European Aviation Safety Agency

EASA Study on single-engined helicopter operations over hostile environment

7th Rotorcraft Symposium

5th December 2013

ALG TRANSPORTATION INFRASTRUCTURE & LOGISTICS

SGI AVIATION

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EASA has decided to review the whole concept of single-engined helicopter operations

- In Europe there is an ongoing debate among the helicopter manufacturers, operators and regulatory oversight bodies regarding the relevance of the number and type of engines, and their suitability for certain types of operations

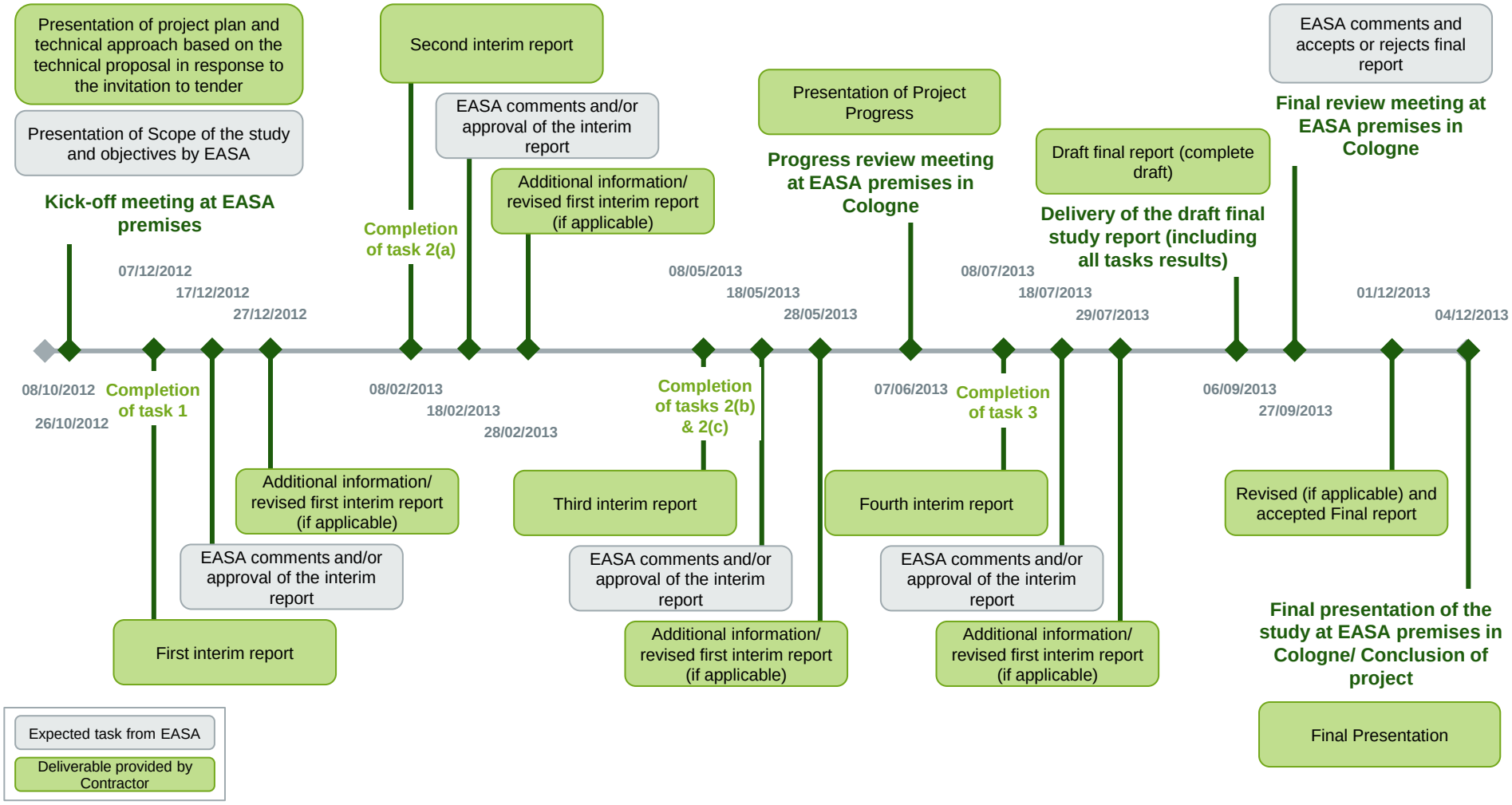
- The discussion focuses in particular on the single-engined helicopters used in commercial air-transport operations over hostile environment

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.

THIS PRESENTATION IS NOT ABOUT TWIN-ENGINED HELICOPTERS AT ALL!

The Consortium led by ALG in partnership with SGI Aviation is selected by EASA to conduct the study

The project has been scheduled to be completed in 13 months

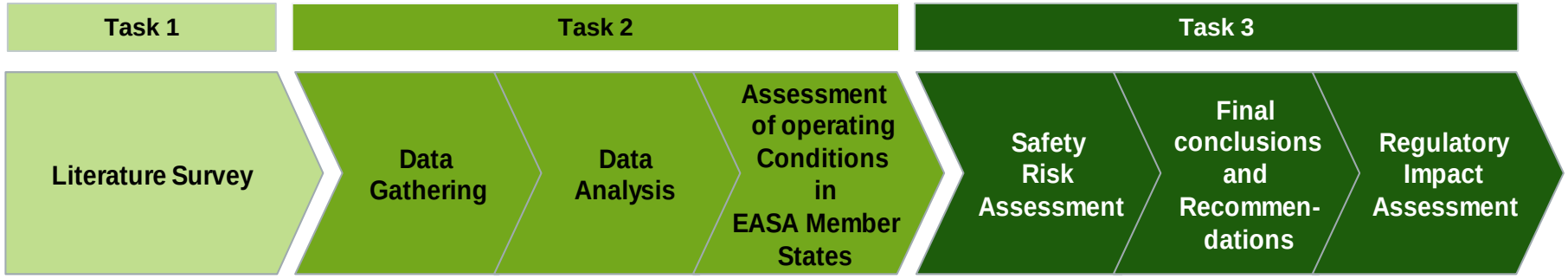


The study focuses on whether or not single-engined helicopter operations over a hostile environment should be allowed

Objectives

- Collecting and analyzing data on the use of single-engined helicopters in EASA Member States in all type of operations
- Conducting a safety risk assessment in support to the decision of whether or not (and under what conditions) commercial air transport operations can take place over a hostile environment
- Potentially conducting a regulatory impact assessment identifying and clearly describing the safety as well as the economic, social and environmental impact of the proposed rulemaking action

Methodology



Target

- Single-engined operations over hostile and non-hostile environment over the most recent ten-year period (01/01/2003 to 31/12/2012) operated in EASA member states
- JAR.OPS. 3.005 (e) Regulations

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In order to determine how EASA Member States implement 3.005(e) a selection of 7 key states were successfully surveyed for the purpose of the operational assessment of JAR.OPS 3.005(e) approvals analysis

Netherlands, United Kingdom	Austria	Finland, France, Sweden	Switzerland
Not apply JAR.OPS 3,005(e) approvals	Not issue JAR.OPS 3,005(e) approvals	Issue JAR.OPS 3.005(e) approvals	Not implement 3.005(e) but allow such operations

National Variants

Regional areas with application of 3.005(e)

Alpine States	Nordic States
France Switzerland Austria	Denmark Finland Sweden
Mountain Operations	**Operations in remote areas**

Number of helicopters under the provision of 3.005(e)

France	100
Switzerland	120
Finland	5

Conditions for 3.005(e) approvals

Airworthiness	Operational Training	SSP SMS
Sweden reports that most operators use VMD on a voluntary basis	Only France emphasises operational procedures and training (safe forced landing areas and engine failure techniques)	Only France emphasises its SSP on helicopter operations, but this is not specific to the 3.005(e) condition

Application of 3.005(e) appears to concentrate in two regional areas: Alpine States & Nordic States, which 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

Literature Survey carried out a comprehensive review of the helicopter industry assessing the suitability of the information sources, to adopt a "multi source" approach to the data gathering process

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

Degree of suitability

Legend:

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

No single source could provide the completeness and quality of data required to produce a meaningful analysis

The potential identified sources for each database were the following

Fleet Database	
Single-Engined EASA Helicopter Fleet	✓
EUROCOPTER	✓
International Register of Civil Aviation	✗
JP Airline Fleets International	✓
Helicopter Blue Book	✓
Rotor Roster Business Class Helicopters	✓
Rotorspot	✓
Helihub	✓

Occurrences Database	
ADREP	✓
European Central Repository	✓
EHSAT	✓
EUROCOPTER Occurrence Data	✓
BELL	✓
World Aircraft Accident Summary	✗
Aviation Safety Net	✓
Helihub	✓
Griffin	✗
Helis	✗

Usage Database	
Civil Aviation Authorities	✓
EUROCOPTER	✓
BELL	✓
ROBINSON	✓

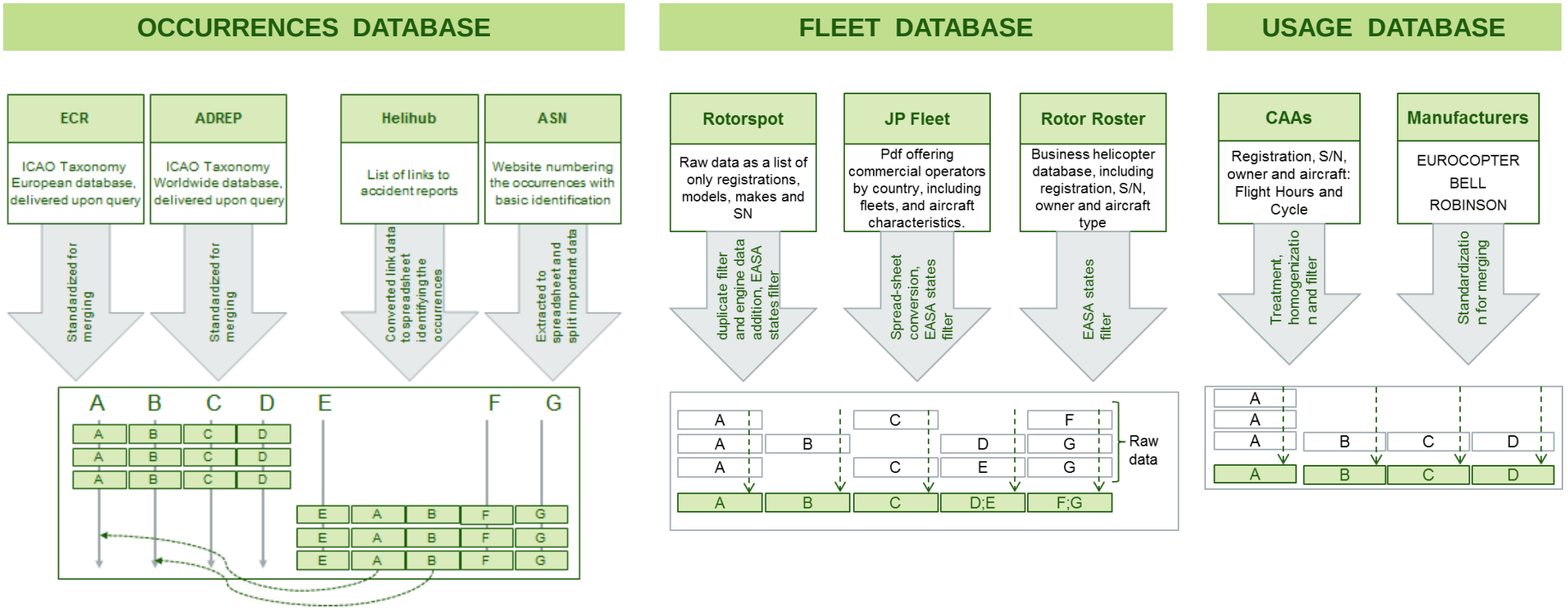
- The current identity and status of all known helicopter operators in the Member States and the composition of their helicopter fleets
- The scope of operations and share of their different types of operation in the overall business model of operators
- The types of helicopter operated and their average 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

The Data Gathering task has developed an exhaustive and detailed procedure for the treatment, merging, and polishing of the credible data to created OCCURRENCES, FLEET and USAGE databases

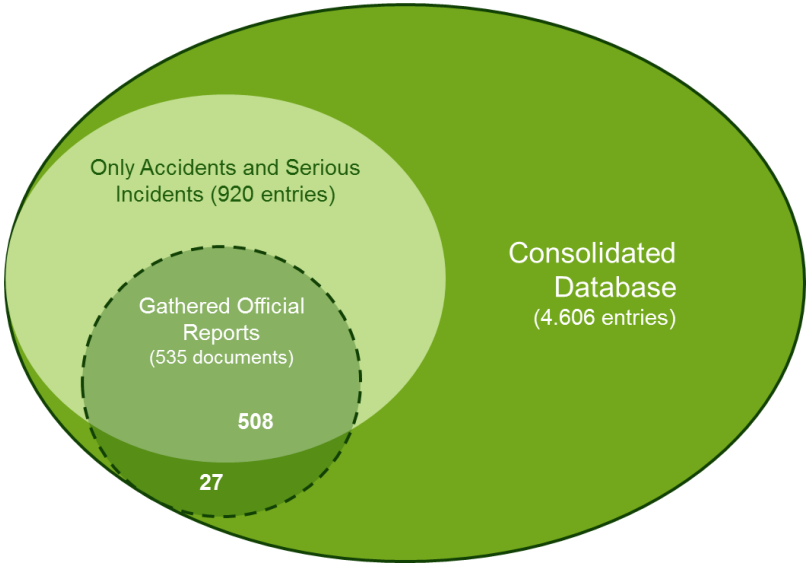


- The final consolidation of the databases consisted of completing all the information gaps possible, cross-checking the three occurrence databases, and standardising the data in order to pull out statistics.
- All the accident reports publicly available from the Air Accident Investigation Boards have been also downloaded and cross-checked

The final Occurrences Database outcome encompasses 4.606 occurrences, of which 920 are accidents and serious incidents

Availability of occurrences reports

It has been considered relevant to obtain as much single-engine accident and serious incident reports as possible, and compare them to the consolidated Database:



Occurrences database gaps

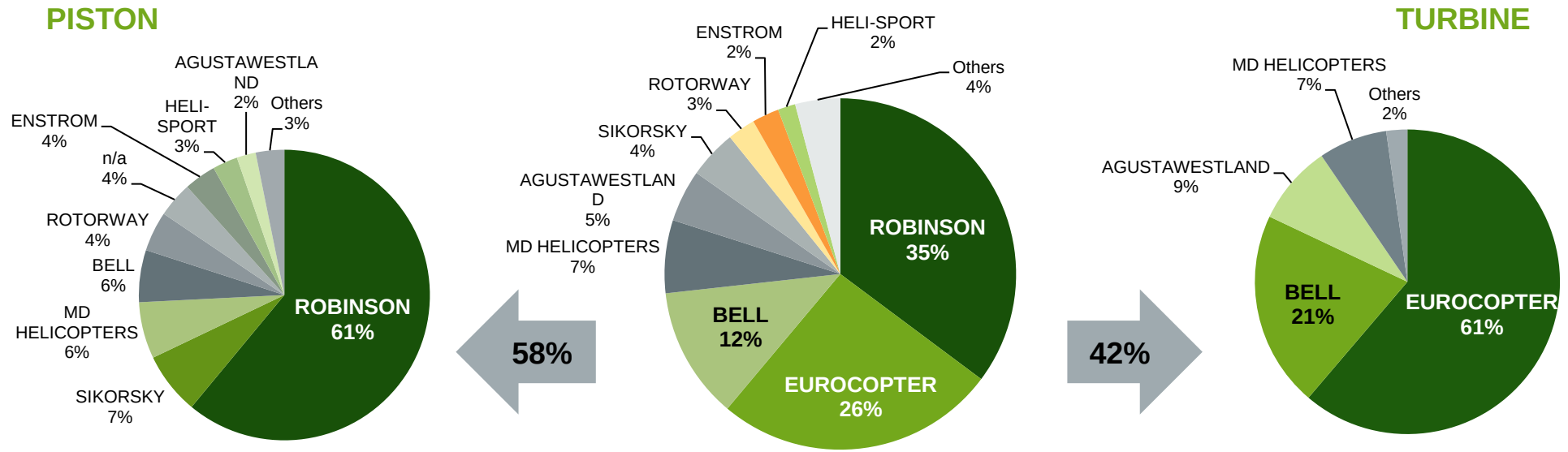
Finding	Whole Data Base	Only Accidents and Serious Incidents
% of entries without a File Number. This is considered a minor problem, but would enhance the identification of duplicated events not yet identified.	11%	**1%**
% of occurrences with unidentified date	0,04%	**0%**
% of occurrences with unknown make, type or model	16%	**2,5%**
% of helicopters with unknown year of manufacture without related official occurrence report (with related official occurrence report)	25%	**0,6% (0%)**
% of occurrences with undefined type of operation without related official occurrence report (with related official occurrence report)	36%	**0,8% (0.5 %)**
% of occurrences with unspecified phase of flight without related official occurrence report (with related official occurrence report)	20%	**0,6% (0%)**

- **535 official reports,** of which **508 are accidents and serious incidents**
- It should be noted that the number of gaps decrease in the case of accidents and serious incidents

The final Fleet Database outcome encompasses a total single-engined fleet composed of more than 6.800 helicopters

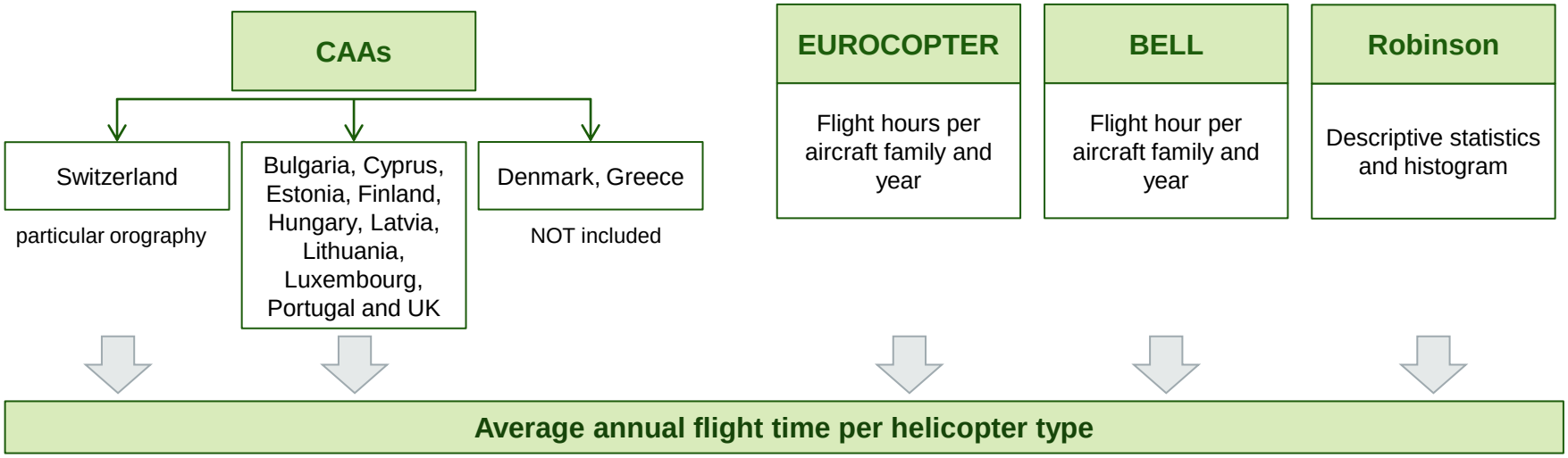
- The most common **single-piston** helicopters are the Robinson 44 and 22 (close to 1.500 and 1.000 aircraft, respectively)
- The most common **single-turbine** models are the AS350 Ecureuil 1 and JetRanger series (close to 1.000 and 650 aircraft, respectively)
- **General consideration:** 82% of the turbine fleet has been manufactured by Eurocopter or by Bell, and 61% of the piston fleet has been manufactured by Robinson.

Single-engined European helicopter fleet share by manufacturer



- Four countries concentrate almost **60%** of the total fleet: **UK, France, Italy and German**
- Three manufacturers concentrate **73%** of the total fleet of single-engined helicopters in Europe: **Robinson, Eurocopter and Bell**

The final Usage Database outcome encompasses around of 10.200.000FH for single-engined helicopter over the ten year period of study



6.600.000 FH correspond to **turbine-engined** helicopters (65% of total FH)

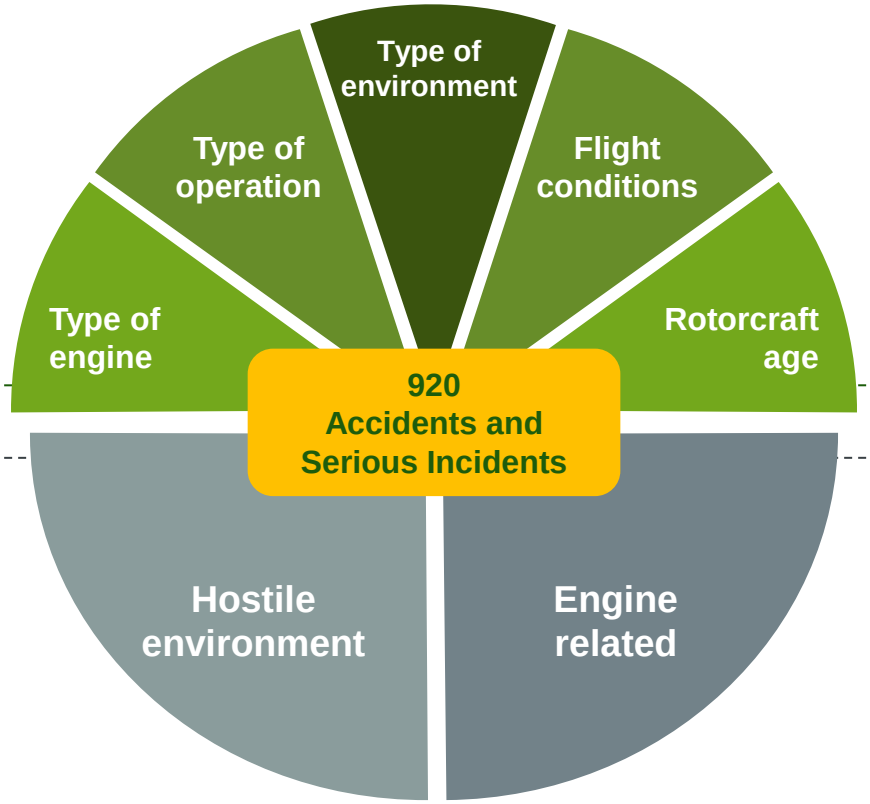
3.600.000 FH correspond to **piston-engined** helicopters (35% of total FH)

- All of the 31 CAAs were consulted, but only 22 CAAs responded positively to the enquiry. Only 13 CAAs delivered information regarding usage data on their helicopter fleets, representing 28% of the total Single-engined Helicopter fleet in Europe.
- Once completed, the data was cross-checked with the accident data sent by Eurocopter and Bell, containing dates and models of their registered occurrences

The plain analysis assessed a fatality study regarding the types of engines, operations, type of environment or flight conditions

Plain Analysis

Multi-Criteria Analysis



Plain Analysis

Multi-Criteria Analysis

Histogram distribution

Annual average of 100 accidents and serious incidents
Clear evidence of an increase in the reporting of minor incidents over the last few years

Personnel Injury

19% of fatality in accidents and serious incidents (920 occurrences)

Aircraft Damage

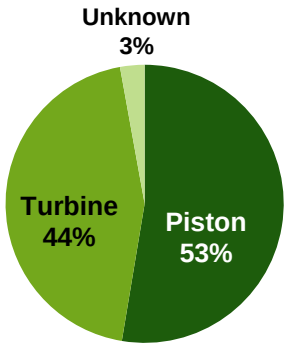
38% of destroyed aircraft and 48% with substantial damage (920 occurrences)

The analysis per type of engine shows a piston accident and serious incident rate per 100,000 FH that is more than 2 times bigger than turbine rate

920
Accidents and Serious Incidents

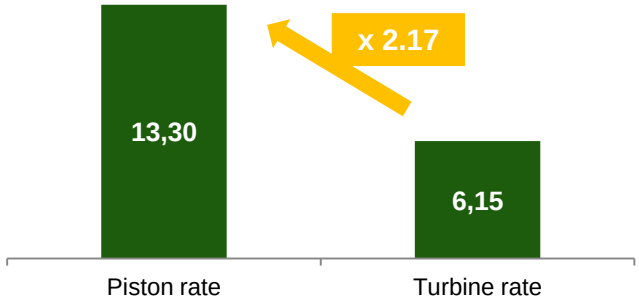
408 Turbine occurrences

482 Piston occurrences

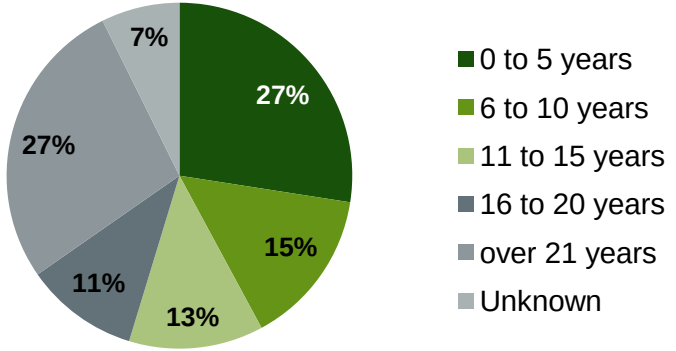


	Piston	Turbine
Occurrences	482	408
Accidents & Serious incidents per 100.000FH	13,30	6,15
Injury: Fatality	14%	24%
Damage: Destroyed	40%	37%

Accidents and serious incidents rate per 100.000 FH per engine type



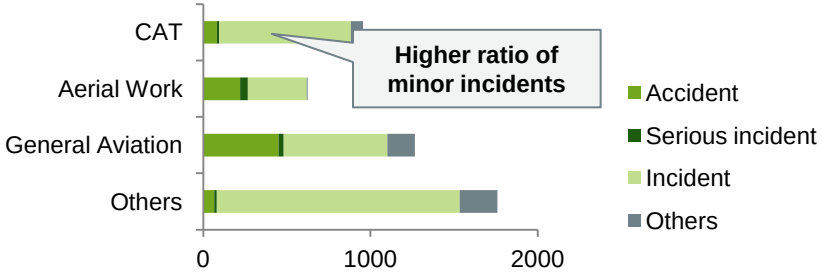
Accidents and serious incidents distributions per age group



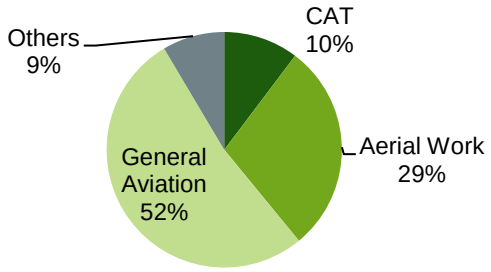
After these parallel analyses, it can be concluded that personal injuries are more common in turbine engines, but the damage of the rotorcraft is more common in piston-engine helicopter occurrences

Regarding environment hostility, the analysis recorded a fatality rate over hostile environment almost double than over non-hostile

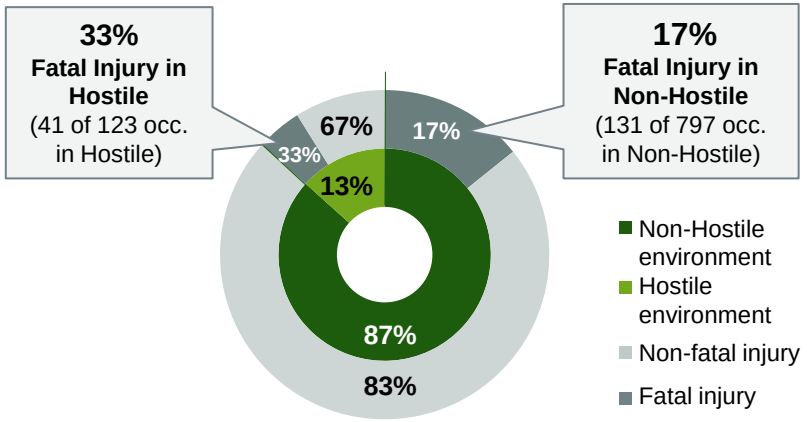
All events distribution per type of operation



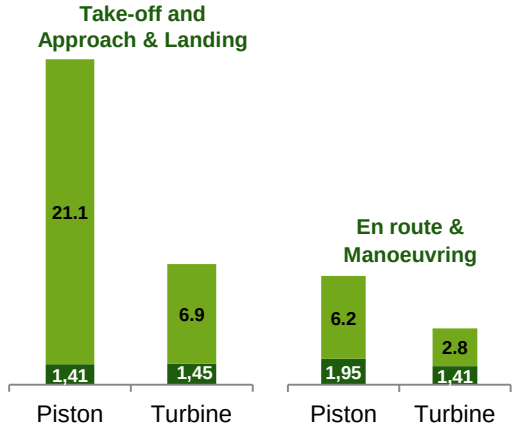
Accidents and serious incidents distribution per type of operation

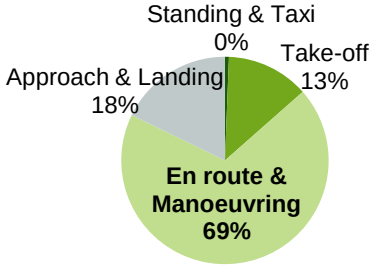


Accidents and serious incidents distribution per fatality share per type of environment



Accidents and serious incidents rate per 100.000 FH per phase of flight





Fatal accidents and serious incidents distribution per phase of flight

It can also be observed that CAT operations have a substantially-higher ratio of minor incidents by accidents and serious incidents, comparing AW and GA. This point confirms the fact that CAT operations are better than the rest of activities.

The multi-criteria analysis has allowed reflecting the joint influence of environment hostility, type of engine and type of operation on the fatality

890 valid accidents and serious incidents filed under piston and turbine have been recorded

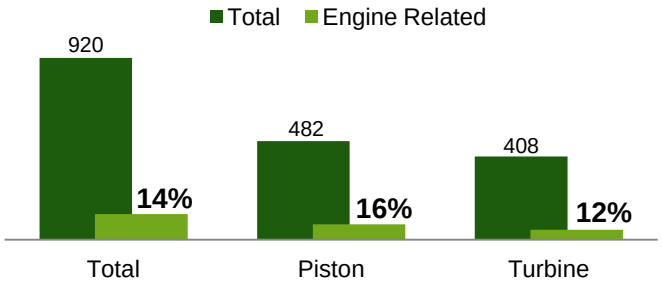
Type of operation	Piston-engined		Turbine-engined	
	Non-Hostile	Hostile	Non-Hostile	Hostile
Commercial Air Transport	6 fatal occurrences over a total of 26 occurrences (23% of fatality)	0 / 2 (0%)	10 / 45 (22%)	6 / 19 (32%)
Aerial Work	5 / 54 (9%)	3 / 11 (27%)	24 / 139 (17%)	18 / 58 (31%)
General Aviation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

Accidents & Serious incidents + **En route & manoeuvring** + **Turbine engined** + **Hostile Environment** + **CAT operations** → **62% of fatality (5 fatal occ. over a total of 8 occ.)**

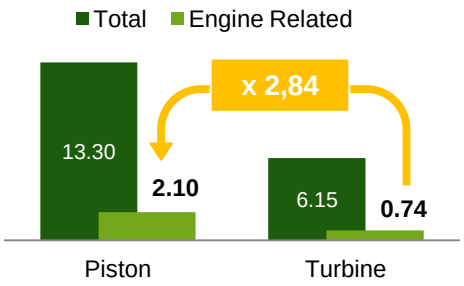
- Piston and turbine-engined helicopters have a similar rate of fatality in hostile environments: 32% of accidents and serious incidents
- In **CAT operations**, turbine-engined presents a 32% fatality rate over hostile environment

Furthermore, a detailed analysis has been focused on engine-related accidents and serious incidents

Engine-related accidents and serious incidents per type of engine

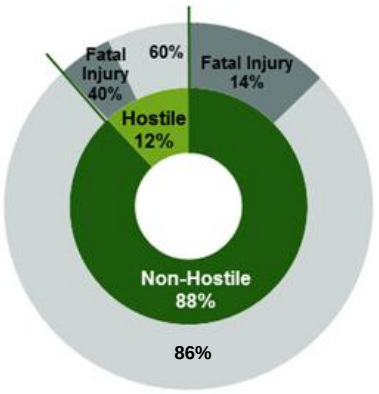


Engine-related accidents and serious incidents rate per 100,000 FH per engine type

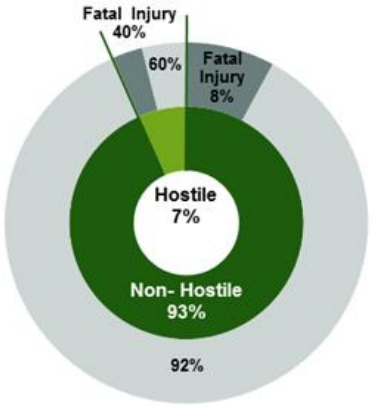


Engine related accidents and serious incidents distribution and fatality share per type of environment and engine

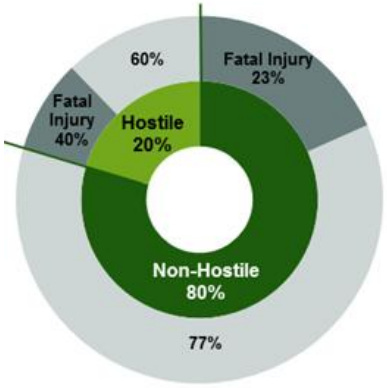
TOTAL



PISTON



TURBINE



Significant higher fatality rate for engine-related events in the case of turbine-engined helicopters (vs. piston)

**It should be noted that the number of engine-related events evaluated is very small*

Engine-related occurrences represents 14% of the total accidents and serious incidents (126 engine-related events over 920 occurrences)

125 valid engine-related accidents and serious incidents filed under piston and turbine have been recorded

Type of operation	Piston-engined		Turbine-engined	
	Non-Hostile	Hostile	Non-Hostile	Hostile
Commercial Air Transport	0 fatal occurrences over a total of 2 occurrences (0% of fatality)	0 / 0 (-)	1 / 4 (25%)	1 / 3 (33%)
Aerial Work	0 / 11 (0%)	0 / 2 (0%)	4 / 17 (24%)	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%)**

12% of engine-related occurrences over hostile environment (15 of 125)

6% of piston engine-related occurrences over hostile environment (5 of 76)

20% of turbine engine-related occurrences over hostile environment (10 of 49)

The relative number of engine-related occurrences per 100.000FH is very influenced by the type of engine:

- 2,10 piston engine-related accidents and serious incident per 100.000FH
- 0,74 turbine engine-related accidents and serious incident per 100.000FH

The factor-identification analysis of 503 accidents and serious incidents (with recorded and published reports) identified the following causes

	Commercial Air Transport	Aerial Work	General Aviation
SPS level 2 >25% of occurrences *Standard Problem Statements Taxonomy*	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 *Human Factors Analysis and Classification System Taxonomy*	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 execution or psycho-behavioural 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 skills and non-proper procedure implementations

% of occurrences that have at least one code of this category

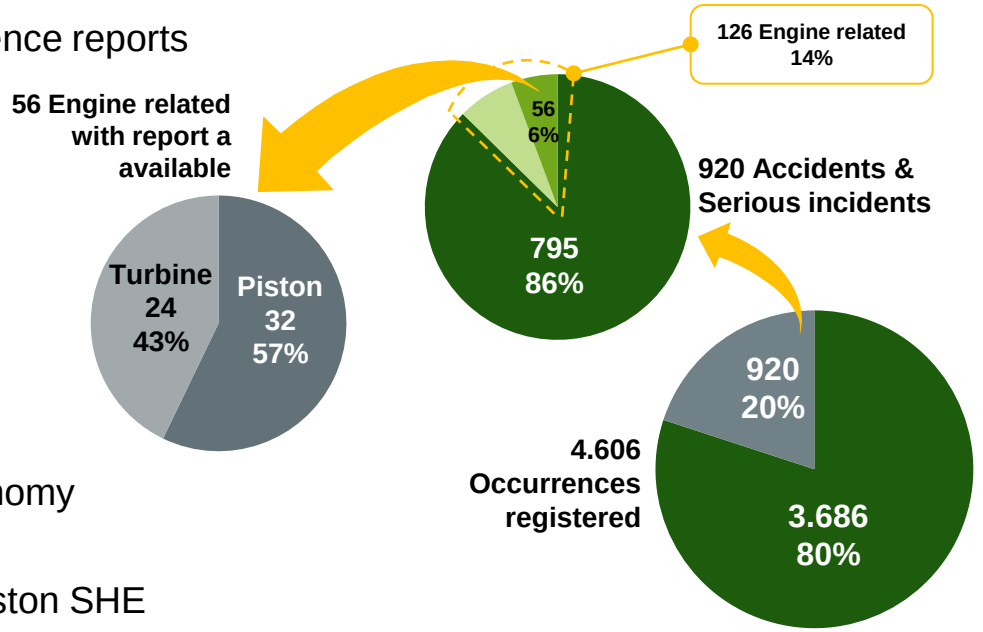
Top 3 level 1 SPS categories : Pilot judgment & actions (76%), Safety Management (61%), Ground Duties (37%)

Top 3 level 1 HFACS categories: Unsafe Acts - Errors (55%), Preconditions - Condition of Individuals (34%), Supervision (19%)

The most common hazard for engine-related occurrences has been identified both for piston and turbine-powered helicopters by using the SPS coding system

1 Filter out all engine-related events by scanning occurrence reports

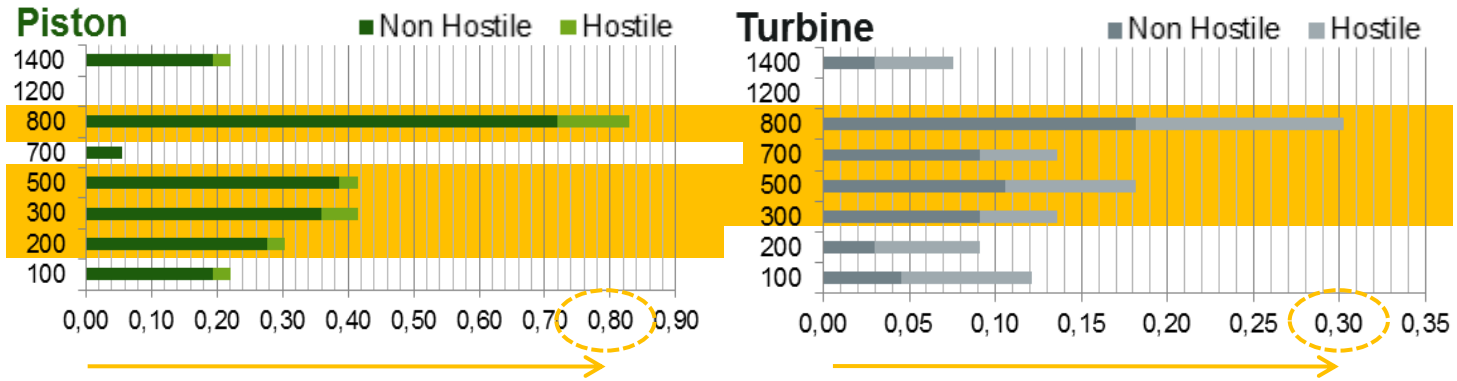
Concept	Number of occurrences	Ratios per 100.000 FH
Occurrences registered	4.606	45,01
Accidents & Serious incidents	920	8,99
Accidents & Serious incidents engine related (with report available)	56	0,55
- Piston	32	0,89
- Turbine	24	0,36



2 Categorize engine-related events based on SPS taxonomy

3 Identify failure ratios per 100,000 FH for turbine vs. piston SHE
(also over hostile / non-hostile environment) to identify the most relevant causes

Aircraft Design (1400)
Ground personnel (1200)
Part / system failure (800)
Pilot situation awareness (700)
Pilot judgment & actions (500)
Maintenance (300)
Safety Management (200)
Ground Duties (100)



Piston occurrences register higher frequency rates

Two combined approaches have been developed to assess the severity and frequency of hazards (methodology explanation)

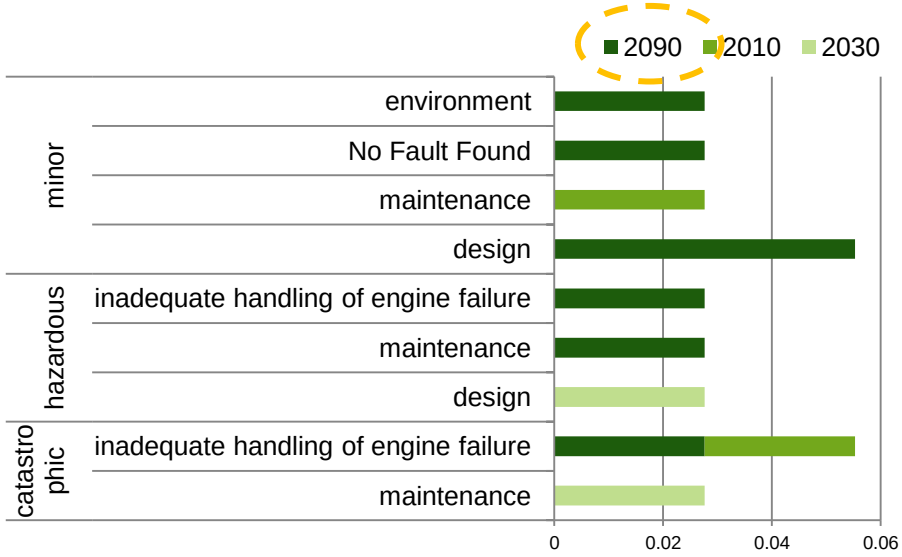
Limitations on standard methodology

1. Severity of events. The number of confirmed engine-related events is relatively low
2. Occurrence rates. Events with minor or no damage/injury are not always reported or remain at operator level

Final methodology

1. Isolate the initial cause of engine-related accidents (SPS) according step 3 of Hazard Identification
2. Assign events to clusters
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
5. Determine the severity of an event
6. Select several SPS Level 2 code groups for piston and turbine-engined SEH as **INPUT FOR MITIGATION STRATEGIES**

Example: Piston relative occurrences rates per 100.000FH of SPS Level 2 codes within Level 1 = 200 (Safety Management)



Example: Piston list of events within SPS Level 1 = 200 (Safety Management (3 first rows)

Occ	Event		SPS L 2	Hostile environment	Actual Severity	Estimated Severity	
	Description	Cluster				Hostile	Non-hostie
7	Engine shutdown due to ignition failure	Design	2030	Y	Hazardous	Catastrophic / Hazardous	Hazardous / Minor
132	Spark plug issues caused loss of power	Maintenance	2030	N	Catastrophic	Catastrophic / Hazardous	Hazardous / Minor
610	Fractured camshaft; engine failure	Design	2090	N	Minor	Hazardous / Minor	Minor

An overview of the technological improvements to improve safety in case of engine failure and in planning and tracking En-route flight has been assessed

To Increase safety in engine failure situations
To improve pilot-awareness conditions and to decrease exposure times and pilot workload

Hybrid Engines

Hybrid engines combine an electric system to create a supplementary power boost in critical phases such as take-off, loitering or/and autorotation landings in case of engine failure

Cameras

Cameras record high-resolution images of the cockpit to investigate the causes of accidents and for documenting flight conditions

Navigational aids

Systems with a lot of potential, in relation to monitoring and tracking the En Route phase

Warning Caution and Advisory systems

It improves the pilot attention

Obstacle recognition systems

It allows safe operation without hindering manoeuvrability

Pilot Vehicle Interfaces

PVI monitor the main vehicle and engine parameters

Ground Proximity Warning System (EGPWS)
Crew Alert System (EICAS)
Safe Flight's Exceedance Warning System

Wire Strike Protection System (WSPS)
Powerline Detector System (PDS)
Radar Systems

Vehicle and Engine Multifunction Display (VEMD)
First-Limit Indicator (FLI)
Full Authority Digital Engine Control (FADEC)

OEMs highlight the incorporation of **hybrid engines,** which combine an electric system to create a supplementary power

- **Eurocopter** has developed an AS350 hybrid demonstrator
- **Turbomeca** has proposed a thermodynamic and electric hybrid-engine solution

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Proactive and reactive mitigation measures will be established for the relevant risks identified, by order of importance and by engine type

		REACTIVE MEASURES	PROACTIVE MEASURES
Piston / turbine	**8020** **Part / system failure – Power plant**	**Hybrid techniques** to support loss of power	**HUMS** on-board coupled with maintenance procedures
Piston / turbine	**500** **Pilot judgment and actions**	**Flight data monitoring** and analysis	**RADAR** altimeter on-board coupled with Audio / tactile warning system **EICAS / EGPWS** on-board
Piston / turbine	**3010** **Maintenance – maintenance management**	Adjustment of **maintenance intervals**	**HUMS** on-board coupled with maintenance procedures
Turbine	**7020** **Pilot SA – environment awareness**	**Flight data monitoring** and analysis	**RADAR** altimeter on-board coupled with Audio / tactile warning system **EICAS / EGPWS** on-board
Piston	**2090** **Safety management – inadequate pilot experience**	**Flight data monitoring** and analysis	**Additional training on Full Flight Simulators** Training on less-complicated trainer helicopters with typical flying characteristics

After concluding the Safety Risk Assessment, final mitigation measures were assigned to the main hazards defined by SPS level 1 and level 2 categories, both related to piston and turbine engine helicopters

After reviewing the whole concept of single-engined helicopter operations, the consortium highlights next facts:

1. The aim of the study is the assessment of on whether or not single-engined helicopter operations over a hostile environment should be allowed according to JAR-OPS 3.005(e) standard and the successor rule, CAT.POL.H.420

2. The operational assessment of JAR.OPS 3.005(e) approvals analysis have showed important variant on the standard implementation between member states

3. The main difficulties found by the consortium in data gathering development were:
   - Lack of information and standardization of the collected occurrences data between countries
   - The fact that some data required was unprocessed producing difficulties in CAA responses and availability

4. Piston-engined accidents and serious incidents rate per 100.000FH is 2,16 times bigger than that of turbine-engined aircraft (13,30 vs. 6,15 piston and turbine-engined accidents and serious incident per 100.000FH)

5. 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

6. Engine-related occurrences represents 14% of the total accidents and serious incidents

7. The safety risk assessment involved only 56 engine-related occurrences due to the associated risk of an engine failure in SEH. It proposed mitigation measures to reduce the risk based on hybrid power techniques, Health Usage Monitoring Systems coupled with maintenance procedures and flight data monitoring (EGPWS, EICAS, RADAR, FFT)

A review of JAR-OPS 3.005(e) approvals under the perspective of SEH established next recommendations:

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, permitting operations along routes or within areas in which the surfaces available permit a safe forced-landing under a specific set of conditions.

1 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**

Turbine engine failure rate
0,74x10^{-5} per flight hour

Piston engine failure rate
2,10x10^{-5} per flight hour
(over the limit of1x10-5 per flight hour)

x 2.5

It is therefore **recommended to**:

- **Retain the alleviation**; but...
- **...not to expand it to piston-engined helicopters**
- **Maintain permanent nature**

2 Regarding seat capacity,

Former regulation:
MAPCS
of 6 passengers
(established by certification TC, STC..)

→

New regulation:
MOPCS
of 6 passengers
(established by each operating helicopter manual)

→

It is therefore recommended to:

- **Maintain the limit of 6 passengers (MOPSC)**; but...
- **...review it with a deeper analysis involving all the stakeholders**

3 It is recommended to ensure that **all states apply the same standards** in the same manner, and ultimately when Implementing Rule 965/2012 takes effect on 28 October 2014

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