI Aviation. The Consortium will also make use of the data sources developed specifically for making economic assessments of regulatory change including that developed by the FAA14.The Consortium will use those databases for analyses in all assessment areas, complemented with data and observations obtained from contacts with stakeholders, as well as experience and knowledge of the experts.

All data used in the assessment will be validated qualitatively by the Consortium experts, using their experience and current knowledge which has been gained as an NAA inspector, industry expert, researcher, etc.

For a RIA, it is important to take into account future changes in the factors that are under consideration. This may include the effects of changes in technology that manufacturers and other parties will disclose in the interviews outlined above.

Finally a comparison will be made of all of the impacts for each of the proposed regulatory options concluding with a recommendation for the preferred option.

7 Implementation

This section describes the implementation process of each phase: data gathering, data analysis, assessment of operation conditions and safety risk assessment.

7.1 Data gathering

7.1.1 Fleet Database

The target of this phase is to consolidate a single helicopter fleet database that pictures the current fleet in EASA member states, with as much information as possible about its ownership and operators, as well as supplementary information that may be useful in further steps of the study.

The procedure to obtain the database includes the gathering, treatment, merging, and polishing of the raw data obtained from the different sources identified in the first task of the project, the literature survey.

The following scheme summarizes the process followed for the consolidation of the single database:

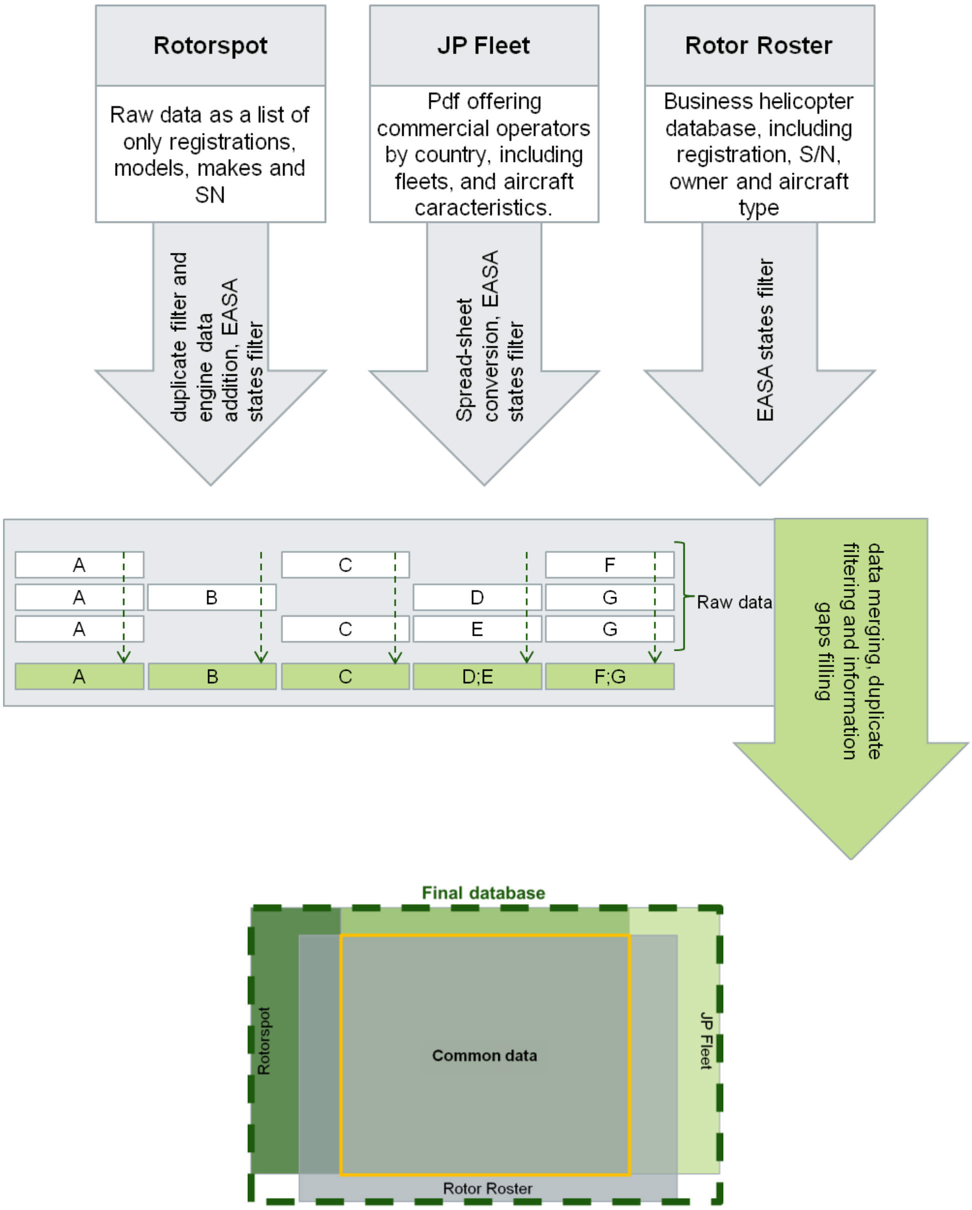


Figure 3: Fleet database building scheme

7.1.1.1 Raw data

The data to build up the fleet database comes from three (3) independent sources, each of which having its own singularities. The choice of these three (3) sources is made based on their suitability for the study, their complementarity and their ease of data treatment.

7.1.1.1.1 Rotorspot

Rotorspot is a simple database that compiles rotorcraft registrations, makes, models and in most cases serial numbers.

Its format is a plain text file on the website, separated by countries. The sources used to compile this information vary from national registries, to spots by aviation professionals. An example of the data is as follows:

Registration	Make & model	Constructors no
F-BGOS	Bell 47D1	609
F-BGXR	Bell 47D1	158
F-BGXY	Bell 47G > 47G-2	690

Figure 4: Rotorspot registration example

Some of the registrations include changes in the helicopter certification (such as upgrades), and previous registrations of the same rotorcraft.

The treatment of this data, when imported to spreadsheet, consists only in a separation by columns of the registration, make, model, and SN. From the EASA member states, the resulting spreadsheet includes **7.660** different registrations.

7.1.1.1.2 JP Airline Fleets International (JP Fleets)

The JP Fleets, identifies the fleet of most of the known commercial aircraft operators. As identified in the first interim report, it classifies the main civilian commercial operators and their fleets with some exceptions. It excludes privately-owned aircraft and those under 2.0 tonnes of maximum take-off weight, for single engine aircraft. Even if the database only includes relevant operators, the information delivered about them is very complete and it has been considered very relevant to the study and therefore has been is merged o the other available information about each registration.

The data in JP Fleets is presented in only in portable document format (pdf), in the following structure:

Helijet Aviation (Yorkshire Helicopters Ltd dba) **Leeds/Bradford**
Leeds Heliport, Harrogate Road, Leeds West Yorkshire LS19 7XS, UK Tel: +44 1132500588 Fax: +44 1132508161 Email: info@helijet.co.uk SITA: n/a
F: 1996 Emps: 8 Head: Mike Thorpe Web: www.helijet.co.uk

☐	G-RAMI	Bell 206B JetRanger III	2955	N1080N	0380	1096	1 RR 250-C20B	1451	Utility	4032DF
300	registration	type of aircraft	cn/fn	exreg	mfd	del	powered by	mtow kg	configuration	hexcode name/fin/specialities/remarks

Figure 5: JP Airline Fleets information example

This format of data, presents difficulties accessing it for treatment in a spreadsheet, as it is not directly recognizable in this format. In addition, the database includes aircraft and rotorcraft, only identifiable by the make and model. To overcome this, a data processing algorithm in Excel has to be used, extracting only the data required.

This source includes **15.602** aircraft, from which **2.295** are single and twin engined helicopters from the **26** EASA states having helicopter companies listed in this database. The information has to be extracted and treated. Twin-engined helicopters will be filtered and excluded from the consolidated Fleet Database.Rotor Roster

The Rotor Roster is mainly a spreadsheet of worldwide fleets, identified as “business class” helicopter, but including commercial aviation and general aviation helicopters information.

The information, classified by registrations, presents at least the make and model of each registration, and in the majority of the registrations is complemented by the ownership, serial number, and some miscellaneous details. An example row of the data that can be pulled is as follows:

Manufactur	Designati	Serial Numb	Registrati	Country of Registratio	Year Bu	Engine Type	Owner	Owner First Name	Owner Last Name	Owner Address 1
Aerospatiale	3160	1524	D-HOSI	Germany	1968	Turboshaft Helicopter	Heli Cargo Helicopter Service GmbH			Kirchgasse 20
Aerospatiale	AS 350 B	1322	D-HFEM	Germany	1980	Turboshaft Helicopter	Canarian Island Helicopter Service	Dietmar	Walhutter	C/San Borondon 12, Sar
Aerospatiale	AS 350 B	1601	D-HCOR	Germany	1982	Turboshaft Helicopter		Rudolf	Seuffer	Ferdinand-Lassall-Str.40
Aerospatiale	AS 350 B	1708	D-HHGB	Germany	1983	Turboshaft Helicopter	Bauhaus GmbH & Co			Gutenbergstr. 21
Aerospatiale	AS 350 B	1781	D-HENA	Germany	1984	Turboshaft Helicopter	FJS-Helicopter Lufttransport GmbH	F. J.	Strathausen	Benediktstr. 17

Figure 6: Rotor Roster Sample Data

The data that can be extracted includes **31.031**, of which **5.654** are from EASA states.

7.1.1.2 Merging process

To consolidate a single database including all the available registrations, compiling as much information as possible from the different sources, the merging process has been fully computerized, using algorithms that identified each registration and all the related information, keeping track of all the information sources used, and minimizing human error.

The methodology followed a linear scheme in three steps::

1. Extraction of data
2. Standardization of data
3. Merge of data

7.1.1.2.1 Methodology

Step 1:

The first step is the treatment of the data in order to obtain a uniform set of rows in a spreadsheet that can be comparable by the merging algorithm.

- To extract the data in Rotorspot, available as plain text in the website, the information has been converted into rows in a spreadsheet, selecting only helicopters registered in EASA member states. For each helicopter, all the information was contained in one single cell. This information has then been split in different columns of the spreadsheet: Registration, helicopter make and model, and possibly a subsequent row of additional information such as previous registrations of the same helicopter. Finally, the single and multi-engine helicopters have been identified, and a simple duplicate check algorithm has been executed.
- To extract the data in JP Fleets, the whole pdf information for each EASA state has been pasted in a spreadsheet, and treated and filtered to obtain a row of cells for every helicopter, identifying its registration and main characteristics.
- The Rotor Roster was already presented as a spreadsheet, needing only to be filtered by EASA states.

The outputs of this step are three different spreadsheets in xls format for each source.

Step 2:

To standardize the data before the merging, the three matrixes have been compiled in a same spreadsheet. The columns of each database containing the same information have been aligned in the same column:

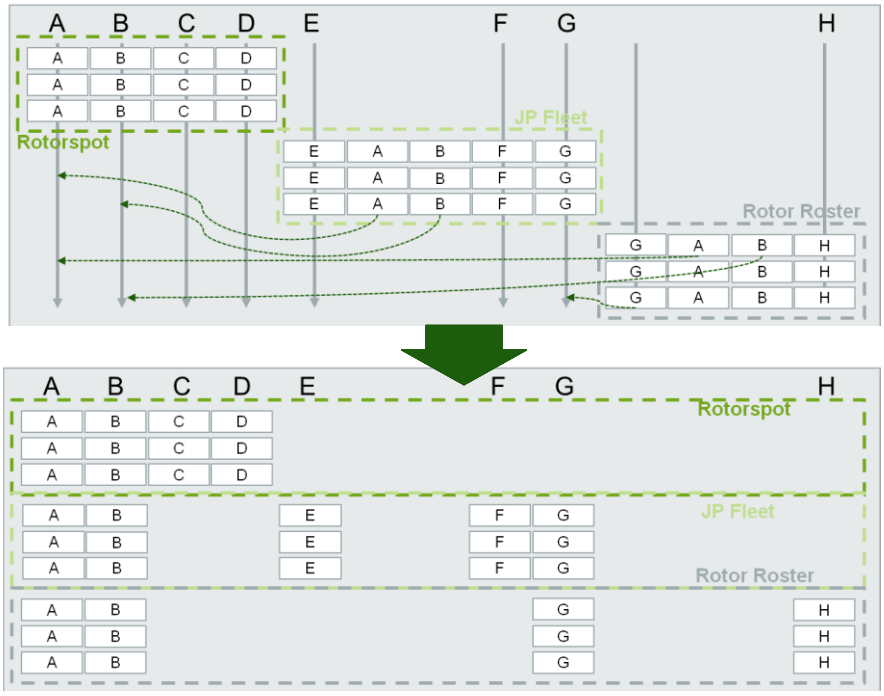


Figure 7: Matrix standardization

The output is a spreadsheet with all the data of three sources classified in columns containing the same type of information:

From this output, it is noticeable that same registration for the same aircraft appear is present in different rows such as in the case of aircraft leased between two operators. For these cases the duplicated rows need to be merged to avoid redundancies and to have an accurate database.

	Make	Model	EASA Country	Registration	MSN	Year built	Owner	Operator	Miscellaneous
Rotor Roster →	Eurocopter	AS350	Romania	YR-XXX	1845	1994	Owner X		################
JP Fleet →	Eurocopter	AS350	Romania	YR-XXX		1994		Operator Y	################
Rotorspot →	Aerospatiale	AS350	Romania	YR-XXX	1845				

Figure 8: Standardized data redundancy for the three sources

In addition, some conflicts with different data for the same registration were expected to be present, needing a meticulous merging algorithm that avoids misinterpretations of the information.

Step 3:

The next step used an algorithm that merged the rows with the same registration code, and identified each of the conflicts between different data for a same registration, while completing the gaps where possible.

This has been done using an SQL database query that identified each registration, and compared the information available in each duplicate row. The single rows have been kept and the gaps between two duplicate registrations have been filled, while the different cells in duplicate registrations have been concatenated adding a tracking character, in order to identify information conflicts.

Subsequently, the spreadsheet only contained rows with single registration numbers, and the conflicts identified by the tracking character have been solved, separated, or cleared, depending on the case. Most of the conflicts were merely typing differences, for example in serial numbers, while some unusual conflicts consisted in helicopters that have been de-registered, and the same registration code has been used in a new unit

The merging resulted in a spreadsheet that contained **6.880 single engine helicopters registered in all 31 EASA member states:**

- **12%** of the helicopters common by the three databases
- **35%** present in at least two databases
- **67%** from JP Fleets or Rotor Roster, considered with complete data

- **33%** only present in Rotorspot, and therefore with few data

7.1.1.3 Final Consolidation

The final consolidation of the fleet database lied on the fine tuning of the data. This phase had three basic procedures:

1. Standardization of the whole database
2. Comparison against other available sources
3. Addition of supplementary data fields

7.1.1.3.1 Methodology

To standardize the database, every column having common fields such as Makes, Models, Engines. It has been checked in order to have the same type of identifier, for statistics purposes.

As an example, all the helicopters that are currently under Eurocopter name, have been updated to this manufacturer, even if the design and construction was under MBB, Sud-Aviation or Bolkow for some cases.

The aircraft model field presented some variations in the identification of helicopter models, depending on the origin of the information. The inconsistencies originated by typing differences or different name configurations have been standardized as well.

After the standardization, the database has been compared against other available sources to assess its accuracy. These sources are:

- The database provided by EASA containing the following information:

Aircraft Registration	Serial Number
Make	Year Built
Model	Engine
Series	Count of Number of Aircraft

Table 44: EASA data fields

- The fleet database provided by the Civil Aviation Authorities. At the time of this report, only the authorities of United Kingdom, Poland and Luxembourg have provided such information.

These sources allowed completing the merged data base with additional **526** entries from the following sources:

- Single-Engined Helicopter Fleet EASA database: **502** additional single-engined helicopters (84 % common entries with multisource merged database)
- United Kingdom CAA: **19** additional single-engined helicopters (98,3 % common entries with multisource merged database)
- Poland CAA: **5** additional single-engined helicopters (**94,4%** common entries with multisource merged database)

The low number of inconsistencies found between the merged database and both the UK CAA and Poland CAA data for single-engined helicopters indicates a high level of completeness of the database resulting from the merging process.

However, the Consortium is investigating the additional **502** entries provided by Single-Engined Helicopter Fleet EASA database.

Finally, the database has been enhanced with the addition of supplementary fields to complement the data available. These fields contain general data about the helicopters, and may be used for pulling out statistics. Some information that has been considered useful, such as weights, performance data, size, capacity, has been extracted for each model available on the Helicopter Blue Book, and complemented with the OEMs information. As some helicopter types usually have few models or variations, and therefore different performances and characteristics, these variations will be reflected in the database when considered relevant.

The information for the supplementary fields such as engine information, weights, or sizes has been extracted from different sources:

- The Helicopter Blue Book, containing specifications for the majority of the helicopters identified
- OEMs information about helicopter models available in internet

Each of the rows of the merged database could then be supplemented by this type of data, distributed in a pivot-table friendly structure.

7.1.1.3.2 Final output

The final output of this phase is a row-based spreadsheet with **10.245** total entries containing the main fields to identify each of the helicopters registered in EASA member states.

The database contains each single registration of an EASA state, and all the non-EASA registrations identified operating in an EASA state, from the three sources identified.

In addition, the final output integrated the fleet information made available by EASA. The merge has used the comparing algorithm, to find common registrations and/or serial numbers, adding the non-duplicate helicopters to the final database.

The whole process resulted in a spreadsheet in which each registration has associated, when available, the following information:

- Make
- Model
- Year of manufacture
- Year of registration
- Number of engines
- Engine model
- Operator
- Operator Country
- Owner
- Miscellaneous information about owner and operator

In addition, the database has been treated to be easily supplemented with any of the specifications available for the majority of the models in a helicopter specifications database. The fields that may supplement the fleet database include:

- Dimensions
- Weights
- Performance data
- …

Any statistics of the mentioned initial fields, and the supplementing data, can be further treated with pivot table software that will allow pulling statistics of each field considered important.

7.1.1.4 Information gaps

Although quite complete, the final output after the merging process contains some information gaps.

Concerning only the single engine data, the database includes 6.880 single entries, including 57% of piston engine registrations and 43% of turbine powered helicopters.

The most relevant and for which it will be necessary to reasonably try to find the missing information delivered the following percentages:

- **2%** entries with no registration number
- **4%** without MSN
- **9%** without year of manufacture (but could be deducted from MSN)

- **40%** with owner and operator both unknown from which 39% are Robinson's, 11% are ultralights, and nearly 50% are other helicopters

The Owner and Operator field has a very high percentage of uncertainty; however the information expected from the Civil Aviation Authorities, as well as the OEMs may lower this number. In addition, at a further stage of the study, most of the small piston helicopters, and generally all kit helicopters, could be considered operated in general aviation category and therefore out of the scope for subtask 2c "Assessment of operating conditions allowed by EASA member states

7.1.2 Occurrence Database

The aim of this phase is to obtain an occurrence (accident/incident) database that covers the 10-year period between 01/01/2003 and 31/12/2012.

The procedure to obtain this database includes the gathering, treatment, merging and polishing of the data obtained from each of the sources identified in the first phase of the project.

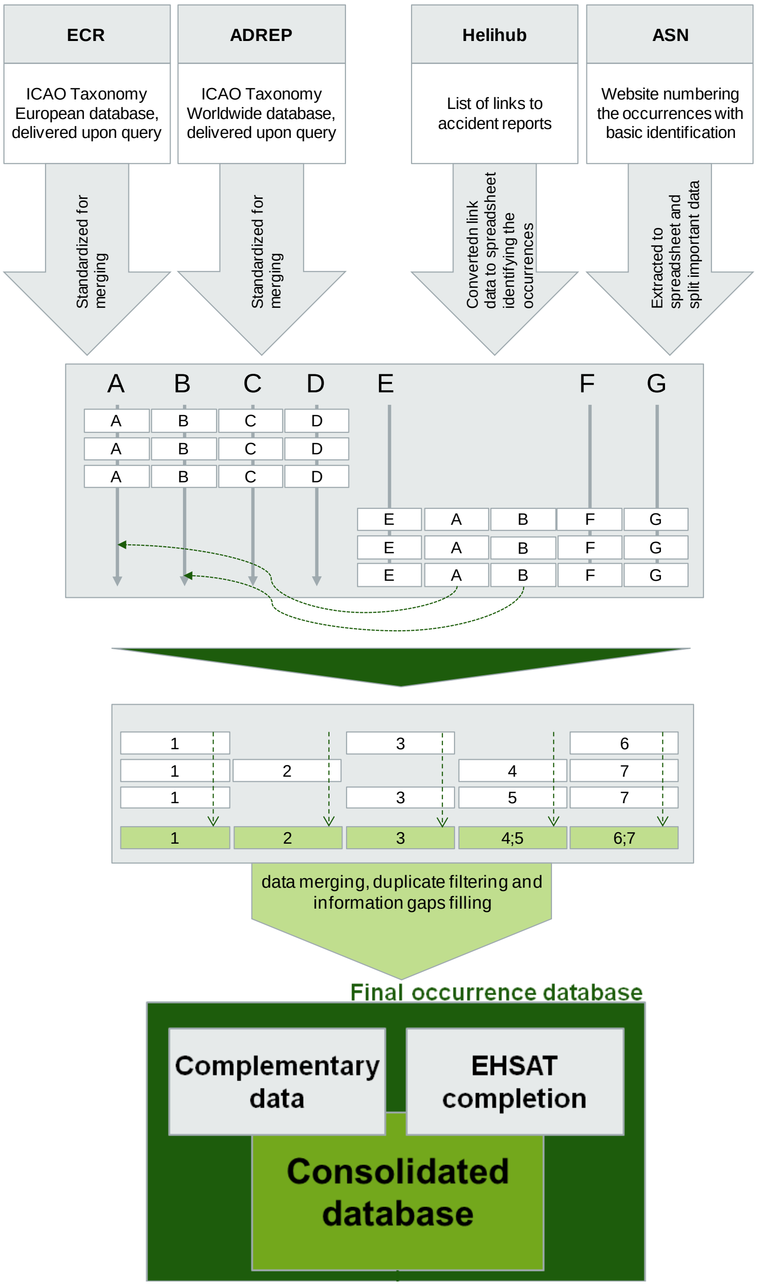


Figure 9: Occurrence database building scheme

7.1.2.1 Raw data

The data to build up the occurrence database comes from seven (7) independent sources, each of which having its own singularities. The choice of these seven sources is made based on their suitability for the study, their complementarity and their ease data treatment.

7.1.2.1.1 European Central Repository (ECR)

The European Central Repository compiles the information provided by the national aviation authorities of the EASA Member States, stored by the ECCAIRS system.

The data available is mainly from 2005 onward, but does not include non-serious incidents. It includes many serious incidents in addition to accidents and contains also details of fixed wing aircraft involved in helicopter occurrences, military occurrences and events involving non-EASA registered aircraft where these have been the subject of an EASA state accident investigation.

The data has been made available by EASA upon request of the Consortium. After an online demonstration of the capabilities of the ECCAIRS system, and after several tests, the final query included the following fields:

Aircraft Registration	Location
Make	Occurrence Class
Model	Occurrence Category
Year Built	Injury Level
Serial Number	Damage Level
Number of Engines	Flight Rules
Engine Make	Flight Phase
Engine Model	Number of Occurrences
Type of Operation	Fatalities
UTC Date (Year)	Serious Injuries Minor Injuries
UTC Date	No Injuries
Local Date (Year)	Total POB (People On Board)
Local Date	File Number
State of Occurrence	LatLong

Table 45: ECR data fields

Depending on the origin of the data and the type of occurrence, some fields are more populated than other, while some other (i.e. helicopter/engine characteristics) need to be completed. We have used our skills and experience to extend the data population, but some significant errors and many omissions remain needing correction.

7.1.2.1.2 Accident/Incident Data Reporting (ADREP)

The ADREP database is similar to the ECR database, but includes worldwide information reported by the ICAO member states. It has the particularity that the occurrences are only included if an aircraft/rotorcraft of more than 2 250 kg of maximum certificated take-off mass, and that excludes most of the small single engine piston helicopters.

The accessing, as for ECR, is through ECCAIRS, belonging to ICAO and delivered upon request by EASA.

Looking after the merging of the data, and knowing that the output will have the same format, the request included the following fields:

Aircraft Registration	Location
Make	Occurrence Class
Model	Occurrence Category
Year Built	Injury Level
Serial Number	Damage Level
Number of Engines	Flight Rules
Engine Make	Flight Phase
Engine Model	Number of Occurrences
Type of Operation	Fatalities
Year	Serious Injuries Minor Injuries
UTC Date	No Injuries
Local Date (Year)	Total POB
Local Date	Total on Board
State of Occurrence	File Number

Table 46: ADREP data fields

As for the data from ECR, some of the missing or erroneous data fields have been completed by us using external data, especially the ones relating to aircraft characteristics.

7.1.2.1.3 Aviation Safety Net (ASN)

Supported by the Flight Safety Foundation, the ASN wiki database compiles information about accidents, mainly based on the information from official sources.

The database is website based, and has been extracted in table format to a spreadsheet, delivering the following fields:

Date (LINK)	Operator
Type	Fatalities
Registration	Location

Table 47: ASN data fields

7.1.2.1.4 Helihub

The Helihub database is presented as a list of accidents, presenting links to an accident report. As reported on the first phase of the study, even if most of the accidents are not complete, some other apparently are not reported elsewhere.

While extracted from the website to a spreadsheet, and splitting the link, the following fields have been covered:

Date of occurrence	Model
Registration	Location
Make	Country

Table 48: Helihub data fields

7.1.2.1.5 Eurocopter

Eurocopter agreed to deliver aggregated data upon query for the purpose of this study. An online demonstration of the capabilities of its database was organized.

The queries defined by the Consortium for the provision of aggregated data and transmitted to Eurocopter are:

1. For 31 EASA member states from 01/2003 to 12/2012:
   - Number of events for each type of occurrence (as defined in ICAO annex 13) and for each Eurocopter model family
2. For all other states from 01/2003 to 12/2012:
   - Number of events for each type of occurrence (as defined in ICAO annex 13) and for each Eurocopter model family
3. For 31 EASA member states and all other states from 01/2003 to 12/2012:
   - Number of events for each type of occurrence (as defined in ICAO annex 13) and for each Eurocopter model family

It has also been considered positive for the study to be able to cross-check Eurocopter data with the other databases available. For this purpose, a list of all occurrences from 01/2003 to 12/2012 with the following data has been requested:

- Type of occurrence
- Date
- Registration

The data received from Eurocopter included a list of occurrences, sorted by date and helicopter registration.

7.1.2.1.6 Bell

Bell agreed to deliver aggregated data upon query for the purpose of this study.

The queries defined by the Consortium for the provision of aggregated data and transmitted to Bell are:

1. For 31 EASA member states from 01/2003 to 12/2012:
   - Number of events for each type of occurrence (as defined in ICAO annex 13) and for each Bell model family
2. For all other states from 01/2003 to 12/2012:
   - Number of events for each type of occurrence (as defined in ICAO annex 13) and for each Bell model family
3. For 31 EASA member states and all other states from 01/2003 to 12/2012:
   - Number of events for each type of occurrence (as defined in ICAO annex 13) and for each Bell model family

It has also been considered positive for the study to be able to cross-check Bell data with the other databases available. For this purpose, a list of all occurrences from 01/2003 to 12/2012 with the following data has been requested:

- Type of occurrence
- Date
- Registration

The data provided by Bell includes a list of accidents and serious incidents, sorted by Country, and including Family, Model, Registration, Date, Location and type of occurrence.

7.1.2.1.7 European Helicopter Safety Analysis Team (EHSAT)

The EHSAT database has been delivered by EASA, being a set of spreadsheets that include the following fields:

Analysis?	VMC/IMC
Year	Light conditions
Ops Type level 1	Engine config.
Analysis completed?	Aircraft Certification basis
Analysis assigned to	Pressure altitude MSL (in ft)
Filenumber or Ref.	Height AGL (in ft)
Occ. Date (Excel date format)	Pilot-in-command experience on ALL AIRCRAFT types (total hrs)
Occurrence Class	Pilot-in-command experience on ALL HELI types (total hrs)
State of occurrence	Pilot-in-command experience on THIS HELI type (total hrs)
Aircraft Registration	Co-pilot experience on ALL AIRCRAFT types (total hrs)
Aircraft Make	Co-pilot experience on ALL HELI types (total hrs)
Aircraft Model	Co-pilot experience on THIS HELI type (total hrs)
Type of operation	AIB Safety Recommendation #1
Aircraft Damage	AIB Safety Recommendation #2
Injury Level	AIB Safety Recommendation #3
Number of fatalities	AIB Safety Recommendation #4
Total number of persons on board	AIB Safety Recommendation#5
Phase of flight	AIB …
In Hover?	

Table 49: EHSAT data fields

7.1.2.2 Merging process

The process to consolidate a single database that includes the information of accidents and incidents from each of the sources available follows a pyramidal scheme. The first step is to merge and filter similar databases as depicted in the figure below, in order to get as much events and information as possible in several databases, that will allow an exhaustive duplicate identification while merging to the final database.

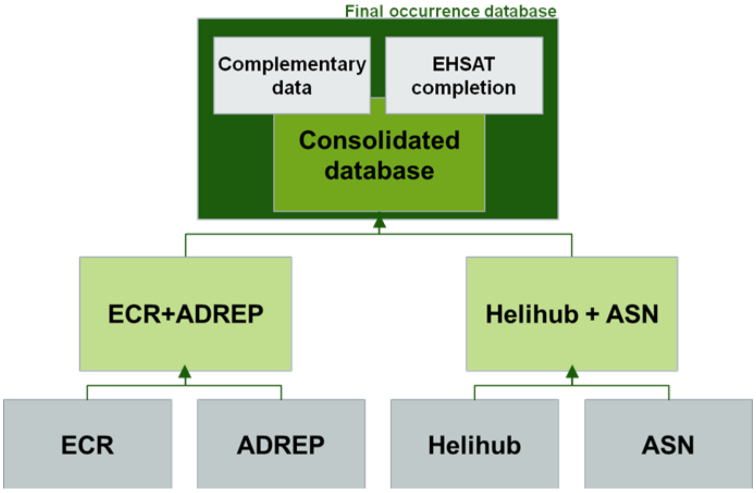


Figure 10: Pyramidal scheme

The process followed these steps, in each of the iterations of the merging:

1. Gathering of data
2. Standardization of data
3. Merge of data

7.1.2.2.1 Merge of ECR with ADREP

ECR and ADREP are two databases with the same software platform, the European Co-ordination Centre for Aviation Incident Reporting System (ECCAIRS). The extractions requested included the same fields for each of the registers, leading to a fast process of merging. However, most of the fields were filled differently in each of the databases and many conflicts appeared during the merging process, needing an accurate post-processing labour of filtering.

The detailed process has been as follows:

4. Query of data to EASA
5. Standardization of data
6. Merge of data

7.1.2.2.1.1 Methodology

Step 1:

The data gathering process has been fully done by EASA upon request. After having an online demonstration of the capabilities of the ECCAIRS system, and a first extraction that has been analysed and studied, a final request of data has been sent to obtain extractions from each of the repositories.

The first problem encountered has been on the extraction format, as each accident/incident could be registered in several rows depending on the information contained in the database. In addition, if the same helicopter had more than one accident/incident in the same day, a filtering and merging of the data by dates of occurrence would give a wrong result. This has been solved adding the field “File Number” included in ECCAIRS system that, even if not present in every single occurrence, allowed the identification of the rows belonging to the same occurrence. Furthermore, the events that had more than one helicopter/aircraft involved could be easily identified.

Step 2:

The standardization of data in the merging of ECR and ADREP, as the fields were mainly the same, included two parts:

- Date of occurrence standardization: The raw data included the fields “Local date” and “UTC date”, not always filled up. To standardize the dates, the “UTC date” has been taken as a base, and the “Local date” has been used when the other field was blank.
- EASA states selection: While ECR is a Europe based repository, ADREP includes loads of foreign occurrences that needed to be filtered in order to shorten and enhance the merging process. An “EASA state” field has been added.

Step 3:

The last step of the ADREP and ECR merging has been the superposition of the two databases already standardized.

The process used an algorithm that merged the information under the same file number, concatenating and adding a tracking character when two fields of the same file number included different information.

This has been done using an SQL database query that identified each different file number and comparing the information contained under the repeated ones.

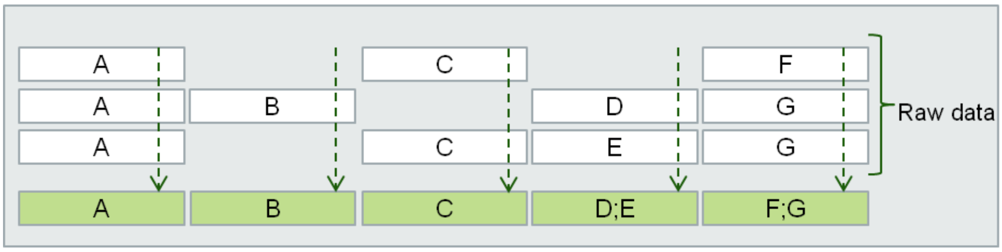


Figure 11: Merging process

After this first merge, based in file numbers, all the information under non-identified file numbers has been checked based on the date, registration and location fields, in order to identify other potential rows containing information about the same occurrence.

The merging resulted in a spread sheet that contained **15.559** single events, all related to helicopters and involving **951** fixed wing aircraft and UAVs.

7.1.2.2.2 Merge of ASN with Helihub

The merging process between ASN and Helihub databases used a merging algorithm that compared important accident data, in order to identify duplicated events between the two databases, and complement the accident data between the two sources.

The process followed this scheme:

1. Data collection
2. Standardization of the data
3. Merging

7.1.2.2.2.1 Methodology

Step 1:

Each of the websites has a particular presentation of the occurrence data that, when extracted into spreadsheets, delivered a list of rows that included a link to the full report, the date of the occurrence, the make and model, the registration, location and few other details.

Both spreadsheets needed a meticulous standardization of the data, in order to be compared and merged.

Step 2:

To standardize the data and find common fields, the two data matrixes have been combined in the same spreadsheet. Some columns contained similar information, but needed to be in the same format prior to the merger. As an example, most of the occurrence dates were not in the same format, and needed to be corrected to be compared later. The same happened with makes and models.

Once all the similar information has been corrected, the columns containing the same type of information, but from different sources, have been arranged to be aligned in the same column:

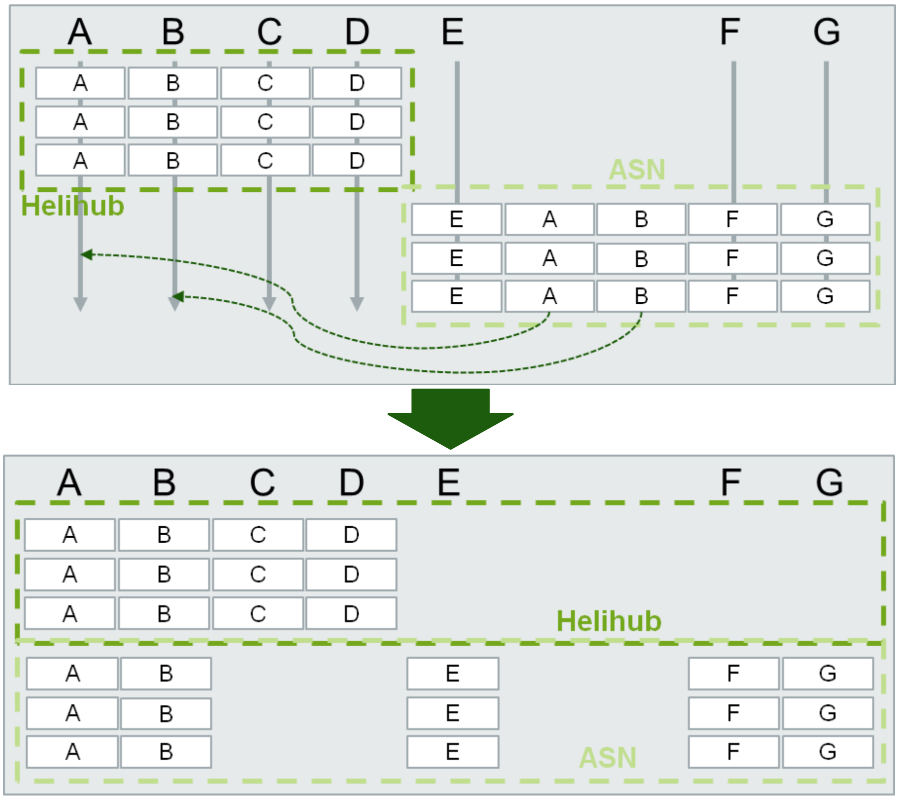


Figure 12: Matrix standardization

After the alignment, the spreadsheet contained all the information from both databases and could be re-arranged by the date of occurrence, to facilitate the merging algorithm work.

<u>Step 3:</u>

The merging of the data used an algorithm that compared the date of occurrence, helicopter, and location, identifying common occurrences between both sources. These duplicated occurrences when merged, complemented each other data offering a more accurate description of the incident/accident. When the data in the same field is different, it is concatenated with a tracking character.

The algorithm used in the merging had the following scheme:

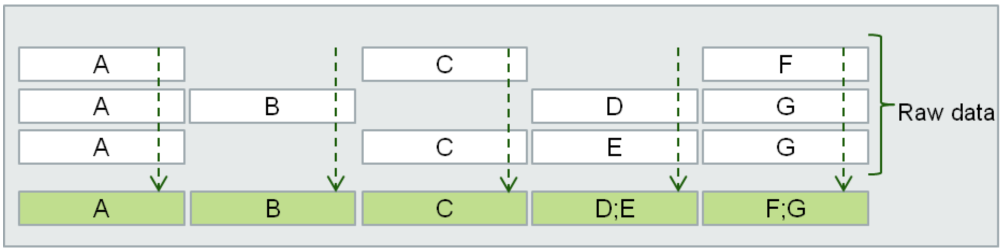


Figure 13: Merging process

The output of this step resulted in a single database of combined data, offering:

- **1.010** common accidents, that have been complemented
- **1.543** accidents only in Helihub
- **1.942** accidents only in ASN

7.1.2.2.3 Whole database

After the first two mergers, the data was split into two databases having as much information as possible about the occurrences, but with considerably different layouts. Additionally, it has been considered relevant to crosscheck the final output with the EHSAT data, which delivers the data from a few accidents, but it is considered the most accurate and extensive about each occurrence.

Again, to obtain a single database, the following process has been applied:

1. Standardization of the data
2. Merging of the data
3. EHSAT data addition

7.1.2.2.3.1 Methodology

<u>Step 1:</u>

To standardize the data, it has been used the usual procedure that leads to a spreadsheet that can be treated by the merging algorithm. Again, the columns containing similar information have been identified, corrected in order to have it in the same format, and re-arranged by aligning the same information into the same columns.

<u>Step 2:</u>

The final merge followed the same algorithm previously used, but with some modifications that allowed the identification of events that were fairly complete, depending on its source database.

The parameters compared in order to identify common events between the two spreadsheets have been:

- Date of occurrence
- Make and model (when available)
- Registration (when available)
- Location of the occurrence (when available)

While the merging following these parameters has been fully computerized, and delivered a good approach to the final database, the data had to be rechecked focusing on particularities like events registered in a 2-3 day interval that could potentially be the same event from the different sources.

<u>Step 3:</u>

The last step of the merging process used the information available in the EHSAT analysis tool, which included several selected accidents with much detail about them, completing some of the accidents in the compiled spreadsheet.

Similarly to the previous step, to identify the accidents the following parameters have been used:

- Date of occurrence
- Make and model (when available)
- Registration (when available)
- Location of the occurrence (when available)

And finally, a manual check of the remaining unidentified accidents has been done, delivering the fully compiled database that included all the accidents in every database available.

The final completion of the database with the information from EHSAT showed only **8** occurrences not recorded in the consolidated database while the rest of occurrences in EHSAT were registered.

7.1.2.3 Final consolidation

The final consolidation of the database consisted on the addition of supplementary data that will deliver valuable statistics in the data analysis phase.

This data has mainly been obtained linking the occurrence database to the fleet database, which in its latest stage included many details for each type of helicopter. The specifications added to the occurrence database, considered useful for the study have been:

- MTOW
- Passenger capacity
- etc

The last treatment to the database consisted in the identification of the available locations for each occurrence, obtaining the coordinates of the identifying field. This will allow the location of the areas through a GIS software, while obtaining altitude statistics, climate characteristics of the area, and areas of high occurrence concentration.

In this final stage, we discovered on the Eurocopter website a list of 145 of their helicopters described as "potentially destroyed Eurocopter aircraft awaiting government report".

We have cross-checked the list with the final consolidated database and identified all the single-engine aircraft already recorded.

The output of the final consolidation delivered an occurrence database that includes **4.606 single occurrences** registered between 01/01/2003 and 31/12/2012.

Selecting only Accidents and Serious Incidents registered in this period, the number gets lowered to **920 occurences.**

The data provided by Bell and Eurocopter has been used to evaluate the completeness of the consolidated database, cross-checking with the list of accidents and serious incidents from all single engine models.

The following has been pulled out from Eurocopter data:

- From the 1.029 accidents/serious incidents in Eurocopter database, 296 have EASA member state registrations.
- From the 296 EASA helicopters occurrences in Eurocopter database, 262 are in our consolidated database, obtaining 34 unidentified occurrences
- These 34 unidentified occurrences have been further clarified by Eurocopter
- And the following has been retrieved from Bell data:From the 96 accidents and incidents registered by Bell, 4 are missing in the consolidated database
- These 4 unidentified occurrences will be further clarified by Bell

7.1.2.4 Information gaps

Although quite complete, the final output after the merging process contains some information gaps. The most relevant and for which it will be necessary to reasonable try to find the missing information delivered the following percentages:

Only Accidents and Serious Incidents	Whole Data Base	Finding
1%	**11%**	% of entries without a File Number. This is considered a minor problem, but would enhance the identification of duplicated events not yet identified.
0%	**0,04%**	% of occurrences with unidentified date
1%	**16%**	% of occurrences with unknown make, type or model
0,6% (0,04 %)	**25%**	% of helicopters with unknown year of manufacture without related official occurrence report (with related official occurrence report)

Only Accidents and Serious Incidents	Whole Data Base	Finding
0,8% (0,6 %)	**36%**	% of occurrences with undefined type of operation without related official occurrence report (with related official occurrence report)
0,6% (0,02 %)	**20%**	% of occurrences with unspecified phase of flight without related official occurrence report (with related official occurrence report)
-	**10%**	% of type of occurrences not classified (unknown or not determined)

Table 50: Information gaps

- In addition, none of the occurrences contains data regarding the terrain/obstacle suitability, neither the environment classification. To overcome this lack of information, we have analyzed, when available, the LatLong, data and placed in a map (see Figure 14). However it has been noticed the following:
  - around 90% of all the occurrences either in ECR or ADREP do not contain LatLong information
  - Around 40% of accident and serious accident in ECR or ADREP do not contain LatLong information
- When LatLong information is available, only degrees and minutes are provided which is not accurate enough (uncertainty of +- 2 Km in each direction).

Figure 14: Accident Map with LatLong information

7.1.2.5 Official Occurrence reports

In addition to the occurrence database, and in order to retrieve as much information as possible for each, all accident reports publicly available from the Air Accident Investigation Boards have been downloaded and crosschecked with the updated database: **535 reports** have been found.

The reports have been cross-checked with the consolidate occurrence database. From the **535** collected reports, **508** relate to accident or serious incident.

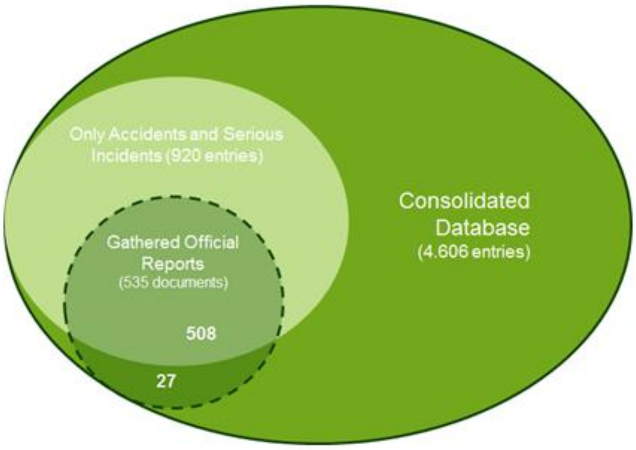


Figure 15: Occurrence database gaps

The countries for which it has not been possible to retrieve the official occurrence reports are:

- Liechtenstein
- Lithuania
- Luxembourg
- Malta

7.1.3 Usage Database

The third database to be obtained is the usage database that integrates all the information regarding the flight hours, cycles and other usage information considered relevant for the aim of the study.

The collection of usage data has proven more challenging and difficult than initially expected by the Consortium and could not be completed.

7.1.3.1 Raw data

The raw data to consolidate the usage database comes from two (2) different sources:

7.1.3.1.1 OEMs

From the OEMs identified in the previous report that were willing to collaborate with the study, only Eurocopter, Bell and Robinson have responded back to our queries. Turbomeca has also replied positively to collaborate with the study, but was not considered relevant for the aim of the study.

The OEMs contacted, in the same context of the query of occurrence data, have been Eurocopter and Bell, the only OEMs collecting usage information from their fleets. As with the incidents and accidents the OEMs agreed to deliver aggregated data upon defined query. The queries transmitted are the following:

1. For 31 EASA member states from 01/2003 to 12/2012:
   - Number of FH and FC accumulated over this period for each model family
2. For all other states from 01/2003 to 12/2012:
   - Number of FH and FC accumulated over this period for each model family
3. For 31 EASA member states and all other states from 01/2003 to 12/2012:
   - Number of FH and FC accumulated over this period for each model family

Eurocopter provided the usage data. This data consisted in the aggregated flight hours and cycles for each Eurocopter model over the studied period.

Bell provided the aggregated flight hours of all his models, as a percentage of the world total flight hours. It has been requested to Bell to further detail these figures because as delivered, data cannot be mined.

Whereas Eurocopter and Bell collect usage information from their fleets, Robinson does not maintain a record of ownership of the helicopters manufactured and therefore do not register usage data from its fleet.

In exchange, Robinson proposed to distribute a survey through its European dealer and service centre network to obtain this data. The Consortium designed a survey form to be filled by the operators. It queried the following information:

- Name of Operator:
- Owner:
- Country:
- Type of operations (Commercial/private):
- Contact Person
- Phone
- E-mail

It also requested to complete one of the tables below:

Helicopter model	Registration	Date of registration (mm/yyyy)	Total Flight hours at 01/01/2003	Total Flight hours at 31/12/2012	Average Passengers transported (commercial or private)	Average yearly operations	Scope of main operations (commercial, training,private,...)

Table 51: Helicopter usage

Fleet type	Number of units	Total Flight hours at 01/01/2003 (For the whole fleet)	Total Flight hours at 31/12/2012 (For the whole fleet)	Average yearly pax transported	Average yearly operations	Scope of main operations (commercial, training,private,...)

Table 52: Fleet usage

7.1.3.1.2 Civil Aviation Authorities

The third source of information about the usage of helicopters is the ensemble of civil aviation authorities with the capabilities to deliver this information from each EASA ember state.

CAAs have been contacted using the e-mail contacts available in International Register of Civil Aircraft (IRCA) in first instance, obtaining response from a few CAAs. Then, after this first round of enquiries, the Consortium advised EASA about the lack of response from many CAAs.

EASA suggested to contact the members of the Regulatory Advisory Group (RAG), Flight Crew Licensing & Air Operations Thematic Advisory Group, and the Production and Maintenance Thematic Advisory Group. All the representatives from countries with needed information have been contacted, however some of the EASA member states do not have representation in these Advisory Groups (TAG).

The contacts are available in http://www.easa.europa.eu/rulemaking/consultative-bodies.php.

The following table states about the progress in the provision of data from the different sources:

Colour	Meaning
White	EASA Member State not represented in TAG
Red	Delivery failure of the enquiry
Orange	Pending response (reminder sent on 21/03)
Blue	Work in progress
Green	Provided (Partial or complete)

EASA Member State - Organisation	IRCA	RAG	Flight Crew Licensing & Air Operations TAG	Production and Maintenance TAG
Austria: Austrocontrol				
Belgium: Service Public Federal Mobilite et Transports				
Bulgaria: Civil Aviation Administration				
Cyprus: Department of Civil Aviation (DCA)				
Czech Republic: Civil Aviation Authority Ministry of Transport				
Denmark: Danish Transport Authority				
Estonia: Ministry of Economic Affairs and Communications				
Finland: CAA Finland				
France: Direction Generale de l'Aviation Civile				
Germany: Luftfahrt-Bundesamt				
Greece: Hellenic Civil Aviation Authority				
Hungary: NKH Nemzeti Kozlekedesi Hatosag - National Transport Authority Hungary				
Iceland: Icelandic Civil Aviation Administration				
Ireland: Irish Aviation Authority				
Italy: Ente Nazionale per l'Aviazione Civile				
Latvia: Civil Aviation Administration of Latvia.				
Lithuania: Civil Aviation Administration				
Luxembourg: Direction de l'Aviation Civile du Luxembourg				
Malta: Transport Malta, Civil Aviation Directorate				
Norway: Luftfartstilsynet - Civil Aviation Authority Norway				
Poland: Civil Aviation Office				
Portugal: Instituto Nacional de Aviacao Civil				
Romania: Romanian civil aeronautical authority				
Slovak Republic: Civil Aviation Authority				
Slovenia: Civil Aviation Authority				
Spain: AESA, Agencia Española de Seguridad Aérea (Spanish Aviation Safety and Security Agency)				
Sweden: Transportstyrelsen				
Switzerland: Federal Office of Civil Aviation (FOCA)				
The Netherlands: Inspectie Verkeer en Waterstaat (IVW)				
United Kingdom: Civil Aviation Authority				

Table 53: Status of the provision of data

The query sent, introduced the study and requested the following information for each single engine helicopter:

- Registration mark
- Manufacturer
- Type
- Model
- Serial Number
- Year of manufacture
- Total Flight Hours (total accumulated flight time over the period 01/01/2003 – 31/12/2012)
- Total Flight Cycles
- Number of Engines
- Engine Manufacturer

The following replies were received:

Bulgaria

Provided full database including accumulated flight hours and cycles over the 10-years period.

Cyprus

Delivered all the information requested.

Czech Republic

Delivered all the registrations, types and operators information. No flight hours and cycles.

Denmark

Provided single-engine helicopter registry, including S/N and year of manufacture. Regarding the usage, provided aggregated data by model of helicopter.

Estonia

Provided single-engine helicopters registry, manufacturer, type, model, serial number, year of manufacturer, total flight hour, number of engines and engine manufacturer. No flight cycles.

Finland

Provided single-engine helicopters registry, manufacturer, type, model, serial number, year of manufacturer, total flight hour, total flight cycle, number of engines and engine manufacturer.

Greece

Provided single-engine helicopters registry, manufacturer, type, serial number, icao designator, number of engines, engine manufacturer, engine type and aircraft hours.

Hungary

Information provided by three operators. FlyCooop provide single-engine helicopters registry, manufacturer, type, model and total flight hours. Fly4Less provides total flight hours and cycles for their whole fleet. For HEMS single-engine, total flight hours and cycle are provided.

Iceland

Delivered the helicopter information, but did not include the operations information.

Ireland

Provided single-engine helicopters registry, and type.

Italy

Currently collecting the information, after several clarification messages.

Latvia

Provided full database, including accumulated usage in the 10 year period requested.

Lithuania

Provided single-engine helicopter registry, manufacturer, type, serial number, icao designator, number of engines, engine manufacturer, engine type and aircraft hours and aircraft cycles. Only one input.

Luxembourg

Delivered all the information requested, concerning the only single-engined helicopter registered in Luxembourg.

Norway

Provided detailed list of all single-engine helicopters registered in Norway, including serial number, year of manufacture and engine type .No usage data provided.

Poland

Delivered the current register file, containing single-engine helicopters registered in the country. The data concerning the flight hours and cycles is not maintained in their register.

Portugal

Agreed to compile all the requested data and deliver it when complete. Not received at the time of the delivery of this report.

Romania

Delivered aircraft registry. Flight hours would only be provided under NDA and payment of a high fee.

Slovakia

Provided single-engine helicopter registry, manufacturer, type, serial number, year of manufacture and type of engine.

Swedeen

Provided single-engine helicopter registry, manufacturer, type, serial number, year of manufacture and engine Manufacturer.

Switzerland

Provided single-engine helicopter registry, manufacturer, type, model, serial number, year of manufacture, flight hours (01/01/2003 – 31/12/2012), flight cycles, landings and engine manufacturer.

The Netherlands

Delivered the helicopter list, including registrations, years of operation, S/N and model. No flight hours and cycles delivered, stating that they do not keep track of those.

United Kingdom

Delivered a detailed spreadsheet, in CICTT IACIS format, containing registrations and flight hours in the 2003-2012 period, split by year. They informed that flight cycle data is not kept in extractable format.

7.2 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 final data of the study were:

- 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.

The statistical analysis - conducted after the consolidation of occurrences, fleet and usage databases - 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.

7.3 Assessment of Operating Conditions

7.3.1 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).

7.3.2 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[4]. 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[5]. 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[6] and now allows performance class 3 operations without the safe forced landing assurance when substantiated by a risk assessment.

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[7].

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.

7.3.3 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.

[4] Notes of JAA Operations Committee Meeting OC 96/3, 96/6, 96/7
[5] 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.'
[6] With Amendment 12, issued in 2007
[7] AGNA minutes 2nd meeting 2008.

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.

7.3.4 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[8]; (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 54: 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.

[8] 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.

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 55: Approached States for the assessment

7.4 Safety risk assessment

This section presents an overview of the methodology applied for completing safety risk analysis tasks. This methodology is comprised of three analysis steps: Hazard identification, Risk Analysis and Risk Mitigation.

7.4.1 Hazard identification

The hazard identification task consists of several steps as elaborated below. The list of these steps is as follows:

1. Determine the number of Flight Hours for piston and turbine single-engine helicopter operations during timeframe of interest;
2. Calculate occurrence ratios per 100.000 FH for piston and turbine SEH;
3. Identify engine-related accidents and serious incidents for further analysis;
4. Calculate the occurrence rates per SPS Level 1 code for both piston and turbine SEH operating in both hostile and non-hostile environment

The gathered events in the database represent occurrences reported in the single engine helicopter sector over the past 10 years. These events have a variety of causes. This risk assessment is conducted in order to support a possible revision of EASA requirements regarding CAT operations with single engine helicopters over hostile environment. Therefore this part of the study focuses on events, which, in case of a similar mishap or failure, would lead to a significantly different outcome between multi- and single-engine helicopters. Events with identical consequences for both multi- and single-engine helicopters (e.g. flight control issues, obstacle strike, atmospheric conditions etc.) would not justify regulatory restrictions for one or the other type of helicopter.

Although the alleviation in JAR OPS 3 is only applicable for CAT operations over hostile environment, all other types of operations, as well as operations over non-hostile environment, are relevant for analysis of risks associated with single-engine helicopter operations. Therefore this part of the study incorporates events regardless of type of operations or environment.

7.4.1.1 Engine related events

In order to capture differences in risk between single- and multi-engine helicopter operations, the main focus lies in engine-related mishaps or failures, which directly or indirectly contributed to the final outcome of the event. Power degradation, loss of power or even intermittent power problems, demand different actions and/or decisions from the pilot when operating a single-engine helicopter rather than a multi engine helicopter. Consequently, the risks associated with such events are different for both types of helicopters.

Besides the engine itself, several other parts of the single-engine helicopter are identified as unique to its design and could potentially result in more severe outcomes may problems occur. The following items are identified:

- Engine air intake, can be part of engine or airframe system. Both are included.
- The engine output driveshaft (between engine and main gearbox) or drive belts are non-redundant parts on a single engine machine together with freewheel units (enabling the rotor to rotate freely when the power is interrupted).
- Fuel system failures are likely to have a different impact on single engine helicopters, as multi engine helicopters mostly have provisions to prevent simultaneous flame out of both engines, giving the pilot at least a little extra time to manage the problem or prepare for complete loss of power.
- Pilot vehicle interface (PVI or HMI) problems can result in an unintended manipulation of engine controls or a delayed response. These are more likely to affect the performance of a single engine helicopter than multi engine machines.

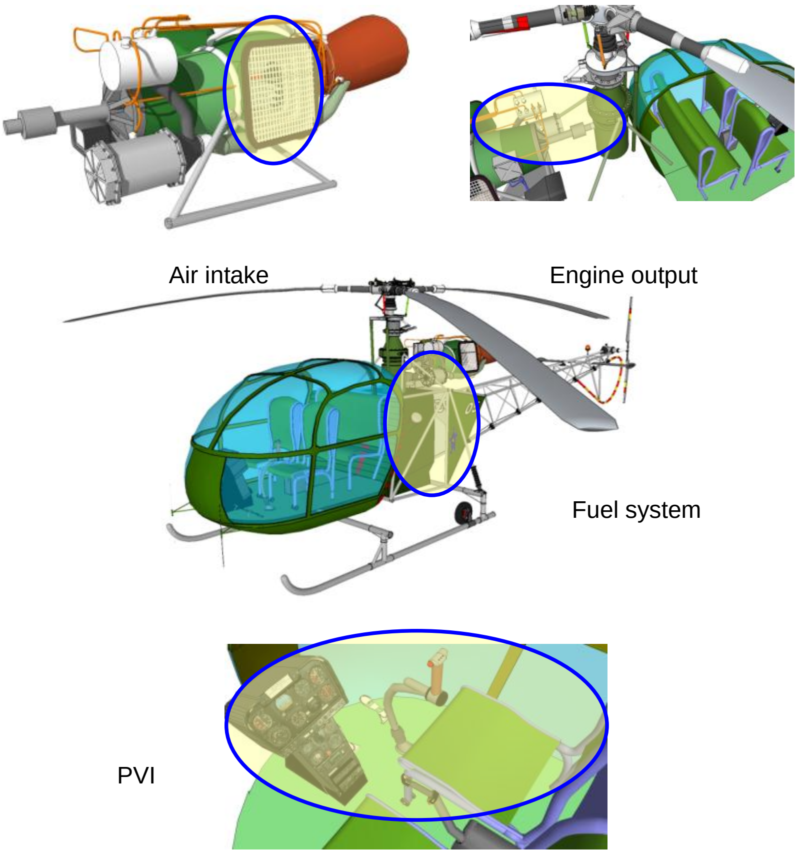


Figure 16: Components with indirect engine relation

7.4.2 Risk assessment

The risk assessment task consists of several steps as elaborated below. The list of these steps is as follows:

1. Isolate the primary / initial cause of engine-related accidents and serious incidents during SEH operations from the multitude of assigned SPS codes by analysing original occurrence reports;
2. Based on primary / initial causes, assign events to clusters in order to set priorities for mitigation measures;
3. Break-down the event chains by SPS Level 2 codes;
4. Determine the occurrence rates of each SPS Level 2 code per 100.000 FH for both piston- and turbine-engine SEH;

5. Determine the actual and estimated (potential) severity of an event based on its primary cause for operations over hostile and non-hostile environment;
6. Based on combination of frequency, severity and respective distribution over clusters, select several SPS Level 2 code groups for piston- and turbine-engined SEH as input for mitigation strategies.

The original accident reports are analysed by an expert helicopter pilot in order to determine primary causes of accidents and serious incidents. For both piston- and turbine-engined SEH, the events are assigned to nine clusters presented in next table. Furthermore, each event is further broken down into SPS Level 2 codes in order to narrow down the factors, which contributed to the accident/incident.

Cluster	Definition	Examples
Design	Factors which are specific to the design and prescribed maintenance schedules and procedures of single-engine 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 iginition switch selection
Environment	Environmental factors[9], which contributed to an event	Carburettor icing, compressor blade failure due to ingestion of ice/snow
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 nigh

Table 56: Clusters of primary engine-related failures

In order to provide a holistic risk analysis of SEH occurrences, both quantitative and qualitative approaches are used. The occurrence rate per 100.000 FH of each SPS Level 2 category and the actual severity of the accident is determined quantitatively based on available data. Furthermore a distinction is made between occurrences in piston and turbine helicopters, since different engine types do not only presuppose different

9 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

problems, but also represent different leagues of aircraft within the single-engine helicopter fleet. For example, turbine helicopters (generally) offer a greater seating capability and are capable of operating in a wider range of atmospheric conditions.

The severity of the events is assessed by using the ADREP 2000 taxonomy coding for damage and injury levels as presented in Table 57. Furthermore, the ALG severity code is comprised of the combination of the assigned ADREP codes by adding up injury and damage codes, which results in a 'severity matrix' presented in Table 58.

Both assignment of events to one of the eight clusters and estimation of potential severity of an event based on its primary cause for operations over both hostile and non-hostile environment, are qualitative judgments provided by an expert helicopter pilot. The results of both approaches help establish a priority list for mitigation measures.

Standard		Severity level				
ICAO / ADREP	**Value**	1	2	3	98	99
	Damage	Destroyed	Substantial	Minor	None	Unknown
	Injury	Fatal	Serious	Minor	None	Unknown

Table 57: Severity codes

Material damage / Injury	Destroyed	Substantial	Minor	None
Fatal	Catastrophic	Catastrophic	Hazardous	Hazardous
Serious	Catastrophic	Hazardous	Hazardous	Minor
Minor	Hazardous	Hazardous	Minor	Minor
None	Hazardous	Minor	Minor	Minor

Table 58: Severity matrix

7.4.2.1 Limitations of employed risk analysis methodology

During processing of the data the following limitations were encountered:

- Severity of events. Although the total number of gathered events for this study would allow for proper statistical analysis, the number of confirmed engine related events is relatively low. This implies that there is a reasonable chance that the results may exceed a reasonable standard deviation.
- Occurrence rates. The database does not represent all events. Only reported events are processed. Events with minor or no damage/injury are not always reported or remain at operator level. It is expected that a significant number of these 'low impact' events can therefore not be assessed. It would require a change of reporting system and/or reporting culture, to have all required data available for future use. The absence of numerous 'low impact' events in the database, calls for use of 'frequency of reported events' instead of actual occurrence frequency.

As a consequence of the mentioned limitations, the study reverts to a more qualitative approach for both severity and frequency of occurrence. To be able to identify unrealistic results, an estimated severity category will be established (what was likely to happen) for each engine related event, for both a hostile and non-hostile environment. The actual severity of each occurrence is evaluated against the estimated severity based on expert helicopter pilot's experience.

7.4.3 Risk mitigation

Mitigation measures are established for the most critical events on the priority list of engine related risks in single-engine helicopter operations. The principles applied for mitigation measures are:

- Low cost solution
- Supporting as much as possible the complete range of operations

- Uncomplicated, easy implementation
- Expected effect (residual risk) of the mitigation measure must be significant compared to existing situation

Only mitigations with estimated significant reduction of risk will be presented in this report. Risk reduction can either be an expected reduction of severity and/or a reduction of frequency of events.

Furthermore, mitigation measures are applied to the relevant events and reassessed by expert judgment (qualitative) on the residual risk over hostile environment. Reduction of severity by one level will be considered significant. The effect of the mitigation on frequency of events can only be qualitatively assessed. The expected effect on frequency of events will be motivated for each mitigation measure. As it is not possible to quantify the effects on frequency in advance, a reasonable likelihood of a mitigation measure to lower the frequency of an event is considered sufficient. Finally, the mitigation measures and their respective residual risks will be presented using a bowtie diagram.

8 Results

This section summarizes the results and analysis discussion of each phase of the project: data gathering, data analysis, assessment of operation conditions and safety risk assessment.

Furthermore, 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.

8.1 Data Gathering

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.

Fleet Database		Occurrences Database		Usage Database	
Single-Engined EASA Helicopter Fleet	✓	ADREP	✓	Civil Aviation Authorities	✓
EUROCOPTER	✓	European Central Repository	✓	EUROCOPTER	✓
International Register of Civil Aviation	✘	EHSAT	✓	BELL	✓
JP Airline Fleets International	✓	EUROCOPTER Occurrence Data	✓	ROBINSON	✓
Helicopter Blue Book	✓	BELL	✓		
Rotor Roster Business Class Helicopters	✓	World Aircraft Accident Summary	✘		
Rotorspot	✓	Aviation Safety Net	✓		
Helihub	✓	Helihub	✓		
		Griffin	✘		
		Helis	✘		
• the current identity and status of all known helicopter operators in the Member States and the composition of their helicopter fleets • the scope of their operations and proportion of different types of operation in the overall business model of the operators • the types of helicopter operated and their average age		• the number and severity of those helicopter accidents occurring during the same period characterized by the date of the event, operator, type and age of helicopter and the number and type (piston or turboshaft) of engines, location, numbers of occupants (passengers and crew), number of serious injuries and/or fatalities and overall severity of accidents. This and the preceding item will form the basis of the single-engined helicopter accident analysis		• the total accumulated flight time for all operators and by helicopter type over the most recent ten-year period (01/01/2003 to 31/12/2012)	

✓ Used ✘ Not used

Figure 17: 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.

8.1.1 Occurrences database

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.

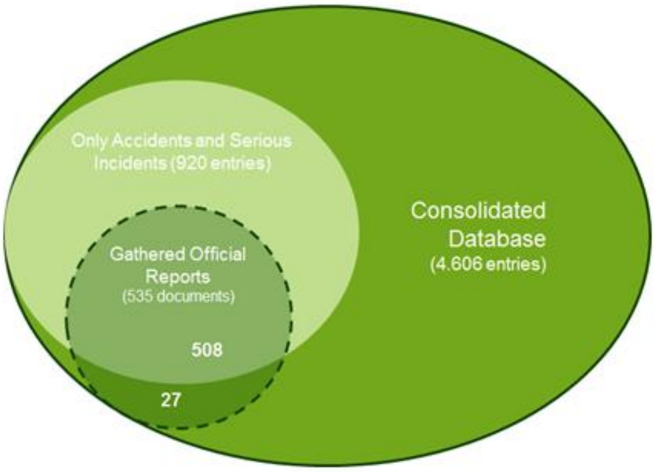


Figure 18: Occurrence database gaps

The information gaps are summarized in Table 81. It should be noted that the number of gaps decrease in the case of accidents and serious incidents comparing 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 without related official occurrence report (with related official occurrence report)
36%	0,8% (0,6%)	% of occurrences with undefined type of operation and without related official occurrence report (with related official occurrence report)
20%	0,6% (0,02%)	% of occurrences with unspecified phase of flight and without related official occurrence report (with related official occurrence report)

Table 59: Occurrences database gaps

8.1.2 Fleet database

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.

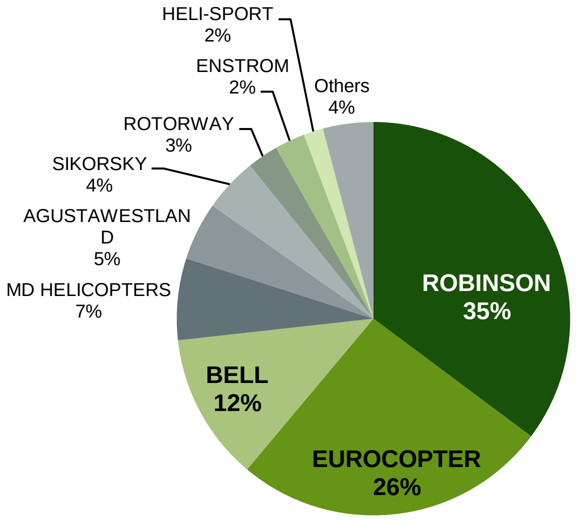


Figure 19: European helicopter fleet share by manufacturer

8.1.3 Usage database

To obtain usage data data, two sources were consulted: the Civil Aviation Authorities (CAA) and manufacturers (OEMs). However, 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)

8.2 Data Analysis

8.2.1 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.

8.2.1.1 Registered events histogram

8.2.1.1.1 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.

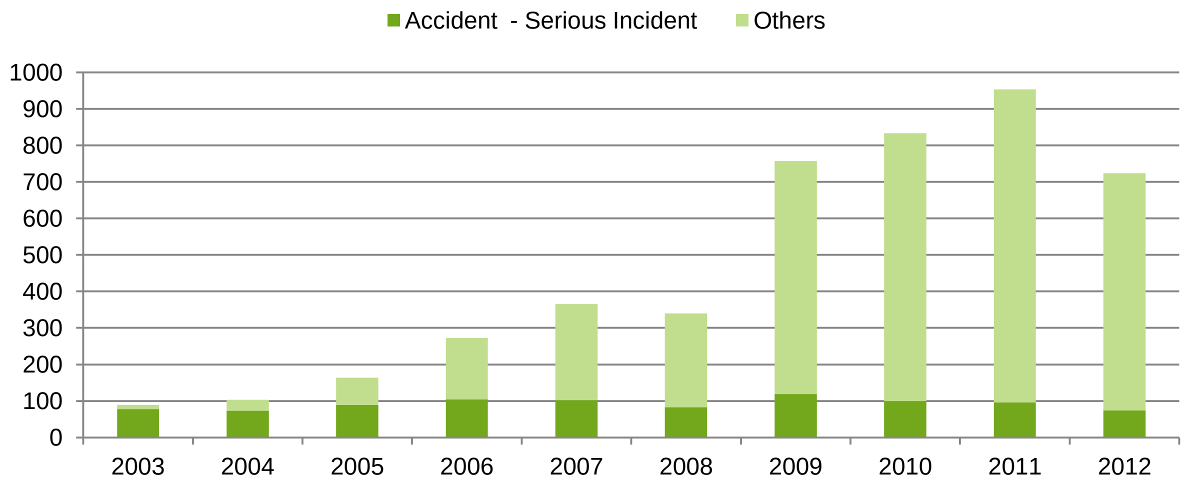


Figure 20: Registered events distribution per event type and year

8.2.1.1.2 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[10]. The annual evolution is shown in next figure.

[10] 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.

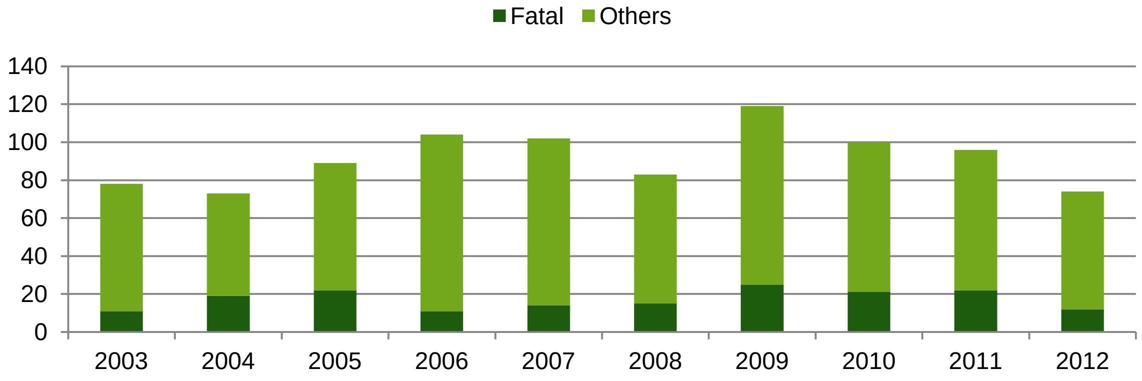


Figure 21: Accidents and serious incidents annual evolution per injury type

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.

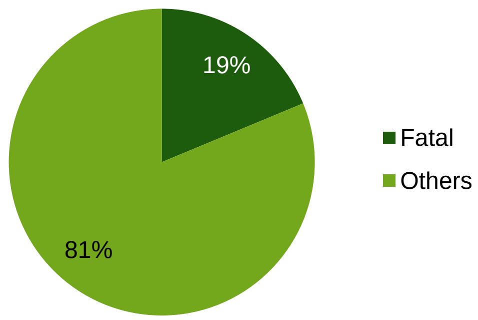


Figure 22: Accidents and serious incidents distribution per injury type

8.2.1.1.3 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[11] 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.

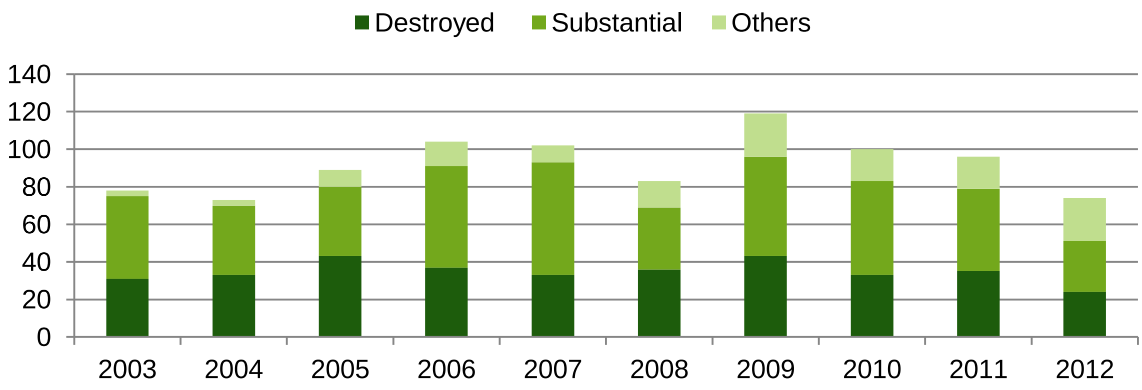


Figure 23: Accidents and serious incidents annual evolution per damage type

[11] 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.

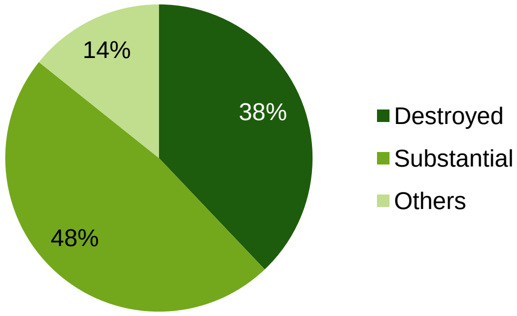


Figure 24: Accidents and serious incidents distribution per damage type

8.2.1.2 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.

8.2.1.2.1 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.

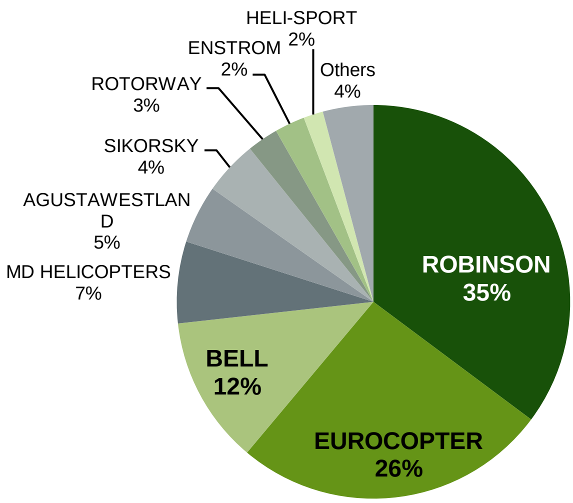


Figure 25: European helicopter fleet share by manufacturer

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).

8.2.1.2.2 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[12] 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 **9.990.000 FH (Flight Hours), 6.000.000 FH corresponding to turbine-engined helicopters and 3.990.000 FH to piston-engined helicopters**.

[12] 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.

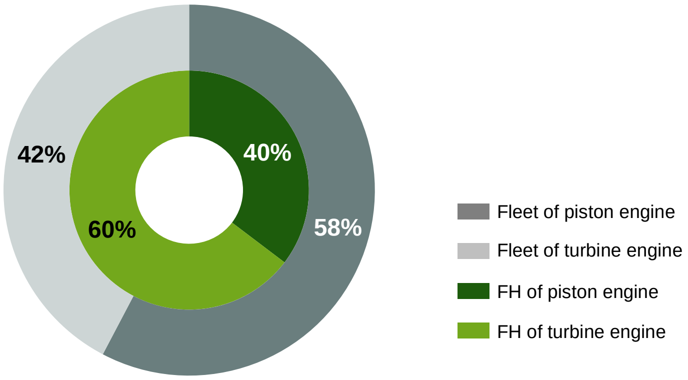


Figure 26: Single-engined helicopter usage share versus fleet by engine type

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.

8.2.1.2.3 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.

8.2.2 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

8.2.2.1 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.

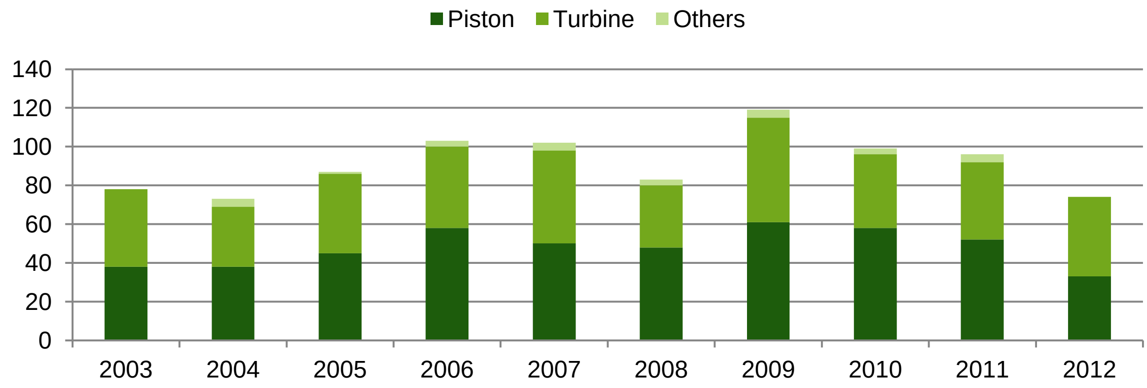


Figure 27: Accidents and serious incidents annual evolution per engine type

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.

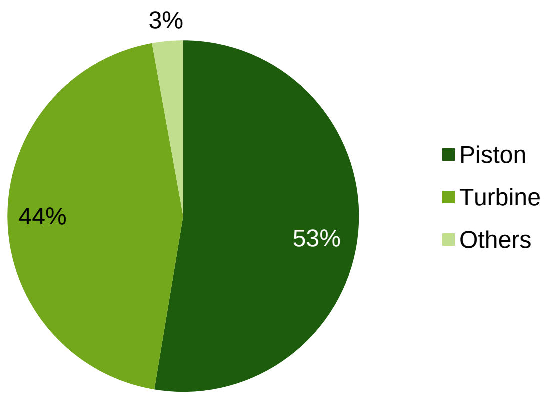


Figure 28: Accidents and serious incidents registered in the consolidated database distribution per engine type

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.

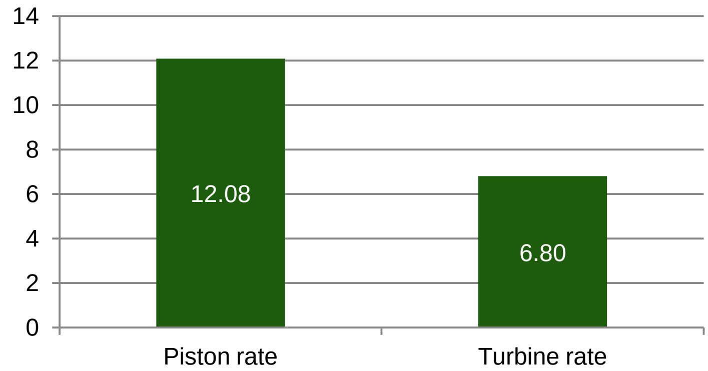


Figure 29: Accidents and serious incidents rate per 100.000 FH by engine type

8.2.2.1.1 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).

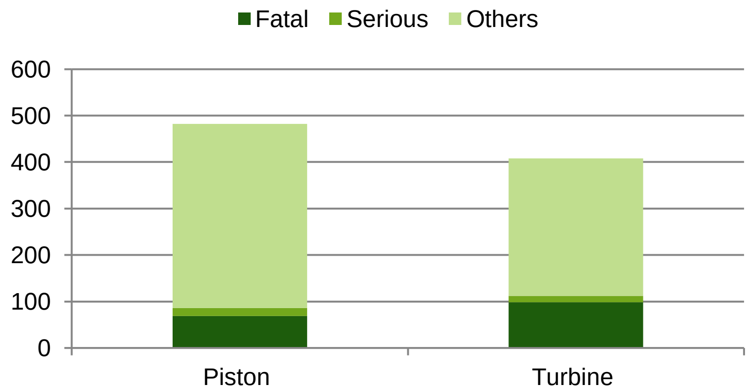


Figure 30: Accidents and serious incidents distribution per engine type and injury level. Absolute number of occurrences

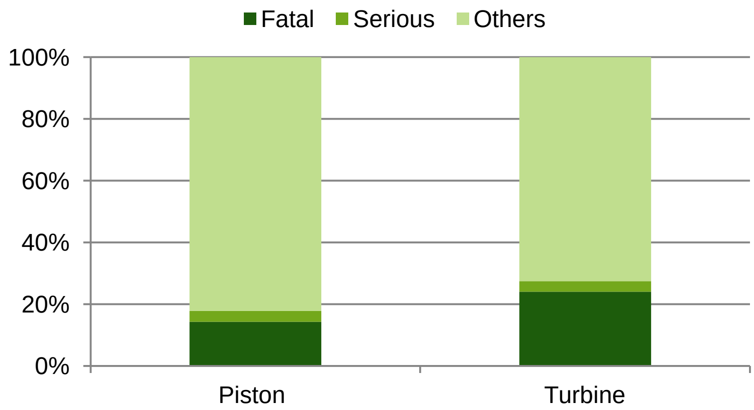


Figure 31: Accidents and serious incidents distribution per engine type and injury level. Relative number of occurrences

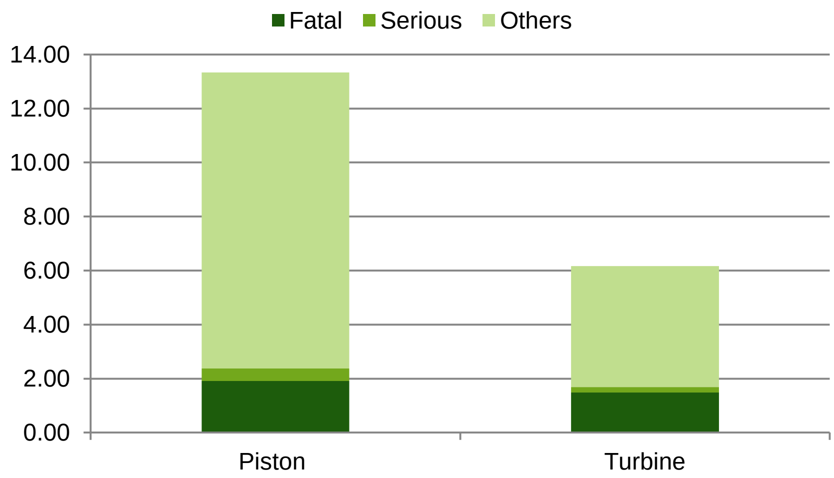


Figure 32: Accidents and serious incidents distribution per engine type and injury level. Occurrences per 100.000 FH

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%).

8.2.2.1.2 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.

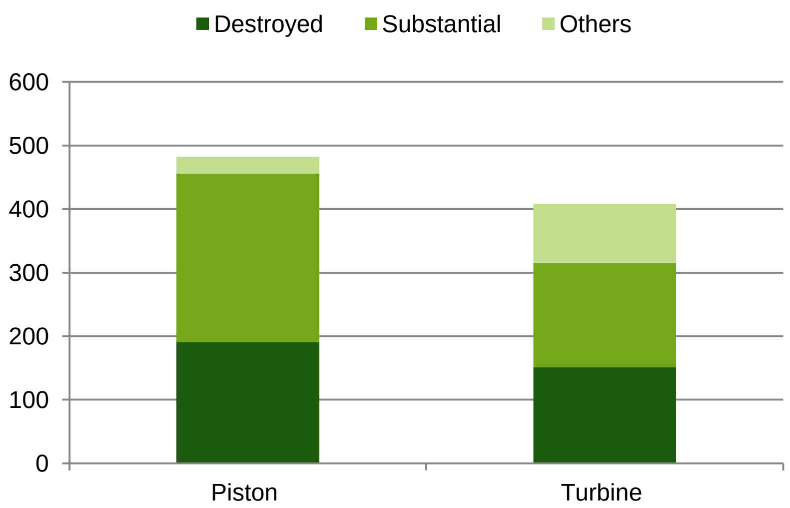


Figure 33: Accidents and serious incidents distribution per engine type and damage level. Absolute number of occurrences

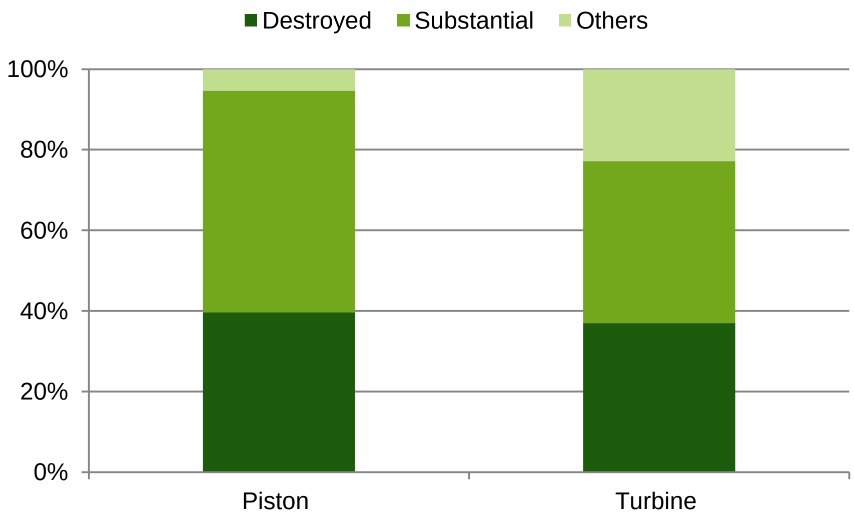


Figure 34: Accidents and serious incidents distribution per engine type and damage level. Relative number of occurrences

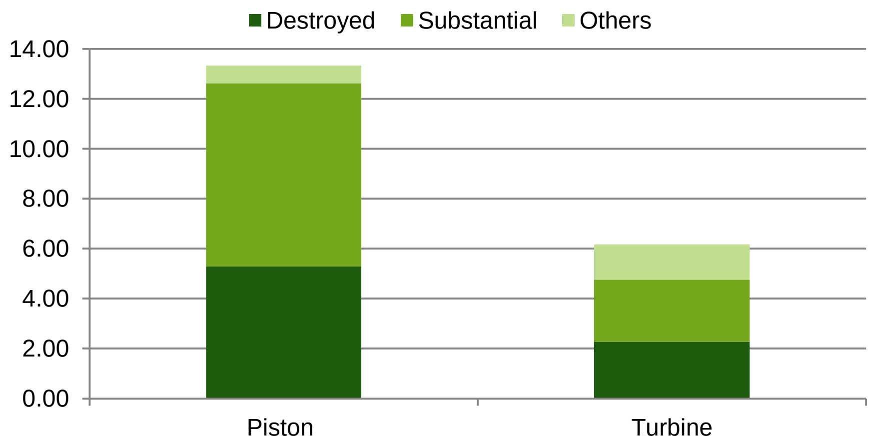


Figure 35: Accidents and serious incidents distribution per engine type and damage level. Occurrences per 100.000 FH

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).

8.2.2.2 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

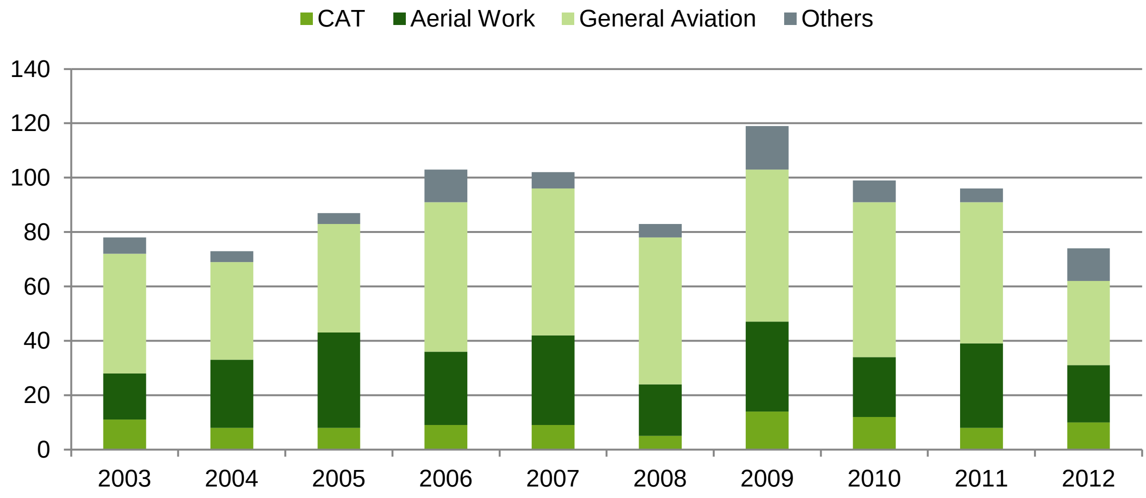


Figure 36: Accidents and serious incidents annual evolution per type of operation

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.

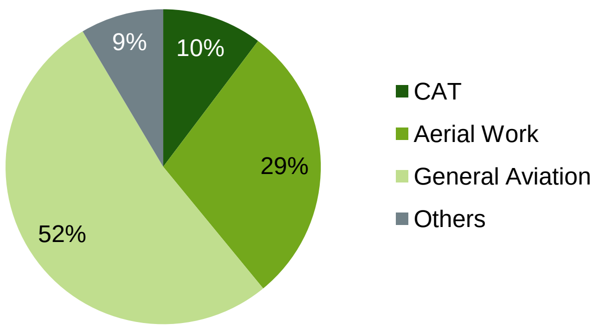


Figure 37: Accidents and serious incidents distribution per type of operation

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).

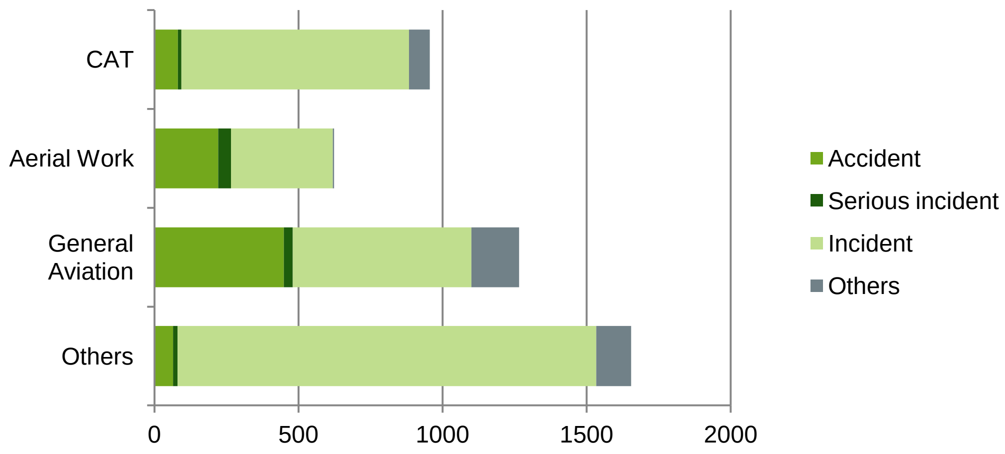


Figure 38: All events distribution per type of operation

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.

8.2.2.3 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.

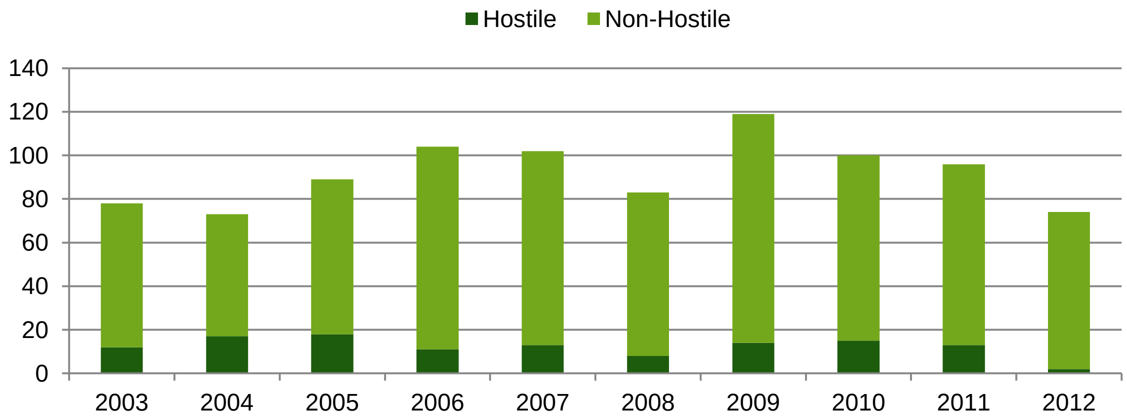


Figure 39: Accidents and serious incidents annual evolution per type of environment

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 60: Accidents and serious incidents distribution and fatality per type of environment

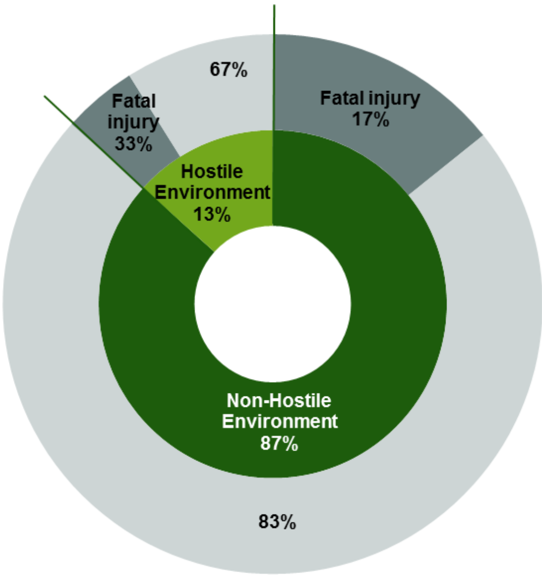


Figure 40: Accidents and serious incidents distribution and fatality share per type of environment

8.2.2.4 Analysis per flight conditions

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

8.2.2.4.1 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.

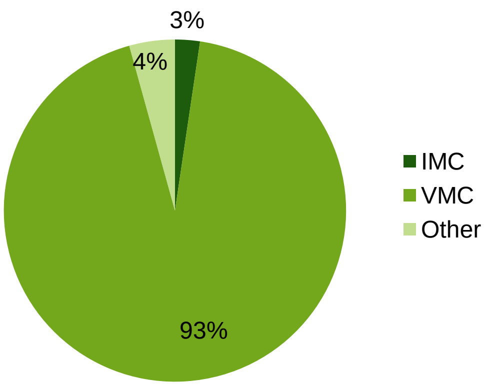


Figure 41: Accidents and serious incidents distribution per flight conditions

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.

8.2.2.4.2 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.

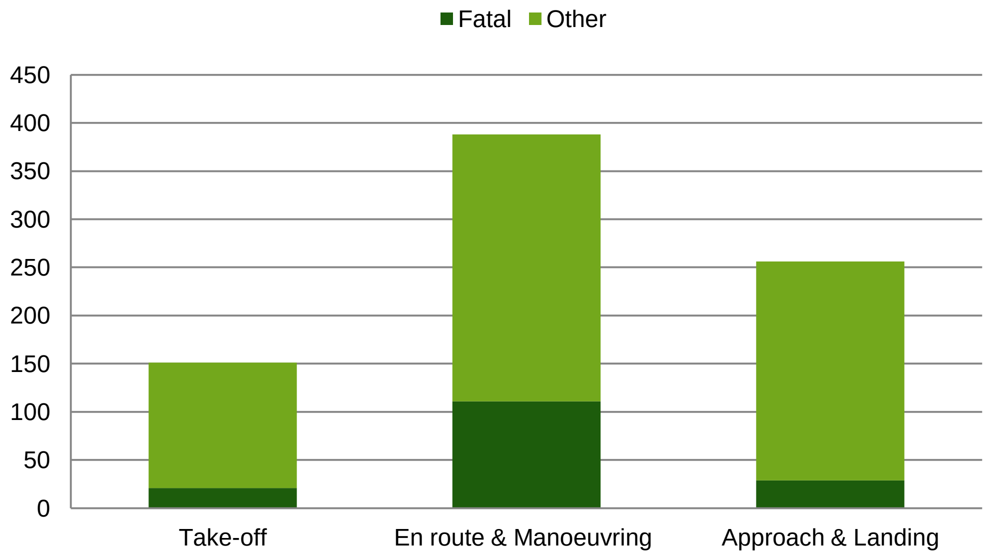


Figure 42: Accidents and serious incidents composition over the phase of flight

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.

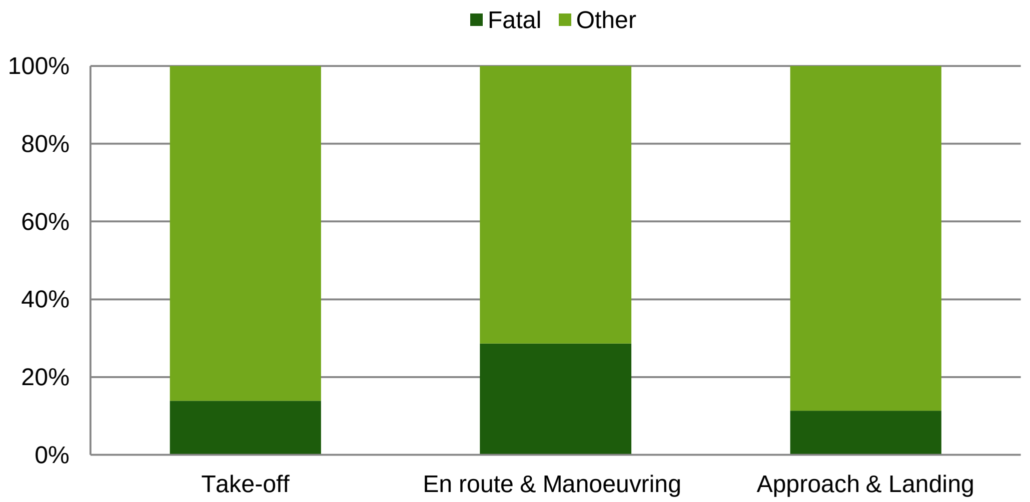


Figure 43: Fatal accidents and serious incidents rate per phase of flight

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.

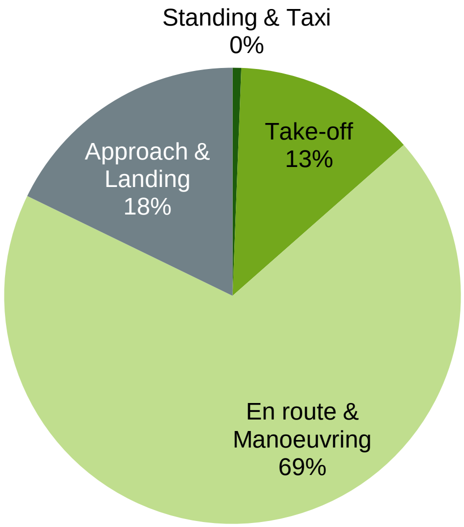


Figure 44: Fatal accidents and serious incidents distribution per phase of flight

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).

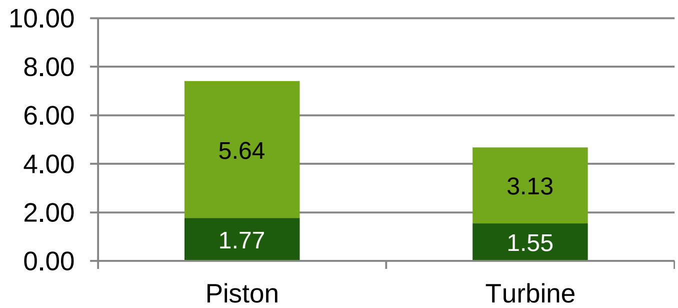


Figure 45: Accidents and serious incidents rate per 100.000 FH during En route & Manoeuvring by engine type

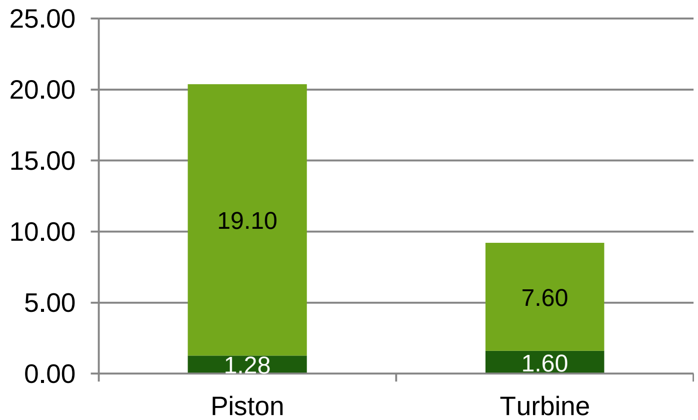


Figure 46: Accidents and serious incidents rate per 100.000 FH during Take-off and Approach & Landing by engine type

8.2.2.5 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.

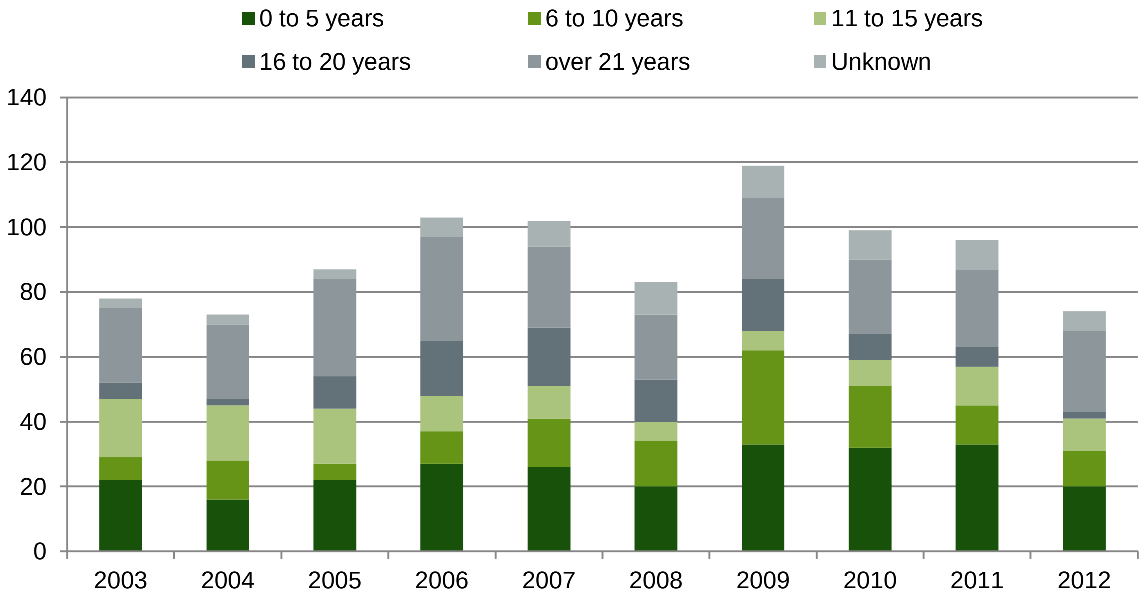


Figure 47: Accidents and serious incidents annual evolution per age group

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

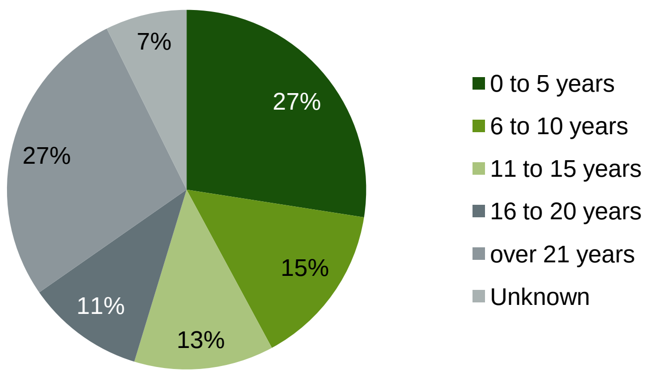


Figure 48: Accidents and serious incidents distribution per age group

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).

8.2.3 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.

8.2.3.1 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.

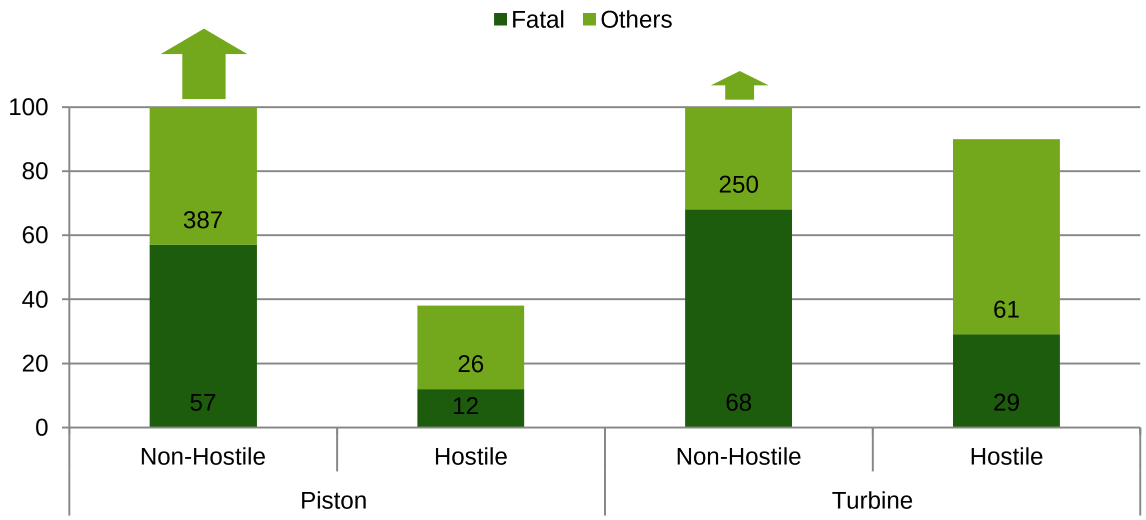


Figure 49: Accidents and serious incidents fatality share per type of engine and environment. Absolute number of occurrences

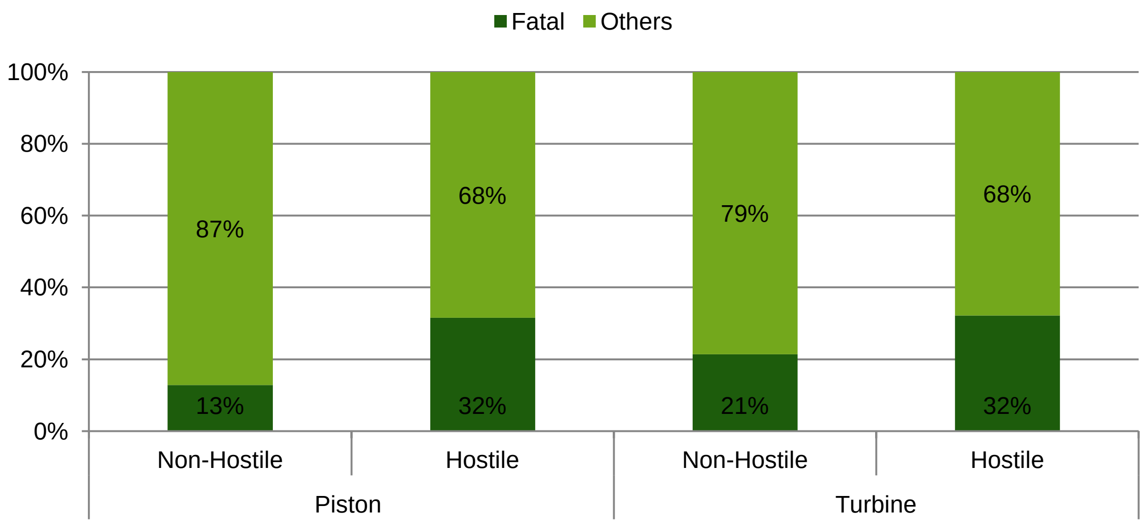


Figure 50: Accidents and serious incidents fatality share per type of engine and environment. Relative number of occurrences

8.2.3.2 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.

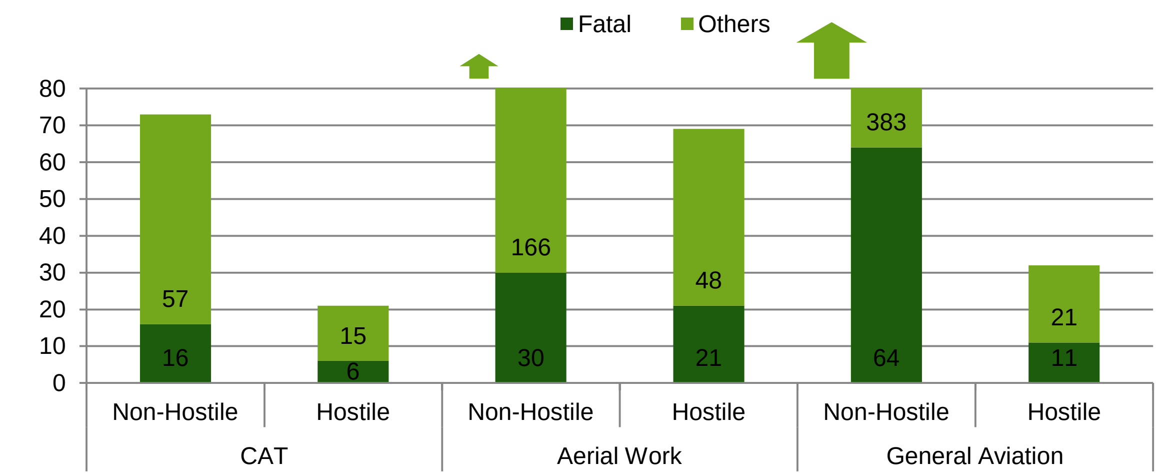


Figure 51: Accidents and serious incidents fatality share per type of operation and environment. Absolute number of occurrences

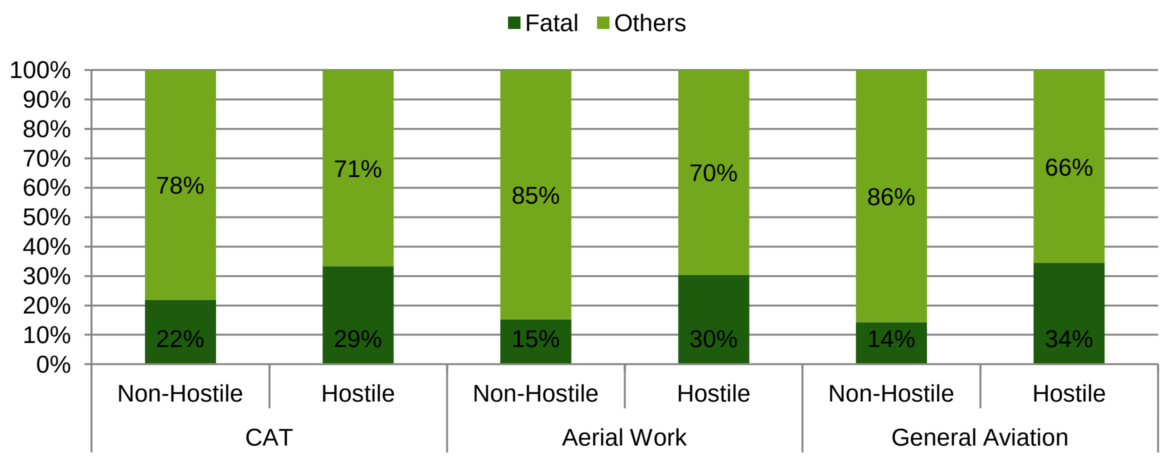


Figure 52: Accidents and serious incidents fatality share per type of operation and environment. Relative number of occurrences

8.2.3.3 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

8.2.3.3.1 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.

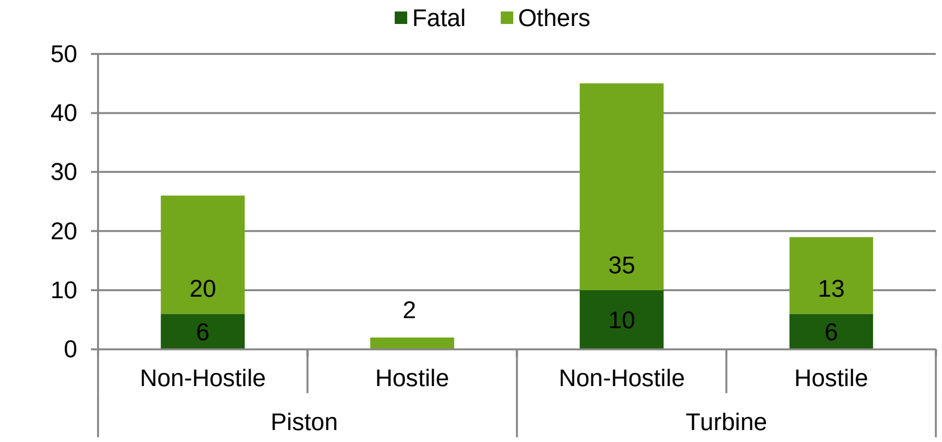


Figure 53: Accidents and serious incidents fatality share per type of engine and environment for CAT operations. Absolute number of occurrences

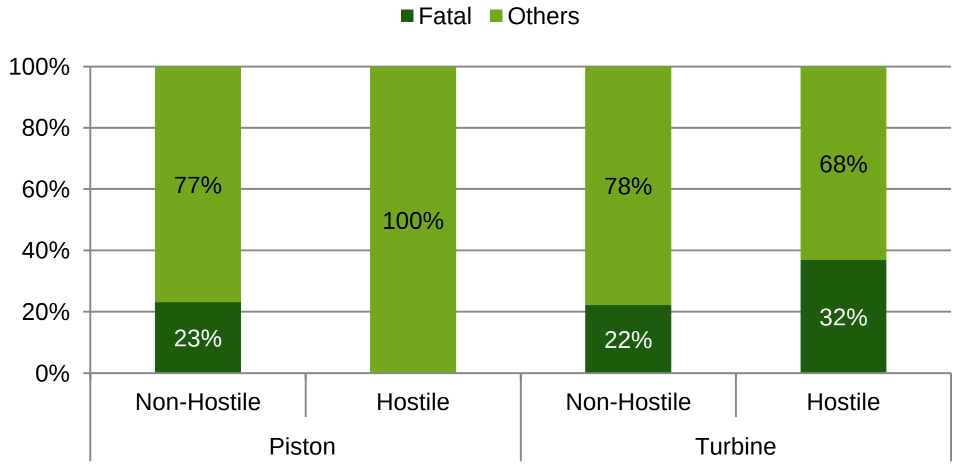


Figure 54: Accidents and serious incidents fatality share per type of engine and environment for CAT operations. Relative number of occurrences

<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[13].

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

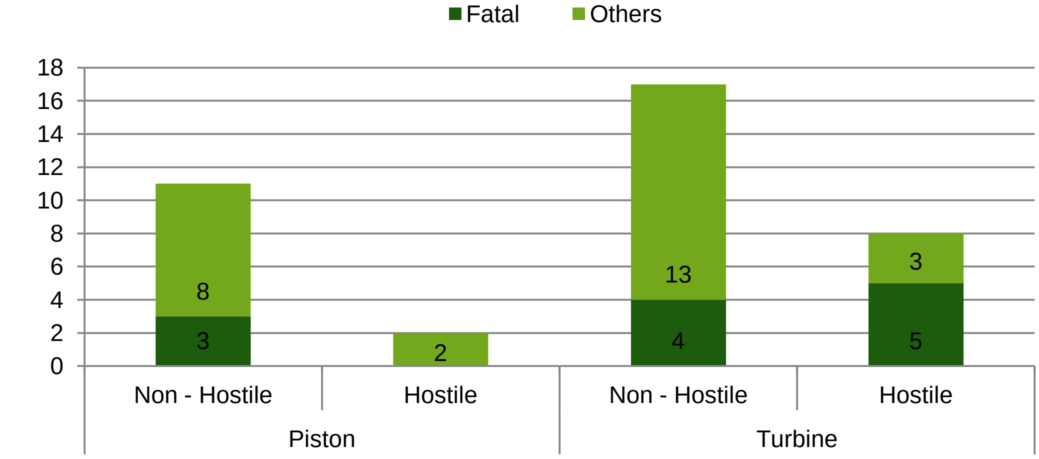


Figure 55: En route & manoeuvring accidents and serious incidents fatality share per type of engine and environment for CAT operations. Absolute number of occurrences

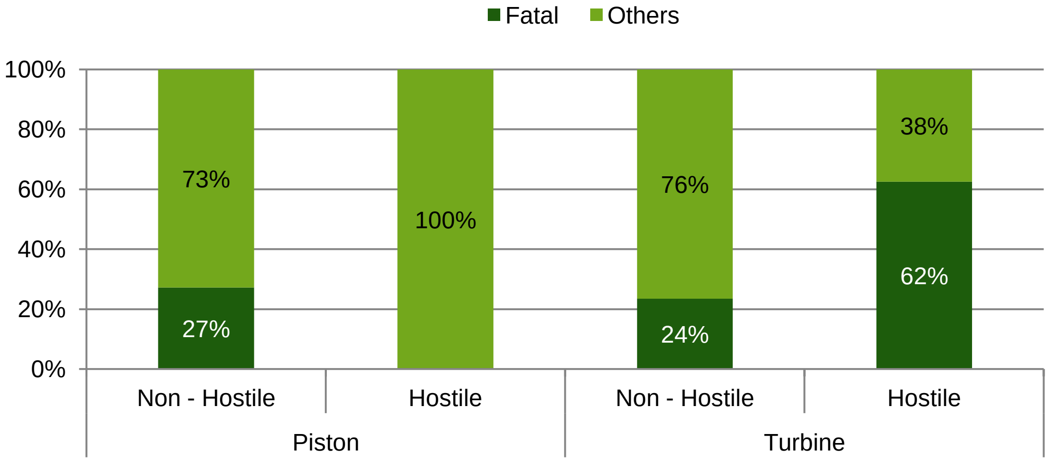


Figure 56: En route & manoeuvring accidents and serious incidents fatality share per type of engine and environment for CAT operations. Relative number of occurrences

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.

8.2.3.3.2 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 61: 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 62: Fatality comparison of en route & manoeuvring accidents and serious incidents per type of engine and environment

8.2.3.4 Engine related analysis by type of engine

Engine related[14] 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 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%).

[14] 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.

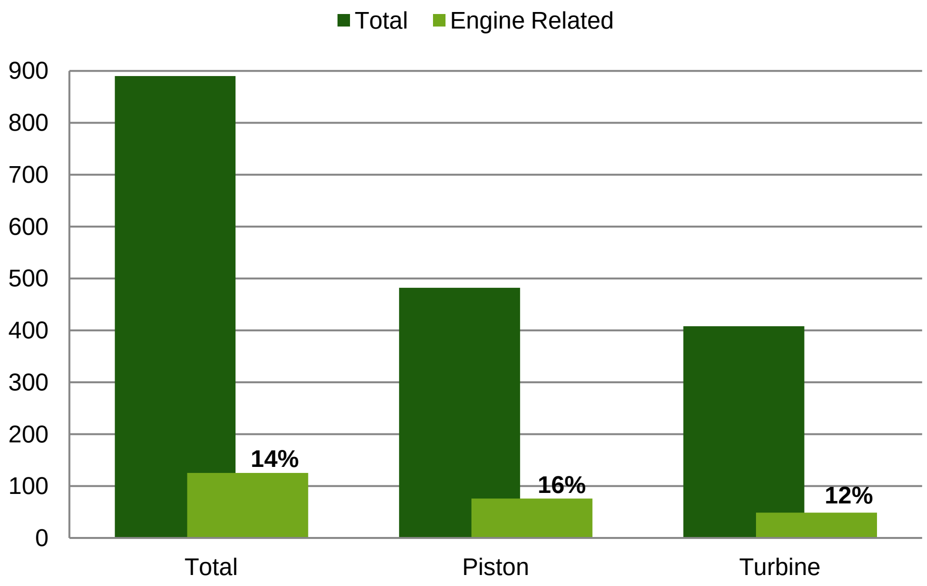


Figure 57: Engine related accidents and serious incidents per type of engine

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.

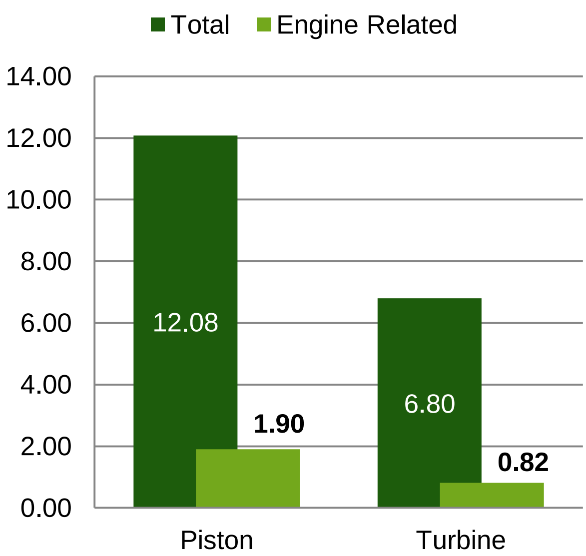


Figure 58: Engine related accidents and serious incidents rate per 100.000 FH by engine type

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).

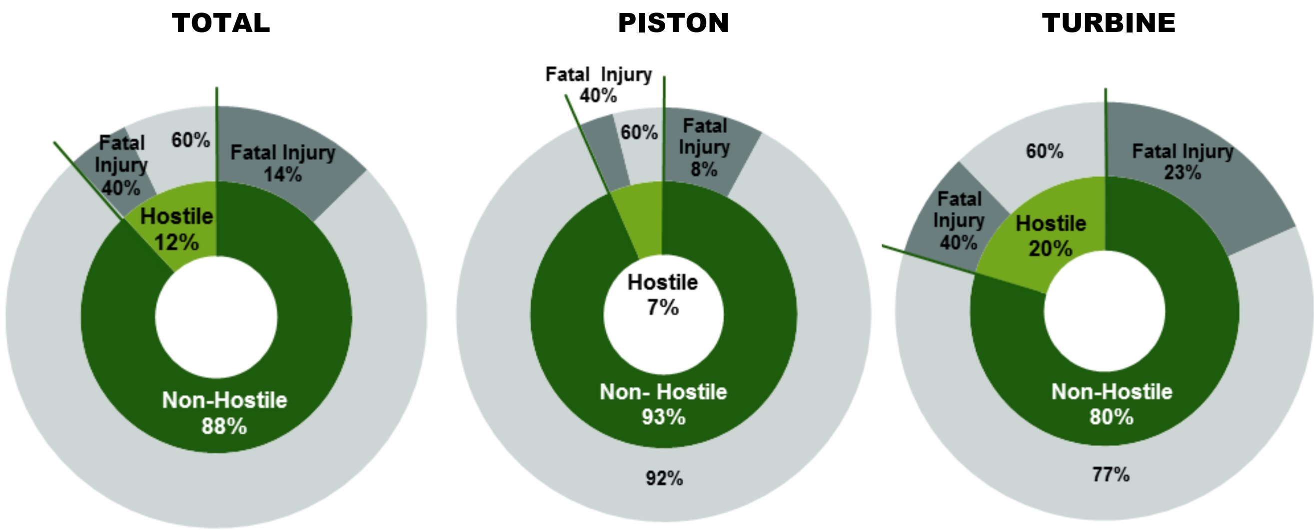


Figure 59: Engine related accidents and serious incidents distribution and fatality share per type of environment and engine

This figure above also shows the fatality rates for the different type of environment and engine. Comparing with the analysis performed in section 8.2.2.3 – 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, it should be noted that the number of engine related events evaluated are very small.

8.2.3.5 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

8.2.3.5.1 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.

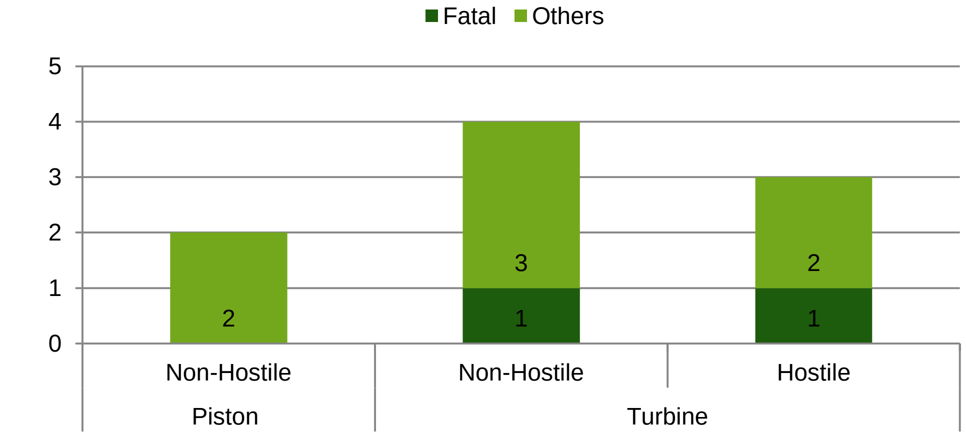


Figure 60: Engine related accidents and serious incidents fatality share per type of engine and environment for CAT operations. Absolute number of occurrences

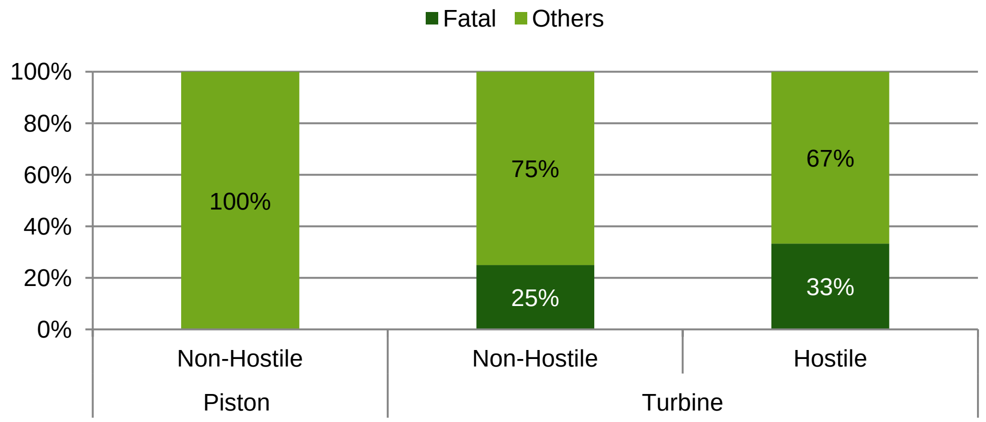


Figure 61: Engine related accidents and serious incidents fatality share per type of engine and environment for CAT operations. Relative number of occurrences

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

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.

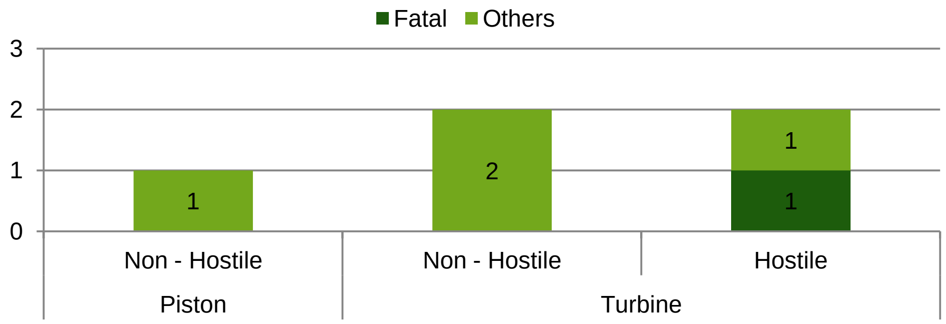


Figure 62: En route & manoeuvring engine related accidents and serious incidents fatality share per type of engine and environment for CAT operations. Absolute number of occurrences

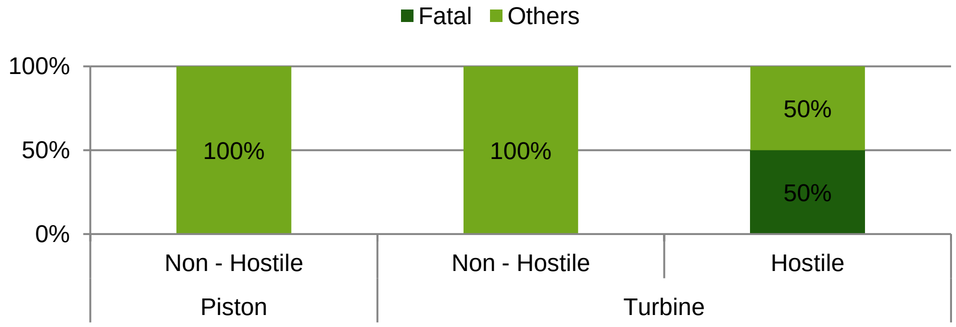


Figure 63: En route & manoeuvring engine related accidents and serious incidents fatality share per type of engine and environment for CAT operations. Relative number of occurrences

8.2.3.5.2 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 63: 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 64: Fatality comparison of en route & manoeuvring engine related accidents and serious incidents per type of engine and environment

8.2.4 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.

8.2.4.1 General factor analysis

8.2.4.1.1 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.

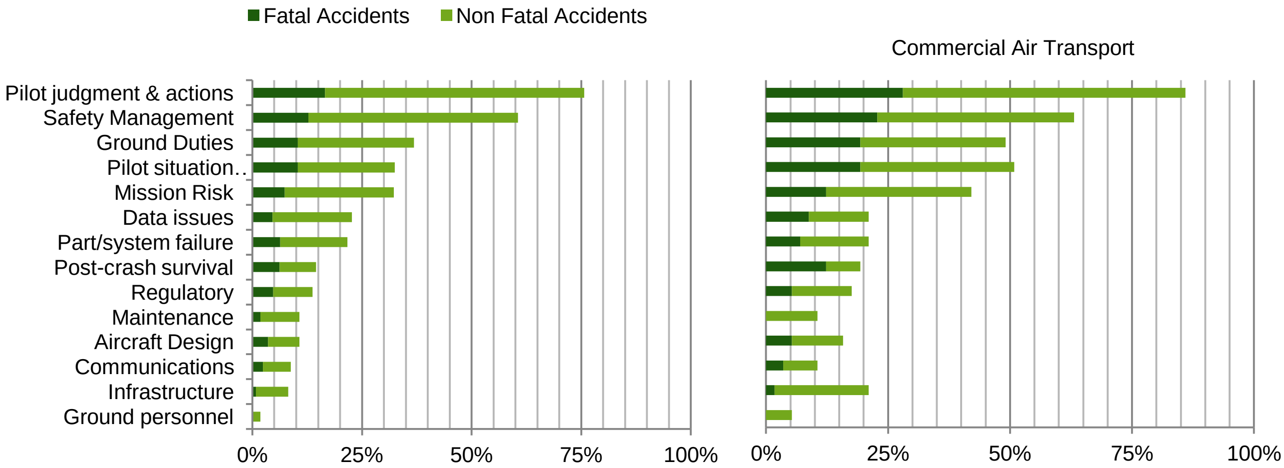


Figure 65: Percentage of TOTAL (left) and CAT (right) occurrences in which SPS category at level 1 was identified at least once

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".

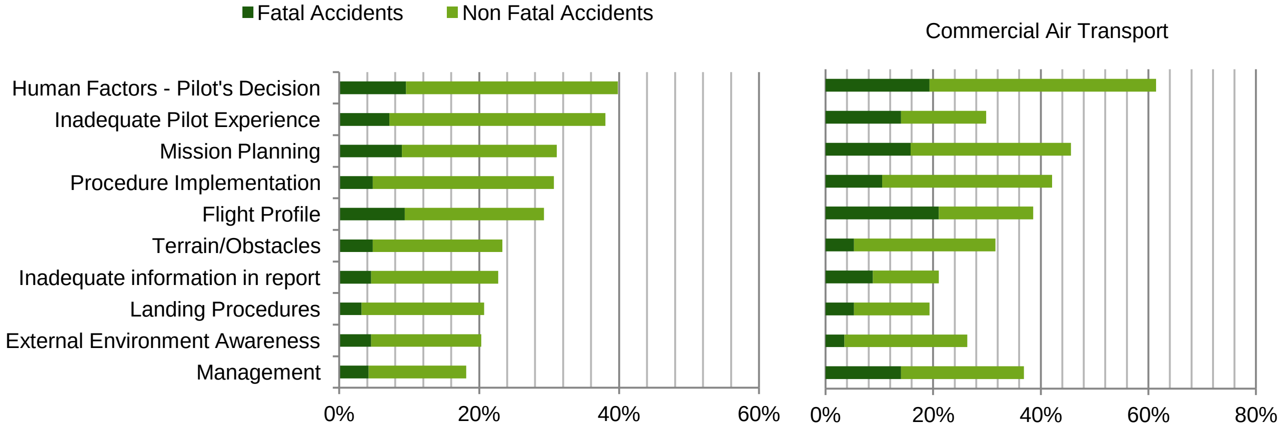


Figure 66: Percentage of TOTAL (left) and CAT (right) occurrences in which SPS category at level 2 was identified at least once

8.2.4.1.2 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%.

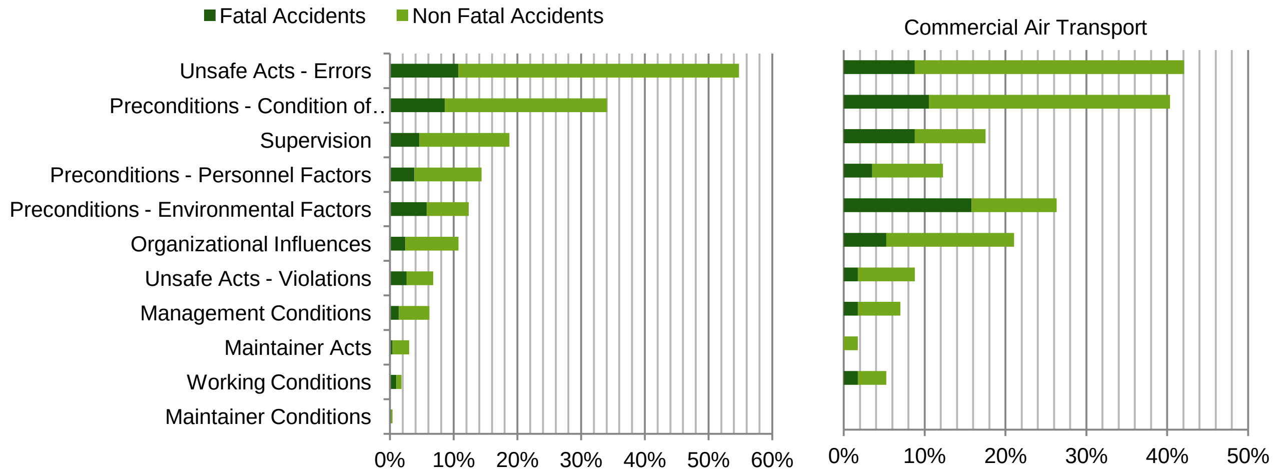


Figure 67: Percentage of TOTAL (left) and CAT (right) occurrences in which HFACS category at level 1 was identified at least once

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.

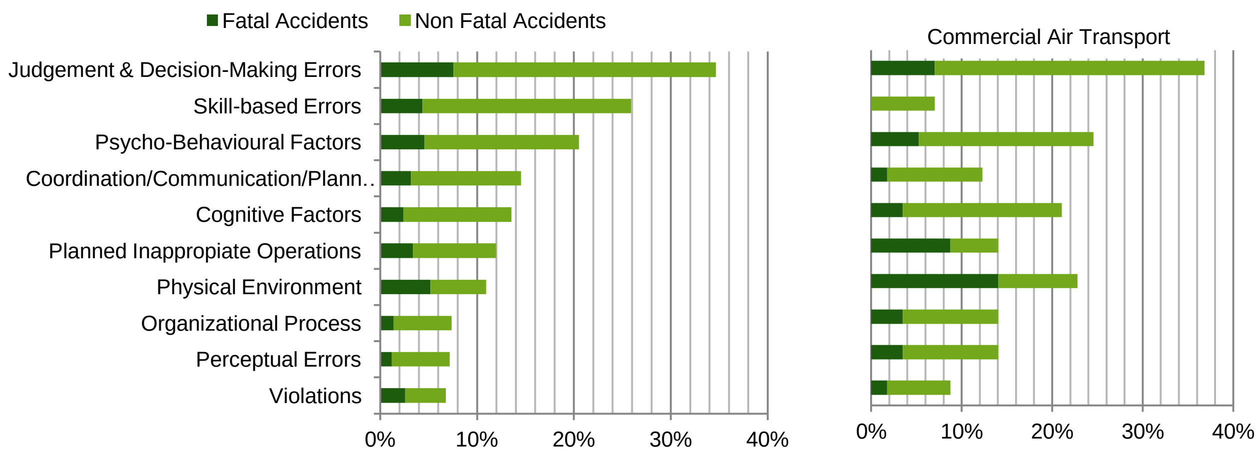


Figure 68: Percentage of TOTAL (left) and CAT (right) occurrences in which HFACS category at level 2 was identified at least once

8.2.4.2 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.

8.2.4.2.1 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 64. Main SPS & HFACS level 2 codes in Commercial Air Transport

8.2.4.2.2 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 65. Main SPS & HFACS level 2 codes in Aerial Work

8.2.4.2.3 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 66. Main SPS & HFACS level 2 codes in General Aviation

8.3 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.

8.3.1 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.

8.3.1.1 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 67: 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.

8.3.1.2 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[15];
- 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	
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[16] 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).’

[15] 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.

[16] 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
Germany	No	5, with national variants	
Greece	Yes	5, not officially transposed	
Hungary	No	1	
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 68: Information on implementation on JAR-OPS 3 and national variants specific to 3.005(e) per Member State

8.3.1.3 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[17] 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).**'
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'	

[17] 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?
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 69: Information on whether states issue approvals per 3.005(e) per applicable Member State

8.3.1.4 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[18]. These machines are equipped with the newest technology to monitor the airframe, engine, gearbox etc. parameters.

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

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

8.3.1.5 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'.

8.3.1.6 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:

Finland

'Risk assessment is not implemented'.

France

'JAR OPS 3 requirements are fully transposed'.

8.3.1.7 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.[19]

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'.

8.3.1.8 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:

'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

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

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.'

8.3.1.9 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.

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

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

8.3.2.1 JAR OPS implementation

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

8.3.2.2 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 piston engined helicopters in addition to turbine-engined.

8.3.2.3 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,

8.3.2.4 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.

8.3.2.5 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.

8.3.2.6 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.

8.3.2.7 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).

8.3.2.8 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.[20]

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.

8.4 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.

8.4.1 Engine related technology

8.4.1.1 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

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

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[21] power range, while the Tech 800 is geared to the 1.000 to 2.000 shp. This full range of demonstrators would 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.

8.4.1.2 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.

8.4.2 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.

8.4.2.1 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

[21] 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.

- 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.

8.4.2.2 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.

8.4.2.3 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.

8.5 Safety Risk Assessment

8.5.1 Hazard identification

The following analysis is intended to identify the proportion of most common generic causes of accidents and serious incidents of single-engine helicopters due to engine failure. For this purpose, it will be necessary to provide occurrence ratios per 100.000 flying hours, evaluating turbine and piston events separately. These ratios are necessary for further estimation of frequency of engine-related failures.

Engine	Flight Hours
Piston	3.990.000
Turbine	6.000.000
Total	**9.990.000**

Table 70: Estimated flight hours for the European fleet (2003-2012)

Occurrence ratios per 100.000 FH for all registered events (4.606), all accidents and serious incidents (920) and, finally, accidents and serious incidents related to engine failure (125) - (56) of them with report available - are collected in next figures. It also shows the ratios of engine-related accidents and serious incidents by engine type using the respective flight hours.

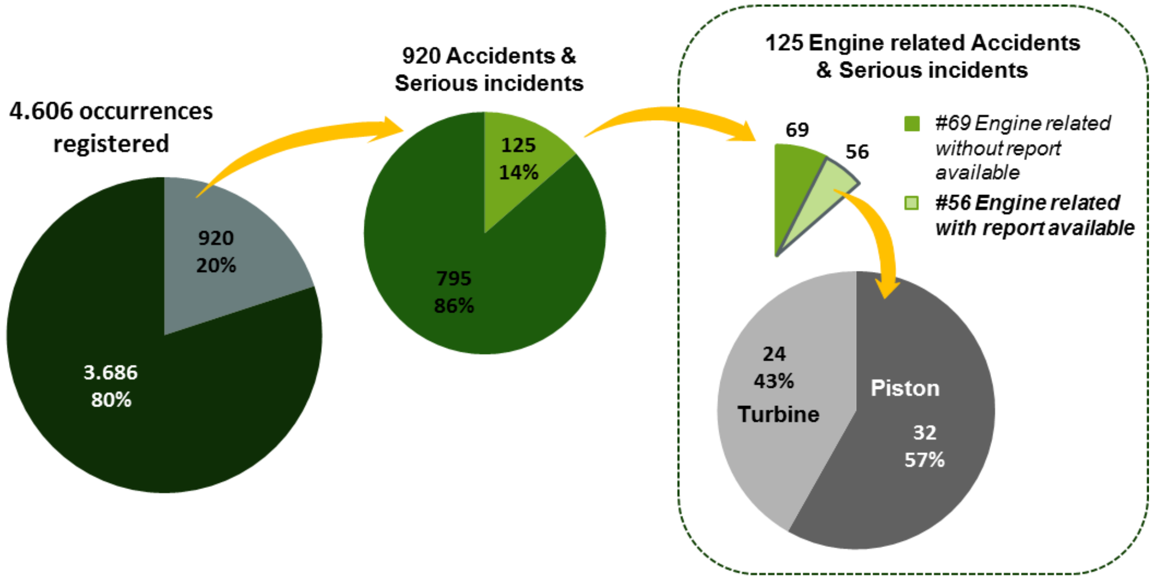


Figure 69: Occurrences categorization

Concept	Total occurrences		Total occurrences with reports available	
	Number of occurrences	**Ratios per 100.000 FH**	**Number of occurrences**	**Ratios per 100.000 FH**
Occurrences registered	4.606	**46,01**		
Accidents & Serious incidents	920	**9,21**		
Accidents & Serious incidents **engine related**	125	**1,25**	56	**0,56**
- *Piston*	*76*	***1,90***	*32*	***0,80***
- *Turbine*	*49*	***0,82***	*24*	***0,40***

Table 71: General ratios

Piston and turbine events will be separately evaluated and categorized by level 1 SPS codes. The reading of engine related accidents and serious incidents reports was required to develop the identification of SPS codes (see methodology in *EASE SEH 3 – Data Analysis and Member States Assessment*). So that, the safety risk assessment is based on the 56 engine related accidents and serious incidents with report available[22].

Eight different categories have been identified as possible causes of engine failure by the expert helicopter pilot: Ground Duties (100), Safety Management (200), Maintenance (300), Pilot judgment & actions (500), Pilot situation awareness (700), Part / system failure (800), Ground personnel (1200) and Aircraft Design (1400). Analysis of available data confirmed that all engine-related events were assigned to at least one of the indicated SPS Level 1 categories, with exception of Ground personnel (1200), which has not occurred at all. Next bar graphs represent the number of engine-related occurrences per 100.000 FH with an SPS category appearing at least once. These bar graphs show that piston- and turbine-engined helicopters have a different distribution of causes of an engine-related failure.

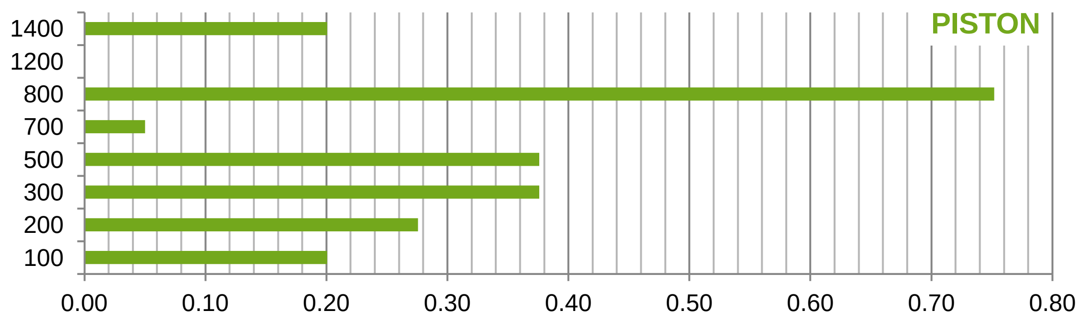


Figure 70: PISTON Engine related occurrences per 100.000 FH in which SPS level 1 category was identified at least once

[22] The absolute ratios are related to the total number of engine related event: 76 piston engine related occurrences vs 49 turbine engine related occurrences. So, final occurrence ratios per 100.000 FH to be used in the rule assessment will be: 1,9 piston engine related occurrences per 100.000 FH and 0,82 turbine engine related occurrences per 100.000 FH. It is the result after extrapolate safety risk assessment ratios:

$$0{,}80\ piston\ engine\ related\ (with\ report\ available)\ x\ 100.000FH \cdot \frac{76\ (total)}{32\ (with\ report\ available)} = 1{,}90\ piston\ engine\ relatedx\ 100.000FH$$

$$0{,}40\ turbine\ engine\ related\ (with\ report\ available)\ x\ 100.000FH \cdot \frac{49\ (total)}{24\ (with\ report\ available)} = 0{,}82\ piston\ engine\ relatedx\ 100.000FH$$

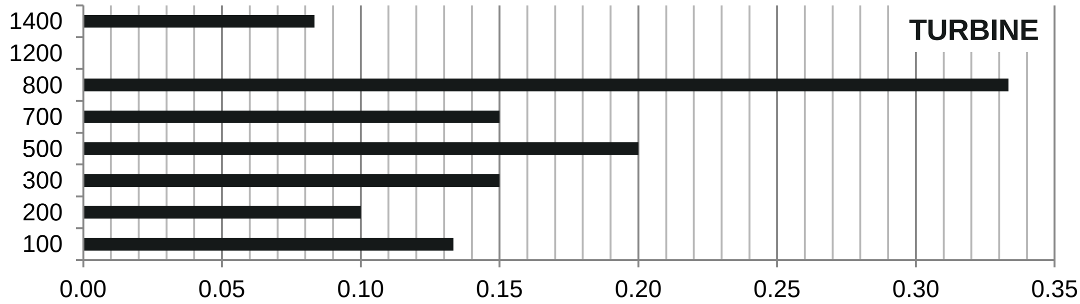


Figure 71: TURBINE Engine related occurrences per 100.000 FH in which SPS level 1 category was identified at least once

The absolute values of occurrence ratios are higher for the piston engine. Comparing the SPS Level 1 categories, the most common cause of failure, both for piston and turbine, is Part / system failure (800). The second most frequent category is Pilot judgment & actions (500), extremely close to Maintenance group (300) in case of piston events. For piston events, Safety Management (200) is also a frequent category. For turbine engine failures, Maintenance (300) and Pilot situation awareness (700) rank in third place. However, it should be noted that Pilot situation awareness (700) is the least frequent category amongst piston events.

The same graphs are presented below, but now with two colour bars depending on number of accidents and serious incidents in hostile and non-hostile environment[23]. The occurrence ratios show a greater number of accidents in hostile environment per 100.000 FH for turbine helicopters.

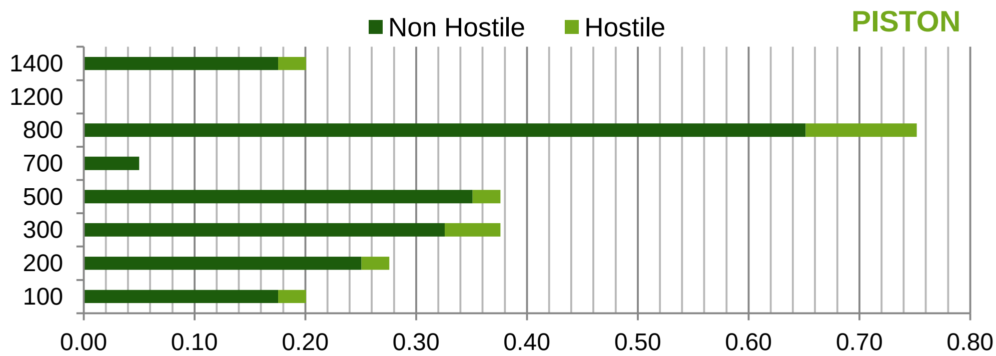


Figure 72: PISTON Engine related occurrences by type of environment per 100.000 FH in which SPS level 1 category was identified at least once

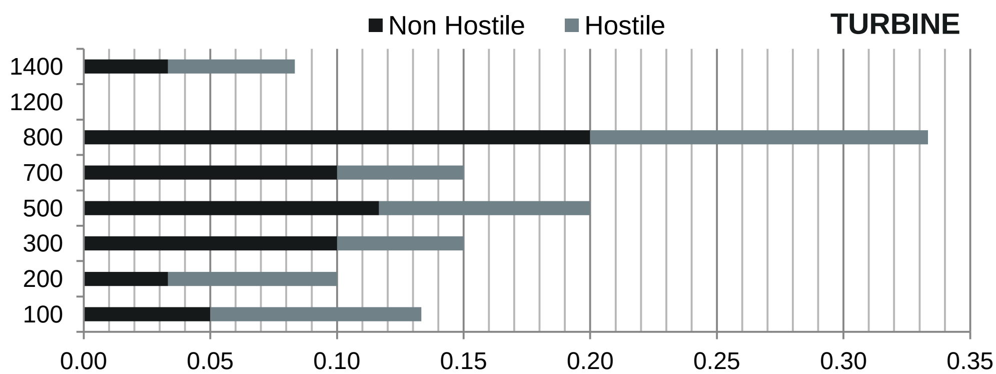


Figure 73: TURBINE Engine related occurrences by type of environment per 100.000 FH in which SPS level 1 category was identified at least once

[23] The ratio is obtained dividing by the flying hours for piston and turbine. The two colour bars only distinguish the number of occurrences according to the environment at the moment of the accident or serious incident registered

8.5.2 Risk analysis

In this chapter further analysis will be performed on most frequent SPS Level 1 occurrences for piston- and turbine-engined helicopters as identified in Chapter 4. Furthermore, relative frequency, severity of the event and its primary cause is evaluated both quantitatively (by analysing the actual event) and qualitatively (by estimation of severity provided by an expert helicopter pilot).

The actual severity of the assessed events is compared to an estimated severity for each individual event. By comparing the two, it is possible to avoid conclusions based on unrealistic figures as a result of low number statistics. The 'estimated severity' columns present the estimated severity bandwidth in which the majority of the events as described would be expected.

The tables in paragraphs 5.1 and 5.2 show significant discrepancies between the actual outcome of events in a non-hostile environment. Loss of engine power in non-hostile environment results in a significant number of event in fatalities and/or destroyed helicopters. From detailed analysis, it was found that, although the general area was non-hostile, the actual local position of the helicopter at the moment of the event, could be considered hostile. Examples are insufficient altitude to be able to manoeuvre to a proper emergency landing area, operating to or from confined areas, or sloping grounds and obstacles. Also a number of these events occurred in combination of altitude and airspeed, at which it is unlikely to accomplish a safe landing. This part of the flight envelope (published by the OEM in a Height-Velocity diagram) is therefore considered hostile for a single engine helicopter.

When taking these local conditions into account, the actual severity regarding the assessed engine related events could be considered realistic.

8.5.2.1 Piston single-engine helicopters

In this section the accidents and incidents of the piston-engined helicopters are analysed based on the most frequent SPS Level 1 categories.

8.5.2.1.1 SPS Level 1: 200 (Safety Management)

Next table provides a list of accidents and serious incidents within the SPS Level 1: 200 category (Safety Management). The events are assigned to respective 'hazard clusters'. Furthermore, for each event, the actual severity is compared to an expert estimation. The occurrence rates per 100.000 FH of the associated SPS Level 2 codes are presented in the figure below.

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
7	Engine shutdown due to ignition failure (magneto break)	Design	2030	Y	hazardous	catastrophic / hazardous	hazardous / minor
132	Spark plug issues caused loss of power	Maintenance	2030	N	catastrophic	catastrophic / hazardous	hazardous / minor
344	Ignition issues, pilot SA, suspected drive belt failure	Inadequate handling of engine failure	2010	N	catastrophic	minor / none	None
352	Suspected ignition issues, power loss, delayed pilot reaction	Inadequate handling of engine failure	2090	N	catastrophic	catastrophic / hazardous	hazardous / minor
610	The camshaft had fractured; engine failure	Design	2090	N	minor	catastrophic / hazardous	hazardous / minor
624	Sudden power loss at low altitude, possibly fuel supply problem	No Fault Found	2090	N	minor	hazardous / minor	minor
681	Engine failure during autorotation exercise handled inadequately	Inadequate handling of engine failure	2090	N	hazardous	catastrophic / hazardous	Minor
724	Engine failure due to damaged valves, probably result of previous overspeed, student pilot, IGE hover.	maintenance	2090	N	hazardous	Minor / none	Minor / none
764	ignition failure, maintenance issues	Maintenance	2010	N	minor	catastrophic / hazardous	hazardous / minor

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
797	carburator icing	Environment	2090	N	minor	catastrophic / hazardous	hazardous / minor
815	bearing failure drive belt pulley	Design	2090	N	minor	catastrophic / hazardous	hazardous / minor

Table 72: PISTON List of events within SPS Level 1 = 200 (Safety Management)

Analysis shows that within Safety Management category (SPS Level 1 200), the most severe events (catastrophic) are attributed to the 'Inadequate handling of engine failure' and 'maintenance' initial cause clusters.

Out of ten events in previous table, only one has occurred over hostile environment with relatively severe consequences. Events 132, 344 and 352 all had catastrophic consequences, which according to the expert pilot's judgment, is not necessarily to be expected based on initial cause of the accident. Even though, the occurrence rates are relatively low, the 2090 SPS Level 2 code associated with 'Inadequate Pilot Experience' occurs in multiple clusters and therefore dominates the Safety Management category. The 2090 SPS code is therefore seen as a priority for mitigation measures to follow in the next chapter.

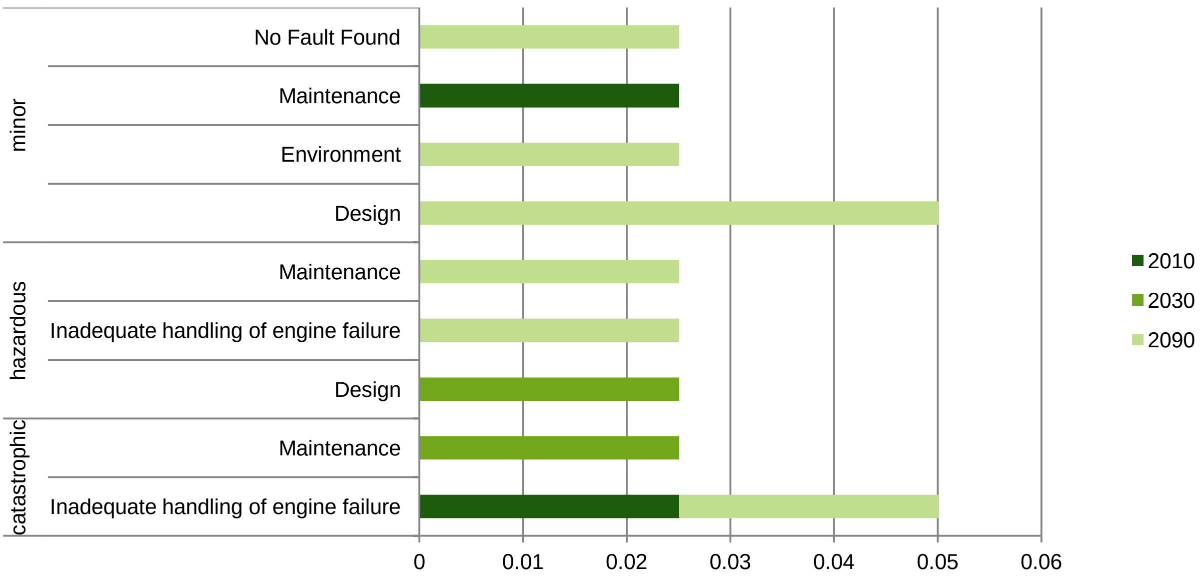


Figure 74: PISTON Relative occurrence rates per 100.000 FH of SPS Level 2 codes within the "Safety Management" category

8.5.2.1.2 SPS Level 1: 300 (Maintenance)

Next table provides a list of accidents and serious incidents within the SPS Level 1: 300 category (Maintenance). The majority of events in this group have occurred over non-hostile environment with minor consequences. The two catastrophic events both occurred over non-hostile environment and have been attributed to inadequate handling of engine failure by the pilot and helicopter's design characteristics. Furthermore it can be said, that events with minor actual severity went according to the 'best case' scenario estimated by the expert pilot.

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
7	Engine shutdown due to ignition failure (magneto break)	design	3010	Y	minor	catastrophic / hazardous	hazardous / minor
241	Failure of carburettor and electrical issues; Metal shards were found in the engine oil	maintenance	3020	Y	minor	catastrophic / hazardous	hazardous / minor
352	Suspected ignition issues, power loss, delayed pilot reaction	inadequate handling of engine failure	3020	N	catastrophic	catastrophic / hazardous	hazardous / minor
387	No direct engine malfunction, but exhaust pipe was detached from the turbocharger (due to fatigue	design	3020	N	minor	catastrophic / hazardous	hazardous / minor
391	Engine malfunction; possibly because the mixture control cable may have become disconnected from the mixture lever on the fuel injector servo.	design	3010	N	catastrophic	catastrophic / hazardous	hazardous / minor
529	Drive belt broke, wrong type of drive belt installed, not spotted during routine maintenance	maintenance	3010 3020	N	minor	catastrophic / hazardous	hazardous / minor
596	Intermittent loss of power during transition from hover to forward flight; the engine had exceeded its rated speed on the previous day; not reported to maintenance	flight preparation	3010	N	minor	catastrophic / minor	hazardous / minor
606	Cylinder clearances adjusted incorrectly; cylinder exhaust valve was blocked in closed position, loss of power	maintenance	3040	N	minor	catastrophic / hazardous	hazardous / minor
674	Driveshaft failure due to fatigue	design	3020	N	minor	catastrophic / hazardous	hazardous / minor
681	Engine failure during autorotation exercise. Applied wrong techniques during autorotation.	inadequate handling of engine failure	3040	N	minor	catastrophic / hazardous	minor
724	Engine failure due to damaged valves, probably result of previous overspeed, student pilot, IGE hover.	maintenance	3010	N	hazardous	Minor / none	Minor / none
764	ignition failure, maintenance issues	maintenance	3040 3010	N	minor	catastrophic / hazardous	hazardous / minor
781	engine component fail, possible maintenance flaw	maintenance	3040 3020 3010	N	minor	catastrophic / hazardous	hazardous / minor
810	Polluted fuel (polymer)	fuel pollution	3040 3020 3010	N	minor	catastrophic / hazardous	hazardous / minor
815	bearing failure drive belt pulley	design	3010	N	minor	catastrophic / hazardous	hazardous / minor

Table 73: PISTON List of events within SPS Level 1 = 300 (Maintenance)

Next figure depicts the breakdown of the SPS Level 2 codes associated with the accidents and incidents in the table above. The list of accidents is represented by three SPS Level 2 codes: 3010 (MX Procedures / Management), 3020 (Performance of MX Duties) and 3040 (Quality of Parts). The 3010 code occurs most frequently and is assigned to several clusters. Therefore failure modes associated with this code are a priority for mitigation measures.

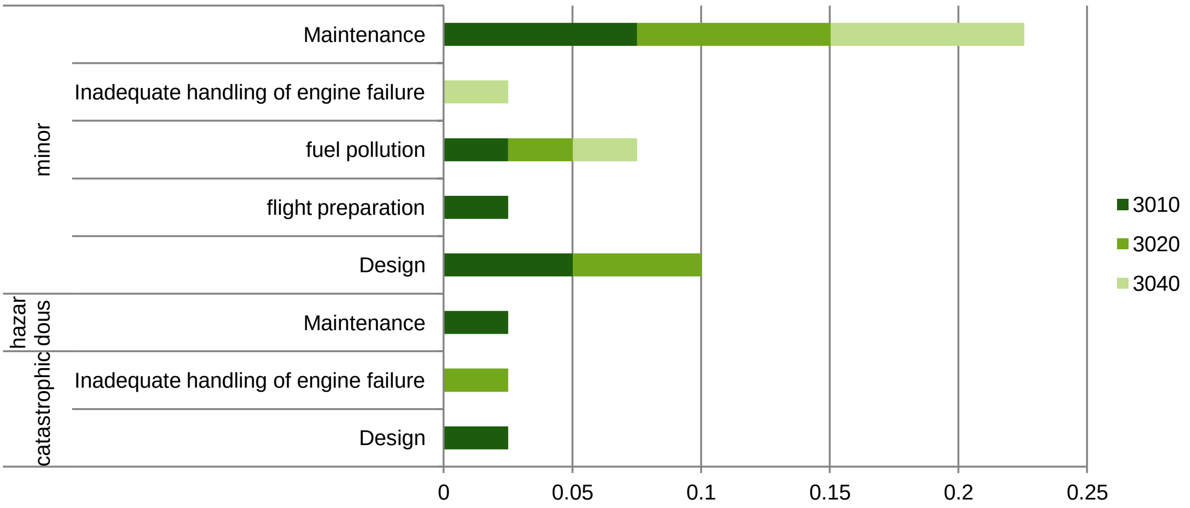


Figure 75: PISTON Relative occurrence rates per 100.000 FH of SPS Level 2 codes within the "Maintenance" category

8.5.2.1.3 SPS Level 1: 500 (Pilot judgment & actions)

Next table provides a list of accidents and serious incidents within the SPS Level 1: 500 category (Pilot Judgment & actions). This category includes several events with catastrophic consequence. Catastrophic consequences of these events have been attributed to a variety of SPS Level 2 codes: 5010 (Human Factors - Pilot's Decision), 5030 (Flight Profile), 5040 (Landing Procedures) and 5060 (Procedure Implementation). Having reviewed the primary / initial causes, the majority of events with catastrophic consequences have been placed into 'Inadequate handling of engine failure' and 'Maintenance' clusters.

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
132	Spark plug issues caused loss of power	maintenance	5010 5060 5030 5040	N	catastrophic	catastrophic / hazardous	hazardous / minor
273	Cylinder blocking the exhaust valve and the valve push rod broke	design	5040	N	minor	catastrophic / hazardous	hazardous / minor
344	Ignition issues, pilot SA, suspected drive belt failure	inadequate handling of engine failure	5040 5010	N	catastrophic	minor / none	none
345	probable engine stall during reduction of power, fuel warning light inoperable	No Fault Found	5040 5030	N	catastrophic	catastrophic / hazardous	hazardous / minor
352	suspected ignition issues, power loss, delayed pilot reaction	inadequate handling of engine failure	5020	N	catastrophic	catastrophic / hazardous	hazardous / minor
371	Possible unidentified transient defect in the fuel or ignition systems may have prevented the engine from producing adequate power. Possible flight technique issues (tail wind, rotor droop, vortex ring state)	inadequate handling of engine failure	5030	N	hazardous	hazardous / none	minor / none
374	Failure of one of the two drive belts transmitting power from the engine to the main transmission	design	5010	Y	hazardous	catastrophic / hazardous	hazardous / minor
387	no direct engine malfunction, but exhaust pipe was detached from the turbocharger (due to fatigue), producing smoke and excessive heat	design	5040	N	minor	catastrophic / hazardous	hazardous / minor

Event			SPS	Hostile env.	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2	(Y/N)		Hostile	Non-hostile
529	Drive belt broke, wrong type of drive belt installed, not spotted during routine maintenance	maintenance	5010	N	minor	catastrophic / hazardous	hazardous / minor
596	intermittent loss of power during transition from hover to forward flight; the engine had exceeded its rated speed on the previous day; not reported to maintenance	flight preparation	5010	N	minor	catastrophic / minor	hazardous / minor
610	The camshaft had fractured; engine failure	design	5040	N	minor	catastrophic / hazardous	hazardous / minor
681	Engine failure during autorotation exercise. Applied wrong techniques during autorotation.	inadequate handling of engine failure	5060 5040 5010	N	minor	catastrophic / hazardous	minor
797	Carburettor icing	environment	5060 5050	N	minor	catastrophic / hazardous	hazardous / minor
717	Most likely belt tension problem, gradual power loss, delayed pilot response.	maintenance	5060	N	catastrophic	catastrophic / hazardous	hazardous / minor
724	Engine failure due to damaged valves, probably result of previous overspeed, student pilot, IGE hover.	maintenance	5010 5060	N	minor	minor / none	minor / none

Table 74: PISTON List of events within SPS Level 1 = 500 (Pilot Judgment & actions)

Next figure depicts the distribution of events over clusters, their severity and relative occurrence rates. It is clear that the SPS Level 1: 500 category is not dominated by any of the Level 2 codes, therefore mitigation measures will be drawn up for this category as a whole.

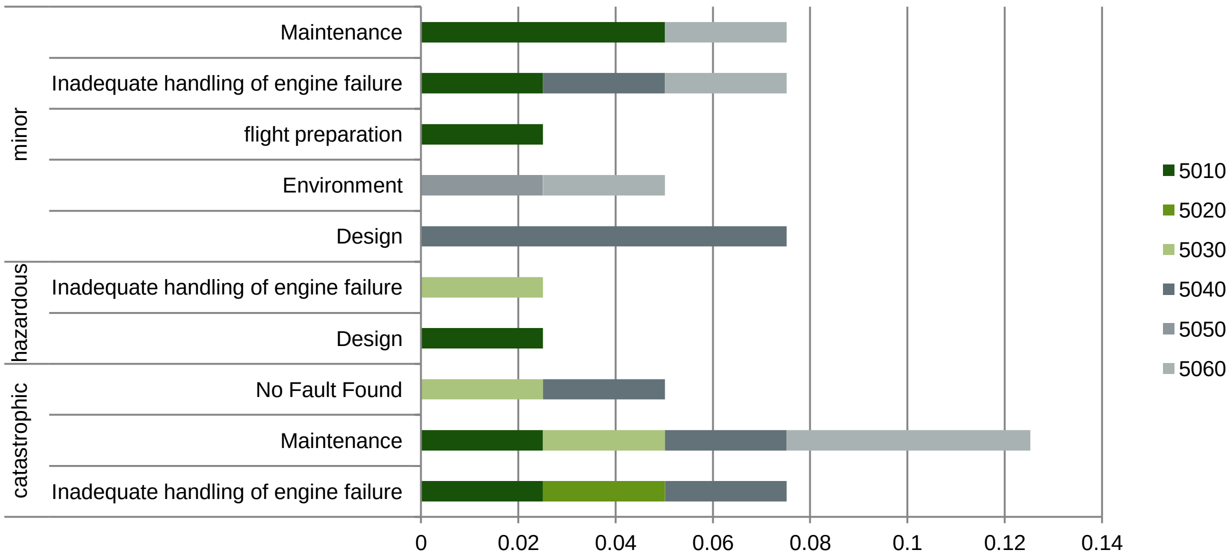


Figure 76: PISTON Relative occurrence rates per 100.000 FH of SPS Level 2 codes within the “Pilot judgment & actions” category

8.5.2.1.4 SPS Level 1: 800 (Part / system failure)

Next table provides a list of accidents and serious incidents within the SPS Level 1: 800 category (Part / system failure). Since only engine-related causes of events are reviewed, this list is quite extensive. The events in this category range from none to catastrophic severity and can attributed to a variety of clusters.

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
7	engine shutdown due to ignition failure (magneto break)	design	8020	Y	minor	catastrophic / hazardous	hazardous / minor
95	insufficient oil for cooling, engine failure	flight preparation	8020	N	minor	catastrophic / hazardous	hazardous / minor
132	spark plug issues caused loss of power	maintenance	8020	N	catastrophic	catastrophic / hazardous	hazardous / minor
202	Pilot reported loss of power, NFF	No Fault Found	8020	N	hazardous	catastrophic / hazardous	hazardous / minor
241	Carburettor was not working properly due to a sticking float, there was also electrical shorting due to a breakdown in the ignition wiring and in addition overheating inside the cylinders. Metal shards were found in the engine oil, and there were signs of abrasion	maintenance	8020	Y	minor	catastrophic / hazardous	hazardous / minor
273	Cylinder blocking the exhaust valve and the valve push rod broke.	design	8020	N	minor	catastrophic / hazardous	hazardous / minor
344	Possible ignition issues, pilot SA	inadequate handling of engine failure	8020	N	catastrophic	minor / none	none
345	probable engine stall during reduction of power, fuel warning light inoperable	No Fault Found	8020	N	catastrophic	catastrophic / hazardous	hazardous / minor
352	Suspected ignition issues, power loss, delayed pilot reaction	inadequate handling of engine failure	8020	N	catastrophic	catastrophic / hazardous	hazardous / minor
368	Significant engine vibration and loss of power; No more information available	No Fault Found	8020	N	minor	catastrophic / hazardous	hazardous / minor
371	Possible unidentified transient defect in the fuel or ignition systems may have prevented the engine from producing adequate power. Possible flight technique issues (tail wind, rotor droop, vortex ring state)	inadequate handling of engine failure	8020	N	hazardous	hazardous / none	minor / none
374	Failure of one of the two drive belts transmitting power from the engine to the main transmission.	design	8010	Y	hazardous	catastrophic / hazardous	hazardous / minor
387	no direct engine malfunction, but exhaust pipe was detached from the turbocharger (due to fatigue), producing smoke and excessive heat	design	8020	N	minor	hazardous / none	minor / none
391	engine malfunction; possibly because the mixture control cable may have become disconnected from the mixture lever on the fuel injector servo.	design	8020	N	catastrophic	catastrophic / hazardous	hazardous / minor
529	Drive belt broke, wrong type of drive belt installed, not spotted during routine maintenance	maintenance	8020	N	minor	catastrophic / hazardous	hazardous / minor
596	intermittent loss of power during transition from hover to forward flight; the engine had exceeded its rated speed on the previous day; not reported to maintenance	flight preparation	8020	N	minor	catastrophic / minor	hazardous / minor
606	cylinder clearances adjusted incorrectly; cylinder exhaust valve was blocked in the closed position, loss of power	maintenance	8020	N	minor	catastrophic / hazardous	hazardous / minor
610	The camshaft had fractured; engine failure	design	8020	N	minor	catastrophic / hazardous	hazardous / minor

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
624	sudden power loss at low altitude, possibly fuel supply problem.	No Fault Found	8011 8020	N	minor	hazardous / minor	minor
674	driveshaft failure due to fatigue	design	8010	N	minor	catastrophic / hazardous	hazardous / minor
681	Engine failure during autorotation exercise. Applied wrong techniques during autorotation.	inadequate handling of engine failure	8020	N	minor	catastrophic / hazardous	minor
703	accidental engine shutdown by switch error	pilot induced	8020	Y	catastrophic	catastrophic / hazardous	hazardous / minor
717	Most likely belt tension problem, gradual power loss, delayed pilot response.	maintenance	8020	N	catastrophic	catastrophic / hazardous	hazardous / minor
751	driveshaft failure due to vibration cracks, causes by possible misalignment of the driveshaft	maintenance	8010	N	minor	catastrophic / hazardous	hazardous / minor
752	fuel supply problem, engine failure during low G manoeuvre (push-over) at 1500 ft, not allowed according flight manual. Successful restart.	pilot induced	8020	N	none	catastrophic / hazardous	hazardous / minor
781	engine component fail, possible maintenance flaw	maintenance	8020	N	minor	catastrophic / hazardous	hazardous / minor
797	carburettor icing	environment	8020	N	minor	catastrophic / hazardous	hazardous / minor
801	Fadec failure - power loss, maintenance status unknown	design	8010 8011	N	minor	catastrophic / hazardous	hazardous / minor
810	polluted fuel (polymer)	fuel pollution	8020	N	minor	catastrophic / minor	hazardous / minor
815	bearing failure drive belt pulley	design	8020	N	minor	catastrophic / hazardous	hazardous / minor

Table 75: PISTON List of events within SPS Level 1 = 800 (Part / system failure)

Next figure depicts the distribution of events over clusters, their severity and relative occurrence rates. The SPS Level 2: 8020 code (Part / system failure – Power plant) dominates this category as expected. Since this code occurs in all clusters and is attributed to events with a wide severity spread, it will be reviewed separately in order to draw up possible measures to mitigate the risk of identified hazards.

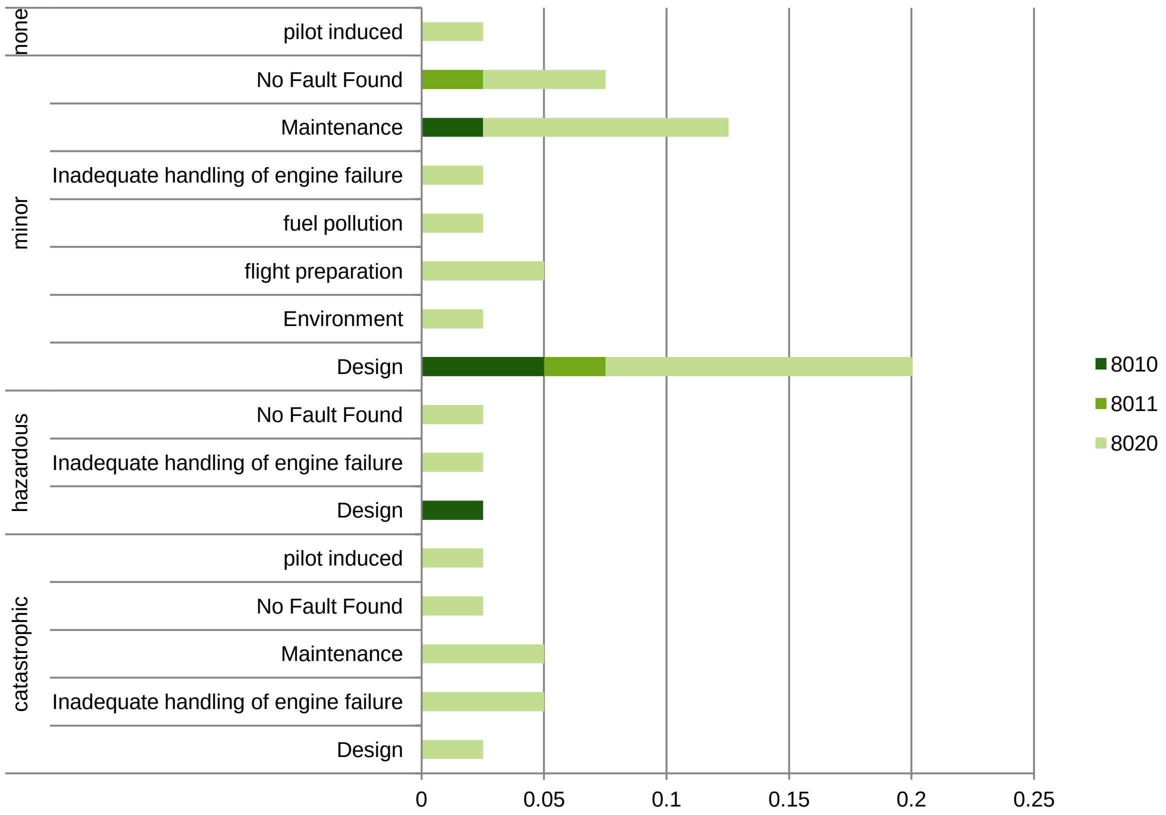


Figure 77: PISTON Relative occurrence rates per 100.000 FH of SPS Level 2 codes within the "Part / system failure" category

8.5.2.2 Turbine single-engine helicopters

In this section the accidents and incidents of the turbine-engined helicopters are analysed based on the most frequent SPS Level 1 categories.

8.5.2.2.1 SPS Level 1: 300 (Maintenance)

Next table provides a list of accidents and serious incidents within the SPS Level 1: 300 category (Maintenance). The events in this category range from minor to catastrophic severity and can be mainly attributed to flight preparation and maintenance- and design flaws. Presence of these three clusters indicates that the events can be attributed to the fact that engine-related flaws have been missed by either maintenance personnel (maintenance / design cluster) or the pilot.

Furthermore it should be noted that event number 643 cannot be addressed according to this methodology, since this event's catastrophic consequences can be attributed to clear violations of maintenance procedures and pilot licensing. Therefore, this event is not strictly engine-related.

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
12	Engine flame-out that was probably caused by the engine ingesting wet snow accumulated on the engine air intake surface. The fact that the engine warning system was turned off, effectively eliminating the automatic reignition system, was a contributing factor.	environment	3040	Y	hazardous	catastrophic / hazardous	hazardous / minor

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
186	breakage of a gear in the module connecting the drive shaft to the accessory box caused power failure. Early warnings missed by maintenance.	maintenance	3040 3010	Y	minor	catastrophic / hazardous	hazardous / minor
240	Engine shutdown has been due to a total breakdown of compressor which in turn is derived to a compressor blade failed due to fatigue. This is most likely initiated by corrosion in the compressor rotor material.	design	3010	N	minor	catastrophic / hazardous	hazardous / minor
569	Loss of fuel supply from the FCU. The drive to the FCU ceased as a result of the disintegration of the 41-tooth Bevel Gear in the accessory drive due to fatigue.	maintenance	3020	N	catastrophic	catastrophic / hazardous	hazardous / minor
635	The cause of the incident was due to the intake of fuel spilled by the mouth of the pipe to access the fuel tank, the inlet of the turbine engine.	flight preparation	3020	N	minor	catastrophic / hazardous	hazardous / minor
643	irregular poorly performed maintenance, pilot not licensed to fly at night, no mechanical failure	other	3010	Y	catastrophic	-	-
668	Fracture of a stage-two blade due to crack progression in fatigue.	design	3010 3020	N	minor	catastrophic / hazardous	hazardous / minor
679	Mechanical problem in the N1 accessory drive gearbox, bad maintenance, early signs not reported.	maintenance	3020 3010	N	minor	catastrophic / hazardous	hazardous / minor
798	Driveshaft adapter burst during flight as a result of a fatigue crack. Fatigue missed by maintenance, design of adapter is weak	maintenance	3020	N	minor	catastrophic / hazardous	hazardous / minor

Table 76: TURBINE List of events within SPS Level 1 = 300 (Maintenance)

Next figure shows that SPS Level 2 code 3010 (MX Procedures/Management) has been assigned to events ranging from minor to catastrophic severity. It occurs in each cluster and therefore the events with this code will be reviewed in detail in order to provide measures to mitigate the associated risks.

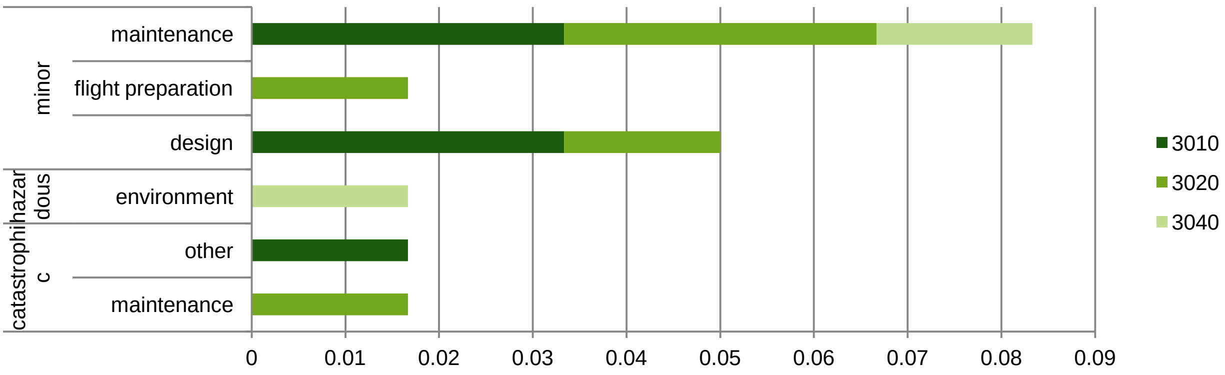


Figure 78: TURBINE Relative occurrence rates per 100.000 FH of SPS Level 2 codes within the “Maintenance” category

8.5.2.2.2 SPS Level 1: 500 (Pilot judgment & actions)

Next table provides a list of accidents and serious incidents within the SPS Level 1: 500 category (Pilot judgment & actions). The events in this category have occurred in both hostile and non-hostile environment and range from minor to catastrophic. As expected several pilot induced accidents can be found in this category, but the majority primary/initial causes can be attributed to maintenance, design and environmental factors.

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
92	Failure of centrifugal compressor due to fatigue cracks on the blade	design	5011	Y	catastrophic	catastrophic / hazardous	hazardous / minor
93	Engine bearing failure, autorotation inadequately managed	design	5040	N	catastrophic	catastrophic / hazardous	hazardous / minor
282	Operation at performance limit under difficult environmental conditions caused loss of control, engine failure is secondary	pilot induced	5060	Y	hazardous	catastrophic / hazardous	hazardous / minor
365	Power fluctuations in flight, loss of power, NFF	no fault found	5020	N	hazardous	catastrophic / none	minor / none
643	Irregular poorly performed maintenance, pilot not licensed to fly at night, no mechanical failure	other	5030	Y	catastrophic	-	-
679	Mechanical problem in the N1 accessory drive gearbox, bad maintenance, early signs not reported.	maintenance	5030	N	minor	catastrophic / hazardous	hazardous / minor
748	Compressor blade failure due to sucking in ice/snow	environment	5030 5010 5040	N	catastrophic	catastrophic / hazardous	hazardous / minor
753	Insufficient fuel, loss of power	flight preparation	5060	Y	minor	catastrophic / hazardous	hazardous / minor
798	Driveshaft adapter burst during flight as a result of a fatigue crack; fatigue missed by maintenance, design of adapter is weak	maintenance	5030 5010	N	minor	catastrophic / hazardous	hazardous / minor

Table 77: TURBINE List of events within SPS Level 1 = 500 (Pilot judgment & actions)

Similar to distribution of SPS Level 2 codes for piston-engined helicopters, as depicted in next figure, turbine-engined events cannot be attributed to a single SPS code. Therefore, SPS 500 category will be addressed as a whole in the risk mitigations chapter.

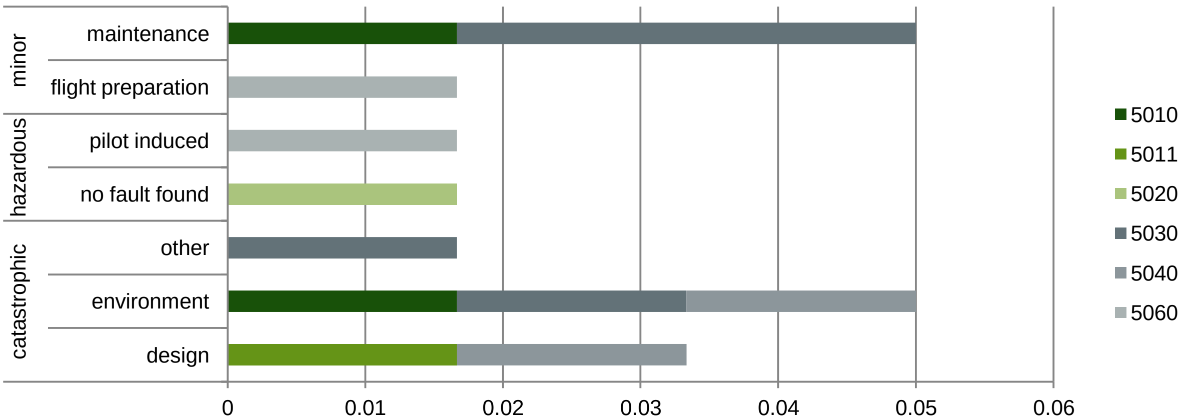


Figure 79: TURBINE Relative occurrence rates per 100.000 FH of SPS Level 2 codes within the “Pilot actions & judgment” category

8.5.2.2.3 SPS Level 1: 700 (Pilot situation awareness)

Next table provides a list of accidents and serious incidents within the SPS Level 1: 700 category (Pilot situation awareness). The events in this category have occurred in both hostile and non-hostile environment. The majority of these events are of high severity and can be attributed to several clusters:

Design, No Fault Found and Environment. It should be noted that this SPS level 1 category is not as dominant as amongst piston-engined occurrences.

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
12	Engine flame-out that was probably caused by the engine ingesting wet snow accumulated on the engine air intake surface. The fact that the engine warning system was turned off, effectively eliminating the automatic reignition system, was a contributing factor.	environment	7010 7020	Y	Hazardous	catastrophic / hazardous	hazardous / minor
92	failure of centrifugal compressor due to fatigue cracks on the blade	design	7030	Y	Catastrophic	catastrophic / hazardous	hazardous / minor
365	power fluctuations in flight, loss of power, NFF	No Fault Found	7030	N	Hazardous	catastrophic / none	minor / none
569	Loss of fuel supply from the FCU. The drive to the FCU ceased as a result of the disintegration of the 41-tooth Bevel Gear in the accessory drive due to fatigue.	design	7020	N	Catastrophic	catastrophic / hazardous	hazardous / minor
577	engine stoppage during a flight, NFF	No Fault Found	7020	N	Catastrophic	catastrophic / hazardous	hazardous / minor
643	irregular poorly performed maintenance, pilot not licensed to fly at night, no mechanical failure	other	7010	Y	Catastrophic	-	-
679	mechanical problem in the N1 accessory drive gearbox, bad maintenance, early signs not reported.	maintenance	7020	N	Minor	catastrophic / hazardous	hazardous / minor
748	compressor blade failure due to sucking in ice/snow	environment	7010	N	Catastrophic	catastrophic / hazardous	hazardous / minor
798	Driveshaft adapter burst during flight as a result of a fatigue crack. Fatigue missed by maintenance, design of adapter is weak	maintenance	7030	N	Minor	catastrophic / hazardous	hazardous / minor

Table 78: TURBINE List of events within SPS Level 1 = 700 (Pilot situation awareness)

Next figure shows that the 7020 SPS Level 2 code (External Environment Awareness) occurs most frequently amongst accidents and incidents in this category. Due to the nature of these events, dominance of the 7020 assignment is not entirely surprising. This code will be addressed in the mitigation measures chapter.

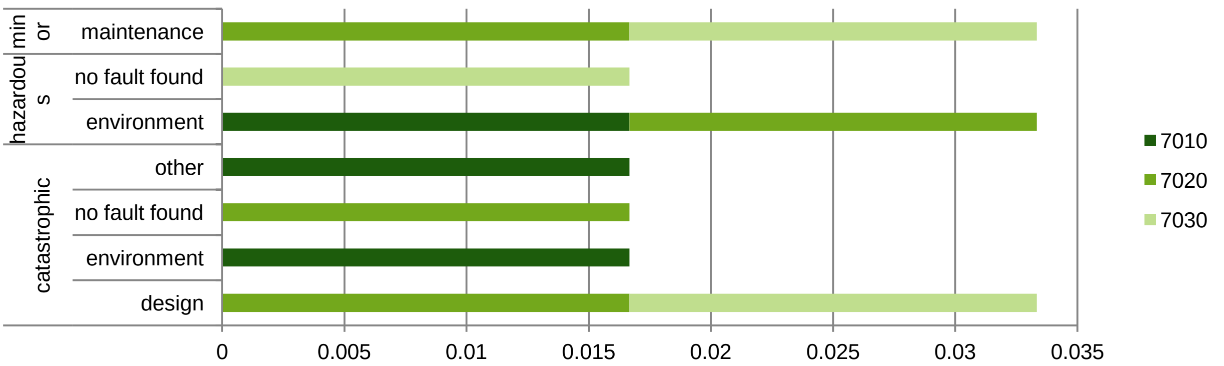


Figure 80: TURBINE Relative occurrence rates per 100.000 FH of SPS Level 2 codes within the “Pilot situation awareness” category

8.5.2.2.4 SPS Level 1: 800 (Part / system failure)

Next table provides a list of accidents and serious incidents within the SPS Level 1: 800 category (Part / system failure). The events in this category have occurred in both hostile and non-hostile environment. The majority of these events are of high severity and can be attributed to design and maintenance clusters. The findings in the turbine-engined category are similar to those of piston-engined.

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
13	The bearing of the Gas Producer Fuel Control Unit failed due to insufficient lubrication	design	8011	Y	hazardous	catastrophic / hazardous	hazardous / minor
92	failure of centrifugal compressor due to fatigue cracks on the blade	design	8020	Y	catastrophic	catastrophic / hazardous	hazardous / minor
93	Engine bearing failure, autorotation inadequately managed	design	8020	N	catastrophic	catastrophic / hazardous	hazardous / minor
186	Breakage of a gear in the module connecting the drive shaft to the accessory box caused power failure. Early warnings missed by maintenance	maintenance	8020	Y	minor	catastrophic / hazardous	hazardous / minor
240	Engine shutdown has been due to a total breakdown of compressor which in turn is derived to a compressor blade failed to due to fatigue. This is most likely initiated by corrosion in the compressor rotor material	design	8020	N	minor	catastrophic / hazardous	hazardous / minor
276	Loss of power due to leak in air control line between the fuel control unit and was leaking accumulator	design	8011	N	minor	catastrophic / minor	hazardous / none
282	operation at performance limit under difficult environmental conditions caused loss of control, engine failure is secondary	pilot induced	8020	Y	hazardous	catastrophic / hazardous	hazardous / minor
286	failure of clutch unit due to stress/fatigue, loss of power	design	8010	Y	catastrophic	catastrophic / hazardous	hazardous / minor
491	cable break in fuel warning system, loss of power due to low fuel	maintenance	8011	N	minor	catastrophic / hazardous	hazardous / minor
500	engine failure, NFF	No Fault Found	8020	Y	catastrophic	catastrophic / hazardous	hazardous / minor
569	Loss of fuel supply from the FCU. The drive to the FCU ceased as a result of the disintegration of the 41-tooth Bevel Gear in the accessory drive due to fatigue..	design	8020	N	catastrophic	catastrophic / hazardous	hazardous / minor
577	engine stoppage during a flight, NFF	No Fault Found	8020	N	catastrophic	catastrophic / hazardous	hazardous / minor
625	required engine power could not be obtained as a result of pollution in the fuel control unit	Fuel pollution	8020 8011	N	minor	catastrophic / hazardous	hazardous / minor
643	irregular poorly performed maintenance, pilot not licensed to fly at night, no mechanical failure	other	8011 8020	Y	catastrophic	0	0
645	The engine to main gearbox drive train was interrupted. Examination of the engine drive shaft revealed a broken KaFlex coupling at the engine to lower pulley drive shaft	design	8020	N	hazardous	catastrophic / hazardous	hazardous / minor
668	Fracture of a stage-two blade due to crack progression in fatigue	design	8020	N	minor	catastrophic / hazardous	hazardous / minor
679	Mechanical problem in the N1 accessory drive gearbox, bad maintenance, early signs not reported	maintenance	8020	N	minor	catastrophic / hazardous	hazardous / minor

Event			SPS	Hostile env. (Y/N)	Severity		
					Actual	Estimated	
ALG seq.	Description	Cluster	Level 2			Hostile	Non-hostile
736	NFF, possible fuel contamination	inadequate handling of engine failure	8020	Y	catastrophic	catastrophic / hazardous	hazardous / minor
748	compressor blade failure due to sucking in ice/snow	environment	8020	N	catastrophic	catastrophic / hazardous	hazardous / minor
798	Driveshaft adapter burst during flight as a result of a fatigue crack. Fatigue missed by maintenance, design of adapter is weak	maintenance	8020	N	minor	catastrophic / hazardous	hazardous / minor

Table 79: TURBINE List of events within SPS Level 1 = 800 (Part / system failure)

Next figure clearly shows that the 8020 SPS Level 2 (Part / system failure – Power plant) code occurs most frequently amongst turbine-engined helicopter events. This result was expected, since only engine-related events are part of this analysis. The 8020 code will be addressed separately in order to provide potential mitigation measures.

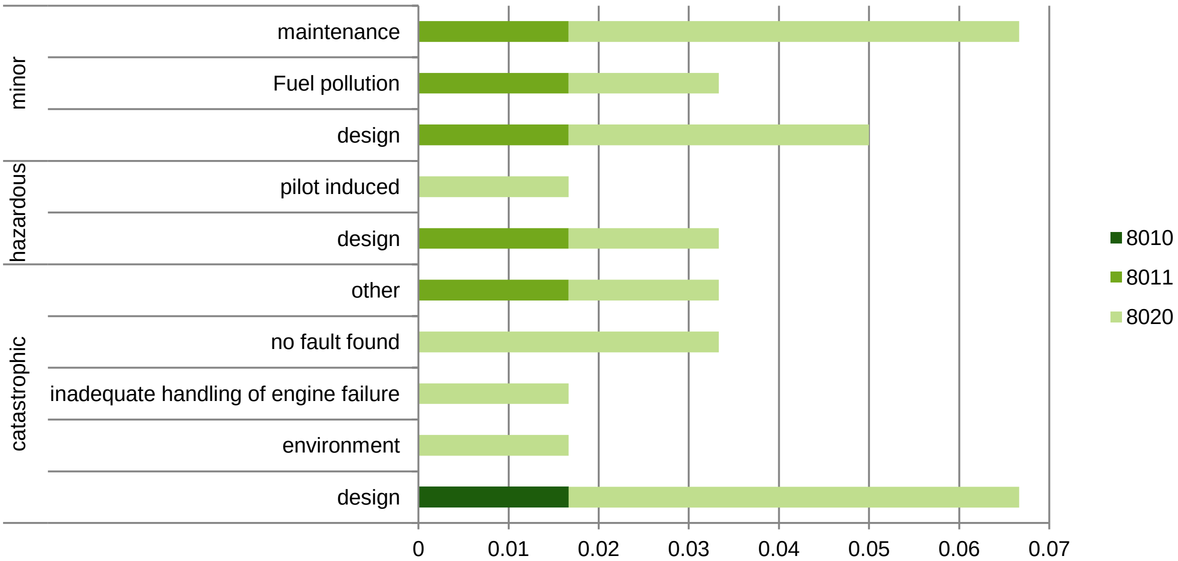


Figure 81: TURBINE Relative occurrence rates per 100.000 FH of SPS Level 2 codes within the “Part / system failure” category

8.5.3 Risk mitigation strategies

Mitigation measures have been established for the identified relevant risks. Mitigations will, when possible, be based on received information regarding technological and/or procedural improvements expected for the next decade.

Further principles applied for mitigation measures are:

- when possible low cost solution,
- supporting as much as possible the complete range of operations,
- uncomplicated, easy implementation, and
- expected effect (residual risk) of the mitigation measure must be significant compared to existing situation.

In general, risk analysis showed a similarity in areas of interest for both piston engine and turbine engine equipped helicopters. As a consequence, most of the mitigations are equally applicable for both types of helicopters.

8.5.3.1 Mitigations piston events

8.5.3.1.1 Piston 2090 Safety management – inadequate pilot experience

Within SPS 200 category of the piston events, compared to the turbine category, a relative high number of codes refer to the factor inexperience, student pilot. This could be explained by the fact that Flight Training Organisations (FTO) use less expensive helicopters to offer reasonable prices for their student pilots. Piston helicopters are generally cheaper.

Student pilots should be trained using uncomplicated helicopters with typical helicopter characteristics. This enables the student pilot understand helicopter behaviour quickly and reduces required system knowledge to analyse possible problems. It would require further detailed analysis of the current fleet to determine whether the FTO's use the best suitable machines for their training operation.

Lack of experience increases the workload for the student pilot, limiting the ability to analyse unexpected situations. Processed information, proper cueing and warning regarding the status of the helicopter can assist the student pilot in the process of analysis and taking the proper action. **EICAS systems** can provide more adequate voice warning and cueing to reduce the student pilot workload and increase the probability of proper response. The warning system can be further improved by adding **tactile warnings, such as a collective stick shaker**.

8.5.3.1.2 Piston 3010 Maintenance – maintenance management

Within the SPS 300 category, 9 out of 14 events had maintenance management as contributing factor. The reports revealed examples where deficiencies were missed by maintenance, possible improper maintenance, and deficiencies not reported to maintenance and the use of inappropriate parts. The available reports contained insufficient information to establish common causes for these mishaps.

Improvements in quality can generally be achieved by improvements in education, recurrent training, implementation of quality and safety management systems etc. As root causes for the observed mishaps could not be determined, the effectiveness of possible mitigations cannot be assessed. **Further investigation would be required to evaluate causes and determine proper mitigations**.

8.5.3.1.3 Piston 500 Pilot judgment and actions

Within the SPS 500 category, a significant number of events had level 2 codes 5010 (pilot's decision), 5040 (landing procedure) and 5060 (procedure implementation) assigned as contributing factors. These events also appear to be in the higher severity categories, although the general environment was indicated as non-hostile. As mentioned earlier, a significant number of events reported, occurred in a generally non-hostile environment, but the reports revealed that the local condition at the moment of the event could be considered hostile. Within this group, helicopters were operated in an altitude band between 50 and 500 ft AGL or operated to/from a confined area or in the vicinity of obstacles limiting their options.

Although helicopters generally have more options to conduct a safe (emergency) landing than an equivalent fixed wing aircraft in case of loss of power, helicopter pilots usually have less time due to a higher sink rate of the machine. Decent rates of helicopters during an established autorotation are approximately 2500 ft/min. This requires rapid analysis and decision-making. Another issue might be the stability of the helicopter. The flight characteristics of a helicopter can also differ for powered flight compared to a similar speed in non-powered flight (autorotation). The pilot needs to adapt to this different behaviour of his helicopter, which can cause control problems. From altitudes below 500 feet AGL it is not always possible to establish a stable autorotation; this increases the workload in the final stage of an autorotation. Important elements for successful entry of an autorotation are: rapid response (analysis and proper action), sufficient altitude to establish a stable autorotation and provide sufficient time for decision making.

A requirement for rapid and adequate response is a good situational awareness (SA). Although not supported by the assigned SPS 700 codes, there is reasonable doubt that the pilots in the evaluated events were well aware of the technical problem and their respective options in the event of a loss of power.

Awareness of the technical status of the helicopter could be increased by providing **good cueing and intuitive warning systems. EICAS systems** could support better SA 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**. More advanced systems like **EGPWS** would provide, besides altitude information, a complete view of the flight path of the helicopter in relation to the surrounding terrain. Therefore, the use of EGPWS could also provide increased local (geographic) situational awareness; for instance, 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.

8.5.3.1.4 Piston 8020 Part / system failure – Power plant

The majority of events in the engine related category are related to failure of critical components of the power plant. The causes for the majority of the assessed events consisted of failure of components caused by wear (bearings, spark plugs), or fading adjustments (belt tension). Another frequently reported cause was fatigue. The nature of wear or fading adjustments is more gradual whereas fatigue cracks mostly cause a sudden disruption of power.

Abrupt failure, for example due to fatigue, will be hard to detect in an impending state, however wear and fading issues present themselves by gradual increase of vibration, 'roughness' of engine, minor fluctuations in power delivery, or gradual delay in response. The gradual nature of some of these impending failures, make it hard for humans to recognise these critical conditions, but these still are perfect measurable indicators of impending failure. **HUMS systems** can record and warn both technicians and aircrew of deteriorating condition of critical components. Proper implementation of HUMS in both maintenance practices and cockpit procedures could reduce the number of serious incidents and accidents significantly.

Loss of power in a helicopter requires rapid decisions and immediate action. Rotor systems of light helicopters tend to have little inertia and therefore loose rotational speed fast. Once below the critical rotor speed, control will be lost without possibility to restore it. **Hybrid techniques**, using 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. This technique is still under development but sure it has great potential for enhancing safety of single engine helicopters in the near future.

8.5.4 Turbine hazards

8.5.4.1.1 Turbine 300 Maintenance

Similar to the piston engine findings, management factors were also reported within the turbine events. Beside SPS level 2 3010 (maintenance management), also 3020 (performance of maintenance duties) were reported in 5 events. Issues observed from the reports were mainly undetected deficiencies, bad quality of maintenance and reporting issues. The addressed issues were unique except for two suspected missed deficiencies. As stated above, the available reports contained insufficient information to establish common causes for these mishaps.

Identical to the piston findings, further investigation would be required to evaluate causes and determine proper mitigations.

8.5.4.1.2 Turbine 500 Pilot judgment and actions

Within the SPS 500 category, a significant number of events had SPS level 2 codes 5030 (flight profile) and 5040 (landing procedure) assigned as contributing factors. Within these two groups the 5040 category appeared to be assigned to events with a higher severity. All reported events occurred in a generally non-hostile environment, and similarly to the piston group, with one exception, the local condition at the moment of the event could be considered hostile. Within this group, helicopters were operated in an altitude band between 50 and 250 ft AGL, with one exception at 1500 ft AGL.

From the event descriptions it could be learned that, in most instances, the low altitude was intended as part of the mission (aerial work). Intentional prolonged operations with these single engine helicopters within the ‘avoid’ area of the H-V diagram will deny a safe escape in the event of a total power loss. Occurrence reports did not provide arguments or considerations for the choices to conduct these operations at low altitude regardless of the inherent dangers. A single report stated however that the operator held a 'low flight permit'.

Although it could not be verified whether flight rules had been ignored, adherence to the rules can relatively easily be monitored by using quick access recorders as required for **Flight Data Monitoring** purposes on large transport category aircraft. Operators could be encouraged or required to store these data.

When **hybrid techniques** will become available, they could enable the use of single engine helicopters within the 'avoid' area of the H-V diagram in the future.

8.5.4.1.3 Turbine 7020 Pilot SA – environment awareness

Within the category Pilot SA, environment awareness was assigned five times as a contributing factor, divided over four events. Three out of four led to catastrophic consequences. All events happened at low altitude, between 50 and 250 feet. The type of operation for most of these events was aerial work.

Although these flights were conducted at low altitude intentionally, the effect of loss of power was severe. The pilots did not have an effective response to these failures despite their intentional flight in unfavourable conditions. Either ignorance towards potential dangers or reduced awareness of limitations of their flight profile and surrounding environment, could have contributed to the outcome of these accidents. Similarly as discussed for piston engines, low-level environment requires quicker response from the pilot in the event of power loss and therefore a better awareness of the status of failures as well. A proper mitigation should provide increased awareness of both machine and surrounding environment.

Awareness of the technical status of the helicopter could be increased by providing good cueing and intuitive warning systems. **EICAS systems** could support better SA and assist in proper decision making as well as reduction of response time. A simple but effective mitigation for unintended loss of altitude could be a **radar altimeter** with adjustable altitude setting for (audio) warning. More advanced systems like **EGPWS** would provide, beside altitude information, a complete picture the flight path of the helicopter in relation to the surrounding terrain.

Besides technical aids to support awareness of actual situation, **additional training on Full Flight Simulators (FFS)** could increase pilot's awareness of his limited options for a favourable forced landing in case of low level operations and/or operation within vicinity of obstacles. There are different or unconventional methods of taking evasive action in risk situations that could be reinforced by FFS practises. For instance, training in autorotation is normally carried out within a speed bracket as prescribed by the OEM in the flight manual. Zero speed autorotation are not as safe as autorotation with (safe) forward speed, but could be a better option in certain conditions. These are never trained for in normal operation as damage or injuries 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. However, limited availability of simulators for this class of helicopters poses a disadvantage, since flight technical aspects cannot easily be trained. It should be noted that awareness training could be conducted on any type of FFS for the single-engine helicopter.

8.5.4.1.4 Turbine 8020 Part / system failure – Power plant

Almost 75% of the events in the SPS 800 category of the assessed engine related turbine events were caused by failures directly related to the power plant. Half of these events were caused by fatigue, other causes were found in maintenance, environment (snow/ice ingestion) and failure due to polluted fuel.

Similar to the piston category, fatigue cracks will be hard to detect in an impending state, but a lot of failures present themselves gradually by increased vibrations. These are measurable indicators of impending failure. **HUMS systems** can record and warn both technicians and crew of deteriorating conditions of critical components. Proper implementation of HUMS in both maintenance practices and cockpit procedures could reduce the number serious incidents and accidents significantly. Furthermore, HUMS real-time monitoring data of component wear can be used to adjust maintenance schedules in order to decrease the risk of component failure due to fatigue.

Again, **hybrid techniques**, using electrical backup power to drive the rotor in case of loss of engine power, could provide valuable time for the pilot to maintain control of the helicopter and concentrate on safe landing options. These techniques are still under development but have great potential for enhancing safety of single engine helicopters in the near future.

8.5.5 Remarks

From the reports it appeared 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 were either ignored or classified as unlikely to affect the operation. Changes in behaviour of engines, drive train or other critical components - as a slight vibrations or noise but within the limits of flight manuals -, could indicate an abnormal situation with an unknown status. Considering general flight conditions for helicopters, helicopters are mostly within one or a few minutes' flight time from a suitable landing area. Off shore or other hostile environments provide less opportunities to land, but on shore, there often are possibilities to land relatively safely. Precautionary landings are not popular within pilot community as they require a lot of subsequent administration and reporting. Another aspect is embedded in pilot culture: pilots rather solve a problem at home than land in a field. Moreover, company level issues regarding planning and costs of precautionary landings will not encourage conduct of a landing when it is not deemed absolutely necessary. It should be **encouraged that, in case of doubt regarding the status of the helicopter, that 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. Companies should 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 on a list of safe operators. These could be used by companies to demonstrate their safety policy to the customers.

8.5.6 Bowtie model

The proposed mitigation measures for both piston- and turbine-engined helicopters are graphically summarised in a bowtie diagram depicted in next figure. Average actual severity of the occurred engine-related events grouped per SPS Level 2 is mitigated by proactive measures (on the left side of the figure) and reactive measures (on the right side of the figure). An expert helicopter pilot has estimated the effectiveness of the proposed mitigation measures. Residual severities of respective SPS groupings are provided on the right side of the figure.

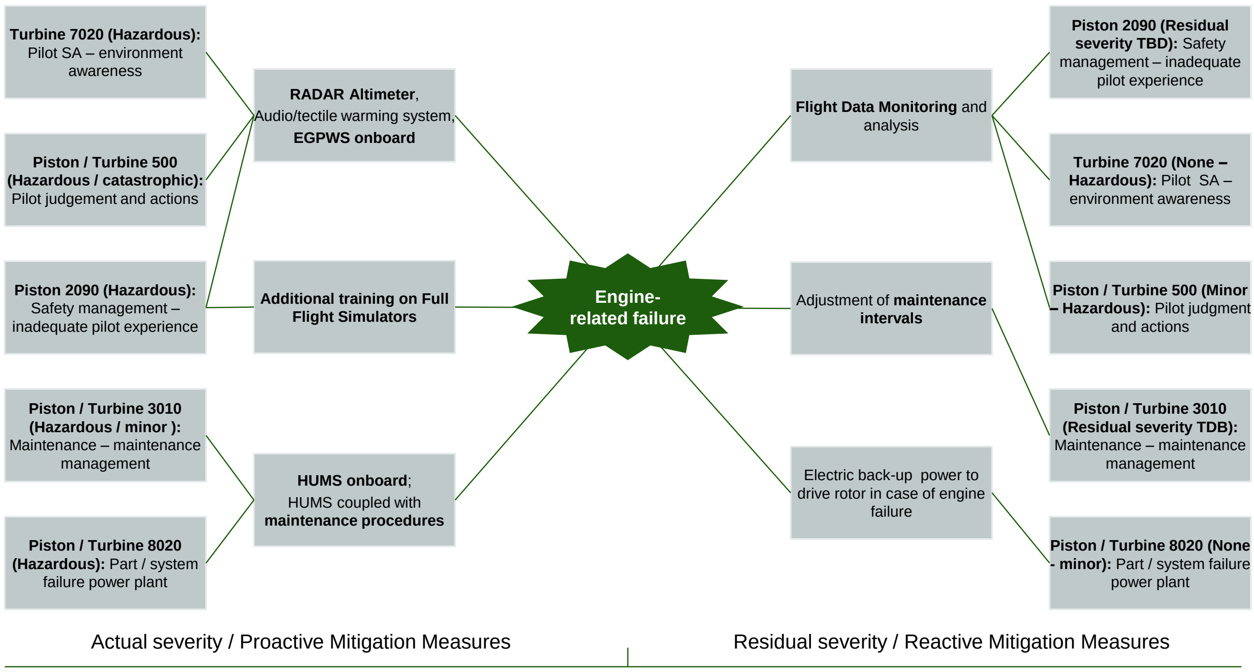


Figure 82: Bowtie diagram

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9 Outcome and Outreach

The aim of this study is to provide EASA with a factual operational picture on the suitability and safety of single-engined helicopters for commercial air transport operations over hostile environment; clarifying if and under which conditions this type of operation can be conducted.

The gathering of information, from sources consisting of Civil Aviation Authorities, operators, manufacturers, associations and independent initiatives, provides a broad overview of the current status of the helicopter sector, and reveals the most important issues and controversies. Therefore, this study is of vital importance to all those involved in the operation of single-engined helicopters.

After an exhaustive process of data processing, the Consortium has succeeded, for the first time, in grouping as a single database all the information relating to accidents and incidents in the last 10 years, as well as creating a common register for the European fleet of single-engined helicopters with an accurate estimate of the flight hours for each engine type. Thanks to this work, it has been possible to conduct a study of accidents which takes into account parameters such as engine type, operation type and the hostility of the environment. Furthermore, the results obtained provide all sectors of the industry with an overview of the most common causes of accidents and incidents. With these factors known, operators of single-engined helicopters need to treat this analysis as a guide for operators on improving policies on action to take to achieve better safety performance.

After identifying the hazards that have contributed directly or indirectly to accidents and serious incidents due to engine failure in CAT operations, the Safety Risk Assessment carried out by the consortium has proposed mitigation measures. These measures are heavily based on the introduction of technology in helicopter electronics and IT systems. Notable aspects include the use of hybrid engines to provide support in case of power loss as well as the incorporation of EICAS systems, EGPWS or radars that increase pilot situational awareness. As well, issues related to maintenance management can be mitigated through extensive use of Health Usage Monitoring Systems. Training of pilots with Flight Simulators (FFS) is also a way to improve pilot skills and reduce human error. Again, the Consortium believes that implementation of these measures by the industry would help to improve safety.

It is important to note that all the above methodology has been adapted and designed in detail to achieve the initial objectives. The approach developed and the proposed phasing may serve as inspiration for others who wish to carry out similar studies or examine any aspect of aviation in detail.

Finally, in reference to the evaluation of JAR-OPS 3.005(e) approvals and Appendices as well as the rule which succeeds it, CAT.POL.H.420, the final recommendation does not see it as necessary to vary guidelines on practices for CAT operations in single-engined helicopters over hostile environments. However, given that new generations of helicopters may expand their current configuration and increase their performance abilities, the authorities should understand our findings as the basis for future assessments of the rules.

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10 Final conclusions

10.1 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 80, 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		
		EASA	CAAs	EHEST	Helicopter Operators	Manufacturers	Associations	Pilot Unions	Multi-client consulting. reports	Independent initiatives	Universities
Type of information	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 80: 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.

10.2 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.

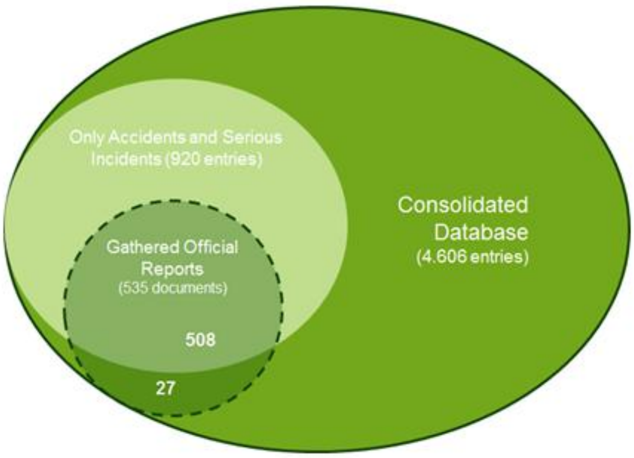

Figure 83: Occurrence database gaps

The information gaps are summarized in Table 81. 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 without related official occurrence report (with related official occurrence report)
36%	0,8% (0,6%)	% of occurrences with undefined type of operation and without related official occurrence report (with related official occurrence report)
20%	0,6% (0,02%)	% of occurrences with unspecified phase of flight and without related official occurrence report (with related official occurrence report)

Table 81: 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.

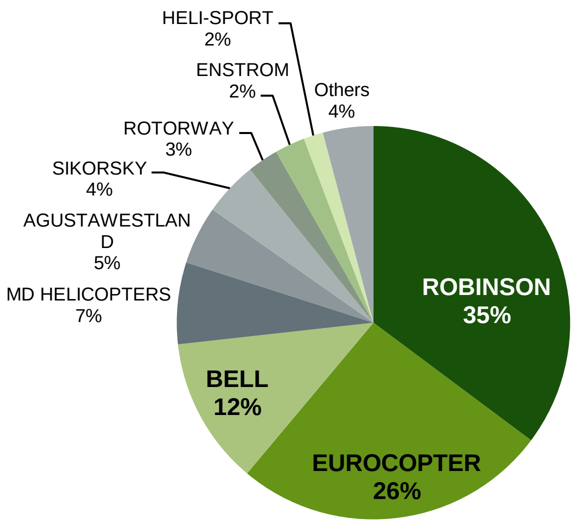

Figure 84: European helicopter fleet share by manufacturer

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[24] 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.

10.3 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.

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

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 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~~ (take-off, en route & manoeuvring , Approach & Landing) with ratios around 1, 4-1, 45 of fatal occurrences per 100.000FH.~~ 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 e~~E~~n-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 82 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 82: 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 83 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 83: 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. Next Figure 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 85: Most common SPS and HFACS level 2 categories per type of operation accidents and serious incidents

10.4 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 piston-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.

10.5 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.

10.6 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 84 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 84: 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 85.

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[25], 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 85: 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.

[25] *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

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11 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.

11.1 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[26] 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.

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

11.1.1 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 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.

11.2 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 86 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[27] 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

Table 86: 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[28]. However, limited availability of simulators for single-engined helicopter class is a disadvantage, since flight technical aspects cannot easily be trained.

[27] 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.

[28] 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)

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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										
		5000	5100	5200	5300	5400	5500	5600	600	6100	6200	6300
SPS	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 87: Factor matrix identification – Total accidents and serious incidents (503 occurrences)

		HFACTS										
		5000	5100	5200	5300	5400	5500	5600	600	6100	6200	6300
SPS	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 88: Factor matrix identification – Commercial Air Transport related events (58 occurrences)

	HFACTS										
SPS	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 89: Factor matrix identification – Commercial Air Transport in hostile environment related events (20 occurrences)

	HFACTS										
SPS	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 90: 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[29] 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.*

[29] 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.*

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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.

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Appendix 5: 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[30] and EASA EU[31] 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.

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

[31] 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.

- 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.

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.

<u>Recommendations</u>

- 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.

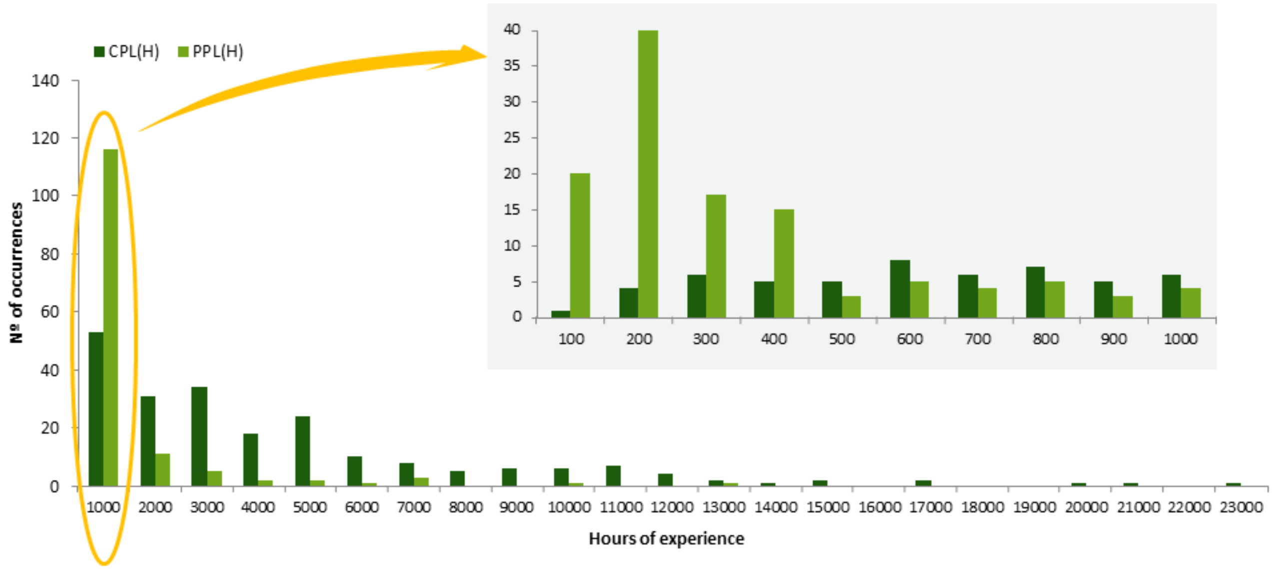

Figure 86: Accidents and serious incidents by hour of experience in helicopters

<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[32], 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.

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

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.

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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Appendix 6: Abbreviations and Acronyms

ADREP: Accident/Incident Data Reporting

ADS-B: Automatic Dependent Surveillance-Broadcast

AFM: Aircraft Flight Manual

AGL: Above Ground Level

AIB: Accident Investigation Bureau

AOC: Air Operators Certificate

AW: Aerial Work

BHA: British Helicopter Association

CAA: Civil Aviation Authority

CAST: Commercial Aviation Safety Team

CAT: Commercial Air Transport

CAT: Commercial Air Transport

CoP: Co-pilot

EADS: European Aeronautic Defence and Space Company

EASA MS: EASA Member States

EASA: European Aviation Safety Agency

EASP: European Aviation Safety Plan

ECA: European Cockpit Association

ECCAIR: European Co-ordination Centre for Aviation Incident Reporting System

ECR: European Central Repository

ECR: European Central Responsory

EDCU: Astronautics' Engine Data Converter Unit

EEA /EFTA: European Economic Area/European Free Trade Association

EGNOSS: European Geostationary Navigation Overlay Service

EGPWS: Enhanced Ground Proximity Warning System

EHA: European Helicopter Association

EHAST: European Helicopter Safety Analysis Team

EHEST: European Helicopter Safety Team

EICAS: Engine Instrumentation and Crew Alert System

ESSI: European Strategic Safety Initiative

ETOPS: Extended-range Twin-engine Operation Performance Standards

EU: European Union

FADEC: Full Authority Digital Engine Control

FDTL: Flight and Duty Time Limitations

FFS: Full Flight Simulators

FH: Flight Hours

FLI: First-Limit Indicator

FLT: Flight Time Limitations

FSF: Flight Safety Foundation

FTO: Flight Training Operators

GA: General Aviation

GAMA: General Aviation Manufacturers Associations

GPS: Global Positioning System

H/V: Height/Velocity

HAC: Helicopter Association of Canada

HAI: Helicopter Association International

HELI: Helicopter

HEMS: Helicopter Emergency Medical Service

HFACS: Factors Analysis and Classification System

HMI: Human Machine Interface

HUMS: Health Usage Monitoring Systems

IATA: International Air Transport Association

ICAO: International Civil Aviation Organization

IGE/OGE: In Ground Effect / Out Ground Effect

IHST: International Helicopter Safety Team

IMC: Instrumental Meteorological Conditions

IORS: Internal Occurrence Reporting System

IR: Instrument Rating

IRCA: International Register of Civil Aviation

JAA: Joint Aviation Authorities

JHSAT: Joint Helicopter Safety Analysis Team

JHSIT: Joint Helicopter Safety Implementation Team

LTE: Loss of Tail rotor Effectiveness

MALGH: Mission Aviation Légère et Helicopters

MOPSC: Maximum Operational Passenger Seating Configuration

MTOW: Maximum Take-Off Weigh

NAA: National Aviation Authority

NDA: Non-Disclosure Agreement

NTSB: National Transportation Safety Board

ODP: Obstacle Departure Procedures

OEMs: Operator Engine Manufacturers

OGP: Oil & Gas Producers

OPST: OSSTMM Professional Security Tester

OSD: On Screen Display

PDS: Powerline Detector System

PiC: Pilot in Command

PIO: Pilot-Induced Oscillation

PPE: Personal Protective Equipment

PVI: Pilot-Vehicle Interfaces

QRA: Quantitative Risk Assessment.

RAG: Regulatory Advisory Group

SAR: Search and Rescue

SE: Single Engine

SEH: Single Engine Helicopter

SMS: Safety Management Systems

SPO: Standard Operational Procedure

SPS: Standard Problem Statements

SSP: State Safety Program

TAG: Thematic Advisory Groups

UMS: Usage Monitoring System

VEMD: Vehicle and Engine Multifunction Display

VMC: Visual Meteorological Conditions

VMD: Vehicle Multifunction Display

WAAS: World Aircraft Accident Summary

WSPS: Wire Strike Protection System

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