



# Notice of Proposed Amendment 2016-01

## Helicopter ditching and water impact occupant survivability

RMT.0120 (27&29.008) — 23.3.2016

### EXECUTIVE SUMMARY

This Notice of Proposed Amendment (NPA) addresses safety issues related to helicopters certified for ditching and performing overwater operations.

Previous studies on and accident investigations into helicopter ditchings and water impact events have highlighted inadequacies in the existing certification specifications (CS-27, CS-29) and in the rules governing offshore operations. In particular, it has been established that in an otherwise survivable water impact, most fatalities occurred as a result of drowning because the occupants were unable either to rapidly escape from a capsized and flooded cabin, or to survive in the sea for sufficient time until rescue. Furthermore, the testing environment in which helicopters are type-certified for ditching bears little resemblance to the sea conditions experienced in operation.

In order to thoroughly address these and other ditching-related issues, and due to the nature of ditching-related hazards, this rulemaking task (RMT.0120 (27&29.008)) has taken a holistic approach to the problem, which crosses traditional airworthiness/operational boundaries. A detailed risk assessment has been undertaken that reflects both certification and operational experience and builds upon data extracted from accident reports and previous studies. The result is a list of identified interventions related to helicopter design, certification, operations, and ditching equipment, all of which could contribute to improving safety. In the case of operations, the Rulemaking Group (RMG) RMT.0120 (27&29.008)) has interfaced with the RMG RMT.0409 & RMT.0410 (OPS.093(a)&(b)), amending Annex V (Part-SPA) to Regulation (EU) No 965/2012 to introduce helicopter offshore operations (HOFO), to ensure a consistent set of rules.

The specific objective of this NPA, however, is to propose changes to CS-27 and CS-29 to mitigate helicopter design-related risks to new helicopter types. Recommendations for safety improvements in other areas have been made by the RMG for subsequent action to be taken under this rulemaking task, other rulemaking tasks or through alternative means. Retroactive rules are to be considered in a second phase of this RMT.

This NPA proposes changes to many CS-27/29 provisions that relate to ditching. However, the primary change proposed aims to establish a new ditching certification methodology by which a target probability of capsize following a ditching can be determined based on the level of capsize mitigation applied to the design. This target probability of capsize is then verified in sea conditions chosen by the applicant, by following a defined tank test specification using irregular waves. For CS-29 and CS-27 Cat A rotorcraft, enhanced capsize mitigation must be provided to relieve the time pressure on occupants to escape. Water impact events are accounted for implicitly within the new ditching methodology. Additional changes are proposed to maximise the likelihood of occupant egress and subsequent survivability.

The proposed changes are expected to increase safety.

Applicability		Process map	
Affected regulations and decisions:	ED Decision No. 2003/15/RM (CS-27) ED Decision No. 2003/16/RM (CS-29)	Terms of reference (ToR), Issue 1	24.10.2012
Affected stakeholders:	Rotorcraft manufacturers and offshore operators	Concept paper (CP):	No
Driver/origin:	Safety	Rulemaking group (RMG):	Yes
Reference:	N/a	Regulatory impact assessment (RIA) type:	Full
		Technical consultation during NPA drafting:	Yes
		Duration of NPA consultation:	3 months
		Review group (RG):	Yes
		Focused consultation:	TBD
		Opinion expected publication in:	N/a
		Decision expected publication in:	2016/Q3



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## 1. Procedural information

### 1.1. The rule development procedure

The European Aviation Safety Agency (hereinafter referred to as the 'Agency') developed this Notice of Proposed Amendment (NPA) in line with Regulation (EC) No 216/2008<sup>1</sup> (hereinafter referred to as the 'Basic Regulation') and the Rulemaking Procedure<sup>2</sup>.

This regulatory activity is included in the Agency's [5-year Rulemaking Programme](#) under RMT.0120 (27&29.008).

The text of this NPA has been developed by the Agency based on the input of RMG RMT.0120 (27&29.008). It is hereby submitted for consultation of all interested parties<sup>3</sup>.

The process map on the title page contains the major milestones of this regulatory activity to date and provides an outlook of the timescale of the next steps.

### 1.2. The structure of this NPA and related documents

Chapter 1 of this NPA contains the procedural information related to this task. Chapter 2 (Explanatory Note) explains the core technical content. Chapter 3 contains the proposed text for the new provisions. Chapter 4 contains the regulatory impact assessment (RIA) showing which options were considered and what impacts were identified, thereby providing the detailed justification for this NPA.

Appendix A details a review of previous reports and their main findings and recommendations.

Appendix B details the hazard identification and risk assessment associated with ditching and survivable water impacts, undertaken as part of this rulemaking task. All mitigations identified are subsequently assessed in each chapter of this Appendix to establish their safety benefit. The outcome and related recommendations are summarised in Chapter 7.2.1 — Table B-1, and in Chapter 5 — Recommendations for future rulemaking. Recommendations related to initial airworthiness are then further assessed in Chapter 4 — RIA. If a recommendation had passed all the steps, then it was implemented in the proposed CS/AMC changes in Chapter 3 — Proposed amendments.

Appendix C contains a list of known helicopter ditching/water impact events worldwide.

### 1.3. How to comment on this NPA

Please submit your comments using the automated **comment-response tool (CRT)** available at <http://hub.easa.europa.eu/crt/><sup>4</sup>.

The deadline for submission of comments is **23 June 2016**.

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<sup>1</sup> Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.3.2008, p. 1).

<sup>2</sup> The Agency is bound to follow a structured rulemaking process as required by Article 52(1) of the Basic Regulation. Such a process has been adopted by the Agency's Management Board and is referred to as the 'Rulemaking Procedure'. See MB Decision 01-2012 of 13 March 2012 concerning the procedure to be applied by the Agency for the issuing of opinions, certification specifications and guidance material.

<sup>3</sup> In accordance with Article 52 of the Basic Regulation and Articles 5(3) and 6 of the Rulemaking Procedure.

<sup>4</sup> In case of technical problems, please contact the CRT webmaster ([crt@easa.europa.eu](mailto:crt@easa.europa.eu)).



#### 1.4. The next steps in the procedure

Following the closing of the NPA public consultation, the Agency will review all comments.

The outcome of the NPA public consultation will be reflected in the respective comment-response document (CRD).

The Agency will publish the CRD concurrently with the Decision.

The Decisions based on this NPA and the outcome of the consultation will contain the changes to certification specifications (CSs)/acceptable means of compliance (AMC) to EU regulations and will be published on the Agency's website.



## 2. Explanatory note

### 2.1. Background

Helicopters have a natural instability when floating on the water with a tendency to capsize and remain inverted due to their high centre of gravity in relation to their centre of buoyancy. To counter this natural instability and to provide opportunities for the occupants to escape, most helicopters used in offshore operations are required by Regulation (EU) No 965/2012<sup>5</sup> (hereinafter referred to as the 'Air Ops Regulation') to be fitted with an emergency flotation system (EFS), normally in the form of inflatable bags that are only deployed immediately before or after water entry. The EFS is designed for a controlled ditching but may also provide some protection when the helicopter is sinking in a water impact event.

Capsize creates particular hazards to occupants. The cockpit/cabin quickly fills with water leading to an inability to breathe, thus creating an urgency to escape. This is a particular concern in cold water, where it is well established that the time necessary for escape can exceed an occupant's breath-hold time. Capsize may also lead to occupant disorientation which would further hinder escape. Operational experience has shown that drowning has been the greatest cause of death following helicopter ditchings and survivable water impacts.

Following a number of helicopter ditching and water impact events in the 1980s and 1990s, and subsequent reports compiled by the United Kingdom Civil Aviation Authority (UK CAA)<sup>6</sup>, the Federal Aviation Administration (FAA)<sup>7</sup> and others, the Joint Aviation Authorities (JAA)/FAA initiated two separate studies<sup>8</sup> to identify possible improvements on the design provisions. These studies, completed in 2000, contain multiple recommendations.

The JAA/FAA categorised these recommendations as referring either to:

- (a) advisory circular (AC)/AMC changes only;
- (b) changes requiring a new rulemaking task; or
- (c) future research.

The JAA/FAA initiated the AC/AMC changes as part of scheduled updates that were published in FAA AC 27-1B and AC 29-2C Change 2 (April 2006). However, due to the establishment of the Agency which replaced JAA, Change 2 was not formally adopted in Europe until November 2008, where it was incorporated in Amendment 2 of CS-27 and CS-29.

<sup>5</sup> Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council (OJ L 296, 25.10.2012, p. 1).

<sup>6</sup> — CAP 491 — Helicopter Airworthiness Review Panel (HARP), UK CAA, June 1984.  
 — CAP 641 — Review of Helicopter Offshore Safety and Survival (RHOSS), UK CAA, February 1995.  
 — CAA Paper 96005 — Helicopter Crashworthiness, UK CAA, July 1996.

<sup>7</sup> — DOT/FAA/CT-92/13 — Rotorcraft Ditchings and Water Related-Impacts that Occurred from 1982 to 1989, Phase I, FAA, 1993.  
 — DOT/FAA/CT-92/14 — Rotorcraft Ditchings and Water Related-Impacts that Occurred from 1982 to 1989, Phase II, FAA, 1993.

<sup>8</sup> — JAA/FAA — Report of the Joint Harmonization Working Group on Water Impact Ditching Design and Crashworthiness (WIDDCWG), January 2000.  
 — JAA HOSS Working Paper HOSS/WP-99/8.5 — Helicopter Safety and Occupant Survivability Following Ditching or Water Impact, JAA, June 2000.



On receipt of the JAA proposals, the Agency created RMT.0120 as a future rulemaking task. The rulemaking task was not immediately initiated due to the need to undertake research, particularly on the practicality of the ‘side-floating’ concept, which was launched in 2007. The ‘side floating’ concept was a solution identified in research commissioned by the UK CAA as one means of preventing helicopter total inversion by fitting additional floats high up on the side of the cabin (see Chapter 6.3, CAA Paper 97010).

In 2010, initial reports from the European Helicopter Safety Team (EHST), and in particular from the European Helicopter Safety Implementation Team addressing rulemaking issues (EHSIT-ST-R), highlighted three of the top 10 rulemaking activities as related to ditching/water impacts. RMT.0120 was therefore given higher priority in the Agency’s Rulemaking Programme (RMP). A dedicated workshop was also organised by the Agency in 2011 in association with the fifth annual EASA Rotorcraft Symposium.

RMT.0120 was formally launched by the Agency in October 2012. The task aims to take a holistic approach to ditching, water impact and survivability, although its prime focus remains on airworthiness.

#### RMT.0120 — Timeline

Date	Task	Comments
2005	Ditching task transferred to the Agency from JAA.	RMT.0120 created.
2006	AC changes developed and published in FAA AC 29-2C Change 2.	Changes formally adopted in CS-27 Amdt 2 and CS-29 Amdt 2 published in 2008.
July 2006	International Helicopter Safety Team (IHST)/EHST launched.	Aimed to enhance helicopter safety through a data-driven approach.
October 2007– December 2008	Research project EASA.2007.C16, Study on Helicopter Ditching and Crashworthiness.	It specifically addressed the practicalities of the ‘side-floating’ concept.
July 2010	EHSIT ST-R, IHST/EHST subgroup, provides a list of priority rulemaking tasks.	Three out of top 10 covered by RMT.0120.
December 2011	Helicopter Ditching, Water Impact and Survivability Workshop held.	Aimed to gather information prior to launching the RMT, and to scope the ToR.
October 2012	RMT.0120 launched.	

It is noteworthy that following the controlled flight into terrain (CFIT) accident on approach to Sumburgh Airport (AS332L2 G-WNSB) in August 2013, there has been raised public awareness of helicopter offshore safety and heightened scrutiny of airworthiness and operational standards applied to helicopters performing offshore operations in the North Sea in support of oil and gas exploration.



Several safety reviews have been initiated, including by the UK CAA (see Chapter 6.3, CAP 1145), and by the Transport Select Committee of the House of Commons in the UK Parliament (see Chapter 6.3). Furthermore, a number of bodies have been established either by regulators or by operators in an attempt to enhance safety and share best practices.

## 2.2. Overview of the issues to be addressed

This RMT focuses on survivability of occupants following a ditching or water impact. How the helicopter comes to enter the water is not the focus of this RMT. It may have been a result of one or more technical failures or a human factors (HF)-related event, or a combination of both. These issues are the subject of other safety initiatives. This RMT focuses on occupant survivability in the event of entering the water, with particular emphasis put on helicopter design.

The essential requirements for airworthiness contained in Annex I (Essential requirements for airworthiness referred to in Article 5) to the Basic Regulation state under 2.c.2. that: (...) *Provisions must be made to give occupants every reasonable chance of avoiding serious injury and quickly evacuating the aircraft and to protect them from the effect of the deceleration forces in the event of an emergency landing on land or water. (...)*

Experience has shown that ditching/water impact events can lead to avoidable loss of life. In otherwise survivable water impacts, there have been avoidable drowning fatalities due to the inability of the occupants to rapidly escape from a capsized and flooded cabin or, after having successfully escaped, their inability to subsequently survive until the rescue services arrive. Even a successful helicopter ditching could still have catastrophic consequences due to the tendency for a helicopter to capsize. Enhanced design standards are therefore proposed to both reduce the likelihood of capsize and further improve the ability of occupants to escape and survive.

The related [ToR RMT.0120](#) were published on the Agency's website in October 2012.

For a more detailed analysis of the issues addressed by this proposal, please refer to Chapter 4 below.

## 2.3. Objectives

The overall objectives of the EASA system are defined in Article 2 of the Basic Regulation. This proposal will contribute to the achievement of the overall objectives by addressing the issues outlined in Chapter 2 of this NPA.

The specific objectives are to improve, with cost-efficient solutions, the safety of helicopter occupants in case of a ditching or a water impact event.

## 2.4. List of definitions used in this NPA

- DITCHING: an emergency landing on water, deliberately executed in accordance with rotorcraft flight manual (RFM) procedures, with the intent of abandoning the rotorcraft as soon as practicable.
- DITCHING EMERGENCY EXIT: an emergency exit designed and installed to facilitate rapid occupant escape from a capsized and flooded rotorcraft.
- DITCHING EQUIPMENT: a subset of safety equipment used exclusively for water survival (e.g. life raft, life preserver, immersion suits, emergency breathing systems (EBSs)).



- EMERGENCY BREATHING SYSTEM (EBS): a form of personal protective equipment that provides the user with a means to breathe underwater for at least one minute, overcoming the need to make a single breath last for the complete duration of an underwater escape. If used correctly, EBS can mitigate the risk of drowning. EBSs are categorised as either:
  - Category A: capable of deployment in air and underwater within 12 seconds; or
  - Category B: capable of deployment in air within 20 seconds.
- EMERGENCY FLOTATION SYSTEM (EFS): a system of floats and any associated parts (gas cylinders, means of deployment, pipework and electrical connections) that is designed and installed on a rotorcraft to provide buoyancy and flotation stability in a ditching. The EFS includes any additional floats which only have a function following capsizing.
- EMERGENCY LANDING ON WATER: no longer used as a defined term and replaced by either 'Ditching' or 'Safe forced landing'.
- EMERGENCY LOCATOR TRANSMITTER (ELT): a generic term describing equipment which broadcasts distinctive signals on designated emergency frequencies and, depending on application, may be automatically activated by impact or be manually activated. An ELT may take different forms.
- RETAINING LINE (sometimes known as a static line, mooring line or painter line): a chord that is attached between a life raft and the rotorcraft. Two retaining lines are typically fitted, a short and a long one. The short retaining line is provided to position the raft during occupant transfer from the rotorcraft to the life raft. The long retaining line is provided to allow the life raft to drift away from the rotorcraft but remain attached thereto, thus facilitating survivor(s) location by rescuers. Both retaining lines are designed to release the life raft without damage should the rotorcraft sink.
- SAFE FORCED LANDING: an unavoidable landing or ditching with a reasonable expectancy of no injuries to persons inside the rotorcraft or on the surface.
- SAFETY EQUIPMENT: installed equipment aimed directly at preventing risks to human life (e.g. fire extinguisher, evacuation slide, emergency flotation system, emergency cabin lighting, ELT, and signalling devices).
- SEA STATE (SS): a classification of sea conditions established by the World Meteorological Organization (WMO). As the WMO no longer recommends the use of sea states, the term is used in this NPA only in a historic context. SS has been replaced by significant wave height ( $H_s$ ).
- SIGNIFICANT WAVE HEIGHT ( $H_s$ ): the average value of the height (vertical distance between trough and crest) of the highest third of the waves present.
- SURVIVAL EQUIPMENT: subset of ditching equipment that is attached to a life raft (e.g. ELT(s), signalling devices, sea sickness tablets, and other life-saving equipment, including means to sustain life).
- SURVIVABLE WATER IMPACT: a water impact with a reasonable expectancy of no incapacitating injuries to a significant proportion of persons inside the rotorcraft, and where the cabin and cockpit remain essentially intact.



- WATER IMPACT: unintentional contact with water or exceeding the demonstrated ditching capability for water entry.

## 2.5. Summary of the RIA

The following options have been considered in the RIA:

Baseline	No change in rules: risk remains as outlined in the issue analysis.
Minimum change	A package of regulatory changes, each of which is considered to be too limited in safety and/or cost impact to warrant separate treatment. Some changes introduce provisions that already exist as requirements in the Air Ops Regulation, some make mandatory design features that are currently embodied in some rotorcraft on a voluntary basis. Others are new.
Capsize mitigation	Post-capsize survivability features (CS-29 and CS-27 Cat A only) and improved guidance regarding EFS design. The former will ensure that occupants of a rotorcraft which capsizes rapidly after a ditching or water impact are provided with an instantly available source of air, and the latter will lead to better assurance that a rotorcraft will float reliably as intended.
Irregular-wave testing	Change of certification methodology and testing to give increased confidence in a rotorcraft's seakeeping performance. A test standard is introduced requiring scale model testing in waves that represent real-world conditions. Pass/fail criteria are probabilistically based.

After due consideration of all the benefits and costs of these options, it has been concluded that the regulatory activity is warranted, i.e. the baseline option is not selected and all three others are selected albeit with some alleviations for rotorcraft certified to CS-27 non-category A standards.

**Table 1: Summary of main impacts**

Impacts	Option 0	Option 1	Option 2	Option 3
	Baseline	Minimum change	Capsize mitigation	Irregular-wave testing
<b>Safety</b>	Safety will remain at the current level	Potential to save 1 life per year	Greatest improvement in safety (2.3 lives saved per year)	Potential to prevent capsize following a ditching
<b>Economics (annual development cost in euros and as share of revenue)</b>	No impact	500 000 0.002% Insignificant	7 300 000 0.030% Very low	300 000 0.0001% Very low
		Options 1, 2 & 3 combined: 8 100 000, 0.033%, Very low		

Full details of the RIA can be found in Chapter 4 below.



## 2.6. Overview of the proposed amendments

This NPA proposes numerous safety enhancements to CS-27 and CS-29. However, the greatest proposed change to the existing certification practice and state-of-the-art rotorcraft designs is the introduction of the following two safety enhancements:

- (a) A new provision that, following post-ditching capsizing, including the case of loss of the most critical float compartment, the rotorcraft must be designed to provide enhanced post-capsizing survivability features for all passengers (only for CS-27 Category A and CS-29). Experience has shown that drowning is the most likely cause of fatalities due to the incompatibility between the breath-hold capability and the time required to escape. Many accident reports highlight that survivors were only able to escape due to fortuitous circumstances where they found themselves in an air pocket, without any recollection of how they arrived there. The existence and availability of air for continued survival in a capsized rotorcraft cabin is not a design consideration at present, and the hazard to passengers is therefore not controlled if an immediate source of air is not available. EBS can offer an additional benefit by providing a limited air source sufficient for an escape; however, due to the uncertainties regarding passengers' response to an emergency situation and their possible panic and shock, EBS cannot be relied upon and is not seen as an alternative for new CS-27 Category A and CS-29 designs.

Enhanced post-capsizing survivability features are required in the proposals which will provide benefit in water impact events where immediate capsizing is almost certain and, historically, the largest number of fatalities has occurred. However, establishing a certification specification that is dependent on varying levels of impact damage was found to be impracticable. The proposed new certification specification is therefore based on post-ditching capsizing, and accepts that the level of mitigation provided may vary with the level of damage sustained in a water impact.

- (b) A new type-certification methodology is introduced aimed at providing greater confidence in a rotorcraft's post-ditching seakeeping performance in the wave climate associated with the intended area(s) of operation. The methodology is based on substantiating a target capsizing probability in sea conditions specified by the applicant, with different required target probabilities dependent on the degree of capsizing mitigation provided. For CS-27 Category A and CS-29 rotorcraft, enhanced capsizing mitigation is in fact required but for CS-27 non-Category A rotorcraft only, a relaxation is accepted in the form of EBS. Demonstration that the target capsizing probability is met is required through model tank tests using irregular waves, following a defined test specification. The demonstrated sea conditions and other information specified by the applicant is required to be placed in the performance section of the RFM. It is strongly recommended that oversight authorities use this information to set appropriate operational limitations.

In addition to the above, other proposed safety enhancements include:

- automatic arming/disarming and deployment of EFS;
- provision for a rotorcraft to float with the largest flotation unit failed;
- demonstration that it is feasible for cabin occupants to easily egress the rotorcraft and enter the life raft(s);
- optimising ditching emergency exits for use following rotorcraft capsizing;



- one pair of ditching emergency exits for every four passengers;
- seat rows located relative to ditching emergency exits to best facilitate escape;
- a minimum size for a ditching emergency exit;
- exit marking and lighting for all ditching emergency exits;
- handhold(s) adjacent to ditching emergency exits;
- enhanced integrity and operability of life rafts; and
- improved availability of ELTs.

This NPA proposes the following detailed changes (justification for these changes is provided in Chapter 7.2 — Appendix B: Risk Assessment and Chapter 4 — Regulatory Impact Assessment):

### General

All references to ‘emergency landing on water’ as a defined term have been removed and replaced by ‘ditching’, where appropriate.

References to SS have been replaced by H<sub>s</sub>.

### CS-27

#### CS 27.563

Terminology has been changed to align with the new definitions, with the aim of clarifying terms used and ensuring compatibility of terminology both within the CSs and between CSs and Air Ops Regulation.

The alleviation allowing an assumption of less than 30 kt forward velocity (i.e. ‘credit’ for the wind speed normally associated with the corresponding sea condition) at water entry has been removed. This is related to the expansion of the ditching definition to cover all failure modes, not just landing following loss of engine power (e.g. tail rotor failure requiring a run-on landing, or catering for night or instrument meteorological conditions (IMC)).

A clarification has been added that the wave particle velocity need not be taken into account. The 30-kt forward speed is therefore relative to the wave/water surface.

Means of compliance have been moved to Book 2 (AMC).

#### CS 27.783

New point (c) has been added (copied from CS 29.783(h)).

#### CS 27.801

(a) has been amended to reference all ditching-related provisions.

Terminology has been changed to align with new definitions.

New (c) has been added to mandate automatic deployment of EFS at water entry.

New (d) clarifies that trim and stability analysis is only necessary following a ditching. Reference to the new AMC 27.801(e) Model test method for post-ditching flotation stability has been added. Further



clarification has been given that compliance by similarity will only be accepted if the reference type has previously been subject to testing in accordance with the aforementioned AMC.

New (e) text on compliance by computation has been removed. Text referring to providing appropriate allowances for damage has been moved to the respective AMC. Text referring to the jettisoning of fuel has been removed. The jettisoning of fuel will not add to the buoyancy of the helicopter, but will likely raise the helicopter's centre of gravity (CG), reducing stability, and may also create an additional hazard to occupants.

New (g) requires high-visibility chevrons to be applied to the rotorcraft's undersurface to aid rescuers locate the capsized rotorcraft and determine its orientation.

New (h) requires that sea conditions and any associated information (i.e. any mitigation used in determining the probability of capsizing) are identified in the performance information section of the RFM.

#### **CS 27.805**

It has been revised to require that flight crew ditching emergency exits are designed to function as intended (including the case of capsized rotorcraft), and are provided with additional illuminated markings, and that operating devices (pull tab, handle) are marked with black and yellow stripes.

#### **CS 27.807**

The title has been changed to align with CS-29.

For ditching certification, an increased number of ditching emergency exits, including handholds, are prescribed, and seats are required to be located relative to exits to best facilitate escape.

The provision for ditching emergency exits to be completely above the waterline has been removed.

It requires ditching emergency exits to be designed to function as intended, even with capsized rotorcraft, and provided with additional illuminated markings, and that operating devices (pull tab, handle) be marked with black and yellow stripes.

#### **CS 27.1415**

All ditching equipment must be approved for all sea conditions within the certification with ditching provisions that is approved.

Life rafts must be deployable via remote controls located within easy reach of flight crew members, occupants of the passenger cabin, and survivors in the water, with the rotorcraft in any foreseeable floating attitude.

Life raft deployment must be shown to be reliable with the rotorcraft in any floating attitude and in the sea conditions chosen for demonstration of compliance with the flotation/trim provisions of CS 27.801(e).

Provisions for life raft retaining lines have been clarified.

#### **CS 27.1470**

A new CS has been created to require that an ELT installation is such as to minimise damage that would prevent its functioning following an accident or incident.



**CS 27.1555**

It has been amended to require that emergency controls which may need to be operated underwater are marked with black and yellow stripes.

**CS 27.1561**

Terminology has been changed.

It has been recognised that emergency controls may be operated by passengers.

All safety equipment requires both identification markings and a method of operation.

**CS 27 Appendix C**

Appendix C has been amended to require compliance with certain CS-29 provisions for CS-27 Category A rotorcraft certified for ditching, or having an emergency flotation system.

**AMC 27.563 (amended version of AC 27.563A)**

Terminology has been changed to align with new definitions.

The alleviation for a lower maximum forward velocity has been removed.

It has been clarified that wave particle velocity need not be considered.

Increased guidance on float buoyancy loads has been inserted.

A clarification has been added that sea conditions selected for compliance with CS 27.801(e) should be taken into consideration for structural calculations.

**AMC 27.801**

The definition of ditching has been amended and new definitions have been added. The current definition of ditching has been expanded to cover failures of other essential systems and not just engines. This would better align with ditching experience and RFM emergency procedures.

Terminology has been changed to align with new definitions.

A background has been added.

A complete list of CS provisions that must be met in order for a certification with ditching provisions to be approved has been added.

This AMC provides a new design objective to establish a capsizing probability. The water conditions on which ditching substantiation is based are selectable by the applicant.

A clarification has been provided that the life raft should be directly accessible from the cabin to allow direct transfer of occupants when the helicopter is floating upright.

Water entry has been clarified as AC 27.563A currently mixes structural provisions with those related to the establishment and demonstration of water entry procedures and testing. All structural provisions have been moved to CS 27.563.

The allowable reduction in forward speed has been removed.

Guidance on automatic EFS arming, actuation and good design practice has been added.

Guidance on information required by the RFM has been added.



**AMC 27.801(e)**

It includes a new model test specification for rotorcraft ditching certification in irregular waves.

**AMC 27.805 (replaces FAA AC 27.805)**

Terminology has been changed.

Guidance on the flight crew emergency exit design has been added.

It has been accepted that flight crew may not have direct access to life raft(s).

**AMC 27.807(d) (supplements FAA AC 27.807)**

It provides AMC and guidance material (GM) relating to the provision of ditching emergency exits and cabin layout.

**AMC 27.1411 (amended version of AC 27.1411)**

(b)(3)(i) (life raft stowage inside the rotorcraft is not permitted) has been deleted.

(b)(3)(ii) to (b)(5) have been moved to AMC 27.1415.

(b)(4) (former (b)(6)) has been amended to include consideration of likely damage during water entry.

(b)(5) has been moved from AMC 27.1415. Signalling equipment useable with a gloved hand has been added.

**AMC 27.1415 (amended version of AC 27.1415)**

Provisions moved from AMC 27.1411 have been inserted.

Life raft must be externally mounted and demonstrated to be deployable in representative sea conditions.

Three life raft actuation methods are required, including externally, in all likely floating attitudes.

Terminology for the life raft lines (mooring, static, painter, retaining) have been standardised on 'retaining line' to align with the Air Ops Regulation.

New (b)(1)(i)(E)(5) provides new guidance to ensure that the length of the life raft retaining line will not create additional hazards.

(b)(2) is not part of the ditching equipment and has been moved to AMC 27.1411.

**AMC 27.1470**

This is a new AMC providing guidance on the installation of ELTs.

**AMC 27.1555**

This new AMC provides additional guidance on black-and-yellow-stripe markings for emergency controls that may need to be operated underwater.

**AMC 27.1561 (amended version of AC 27.1561)**

Some text on markings and placards has been added from AC 29.1561.

Operating instructions for life rafts have been added from AC 29.1561.



**AMC 27 MG 10**

FAA AC 27 Miscellaneous Guidance (MG) 10 contains identical provisions, for an emergency flotation system certification alone, to those set for the emergency flotation system portion of a full certification with ditching provisions, except that the water entry condition of 56 km/h (30 kt) has been replaced with the normal speed for an autorotational landing. It is not efficient to maintain multiple ACs that effectively contain the same information in different forms and, following a review, it has been noticed that there were some discrepancies regarding the specific details. It was therefore concluded that MG 10 should no longer be used and a note has been added to the AMC to indicate the relevant provisions that must be complied with to obtain certification of an emergency flotation system alone.

**CS-29****CS 29.563**

Terminology has been changed to align with new definitions, with the aim of clarifying terms used and ensuring compatibility both within the CSs and between CSs and the Air Ops Regulation.

The alleviation allowing to have less than 30 kt forward velocity at water entry has been removed. This is related to the expansion of the ditching definition to cover all failure modes, not just landing following loss of engine power (e.g. tail rotor failure requiring a run-on landing, or catering for night or IMC conditions).

Means of compliance have been moved to Book 2 (AMC).

**CS 29.783**

It has been moved to CS 29.803(c)(3).

**CS 29.801**

The list of applicable CS has been expanded.

Terminology has been changed to align with new definitions.

New (c) has been added to mandate automatic arming/disarming and deployment of EFS and ensure its reliability and durability.

The text of (d) (former (c)) has been amended to refer to model testing for water entry. Further clarification has been given that compliance by similarity will only be accepted if the reference type has previously been subject to testing in accordance with AMC 29.801(e).

(e) (former (d)) is dedicated to post-ditching flotation stability. A new test objective has been added. Text on compliance by computation has been removed as this is considered impractical with the present state of the art; however, it has been left open in the respective AMC. Text referring to providing appropriate allowances for damage has been moved to the AMC. Text referring to the jettisoning of fuel has been removed. The jettisoning of fuel will not add to the buoyancy of the rotorcraft, but will likely raise the helicopter's CG, reducing stability, and may also create an additional hazard to occupants.

New (g) requires high-visibility chevrons to be applied to the rotorcraft's undersurface to aid rescuers locate the capsized rotorcraft and determine its orientation.



New (h) requires sea conditions and any associated information (i.e. any mitigation used in determining the probability of capsizing) to be identified in the performance information section of the RFM.

New (i) has been created as a design objective for enhanced post-capsizing survivability features. This will also provide mitigation of survivable water impacts, although this cannot be quantified due to the unknown nature and variability of damage likely to be sustained. Flight crew are expected to be better trained and be able to escape directly.

New (j) has been added to address survivable water impact events and ensure that the rotorcraft will not sink following loss of the largest flotation unit.

#### **CS 29.803**

New CS 29.803(c) introduced requiring means be provided to allow passengers to step directly into the life raft(s) following a ditching and with the rotorcraft in an upright position. Any doors used as (part of) this means must meet certain of the provisions for emergency exits.

Non-jettisonable doors must be secured in the open position for all sea conditions which form part of the certification with ditching provisions (this has been moved from CS 29.783(h)).

#### **CS 29.805**

As ditching can be optionally approved, the original text could be misunderstood. The last sentence does not add to the provision and has been deleted.

#### **CS 29.807**

The number of ditching emergency exits has been increased. The provision for ditching emergency exits to be completely above the waterline has been removed.

#### **CS 29.809**

Push-out windows have been recognised as an acceptable emergency exit.

New (j)(1) reiterates the need to design and optimise ditching emergency exits for use following a capsizing. The normal door(s) should be used when the rotorcraft is in the upright position.

New (j)(2) ensures that ditching emergency exits are not blocked when a sliding door is in the open and locked position. Jamming of the door in any intermediate position need not be considered, as compounded probabilities are small and no damage should arise that would result in jamming (CS 29.783(d)).

New (j)(3) has been created for the installation of handholds inside the cabin to assist in emergency egress.

#### **CS 29.811**

CS 29.811 Emergency exit markings has been extended to include flight crew emergency exits.

The intent of the second sentence has been moved to the new (h), especially applicable when ditching is requested by the applicant.

(h)(2) has been added to improve underwater conspicuity of emergency exit operating devices.

#### **CS 29.812**



Exterior lighting is not required for a ditching emergency exit.

**CS 29.813**

New (d)(1) has been created to ensure that seat rows are located relative to ditching emergency exits to best facilitate escape.

New (d)(2) requires handholds to be available to assist in cross-cabin egress from a submerged cabin. Guidance on what constitutes a handhold is provided in the respective AMC.

**CS 29.1411**

Terminology has been changed.

Specific references to life raft and life preservers have been transferred to CS 29.1415 to keep all ditching equipment provisions together.

**CS 29.1415**

A clarification has been added that this is an optional provision.

(a) requires that ditching equipment be suitable for the approved ditching envelope.

(b) has been expanded to include all life raft provisions.

(b)(1) requires that life rafts provide excess capability.

(b)(2) provides that it is no longer acceptable to internally install life rafts that require a physical effort to deploy.

According to (b)(3), life raft deployment controls must be located both internally within the cockpit/cabin and externally. It is impractical to require all possible attitudes of the rotorcraft to be considered so an assessment of foreseeable attitudes is necessary.

Terminology in (b)(4) has been changed to align with European technical standard orders (ETSOs).

Text has been added in (b)(5) to prevent rotorcraft parts (e.g. main and tail rotors) from injuring life raft occupants or puncturing the life raft due to their relative position and movement.

(b)(6) has been copied from CS 29.1561(d).

(b)(7) has been removed as this is covered by the Air Ops Regulation and new CS 29.1470.

New (c) has been transferred from CS 29.1411(f).

**CS 29.1470**

It has been created to cover ELT installation.

**CS 29.1555**

It has been amended to require that emergency controls which may need to be operated underwater are marked with black and yellow stripes.

**CS 29.1561**

Terminology has been changed.

It has been recognised that emergency controls may be operated by passengers.



All safety equipment requires both identification markings and a method of operation.

**AMC 29.563 (replaces FAA AC 29.563A)**

Terminology has been changed to align with new definitions.

Clarification has been added that the wave particle velocity need not be taken into account. The 30-kt forward speed is therefore relative to the wave/water surface.

The previous note that alleviates the 30-kt forward speed has been removed to align with the respective CS.

Text in (a)(2) has been transferred from the CS. In addition, the need to take into account expected damage has been added.

Sea state 4 has been removed and a reference to AMC 29.801(e) has been added for selection of sea conditions.

The type inspection report is not used by the Agency and the reference has been removed.

**AMC 29.801 (replaces FAA AC 29.801)**

The definition of ditching has been amended and new definitions have been added. The current definition of ditching has been expanded to cover failures of other essential systems and not just engines. This would better align with ditching experience and RFM emergency procedures.

Terminology has been changed to align with new definitions.

A background has been added.

A complete list of CS forming part of a certification with ditching provisions has been added.

This AMC provides a new design objective to establish a capsized probability. The water conditions on which ditching substantiation is based are selectable by the applicant.

A clarification has been provided that the life raft should be directly accessible from the cabin to allow direct transfer of occupants when the helicopter is floating upright.

Water entry has been clarified, as AC 29.563A currently mixes structural provisions with those related to the establishment and demonstration of water entry procedures and testing. All structural provisions have been moved to CS 29.563.

The allowable reduction in forward speed has been removed.

Guidance on automatic EFS arming, actuation and good design practice has been added.

Guidance on the size and accessibility of the air pocket (if selected as the design solution for post-capsized survivability) has been provided together with a potential means of compliance (e.g. 'side-floating' scheme).

Clarification that EBS is considered to only provide limited mitigation for the egress issues presented by a post-capsized flooded cabin has been provided, and thus compliance to related CS will not be accepted through the provision of EBS alone.

Guidance on information required by the RFM has been added.



**AMC 29.801(e) (new AMC)**

It includes a new model test specification for rotorcraft ditching certification in irregular waves.

**AMC 29.803(c) (new AMC)**

It provides guidance and means of compliance on designating doors for use in a ditching.

**AMC 29.805 (replaces FAA AC 29.805A)**

Terminology has been changed.

Guidance on the flight crew emergency exit design.

It has been accepted that flight crew may not have direct access to life raft(s).

**AMC 29.807 (supplements FAA AC 29.807)**

It provides AMC/GM relating to the provision for ditching emergency exits and cabin layout.

**AMC 29.809 (supplements FAA AC 809)**

It provides AMC/GM relating to ditching emergency exits and in particular to features that would not be considered to meet the 'simple and obvious' provision of CS 29.809(c).

The provisions of the new (j) include that exits should be useable underwater, escape from a capsized rotorcraft should be feasible in the case that any door(s) may be open, and handholds should be provided adjacent to exits.

Standardisation of push-out window operating tab position etc. is also added as a new provision.

**AMC 29.811(h) (supplements FAA AC 811 and AC 29.811A)**

It provides AMC/GM relating to the marking of ditching emergency exits.

**AMC 29.813 (supplements FAA AC 813)**

It provides AMC/GM on the location of passenger seats in relation to ditching emergency exits in order to best facilitate underwater escape.

**AMC 29.1411 (amended version of AC 29.1411)**

Terminology has been changed to aid clarity.

**AMC 29.1415 (amended version of AC 29.1415)**

Terminology has been changed to aid clarity.

Guidance on life raft deployment has been added.

**AMC 29.1470**

New AMC has been created to provide guidance on the installation of ELTs.

**AMC 29.1561 (amended version of AC 29.1561)**

This is an amended version of AC 29.1561 to better align with the proposed changes to CS 29.1561.

**AMC 29 MG 10 (amended version of AC 29 MG 10)**

FAA AC 29 MG 10 contains provisions for an emergency flotation system certification identical to those set for the emergency flotation system portion of a full certification with ditching provisions, except



that the water entry condition of 56 km/h (30 kt) has been replaced with the normal speeds for an autorotational landing. It is not efficient to maintain multiple AMCs that effectively contain the same information in different forms and, following a review, it has been noticed that there was some divergence on the specific details. It was therefore concluded that MG 10 should no longer be used and a note has been added to the AMC to indicate that the relevant provisions must be complied with to obtain certification of an emergency flotation system alone.



### 3. Proposed amendments

The text of the amendment is arranged to show deleted text, new or amended text as shown below:

- (a) deleted text is marked with ~~strike through~~;
- (b) new or amended text is highlighted in grey;
- (c) an ellipsis (...) indicates that the remaining text is unchanged in front of or following the reflected amendment.

#### 3.1. Draft regulation (Draft EASA Opinion)

N/a.

#### 3.2. Draft Certification Specifications (Draft EASA Decision)

##### 3.2.1. Draft amendment to CS-27 — Book 1

## BOOK 1

### SUBPART C — STRENGTH REQUIREMENTS

1. Amend CS 27.563 as follows:

#### CS 27.563 Structural ditching provisions

If certification with ditching provisions is requested by the applicant, structural strength for ditching must meet the ~~requirements~~ provisions of this paragraph ~~CS~~ and CS 27.801(fe).

- (a) *Forward-speed landing conditions.* The rotorcraft must initially contact the most critical wave for reasonably probable water conditions at forward velocities from zero up to 56 km/h (30 knots) in likely pitch, roll, and yaw attitudes. The rotorcraft limit vertical descent velocity may not be less than 1.5 metres per second (5 ft/s) relative to the mean water surface. Rotor lift may be used to act through the centre of gravity during water entry throughout the landing impact. This lift may not exceed two-thirds of the design maximum weight. ~~A maximum forward velocity of less than 30 knots may be used in design if it can be demonstrated that the forward velocity selected would not be exceeded in a normal one-engine-out touchdown.~~
- (b) *Auxiliary or emergency float conditions:*
  - (1) *Floats fixed or deployed before initial water contact.* In addition to the landing loads in ~~sub-paragraph (a),~~ each auxiliary or emergency float, ~~and~~ its support and attaching structure in the airframe or fuselage, must be designed for the load developed by a fully immersed float unless it can be shown that full immersion is unlikely. If full immersion is unlikely, the highest likely float buoyancy load must be applied. ~~The highest likely buoyancy load must include consideration of a partially immersed float creating restoring moments to compensate the upsetting moments caused by side wind, unsymmetrical rotorcraft loading, water wave action, rotorcraft inertia, and probable structural damage and leakage considered under CS 27.801(d). Maximum roll and pitch angles determined~~



from compliance with CS 27.801(d) may be used, if significant, to determine the extent of immersion of each float. If the floats are deployed in flight, appropriate air loads derived from the flight limitations with the floats deployed shall be used in substantiation of the floats and their attachment to the rotorcraft. For this purpose, the design airspeed for limit load is the float deployed airspeed operating limit multiplied by 1.11.

- (2) *Floats deployed after initial water contact.* Each float must be designed for full or partial immersion prescribed in sub-paragraph (b)(1). In addition, each float must be designed for combined vertical and drag loads using a relative limit speed of 37 km/h (20 knots) between the rotorcraft and the water. The vertical load may not be less than the highest likely buoyancy load determined under paragraph (b)(1).

## SUBPART D — DESIGN AND CONSTRUCTION

2. Amend CS 27.783 as follows:

### CS 27.783 Doors

(...)

- (c) Non-jettisonable doors used as ditching emergency exits must have means to enable them to be secured in the open position and remain secure for emergency egress in the most severe sea conditions covered by the certification with ditching provisions.

3. Amend CS 27.801 as follows:

### CS 27.801 Ditching

- (a) If certification with ditching provisions is requested by the applicant, the rotorcraft must meet the requirement provisions of this paragraph CS and CS 27.563, CS 27.783(c), CS 27.805(c), CS 27.807(d), CS 27.1411, and CS 27.1415, CS 27.1470, CS 27.1555(d) and CS 27.1561.
- (b) Each practicable design measure, compatible with the general characteristics of the rotorcraft, must be taken to minimise the probability that in an emergency landing on water a ditching, the behaviour of the rotorcraft would cause immediate injury to the occupants or would make it impossible for them to escape.
- (c) Emergency flotation systems that are stowed in a deflated condition during normal flight must:
- (1) be designed to be resistant to damage from the effects of a water impact (i.e. crash);
  - (2) if operable within a restricted flight envelope, have an automatic means of arming, disarming and rearming, to enable the system to function, except in flight conditions in which float deployment may be hazardous to the rotorcraft; otherwise, the system shall be armed at all times in flight; and
  - (3) have a means of automatic deployment following water entry.
- (ed) The probable behaviour of the rotorcraft during and following a ditching in a water landing must be investigated by scale model tests or by comparison with rotorcraft of similar configuration for which the ditching characteristics have already been substantiated by equivalent model tests are



known. Scoops, flaps, projections, and any other factors likely to affect the hydrodynamic characteristics of the rotorcraft must be considered.

- (de) The rotorcraft must be shown to resist capsizing in the sea conditions selected by the applicant. The probability of capsizing in a 5-minute exposure to the sea conditions must be demonstrated to be less than or equal to the target probability of capsizing given in the following table, with 95 % confidence.

	Probability of Capsize	
	Serviceable emergency flotation system	Critical float compartment failed
Without mitigation	2.9 %	29.0 %
With capsizing mitigation	29.0 %	>100 % (i.e. no demonstration required)

Allowances must be made for probable structural damage and leakage. ~~It must be shown that, under reasonably probable water conditions, the flotation time and trim of the rotorcraft will allow the occupants to leave the rotorcraft and enter the life rafts required by CS 27.1415. If compliance with this provision is shown by buoyancy and trim computations, appropriate allowances must be made for probable structural damage and leakage. If the rotorcraft has fuel tanks (with fuel jettisoning provisions) that can reasonably be expected to withstand a ditching without leakage, the jettisonable volume of fuel may be considered as buoyancy volume.~~

- (ef) Unless the effects of the collapse of external doors and windows are accounted for in the investigation of the probable behaviour of the rotorcraft in a ditching water landing (as prescribed in subparagraphs (ed) and (de)), the external doors and windows must be designed to withstand the probable maximum local pressures.
- (g) To assist the rescue services in establishing the location and orientation of a capsized rotorcraft, the underside of the rotorcraft must be marked with a series of high-visibility chevrons.
- (h) The sea conditions and any associated information relating to the certification with ditching provisions obtained must be included in the performance information section of the rotorcraft flight manual (RMF).

4. Amend CS 27.805 as follows:

**CS 27.805 Flight crew emergency exits**

(...)

- (c) *Ditching emergency exits for flight crew.* If certification with ditching provisions is requested by the applicant, ~~Each flight crew emergency exit must not be obstructed by water or flotation devices after an emergency landing on water. This must be shown by test, demonstration, or analysis to provide for rapid escape with the rotorcraft in the upright floating position or capsized. Furthermore, the means of access to and of opening each flight crew emergency exit must be provided using conspicuous illuminated markings that illuminate automatically and are designed to remain visible with the rotorcraft capsized and the cabin flooded. The operating~~



device for each ditching emergency exit (pull tab(s), operating handle, etc.) must be marked with black and yellow stripes.

5. Amend CS 27.807 as follows:

**CS 27.807 Passenger eEmergency exits**

- (a) *Number and location.*

- (1) There must be at least one emergency exit on each side of the cabin readily accessible to each passenger. One of these exits must be usable in any probable attitude that may result from a crash;
- (2) Doors intended for normal use may also serve as emergency exits, provided that they meet the ~~requirement~~ provisions of this ~~paragraph~~ CS; and
- (3) If emergency flotation devices are installed, there must be an emergency exit accessible to each passenger on each side of the cabin that is shown by test, demonstration, or analysis to:
  - ~~(i) Be above the waterline; and~~
  - ~~(ii) Open without interference from flotation devices, whether stowed or deployed.~~

- (b) *Type and operation.* Each emergency exit prescribed by ~~sub-paragraph (a)~~ or (d) must:

- (1) Consist of a moveable window or panel, or additional external door, providing an unobstructed opening that will admit a 0.48 m by 0.66 m (19 inch by 26 inch) ellipse;
- (2) Have simple and obvious methods of opening, from the inside and from the outside, which do not require exceptional effort;
- (3) Be arranged and marked so as to be readily located and operated even in darkness; and
- (4) Be reasonably protected from jamming by fuselage deformation.

- (c) *Tests.* The proper functioning of each emergency exit must be shown by test.

- (d) *Ditching emergency exits for passengers.* If certification with ditching provisions is requested by the applicant, ditching emergency exits must be provided in accordance with the following provisions and must be proven by test, demonstration, or analysis unless the emergency exits required by (a) above already meet these provisions:

- (1) One ditching emergency exit, meeting the size provisions of (b) above, must be installed in each side of the rotorcraft for each unit (or part of a unit) of four passenger seats. However, the seat-to-exit ratio may be increased for exits large enough to permit the simultaneous egress of two passengers side by side. Passenger seats must be located in relation to the ditching emergency exits in a way to best facilitate escape with the rotorcraft capsized and the cabin flooded.
- (2) The design of ditching emergency exits, including their means of operation, markings, lighting and accessibility, must be optimised for use in a flooded and capsized cabin.



- (3) Each ditching emergency exit must be provided with a suitable handhold, or handholds adjacently located inside the cabin, to assist in the location and operation of as well as egress through the ditching emergency exit(s).
- (4) In addition to the markings required by ~~sub-paragraph (b)(3)~~, each ditching emergency exit, the means of access to it, and its means of opening must be provided with conspicuous illuminated markings that illuminate automatically, and are designed to remain visible with the rotorcraft capsized and the cabin flooded.
- (5) The operating device for each ditching emergency exit (pull tab(s), operating handle, etc.) must be marked with black and yellow stripes. ~~must be designed to remain visible if the rotorcraft is capsized and the cabin is submerged.~~

6. Amend CS 27.1411 as follows:

**CS 27.1411 General**

- (a) Required safety equipment to be used by the crew in an emergency, ~~such as flares and automatic life raft releases,~~ must be readily accessible.
- (b) Stowage provisions for required safety equipment must be furnished and must:
  - (1) Be arranged so that the equipment is directly accessible and its location is obvious; and
  - (2) Protect the safety equipment from inadvertent damage caused by being subjected to the inertia loads specified in CS 27.561.

**SUBPART F — EQUIPMENT**

7. Amend CS 27.1415 as follows:

**CS 27.1415 Ditching equipment**

If certification with ditching provisions is requested by the applicant, the ditching ~~(a) Emergency flotation and signalling equipment required by Regulation (EU) No 965/2012 any applicable operating rule must meet the requirement provisions of this paragraph CS.~~

- ~~(a)(b)~~ Ditching equipment Each raft and each life preserver must be approved and for use in all sea conditions covered by the certification with ditching provisions.
- (b) If life preservers are stowed, they must be installed ~~so~~ in a way that they are ~~it is~~ readily available to the crew and passengers. The stowage provisions for life preservers must accommodate one life preserver for each occupant for which certification for ditching is requested by the applicant.
- (c) Each life raft ~~released automatically or by the pilot~~ must be remotely deployable for ready use in an emergency. Remote controls capable of deploying the life rafts must be located within easy reach of the flight crew, occupants of the passenger cabin and survivors in the water with the rotorcraft in the upright floating or capsized position. It must be demonstrated that life rafts sufficient to accommodate all rotorcraft occupants, without exceeding the rated capacity of any life raft, can be reliably deployed with the rotorcraft in any reasonably foreseeable floating



attitude, including capsized, and in the sea conditions chosen for showing compliance with CS 27.801(e). Each life raft must be attached to the rotorcraft by a short retaining line to keep it alongside the rotorcraft and a long retaining line designed to keep it attached to the rotorcraft. ~~This line~~ Both retaining lines must be weak enough to break before submerging the empty life raft to which they are ~~it is~~ attached. The long retaining line must be of sufficient length that a drifting life raft will not be drawn towards any part of the rotorcraft that would pose a danger to the life raft itself or the persons on board.

(...)

8. Create a new CS 27.1470 as follows:

**CS 27.1470 Emergency locator transmitter**

Each emergency locator transmitter, including crash sensors and antenna, required by Regulation (EU) No 965/2012, must be installed so as to minimise damage that would prevent its functioning following an accident or incident.

**SUBPART G — OPERATING LIMITATIONS AND INFORMATION**

9. Amend CS 27.1555 as follows:

**CS 27.1555 Control markings**

(...)

- (d) For accessory, auxiliary, and emergency controls:

- (1) ~~Each~~ essential visual position indicator, such as those showing rotor pitch or landing gear position, must be marked so that each crew member can determine at any time the position of the unit to which it relates; and
- (2) ~~Each~~ emergency control must be ~~red and must be~~ marked as to the method of operation and be red unless it may need to be operated underwater, in which case it must be marked with yellow and black stripes.

(...)

10. Amend CS 27.1561 as follows;

**CS 27.1561 Safety equipment**

- (a) Each safety equipment control to be operated by the crew or passenger in an emergency, ~~such as controls for automatic life raft releases,~~ must be plainly marked for identification and as to its method of operation.
- (b) Each location, such as a locker or compartment that carries any fire extinguishing, signalling, or other ~~safety life-saving~~ equipment, must be so marked to identify the contents and facilitate removal of the equipment.
- (c) Each item of safety equipment carried must have obviously marked operating instructions.



(d) Approved safety equipment must be marked for identification and method of operation.

11. Amend Appendix C as follows:

### Appendix C — Criteria for Category A

(...)

C27.2 *Applicable CS-29 paragraph provisions*. The following paragraphs provisions of CS-29 must be met in addition to the requirement provisions of this paragraph CS:

(...)

29.1587(a) — Performance Information.

If certification with ditching provisions is requested by the applicant, the following provisions of CS-29 must also be met in addition to the ones of this CS:

29.801(b) to (j) — Ditching

29.803(c) — Emergency evacuation

29.809(j) — Emergency exit arrangement

29.1415(d) — Ditching equipment

If certification of an emergency flotation system alone is requested by the applicant, the following provisions of CS 29 must also be met in addition to the ones of this CS:

29.801(b) to (j) — Ditching

#### 3.2.2. Draft amendment to CS-27 — Book 2

1. Create a new AMC 27.563 as follows:

#### **AMC 27.563**

#### **Structural ditching provisions**

(a) Explanation. This AMC contains specific structural conditions to be considered to support the overall ditching provisions of CS 27.801. These conditions are to be applied to rotorcraft for which certification with ditching provisions is requested by the applicant.

(1) The forward-speed landing conditions are specified as follows:

(i) The rotorcraft should contact the most critical wave in the probable sea conditions for which certification with ditching provisions is requested by the applicant in the likely pitch, roll, and yaw attitudes.

(ii) The forward velocity relative to the wave surface should be in a range of 0–56 km/h (30 kt) with a vertical-descent rate of not less than 1.5 m/s (5 ft/s) relative to the mean wave surface. No account need be taken of the wave particle velocity.



- (iii) A rotor lift of not more than two-thirds of the design maximum weight may be used to act through the rotorcraft's centre of gravity during water entry.
- (2) For floats fixed or deployed before water contact, the auxiliary or emergency float conditions are specified in CS 27.563(b)(1). Loads for a fully immersed float should be applied (unless it is shown that full immersion is unlikely). If full immersion is unlikely, the highest likely buoyancy load should include consideration of a partially immersed float creating restoring moments to compensate for the upsetting moments caused by side wind, unsymmetrical rotorcraft loading, water wave action, rotorcraft inertia, and probable structural damage and leakage considered under CS 27.801(e). Maximum roll and pitch angles established by compliance with CS 27.801(e) may be used, if significant, to determine the extent of immersion of each float. When determining this, damage to the rotorcraft that could be reasonably expected should be accounted for (e.g. loss of the tail boom resulting in a nose-down attitude in the water).
- (3) Floats deployed after water contact are normally considered fully immersed during and after full inflation. An exception would be when the inflation interval is so long that full immersion of the inflated floats does not occur (e.g. deceleration of the rotorcraft during water entry and natural buoyancy of the hull prevent full immersion loads on the fully inflated floats).

(b) Procedures

- (1) The rotorcraft support structure, structure-to-float attachments, and floats should be substantiated for rational limit and ultimate ditching loads.
- (2) The most severe sea conditions for which certification with ditching provisions is requested by the applicant are to be considered. The sea conditions should be selected in accordance with AMC 27.801(e).
- (3) The landing structural design consideration should be based on water entry with a rotor lift of not more than two-thirds of the maximum design weight acting through the rotorcraft's centre of gravity under the following conditions:
  - (i) forward velocities of 0–56 km/h (30 kt) relative to the mean wave surface;
  - (ii) the rotorcraft pitch attitude that would reasonably be expected to occur in service; autorotation, run-on landing or one-engine-inoperative flight tests, or validated simulation, as applicable, should be used to confirm the attitude selected;
  - (iii) likely roll and yaw attitudes; and
  - (iv) vertical-descent velocity of 1.5 m/s (5 ft/s) or greater relative to the mean wave surface.
- (4) Landing load factors and water load distribution may be determined by water drop tests or analysis based on tests.
- (5) Auxiliary or emergency float loads should be determined by full immersion or by the use of restoring moments required to react the upsetting moments caused by side wind, asymmetrical rotorcraft landing, water wave action, rotorcraft inertia, and probable



structure damage and punctures considered under CS 27.801. Auxiliary or emergency float loads may be determined by tests or analysis based on tests.

- (6) Floats deployed after water entry are required to be substantiated by tests or analysis for the specified immersion loads (same as for (5) above and for the specified combined vertical and drag loads).

2. Create a new AMC 27.801 (amended AC 27.801) as follows:

**AMC 27.801**

**Ditching**

(a) Definitions

- (1) Ditching: an emergency landing on the water, deliberately executed in accordance with rotorcraft flight manual (RFM) procedures, with the intent of abandoning the rotorcraft as soon as practical.
- (2) Emergency flotation system (EFS): a system of floats and any associated parts (gas cylinders, means of deployment, pipework and electrical connections) that is designed and installed on a rotorcraft to provide buoyancy and flotation stability in a ditching. The EFS includes any additional floats which provide a function only following capsizes.

(b) Explanation

- (1) Ditching certification is performed only if requested by the applicant.
- (2) For a rotorcraft to be certified for ditching, in addition to the other applicable provisions of CS-27, the rotorcraft must specifically satisfy CS 27.801 together with the provisions detailed in CS 27.801(a).
- (3) Ditching certification encompasses four primary areas of concern: rotorcraft water entry, rotorcraft flotation stability, occupant egress, and occupant survival. CS-27 Amendment X has developed enhanced standards in all of these areas.
- (4) The scope of the ditching provisions is expanded through a change in the ditching definition. All potential failure conditions that could result in a 'land immediately' action by the pilot are now included (e.g. engine, transmission, systems, tail rotor, lightning strike, etc.). This primarily relates to changes in water entry conditions. While the limiting conditions for water entry have been retained (30 kt, 5 fps), the alleviation that allows less than 30-kt forward speed to be demonstrated has been removed (also from CS 27.563), and Miscellaneous Guidance (MG) 10 has been removed as an alternative means for substantiation of an emergency flotation system.
- (5) Flotation stability is enhanced through the introduction of a new standard based on a probabilistic approach to capsizes. Historically, helicopters have frequently operated over sea conditions more severe than those assumed in their certification with ditching provisions, where there is a higher risk of capsizes following a ditching. Operational experience has shown that fatalities have occurred in otherwise survivable water impact events due to the inability of occupants to escape from a capsized or sinking helicopter.



- (6) Failure of the EFS to operate when required will lead to the rotorcraft rapidly capsizing and sinking. Operational experience has shown that localised damage or failure of a single component of an EFS, or the failure of the flight crew to activate or deploy the EFS, can lead to loss of the complete system. Therefore, the design of the EFS needs careful consideration; automatic arming and deployment have been shown to be practicable and offer a significant safety benefit.
- (7) Ditching certification should be performed with the maximum required quantity and the type of ditching equipment for the anticipated areas of operation.
- (8) The water conditions on which certification with ditching provisions is to be based are selected by the applicant and should take into account the expected water conditions in the intended areas of operation. The wave climate of the northern North Sea is adopted as the default wave climate as it represents a conservative condition. The applicant may also select alternative/additional sea areas with any associated certification then being limited to those geographical regions. The certification with ditching provisions obtained will be included in the RFM as performance information.
- (9) Tests with a scale model of the appropriate ditching configuration should be conducted in a wave tank to demonstrate satisfactory water entry and flotation stability characteristics. Appropriate allowances should be made for probable structural damage and leakage. Previous model tests and other data from rotorcraft of similar configurations that have already been substantiated based on equivalent test conditions may be used to satisfy the ditching provisions.
- (10) CS-27 Amendment X removes a potential source of confusion and simplifies the tests necessary for showing compliance with CS 27.801(d), by removing the reference to two-thirds lifts.
- (11) CS 27.801 requires that after ditching in sea conditions for which certification with ditching provisions is requested by the applicant, the flotation time (5 minutes) and stability of the rotorcraft will allow the occupants to leave the rotorcraft and enter life rafts. This should be interpreted to mean that up to and including the worst-case sea conditions for which certification with ditching provisions is requested by the applicant, the probability that the rotorcraft will capsize should be not higher than the target stated in CS 27.801(e). An acceptable means of demonstrating post-ditching flotation stability is through model testing using irregular waves. AMC 27.801(e) contains a test specification that has been developed for this purpose.
- (12) Providing a 'wet floor' concept (water in the cabin) by positioning the floats higher on the fuselage sides and allowing the rotorcraft to float lower in the water can be a way of increasing the stability of a ditched rotorcraft (although this was inconclusive in previous research and would need to be verified for the individual rotorcraft type for all weight and loading conditions) or may be desired for other reasons. This is permissible provided that the mean level of water in the cabin is limited to below the seat cushion upper surface height, and that the presence of water will not unduly restrict the ability of occupants to evacuate the rotorcraft.



- (13) The water conditions approved for ditching will be stated in the performance information section of the RFM and are expected to become an operational limitation on normal operations.
- (14) Current practices allow wide latitude in the design of cabin interiors and, consequently, of stowage provisions for safety and ditching equipment. Rotorcraft manufacturers may deliver aircraft with unfinished (green) interiors that are to be completed by a modifier. These various configurations present problems for certifying the rotorcraft for ditching.
- (i) Segmented certification is permitted to accommodate this practice. That is, the rotorcraft manufacturer shows compliance with the flotation time, stability, and emergency exit provisions while a modifier shows compliance with the equipment provisions and egress provisions with the interior completed. This procedure requires close cooperation and coordination between the manufacturer, modifier, and the Agency.
- (ii) The rotorcraft manufacturer may elect to establish a token interior for ditching certification. This interior may subsequently be modified by a supplemental type certificate (STC). Compliance with the ditching provisions should be reviewed after any interior configuration and limitation changes, where applicable.
- (iii) The RFM and any RFM supplements (RFMSs) deserve special attention if a segmented certification procedure is pursued.

(c) Procedures

(1) Flotation system design

- (i) Structural integrity should be established in accordance with CS 27.563.
- (ii) Rotorcraft handling qualities should be verified to comply with the applicable certification specifications throughout the approved flight envelope with floats installed. Where floats are normally deflated and deployed in flight, the handling qualities should be verified for the approved operating envelopes with the floats in:
- (A) the deflated and stowed condition;
- (B) the fully inflated condition; and
- (C) the in-flight inflation condition; for float systems which may be inflated in flight, rotorcraft controllability should be verified by test or analysis taking into account all possible emergency flotation system inflation failures.
- (iii) Reliability should be considered in the basic design to assure approximately equal inflation of the floats to preclude excessive yaw, roll, or pitch in flight or in the water:
- (A) Maintenance procedures should not degrade the flotation system (e.g. introducing contaminants which could affect normal operation, etc.).
- (B) The flotation system design should preclude inadvertent damage due to normal personnel traffic flow and excessive wear and tear. Protection covers should be evaluated for function and reliability.



- (C) Float design should provide a means to minimise the likelihood of damage or tear propagation between compartments. Single compartment float designs should be avoided.
- (D) Where practicable, design of the flotation system should consider the likely effects of water impact (i.e. crash) loads. For example:
  - (a) locate system components away from the major effects of structural deformation;
  - (b) use flexible pipes/hoses; and
  - (c) avoid passing pipes/hoses or electrical wires through bulkheads that could act as a 'guillotine' when the structure is subject to water impact loads.
- (iv) The floats should be fabricated from material of high visual conspicuity to assist in the location of the rotorcraft following a ditching (and possible capsizing).
- (2) Flotation system inflation. Emergency flotation systems (EFSs) which are normally stowed in a deflated condition and are inflated either in flight or after water contact should be evaluated as follows:
  - (i) The emergency flotation system should include a means to verify system integrity prior to each flight.
  - (ii) If a manual means of inflation is provided, the float activation switch should be located on one of the primary flight controls and should be safeguarded against spontaneous or inadvertent actuation.
  - (iii) The inflation system should be safeguarded against spontaneous or inadvertent actuation in flight conditions for which float deployment has been demonstrated to be hazardous. If this requires arming/disarming of the inflation system (e.g. above a given height and airspeed), this should be achieved by the use of an automatic arming/disarming system employing appropriate input parameters. The system should automatically rearm when flight conditions permit safe deployment.
  - (iv) The maximum airspeeds for intentional in-flight actuation of the emergency flotation system and for flight with the floats inflated should be established as limitations in the RFM unless in-flight actuation is prohibited by the RFM.
  - (v) Activation of the emergency flotation system upon water entry (irrespective of whether or not inflation prior to water entry is the intended operation mode) should result in an inflation time short enough to prevent the rotorcraft from becoming excessively submerged.
  - (vi) A means should be provided for checking the pressure of the gas stowage cylinders prior to take-off. A table of acceptable gas cylinder pressure variation with ambient temperature and altitude (if applicable) should be provided.
  - (vii) A means should be provided to minimise the possibility of overinflation of the flotation units under any reasonably probable actuation conditions.



- (viii) The ability of the floats to inflate without puncture when subjected to actual water pressures should be substantiated. A demonstration of a full-scale float immersion in a calm body of water is one acceptable method of substantiation.
- (3) Injury prevention during and following water entry. An assessment of the cabin and cockpit layout should be undertaken to minimise the potential for injury to occupants in a ditching. This may be performed as part of the compliance with CS 27.785. Attention should be given to the avoidance of injuries due to leg/arm flailing, as these can be a significant impediment to occupant egress and subsequent survivability. Practical steps that could be taken include:
- (i) locating potentially hazardous items away from occupants;
  - (ii) installing energy-absorbing padding onto interior components;
  - (iii) using frangible materials; and
  - (iv) designs that exclude hard or sharp edges.
- (4) Water entry conditions and procedures. Tests or simulations (or a combination of both) should be conducted to establish procedures and techniques to be used for water entry. These tests/simulations should include determination of the optimum pitch attitude and forward velocity for ditching in a calm sea, as well as entry procedures for the most severe sea condition to be certified. Procedures for all failure conditions that may lead to a 'land immediately' action (e.g. one engine inoperative, all engines inoperative, tail rotor/drive failure) should be established. However, only the procedures for the most critical all-engines-inoperative condition need be verified by water entry tests.
- (5) Water entry tests. Scale model testing to verify water entry procedures and the capability of the rotorcraft to remain upright should be based on water entry under the following conditions:
- (i) for entry into a calm sea:
    - (A) the optimum pitch, roll and yaw attitudes determined in (c)(4) above, with consideration for variations that would reasonably be expected to occur in service;
    - (B) ground speeds from 0–56 km/h (0–30 kt); and
    - (C) descent rate of 1.5 m/s (5 ft/s) or greater;
  - (ii) for entry into the most severe sea condition:
    - (A) the optimum pitch attitude and entry procedure determined in (c)(4) above;
    - (B) ground speed of 56 km/h (30 kt);
    - (C) descent rate of 1.5 m/s (5 ft/s) or greater;
    - (D) likely roll and yaw attitudes; and
    - (E) sea conditions may be represented by regular waves having a height at least equal to the significant wave height ( $H_s$ ), and a period no larger than the mode of the wave zero-crossing period ( $T_z$ ), that is the wave spectrum chosen



for demonstration of rotorcraft flotation stability after water entry (see (c)(6) below and AMC 27.801(e));

- (iii) probable damage to the structure due to water entry should be considered during the water entry evaluations (e.g. failure of windows, doors, skins, panels, tail boom, etc.); and
  - (iv) rotor lift does not have to be considered.
- (6) Flotation stability tests. An acceptable means of flotation stability testing is contained in AMC 27.801(e). Note that model tests in a wave basin on a number of different rotorcraft types have indicated that an improvement in seakeeping performance can consistently be achieved by fitting float scoops.
- (7) Occupant egress and survival. The ability of the occupants to deploy life rafts, egress the rotorcraft, and board the life rafts (directly, in the case of passengers), should be evaluated. For configurations which are considered to have critical occupant egress capabilities due to life raft locations or ditching emergency exit locations and float proximity (or a combination of both), an actual demonstration of egress may be required. When a demonstration is required, it may be conducted on a full-scale rotorcraft actually immersed in a calm body of water or using any other rig or ground test facility shown to be representative. The demonstration should show that floats do not impede a satisfactory evacuation. Service experience has shown that it is possible for occupants to have escaped from the cabin but have not been able to board a life raft and have had difficulties finding handholds to stay afloat and together. Handholds or lifelines should be provided on appropriate parts of the rotorcraft. The normal attitude of the rotorcraft and the possibility of a capsize should be considered when positioning the handholds or lifelines.
- (8) Rescue. In order to aid rescue services in visually locating a capsized helicopter, the bottom surface of the fuselage should be painted with at least three chevrons. The chevron tips should be on the centre line of the fuselage and should point to the nose of the rotorcraft. Their overall width should not be less than half that of the fuselage. The thickness of the chevrons should be between a quarter and a third of their overall width. The colour of the chevrons should be chosen to provide a good contrast to the sea (e.g. red, yellow) and the fuselage bottom surface.
- (9) Rotorcraft Flight Manual. The RFM is an important element in the certification process of the rotorcraft for ditching. The material related to ditching may be presented in the form of a supplement or a revision to the basic manual. This material should include:
- (i) A statement in the 'Limitations' section stating that the rotorcraft is approved for ditching.

If the certification with ditching provisions is obtained in a segmented fashion (i.e. one applicant performing the safety equipment installation and operations portion and another designing and substantiating the safety equipment's performance and deployment facilities), the RFM limitations should state that the ditching provisions are not approved until all segments are completed. The outstanding ditching



provisions for a complete certification should be identified in the 'Limitations' section.

- (ii) Procedures and limitations for flotation device inflation.
- (iii) A statement in the performance information section of the RFM, identifying the demonstrated sea conditions and any other pertinent information. If demonstration was performed using the default North Sea wave climate (JONSWAP), the maximum significant wave height ( $H_s$ ), demonstrated in metres, should be stated. If extended testing was performed in accordance with AMC 27.801(e) to demonstrate that the target level of capsize probability can be reached without operational limitation, this should also be stated. If demonstration was performed for other sea conditions, the maximum significant wave height ( $H_s$ ), demonstrated in metres, and the limits of the geographical area represented should be stated.
- (iv) Recommended rotorcraft water entry attitude, speed, and wave position.
- (v) Procedures for use of safety equipment.
- (v) Ditching egress and life raft entry procedures.

3. Create a new AMC 27.801(e) as follows:

**AMC 27.801(e)**

**Model test method for post-ditching flotation stability**

(a) Explanation

(1) Model test objectives

The objective of the model tests described in the certification specification is to establish the ditching performance of the rotorcraft in terms of stability. Together with the certification of the water entry phase, this will enable the overall ditching performance of the rotorcraft to be established for inclusion in the rotorcraft flight manual (RFM) as required by CS 27.801(h).

The rotorcraft design is to be tested with its flotation system intact, and its single most critical flotation compartment damaged (i.e. the single-puncture case which has the worst adverse effect on flotation stability).

The wave conditions in which the rotorcraft is to be certified for ditching should be selected according to the desired level of operability (see (a)(2) below).

(2) Model test wave conditions

The rotorcraft is to be tested in a single sea condition comprising a single combination of significant wave height ( $H_s$ ) and zero-crossing period ( $T_z$ ). This approach is necessary in order to constrain the quantity of testing required within reasonable limits and is considered to be conservative. The justification is detailed in Appendix 2.

The rotorcraft designer/operator is at liberty to certify the rotorcraft at any  $H_s$ . This  $H_s$  will be noted as performance information in the RFM.



Using reliable wave climate data for an appropriate region of the ocean for the anticipated flight operations, a  $T_z$  is selected to accompany the  $H_s$ . It is proposed that this  $T_z$  should be typical of those occurring at  $H_s$  as determined in the wave scatter table for the region. The mode or median of the  $T_z$  distribution at  $H_s$  should be used.

It is considered that the northern North Sea represents a conservatively 'hostile' region of the ocean worldwide and should be adopted as the default wave climate for ditching certification. However, this does not preclude an applicant certifying a rotorcraft specifically for a different region. Such certification for a specific region would require the geographical limits of that ditching certification region to be noted as performance information in the RFM. Certification for the default northern North Sea wave climate does not require any geographical limits.

Northern North Sea wave climate data were obtained from the United Kingdom Meteorological Office (UK Met Office) for a typical 'hostile' helicopter route. The route selected was from Aberdeen to Block 211/27 in the UK sector of the North Sea. Data tables were derived from a UK Met Office analysis of 34 years of three-hourly wave data generated within an 8-km, resolved wave model hindcast for European waters. This data represents the default wave climate.

Table 1 below has been derived from this data and contains combinations of  $H_s$  and  $T_z$ . Table 1 also includes the probability of exceedance ( $P_e$ ) of the  $H_s$ .

**Table 2 — Northern North Sea wave climate**

Spectrum shape: JONSWAP, peak enhancement factor $\gamma = 3.3$			
	Significant wave height $H_s$	Mean wave period $T_z$	$H_s$ probability of exceedance $P_e$
Intact flotation system	6 m	7.9	1.2 %
	5.5 m	7.6	2 %
	5 m	7.3	3 %
	4.5 m	7.0	5 %
	4 m	6.7	8 %
	3.5 m	6.3	13 %
	3 m	5.9	20 %
	2.5 m	5.5	29 %
	2 m	5.1	43 %
	1.25 m	4.4	72 %

(3) Target probability of capsizing

Target probabilities of capsizing have been derived from a risk assessment. The target probabilities to be applied are stated in CS 27.801(e). Different target probabilities apply depending on whether the rotorcraft is equipped for mitigating the consequences of capsizing. Mitigation may be provided either by an RFM limitation that for all flights requiring the rotorcraft be certified for ditching, all occupants are equipped with and



trained in the use of an approved emergency breathing system (EBS) that is capable of rapid underwater deployment, or by the post-capsize survivability features of CS 29.801(i).

(4) Intact flotation system

For the case of an intact flotation system, if the northern North Sea default wave climate has been chosen for certification, the rotorcraft should be shown to resist capsize in a sea condition selected from Table 1. The probability of capsize in a five-minute exposure to the selected sea condition is to be demonstrated to be less than or equal to the appropriate value provided in CS 27.801(e) with a confidence of 95 % or greater.

(5) Damaged flotation system

For the case of a damaged flotation compartment (see (1) above), the same sea condition may be used, but a 10-fold increased probability of capsize is permitted. This is because it is assumed that flotation system damage will occur in approximately one out of ten ditchings. Thus, the probability of capsize in a five-minute exposure to the sea condition is to be demonstrated to be less than or equal to 10 times the probability provided in CS 27.801(e) for the intact flotation system case, with a confidence of 95 % or greater. Where a 10 times probability is greater than 100 %, it is not necessary to perform a model test to determine the capsize probability with a damaged flotation system. However, in this case, it is necessary to perform a capsized rotorcraft seakeeping test as specified in (6) below.

Alternatively, the designer/operator may select a wave condition with 10 times the probability of exceedance  $P_e$  of the significant wave height ( $H_s$ ) selected for the intact flotation condition. In this case, the probability of capsize in a five-minute exposure to the sea condition is to be demonstrated to be less than or equal to the appropriate value provided in CS 27.801(e) with a confidence of 95 % or greater.

(6) Capsized rotorcraft seakeeping test

The probabilities given in CS 27.801(e) depend on whether or not capsize mitigation is provided. This may be either by an RFM limitation that for all flights requiring the rotorcraft be certified for ditching, all occupants are equipped with and trained in the use of an approved emergency breathing system (EBS) that is capable of rapid underwater deployment, or by the post-capsize survivability features of CS 29.801(i).

In the latter case, one possible design solution could consist of the fitment of additional emergency flotation units intended to prevent complete inversion of the capsized rotorcraft. Alternatively, the existing flotation units may be repositioned higher up on the fuselage. Both of these approaches will ensure the availability of an air pocket following total inversion.

If the chosen mitigation means is the provision of a post-capsize air pocket, it is required that capsized seakeeping model tests be conducted to demonstrate that following capsize, the rotorcraft does not show a tendency to continue to roll over in response to larger waves. These tests are to be conducted in the same wave condition as for the intact flotation system.



Some designs of additional emergency flotation units using a symmetrical layout relative to the rotorcraft centre line may show a second rotation following the initial capsize before the final stable floating attitude is achieved. This is considered to be acceptable.

Video evidence of post-capsize stability during a one-hour (full-scale time) exposure to the wave condition will be accepted as sufficient evidence that the rotorcraft achieves a stable floating attitude.

(7) Long-crested waves

Whilst it is recognised that ocean waves are in general multidirectional (short-crested), the model tests are to be performed in unidirectional (long-crested) waves, this being regarded as a conservative approach to capsize probability.

(b) Procedures

(1) Rotorcraft model

(i) Model construction and scale

The rotorcraft model, including its emergency flotation, is to be constructed to be geometrically similar to the full-scale rotorcraft design at a scale that will permit the required wave conditions to be accurately represented in the model basin. It is recommended that the model scale should be not smaller than 1/15.

The model construction is to be sufficiently light to permit the model to be ballasted to achieve the desired weight and rotational inertias specified in the mass conditions (see (b)(1)(ii) below).<sup>9</sup>

Where it is likely that water may flood into the internal spaces following ditching, for example through doors opened to permit escape, the model should represent these internal spaces and opened doors and windows as realistically as possible.

It is permissible to omit the main rotor(s) from the model, but its (their) mass is to be represented in the mass and inertia conditions<sup>10</sup>.

(ii) Mass conditions

It is required that the model is tested in the most critical mass condition. As it is unlikely that this most critical condition can be determined reliably prior to testing, the model is to be capable of being tested in two mass conditions:

(A) maximum mass condition; and

(B) minimum mass condition.

In the analysis of the test results, it is the worst capsize performance of these mass conditions that will determine if the ditching provision has been met or not.

(iii) Mass properties

<sup>9</sup> It should be noted that rotorcraft tend to have a high centre of gravity due to the position of the engines and gearbox on top of the cabin. It therefore follows that most of the ballast is likely to be required to be installed in these high locations of the model.

<sup>10</sup> Rotors touching the waves can promote capsize, but they can also be a stabilising factor depending on the exact circumstances. Furthermore, rotor blades are often lost during the ditching due to contact with the sea. It is therefore considered acceptable to omit them from the model.



The model is to be ballasted in order to achieve the required scale weight, centre of gravity, roll and yaw inertia for each of the mass conditions to be tested.

Once ballasted, the model's floating draft and trim in calm water is to be checked and compared with the design floating attitude. Where a post-capsize air pocket is part of the design, then this capsized floating attitude is also to be similarly checked and compared.

The required mass properties and floating draft and trim, and those measured during model preparation, are to be fully documented and compared in the report.

(iv) Model restraint system

A flexible restraint or mooring system is to be provided to restrain the model in order for it to remain beam-on to the waves in the model basin.<sup>11</sup>

This restraint system should meet the following:

(A) be attached to the model on the centre line at front and rear of the fuselage in such a position that roll motion coupling is minimised; an attachment at or near the waterline is preferred; and

(B) be sufficiently flexible that natural frequencies of the model surging/swaying on this restraint system are much lower than the lowest wave frequencies in the spectrum.

(v) Sea anchor

Whether or not the rotorcraft is to be fitted with a sea anchor, such an anchor is not to be represented in these model tests.<sup>12</sup>

(2) Test facility

The model test facility is to have the capability to generate realistic long non-repeating sequences of unidirectional (long-crested) irregular waves, as well as the characteristic wave condition at the chosen model scale. The facility is to be deep enough to ensure that the waves are not influenced by the depth (i.e. deep-water waves).

The dimensions of the test facility are to be sufficiently large to avoid any significant reflection/refraction effects influencing the behaviour of the rotorcraft model.

The facility is to be fitted with a high-quality wave-absorbing system or beach.

The model basin is to provide full details of the performance of the wave maker and the wave absorption system prior to testing.

(3) Model test setup

(i) General

<sup>11</sup> The model cannot be permitted to float freely in the basin because in the necessarily long-wave test durations, the model would otherwise drift down the basin and out of the calibrated wave region. Constraining the model to remain beam-on to the waves and not float freely is regarded as a conservative approach to the capsized test.

<sup>12</sup> A sea anchor deployed from the rotorcraft nose is intended to improve stability by keeping the rotorcraft nose into the waves. However, such devices take a significant time to deploy and become effective, and so, their beneficial effect is to be ignored. The rotorcraft model will be restrained to remain beam-on to the waves.



The model is to be installed in the wave facility in a location sufficiently distant from the wave maker, tank walls and beach/absorber such that the wave conditions are repeatable and not influenced by the boundaries.

The model is to be attached to the model restraint system (see (b)(1)(iv) above).

(ii) Instrumentation and visual records

During wave calibration tests, three wave elevation probes are to be installed and continuously recorded. These probes are to be installed at the intended model location, a few metres to the side and a few metres ahead of this location.

The wave probe at the model location is to be removed during tests with the rotorcraft model present.

All tests are to be continuously recorded on digital video. It is required that at least two simultaneous views of the model are to be recorded. One is to be in line with the model axis (i.e. viewing along the wave crests), and the other is to be a three-quarter view of the model from the up-wave direction. Video records are to incorporate a time code to facilitate synchronisation with the wave elevation records in order to permit the investigation of the circumstances and details of a particular capsize event.

(iii) Wave conditions and calibration

Prior to the installation of the rotorcraft model in the test facility, the required wave conditions are to be pre-calibrated.

Wave elevation probes are to be installed at the model location, alongside and ahead of the intended model location.

The intended wave condition(s) is(are) to be applied for a long period (at least one-hour full-scale time). The analysis of these wave calibration runs is to be used to:

- (A) confirm that the required wave spectrum has been obtained at the model location; and
- (B) determine the extent to which the wave conditions deteriorate during the run in order to help establish how long model test runs can be.

It should be demonstrated that the wave spectra measured at the three locations are the same.

It should be demonstrated that the time series of the waves measured at the model location does not repeat during the run duration. Furthermore, it should be demonstrated that one or more continuation runs can be performed using exactly the same wave spectrum and period, but with different wave time series. This is to permit a long exposure to the wave conditions to be built up from a number of separate runs without any unrealistic repetition of the time series.

No wind simulation is to be used.<sup>13</sup>

<sup>13</sup> Wind generally has a tendency to redirect the rotorcraft nose into the wind/waves, thus reducing the likelihood of capsize. Therefore, this conservative testing approach does not include a wind simulation.



(iv) Required wave run durations

The total duration of runs required to demonstrate that the required probability of capsize has been achieved (or bettered) is dependent on that probability itself, and on the reliability or confidence of the capsize probability required to be demonstrated.

With the assumption that each five-minute exposure to the wave conditions is independent, the equations provided in (b)(5) below can be used to determine the duration without capsize required to demonstrate the required performance.<sup>14</sup> (See Appendix 1 below for examples.)

(4) Test execution and results

Tests are to start with the model at rest and the wave basin calm.

Following start of the wave maker, sufficient time is to elapse to permit the slowest (highest-frequency) wave components to arrive at the model, before data recording starts.

Wave runs are to continue for the maximum permitted run duration determined in the wave calibration test. Following time to allow the basin to calm, additional runs are to be conducted until the necessary total exposure duration ( $T_{\text{Test}}$ ) has been achieved (see (b)(5) below).

If and when a model capsize occurs, the time of capsize from the run start is to be recorded, and the run stopped. The model is to be recovered, drained of any water, and reset in the basin for a continuation run to be performed. Following time to allow the basin to calm, this continuation run is to be performed in the same wave spectrum, height and period.

If the test is to be continued with the same model configuration, the test can restart with a different wave time series, or continue from the point of capsize in a pseudorandom time series.

If instead it is decided to modify the model flotation with the intention of demonstrating that the modified model does not capsize in the wave condition, then the pseudorandom wave maker time series should be restarted at a point at least 5 minutes prior to the capsize event so that the model is seen to survive the wave that caused capsize prior to modification. Credit can then be taken for the run duration successfully achieved prior to capsize. Clearly, such a restart is only possible with a model basin using pseudorandom wave generation.

Continuation runs are to be performed until the total duration of exposure to the wave condition is sufficient to establish that the five-minute probability of capsize has been determined with the required confidence of 95 %.

(5) Results analysis

<sup>14</sup> Each five-minute exposure might not be independent if for example, there was flooding of the rotorcraft, progressively degrading its stability. However, in this context, it is considered that the assumption of independence is conservative.



Given that it has been demonstrated that the wave time series are non-repeating and statistically random, the results of the tests may be analysed on the assumption that each five-minute element of the total time series is independent.

If the model rotorcraft has not capsized during the total duration of the tests, the confidence that the probability of capsize within 5 minutes is less than the target value of  $P_{Criteria}$ , as shown below:

$$C = 1 - (1 - P_{Criteria})^{\lceil T_{Test}/T_{Criteria} \rceil}$$

$$(i) \quad \approx 1 - \exp\left(-\frac{P_{Criteria}T_{Test}}{T_{Criteria}}\right)$$

and so the total duration of the model test required without capsize is provided by:

$$T_{Test} \approx -\frac{T_{Criteria} \ln(1 - C)}{P_{Criteria}}$$

where:

- (A)  $T_{Test}$  is the required full-scale duration of the test (in seconds);
- (B)  $P_{Criteria}$  is the required maximum probability of capsize within 5 minutes;
- (C)  $T_{Criteria}$  is the duration (in seconds) in which the rotorcraft must meet the no-capsize probability (= 5 x 60 s), as defined in CS 27.801(e); and
- (D)  $C$  is the required confidence that the probability of capsize has been achieved (0.95).

If the rotorcraft has capsized  $N_{Capsize}$  times during the tests, the probability of capsize within 5 minutes can be estimated as:

$$P_{Capsize} = \frac{N_{Capsize} T_{Criteria}}{T_{Test}}$$

and the confidence that the required capsize criteria have been met is:

$$(ii) \quad C = 1 - \sum_{k=0}^{N_{Capsize}} \frac{\left(\lceil T_{Test}/T_{Criteria} \rceil\right)!}{k! \left(\lceil T_{Test}/T_{Criteria} \rceil - k\right)!} \left\{ (P_{Criteria})^k \times (1 - P_{Criteria})^{\left(\lceil T_{Test}/T_{Criteria} \rceil - k\right)} \right\}$$

$$\approx 1 - \left\{ \sum_{k=0}^{N_{Capsize}} \frac{1}{k!} \left(\frac{P_{Criteria} T_{Test}}{T_{Criteria}}\right)^k \right\} \exp\left(-\frac{P_{Criteria} T_{Test}}{T_{Criteria}}\right)$$

It should be noted that, if the rotorcraft is permitted to fly in significant wave heights ( $H_s$ ) above the certification limit, then  $P_{Criteria}$  should be reduced by the probability of exceedance of the certification limit for the significant wave height ( $P_e$ ) (see Appendix 2 below).

### (c) Deliverables



- (1) A comprehensive report describing the model tests, the facility they were performed in, the model properties, the wave conditions used, the results of the tests, and the method of analysis to demonstrate compliance with CS 27.801(d) and (e).
- (2) Conclusions in this report are to clarify the compliance (or otherwise) with those provisions.
- (3) Digital video and data records of all tests performed.
- (4) A specification for an actual rotorcraft ditching certification model test should also be expected to include:
  - (i) an execution plan and timescale;
  - (ii) formal progress reports on content and frequency; and
  - (iii) quality assurance requirements.

#### Appendix 1 — Worked example

The target five-minute capsizes probability for a CS 27.801 certified rotorcraft, with post-capsizes mitigation provided, is 29 %. One option available to the rotorcraft designer is to test at the selected wave height and demonstrate a probability of capsizes no greater than 29 %. However, to enhance offshore helicopter safety, some national aviation authorities, have imposed restrictions that prevent normal operations (i.e. excluding emergencies, search and rescue (SAR) etc.) in sea conditions above the demonstrated ditching performance; so, in this case, the helicopter may be operationally limited.

These operational restrictions may be avoided by accounting for the probability of exposure to sea conditions exceeding the selected wave height by certifying the rotorcraft for a lower probability of capsizes. Since it is conservatively assumed that the probability of capsizes in sea conditions exceeding the certified wave height is unity, the lower capsizes probability required to be met is 29 % minus the probability of the selected wave height being exceeded. Clearly, the resulting probability of capsizes is greater than zero, which means that this option is only available for wave heights with a probability of exceedance of less than 29 %.

Referring to Table 1 above, it can be seen that this condition is met for wave heights greater than 2.5 m. In particular, the significant wave height ( $H_s$ ) probabilities of exceedance  $P_e$  for six-metre and four-metre wave heights are 1.2 % and 8 % respectively. The applicant, therefore, has the option of certifying the rotorcraft for either of these wave heights without operating restriction(s).

Provided it can be demonstrated that a capsizes probability of  $\leq 29 - 1.2 = 27.8$  % in an  $H_s = 6$  m,  $T_z = 7.9$  s sea condition, or a capsizes probability of  $\leq 29 - 8 = 21$  % in an  $H_s = 4$  m,  $T_z = 6.7$  s condition (i.e. in the northern North Sea default wave height/period combinations provided in Table 1), the rotorcraft would have demonstrated acceptable ditching capability in any part of the world, and should be unaffected by the operational restrictions mentioned above.

#### (a) $H_s = 6$ m option

Taking first the  $H_s = 6$  m option, we need to demonstrate a  $\leq 27.8$  % probability of capsizes with a 95 % confidence. Applying equation (5)(i) above, this can be achieved with a 54-minute (full-scale time) exposure to the sea condition without capsizes.

Rearranging this equation, we have:



$$T_{Test} \approx -\ln(1 - C) \frac{T_{criterion}}{P_{criterion}}$$

$$T_{Test} \approx -\ln(1 - 0.95) \frac{5 \times 60}{0.278} = 3232.8 \text{ s} = 53.9 \text{ min}$$

Alternatively, applying equation (5)(ii) above, the criterion would also be met if the model were seen to capsize just three times (for example) in a total 2.4 hours of exposure to the sea condition, or four times (for example) in a total of 2.8 hours of exposure.

Equation (ii) cannot be readily rearranged to solve  $T_{Test}$ , so the easiest way to solve it is using a spreadsheet on a trial-and-error method. For the four-capsizes case, we find that a 2.8-hour exposure gives a confidence of 0.95.

$$C \approx 1 - \left\{ \sum_{k=0}^{4e} \frac{1}{k!} \left( \frac{0.278 \times 2.8 \times 60 \times 60}{5 \times 60} \right)^k \right\} \exp \left( - \frac{0.278 \times 2.8 \times 60 \times 60}{5 \times 60} \right) = 0.95$$

(b)  $H_s = 4 \text{ m}$  option

Now, taking the  $H_s = 4 \text{ m}$  option, we need to demonstrate a  $\leq 21 \%$  probability of capsize with a 95 % confidence. Equation (5)(i) above shows that we can demonstrate compliance with a 71-minute (full-scale time) exposure to the 4-m sea condition without capsize.

$$T_{Test} \approx -\ln(1 - 0.95) \frac{5 \times 60}{0.21} = 4279.8 \text{ s} = 71.3 \text{ min}$$

Alternatively, applying equation (5)(ii) above, the criterion would also be met if the model were seen to capsize just three times (for example) in a total 3.1-hour exposure to the sea condition, or four times (for example) in a total 3.7-hour exposure.

Similarly to the six-metre example above, for the four-capsize case, we find by trial and error that a 3.7-hour exposure gives a confidence of 0.95.

$$C \approx 1 - \left\{ \sum_{k=0}^{4e} \frac{1}{k!} \left( \frac{0.21 \times 3.7 \times 60 \times 60}{5 \times 60} \right)^k \right\} \exp \left( - \frac{0.21 \times 3.7 \times 60 \times 60}{5 \times 60} \right) = 0.95$$

Note: In addition to restricting normal helicopter offshore operations to the demonstrated ditching capability, i.e. the applicant's chosen significant wave height limit ( $H_{sL}$ ), a national aviation authority (NAA) may declare a maximum limit above which all operations will be suspended due to the difficulty of rescuing persons from the sea in extreme conditions. There will, therefore, be no operational benefit in certifying a rotorcraft for sea conditions exceeding national limits for rescue.

Appendix 2 — Test specification rationale

(a) Introduction

The overall risk of capsize within the five-minute exposure period consists of two components: the probability of capsize in a given wave condition, and the probability of experiencing that wave condition in a ditching event.



If it is assumed that a ditching event occurs at random and is not linked with weather conditions, the overall risk of a capsized helicopter can be established by combining two pieces of information:

- (1) The wave climate scatter table, which shows the probability of meeting any particular combination of  $H_s$  and  $T_z$ . An example scatter table is shown below in Figure 1 — Example of all-year wave scatter table. Each cell of the table contains the probability of experiencing a wave condition with  $H_s$  and  $T_z$  in the range provided. Thus, the total of all cells in the table adds up to unity.
- (2) The probability of capsizing in a five-minute exposure for each of these height/period combinations. This probability of capsizing is different for each helicopter design and for each wave height/period combination, and is to be established through model testing using the method defined above.

In theory, a model test for the rotorcraft design should be performed in the full range of wave height/period combinations covering all the cells in the scatter table. Clearly, wave height/period combinations with zero or very low probabilities of occurrence might be ignored. It might also be justifiably assumed that the probability of capsizing at very high wave heights is unity, and at very low wave heights zero. However, there would still remain a very large number of intermediate wave height/period combinations that would need to be investigated in model tests, and it is considered that such a test programme would be too lengthy and costly to be practicable.

The objective here is therefore to establish a justifiable method of estimating the overall five-minute capsizing probability using model test results for a single-wave condition. That is a single combination of  $H_s$  and  $T_z$ .

Such a method can never be rigorously linked with the safety objective, but it is proposed that it may be regarded as a conservative approximation.

#### (b) Test methodology

The proposed test methodology is as follows:

The rotorcraft designer selects an  $H_{sL}$  for ditching certification of his helicopter. Model tests are performed in the sea condition  $H_{sL} T_{zL}$  (where  $T_{zL}$  is the zero-crossing period most likely to accompany  $H_{sL}$ ) with the selected spectrum shape using the method specified above, and the five-minute probability of capsizing ( $P_c$ ) established in this sea condition.

The way in which  $P_c$  varies for other values of  $H_s$  and  $T_z$  is not known because it is not proposed to perform model tests in all the other possible combinations. Furthermore, there is no theoretical method to translate a probability of capsizing from one sea condition to another.

However, it is known that the probability of capsizing is related to exposure to breaking waves of sufficient height, and that this is in turn linked with wave steepness. Hence:

- (1) the probability of capsizing is likely to be higher for wave heights just less than  $H_{sL}$  but with wave periods shorter than  $T_{zL}$ ; and
- (2) the probability of capsizing will be lower for the larger population of wave conditions with wave heights lower than  $H_{sL}$  and with wave periods longer than  $T_{zL}$ .

So a reasonable and conservative assumption is that on average, the same  $P_c$  holds good for all wave conditions with heights equal to or lower than  $H_{sL}$ .





4. Create a new AMC 27.805(c) as follows:

**AMC 27.805(c)**

**Flight crew emergency exits**

This AMC supplements FAA AC 27.805.

(a) Explanation

To facilitate a rapid escape, flight crew emergency exits should be designed for use following a ditching or water impact, with the rotorcraft in both the upright position and in any foreseeable floating attitude. The flight crew emergency exits should not be obstructed during their operation by water or floats to the extent that rapid escape would not be possible or that damage to the flotation system may occur. This should be shown for any rotorcraft floating attitude, upright and capsized, and with the emergency flotation system intact and with any single compartment failed. In the capsized rotorcraft floating attitude, the flight crew emergency exits should be usable with the cabin flooded.

(b) Procedures

- (1) It should be shown by test, demonstration or analysis that flight crew emergency exits are free from interference from water and from stowed and deployed emergency flotation devices, with the rotorcraft in any foreseeable floating attitude.
- (2) Flight crew should be able to reach the operating device for their emergency exit, whilst seated, with restraints fastened, and with the rotorcraft in any attitude.
- (3) Likely damage sustained during a ditching should be considered (e.g. loss of the tail boom).
- (4) It is acceptable that the emergency exit threshold is below the waterline but in such a case, it should be demonstrated that there is no obstruction to the use of the exit and that no excessive force is required.
- (5) It is permissible that flight crew may be unable to directly enter life rafts from the flight crew emergency exits and may need to take a more indirect route, e.g. by climbing over a forward flotation unit. In such a case, an assessment of the feasibility of such a procedure should be made. Handholds may need to be provided on the rotorcraft.

5. Create a new AMC 27.807(d) as follows:

**AMC 27.807(d)**

**Ditching emergency exits for passengers**

This AMC supplements FAA AC 27.807 and replaces AC 27.807A and AC 27.807B.

(a) Explanation

CS-27 Amendment X re-evaluates the need for and concept of ditching emergency exits. Prior to CS-27 Amendment X, there were no additional ditching provisions for rotorcraft certified for ditching with regard to the number of emergency exits.



Operational experience has shown that in a ditching with the rotorcraft remaining upright, use of the passenger doors can be very beneficial in ensuring a rapid and orderly evacuation onto the life raft(s). However, when a rotorcraft capsizes, doors may be unusable and the number and availability of ditching emergency exits will be crucial to ensuring that passengers are able to escape in a timely manner. Experience has shown that the number of ditching emergency exits mandated in the past by design provisions has been inadequate, and a common design solution has been to use the passenger cabin windows as ditching emergency exits by including a jettison feature. The use of such 'push-out' windows is mandated by some air operations regulations.

CS 27.807(d)(1) requires that one pair of ditching emergency exits, i.e. one on each side of the rotorcraft, be provided for each unit, or part of a unit, of four passenger seats, and that passenger seats be located relative to these exits in a way to best facilitate escape. The objective is that no passenger is in a worse position than the second person to egress through an exit. The size of each ditching emergency exit should at least meet the dimensional provisions of CS 27.807(b)(1), i.e. provide an unobstructed opening that will admit of a 0.48 m x 0.66 m (19 in. x 26 in.) ellipse.

This provision is based on the need to facilitate egress in the case of capsize occurring soon after the rotorcraft has alighted on the water or in the event of a survivable water impact in which the cabin will likely be immediately flooded. The time available for evacuation is very short in such situations, and therefore, CS-27 Amendment X has increased the safety level by mandating additional exits, in the form of ditching emergency exits, to both shorten available escape routes and to ensure that no occupant should need to wait for more than one other person to escape before being able to make their own escape. The provision of a ditching emergency exit in each side of the fuselage for each unit (or part of a unit) of four passenger seats will make this possible provided that seats are positioned relative to the exits in a favourable manner.

Critical evacuation factors are the distance to an emergency exit and how direct and obvious the exit route is, taking into account likely passenger disorientation.

#### (b) Procedures

- (1) The number and size of ditching emergency exits should be as specified above.
- (2) Care should be taken regarding oversize exits to avoid potential blockage if more than one passenger attempts to use the exit simultaneously.
- (3) A higher seat-to-exit ratio may be accepted if the exit size is large enough to allow the simultaneous escape of more than one passenger. For example, a pair of exits may be approved for eight passengers if the size of each exit provides an unobstructed area that encompasses two ellipses of 0.48 m x 0.66 m (19 in. x 26 in.) side by side.
- (4) Test, demonstration, compliance inspection, or analysis is required to show freedom from interference from stowed and deployed emergency flotation devices. In the event that an analysis is insufficient or a given design is questionable, a demonstration may be required. Such a demonstration would consist of an accurate, full-size replica (or true representation) of the rotorcraft and flotation devices when stowed and after their deployment.
- (5) Consideration should be given to reducing the potential confusion caused by the lack of standardisation of the location of the operating devices (pull tab, handle) for ditching



emergency exits. For example, the operating device should be located next to the handhold (see (10) below). The occupant then has only to find the handhold to locate the operating device. Each adjacent occupant should be able to reach the handhold and operating device whilst seated, with restraints fastened, with seat energy absorption features at any design position, and with the rotorcraft in any attitude.

- (6) Ditching emergency exits should be demonstrated as operable with the rotorcraft in any foreseeable attitude, including with the rotorcraft capsized.
- (7) The design of ditching emergency exits should be optimised for use with the rotorcraft capsized. For example, the handhold(s) should be located close to the bottom of the window (top if inverted) to assist an occupant in overcoming the buoyancy loads of the immersion suit, or by ensuring that markings and lighting will help identify the exit(s) and readily assist in an escape.
- (8) Ditching emergency exit opening means should be simple and obvious and not require exceptional effort. Designs with any of the following characteristics (non-exhaustive list) are considered to be non-compliant:
  - (i) the need to use more than one hand to operate the exit itself (use of the handhold may occupy the other hand);
  - (ii) any part of the opening means, e.g. operating handle or control, being located remotely from the exit such that it would be outside of a person's direct vision when looking directly at the exit, or that the person needs to move away from the immediate vicinity of the exit in order to reach it; and
  - (iii) an exit not meeting the opening effort limitations set by FAA AC 29.809.
- (9) Any operating handle or control should be readily grasped and operated by a gloved hand.
- (10) Handholds, as required by CS 27.807(d)(3), should be mounted close to the bottom of each ditching emergency exit such that they fall easily to hand for a normally seated occupant. In the case of exits between face-to-face seating, the provision of two handholds is required.
- (11) For rotorcraft certified for ditching, disorientation of occupants may result in the normal emergency exit markings in the cockpit and passenger cabin being ineffective following rotorcraft capsizing and flooding. As required by CS 27.805(c) and CS 27.807(d), additional illuminated markings should be provided along the periphery of each ditching emergency exit, giving a clear indication of the aperture.

The additional marking of ditching emergency exits should be in the form of illuminated stripes that give a clear indication in all environments (e.g. at night, underwater) of the location of a ditching emergency exit. The markings should comprise straight markings along all four edges.

The additional illuminated markings should function automatically, when needed, and remain visible for at least 10 minutes following rotorcraft flooding. The method chosen to automatically activate the system (e.g. water immersion switch(es), tilt switch(es) etc.) should be such as to ensure that the markings are illuminated immediately, or are already illuminated when the rotorcraft reaches a point where a capsize is inevitable.



The location of the ditching emergency exit operating device (e.g. handle, or pull tab in the case of a push-out window) should be distinctively illuminated. The illumination should provide sufficient lighting to illuminate the handle or tab itself in order to assist in its identification. In the case of push-out windows, the optimum place(s) for pushing out (e.g. in a corner) should be highlighted.

For ease of recognition underwater, black and yellow markings with at least two bands of each colour of approximately equal width should be used for the ditching emergency exit operating device. The highlighted place(s) for push-out windows should also incorporate black-and-yellow-striped markings.

- (12) With regard to the location of seats relative to exits, the most obvious layout that maximises achievement of the objective that no passenger is in a worse position than the second person to egress through an exit is a four-abreast arrangement with all seats in each row located appropriately and directly next to the emergency exits. However, this might not be possible in all rotorcraft designs due to issues such as limited cabin width, the need to locate seats such as to accommodate normal boarding and egress, and the installation of items other than seats in the cabin. Notwithstanding this, an egress route necessitating movement such as along an aisle, around a cabin item, or in any way other than directly towards the nearest emergency exit, to escape the rotorcraft is not considered to be compliant with CS 27.807(d)(1).

6. Create a new AMC 27.1411 as follows:

**AMC 27.1411**

**Safety equipment — General**

(a) Explanation

CS-27 Amendment X introduced changes related to ditching and associated equipment. In particular, it defined a standard terminology, re-established CS 27.1411 as a general certification specification for all safety equipment, reorganised CS 27.1415 specifically for ditching equipment, and created a new CS 27.1470 on the installation and carriage of emergency locator transmitters (ELTs). All provisions relating to life rafts are now co-located in CS 27.1415.

- (1) The safety equipment should be accessible and appropriately stowed, and it should be ensured that:
- (i) locations for stowage of all required safety equipment have been provided;
  - (ii) safety equipment is readily accessible to both crew members and passengers, as appropriate, during any reasonably probable emergency situation;
  - (iii) stowage locations for all required safety equipment will adequately protect such equipment from inadvertent damage during normal operations; and
  - (iv) safety equipment stowage provisions will protect the equipment from damage during emergency landings when subjected to the inertia loads specified in CS 27.561.



(2) It is a frequent practice for the rotorcraft manufacturer to provide the substantiation for only those portions of the ditching provisions relating to rotorcraft flotation and ditching emergency exits. Completion of the ditching certification to include the safety equipment installation and stowage provisions is then left to the affected operator to arrange via a modifier so that those aspects can best be adopted to the selected cabin interior. In such cases, the 'Limitations' section of the rotorcraft flight manual (RFM) should identify the substantiations yet to be provided in order to justify the full certification with ditching provisions. The modifier performing these final installations is then concerned directly with the details of this AMC. Any issues arising from aspects of the basic rotorcraft flotation and ditching emergency exits certification that are not compatible with the modifier's proposed safety equipment provisions should be resolved between the type certificate (CT) holder and the modifier prior to the certifying authority's certification with ditching provisions (see AMC 27.801(b)(14) and AMC 27.1415(a)(2)(ii)).

(b) Procedures

(1) A cockpit evaluation should be conducted to demonstrate that all required emergency equipment to be used by the flight crew will be readily accessible during any probable emergency situation, including the possibility of inertia reel seat belts 'locking'. This evaluation should include, for example, emergency flotation equipment actuation devices, remote life raft releases, door jettison handles, handheld fire extinguishers, and protective breathing equipment.

(2) Stowage provisions for safety equipment shown to be compatible with the vehicle configuration presented for certification should be provided and identified so that:

(i) equipment is readily accessible regardless of the operational configuration;

(ii) stowed equipment is free from inadvertent damage from passengers and handling;  
and

(iii) stowed equipment is adequately restrained to withstand the inertia forces specified in CS 27.561(b)(3) without sustaining damage.

(3) Life raft stowage provisions should be sufficient to accommodate rafts for the maximum number of occupants for which certification for ditching is requested by the applicant.

(4) Service experience has shown that following deployment, life rafts are susceptible to damage while in the water adjacent to the rotorcraft due to projections on the exterior of the rotorcraft such as antennas, overboard vents, guttering, etc. Projections likely to cause damage to a deployed life raft should be avoided by design, or suitably protected to minimise the likelihood of their causing damage to a deployed life raft. Relevant maintenance information should also provide procedures for maintaining such protection for rotorcraft equipped with life rafts. Furthermore, consideration should be given to the likely damage that may occur (e.g. disintegration of carbon-fibre panels or structure) during water entry at or slightly above the demonstrated ditching envelope and its potential hazard to deployed life rafts.

(5) Emergency signalling equipment required by Regulation (EU) No 965/2012 should be free from hazard in its operation, and operable using gloved hands. Required signalling



equipment should be easily accessible to the passengers or crew and located near a ditching emergency exit or included in the survival equipment attached to life rafts.

7. Create a new AMC 27.1415 as follows:

**AMC 27.1415**

**Ditching equipment**

(a) Explanation

- (1) Ditching equipment is not required for all rotorcraft overwater operations. However, if such equipment is required by Regulation (EU) No 965/2012, the equipment supplied for compliance with said Regulation should satisfy this AMC.
- (2) Compliance with the provisions of CS 27.801 for rotorcraft ditching requires compliance with the safety equipment stowage provisions and ditching equipment provisions of CS 27.1411 and CS 27.1415, respectively.
  - (i) Ditching equipment, installed to complete ditching certification, or required by Regulation (EU) No 965/2012, should be compatible with the basic rotorcraft configuration presented for ditching certification. It is satisfactory if the operating equipment is not incorporated at the time of the original rotorcraft type certification provided that suitable information is included in the 'Limitations' section of the rotorcraft flight manual (RFM) to identify the extent of ditching certification not yet completed.
  - (ii) When the ditching equipment required by CS 27.1415 is being installed by a person other than the applicant who provided the rotorcraft flotation system and ditching emergency exits, special care should be taken to avoid degrading the functioning of those items, and to make the ditching equipment compatible with them (see AMC 27.801(b)(14) and AMC 27.1411(a)(2)).

(b) Procedures

All ditching equipment, including life rafts, life preservers, immersion suits, emergency breathing systems, etc., used to show compliance with the ditching provisions or Regulation (EU) No 965/2012 should be of an approved type for use in all sea conditions covered by the certification with ditching provisions.

(1) Life rafts

- (i) Life rafts are rated during their approval according to the number of people that can be carried under normal conditions and the number that can be accommodated in an overload condition. Only the normal rating may be used in relation to the number of occupants permitted to fly in the rotorcraft.
- (ii) Where two life rafts are installed, each should deploy on opposite sides of the rotorcraft in order to minimise the probability that both will be damaged during water entry/impact, and to provide the maximum likelihood that at least one raft will be useable in any wind condition.



- (iii) Successful deployment of life raft installations should be demonstrated in all representative conditions. Testing should be performed, including underwater deployment, if applicable, to demonstrate that life rafts sufficient to accommodate all rotorcraft occupants, without exceeding the rated capacity of any life raft, will deploy reliably with the rotorcraft in any reasonably foreseeable floating attitude, including capsized. It should also be substantiated that reliable deployment will not be compromised by inertia effects from the rolling/pitching/heaving of the rotorcraft in the sea conditions chosen for demonstration of compliance with the flotation/trim provisions of CS 27.801(e), or by intermittent submerging of the stowed raft location (if applicable) and the effects of wind. This substantiation should also consider all reasonably foreseeable rotorcraft floating attitudes, including capsized. Reasonably foreseeable floating attitudes are considered to be, as a minimum, upright, with and without loss of the critical emergency flotation system (EFS) compartment, and capsized, also with and without loss of the critical EFS compartment. Consideration should also be given towards maximising, where practicable, the likelihood of life raft deployment for other cases of EFS damage.
- (iv) Rotorcraft fuselage attachments for the life raft retaining lines should be provided.
- (A) Each life raft must be equipped with two retaining lines to be used for securing the life raft to the rotorcraft. The short retaining line should be of such a length as to hold the raft at a point next to an upright floating rotorcraft such that the occupants can enter the life raft directly without entering the water. If the design of the rotorcraft is such that the flight crew cannot enter the passenger cabin, it is acceptable that they would need to take a more indirect route when boarding the life raft. After life raft boarding is completed, the short retaining line may be cut and the life raft then remain attached to the rotorcraft by means of the long retaining line.
- (B) Attachments on the rotorcraft for the retaining lines should not be susceptible to damage when the rotorcraft is subjected to the maximum water entry loads established by CS 27.563.
- (C) Attachments on the rotorcraft for the retaining lines should be structurally adequate to restrain a fully loaded life raft.
- (D) Life rafts should be attached to the rotorcraft by the required retaining lines after deployment without further action from the crew or passengers.
- (E) It should be verified that the length of the long retaining line will not result in the life raft taking up a position which could create a potential puncture risk or hazard to the occupants, such as directly under the tail boom, tail rotor or main rotor disc.
- (v) Life raft activation
- The following should be provided for each life raft:
- (A) primary actuation: an independent manual activation control, readily accessible to each pilot on the flight deck whilst seated. Alternatively, life rafts may be deployed automatically following water entry. In this case, it will



need to be shown that inadvertent deployment in flight will be appropriately unlikely or would not cause a hazard to the rotorcraft;

(B) secondary actuation: an independent manual activation control accessible from the passenger cabin; if the device is located within the cabin, it should be protected from inadvertent operation; and

(C) tertiary actuation: an independent manual activation control accessible to a person in the water with the rotorcraft in all foreseeable floating attitudes, including capsized.

Placards should be installed, of appropriate size, number and location, to highlight the location of each of the above life raft activation controls. All reasonably foreseeable rotorcraft floating attitudes should be considered.

(2) Life preservers. No provision for stowage of life preservers is necessary if Regulation (EU) No 965/2012 mandates the need for constant-wear life preservers.

8. Create a new AMC 27.1470 as follows:

**AMC 27.1470**

**Emergency locator transmitters (ELTs)**

(a) Explanation

The purpose of this AMC is to provide specific guidance for compliance with CS 27.1301, CS 27.1309, CS 27.1470, CS 27.1529 and CS 27.1581 regarding emergency locator transmitters (ELT) and their installation.

An ELT is considered a passive and dormant device whose status is unknown until it is required to perform its intended function. As such, its performance is highly dependent on proper installation and post-installation testing.

(b) References

Further guidance on this subject can be found in the following references:

- (1) ETSO-2C126 406 MHz Emergency Locator Transmitter (ELT);
- (2) ETSO-2C91a Emergency Locator Transmitter (ELT) Equipment;
- (3) ETSO-C126a 406 MHz Emergency Locator Transmitter;
- (4) FAA TSO-C126b 406 MHz Emergency Locator Transmitter (ELT);
- (5) EUROCAE ED-62A Minimum Operational Performance Specification For Aircraft Emergency Locator Transmitters (406 MHz and 121.5 MHz (Optional 243 MHz));
- (6) RTCA DO-182 Emergency Locator Transmitter (ELT) Equipment Installation and Performance; and
- (7) RTCA DO-204A Minimum Operational Performance Standards (MOPS) for 406 MHz Emergency Locator Transmitters (ELTs).

(c) Definitions



- (1) ELT (AF): ELT (automatic fixed) is intended to be permanently attached to the rotorcraft before and after a crash, is automatically activated by the shock of the crash, and is designed to aid search and rescue (SAR) teams in locating a crash site.
- (2) ELT (AP): ELT (automatic portable) is intended to be rigidly attached to the rotorcraft before a crash and is automatically activated by the shock of the crash, but is readily removable from the rotorcraft after a crash. It functions as an ELT (AF) during the crash sequence. If the ELT does not employ an integral antenna, the rotorcraft mounted antenna may be disconnected and an auxiliary antenna (stowed in the ELT case) connected in its place. The ELT can be tethered to a survivor or a life raft. This type of ELT is intended to assist SAR teams in locating the crash site or survivor(s).
- (3) ELT (S): ELT (survival) should survive the crash forces, be capable of transmitting a signal, and have an aural or visual indication (or both) that power is on. Activation of an ELT (S) usually occurs by manual means but automatic activation (e.g. activation by water) may also apply.
- (4) ELT (S) Class A (buoyant): this type of ELT is intended to be removed from the rotorcraft, deployed and activated by survivors of a crash. It can be tethered to a life raft or a survivor. The equipment should be buoyant and it should be designed to operate when floating in fresh or salt water, and should be self-righting to establish the antenna in its nominal position in calm conditions.
- (5) ELT (S) Class B (non-buoyant): this type of ELT should be integral to a buoyant device in the rotorcraft, deployed and activated by the survivors of a crash.
- (6) ELT (AD) or automatically deployable emergency locator transmitter (ADELT): this type of automatically deployable ELT is intended to be rigidly attached to the rotorcraft before a crash and automatically deployed after the crash sensor determines that a crash has occurred or after activation by hydrostatic sensor. This type of ELT should float in water and is intended to aid SAR teams in locating the crash site.
- (7) Crash acceleration sensor (CAS) is a device which detects an acceleration and initiates the transmission of emergency signals when such acceleration exceeds a predefined threshold (Gth). It is also designated as g switch.

(d) Procedures

(1) Installation aspects of ELTs

The equipment should be installed in accordance with the guidance provided in this AMC.

(i) Installation of the ELT transmitter unit and crash acceleration sensors

The location of the ELT should be chosen to minimise the potential for inadvertent activation or damage by impact, fire, or contact with passengers, baggage or cargo.

The ELT transmitter unit should ideally be mounted to primary rotorcraft load-carrying structures such as trusses, bulkheads, longerons, spars or floor beams (not rotorcraft skin). Alternatively, the structure should meet the requirements of the test specified in 6.1.8 of ED-62A.



The structure on which an ELT is mounted should not be likely to separate in case of a crash, such as a rotorcraft tail boom. However, this does not apply to ELT(s), which should be installed or stowed in a location that is conspicuously marked and readily accessible, or should be integral to a buoyant device such as a life raft, depending on whether it is Class A or B.

The crash acceleration sensor installation can be a source of nuisance triggers, non-activation or missed deployment due to improper installation.

Nuisance triggers can occur when the crash acceleration sensor does not work as expected or is installed in a way that it is exposed to shocks or vibration levels outside those assumed during equipment qualification, making it susceptible to inadvertent activation. It can also be activated as a result of improper handling and installation practices.

Non-activation can occur when operational ELTs are installed in such a way that prevents the crash sensor from sensing actual crash forces.

Particular attention should be paid to the installation orientation of the crash acceleration sensor. If the equipment contains a crash sensor, that part of the equipment containing the crash sensor should be clearly marked by the ELT manufacturer to indicate the correct installation orientation(s), if appropriate, for crash sensing.

Installation design should follow the instructions contained in the installation manual provided by the equipment manufacturer. In the absence of an installation manual, in general, in the case of a helicopter installation, if the equipment has been designed to be installed on fixed-wing aircraft, the equipment manufacturer has historically recommended the installation to be oriented with an angle of 45 degrees with respect to the main longitudinal axis. This may help the sensor to detect forces in directions other than the main longitudinal axis since during a helicopter crash, the direction of the impact may easily differentiate from the main aircraft axis. Nevertheless, it should be noted that this is not the unique solution for helicopters. There are products currently available on the market that are designed specifically for helicopters or designed to sense forces in several axes.

(ii) Use of hook and loop style fasteners

In several recent aircraft accidents, ELTs mounted with hook and loop style fasteners, commonly referred to as 'Velcro', have detached from their aircraft mounting as a result of the crash forces experienced. The separation of the ELT from its mount could cause the antenna connection to be severed, rendering the ELT ineffective.

Inconsistent installation and reinstallation practices can lead to the hook and loop style fastener not having the necessary tension to perform its intended function. Furthermore, the retention capability of the hook and loop style fastener may degrade over time, due to wear and environmental factors such as vibration, temperature, or contamination. The safety concern about these attachments increases when the ELT manufacturer's instructions for continued airworthiness



(ICA) do not contain specific instructions for regularly inspecting the hook and loop style fasteners, or a replacement interval (e.g. Velcro life limit). This concern applies, regardless of how the hook and loop style fastener is installed in the aircraft.

(iii) ELT antenna installation

The most recurrent issue found during accident investigations concerning ELTs is the detachment of the antenna (coaxial cable), causing the transmission of the ELT unit to be completely inefficient.

Chapter 6 of ED-62A addresses the external antenna installation and provides guidance, in particular, on:

- (A) antenna location;
- (B) antenna-to-ELT transmission unit relative position;
- (C) coaxial-cable characteristics; and
- (D) coaxial-cable installation.

Any ELT antenna should be located away from other antennas to avoid disruption of antenna radiation patterns. In any case, during installation of the antenna, it should be ensured that the antenna has a free line of sight to the orbiting COSPAS-SARSAT satellites at most times when the aircraft is in the normal flight attitude.

Ideally, for the 121.5-MHz ELT antenna, a separation of 2.5 metres from antennas receiving very high frequency (VHF) communications and navigation is sufficient to minimise unwanted interference. The 406 MHz ELT antenna should be positioned at least 0.8 metres from antennas receiving VHF communications and navigation to minimise interference.

External antennas which have been shown to be compatible with a particular ELT will either be part of the ETSO/TSO-approved ELT or will be identified in the ELT manufacturer's installation instructions. Recommended methods for installing antennas are outlined in FAA AC 43.13-2B.

The antenna should be mounted as close to the respective ELT as practicable. Provision should be taken to protect coaxial cables from disjunction or from being cut. Therefore, installation of the external antenna close to the ELT unit is recommended. Coaxial cables connecting the antenna to the ELT unit should not cross rotorcraft production breaks.

In the case of external antenna installation, ED-62A recommends that its mounting surface should be able to withstand a static load equal to 100-times the antenna's weight applied at the antenna mounting base along the longitudinal axis of the rotorcraft. This strength can be demonstrated by either test or conservative analysis.

If the antenna is installed within a fin cap, the fin cap should be made of a material that is RF-transparent and will not unduly attenuate the radiated transmission or adversely affect the antenna radiation pattern shape.



In the case of internal antenna location, the antenna should be installed as close to the ELT unit as practicable, insulated from metal window casings and restrained from movement within the cabin area. The antenna should be located such that its vertical extension is exposed to an RF-transparent window. The antenna's proximity to the vertical sides of the window and to the window pane and casing as well as the minimum acceptable window dimensions should be in accordance with the equipment manufacturer's instructions.

The voltage standing wave ratio (VSWR) of the installed external antenna should be checked at all working frequencies according to the test equipment manufacturer's recommendations.

Coaxial cables between the antenna and the ELT unit should have vibration-proof RF connectors on each end. When the coaxial cable is installed and the connectors mated, each end should have some slack in the cable, and the cable should be secured to rotorcraft structures for support and protection.

In order to withstand exposure to fire or flame, the use of fire-resistant coaxial cable or the application of fire-resistant material around the coaxial cable is recommended.

## (2) Deployment aspects of ELTs

Unlike the general recommendations on ELT installation found in ED-62A, this standard does not provide detailed or extensive guidance for the particular case of ADELTS. ADELTS have particularities of the design and installation that need to be addressed independently of the general recommendations.

The location of the ADELTS and its manner of installation should minimise the risk of injury to persons or damage to the rotorcraft in the event of inadvertent activation. The means to manually deploy the ADELTS should be located in the cockpit in such a way, and should be guarded so, that inadvertent manual activation of the ADELTS is minimised.

Automatic deployable ELTs should be located so as to minimise damage to the rotorcraft structure and surfaces during deployment. The ELT deployment trajectory should be demonstrated to be clear of interference from the airframe or other part of the rotorcraft, or with the rotor in the case of helicopters. The installation should also not compromise the operation of emergency exits or of any other safety features.

In some helicopters, where an ADELTS is installed aft of the transport joint in the tail boom, any disruption of the tail rotor drive shaft has the potential to disrupt or disconnect the ADELTS wiring. From accident investigations, it can be seen that if tail boom becomes detached, an ADELTS that is installed there, aft of the transport joint, will also become detached before signals from sensors triggering its deployment can be received.

Therefore, it is recommended to install the ADELTS forward of the transport joint of the tail boom.

The hydrostatic sensor used for automatic deployment should be installed in a location shown to be immersed in water within a short time following a ditching or water impact, but not subject to water exposure in the expected rotorcraft operations. This assessment



should include the most probable rotorcraft attitude when crashed, i.e. its capability to keep an upright position after a ditching or a crash into water.

It should also be shown that the risk of unsuccessful ADELTS deployment, due to rotorcraft floating attitude, including capsized, has been minimised.

The installation supporting the deployment feature should be demonstrated to be robust to immersion. Assuming a crash over water or a ditching, water may immerse not only the beacon and the hydrostatic sensor which is designed for this, but also any electronic component, wires and the source of power used for the deployment.

(3) Additional considerations

(i) Human factors (HF)

The ELT controls should be designed and installed so that they are not activated unintentionally. These considerations should address the control panel locations, which should be clear from normal flight crew movements when getting into and out of the cockpit and when operating the rotorcraft, and the control itself. As already indicated in 3.1.2, the means for manually activating the ELT should be guarded in order to avoid unintentional activation.

The Aircraft Flight Manual (RFM) should document the operation of the ELT, and in particular, any feature specific to the installed model.

(ii) Batteries

The ELT operates using its own power source. The ELT manufacturer indicates the useful life and expiration date of the batteries by means of dedicated label. The installation of the ELT should be such that the label indicating the battery expiration date is clearly visible without equipment removal. This would facilitate replacement of the battery and maintenance activities.

(4) Maintenance and inspection aspects

This Chapter provides guidance for the applicant to produce ICA related to ELT systems. The guidance is based on Chapter 7 of ED-62A.

(i) The ICA should explicitly mention that:

(A) The self-test function should be performed according to the manufacturer's recommendation but no less than once every 6 months. Regulation at the place of operation should be considered when performing self-tests, as national aviation authorities (NAAs) may have established specific procedures to perform self-tests.

(B) As a minimum, periodic inspection should occur at every battery replacement unless required more frequently by airworthiness authorities or the manufacturer.

(ii) Inspection should include:

(A) removal of all interconnections to the ELT antenna, and inspection of cables and terminals;



- (B) removal of the ELT unit, and inspection of the mounting;
- (C) access to battery to check that there is no corrosion;
- (D) check of the crash sensor (G-switch) is recommended (refer to Chapter 7.6 of ED-62A — Periodic inspection for further guidance); and
- (E) measurement of transmission frequencies and power output.

(5) Rotorcraft flight manual supplement (RFMS)

The rotorcraft flight manual (RFM) should contain all pertinent information related to the operation of the ELT, including the use of the remote control panel in the cockpit. If there are any limitations on its use, these should be declared in the 'Limitations' section of the RFM or RFMS.

It should also contain detailed instructions for preflight and postflight checks. As a preflight check, the ELT remote control should be checked to ensure that it is in the armed position. Postflight, the ELT should be checked to ensure that it does not transmit by means of activation of the indicator on the remote control or monitoring 121.5 MHz (or both).

RFMs, or supplemental type certificate (STC) supplements to RFMs, should also contain information on the location and deactivation of ELTs. Indeed, accident investigations have shown that following aircraft ground impact, the remote control switch on the instrument panel may become inoperative, and extensive fuselage disruption may render the localisation of, and the access to, the ELT unit difficult. As a consequence, in the absence of information available to the accident investigators and first responders, this has led to situations where the ELT transmitted for a long time before being shut down, thus blocking the SAR channel for an extended time period. It is therefore recommended that the RFM or its supplements (RFMS) contain information explaining how to disarm or shut down the ELT after an accident, including when the remote control switch is inoperative.

9. Create a new AMC 27.1555 as follows:

**AMC 27.1555**

**Control markings**

This AMC supplements FAA AC 27.1555.

**Explanation**

CS-27 Amendment X introduced the need to mark emergency controls for use following a ditching or water impact with black and yellow stripes, instead of red, to enhance conspicuity when viewed underwater.

- (a) Any emergency control that may be required to be operated underwater (e.g. emergency flotation system deployment switch, life raft deployment switch or handle) should be coloured with black and yellow stripes.
- (b) Black and yellow markings should consist of at least two bands of each colour of approximately equal width.



10. Create a new AMC 27.1561 as follows:

**AMC 27.1561****Safety equipment****(a) Explanation**

This AMC requires that each safety equipment control that can be operated by a crew member or passenger is plainly marked to identify its function and method of operation. (Note that the marking of safety equipment controls located within the cockpit and intended for use by the flight crew are addressed in CS 29.1555). In addition, a location marking for each item of stowed safety equipment should be provided that identifies the contents and how to remove them. All safety equipment, including ditching and survival equipment, should be clearly identifiable and provided with operating instructions. Markings and placards should be conspicuous and durable as per CS 27.1541. Both passengers and crew should be able to identify easily and then use the safety equipment.

**(b) Procedures**

- (1) Release devices such as levers or latch handles for life rafts and other safety equipment should be plainly marked to identify their function and method of operation. The method of operation should be also marked. Stencils, permanent decals, placards, or other permanent labels or instructions may be used.
- (2) Lockers, compartments, or pouches used to contain safety equipment such as life vests, etc. should be marked to identify the equipment therein and to also identify, if not obvious, the method or means of accessing or releasing the equipment.
- (3) Safety equipment should be labelled and provided with instructions for use or operation.
- (4) Locating signs for safety equipment should be legible in daylight from the furthest seated point in the cabin or recognisable from a distance equal to the width of the cabin. Letters, 2.5 cm (1 in) high, should be acceptable to satisfy the recommendation. Operating instructions should be legible from a distance of 76 cm (30 in). These are recommendations based on the exit provisions of CS 27.811(b) and (e)(1).
- (5) As prescribed, each life raft and its installed equipment should be provided with operating instructions that are permanently marked in bold letters and readable at low levels of illumination.
- (6) Easily recognised or identified and easily accessible safety equipment located in view of the occupants may not require locating signs, stencils or decals. However, operating instructions are required. A passenger compartment fire extinguisher that is in view of the passengers is an example.



11. Create a new AMC 27 MG 10 as follows:

**AMC 27 MG 10**

**Advisory material for substantiation of an emergency flotation system (EFS) alone**

Regulation (EU) No 965/2012 may allow for the installation of only emergency flotation equipment, rather than certification for full ditching provisions. However, the provisions for certification of the emergency flotation equipment in such a case remain the same as those for full ditching certification, i.e. compliance with the ditching provisions of CS 27.563 and CS 27.801(b) to (h) should be shown.

**3.2.3. Draft amendment to CS-29 — Book 1**

**SUBPART C — STRENGTH REQUIREMENTS**

1. Amend CS 29.563 as follows:

**CS 29.563 Structural ditching provisions**

If certification with ditching provisions is requested by the applicant, structural strength for ditching must meet the requirement provisions of this paragraph CS and CS 29.801(fe).

- (a) *Forward-speed landing conditions.* The rotorcraft must initially contact the most critical wave for reasonably probable water conditions at forward velocities from zero up to 56 km/h (30 knots) in likely pitch, roll, and yaw attitudes. The rotorcraft limit vertical descent velocity may not be less than 1.5 metres per second (5 ft/s) relative to the mean water surface. Rotor lift may be used to act through the centre of gravity during water entry throughout the landing impact. This lift may not exceed two-thirds of the design maximum weight. ~~A maximum forward velocity of less than 30 knots may be used in design if it can be demonstrated that the forward velocity selected would not be exceeded in a normal one-engine-out touchdown.~~
- (b) *Auxiliary or emergency float conditions*
- (1) *Floats fixed or deployed before initial water contact.* In addition to the landing loads in sub-paragraph (a), each auxiliary or emergency float, ~~and~~ its support and attaching structure ~~in the airframe or fuselage,~~ must be designed for the load developed by a fully immersed float unless it can be shown that full immersion is unlikely. If full immersion is unlikely, the highest likely float buoyancy load must be applied. ~~The highest likely buoyancy load must include consideration of a partially immersed float creating restoring moments to compensate the upsetting moments caused by side wind, unsymmetrical rotorcraft loading, water wave action, rotorcraft inertia, and probable structural damage and leakage considered under CS 29.801(d). Maximum roll and pitch angles determined from compliance with CS 29.801(d) may be used, if significant, to determine the extent of immersion of each float.~~ If the floats are deployed in flight, appropriate air loads derived from the flight limitations with the floats deployed shall be used in substantiation of the floats and their attachment to the rotorcraft. For this purpose, the design airspeed for limit load is the float deployed airspeed operating limit multiplied by 1.11.
- (2) *Floats deployed after initial water contact.* Each float must be designed for full or partial immersion prescribed in sub-paragraph (b)(1). In addition, each float must be designed for



combined vertical and drag loads using a relative limit speed of 37 km/h (20 knots) between the rotorcraft and the water. The vertical load may not be less than the highest likely buoyancy load determined under paragraph (b)(1).

## SUBPART D — DESIGN AND CONSTRUCTION

2. Amend CS 29.783(h) as follows:

### CS 29.783 Doors

(...)

~~(h) Non jettisonable doors used as ditching emergency exits must have means to enable them to be secured in the open position and remain secure for emergency egress in sea state conditions prescribed for ditching.~~

3. Amend CS 29.801 as follows:

### CS 29.801 Ditching

- (a) If certification with ditching provisions is requested by the applicant, the rotorcraft must meet the requirement provisions of this paragraph CS and CS 29.563, CS 29.803(c), CS 29.805(c), CS 29.807(d), CS 29.809(j), CS 29.811(h), CS 29.813(d), 29.1411 and CS 29.1415, CS 29.1470, and CS 29.1555(d)(3) and CS 29.1561.
- (b) Each practicable design measure, compatible with the general characteristics of the rotorcraft, must be taken to minimise the probability that in an emergency landing on water a ditching, the behaviour of the rotorcraft would cause immediate injury to the occupants or would make it impossible for them to escape.
- (c) Emergency flotation systems that are stowed in a deflated condition during normal flight must:
- (1) be designed to be resistant to damage from the effects of a water impact (i.e. crash);
  - (2) if operable within a restricted flight envelope, have an automatic means of arming, disarming and rearming, to enable the system to function, except in flight conditions in which float deployment may be hazardous to the rotorcraft; otherwise the system shall be armed at all times in flight; and
  - (3) have a means of automatic deployment following water entry.
- (ed) The probable behaviour of the rotorcraft during and following a ditching in a water landing must be investigated by scale model tests or by comparison with rotorcraft of similar configuration for which the ditching characteristics have already been substantiated by equivalent model tests. are known. Scoops, flaps, projections, and any other factors likely to affect the hydrodynamic characteristics of the rotorcraft must be considered.
- (de) It must be shown that, under reasonably probable water conditions, the flotation time and trim of the rotorcraft will allow the occupants to leave the rotorcraft and enter the life rafts required by CS 29.1415. If compliance with this provision is shown by buoyancy and trim computations, appropriate allowances must be made for probable structural damage and leakage. If the



rotorcraft has fuel tanks (with fuel jettisoning provisions) that can reasonably be expected to withstand a ditching without leakage, the jettisonable volume of fuel may be considered as buoyancy volume. The rotorcraft must be shown to resist post-ditching capsizing in the sea conditions selected by the applicant. The probability of capsizing in a five-minute exposure to the sea conditions must be demonstrated to be less than or equal to the target probability of capsizing of 29 % with 95 % confidence. Scoops, flaps, projections, and any other installed feature likely to affect the hydrodynamic characteristics of the rotorcraft must be taken into account. Allowances must be made for probable structural damage and leakage.

- (ef) Unless the effects of the collapse of external doors and windows are accounted for in the investigation of the probable behaviour of the rotorcraft in a ditching water landing (as prescribed in subparagraphs (ed) and (de)), the external doors and windows must be designed to withstand the probable maximum local pressures.
- (g) To assist the rescue services in establishing the location and orientation of a capsized rotorcraft, the underside of the rotorcraft must be marked with a series of high-visibility chevrons.
- (h) The sea conditions and any associated information relating to the certification with ditching provisions obtained must be included in the performance information section of the rotorcraft flight manual (RFM).
- (i) The rotorcraft design must incorporate appropriate post-capsizing survivability features to enable all passenger cabin occupants to safely egress the rotorcraft, taking into account the human breath hold capability.
- (j) It must be shown that the rotorcraft will not sink following functional loss of the largest complete ditching flotation unit.

4. Amend CS 29.803 as follows:

**CS 29.803 Emergency evacuation**

(...)

- (c) ~~Reserved.~~ If certification with ditching provisions is requested by the applicant:
  - (1) it must be demonstrated that following a ditching in all sea conditions for which ditching capability is requested by the applicant, passengers are able to evacuate the rotorcraft and step directly into any of the required life rafts, without first entering the water;
  - (2) any exit used in the demonstration under (1), irrespective of whether it is required by any of the provisions of CS 29.807, must meet all the provisions of CS 29.807(d)(2), CS 29.809(c), CS 29.811(a), (c), (d), (e) and CS 29.812(b); and
  - (3) all non-jettisonable doors used in showing compliance with (1) must have means to enable them to be secured in the open position and remain secure for emergency egress in all sea conditions for which ditching capability is requested by the applicant.

(...)



5. Amend CS 29.805 as follows:

**CS 29.805 Flight crew emergency exits**

(...)

- (c) *Ditching emergency exits for flight crew.* If certification with ditching provisions is requested by the applicant, ~~Each flight crew emergency exit must not be obstructed by water or flotation devices after a ditching. This must be shown by test, demonstration, or analysis to provide for rapid escape when the rotorcraft is in the upright floating position or capsized.~~

6. Amend CS 29.807 as follows:

**CS 29.807 Passenger emergency exits**

(...)

- (d) *Ditching emergency exits for passengers.* If certification with ditching provisions is requested by the applicant, ditching emergency exits must be provided in accordance with the following requirement provisions and must be proven by test, demonstration, or analysis unless the emergency exits required by subparagraph (b) above already meet these requirement provisions:

- (1) ~~For rotorcraft that have a passenger seating configuration, excluding pilots seats, of nine seats or less, One ditching emergency exit above the waterline in each side of the rotorcraft, meeting at least the dimensions of a Type IV exit: for each unit (or part of a unit) of four passenger seats. However, the passenger seat-to-exit ratio may be increased for exits large enough to permit the simultaneous egress of two passengers side by side.~~
- (2) ~~For rotorcraft that have a passenger seating configuration, excluding pilots seats, of 10 seats or more, one exit above the waterline in a side of the rotorcraft meeting at least the dimensions of a Type III exit, for each unit (or part of a unit) of 35 passenger seats, but no less than two such exits in the passenger cabin, with one on each side of the rotorcraft. However, where it has been shown through analysis, ditching demonstrations, or any other tests found necessary by the Agency, that the evacuation capability of the rotorcraft during ditching is improved by the use of larger exits, or by other means, the passenger seat to exit ratio may be increased.~~
- (3) Flotation devices, whether stowed or deployed, may not interfere with or obstruct the ditching emergency exits.

(...)

7. Amend CS 29.809 as follows:

**CS 29.809 Emergency exit arrangement**

- (a) Each emergency exit must consist of a movable door, push-out window, or hatch in the external walls of the fuselage and must provide an unobstructed opening to the outside.

(...)



- (j) If certification with ditching provisions is requested by the applicant, ditching emergency exits must meet the following:
- (1) the design of ditching emergency exits, including their means of operation, markings, lighting and accessibility, must be optimised for use in a flooded and capsized cabin;
  - (2) it must be possible to egress the rotorcraft when capsized, with any door in the open and locked position; and
  - (3) each ditching emergency exit must be provided with a suitable handhold, or handholds, adjacently located inside the cabin to assist in the location and operation of as well as the egress through the ditching emergency exit.

8. Amend CS 29.811 as follows:

#### **CS 29.811 Emergency exit marking**

- (a) Each ~~passenger~~ emergency exit, its means of access, and its means of opening must be conspicuously marked for the guidance of occupants using the exits in daylight or in the dark. ~~Such markings must be designed to remain visible for rotorcraft equipped for overwater flights if the rotorcraft is capsized and the cabin is submerged.~~

(...)

- (h) If certification with ditching provisions is requested by the applicant, in addition to the markings required by (a) above:
- (1) each ditching emergency exit required by CS 29.805(c) or CS 29.807(d), its means of access and its means of opening, must be provided with conspicuous illuminated markings that illuminate automatically and are designed to remain visible with the rotorcraft capsized and the cabin flooded; and
  - (2) the operating device for each ditching emergency exit (pull tab(s), operating handle, etc.) must be marked with black and yellow stripes.

9. Amend CS 29.812 as follows:

#### **CS 29.812 Emergency lighting**

For ~~transport~~ Category A rotorcraft, the following apply:

(...)

- (b) Exterior emergency lighting must be provided at each emergency exit as required by CS 29.807(a) and at each door used in the demonstration as required by CS 29.803(c)(1). The illumination may not be less than 0.5 lux (0.05 foot-candle) (measured normal to the direction of incident light) for minimum width on the ground surface, with landing gear extended, equal to the width of the emergency exit where an evacuee is likely to make first contact with the ground or life raft outside the cabin. The exterior emergency lighting may be provided by either interior or exterior sources with light intensity measurements made with the emergency exits open.

(...)



10. Add a new CS 29.813(d) as follows:

**CS 29.813 Emergency exit access**

(...)

- (d) If certification with ditching provisions is requested:

- (1) passenger seats must be located in relation to the ditching emergency exits provided in accordance with CS 29.807(d)(1) in a way to best facilitate escape with the rotorcraft capsized and the cabin flooded; and
- (2) the cabin design must provide handholds to assist in cross-cabin egress.

**SUBPART F — EQUIPMENT**

11. Amend CS 29.1411 as follows:

**CS 29.1411 General**

- (a) *Accessibility.* Required safety equipment to be used by the crew in an emergency, ~~such as automatic life raft releases,~~ must be readily accessible.
- (b) *Stowage provisions.* Stowage provisions for required **safety** emergency equipment must be furnished and must:
- (1) ~~B~~be arranged so that the equipment is directly accessible and its location is obvious; and
- (2) ~~P~~protect the safety equipment from inadvertent damage.
- (c) *Emergency exit descent device.* The stowage provisions for the emergency exit descent device required by CS 29.809 (f) must be at the exits for which they are intended.
- ~~(d) *Life rafts.* Life rafts must be stowed near exits through which the rafts can be launched during an unplanned ditching. Rafts automatically or remotely released outside the rotorcraft must be attached to the rotorcraft by the static line prescribed in CS 29.1415.~~
- ~~(e) *Long-range signalling device.* The stowage provisions for the long-range signalling device required by CS 29.1415 must be near an exit available during an unplanned ditching.~~
- ~~(f) *Life preservers.* Each life preserver must be within easy reach of each occupant while seated.~~

12. Amend CS 29.1415 as follows:

**CS 29.1415 Ditching equipment**

If certification with ditching provisions is requested, the ditching ~~(a) Emergency flotation and signalling equipment required by Regulation (EU) No 965/2012 any applicable operating rule must meet the requirements provisions of this paragraph CS.~~

- ~~(b)(a) General. Ditching equipment~~ Each life raft and each life preserver must be approved **for use in all sea conditions covered by the certification with ditching provisions.** ~~In addition:~~

- (b) Life rafts**



- (1) ~~Provide not less than two rafts.~~ The number of life rafts installed must be no smaller than that stipulated in Regulation (EU) No 965/2012. If more than one life raft is installed, the life rafts must be of an approximately equal rated capacity and buoyancy, to accommodate all the occupants of the rotorcraft; and unless excess life rafts of sufficient capacity are provided, the buoyancy and seating capacity beyond the rated capacity of each life raft (overload rating) must accommodate all occupants of the rotorcraft in the event of loss of one life raft of the largest rated capacity.
- (2) Required life raft(s) must be remotely deployable for use in an emergency. Remote controls capable of deploying the life raft(s) must be located within easy reach of the flight crew, occupants of the passenger cabin and survivors in the water. It must be demonstrated that life raft(s) sufficient to accommodate all rotorcraft occupants, without exceeding the rated capacity of any life raft, can be reliably deployed with the rotorcraft in any reasonably foreseeable floating attitude, including capsized, and in the sea conditions chosen for demonstrating compliance with CS 29.801(e).
- ~~(2)~~(3) Each life raft must have a ~~trailing line, and must have a static~~ short retaining line designed to hold the life raft near the rotorcraft, and a long retaining line designed to keep the life raft attached to the rotorcraft. Both retaining lines must be designed ~~but to~~ break before submerging the empty raft to which they are attached ~~release it~~ if the rotorcraft becomes totally submerged. The long retaining line must be of sufficient length that a drifting life raft will not be drawn towards any part of the rotorcraft that would pose a danger to the life raft itself or the persons on board.
- (4) Each life raft must have obviously marked operating instructions.
- (c) Life preservers. If Regulation (EU) No 965/2012 allows for life preservers not to be worn at all times, they must be stowed within easy reach of each occupant while seated in the rotorcraft.
- (ed) Survival equipment. Approved survival equipment must be attached to each life raft.
- ~~(d) There must be an approved survival type emergency locator transmitter for use in each life raft.~~

13. Create a new CS 29.1470 as follows:

**CS 29.1470 Emergency locator transmitter (ELT)**

Each ELT, including crash sensors and antenna, required by Regulation (EU) No 965/2012, must be installed so as to minimise damage that would prevent its functioning following an accident or incident.

14. Amend CS 29.1555 as follows:

**CS 29.1555 Control markings**

(...)

(d) For accessory, auxiliary, and emergency controls:



- (1) Each essential visual position indicator, such as those showing rotor pitch or landing gear position, must be marked so that each crew member can determine at any time the position of the unit to which it relates; and
- (2) Each emergency control must be red and must be marked as to the method of operation and be red unless it may need to be operated underwater, in which case it must be marked with yellow and black stripes.

15. Amend CS 29.1561 as follows:

#### CS 29.1561 Safety equipment

- (a) Each safety equipment control to be operated by the crew or passenger in an emergency, such as controls for automatic life raft releases, must be plainly marked for its identification and as to its method of operation.
- (b) Each location, such as a locker or compartment that carries any fire extinguishing, signalling, or other safety life-saving equipment, must be so marked.
- ~~(c) Stowage provisions for required safety emergency equipment must be conspicuously marked to identify the contents and facilitate removal of the equipment.~~
- ~~(d)~~ Each item of safety equipment carried life raft must have obviously marked operating instructions.
- ~~(e)~~ Approved survival equipment must be marked for its identification and method of operation.

#### 3.2.4. Draft amendment to CS-29 — Book 2

1. Create a new AMC 29.563 as follows:

#### AMC 29.563

##### Structural Ditching Provisions

- (a) Explanation. This AMC includes specific structural conditions to be considered to support the overall ditching provisions of CS 29.801. These conditions are to be applied to rotorcraft for which certification with ditching provisions is requested by the applicant.
  - (1) The forward-speed landing conditions are specified as follows:
    - (i) The rotorcraft should contact the most critical wave in the probable sea conditions for which certification with ditching provisions is requested by the applicant in the likely pitch, roll, and yaw attitudes.
    - (ii) The forward velocity relative to the wave surface should be in a range of 0–56 km/h (30 kt) with a vertical-descent rate of not less than 1.5 m/s (5 ft/s) relative to the mean wave surface. No account need be taken of the wave particle velocity.
    - (iii) A rotor lift of not more than two-thirds of the design maximum weight may be used to act through the rotorcraft's centre of gravity during water entry.
  - (2) For floats fixed or deployed before water contact, the auxiliary or emergency float conditions are specified in CS 29.563(b)(1). Loads for a fully immersed float should be



applied (unless it is shown that full immersion is unlikely). If full immersion is unlikely, the highest likely buoyancy load should include consideration of a partially immersed float, creating restoring moments to react the upsetting moments caused by side wind, unsymmetrical rotorcraft loading, water wave action, rotorcraft inertia, and probable structural damage and leakage considered under CS 29.801(e). Maximum roll and pitch angles established by compliance with CS 29.801(e) may be used, if significant, to determine the extent of immersion of each float. When determining this, damage to the rotorcraft that could be reasonably expected should be accounted for (e.g. loss of the tail boom resulting in a nose-down attitude in the water).

- (3) Floats deployed after water contact are normally considered fully immersed during and after full inflation. An exception would be when the inflation interval is so long that full immersion of the inflated floats does not occur (e.g. deceleration of the rotorcraft during water entry and natural buoyancy of the hull prevent full immersion loads on the fully inflated floats).

(b) Procedures

- (1) The rotorcraft support structure, structure-to-float attachments, and floats should be substantiated for rational limit and ultimate ditching loads.
- (2) The most severe sea conditions for which certification with ditching provisions is requested by the applicant are to be considered. The sea conditions should be selected in accordance with AMC 29.801(e).
- (3) The landing structural design consideration should be based on water entry with a rotor lift of not more than two-thirds of the maximum design weight acting through the rotorcraft's centre of gravity under the following conditions:
  - (i) forward velocities of 0–56 km/h (30 kt) relative to the mean wave surface;
  - (ii) the rotorcraft pitch attitude that would reasonably be expected to occur in service; autorotation, run-on landing, or one-engine-inoperative flight tests, or validated simulation, as applicable, should be used to confirm the attitude selected;
  - (iii) likely roll and yaw attitudes; and
  - (iv) vertical-descent velocity of 1.5 m/s (5 ft/s) or greater relative to the mean wave surface.
- (4) Landing load factors and water load distribution may be determined by water drop tests or analysis based on tests.
- (5) Auxiliary or emergency float loads should be determined by full immersion or by the use of restoring moments required to compensate for upsetting moments caused by side wind, asymmetrical rotorcraft landing, water wave action, rotorcraft inertia, and probable structure damage and punctures considered under CS 29.801. Auxiliary or emergency float loads may be determined by tests or analysis based on tests.
- (6) Floats deployed after water entry are required to be substantiated by tests or analysis for the specified immersion loads (same as for (5) above and for the specified combined vertical and drag loads).



2. Create a new AMC 29.801 (amended AC 29.801) as follows:

### **AMC 29.801**

#### **Ditching**

##### **(a) Definitions**

- (1) Ditching: an emergency landing on the water, deliberately executed in accordance with rotorcraft flight manual (RFM) procedures, with the intent of abandoning the rotorcraft as soon as practical.
- (2) Emergency flotation system (EFS): a system of floats and any associated parts (gas cylinders, means of deployment, pipework and electrical connections) that is designed and installed on a rotorcraft to provide buoyancy and flotation stability in a ditching. The EFS includes any additional floats which provide a function only following capsizes.

##### **(b) Explanation**

- (1) Ditching certification is performed only if requested by the applicant.
- (2) For a rotorcraft to be certified for ditching, in addition to the other applicable provisions of CS-29, the rotorcraft must specifically meet CS 29.801 together with the provisions detailed in CS 29.801(a).
- (3) Ditching certification encompasses four primary areas of concern: rotorcraft water entry, rotorcraft flotation stability, occupant egress, and occupant survival. CS-29 Amendment X has developed enhanced standards in all of these areas.
- (4) The scope of the ditching provisions is expanded through a change in the ditching definition. All potential failure conditions that could result in a 'land immediately' action by the pilot are now included (e.g. engine, transmission, systems, tail rotor, lightning strike, etc.). This primarily relates to changes in water entry conditions. While the limiting conditions for water entry have been retained (30 kt, 5 fps), the alleviation that allows less than 30 kt forward speed to be demonstrated has been removed (also from CS 29.563), and Miscellaneous Guidance (MG) 10 has been removed as an alternative means for substantiation of an emergency flotation system.
- (5) Flotation stability is enhanced through the introduction of a new standard based on a probabilistic approach to capsizes. Occupant egress is enhanced through the post-capsize survivability features of CS 29.801(i) to mitigate the consequences of capsizes. Historically, helicopters have frequently operated over sea conditions more severe than those assumed in their certification with ditching provisions, where there is a higher risk of capsizes following a ditching. Operational experience has shown that fatalities have occurred in otherwise survivable water impact events due to the inability of occupants to escape from a capsized or sinking helicopter within their breath hold time.
- (6) Failure of the EFS to operate when required will lead to the rotorcraft rapidly capsizing and sinking. Operational experience has shown that localised damage or failure of a single component of an EFS, or the failure of the flight crew to activate or deploy the EFS, can lead to loss of the complete system. Therefore, the design of the EFS needs careful



- consideration; automatic arming and deployment have been shown to be practicable and offer a significant safety benefit.
- (7) Ditching certification should be performed with the maximum required quantity and the type of ditching equipment for the anticipated areas of operation.
  - (8) The water conditions on which certification with ditching provisions is to be based are selected by the applicant and should take into account the expected water conditions in the intended areas of operation. The wave climate of the northern North Sea is adopted as the default wave climate as it represents a conservative condition. The applicant may also select alternative/additional sea areas with any associated certification then being limited to those geographical regions. The certification with ditching provisions obtained will be included in the RFM as performance information.
  - (9) Tests with a scale model of the appropriate ditching configuration should be conducted in a wave tank to demonstrate satisfactory water entry and flotation stability characteristics. Appropriate allowances should be made for probable structural damage and leakage. Previous model tests and other data from rotorcraft of similar configurations that have already been substantiated based on equivalent test conditions may be used to satisfy the ditching provisions.
  - (10) CS-29 Amendment X removes a potential source of confusion and simplifies the tests necessary for showing compliance with CS 29.801(d) by removing the reference to two-thirds lifts.
  - (11) CS 29.801(e) requires that after ditching in sea conditions for which certification with ditching provisions is requested by the applicant, the flotation time (5 minutes) and stability of the rotorcraft will allow the occupants to leave the rotorcraft and enter life rafts. This should be interpreted to mean that up to and including the worst-case sea conditions for which certification with ditching provisions is requested by the applicant, the probability that the rotorcraft will capsize should be not higher than the target stated in the certification specification. An acceptable means of demonstrating post-ditching flotation stability is through model testing using irregular waves. AMC 29.801(e) contains a test specification that has been developed for this purpose.
  - (12) Providing a 'wet floor' concept (water in the cabin) by positioning the floats higher on the fuselage sides and allowing the rotorcraft to float lower in the water, can be a way of increasing the stability of a ditched rotorcraft (although this was inconclusive in previous research and would need to be verified for the individual rotorcraft type for all weight and loading conditions) or may be desired for other reasons. This is permissible provided that the mean level of water in the cabin is limited to below the seat cushion upper surface height, and that the presence of water will not unduly restrict the ability of occupants to evacuate the rotorcraft.
  - (13) According to CS 29.801(i), the rotorcraft design should incorporate post-capsize survivability features. The probability of capsize used in the post-ditching stability tests does not preclude capsize, and a probability of 29 % has been retained even when operating within the sea conditions approved for ditching. In order to provide risk mitigation if a rotorcraft were to capsize, suitable design provisions are required to allow



more time for egress as escape time will exceed breath hold capability of at least some of the occupants for typical rotorcraft cabin layouts and in typical sea temperatures. While this will offer a safety benefit if a rotorcraft were to capsize post-ditching, the main safety benefit comes in survivable water impact events where the rotorcraft will likely capsize immediately.

- (14) It should be shown by analysis or other means that the rotorcraft will not sink following functional loss of the largest complete ditching flotation unit. Experience has shown that in water impact events, the forces exerted on the emergency flotation unit that first comes into contact with the water surface, together with structural deformation and other damage, can render the unit unusable. The ability of occupants to egress successfully is significantly increased if the rotorcraft remains on the surface.
- (15) The water conditions approved for ditching will be stated in the performance information section of the RFM and are expected to become an operational limitation on normal operations.
- (16) Current practices allow wide latitude in the design of cabin interiors and, consequently, of stowage provisions for safety and ditching equipment. Rotorcraft manufacturers may deliver aircraft with unfinished (green) interiors that are to be completed by a modifier. These various configurations present problems for certifying the rotorcraft for ditching.
- (i) Segmented certification is permitted to accommodate this practice. That is, the rotorcraft manufacturer shows compliance with the flotation time, stability, and emergency exit provisions while a modifier shows compliance with the equipment and egress provisions with the interior completed. This procedure requires close cooperation and coordination between the manufacturer, modifier, and the Agency.
- (ii) The rotorcraft manufacturer may elect to establish a token interior for ditching certification. This interior may subsequently be modified by a supplemental type certificate (STC). Compliance with the ditching provisions should be reviewed after any interior configuration and limitation changes, where applicable.
- (iii) The RFM and any RFM supplements (RFMSs) deserve special attention if a segmented certification procedure is pursued.

(c) Procedures

(1) Flotation system design

- (i) Structural integrity should be established in accordance with CS 29.563.
- (ii) Rotorcraft handling qualities should be verified to comply with the applicable certification specifications throughout the approved flight envelope with floats installed. Where floats are normally deflated and deployed in flight, the handling qualities should be verified for the approved operating envelopes with the floats in:
- (A) the deflated and stowed condition;
- (B) the fully inflated condition; and



- (C) the in-flight inflation condition; for float systems which may be inflated in flight, rotorcraft controllability should be verified by test or analysis, taking into account all possible emergency flotation system inflation failures.
  - (iii) Reliability should be considered in the basic design to assure approximately equal inflation of the floats to preclude excessive yaw, roll, or pitch in flight or in the water:
    - (A) Maintenance procedures should not degrade the flotation system (e.g. introducing contaminants which could affect normal operation, etc.).
    - (B) The flotation system design should preclude inadvertent damage due to normal personnel traffic flow and excessive wear and tear. Protection covers should be evaluated for function and reliability.
    - (C) Float design should provide a means to minimise the likelihood of damage or tear propagation between compartments. Single compartment float designs should be avoided.
    - (D) Where practicable, design of the flotation system should consider the likely effects of water impact (i.e. crash) loads. For example:
      - (a) locate system components away from the major effects of structural deformation;
      - (b) use redundant or distributed systems;
      - (c) use flexible pipes/hoses; and
      - (d) avoid passing pipes/hoses or electrical wires through bulkheads that could act as a 'guillotine' when the structure is subject to water impact loads.
  - (iv) The floats should be fabricated from material of high visual conspicuity to assist in the location of the rotorcraft following a ditching (and possible capsizing).
- (2) Flotation system inflation. Emergency flotation systems (EFSs) which are normally stowed in a deflated condition and are inflated either in flight or after water contact should be evaluated as follows:
- (i) The inflation system design should, where practicable, minimise the possibility of foreseeable damage preventing the operation or partial operation of the EFS (e.g. interruption of the electrical supply or pipework). This could be achieved through the use of redundant systems or through distributed systems where each flotation unit is capable of autonomous operation (i.e. through the provision of individual inflation gas sources, electrical power sources and float activation switches).
  - (ii) The inflation system design should minimise the probability that the floats do not inflate properly or inflate asymmetrically in the event of a ditching. This may be accomplished by interconnecting inflation gas sources, for which flexible hoses should be used to minimise potential damage, or by synchronising the deployment of autonomous flotation units. Note that the main concern in the event of a water



- impact is to provide appropriate post-capsize survivability features and prevent the rotorcraft from sinking; asymmetric deployment is a lesser concern.
- (iii) The emergency flotation system should include a means to verify system integrity prior to each flight.
  - (iv) If a manual means of inflation is provided, the float activation switch should be located on one of the primary flight controls and should be safeguarded against spontaneous or inadvertent actuation.
  - (v) The inflation system should be safeguarded against spontaneous or inadvertent actuation in flight conditions for which float deployment has been demonstrated to be hazardous. If this requires arming/disarming of the inflation system (e.g. above a given height and airspeed), this should be achieved by the use of an automatic arming/disarming system employing appropriate input parameters. The system should automatically rearm when flight conditions permit safe deployment.
  - (vi) The maximum airspeeds for intentional in-flight actuation of the emergency flotation system and for flight with the floats inflated should be established as limitations in the RFM unless in-flight actuation is prohibited by the RFM.
  - (vii) Activation of the emergency flotation system upon water entry (irrespective of whether or not inflation prior to water entry is the intended operation mode) should result in an inflation time short enough to prevent the rotorcraft from becoming excessively submerged.
  - (viii) A means should be provided for checking the pressure of the gas storage cylinders prior to take-off. A table of acceptable gas cylinder pressure variation with ambient temperature and altitude (if applicable) should be provided.
  - (ix) A means should be provided to minimise the possibility of overinflation of the flotation units under any reasonably probable actuation conditions.
  - (x) The ability of the floats to inflate without puncture when subjected to actual water pressures should be substantiated. A demonstration of a full-scale float immersion in a calm body of water is one acceptable method of substantiation.
- (3) Injury prevention during and following water entry. An assessment of the cabin and cockpit layout should be undertaken to minimise the potential for injury to occupants in a ditching. This may be performed as part of the compliance with CS 29.785. Attention should be given to the avoidance of injuries due to arm/leg flailing, as these can be a significant impediment to occupant egress and subsequent survivability. Practical steps that could be taken include:
- (i) locating potentially hazardous equipment away from occupants;
  - (ii) installing energy-absorbing padding onto interior components;
  - (iii) using frangible materials; and
  - (iv) designs that exclude hard or sharp edges.



- (4) Buoyancy. It should be shown by analysis or test that the rotorcraft will not sink with the largest flotation unit failed. The flooding of internal spaces of the rotorcraft should be considered or a conservative assumption made.
- (5) Water entry conditions and procedures. Tests or simulations (or a combination of both) should be conducted to establish procedures and techniques to be used for water entry. These tests/simulations should include determination of the optimum pitch attitude and forward velocity for ditching in a calm sea as well as entry procedures for the most severe condition to be certified. Procedures for all failure conditions that may lead to a 'land immediately' action (e.g. one engine inoperative, all engines inoperative, tail rotor/drive failure), should be established. However, only the procedures for the most critical all-engines-inoperative condition need be verified by water entry tests.
- (6) Water entry tests. Scale model testing to verify water entry procedures and the capability of the rotorcraft to remain upright should be based on water entry under the following conditions:
- (i) for entry into a calm sea:
    - (A) the optimum pitch, roll and yaw attitudes determined in (c)(5) above, with consideration for variations that would reasonably be expected to occur in service;
    - (B) ground speeds from 0–56 km/h (30 kt); and
    - (C) descent rate of 1.5 m/s (5 ft/s) or greater;
  - (ii) for entry into the most severe sea condition:
    - (A) the optimum pitch attitude and entry procedure as determined in (c)(5) above;
    - (B) 56 km/h (30 kt) ground speed;
    - (C) descent rate of 1.5 m/s (5 ft/s) or greater;
    - (D) likely roll and yaw attitudes; and
    - (E) sea conditions may be represented by regular waves having a height at least equal to the significant wave height ( $H_s$ ), and a period no larger than the mode of the wave zero-crossing period ( $T_z$ ), that is the wave spectrum chosen for demonstration of rotorcraft flotation stability after water entry (see (c)(7) below and AMC 29.801(e));
  - (iii) probable damage to the structure due to water entry should be considered during the water entry evaluations (e.g. failure of windows, doors, skins, panels, tail boom, etc.); and
  - (iv) rotor lift does not have to be considered.
- (7) Flotation stability tests. An acceptable means of flotation stability testing is contained in AMC 29.801(e). Note that model tests in a wave basin on a number of different rotorcraft types have indicated that an improvement in seakeeping performance can consistently be achieved by fitting float scoops.



- (8) One method of meeting the post-capsize survivability provisions of CS 29.801(i) is to create a post-capsize rotorcraft floating attitude which will create an air pocket in the passenger cabin. This can be achieved by means of additional buoyancy.

An air pocket will remove the time pressure for escape. Passengers will not need to immediately escape through a ditching emergency exit. They can utilise the air in the pocket for continued survival during the time needed for all to make their escape.

- (i) The required additional buoyancy should not be placed in a location vulnerable to damage or likely to detach (e.g. the tail boom), but located away from the normal flotation units such as high up on the side of the fuselage in the form of buoyant cowlings or redundant flotation units (or both). Any use of additional flotation units should be considered as part of the emergency flotation system and meet the same standards of float design. Consideration will need to be given to the automatic activation of additional floats and the inflation sequence to avoid possible damage from turning rotor blades or impact debris.
- (ii) An alternative means of compliance may be to relocate the existing flotation units higher up on the sides of the fuselage to form the 'wet floor' concept. An air pocket would then form if the rotorcraft were to fully invert.
- (iii) The size and shape of the air pocket should be sufficient to accommodate all passengers. A minimum volume per passenger, in the form of an elliptical column of 70 cm x 50 cm (27 in. x 19 in.) and height of 30 cm (11 in.) relative to the static waterline should be established and demonstrated as fitting into the air pocket, including with the critical float compartment failed. This will accommodate all passengers up to and including those classified as extra-broad (shoulder width  $\geq$  68.6 cm). As the rotorcraft will have capsized, seats will consume a significant amount of otherwise useable volume and this will need to be taken into consideration in the non-stroked position.
- (iv) The air pocket should be accessible and immediately available without passengers needing to cross seat backs. Where the cabin is divided by the presence of seat backs, a sufficient volume of air to accommodate all passengers seated within that row should be provided. E.g., if there are three seats facing a further three seats, the minimum between-row air pocket should accommodate six passengers (six of the elliptical columns should fit). If all seats are forward-facing, and there are four seats in each row, the minimum air pocket should accommodate four passengers (four of the elliptical columns should fit).
- (v) Egress from the air pocket will ideally be via exits with a significant portion remaining above the water line. It should be substantiated that egress is feasible, for instance, that opening of the exit will remain reasonably easy (e.g. not involve the need to find the opening handle under an appreciable water depth) and that seats or other cabin items provide sufficient stepping points, if needed. Alternatively, if exits with a significant portion above the waterline will not be available, or the opening handle/handles is/are difficult to find, or if other obstacles to egress exist, it may be acceptable to mitigate this by an RFM limitation entry requiring all occupants to be provided with and trained in the use of a suitable



emergency breathing system (EBS). This will allow occupants to deploy the EBS when in the air pocket, and then escape using its benefits. The provision of sufficient light in the air pocket to enable preparation for egress and actual egress, including at night, should be ensured.

(vi) Due to the unknown extent of damage, and inability to realistically predict the amount of it, that may occur in a survivable water impact event, the air pocket should satisfy the above design considerations in the ditching case, including with a single float compartment failed. Such a design is expected to provide an adequate air pocket within the cabin in a high proportion of water impact events albeit the size and location of this air pocket cannot be predicted with any level of confidence.

(9) CS 29.801(i) requires design provisions to mitigate the fact that the human breath hold capability provides for insufficient time for all passengers to escape from a fully flooded cabin.

Emergency breathing systems (EBSs) that are capable of being quickly deployed underwater do exist. This type of personal protective equipment (PPE) may provide a limited level of mitigation for the issues related to human breath hold capability, but it should not be considered alone as being sufficient means of compliance with CS 29.801(i).

This is due to the following reasons:

- (i) such equipment relies on an individual's ability to deploy and use the EBS, and utilise prior training;
- (ii) the effectiveness of such equipment in the absence of a mandate for practical training is questionable;
- (iii) individual physiological variations will affect the duration of use of the EBS;
- (iv) human behaviours in an emergency, including panic and inaction, will affect the likelihood of successful usage;
- (v) an individual may be overtaken by the desire to escape, without using the EBS, and eventually fail to escape due to the human breath hold limitation; and
- (vi) conversely, an individual sitting immediately next to an exit may in fact be in the most advantageous position for escaping immediately, but may delay the overall evacuation by deploying their EBS, thus further compromising the successful escape of another individual acting as described in (v) above.

(10) Occupant egress and survival. The ability of the occupants to deploy life rafts, egress the rotorcraft, and board the life rafts (directly, in the case of passengers), should be evaluated. For configurations which are considered to have critical occupant egress capabilities due to life raft locations or ditching emergency exit locations and float proximity (or a combination of both), an actual demonstration of egress may be required. When a demonstration is required, it may be conducted on a full-scale rotorcraft actually immersed in a calm body of water or using any other rig or ground test facility shown to be representative. The demonstration should show that floats do not impede a satisfactory evacuation. Service experience has shown that it is possible for occupants to have escaped from the cabin but have not been able to board a life raft and have had



difficulties finding handholds to stay afloat and together. Handholds or lifelines should be provided on appropriate parts of the rotorcraft. The normal attitude of the rotorcraft and the possibility of a capsized rotorcraft should be considered when positioning the handholds or lifelines.

- (11) Rescue. In order to aid rescue services in visually locating a capsized helicopter, the bottom surface of the fuselage should be painted with at least three chevrons. The chevron tips should be on the centre line of the fuselage and should point to the nose of the rotorcraft. Their overall width should not be less than half that of the fuselage. The thickness of the chevrons should be between a quarter and a third of their overall width. The colour of the chevrons should be chosen to provide a good contrast to the sea (e.g. red, yellow) and the fuselage bottom surface.
- (12) Rotorcraft Flight Manual. The RFM is an important element in the certification process of the rotorcraft for ditching. The material related to ditching may be presented in the form of a supplement or a revision to the basic manual. This material should include:
- (i) A statement in the 'Limitations' section stating that the rotorcraft is approved for ditching.

If the certification with ditching provisions is obtained in a segmented fashion (i.e. one applicant performing the safety equipment installation and operations portion and another designing and substantiating the safety equipment's performance and deployment facilities), the RFM limitations should state that the ditching provisions are not approved until all segments are completed. The outstanding ditching provisions for a complete certification should be identified in the 'Limitations' section.
  - (ii) Procedures and limitations for flotation device inflation.
  - (iii) A statement in the performance information section of the RFM, identifying the demonstrated sea conditions and any other pertinent information. If demonstration was performed using the default North Sea wave climate (JONSWAP), the maximum significant wave height ( $H_s$ ), demonstrated in metres, should be stated. If extended testing was performed in accordance with AMC 29.801(e) to demonstrate that the target level of capsized probability can be reached without operational limitation, this should also be stated. If demonstration was performed for other sea conditions, the maximum significant wave height ( $H_s$ ), demonstrated in metres, and the limits of the geographical area represented should be stated.
  - (iv) Recommended rotorcraft water entry attitude, speed, and wave position.
  - (v) Procedures for use of safety equipment.
  - (v) Ditching egress and life raft entry procedures.



3. Create a new AMC 29.801(e) as follows:

**AMC 29.801(e)**

**Model test method for post-ditching flotation stability**

(a) Explanation

(1) Model test objectives

The objective of the model tests described in the certification specification is to establish the ditching performance of the rotorcraft in terms of stability. Together with the certification of the water entry phase, this will enable the overall ditching performance of the rotorcraft to be established for inclusion in the rotorcraft flight manual (RFM) as required by CS 29.801(h).

The rotorcraft design is to be tested with its flotation system intact, and its single most critical flotation compartment damaged (i.e. the single-puncture case which has the worst adverse effect).

The wave conditions in which the rotorcraft is to be certified for ditching should be selected according to the desired level of operability (see (a)(2) below).

(2) Model test wave conditions

The rotorcraft is to be tested in a single sea condition comprising a single combination of significant wave height ( $H_s$ ) and zero-crossing period ( $T_z$ ). This approach is necessary in order to constrain the quantity of testing required within reasonable limits and is considered to be conservative. The justification is detailed in Appendix 2.

The rotorcraft designer/operator is at liberty to certify the rotorcraft to any significant wave height  $H_s$ . This wave height will be noted as performance information in the RFM.

Using reliable wave climate data for an appropriate region of the ocean for the anticipated flight operations, a  $T_z$  is selected to accompany the  $H_s$ . It is proposed that this  $T_z$  should be typical of those occurring at  $H_s$  as determined in the wave scatter table for the region. The mode or median of the  $T_z$  distribution at  $H_s$  should be used.

It is considered that the northern North Sea represents a conservatively 'hostile' region of the ocean worldwide and should be adopted as the default wave climate for ditching certification. However, this does not preclude an applicant certifying a rotorcraft specifically for a different region. Such certification for a specific region would require the geographical limits of that ditching certification region to be noted as performance information in the RFM. Certification for the default northern North Sea wave climate does not require any geographical limits.

Northern North Sea wave climate data were obtained from the United Kingdom (UK) Met (Meteorological) Office for a typical 'hostile' helicopter route. The route selected was from Aberdeen to Block 211/27 in the UK sector of the North Sea. Data tables were derived from a UK Met Office analysis of 34 years of three-hourly wave data generated within an 8-km, resolved wave model hindcast for European waters. This data represents the default wave climate.



Table 1 below has been derived from this data and contains combinations of significant  $H_s$  and  $T_z$ . Table 1 also includes the probability of exceedance ( $P_e$ ) of the  $H_s$ .

**Table 3 — Northern North Sea wave climate**

Spectrum shape: JONSWAP, peak enhancement factor $\gamma = 3.3$			
	Significant wave height $H_s$	Mean wave period $T_z$	$H_s$ probability of exceedance $P_e$
Intact flotation system	6 m	7.9	1.2 %
	5.5 m	7.6	2 %
	5 m	7.3	3 %
	4.5 m	7.0	5 %
	4 m	6.7	8 %
	3.5 m	6.3	13 %
	3 m	5.9	20 %
	2.5 m	5.5	29 %
	2 m	5.1	43 %
	1.25 m	4.4	72 %

(3) Target probability of capsizing

The target probability of capsizing has been derived from a risk assessment. The target probability to be applied is stated in CS 29.801(e).

(4) Intact flotation system

For the case of an intact flotation system, if the northern North Sea default wave climate has been chosen for certification, the rotorcraft should be shown to resist capsizing in a sea condition selected from Table 1. The probability of capsizing in a 5-minute exposure to the selected sea condition is to be demonstrated to be less than or equal to the value provided in CS 29.801(e) with a confidence of 95 % or greater.

(5) Damaged flotation system

For the case of a damaged flotation compartment (see (1) above), the same sea condition may be used, but a 10-fold increased probability of capsizing is permitted. This is because it is assumed that flotation system damage will occur in approximately one out of ten ditchings. Thus, the probability of capsizing in a five-minute exposure to the sea condition may be less than or equal to 10 times the probability provided in CS 29.801(e) with a confidence of 95 % or greater. However, because high-level capsizing mitigation is required for CS-29-certified rotorcraft and CS-27-certified rotorcraft for Category A operation (i.e. the post-capsizing survivability provisions of CS 29.801(i)), 10 times the probability provided in CS 29.801(e) is greater than 100%. It is, therefore, not necessary to perform a model test to determine the capsizing probability with a damaged flotation system. However, it is necessary to perform a capsized rotorcraft seakeeping test as specified in (6) below.

(6) Capsized rotorcraft seakeeping test



In accordance with CS 29.801(i), the rotorcraft design should ensure that the time pressure for the occupants to escape is negated.

One possible design solution is the fitment of additional emergency flotation units intended to prevent complete inversion of the capsized rotorcraft. Alternatively, the existing flotation units may be repositioned higher up on the fuselage to ensure the availability of an air pocket following total inversion.

If any such solution is selected by the applicant, model tests should be conducted to demonstrate that following capsize, the rotorcraft does not show a tendency to continue to roll over in response to larger waves. These tests are to be conducted in the same wave condition as for the intact flotation system.

Some designs of additional emergency flotation units using a symmetrical layout relative to the rotorcraft centre line may show a second rotation following the initial capsize before the final stable floating attitude is achieved. This is considered to be acceptable.

Video evidence of post-capsize stability during a one-hour (full-scale time) exposure to the wave condition will be accepted as sufficient evidence that the rotorcraft achieves a stable floating attitude.

(7) Long-crested waves

Whilst it is recognised that ocean waves are in general multidirectional (short-crested), the model tests are to be performed in unidirectional (long-crested) waves, this being regarded as a conservative approach to capsize probability.

(b) Procedures

(1) Rotorcraft model

(i) Model construction and scale

The rotorcraft model, including its emergency flotation, is to be constructed to be geometrically similar to the full-scale rotorcraft design at a scale that will permit the required wave conditions to be accurately represented in the model basin. It is recommended that the model scale should be not smaller than 1/15.

The model construction is to be sufficiently light to permit the model to be ballasted to achieve the desired weight and rotational inertias specified in the mass conditions (see (b)(1)(ii) below).<sup>15</sup>

Where it is likely that water may flood into the internal spaces following ditching, for example through doors opened to permit escape, the model should represent these internal spaces and opened doors and windows as realistically as possible.

It is permissible to omit the main rotor(s) from the model, but its(their) mass is to be represented in the mass and inertia conditions<sup>16</sup>.

<sup>15</sup> It should be noted that rotorcraft tend to have a high centre of gravity due to the position of the engines and gearbox on top of the cabin. It therefore follows that most of the ballast is likely to be required to be installed in these high locations of the model.

<sup>16</sup> Rotors touching the waves can promote capsize, but they can also be a stabilising influence depending on the exact circumstances. Furthermore, rotor blades are often lost during the ditching due to contact with the sea. It is therefore considered acceptable to omit them from the model.



**(ii) Mass conditions**

It is required that the model be tested in the most critical mass condition. As it is unlikely that this most critical condition can be determined reliably prior to testing, the model is to be capable of being tested in two mass conditions:

(A) maximum mass condition; and

(B) minimum mass condition.

In the analysis of the test results, it is the worst capsize performance of these mass conditions that will determine if the ditching provision has been met or not.

**(iii) Mass properties**

The model is to be ballasted in order to achieve the required scale weight, centre of gravity, roll and yaw inertia for each of the mass conditions to be tested.

Once ballasted, the model's floating draft and trim in calm water is to be checked and compared with the design floating attitude. Where a post-capsize air pocket is part of the design, then this capsized floating attitude is also to be similarly checked and compared.

The required mass properties and floating draft and trim, and those measured during model preparation, are to be fully documented and compared in the report.

**(iv) Model restraint system**

A flexible restraint or mooring system is to be provided to restrain the model in order for it to remain beam-on to the waves in the model basin.<sup>17</sup>

This restraint system should meet the following:

(A) be attached to the model on the centre line at front and rear of the fuselage in such a position that roll motion coupling is minimised; an attachment at or near the waterline is preferred; and

(B) be sufficiently flexible that natural frequencies of the model surging/swaying on this restraint system are much lower than the lowest wave frequencies in the spectrum.

**(v) Sea anchor**

Whether or not the rotorcraft is to be fitted with a sea anchor, such an anchor is not to be represented in these model tests.<sup>18</sup>

**(2) Test facility**

The model test facility is to have the capability to generate realistic long non-repeating sequences of unidirectional (long-crested) irregular waves, as well as the characteristic

<sup>17</sup> The model cannot be permitted to float freely in the basin because in the necessarily long wave test durations, the model would otherwise drift down the basin and out of the calibrated wave region. Constraining the model to remain beam-on to the waves and not float freely is regarded as a conservative approach to the capsize test.

<sup>18</sup> A sea anchor deployed from the rotorcraft nose is intended to improve stability by keeping the rotorcraft nose into the waves. However, such devices take a significant time to deploy and become effective, and so, their beneficial effect is to be ignored. The rotorcraft model will be restrained to remain beam-on to the waves.



wave condition at the chosen model scale. The facility is to be deep enough to ensure that the waves are not influenced by the depth (i.e. deep-water waves).

The dimensions of the test facility are to be sufficiently large to avoid any significant reflection/refraction effects influencing the behaviour of the rotorcraft model.

The facility is to be fitted with a high-quality wave-absorbing system or beach.

The model basin is to provide full details of the performance of the wave maker and the wave absorption system prior to testing.

(3) Model test setup

(i) General

The model is to be installed in the wave facility in a location sufficiently distant from the wave maker, tank walls and beach/absorber such that the wave conditions are repeatable and not influenced by the boundaries.

The model is to be attached to the model restraint system (see (b)(1)(iv) above).

(ii) Instrumentation and visual records

During wave calibration tests, three wave elevation probes are to be installed and continuously recorded. These probes are to be installed at the intended model location, a few metres to the side and a few metres ahead of this location.

The wave probe at the model location is to be removed during tests with the rotorcraft model present.

All tests are to be continuously recorded on digital video. It is required that at least two simultaneous views of the model are to be recorded. One is to be in line with the model axis (i.e. viewing along the wave crests), and the other is to be a three-quarter view of the model from the up-wave direction. Video records are to incorporate a time code to facilitate synchronisation with the wave elevation records in order to permit the investigation of the circumstances and details of a particular capsizing event.

(iii) Wave conditions and calibration

Prior to the installation of the rotorcraft model in the test facility, the required wave conditions are to be pre-calibrated.

Wave elevation probes are to be installed at the model location, alongside and ahead of the intended model location.

The intended wave condition(s) is (are) to be applied for a long period (at least one-hour full-scale time). The analysis of these wave calibration runs is to be used to:

(A) confirm that the required wave spectrum has been obtained at the model location; and

(B) determine the extent to which the wave conditions deteriorate during the run in order to help establish how long model test runs can be.



It should be demonstrated that the wave spectra measured at the three locations are the same.

It should be demonstrated that the time series of the waves measured at the model location does not repeat during the run duration. Furthermore, it should be demonstrated that one or more continuation runs can be performed using exactly the same wave spectrum and period, but with different wave time series. This is to permit a long exposure to the wave conditions to be built up from a number of separate runs without any unrealistic repetition of the time series.

No wind simulation is to be used.<sup>19</sup>

(iv) Required wave run durations

The total duration of runs required to demonstrate that the required probability of capsizing has been achieved (or bettered) is dependent on that probability itself, and on the reliability or confidence of the capsizing probability required to be demonstrated.

With the assumption that each five-minute exposure to the wave conditions is independent, the equations provided in (b)(5) below can be used to determine the duration without capsizing required to demonstrate the required performance.<sup>20</sup> (See Appendix 1 below for examples.)

(4) Test execution and results

Tests are to start with the model at rest and the wave basin calm.

Following start of the wave maker, sufficient time is to elapse to permit the slowest (highest-frequency) wave components to arrive at the model, before data recording starts.

Wave runs are to continue for the maximum permitted run duration determined in the wave calibration test. Following time to allow the basin to calm, additional runs are to be conducted until the necessary total exposure duration ( $T_{\text{Test}}$ ) has been achieved (see (b)(5) below).

If and when a model capsizes occurs, the time of capsizing from the run start is to be recorded, and the run stopped. The model is to be recovered, drained of any water, and reset in the basin for a continuation run to be performed. Following time to allow the basin to calm, this continuation run is to be performed in the same wave spectrum, height and period.

If the test is to be continued with the same model configuration, the test can restart with a different wave time series, or continue from the point of capsizing in a pseudorandom time series.

If instead it is decided to modify the model flotation with the intention of demonstrating that the modified model does not capsize in the wave condition, then the pseudorandom

<sup>19</sup> Wind generally has a tendency to redirect the rotorcraft nose into the wind/waves, thus reducing the likelihood of capsizing. Therefore, this conservative testing approach does not include a wind simulation.

<sup>20</sup> Each five-minute exposure might not be independent if, for example, there was flooding of the rotorcraft, progressively degrading its stability. However, in this context, it is considered that the assumption of independence is conservative.



wave maker time series should be restarted at a point at least 5 minutes prior to the capsize event so that the model is seen to survive the wave that caused capsize prior to modification. Credit can then be taken for the run duration successfully achieved prior to capsize. Clearly, such a restart is only possible with a model basin using pseudorandom wave generation.

Continuation runs are to be performed until the total duration of exposure to the wave condition is sufficient to establish that the five-minute probability of capsize has been determined with the required confidence of 95 %.

#### (5) Results analysis

Given that it has been demonstrated that the wave time series are non-repeating and statistically random, the results of the tests may be analysed on the assumption that each five-minute element of the total time series is independent.

If the model rotorcraft has not capsized during the total duration of the tests, the confidence that the probability of capsize within 5 minutes is less than the target value of  $P_{Criteria}$ , as shown below:

$$C = 1 - (1 - P_{Criteria})^{\left[ \frac{T_{Test}}{T_{Criteria}} \right]}$$

$$(i) \quad \approx 1 - \exp\left(-\frac{P_{Criteria} T_{Test}}{T_{Criteria}}\right)$$

and so the total duration of the model test required without capsize is provided by:

$$T_{Test} \approx -\frac{T_{Criteria} \ln(1 - C)}{P_{Criteria}}$$

where:

- (A)  $T_{Test}$  is the required full-scale duration of the test (in seconds);
- (B)  $P_{Criteria}$  is the required maximum probability of capsize within 5 minutes;
- (C)  $T_{Criteria}$  is the duration (in seconds) in which the rotorcraft must meet the no-capsize probability (= 5 x 60 s), as defined in CS 29.801(e); and
- (D)  $C$  is the required confidence that the probability of capsize has been achieved (0.95).

If the rotorcraft has capsized  $N_{Capsize}$  times during the tests, the probability of capsize within 5 minutes can be estimated as:

$$P_{Capsize} = \frac{N_{Capsize} T_{Criteria}}{T_{Test}}$$

and the confidence that the required capsize criteria have been met is:



$$(ii) \quad C = 1 - \sum_{k=0}^{N_{Capsize}} \frac{\left(\left\lceil \frac{T_{Test}}{T_{Criteria}} \right\rceil\right)!}{k! \left(\left\lceil \frac{T_{Test}}{T_{Criteria}} \right\rceil - k\right)!} \left\{ \begin{array}{l} (P_{Criteria})^k \\ (1 - P_{Criteria})^{\left(\left\lceil \frac{T_{Test}}{T_{Criteria}} \right\rceil - k\right)} \end{array} \right\}$$

$$\approx 1 - \left\{ \sum_{k=0}^{N_{Capsize}} \frac{1}{k!} \left( \frac{P_{Criteria} T_{Test}}{T_{Criteria}} \right)^k \right\} \exp\left(-\frac{P_{Criteria} T_{Test}}{T_{Criteria}}\right)$$

It should be noted that, if the rotorcraft is permitted to fly in significant wave heights above the certification limit, then  $P_{Criteria}$  should be reduced by the probability of exceedance of the certification limit for the significant wave height ( $P_e$ ) (see Appendix 2 below).

### (c) Deliverables

- (1) A comprehensive report describing the model tests, the facility they were performed in, the model properties, the wave conditions used, the results of the tests, and the method of analysis to demonstrate compliance with CS 29.801(d) and (e).
- (2) Conclusions in this report are to clarify the compliance (or otherwise) with those provisions.
- (3) Digital video and data records of all tests performed.
- (4) A specification for an actual rotorcraft ditching certification model test should also be expected to include:
  - (i) an execution plan and time scale;
  - (ii) formal progress reports on content and frequency; and
  - (iii) quality assurance requirements.

### Appendix 1 — Worked example

The target five-minute capsizes probability for a CS 29.801 certified rotorcraft is 29 %. One option available to the rotorcraft designer is to test at the selected wave height and demonstrate a probability of capsizes of no greater than 29 %. However, to enhance offshore helicopter safety, some national aviation authorities (NAAs) have imposed restrictions that prevent normal operations (i.e. excluding emergencies, search and rescue (SAR) etc.) in sea conditions above the demonstrated ditching performance; so, in this case, the helicopter may be operationally limited.

These operational restrictions may be avoided by accounting for the probability of exposure to sea conditions exceeding the selected wave height by certifying the rotorcraft for a lower probability of capsizes. Since it is conservatively assumed that the probability of capsizes in sea conditions exceeding the certified wave height is unity, the lower capsizes probability required to be met is 29 % minus the probability of the selected wave height being exceeded. Clearly, the resulting probability of capsizes is greater than zero, which means that this option is only available for wave heights with a probability of exceedance of less than 29 %.

Referring to Table 1 above, it can be seen that this condition is met for wave heights greater than 2.5 m. In particular, the significant wave height probabilities of exceedance for six-metre and four-



metre wave heights are 1.2 % and 8 % respectively. The applicant, therefore, has the option of certifying the rotorcraft for either of these wave heights without operating restriction(s).

Provided it can be demonstrated that a capsize probability of  $\leq 29 - 1.2 = 27.8$  % in an  $H_s = 6$  m,  $T_z = 7.9$  s sea condition, or a capsize probability of  $\leq 29 - 8 = 21$  % in an  $H_s = 4$  m,  $T_z = 6.7$  s condition (i.e. in the Northern North Sea default wave height/period combinations provided in Table 1), the rotorcraft would have demonstrated acceptable ditching capability in any part of the world, and should be unaffected by the operational restrictions mentioned above.

(a)  $H_s = 6$  m option

Taking first the  $H_s = 6$  m option, we need to demonstrate a  $\leq 27.8$  % probability of capsize with a 95 % confidence. Applying equation (5)(i) above, this can be achieved with a 54-minute (full-scale time) exposure to the sea condition without capsize.

Rearranging this equation, we have:

$$T_{Test} \approx -\ln(1 - C) \frac{T_{criterion}}{P_{criterion}}$$

$$T_{Test} \approx -\ln(1 - 0.95) \frac{5 \times 60}{0.278} = 3232.8 \text{ s} = 53.9 \text{ min}$$

Alternatively, applying equation (5)(ii) above, the criterion would also be met if the model were seen to capsize just three times (for example) in a total 2.4 hours of exposure to the sea condition, or four times (for example) in a total of 2.8-hour exposure.

Equation (ii) cannot be readily rearranged to solve  $T_{Test}$ , so the easiest way to solve it is using a spreadsheet on a trial-and-error method. For the four-capsizes case, we find that a 2.8-hour exposure gives a confidence of 0.95.

$$C \approx 1 - \left\{ \sum_{k=0}^{4e} \frac{1}{k!} \left( \frac{0.278 \times 2.8 \times 60 \times 60}{5 \times 60} \right)^k \right\} \exp \left( - \frac{0.278 \times 2.8 \times 60 \times 60}{5 \times 60} \right) = 0.95$$

(b)  $H_s = 4$  m option

Now, taking the  $H_s = 4$  m option, we need to demonstrate a  $\leq 21$  % probability of capsize with a 95 % confidence. Equation(5)(i) above shows that we can demonstrate compliance with a 71-minute (full-scale time) exposure to the 4-m sea condition without capsize.

$$T_{Test} \approx -\ln(1 - 0.95) \frac{5 \times 60}{0.21} = 4279.8 \text{ s} = 71.3 \text{ min}$$

Alternatively, applying equation (5)(ii) above, the criterion would also be met if the model were seen to capsize just three times (for example) in a total 3.1-hour exposure to the sea condition, or four times (for example) in a total 3.7-hour exposure.

Similarly to the six-metres example above, for the four-capsizes case, we find by trial and error that a 3.7-hour exposure gives a confidence of 0.95.

$$C \approx 1 - \left\{ \sum_{k=0}^{4e} \frac{1}{k!} \left( \frac{0.21 \times 3.7 \times 60 \times 60}{5 \times 60} \right)^k \right\} \exp \left( - \frac{0.21 \times 3.7 \times 60 \times 60}{5 \times 60} \right) = 0.95$$



**Note:** In addition to restricting normal helicopter offshore operations to the demonstrated ditching capability, i.e. the applicant's chosen significant wave height limit ( $H_sL$ ), a national aviation authority (NAA) may declare a maximum limit above which all operations will be suspended due to the difficulty of rescuing persons from the sea in extreme conditions. There will therefore be no operational benefit in certifying a rotorcraft for sea conditions exceeding national limits for rescue.

## Appendix 2 — Test specification rationale

### (a) Introduction

The overall risk of capsizing within the five-minute exposure period consists of two components: the probability of capsizing in a given wave condition, and the probability of experiencing that wave condition in a ditching event.

If it is assumed that a ditching event occurs at random and is not linked with weather conditions, the overall risk of a capsizing can be established by combining two pieces of information:

- (1) The wave climate scatter table, which shows the probability of meeting any particular combination of  $H_s$  and  $T_z$ . An example scatter table is shown below in Figure 1 — Example of all-year wave scatter table. Each cell of the table contains the probability of experiencing a wave condition with  $H_s$  and  $T_z$  in the range provided. Thus, the total of all cells in the table adds up to unity.
- (2) The probability of capsizing in a five-minute exposure for each of these height/period combinations. This probability of capsizing is different for each helicopter design and for each wave height/period combination, and is to be established through model testing using the method defined above.

In theory, a model test for the rotorcraft design should be performed in the full range of wave height/period combinations covering all the cells in the scatter table. Clearly, wave height/period combinations with zero or very low probabilities of occurrence might be ignored. It might also be justifiably assumed that the probability of capsizing at very high wave heights is unity, and at very low wave heights zero. However, there would still remain a very large number of intermediate wave height/period combinations that would need to be investigated in model tests, and it is considered that such a test programme would be too lengthy and costly to be practicable.

The objective here is therefore to establish a justifiable method of estimating the overall five-minute capsizing probability using model test results for a single-wave condition. That is a single combination of  $H_s$  and  $T_z$ .

Such a method can never be rigorously linked with the safety objective, but it is proposed that it may be regarded as a conservative approximation.

### (b) Test methodology

The proposed test methodology is as follows:

The rotorcraft designer selects an  $H_sL$  for ditching certification of his helicopter. Model tests are performed in the sea condition  $H_sL$   $T_{zL}$  (where  $T_{zL}$  is the zero-crossing period most likely to accompany  $H_sL$ ) with the selected spectrum shape using the method specified above, and the five-minute probability of capsizing ( $P_c$ ) established in this sea condition.





4. Create a new AMC 29.803(c) as follows:

**AMC 29.803(c)****Emergency evacuation**

It is intended that the rotorcraft design will allow all passengers to egress the rotorcraft and enter a life raft without undue effort or skill, and with a very low risk of water entry. Boarding a life raft from the water is difficult, even in ideal conditions, and survival time is significantly increased once aboard a life raft, particularly if the survivor has remained at least partly dry.

The general arrangement of most rotorcraft and the location of the deployed life rafts will be such that the normal entry/egress doors will best facilitate life raft entry.

It should also be shown that the life rafts can be restrained in a position that allows passengers to step directly from the cabin into the life rafts. This is expected to require provisions to enable a cabin occupant to pull the deployed life raft to the exit, using the retaining line, and maintain it in that position while others board.

It is not considered disadvantageous if opening the normal entry/egress doors will result in water entering the cabin provided that the depth of water would not be such as to hinder evacuation. However, it should be substantiated that water pressure on the door will not excessively increase operating loads.

If exits such as normal entry/egress doors, which are not already being used to meet the provisions for emergency exits or ditching emergency exits (or both), are used for compliance with CS 29.803(c)(1), they should be designed to meet certain of the standards applied to emergency exits. Their means of opening should be simple and obvious and not require exceptional effort (see CS 29.809(c)), their means of access and opening should be conspicuously marked, including in the dark (see CS 29.811(a)), their location should be indicated by signs (see CS 29.811(c) and (d)), and their operating handles should be clearly marked (see CS 29.811(e)).

5. Create a new AMC 29.805 as follows:

**AMC 29.805****Flight crew emergency exits****(a) Explanation**

To facilitate a rapid escape, flight crew emergency exits should be designed for use following a ditching or water impact, with the rotorcraft in both the upright position and in any foreseeable floating attitude. The flight crew emergency exits should not be obstructed during their operation by water or floats to the extent that rapid escape would not be possible or that damage to the flotation system may occur. This should be shown for any rotorcraft floating attitude, upright and capsized, and with the emergency flotation system intact and with any single compartment failed. In the capsized rotorcraft floating attitude, the flight crew emergency exits should be usable with the cabin flooded.

**(b) Procedures**

- (1) It should be shown by test, demonstration or analysis that flight crew emergency exits are free from interference from water and from stowed and deployed emergency flotation devices, with the rotorcraft in any foreseeable floating attitude.
- (2) Flight crew should be able to reach the operating device for their emergency exit, whilst seated, with restraints fastened, and with the rotorcraft in any attitude.
- (3) Likely damage sustained during a ditching should be considered (e.g. loss of the tail boom).
- (4) It is acceptable that the emergency exit threshold is below the waterline but in such a case, it should be demonstrated that there is no obstruction to the use of the exit and that no excessive force is required.
- (5) It is permissible that flight crew may be unable to directly enter life rafts from the flight crew emergency exits and may need to take a more indirect route, e.g. by climbing over a forward flotation unit. In such a case, an assessment of the feasibility of such a procedure should be made. Handholds may need to be provided on the rotorcraft.

6. Create a new AMC 29.807(d) as follows:

**AMC 29.807(d)**

**Ditching emergency exits for passengers**

This AMC supplements FAA AC 29.807 and replaces AC 29.807A.

(a) Explanation

CS-29 Amendment X re-evaluates the need for and concept of ditching emergency exits. Prior to CS-29 Amendment X, rotorcraft that had a passenger seating configuration, excluding pilots seats, of nine seats or less were required to have one ditching emergency exit above the waterline in each side of the rotorcraft, having at least the dimensions of a Type IV exit. For rotorcraft that had a passenger seating configuration, excluding pilots seats, of 10 seats or more, one exit was required above the waterline in one side of the rotorcraft having at least the dimensions of a Type III exit, for each unit (or part of a unit) of 35 passenger seats, but no less than two such exits in the passenger cabin, with one on each side of the rotorcraft.

Operational experience has shown that in a ditching with the rotorcraft remaining upright, use of the passenger doors can be very beneficial in ensuring a rapid and orderly evacuation onto the life raft(s). However, when a rotorcraft capsizes, doors may be unusable and the number and availability of ditching emergency exits will be crucial to ensuring that passengers are able to escape in a timely manner. Experience has shown that the number of ditching emergency exits mandated in the past by design provisions has been inadequate, and a common design solution has been to use the passenger cabin windows as ditching emergency exits by including a jettison feature. The use of such push-out windows is mandated by some air operations regulations.

CS 29.807(d)(1) requires that one pair of ditching emergency exits, i.e. one on each side of the rotorcraft, is provided for each unit, or part of a unit, of four passenger seats. Furthermore, CS 29.813(d)(1) requires that passenger seats are located relative to these exits in a way to best facilitate escape. The objective is that no passenger is in a worse position than the second



person to egress through an exit. The size of each ditching emergency exit should at least have the dimensions of a Type IV exit (0.48 m x 0.66 m or 19 in. x 26 in.).

(b) Procedures

- (1) The number and size of ditching emergency exits should be as specified above.
- (2) Care should be taken regarding oversized exits to avoid potential blockage if more than one passenger attempts to use the exit simultaneously.
- (3) A higher seat-to-exit ratio may be accepted if the exit size is large enough to allow the simultaneous escape of more than one passenger. For example, a pair of exits may be approved for eight passengers if the size of each exit provides an unobstructed area that encompasses two ellipses of 0.48 m x 0.66 m (19 in. x 26 in.) side by side.
- (4) Test, demonstration, compliance inspection, or analysis is required to show freedom from interference from stowed and deployed emergency flotation devices. In the event that an analysis is insufficient or a given design is questionable, a demonstration may be required. Such a demonstration would consist of an accurate, full-size replica (or true representation) of the rotorcraft and flotation devices while stowed and after their deployment.
- (5) The cabin layout should be designed with seats located relative to the ditching emergency exits, in compliance with CS 29.813(d)(1).

7. Create a new AMC 29.809 as follows:

**AMC 29.809**

**Emergency exit arrangement**

This AMC supplements FAA AC 29.809

(a) Explanation

CS-29 Amendment X added a new provision (j) to CS 29.809 related to the design, installation and operation of ditching emergency exits. Ditching emergency exits should be optimised for use with the rotorcraft capsized and flooded.

To facilitate passenger escape if a rotorcraft were to capsize during transfer to the life rafts, it should still be possible for occupants to escape from the rotorcraft. If the applicant has chosen to meet the provisions for post-capsize survivability features by means of a post-capsize air pocket, escape should still be possible with one or more doors in the open and locked position (e.g. the door(s) used in the demonstration of compliance with CS 29.803(c)(1)).

A particular issue exists in regard to sliding doors which overlap ditching emergency exits when open. In the case of a rotorcraft with such an arrangement, it should be substantiated that survivors in any part of the air pocket will have sufficient visual cues to enable them to find and use an egress route, including at night.

This might be by demonstrating that the route, possibly via movement between seats, to the open door is obvious, or perhaps by opening two push-out windows, one in the fuselage and one in the open sliding door. Such a solution will depend on the rotorcraft design ensuring that the



windows will be sufficiently aligned (i.e. such that the resultant unobstructed opening will admit an ellipse of 0.48 m x 0.66 m (19 in. x 26 in.). Sufficient lighting will also need to be available to highlight this option and enable its use, including at night.

Push-out windows have some advantages in that they are not susceptible to jamming and may open by themselves in a water impact due to flexing of the fuselage upon water entry.

Push-out windows can require an appreciable pushing force from the occupant. When floating free inside a flooded cabin, and perhaps even if still seated, generation of this force may be difficult. An appropriately positioned handhold or handholds adjacent to the ditching emergency exit(s) should be provided to facilitate an occupant in generating the opening force. Additionally, in the design of the handhold, consideration should be given to it assisting in locating the ditching emergency exit and in enabling to overcome buoyancy forces during egress.

Consideration should be given to reducing the potential confusion caused by the lack of standardisation of the location of the operating devices (pull tab, handle) for ditching emergency exits. For instance, the device could be located next to the handhold. The occupant then has only to find the handhold to locate the operating device. Each adjacent occupant should be able to reach the handhold and operating device whilst seated, with restraints fastened, with seat energy absorption features in any design position, and with the rotorcraft in any attitude.

#### (b) Procedures

- (1) Ditching emergency exits should be demonstrated as operable with the rotorcraft in any foreseeable floating attitude, including with the rotorcraft capsized.
- (2) If an air pocket is part of the rotorcraft design, ease of escape of passengers from within the air pocket should be optimised, to the greatest extent possible, by positioning the ditching emergency exits such that they remain above the waterline when the rotorcraft is capsized and in a stable position.
- (3) The design of ditching emergency exits should be optimised for use with the rotorcraft capsized. For example, the handhold(s) should be located close to the bottom of the window (top if inverted) to assist an occupant in overcoming the buoyancy loads of the immersion suit, or it should be ensured that markings and lighting will help identify the exit(s) and readily assist in an escape.
- (4) Ditching emergency exit opening means should be simple and obvious and not require exceptional effort. Designs with any of the following characteristics (non-exhaustive list) are considered to be non-compliant:
  - (i) the need to use more than one hand to operate the exit itself (use of the handhold may occupy the other hand);
  - (ii) any part of the opening means, e.g. operating handle or control, being located remotely from the exit such that it would be outside of a person's direct vision when looking directly at the exit, or that the person should move away from the immediate vicinity of the exit in order to reach it; and
  - (iii) an exit not meeting the opening effort limitations set by FAA AC 29.809.
- (5) Any operating handle or control should be readily grasped and operated by a gloved hand.



- (6) Handholds should be mounted close to the bottom of each ditching emergency exit such that they fall easily to hand for a normally seated occupant. In the case of exits between face-to-face seating, the provision of two handholds is required.
- (7) The operating handle or tab for ditching emergency exits should be located next to the handhold.

8. Create a new AMC 29.811(h) as follows:

**AMC 29.811(h)**

**Ditching emergency exit markings**

This AMC supplements FAA AC 29.811 and AC 29.811A.

(a) Explanation

This AMC provides additional means of compliance and guidance material relating to ditching emergency exit markings.

CS-29 Amendment X widened the scope of this certification specification from passenger emergency exits to all emergency exits, including flight crew emergency exits and doors for use when boarding life rafts (see CS 29.803(c)).

For rotorcraft certified for ditching, disorientation of occupants may result in the normal emergency exit markings in the cockpit and passenger cabin being ineffective following the rotorcraft capsizing and flooding. Additional illuminated markings should be provided along the periphery of each ditching emergency exit, giving a clear indication of the aperture.

(b) Procedures

- (1) The additional marking of ditching emergency exits should be in the form of illuminated strips that give a clear indication in all environments (e.g. at night, underwater) of the location of a ditching emergency exit. The markings should comprise straight markings along all four edges.
- (2) The additional illuminated markings should function automatically, when needed, and remain visible for at least 10 minutes following rotorcraft flooding. The method chosen to automatically activate the system (e.g. water immersion switch(es), tilt switch(es) etc.) should be such as to ensure that the markings are illuminated immediately, or are already illuminated, when the rotorcraft reaches a point where a capsize is inevitable.
- (3) The location of the ditching emergency exit operating device (e.g. handle, or pull tab in the case of a push-out window) should be distinctively illuminated. The illumination should provide sufficient lighting to illuminate the handle or tab itself in order to assist in its identification. In the case of push-out windows, the optimum place(s) for pushing out (e.g. in a corner) should be highlighted.
- (4) For ease of recognition underwater, black and yellow markings with at least two bands of each colour of approximately equal width should be used for the ditching emergency exit operating device. The highlighted place(s) for push-out windows should also incorporate black-and-yellow-striped markings.



9. Create a new AMC 29.813 as follows:**AMC 29.813****Emergency exit access**

This AMC supplements FAA AC 29.813

## (a) Explanation

The provision for ditching emergency exits for passengers (see CS 29.807(d)) is based on the need to facilitate egress in the case of a capsizing occurring soon after the rotorcraft has alighted on the water or in the event of a survivable water impact in which the cabin may be immediately flooded. The time available for evacuation is very short in such situations, and therefore, CS-29 Amendment X has increased the safety level by mandating additional exits, in the form of ditching emergency exits, to both shorten available escape routes and to ensure that no occupant should need to wait for more than one other person to escape before being able to make their own escape. The provision of a ditching emergency exit in each side of the fuselage of at least the size of a Type IV exit for each unit (or part of a unit) of four passenger seats will make this possible provided that seats are positioned relative to the exits in a favourable manner.

Critical evacuation factors are the distance to an emergency exit and how direct and obvious the exit route is, taking into account likely passenger disorientation.

Furthermore, consideration should be given to occupants having to make a cross-cabin escape due to the nearest emergency exit being blocked or otherwise unusable.

## (b) Procedures

(1) The most obvious layout that maximises achievement of the objective that no passenger is in a worse position than the second person to egress through an exit is a four-abreast arrangement with all seats in each row located appropriately and directly next to the emergency exits. However, this might not be possible in all rotorcraft designs due to issues such as limited cabin width, the need to locate seats such as to accommodate normal boarding and egress, and the installation of items other than seats in the cabin. Notwithstanding this, an egress route necessitating movement such as along an aisle, around a cabin item, or in any way other than directly towards the nearest emergency exit, to escape the rotorcraft, is not considered to be compliant with CS 29.813(d).

(2) If overall rotorcraft configuration constraints do not allow for easy and direct achievement of the above, one alternative may be to provide one or more ditching emergency exits larger than a Type IV in each side of the fuselage.

(3) Handholds should be provided to facilitate cross-cabin egress.

10. Create a new AMC 29.1411 as follows:**AMC 29.1411****Safety equipment — General**

## (a) Explanation



CS-29 Amendment X introduced changes related to ditching and associated equipment. In particular, it defined a standard terminology, re-established CS 29.1411 as a general certification specification for all safety equipment, reorganised CS 29.1415 specifically for ditching equipment, and created a new CS 29.1470 on the installation and carriage of emergency locator transmitters (ELTs). All provisions relating to life rafts are now co-located in CS 29.1415.

- (1) Provisions for the accessibility and stowage of required safety equipment are contained below. Compliance therewith should ensure that:
  - (i) locations for stowage of all required safety equipment have been provided;
  - (ii) safety equipment is readily accessible to both crew members and passengers, as appropriate, during any reasonably probable emergency situation;
  - (iii) stowage locations for all required safety equipment will adequately protect such equipment from inadvertent damage during normal operations; and
  - (iv) safety equipment stowage provisions will protect the equipment from damage during emergency landings when subjected to the inertia loads specified in CS 29.561.
- (2) It is a frequent practice for the rotorcraft manufacturer to provide the substantiation for only those portions of the ditching provisions relating to rotorcraft flotation and ditching emergency exits. Completion of the ditching certification to include the safety equipment installation and stowage provisions is then left to the affected operator so that those aspects can best be adapted to the selected cabin interior. In such cases, the 'Limitations' section of the rotorcraft flight manual (RFM) should identify the substantiations yet to be provided in order to justify the full certification with ditching provisions. The modifier performing these final installations is then concerned directly with the details of this AMC. Any issues arising from aspects of the basic rotorcraft flotation and ditching emergency exits certification that are not compatible with the modifier's proposed safety equipment provisions should be resolved between the type certificate (TC) holder and the modifier prior to the certifying authority's certification with ditching provisions (see AMC 29.801(b)(16) and AMC 29.1415(a)(3)).

(b) Procedures

- (1) A cockpit evaluation should be conducted to demonstrate that all required emergency equipment to be used by the flight crew will be readily accessible during any foreseeable emergency situation, including the possibility of inertia reel seat belts 'locking'. This evaluation should include, for example, emergency flotation equipment actuation devices, remote life raft releases, door jettison handles, handheld fire extinguishers, and protective breathing equipment.
- (2) Stowage provisions for safety equipment shown to be compatible with the vehicle configuration presented for certification should be provided and identified so that:
  - (i) equipment is readily accessible regardless of the operational configuration;
  - (ii) stowed equipment is free from inadvertent damage from passengers and handling;and



- (iii) stowed equipment is adequately restrained to withstand the inertia forces specified in CS 29.561(b)(3) without sustaining damage.
- (3) For rotorcraft required to have an emergency descent slide or rope according to CS 29.809(f), the stowage provisions for these devices should be located at the exits where those devices are intended to be used.
- (4) Life raft stowage provisions should be sufficient to accommodate rafts for the maximum number of occupants for which certification for ditching is requested by the applicant.
- (5) Service experience has shown that following deployment, life rafts are susceptible to damage while in the water adjacent to the rotorcraft due to projections on the exterior of the rotorcraft such as antennas, overboard vents, guttering, etc. Projections likely to cause damage to a deployed life raft should be avoided by design, or suitably protected to minimise the likelihood of their causing damage to a deployed life raft. Relevant maintenance information should also provide procedures for maintaining such protection for rotorcraft equipped with life rafts. Furthermore, consideration should be given to the likely damage that may occur (e.g. disintegration of carbon-fibre panels or structure) during water entry at or slightly above the demonstrated ditching envelope and its potential hazard to deployed life rafts.
- (6) Emergency signalling equipment required by Regulation (EU) No 965/2012 should be free from hazard in its operation, and operable using gloved hands. Required signalling equipment should be easily accessible to the passengers or crew and located near a ditching emergency exit or included in the survival equipment attached to life rafts. Configurations supplying an ELT as part of an approved life raft package have been accepted as meeting the intent of CS 29.1411(e).

11. Create a new AMC 29.1415 as follows:

**AMC 29.1415**

**Ditching equipment**

(a) Explanation

- (1) Ditching equipment is not required for all rotorcraft overwater operations. However, if such equipment is required by Regulation (EU) No 965/2012, the equipment supplied for compliance with Regulation (EU) No 965/2012 should satisfy this AMC.
- (2) Compliance with the provisions of CS 29.801 for rotorcraft ditching requires compliance with the safety equipment stowage provisions and ditching equipment provisions of CS 29.1411 and CS 29.1415, respectively.
  - (i) Ditching equipment installed to complete ditching certification, or required by Regulation (EU) No 965/2012, should be compatible with the basic rotorcraft configuration presented for ditching certification. It is satisfactory if the ditching equipment is not incorporated at the time of the original rotorcraft type certification provided that suitable information is included in the 'Limitations' section of the rotorcraft flight manual (RFM) to identify the extent of ditching certification not yet completed.



- (ii) When the ditching equipment required by CS 29.1415 is being installed by a person other than the applicant who provided the rotorcraft flotation system and ditching emergency exits, special care should be taken to avoid degrading the functioning of those items, and to make the ditching equipment compatible with them (see AMC 29.801(a)(10) and AMC 29.1411(a)(2)).

(b) Procedures

All ditching equipment, including life rafts, life preservers, immersion suits, emergency breathing systems, etc., used to show compliance with the ditching provisions or Regulation (EU) No 965/2012 should be of an approved type for use in all sea conditions covered by the certification with ditching provisions.

(1) Life rafts

- (i) Life rafts are rated during their certification according to the number of people that can be carried under normal conditions and the number that can be accommodated in an overload condition. Only the normal rating may be used in relation to the number of occupants permitted to fly in the rotorcraft.
- (ii) Where two life rafts are installed, each should deploy on opposite sides of the rotorcraft in order to minimise the probability that both may be damaged during water entry/impact, and to provide the maximum likelihood that at least one raft will be useable in any wind condition.
- (iii) Successful deployment of life raft installations should be demonstrated in all representative conditions. Testing should be performed, including underwater deployment, if applicable, to demonstrate that life rafts sufficient to accommodate all rotorcraft occupants, without exceeding the rated capacity of any life raft, will deploy reliably with the rotorcraft in any reasonably foreseeable floating attitude, including capsized. It should also be substantiated that reliable deployment will not be compromised by inertia effects from the rolling/pitching/heaving of the rotorcraft in the sea conditions chosen for demonstration of compliance with the flotation/trim provisions of CS 27.801(e), or by intermittent submerging of the stowed raft location (if applicable) and the effects of wind. This substantiation should also consider all reasonably foreseeable rotorcraft floating attitudes, including capsized. Reasonably foreseeable floating attitudes are considered to be, as a minimum, upright, with and without loss of the critical emergency flotation system (EFS) compartment, and capsized, also with and without loss of the critical EFS compartment. Consideration should also be given towards maximising, where practicable, the likelihood of life raft deployment for other cases of EFS damage.
- (iv) Rotorcraft fuselage attachments for the life raft retaining lines should be provided.
  - (A) Each life raft should be equipped with two retaining lines to be used for securing the life raft to the rotorcraft. The short retaining line should be of such a length as to hold the raft at a point next to an upright floating rotorcraft such that the occupants can enter the life raft directly without entering the water. If the design of the rotorcraft is such that the flight crew cannot enter the passenger cabin, it is acceptable that they would need to



take a more indirect route when boarding the life raft. After life raft boarding is completed, the short retaining line may be cut and the life raft then remain attached to the rotorcraft by means of the long retaining line.

- (B) Attachments on the rotorcraft for the retaining lines should not be susceptible to damage when the rotorcraft is subjected to the maximum water entry loads established by CS 29.563.
- (C) Attachments on the rotorcraft for the retaining lines should be structurally adequate to restrain a fully loaded life raft.
- (D) Life rafts should be attached to the rotorcraft by the required retaining lines after deployment without further action from the crew or passengers.
- (E) It should be verified that the length of the long retaining line will not result in the life raft taking up a position which could create a potential puncture risk or hazard to the occupants, such as directly under the tail boom, tail rotor or main rotor disc.

(vi) Life raft activation

The following should be provided for each life raft:

- (A) Primary actuation: an independent manual activation control, readily accessible to each pilot on the flight deck whilst seated. Alternatively, life rafts may be deployed automatically following water entry. In this case, it will need to be shown that inadvertent deployment in flight will be appropriately unlikely or would not cause a hazard to the rotorcraft.
- (B) Secondary actuation: an independent manual activation control accessible from the passenger cabin with the rotorcraft in the upright or capsized position. Any control located within the cabin should be protected from inadvertent operation.
- (C) Tertiary actuation: an independent manual activation control accessible to a person in the water with the rotorcraft in any foreseeable floating attitude, including capsized.

Placards should be installed, of appropriate size, number and location, to highlight the location of each of the above life raft activation controls. All reasonably foreseeable rotorcraft floating attitudes should be considered.

- (2) Life preservers. No provision for stowage of life preservers is necessary if Regulation (EU) No 965/2012 mandates the need for constant-wear life preservers.
- (3) Survival equipment. Approved survival equipment, if required by Regulation (EU) No 965/2012, should be attached to each life raft. Provisions for the attachment and stowage of the appropriate survival equipment should be addressed during the ditching equipment segment of the basic ditching certification.



12. Create a new AMC 29.1470 as follows:

**AMC 29.1470****Emergency locator transmitters (ELTs)****(a) Explanation**

The purpose of this AMC is to provide specific guidance for compliance with CS 29.1301, CS 29.1309, CS 29.1470, CS 29.1529 and CS 29.1581 regarding emergency locator transmitters (ELT) and their installation.

An ELT is considered a passive and dormant device whose status is unknown until it is required to perform its intended function. As such, its performance is highly dependent on proper installation and post-installation testing.

**(b) References**

Further guidance on this subject can be found in the following references:

- (1) ETSO-2C126 406 MHz Emergency Locator Transmitter (ELT);
- (2) ETSO-2C91a Emergency Locator Transmitter (ELT) Equipment;
- (3) ETSO-C126a 406 MHz Emergency Locator Transmitter;
- (4) FAA TSO-C126b 406 MHz Emergency Locator Transmitter (ELT);
- (5) EUROCAE ED-62A Minimum Operational Performance Specification For Aircraft Emergency Locator Transmitters (406 MHz and 121.5 MHz (Optional 243 MHz));
- (6) RTCA DO-182 Emergency Locator Transmitter (ELT) Equipment Installation and Performance; and
- (7) RTCA DO-204A Minimum Operational Performance Standards (MOPS) for 406 MHz Emergency Locator Transmitters (ELTs).

**(c) Definitions**

- (1) ELT (AF): ELT (automatic fixed) is intended to be permanently attached to the rotorcraft before and after a crash, is automatically activated by the shock of the crash, and is designed to aid search and rescue (SAR) teams in locating a crash site.
- (2) ELT (AP): ELT (automatic portable) is intended to be rigidly attached to the rotorcraft before a crash and is automatically activated by the shock of the crash, but is readily removable from the rotorcraft after a crash. It functions as an ELT (AF) during the crash sequence. If the ELT does not employ an integral antenna, the rotorcraft mounted antenna may be disconnected and an auxiliary antenna (stowed in the ELT case) connected in its place. The ELT can be tethered to a survivor or a life raft. This type of ELT is intended to assist SAR teams in locating the crash site or survivor(s).
- (3) ELT (S): ELT (survival) should survive the crash forces, be capable of transmitting a signal, and have an aural or visual indication (or both) that power is on. Activation of an ELT (S) usually occurs by manual means but automatic activation (e.g. activation by water) may also apply.



- (4) ELT (S) Class A (buoyant): this type of ELT is intended to be removed from the rotorcraft, deployed and activated by survivors of a crash. It can be tethered to a life raft or a survivor. The equipment should be buoyant and it should be designed to operate when floating in fresh or salt water, and should be self-righting to establish the antenna in its nominal position in calm conditions.
- (5) ELT (S) Class B (non-buoyant): this type of ELT should be integral to a buoyant device in the rotorcraft, deployed and activated by the survivors of a crash.
- (6) ELT (AD) or automatically deployable emergency locator transmitter (ADELT): this type of automatically deployable ELT is intended to be rigidly attached to the rotorcraft before a crash and automatically deployed after the crash sensor determines that a crash has occurred or after activation by hydrostatic sensor. This type of ELT should float in water and is intended to aid SAR teams in locating the crash site.
- (7) Crash acceleration sensor (CAS) is a device which detects an acceleration and initiates the transmission of emergency signals when such acceleration exceeds a predefined threshold (Gth). It is also designated as g switch.

(d) Procedures

(1) Installation aspects of ELTs

The equipment should be installed in accordance with the guidance provided in this AMC.

(iv) Installation of the ELT transmitter unit and crash acceleration sensors

The location of the ELT should be chosen to minimise the potential for inadvertent activation or damage by impact, fire, or contact with passengers, baggage or cargo.

The ELT transmitter unit should ideally be mounted to primary rotorcraft load-carrying structures such as trusses, bulkheads, longerons, spars or floor beams (not rotorcraft skin). Alternatively, the structure should meet the requirements of the test specified in 6.1.8 of ED-62A.

The structure on which an ELT is mounted should not be likely to separate in case of a crash, such as a rotorcraft tail boom. However, this does not apply to ELT(s), which should be installed or stowed in a location that is conspicuously marked and readily accessible, or should be integral to a buoyant device such as a life raft, depending on whether it is Class A or B.

The crash acceleration sensor installation can be a source of nuisance triggers, non-activation or missed deployment due to improper installation.

Nuisance triggers can occur when the crash acceleration sensor does not work as expected or is installed in a way that it is exposed to shocks or vibration levels outside those assumed during equipment qualification, making it susceptible to inadvertent activation. It can also be activated as a result of improper handling and installation practices.

Non-activation can occur when operational ELTs are installed in such a way that prevents the crash sensor from sensing actual crash forces.



Particular attention should be paid to the installation orientation of the crash acceleration sensor. If the equipment contains a crash sensor, that part of the equipment containing the crash sensor should be clearly marked by the ELT manufacturer to indicate the correct installation orientation(s), if appropriate, for crash sensing.

Installation design should follow the instructions contained in the installation manual provided by the equipment manufacturer. In the absence of an installation manual, in general, in the case of a helicopter installation, if the equipment has been designed to be installed on fixed-wing aircraft, the equipment manufacturer has historically recommended the installation to be oriented with an angle of 45 degrees with respect to the main longitudinal axis. This may help the sensor to detect forces in directions other than the main longitudinal axis since during a helicopter crash, the direction of the impact may easily differentiate from the main aircraft axis. Nevertheless, it should be noted that this is not the unique solution for helicopters. There are products currently available on the market that are designed specifically for helicopters or designed to sense forces in several axes.

(ii) Use of hook and loop style fasteners

In several recent aircraft accidents, ELTs mounted with hook and loop style fasteners, commonly referred to as 'Velcro', have detached from their aircraft mounting as a result of the crash forces experienced. The separation of the ELT from its mount could cause the antenna connection to be severed, rendering the ELT ineffective.

Inconsistent installation and reinstallation practices can lead to the hook and loop style fastener not having the necessary tension to perform its intended function. Furthermore, the retention capability of the hook and loop style fastener may degrade over time, due to wear and environmental factors such as vibration, temperature, or contamination. The safety concern about these attachments increases when the ELT manufacturer's instructions for continued airworthiness (ICA) do not contain specific instructions for regularly inspecting the hook and loop style fasteners, or a replacement interval (e.g. Velcro life limit). This concern applies, regardless of how the hook and loop style fastener is installed in the aircraft.

(iii) ELT antenna installation

The most recurrent issue found during accident investigations concerning ELTs is the detachment of the antenna (coaxial cable), causing the transmission of the ELT unit to be completely inefficient.

Chapter 6 of ED-62A addresses the external antenna installation and provides guidance, in particular, on:

- (A) antenna location;
- (B) antenna-to-ELT transmission unit relative position;
- (C) coaxial-cable characteristics; and



(D) coaxial-cable installation.

Any ELT antenna should be located away from other antennas to avoid disruption of antenna radiation patterns. In any case, during installation of the antenna, it should be ensured that the antenna has a free line of sight to the orbiting COSPAS-SARSAT satellites at most times when the aircraft is in the normal flight attitude.

Ideally, for the 121.5-MHz ELT antenna, a separation of 2.5 metres from antennas receiving very high frequency (VHF) communications and navigation is sufficient to minimise unwanted interference. The 406 MHz ELT antenna should be positioned at least 0.8 metres from antennas receiving VHF communications and navigation to minimise interference.

External antennas which have been shown to be compatible with a particular ELT will either be part of the ETSO/TSO-approved ELT or will be identified in the ELT manufacturer's installation instructions. Recommended methods for installing antennas are outlined in FAA AC 43.13-2B.

The antenna should be mounted as close to the respective ELT as practicable. Provision should be taken to protect coaxial cables from disjunction or from being cut. Therefore, installation of the external antenna close to the ELT unit is recommended. Coaxial cables connecting the antenna to the ELT unit should not cross rotorcraft production breaks.

In the case of external antenna installation, ED-62A recommends that its mounting surface should be able to withstand a static load equal to 100-times the antenna's weight applied at the antenna mounting base along the longitudinal axis of the rotorcraft. This strength can be demonstrated by either test or conservative analysis.

If the antenna is installed within a fin cap, the fin cap should be made of a material that is RF-transparent and will not unduly attenuate the radiated transmission or adversely affect the antenna radiation pattern shape.

In the case of internal antenna location, the antenna should be installed as close to the ELT unit as practicable, insulated from metal window casings and restrained from movement within the cabin area. The antenna should be located such that its vertical extension is exposed to an RF-transparent window. The antenna's proximity to the vertical sides of the window and to the window pane and casing as well as the minimum acceptable window dimensions should be in accordance with the equipment manufacturer's instructions.

The voltage standing wave ratio (VSWR) of the installed external antenna should be checked at all working frequencies according to the test equipment manufacturer's recommendations.

Coaxial cables between the antenna and the ELT unit should have vibration-proof RF connectors on each end. When the coaxial cable is installed and the connectors mated, each end should have some slack in the cable, and the cable should be secured to rotorcraft structures for support and protection.



In order to withstand exposure to fire or flame, the use of fire-resistant coaxial cable or the application of fire-resistant material around the coaxial cable is recommended.

(2) Deployment aspects of ELTs

Unlike the general recommendations on ELT installation found in ED-62A, this standard does not provide detailed or extensive guidance for the particular case of ADELTS. ADELTS have particularities of the design and installation that need to be addressed independently of the general recommendations.

The location of the ADELTS and its manner of installation should minimise the risk of injury to persons or damage to the rotorcraft in the event of inadvertent activation. The means to manually deploy the ADELTS should be located in the cockpit in such a way, and should be guarded so, that inadvertent manual activation of the ADELTS is minimised.

Automatic deployable ELTs should be located so as to minimise damage to the rotorcraft structure and surfaces during deployment. The ELT deployment trajectory should be demonstrated to be clear of interference from the airframe or other part of the rotorcraft, or with the rotor in the case of helicopters. The installation should also not compromise the operation of emergency exits or of any other safety features.

In some helicopters, where an ADELTS is installed aft of the transport joint in the tail boom, any disruption of the tail rotor drive shaft has the potential to disrupt or disconnect the ADELTS wiring. From accident investigations, it can be seen that if tail boom becomes detached, an ADELTS that is installed there, aft of the transport joint, will also become detached before signals from sensors triggering its deployment can be received.

Therefore, it is recommended to install the ADELTS forward of the transport joint of the tail boom.

The hydrostatic sensor used for automatic deployment should be installed in a location shown to be immersed in water within a short time following a ditching or water impact, but not subject to water exposure in the expected rotorcraft operations. This assessment should include the most probable rotorcraft attitude when crashed, i.e. its capability to keep an upright position after a ditching or a crash into water.

It should also be shown that the risk of unsuccessful ADELTS deployment, due to rotorcraft floating attitude, including capsized, has been minimised.

The installation supporting the deployment feature should be demonstrated to be robust to immersion. Assuming a crash over water or a ditching, water may immerse not only the beacon and the hydrostatic sensor which is designed for this, but also any electronic component, wires and the source of power used for the deployment.

(3) Additional considerations

(i) Human factors (HF)

The ELT controls should be designed and installed so that they are not activated unintentionally. These considerations should address the control panel locations, which should be clear from normal flight crew movements when getting into and



out of the cockpit and when operating the rotorcraft, and the control itself. As already indicated in 3.1.2, the means for manually activating the ELT should be guarded in order to avoid unintentional activation.

The Aircraft Flight Manual (RFM) should document the operation of the ELT, and in particular, any feature specific to the installed model.

(v) Batteries

The ELT operates using its own power source. The ELT manufacturer indicates the useful life and expiration date of the batteries by means of dedicated label. The installation of the ELT should be such that the label indicating the battery expiration date is clearly visible without equipment removal. This would facilitate replacement of the battery and maintenance activities.

(4) Maintenance and inspection aspects

This Chapter provides guidance for the applicant to produce ICA related to ELT systems. The guidance is based on Chapter 7 of ED-62A.

(ii) The ICA should explicitly mention that:

(B) The self-test function should be performed according to the manufacturer's recommendation but no less than once every 6 months. Regulation at the place of operation should be considered when performing self-tests, as national aviation authorities (NAAs) may have established specific procedures to perform self-tests.

(B) As a minimum, periodic inspection should occur at every battery replacement unless required more frequently by airworthiness authorities or the manufacturer.

(ii) Inspection should include:

(B) removal of all interconnections to the ELT antenna, and inspection of cables and terminals;

(B) removal of the ELT unit, and inspection of the mounting;

(C) access to battery to check that there is no corrosion;

(D) check of the crash sensor (G-switch) is recommended (refer to Chapter 7.6 of ED-62A — Periodic inspection for further guidance); and

(E) measurement of transmission frequencies and power output.

(5) Rotorcraft flight manual supplement (RFMS)

The rotorcraft flight manual (RFM) should contain all pertinent information related to the operation of the ELT, including the use of the remote control panel in the cockpit. If there are any limitations on its use, these should be declared in the 'Limitations' section of the RFM or RFMS.

It should also contain detailed instructions for preflight and postflight checks. As a preflight check, the ELT remote control should be checked to ensure that it is in the armed position. Postflight, the ELT should be checked to ensure that it does not transmit by



means of activation of the indicator on the remote control or monitoring 121.5 MHz (or both).

RFMs, or supplemental type certificate (STC) supplements to RFMs, should also contain information on the location and deactivation of ELTs. Indeed, accident investigations have shown that following aircraft ground impact, the remote control switch on the instrument panel may become inoperative, and extensive fuselage disruption may render the localisation of, and the access to, the ELT unit difficult. As a consequence, in the absence of information available to the accident investigators and first responders, this has led to situations where the ELT transmitted for a long time before being shut down, thus blocking the SAR channel for an extended time period. It is therefore recommended that the RFM or its supplements (RFMS) contain information explaining how to disarm or shut down the ELT after an accident, including when the remote control switch is inoperative.

13. Create a new AMC 29.1555 as follows:

**AMC 29.1555**

**Control markings**

This AMC supplements FAA AC 29.1555.

(a) Explanation

CS-29 Amendment X introduced the need to mark emergency controls for use following a ditching or water impact with black and yellow stripes, instead of red, to enhance conspicuity when viewed underwater.

(b) Procedures

(1) Any emergency control that may be required to be operated underwater (e.g. emergency flotation system deployment switch, life raft deployment switch or handle) should be coloured with black and yellow stripes.

(2) Black and yellow markings should consist of at least two bands of each colour of approximately equal width.

14. Create a new AMC 29.1561 as follows:

**AMC 29.1561**

**Safety Equipment**

(a) Explanation

This AMC requires that each safety equipment control that can be operated by a crew member or passenger be plainly marked to identify its function and method of operation. (Note that the marking of safety equipment controls located within the cockpit and intended for use by the flight crew are addressed in CS 29.1555). In addition, a location marking for each item of stowed safety equipment should be provided that identifies the contents and how to remove them. All safety equipment, including ditching and survival equipment, should be clearly identifiable and provided with operating instructions. Markings and placards should be conspicuous and durable



as per CS 29.1541. Both passengers and crew should be able to identify easily and then use the safety equipment.

(b) Procedures

- (1) Release devices such as levers or latch handles for life rafts and other safety equipment should be plainly marked to identify their function and method of operation. Stencils, permanent decals, placards, or other permanent labels or instructions may be used.
- (2) Lockers, compartments, or pouches used to contain safety equipment such as life vests, etc. should be marked to identify the equipment therein and to also identify, if not obvious, the method or means of accessing or releasing the equipment.
- (3) Safety equipment should be labelled and provided with operating-instructions for use or operation.
- (4) Locating signs for safety equipment should be legible in daylight from the furthest seated point in the cabin or recognisable from a distance equal to the width of the cabin. Letters, 2.5 cm (1 in) high, should be acceptable to satisfy the recommendation. Operating instructions should be legible from a distance of 76 cm. (30 in). These are recommendations based on the exit provisions of CS 29.811(b) and (e)(1).
- (5) Each life raft and its installed equipment should be provided with operating instructions that are permanently marked in bold letters and readable in low levels of illumination.
- (6) Easily recognised or identified and easily accessible safety equipment located in view of the occupants, such as a passenger compartment fire extinguisher that is in view of the passengers, may not require locating signs, stencils, or decals. However, operating instructions are required.

15. Create new AMC 29.MG 10 as follows:

**AMC 29.MG 10**

**Advisory material for substantiation of an emergency flotation system (EFS) alone**

Regulation (EU) No 965/2012 may allow for the installation of only emergency flotation equipment, rather than certification for full ditching provisions. However, the provisions for certification of the emergency flotation equipment in such a case remain the same as those for full ditching certification, i.e. compliance with the ditching provisions of CS 29.563 and CS 29.801(b) to (j) should be shown.



## 4. Regulatory impact assessment (RIA)

### 4.1. Issues to be addressed

#### 4.1.1. General issues

Experience has shown that in otherwise survivable ditchings and water impact events, there have been avoidable drowning fatalities due to the inability of the occupants to rapidly escape from a capsized and submerged cabin or, after having successfully escaped, their inability to subsequently survive until they can be rescued.

In addition, it has been recognised that the current methodology of certifying a rotorcraft for ditching stability is somewhat simplistic. It provides less than ideal correlation with real sea conditions, and does not rigorously investigate the likelihood that following a successful ditching, a rotorcraft will remain upright for sufficient time for the occupants to escape.

#### 4.1.2. Safety risk assessment

##### (a) Accident statistics

A database of known helicopter ditching and water impact events was established for this RMT. It contains a primary database, consisting of worldwide events to western-built helicopters over a 10-year period (2003–2012), together with a secondary database of North Sea (NS) occurrences over the longer period 1976–2002 (see Chapter 4.4.2 and Appendix C for details).

All occurrences have been categorised as either a:

- ditching; or
- survivable water impact (SWI); or
- non-survivable water impact (NSWI).

Using the primary database, the distribution of occurrence category is illustrated in Figures 4.1 and 4.2 below:

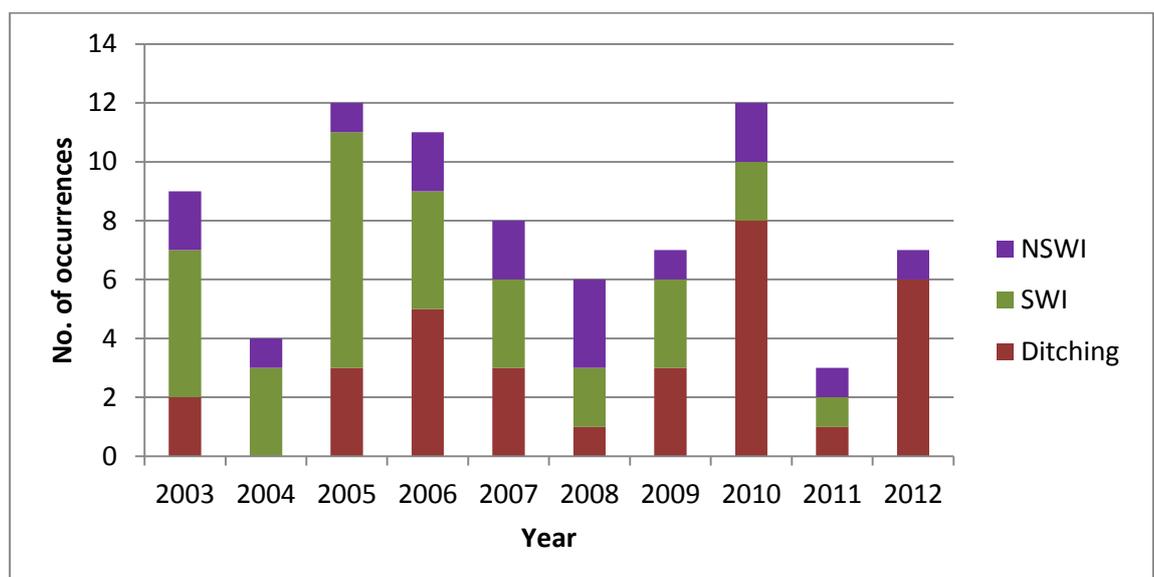
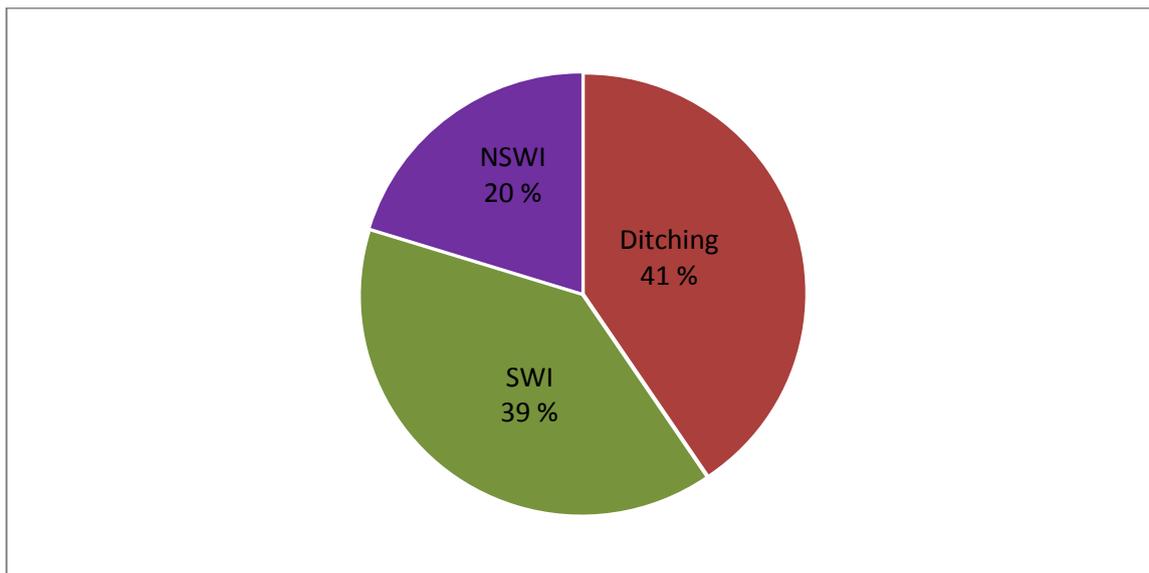


Figure 4.1 — Distribution of occurrence type by year (2003–2012 worldwide)

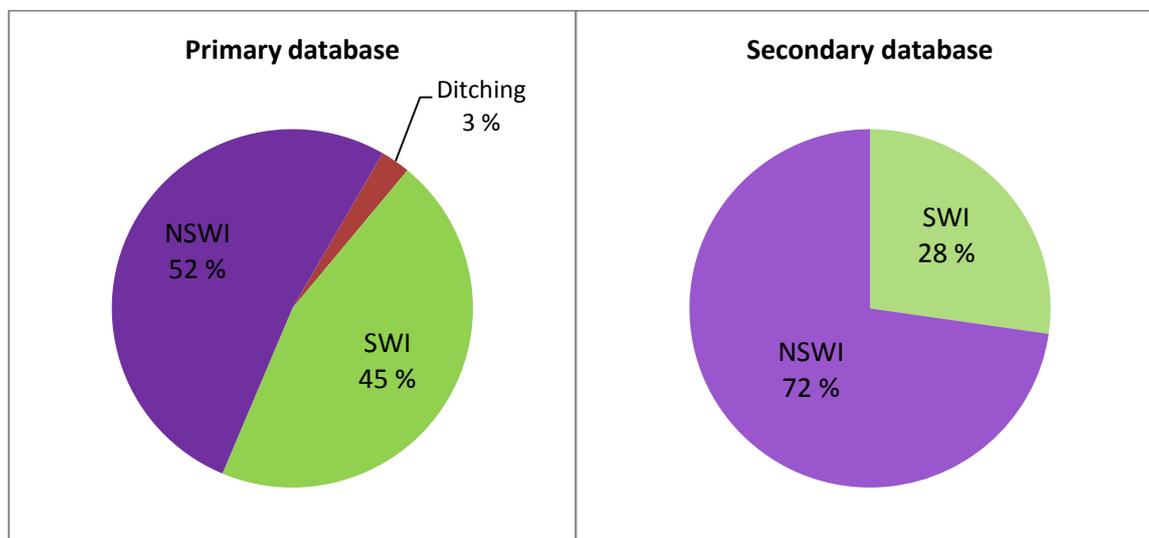




**Figure 4.2 — Proportion of events by category over 10 years (2003–2012 worldwide)**

Ditchings represent the majority of occurrences (41 %) in this 10-year period, closely followed by SWI (39 %) and NSWI (20 %). These values are similar to the NS experience contained in the secondary database (38 %, 38 %, and 24 %, respectively).

If the focus now moves towards fatal accidents and number of fatalities, the result is a different picture.



**Figure 4.3 — Proportion of fatalities by occurrence category**

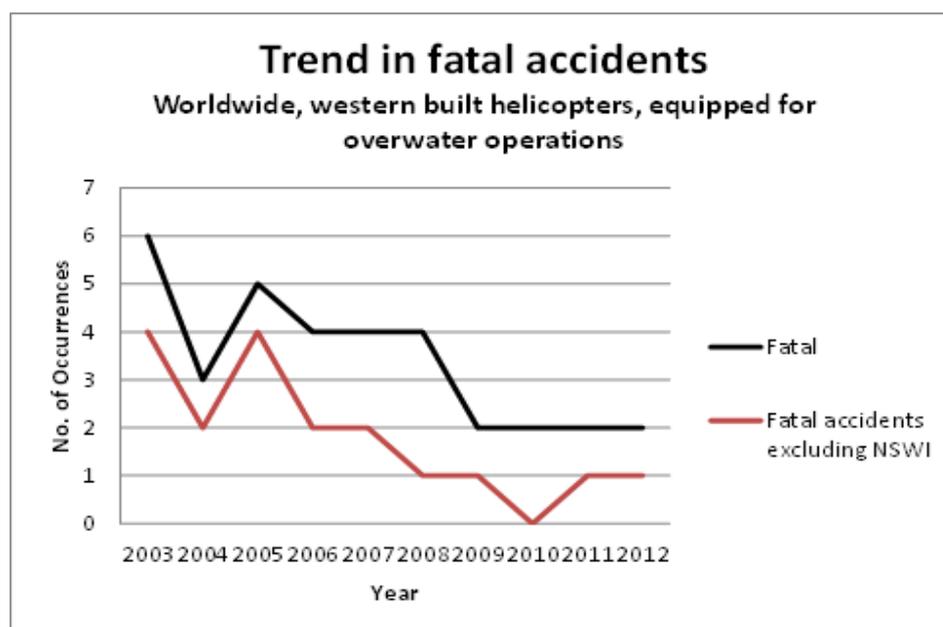
The greatest proportion of fatalities have occurred in non-survivable water impacts. Some 52 % worldwide in the 10-year period (2003–2012), which equates to 78 fatalities, or 72 % in the NS over the longer 27-year period (1976–2002), which equates to 107 fatalities. The difference between the two figures probably relates to the type of helicopters used. In the NS, the helicopters used tend to be all large types, thus resulting in a higher number of fatalities per

event. Although NSWI contains the majority of fatalities, NSWI is not the focus of this RMT and is being addressed through other safety initiatives.

Ditching events have resulted in few fatalities. In the NS, there has never been any loss of life due to a ditching. In the 10-year period worldwide, 3 ditching events have resulted in fatalities. However, it must be borne in mind that these figures may be misleading as a pilot's decision whether to ditch may be influenced by the environment and, in particular, the sea conditions existing at the time. The pilot's decision not to ditch may result in a NSWI (as happened with C-GZCH, for example).

The prime objectives of this RMT focus on survivable water impacts and how to mitigate the associated hazards. This aligns with many of the previous reports aimed at improving offshore helicopter survivability.

A look at the trend in fatal accidents and fatal accidents excluding NSWI, over the 10-year period, shows a reduction in the number of accidents in both categories (see Figure 4.4 below). As NSWI events have remained relatively flat over that period, this trend can be directly attributed to a reduction in the number of SWI events. However, to establish whether this is a real effect, data on hours flown is required, which is not readily available.



**Figure 4.4 — Trend in fatal offshore accidents (2003–2012, worldwide)**

(b) Regional variation

In order to establish whether there is any regional variation in ditching/water impact occurrences and, in particular, whether the level of fatalities is a function of sea conditions, Figures 4.5 and 4.6 below have been created.

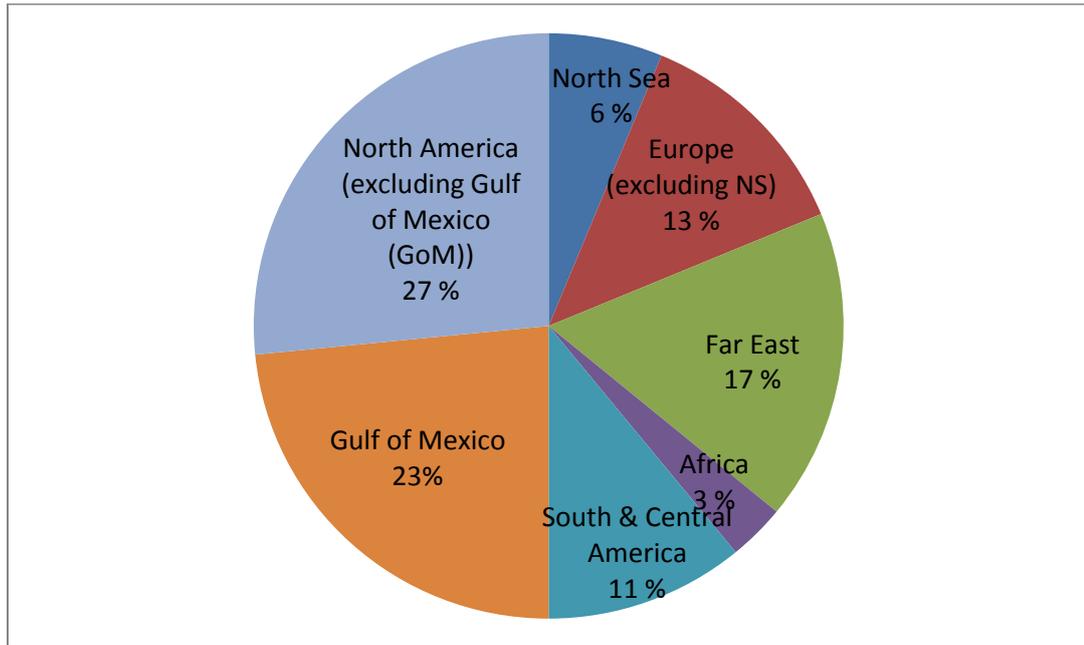


Figure 4.5 — Distribution of ditching/SWI accidents by region (2003–2012)

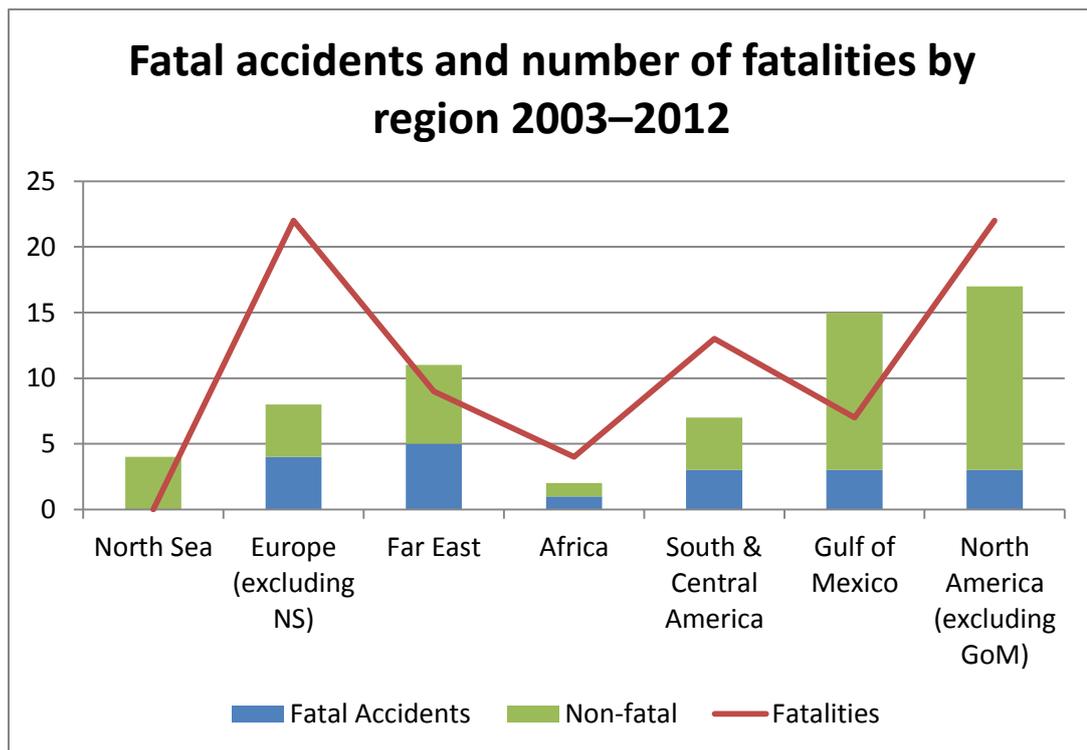


Figure 4.6 — Fatal ditching/SWI accidents and number of fatalities by region (2003–2012)

The absolute numbers of ditchings and SWI in North America and the Gulf of Mexico are perhaps not surprising, due to the high number of helicopter flight hours in these regions. In the NS, there has been no loss of life in the 10-year period resulting from a ditching or SWI. Perhaps, the most interesting fact is that there are more accidents, fatal accidents and fatalities in Europe in areas other than the NS, despite the fact that the rotorcraft operating in this area represent only



19 % of the European offshore helicopter fleet. This indicates that this RMT should not only be focused on hostile sea areas but must also target survivability in non-hostile sea areas if the number of accidents and fatalities is to be reduced.

(c) Ditching/water impact probability/severity

From an analysis of the accident database, and from studies previously undertaken, the following can be stated:

- All ditching events in the NS have been non-fatal. Two events (G-BBHN and G-BDES) resulted in the helicopters capsizing immediately at water entry due to the high-sea and wind conditions, but both remained afloat. Egress was successfully accomplished from an inverted and flooded cabin. One ditching (G-TIGK) resulted in the helicopter remaining afloat upright for some hours despite waves of 6–7 metres<sup>21</sup>. In all other cases, ditchings were performed in sea conditions that were SS 4 or less and in many cases, calm. In these cases, the helicopter remained upright supported by its emergency flotation system (EFS).
- Gulf of Mexico experience during the period (2003–2012) shows that none of 9 ditchings were fatal, and all occupants were able to egress from the helicopter, despite the helicopter capsizing in some cases.
- Three ditching events from the 2003–2012 worldwide database were fatal. In all cases, 1 or 2 occupants had successfully egressed from the helicopter but subsequently died prior to rescue.

Experience, therefore, indicates that a ditching should be considered a **hazardous** event on account of the fact that there may be fatal injuries to a relatively small number of the occupants. However, the accident experience represents only a subset of what could occur, and due to the mismatch between breath-hold time and escape time at least for non-window seat passengers, it is reasonable to expect fatalities in the event of a post-ditching capsize (see Appendix B, Risk Matrix Item 10 below).

With regard to SWI events, the following facts can be determined from the data analysis:

There have been 31 accidents worldwide in the period 2003–2012, of which 15 were fatal resulting in the loss of 68 lives. There were 11 SWI events in the NS (1976–2002), 6 of which were fatal resulting in the loss of 42 lives.

- In all but 1 of the total of 42 SWI events, the helicopter capsized immediately and the cabin flooded. The helicopter sank before egress was completed in 14 events due to non-activation of the emergency flotation system (EFS), or as a result of damage sustained by the EFS on water impact. The fact that the helicopter in the one SWI (G-REDU) did not capsize is primarily attributed to it having been fitted with a non-mandatory, automatic EFS water activation switch. This successfully deployed the EFS at water entry resulting in the helicopter remaining in an upright and stable condition, thus significantly contributing to this being a non-fatal accident.
- In at least 14 of the 42 SWI events, the EFS was not armed or activated by the flight crew (in some accidents, no such information was available).

<sup>21</sup> Subsequent analysis of the sea conditions showed that the wave period was much longer than it is typical for NS conditions, and that this had a bearing on the helicopter's seakeeping ability.



- In at least 9 of the 42 SWI events, the EFS was substantially damaged. However, even in a damaged state, the EFS provided sufficient buoyancy to prevent sinking. There is evidence (G-BIJF, PP-MUM) that successful deployment of a single float can prevent sinking.

Experience indicates that irrespective of helicopter type or operational environment, an SWI should be considered a **catastrophic** event due to the expectation of multiple fatalities.

An NSWI is by definition catastrophic (multiple fatalities).

The frequency of ditching/water impact events may be estimated from UK historical data for which accurate and reliable operating hours are available. During the period 1976–2012, there have been 11 ditchings, 11 SWI and 7 NSWI over 3.5 million flight hours flown. This gives:

- overall frequency of ditching/water impact event =  $8.0 \times 10^{-6}$  per flight hour;
- frequency of ditching =  $3.1 \times 10^{-6}$  per flight hour;
- frequency of SWI =  $3.1 \times 10^{-6}$  per flight hour; and
- frequency of NSWI =  $2.0 \times 10^{-6}$  per flight hour.

A probability of  $10^{-6}$  per flight hour equates to a qualitative frequency of **remote**.

It is acknowledged that these figures may not fully represent current rates as no account has been taken of the trend information contained in Figure 4.4 above. However, considering future trends, it could be assumed that in the NS, more flight hours may be needed as oil and gas fields further from shore are developed, and the offshore wind energy industry creates an increasing demand for helicopter flights. However, it is not clear whether this assumption is valid for other types of operations. More information on projected flight hours would be required to complete this assessment.

The Agency applies a risk assessment approach to rulemaking. The different risk levels are summarised in Table 4.1 below. The levels range from red, which represents a risk of high significance and for which regulatory activity is required, to green which is of low significance and seen as an acceptable risk.

**Table 4.1 — Risk index matrix**

Probability of occurrence	Severity of occurrence				
	Negligible	Minor	Major	Hazardous	Catastrophic
Extremely improbable	Green	Green	Green	Green	Yellow
Improbable	Green	Green	Light Green	Yellow	Brown
Remote	Green	Light Green	Yellow	Brown	Red (Survivable Water Impact (SWI))



Occasional					
Frequent					

Table 4.1 clearly indicates that SWI events represent an unacceptable risk and must be the prime focus of any regulatory activity.

Ditching events are of medium significance. Over the period investigated, there have been no fatalities from ditchings in the hostile waters of the NS. The four recorded fatalities were in non-hostile waters and have occurred as a result of exposure to the water due to the time spent prior to rescue (possibly exacerbated by injuries sustained in the ditching).

Another factor that must be considered is the probability of a ditched helicopter capsizing before or during occupant egress. Worldwide experience indicates that this is a distinct possibility, either due to the sea conditions, thus the water entry being non-optimum, or as a result of a failure in the EFS. Item 10 of Appendix B has established that post-ditching capsize without any mitigation must be considered having catastrophic consequences, with the potential for multiple fatalities. Many of the ditchings that have been performed have fortunately occurred when sea conditions were relatively calm, and therefore, the accident data does not reflect this hazard. This cannot be assumed in the future. Furthermore, the way helicopters are tested for their seakeeping performance today has been discredited by naval architects as it bears little resemblance to real sea conditions. If reliance is to be placed on ditching as a means of mitigating technical and human factors (HF) failures, then the ditching performance of the helicopter must be ensured.

So, to summarise:

- SWI events occur at a much higher frequency than acceptable and result in loss of life, which may be preventable. This risk must therefore be the prime focus of the rulemaking activities. This conclusion aligns with previous safety investigations performed by the FAA, UK CAA and others.
- Ditching events are of medium significance. There is a need for regulatory activity to ensure that a helicopter's approved ditching performance truly represents the sea conditions over which operations take place. This will provide additional confidence in a helicopter's seakeeping performance and the avoidance of post-ditching capsize, which otherwise may prevent occupants from successfully egressing the helicopter.
- It would be difficult to produce separate CS for SWI, mainly due to the inherent difficulty in adequately defining an SWI. Hence, the approach adopted has been to address SWIs by improving the ditching CS; in other words, to regulate for the SWI case implicitly, by raising the ditching CS explicitly. In this way, both objectives are addressed and the changes can be justified by the accident data.



#### 4.1.3. Who is affected?

These changes will affect manufacturers of helicopters intended for offshore operation, suppliers of the associated equipment to enable such operations, and operators of these helicopters.

An estimate of the size of the current helicopter offshore fleet within Europe is shown in Table 4.2 below. This indicates that there are 245 helicopters being used in 11 countries. UK and Norway operate almost two-thirds of the fleet.

**Table 4.2 — European offshore helicopter fleet**

*European offshore fleet by type (2014)*

Manufacturer	Type	In service
AgustaWestland	AW109	3
	AW139	36
Airbus Helicopters	AS332 Super Puma	39
	AS365	30
	EC135	6
	EC155	17
	EC225	36
Bell Helicopter Textron	Bell 429	1
Sikorsky	S-76	17
	S-92	60
Total		245

*European offshore fleet by operator state (2014)*

Operator	In service
United Kingdom	101
Norway	54
France	22
Belgium	17
Denmark	16
Netherlands	14
Germany	11
Ireland	6
Italy	2
Romania	1
Spain	1

From this data, it can be estimated that the split between hostile and non-hostile operations is as follows:

- **hostile:** Belgium, Denmark, Ireland, Netherlands, Norway, UK, that is 208 out of 245 (85 %); and
- **non-hostile:** France, Germany, Italy, Spain, Romania, that is 37 out of 245 (15 %).

The helicopter types used in offshore operations are shown in Table 4.3 below:



Table 4.3 — Helicopters used in offshore operations or overwater flights

Type	AS332	AS365	AW109	AW139	Bell 429	EC135	EC155	EC225	S-76	S-92	Total
Belgium	2	9					6				17
Denmark				7			6	3			16
France	2	16							4		22
Germany			1	1		4			5		11
Ireland	6										6
Italy			2								2
Netherlands				9			4			1	14
Norway	11	2		1				7	1	32	54
Romania					1						1
Spain				1							1
UK	18	3		17		2	1	26	7	27	101
<b>Total</b>	<b>39</b>	<b>30</b>	<b>3</b>	<b>36</b>	<b>1</b>	<b>6</b>	<b>17</b>	<b>36</b>	<b>17</b>	<b>60</b>	<b>245</b>

Source: Ascend Flightglobal fleet database (2014)

The split between small (CS-27) and large (CS-29) offshore helicopters registered in Europe can be determined as:

- for **small helicopters** (AW109, Bell 429, EC135), 10 out of 245 (4 %); and
- for **large helicopters** (all other types), 235 out of 245 (96 %).

Worldwide, the offshore fleet has been estimated, using the same data source, as 2 095 helicopters, of which 1 553 (74 %) are large and 542 (26 %) are small rotorcraft.

#### 4.1.4. How could the issue/problem evolve?

##### Deep-water oil and gas industry forecast

The forecast of the deep-water oil and gas industry is based on publications released by energy analysts and the largest companies in the industry, including Exxon, BP and Lukoil.

*Offshore extraction is an increasingly important part of the global oil and gas supply. As production of onshore sources is slowing, the growth in offshore production can help meet the increasing energy demand fuelled by growing population and global wealth (Infield, 2012).*

Since the early 1980s, onshore production has levelled off while more exploration and production has been taking place in deeper waters, remote locations and harsher climates. According to Infield estimates (2013), by the year 2015, almost one-third of the world's oil production is estimated to be from offshore areas (see Figure 4.7 below).



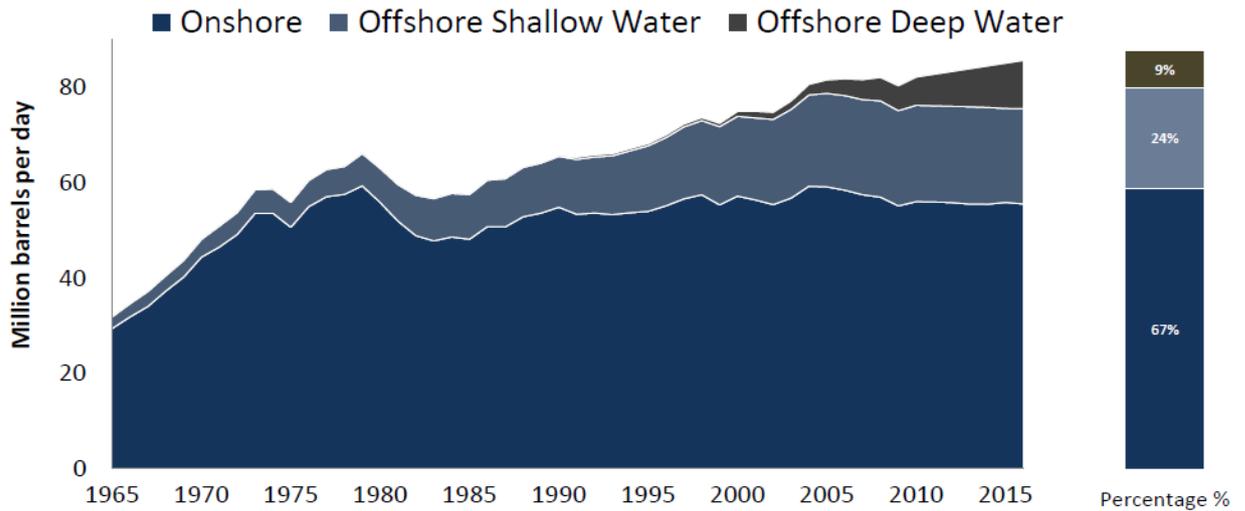


Figure 4.7 — Onshore and offshore oil production

In future, the number of ultradeep water rigs is also expected to further grow, although at a somewhat slower pace than in the 2009–2014 period (see Figure 4.8 below).

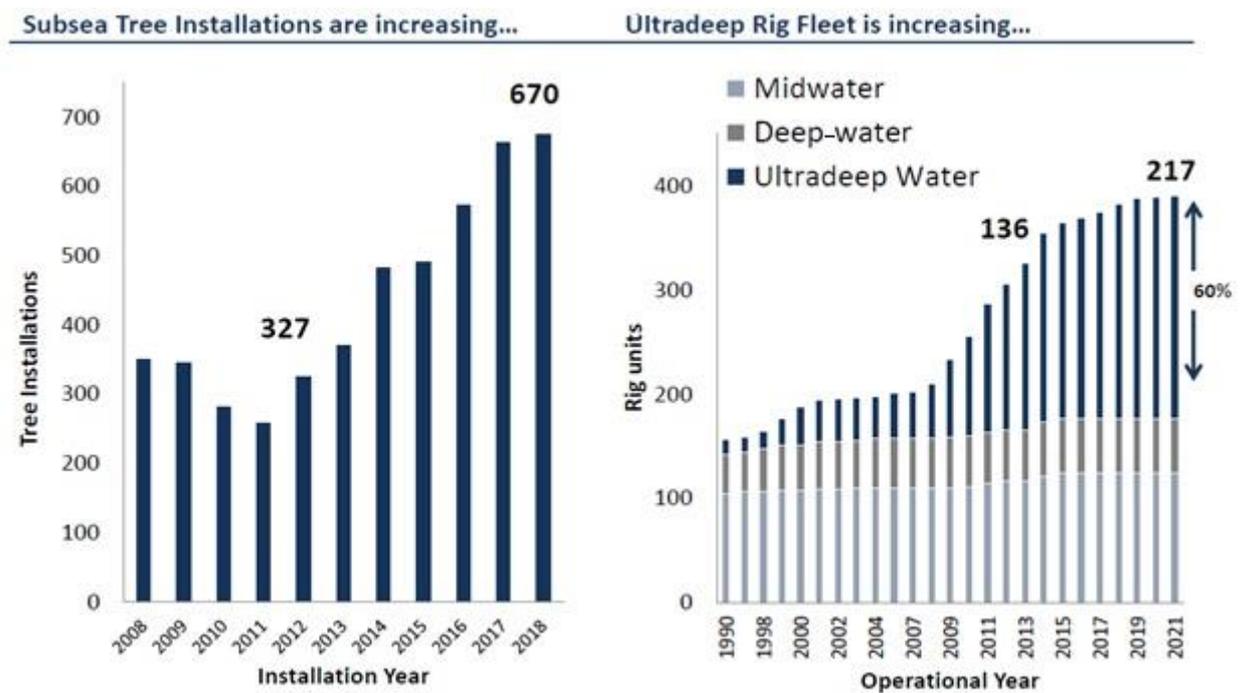


Figure 4.8 — Increasing ultradeep water activity

A long-term forecast by Lukoil (2013, p. 16) also confirms that offshore resources are going to play a greater role in supplying the growing demand as traditional onshore reserves are depleted. Over the last 20 years, the number of large shelf discoveries has been greater than the number of big onshore discoveries.

Lukoil expects to see a significant production growth after 2015 (see Figure 4.9 below) when a number of new large fields will be put in operation, despite the high cost of production and operating risks.



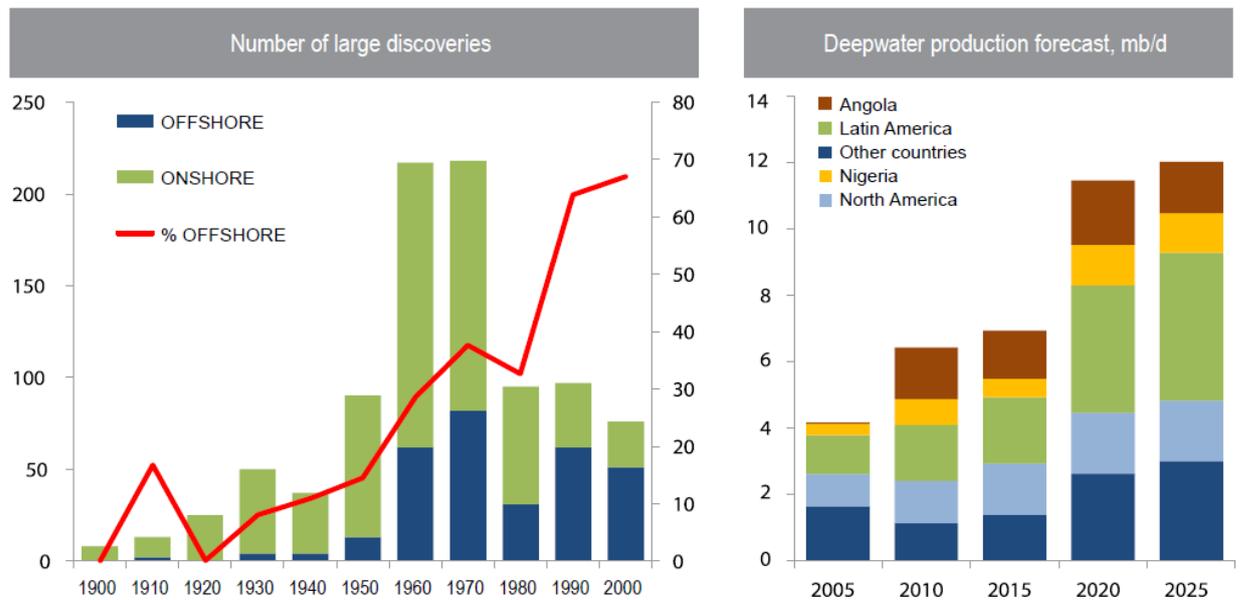


Figure 4.9 — Deep-water production, 1900–2000 and 2005–2025

BP publishes several annual forecasts and analyses on the oil and gas industry. Its latest Energy Outlook (2013) estimates oil to remain the dominant fuel used in 2035. Production of all fossil fuels is going to decline in the EU, however led by oil (–57 % in 2035 compared to 2012).

Exxon Mobil (2014) forecasts deep-water technologies to be the most significant emerging liquid supply source from 2010 to 2040. Deepwater supplies will grow by more than 150 % plateauing near the end of the Energy Outlook (2040). Demand for oil is projected to rise by around 28 % worldwide through 2040, although demand in Europe is expected to decrease by 22 %.

**Helicopter industry forecast**

The 2012 annual report of the Airbus Group (EADS, 2012) expects increasing demand from offshore operators to boost commercial helicopter sales. The oil and gas sector is described as an important driver of civil helicopter sales.

Duncan and Frank (2007) also see the explosion of offshore production activity around the globe, especially in harsh environment, as a key demand-side driver of helicopter sales. Without helicopters, offshore operators would be unable to transport crews and equipment quickly and would face significant risk related to emergency transport and storm response.

Their demand forecast for helicopters is surprisingly flat in light of future exploration and development plans. This is caused by two factors. Firstly, the number of platforms required for future oil and gas production is dropping. With large deep-water fields, larger floating platforms are being designed with higher production capacities. One platform produces more oil and gas with fewer people, and less helicopter transportation is needed per barrel produced. Secondly, as shallow-water reserves are exhausted in some mature markets, platforms will be decommissioned, reducing transport demand.

The type of helicopter required for deep-water fields further from shore is different. The offshore oil and gas helicopter fleet is expected to change to a higher number of medium- and heavy-type helicopters.



Safran (2014) sees the helicopter industry as a growth market fundamentally, driven by the replacement of aging fleets and burgeoning demand from emerging countries. The overall net growth is highest in the area of utility missions and offshore transport for the oil and gas industry.

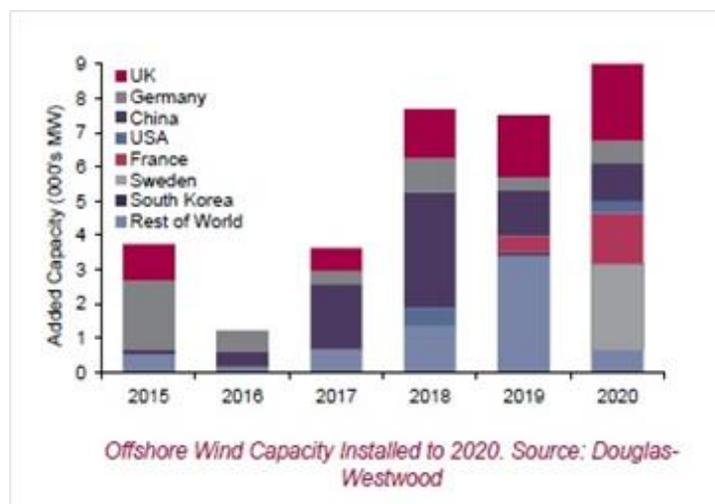
Ascend (2014) also evaluates the market for offshore helicopter transportation services as booming. As oil and gas exploration companies are increasingly moving into deep-water and ultradeep-water environments, new equipment is required to support this shift. A new class of seven-tonne-plus helicopters, so-called 'super-mediums', are designed specifically to meet these new provisions.

#### Offshore wind energy sector forecast

The European energy sector is undergoing a long-term transformation towards an ever-increasing use of renewable energy. In 2000, only 2 % of EU's electricity generation was based on renewable energy while the figure has grown to 15 % in 2014 according to DONG Energy (February 2015). By 2030, renewable energy is expected to increase to one-third of the total European electricity supply. At the same time, the need for oil and gas is predicted to represent only 50 % of the EU's total primary energy consumption in 2030.

With Directive 2009/28/EC<sup>22</sup> on the promotion of the use of energy from renewable sources issued on 23 April 2009, the EU establishes a common framework for the promotion of energy from renewable sources. It sets mandatory national targets for the overall share of energy from renewable sources, including wind and solar energy.

According to International Energy Agency (IEA) statistics (2015), offshore wind should more than triple by 2020.



**Figure 4.10 — Offshore wind capacity installed (2015–2020)**

According to the HTM Helicopters' outlook (October 2015), helicopters such as the EC135P2 and EC135T3 are used for transportation of personnel to offshore wind farm locations and for helicopter hoist missions onto individual turbines. Waypoint North (aviation adviser and insurance provider) reports that helicopters such as the AW139 are used for crew change (EC225 and AW189 in the future)

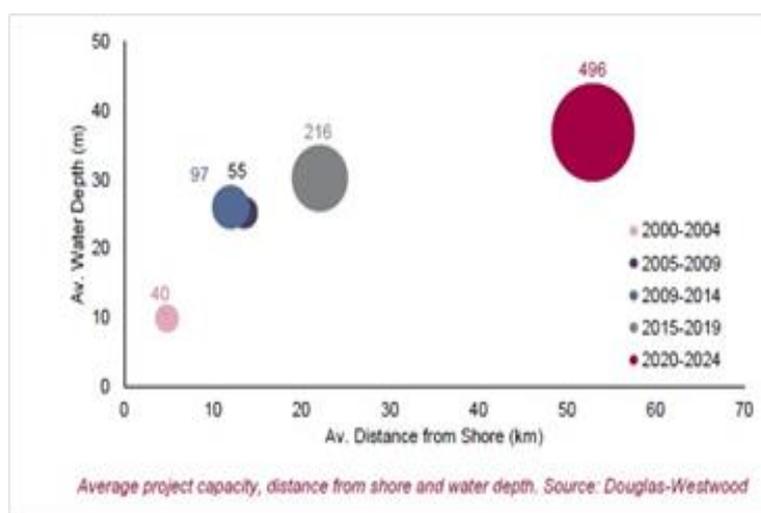
<sup>22</sup> Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (OJ L 140, 5.6.2009, p. 16).

and helicopters such as EC135 and AW139 are used for hoisting onto wind turbines (EC145 and AW169 in the future).

According to Douglas-Westwood's outlook (October 2015), pure crew transfer operations do not currently feature highly in offshore helicopter use for the renewable sector. Helicopters are rarely used for this purpose alone as they are used for hoist operations as well; however, they predict that crew transfer in dedicated helicopters will gain in importance for far from shore wind farms in the future, especially if there is use of accommodation vessels for the personnel.

Another use of helicopters is during the construction phase where 'heli-hoist' helicopters are used to transport vital pieces of equipment. Douglas-Westwood also outline as a key market the so called 'unplanned operations' — such as emergency repair or medical evacuation — as developers suffer severe economic penalty when a wind turbine or farm does not produce to the grid; thus, the quick transportation of personnel is vital.

Currently, around 70 % of the European offshore wind energy capacity is concentrated in the NS with use of helicopter models such as H135, AW139, AS 355 and AS365. A trend for larger helicopters (due to their capability of accessing deep water installations farther from shore) can be seen although the larger types may be unable to hoist in some situations due to the location of the wind turbine blades relative to the set-down point on the nacelle.



**Figure 4.11 — Average offshore project capacity 2000–2024**

There is a tendency for distances to grow — the average distance from shore to oil and gas platforms was 115 km in 2000, nowadays, it is more than 160 km. The average distance from shore to offshore wind installations was below 5 km in 2000 and is expected to increase to more than 50 km in the next decade (see Figure 4.11 above).

Offshore wind farm operations present a number of challenges, such as extensive hoist operations in varying weather conditions, and larger projects may start to take on characteristics more like oil and gas exploitation, with operations associated with the construction phase, and continued operation for far-from-shore installations, involving accommodation vessels on site with helidecks.

The offshore wind farm sector, therefore, presents several interesting issues in regard to the proposed rule changes of this NPA. Offshore helicopter operations are going to increase markedly over the

coming years, at longer ranges, and with an increasing portion of the offshore helicopter fleet comprising smaller types than those currently serving the oil and gas industry. It is therefore of importance that the increased risk of these types (i.e. CS 27 Category A) being involved in ditchings or water impact accidents is mitigated by their inclusion in the applicability of the safety improvements proposed by this RMT. Furthermore, the ramping-up of the overall offshore wind energy industry's needs for helicopter flights could both compensate to some extent for the historic variations in total offshore operations numbers, due to changes in oil and gas industry activity, as well as significantly add to the total.

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- [Exxon Mobil: The Outlook for Energy, A View to 2040, 2015](#)
  - [HTM Helicopters' outlook: Helicopter Operations in the evolving Offshore Wind Sector presentation on the Helitech International Business and Strategy Conference, 7 October 2015](#)
  - [International Energy Agency \(IEA\): Renewable Energy, Medium-Term Renewable Market Report 2015, Market Analysis and Forecasts to 2020](#)
  - [Infield: Offshore Outlook, 2012](#)
  - [Infield: Global Offshore Oil and Gas Outlook, 2013](#)
  - [Lukoil: Global Trends in Oil & Gas Markets to 2025, 2013](#)
  - Safran Magazine: Special Report, Markets — Ensuring a Long-Term Future, January 2014



## 4.2. Objectives

The primary objective is to improve the safety of helicopter occupants in case of ditching and survivable water impacts.

## 4.3. Policy options

The detailed risk assessment performed as part of this RMT (see Appendix B), together with information from accident reports, previous studies, and certification and operational experience, have been reviewed and analysed to provide proposed enhanced design provisions and GM.

The risk assessment conducted in Appendix B has identified many potential changes to the provisions, including changes to the rotorcraft certification specifications (CS-27, CS-29), changes to equipment standards (CS-ETSO), and changes to the Air Ops Regulation, including provisions for personal protective equipment (PPE) and training. Furthermore, some of these proposals would be applicable to both new rotorcraft types, and as retroactive provisions to the existing fleet (Part-26/CS-26). This NPA is constrained to address changes to CS-27 and CS-29 only, and the options identified reflect this limitation. It is planned that a second NPA is issued to assess and possibly cover the retroactive provisions.

A risk matrix has been developed to identify the hazards associated with helicopter ditching/water impact and potential mitigations (see Appendix B, Table B-1). This was performed by considering the complete chain of events from the crashworthiness aspects of the water entry phase, through issues such as egress/escape from the helicopter and entry into life rafts, to the final rescue of survivors.

Columns in the matrix indicate the sources of the identified hazard, which can be broadly categorised as follows:

- a safety recommendation from an accident investigation board;
- an analysis of accidents and serious incidents; and
- previous safety studies and reports (see Appendix A).

Following Table B-1 of Appendix B, each issue/mitigation is discussed in depth and concludes with a recommendation for rule change (or not) for each item. This is then summarised in the final column of the Table.

Where 'No further action by this RMT' is indicated, either the risk is considered to be sufficiently addressed by existing rules, or as in some cases, recommendations are made for future research or regulatory activity.

Many of the potential benefits identified offer a small safety benefit which cannot be reasonably quantified in isolation. The policy in this NPA is therefore to package options that have little impact, both in order to reduce the number of options to a practical level, and to highlight those options where the impacts are expected to have the highest significance. Each option identified is therefore not exclusive but can be combined with others to create combinations of options.

Table 4.4 below summarises the outcome of the risk assessment and how this has been packaged into the various options. It contains only those mitigations which have been assessed to have a safety benefit and are applicable to both CS-27 and CS-29.



**Table 4.4 — Content of options** (numbers are references used in Table B-1 of Appendix B)

<b>Option 1 — Minimum change</b>
<ul style="list-style-type: none"> <li>2. Crashworthiness of structure</li> <li>4. ‘Delethalisation’ of cockpit/cabin interior</li> <li>7. Personal protective equipment (PPE) and exits operable one-handed</li> <li>12. Enhanced EFS Crashworthiness</li> <li>14. Automatic EFS activation</li> <li>15. Automatic arming/disarming of EFS</li> <li>16. Increase flotation stability by fitting float scoops/remove fuel jettison aspects from the rule</li> <li>23. Illuminated exit markings</li> <li>25. Ensure all suitable fuselage apertures are available for underwater escape</li> <li>26. Cabin layout and alignment of seat rows with exits</li> <li>27. Ease of exit operation</li> <li>28. Handholds adjacent to doors/windows</li> <li>31. Standardisation of emergency exits</li> <li>36. Size of occupants</li> <li>39. Evacuation procedures &amp; ease of life raft boarding (CS-29 only)</li> <li>41. External carriage &amp; remote release of life rafts</li> <li>47. Ensure life raft floats at a safe distance</li> <li>52. ELT installation, reliability and compatibility</li> <li>54. Improve paint scheme/retroreflective markings</li> </ul>
<b>Option 2 — Capsize mitigation</b>
<ul style="list-style-type: none"> <li>9. Prevent capsizing</li> <li>17. Novel solutions (e.g. ‘side-floating’ concept) — not considered practicable for CS-27 (non-Category A) types</li> <li>18. Float redundancy</li> <li>19. Provide enhanced post-capsizing survivability features — not considered practicable for CS-27 (non-Category A) types</li> <li>29. Jettisoning of doors (ensure opened doors cannot prevent egress from a capsized rotorcraft by overlapping other exits)</li> </ul>
<b>Option 3 — Irregular-wave testing</b>
<ul style="list-style-type: none"> <li>10. Improve certification of seakeeping performance</li> <li>11. Move towards compliance with more realistic sea conditions</li> <li>44. Use of a sea anchor to stabilise the rotorcraft (but prevent sea anchor use in wave tank testing)</li> </ul>



The selected options for further analysis are summarised in Table 4.5 below.

**Table 4.5 — Selected policy options**

Option No	Short title	Description
0	Baseline	No change in rules; risks remain as outlined in the issue analysis.
1	Minimum change	Package of changes, each of which is considered to be too limited in safety or cost impact to warrant separate treatment.
2	Capsize mitigation	Provision of enhanced post-capsize survivability features (CS-29 and CS-27 Cat A rotorcraft only) and improved guidance regarding EFS design.
3	Irregular-wave testing	Change of certification methodology and testing to give increased confidence in a rotorcraft's seakeeping performance.

#### 4.4. Methodology and data

##### 4.4.1. Applied methodology

The methodology applied for this RIA is the multi-criteria analysis (MCA), which allows comparing all options by scoring them against a set of criteria.

MCA covers a wide range of techniques that aim at combining a range of positive and negative impacts into a single framework to allow easier comparison of scenarios. Essentially, it applies cost-benefit thinking to cases where there is a need to present impacts that are a mixture of qualitative, quantitative, and monetary data, and where there are varying degrees of certainty. The MCA key steps generally include:

- establishing the criteria to be used to compare the options (these criteria must be measurable, at least in qualitative terms);
- attributing weight to each criterion to reflect its relative importance to the decision;
- scoring how well each option meets the criteria; the scoring needs to be relative to the baseline scenario;
- ranking the options by combining their respective weights and scores; and
- performing sensitivity analysis on the scoring to test the robustness of the ranking.

The criteria used to compare the options were derived from the Basic Regulation and the guidelines for the RIA developed by the European Commission (EC). The principal objective of the Agency is to 'establish and maintain a high uniform level of safety' (Article 2(1) of the Basic Regulation). As additional objectives, the Basic Regulation identifies environmental, economic, proportionality, and harmonisation aspects, which are reflected below.



The scoring of the impacts uses a scale of –5 to +5 to indicate the negative and positive impacts of each options (i.e. from ‘very high’ negative/positive impacts). Intermediate levels of benefit are termed ‘high’, ‘medium’, ‘low’, and ‘very low’ to provide for a total of five levels in each of the positive and negative directions, with also a ‘no impact’ score possible.

#### 4.4.2. Approach to assess the issues

This rulemaking task (RMT) aims to identify and assess the various hazards to occupants following a ditching or water impact. Its primary objective is to propose enhancements to the rotorcraft design provisions in order to mitigate the associated risks and to further improve the ability of occupants to escape a capsized rotorcraft and subsequently survive until rescued.

The following activities have been performed during the development of the rulemaking tasks:

- (a) Review the accepted definitions of ‘ditching’, ‘emergency landing on water’ and ‘water impact’, and determine, based on experience from previous accidents and incidents, whether there is an identified safety need to amend or expand the regulatory scope.
- (b) Review the FAA/JAA Water Impact, Ditching Design and Crashworthiness Working Group (WIDDCWG) and JAA Helicopter Offshore Safety and Survival (HOSS) Working Group recommendations and other relevant documents relating to water impact, ditching design and survivability.
- (c) Assess whether the current interpretation of CS 27.801(d)/CS 29.801(d), namely that to demonstrate flotation stability in reasonably probable water conditions means up to sea state (SS) 4, should be amended to address a broader consideration of regional climatic sea conditions. Consideration should be given to different operating environments, the need to align with the Air Ops Regulation, different categories of rotorcraft, and the possibility of multiple standards. The definition of reasonably probable water conditions in terms of significant wave height ( $H_s$ ), zero-crossing period ( $T_z$ ) and wave spectrum should also be taken into account.
- (d) Review the acceptable means of compliance demonstration in terms of regular- vs irregular-wave tank testing.
- (e) Identify regulatory changes that could enhance crashworthiness of emergency flotation systems (EFSs), both in ditching and water impact events. For example, by assessing the pros/cons of both pre-ditching and post-ditching float inflation, with regard to minimising/avoiding float damage, by providing float redundancy, and by providing an improved design of activation and gas distribution systems.
- (f) Identify and assess novel solutions, including the side-floating rotorcraft emergency flotation scheme, as a means both of mitigating the risk of post-ditching capsize, and of improving emergency flotation system crashworthiness in respect of water impacts.
- (g) Develop appropriate rule change proposals for the following:
  - (1) automatic activation of flotation system: the flotation system should be automatically activated (either by primary or secondary means) upon sensing water immersion;
  - (2) flotation system arming/disarming: during any flight over water, the possibility of the automatic float activation feature being disabled, e.g. deactivation of the system, should be minimised; and



- (3) use of fuel jettison: fuel jettison aspects should be removed from CS 27.801(d) and CS 29.801(d).
- (h) Consider the technical viability of deploying external life rafts with the rotorcraft in any probable attitude.
- (i) Review existing European technical standard orders (ETSOs) for life rafts (ETSO-2C70a and ETSO-2C505) and determine how to mandate their installation and protection from damage when installed.
- (j) Review the emergency exit design, including type, number, location, marking, helicopter emergency egress lighting system (HEELS), ease of operation, operation at all fuselage attitudes, and the possible standardisation of opening procedures.
- (k) Develop appropriate rule change proposals regarding push-out windows, taking into account the need to clarify:
  - (1) the minimum practical dimensions for suitable escape openings (considering passengers wearing survival suits);
  - (2) the provision of handles or other aids to facilitate the pushing-out of windows;
  - (3) the non-acceptability of seating restrictions imposed either because of passenger size, physical abilities or the prescribed need to align seat rows with windows;
  - (4) an appropriate standard of marking and lighting with regard to the status of the opening intended only for underwater escape; and
  - (5) the justification for requiring push-out windows in small cabins if crew and passenger doors are jettisonable.
- (l) Review CAA Paper 2003/13 and draft a certification specification (CS) for an emergency breathing system (EBS), and determine if its content and maturity is suitable for development of an ETSO. Consider requiring an EBS to enhance occupant escape and survivability.
- (m) Based on accident and incident data, identify issues related to emergency locator transmitter (ELT)/personal locator beacons (PLB) installation and functioning that have resulted in poor in-service experience.
- (n) Where applicable, draft text changes for CS-27 and CS-29, together with revised GM, based on the reviews performed, and recommend changes to other regulatory documents, such as ETSOs and the Air Ops Regulation.
- (o) Consider the need for retroactive application in Annex I (Part-26) to Regulation (EU) No 2015/640<sup>23</sup> or in CS-26 of any of the rule changes proposed. This will be addressed in a second phase of this RMT.

#### 4.4.3. Data collection

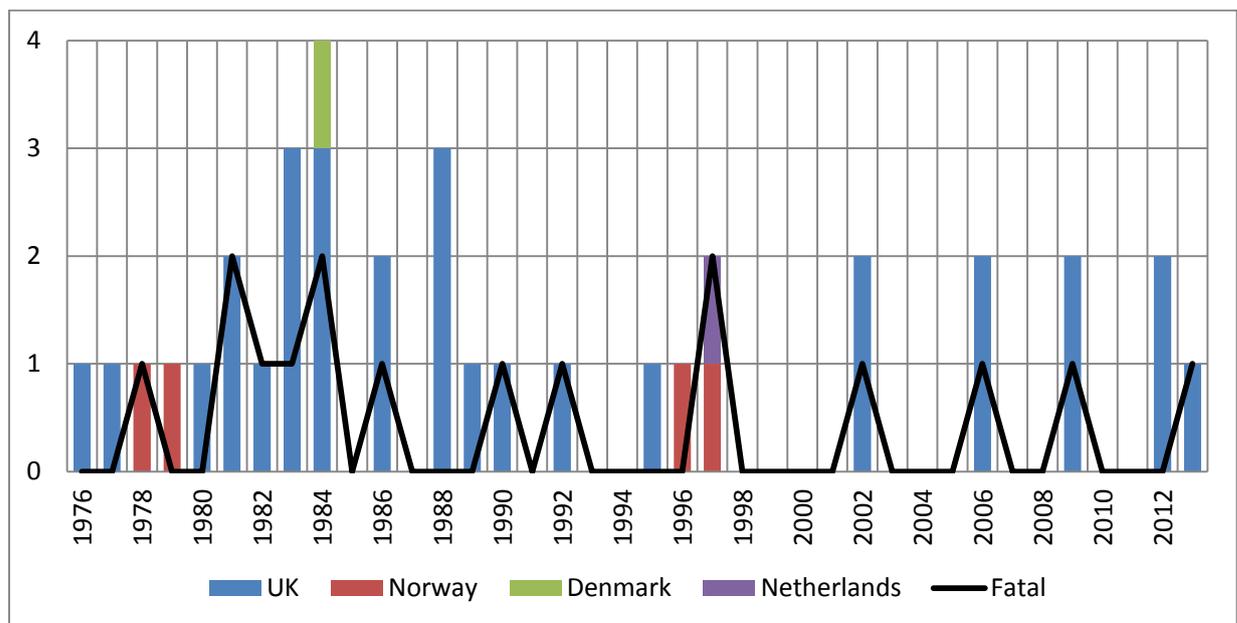
In order to perform the safety risk assessment, a database of known helicopter ditching and water impact events has been established (see Appendix C).

<sup>23</sup> Commission Regulation (EU) 2015/640 of 23 April 2015 on additional airworthiness specifications for a given type of operations and amending Regulation (EU) No 965/2012 (OJ L 106, 24.4.2015, p. 18).



The database has two parts:

- the primary database which covers worldwide events over a 10-year period (2003–2012 inclusive) and contains 79 events, of which 34 are fatal with a total of 150 fatalities; and
- the secondary database which covers NS occurrences only over a 27-year period (1976–2002 inclusive) and contains 29 events, of which 13 are fatal with a total of 149 fatalities; Figure 4.12 below summarises the NS experience (extended to cover the period up to and including 2012).



**Figure 4.12 — History of NS ditching/water impact events**

In both cases, the databases contain only western-built helicopters that are fitted with an EFS and equipped for overwater operations.

The database has been created using a number of sources, including:

- EASA Accident/Incident Reporting (ADREP) database and the European Central Repository (ECR);
- FAA/National Transportation Safety Board (NTSB);
- UK CAA Mandatory Occurrence Reporting Scheme (MORS); and
- worldwide air accident investigation board reports.

Worldwide ditching data is used as the primary database in this RMT for the following reasons:

- under ICAO, the Agency is the State of Design, and has responsibility for the design and continued airworthiness of all European products, irrespective of where they may be operated;
- helicopters registered in Europe may, and are, operated worldwide; and
- using worldwide experience increases knowledge and provides a more accurate picture of the hazards arising from ditching and water impact events.



The downside to using worldwide data is that other factors, such as fleet usage and detailed investigations of accident causes, may not be readily available. In the absence of such data, NS data has been substituted, where appropriate.

The number of helicopters in offshore operations are based on data from Ascend fleets. They include helicopters in service and those out of service and temporarily stored on 1 January 2014, used in offshore oil and gas support.

#### 4.5. Analysis of impacts

Due to the potential for different impact levels arising from different helicopter types (i.e. small (CS-27) and large ones (CS-29)), and the types of environment in which they operate (i.e. hostile or non-hostile ones), each of these factors has been taken into account in the analysis, creating three scenarios, named as follows:

- 27 small rotorcraft (CS-27);
- 27A small rotorcraft (CS-27 Category A); and
- 29 large rotorcraft (CS-29).

Each of these scenarios is assessed separately in the following analysis.

##### 4.5.1. Safety impact

In an attempt to quantify the safety effectiveness of each proposed option, engineering judgement has been used to reconstruct the scenario of each accident within the database and to reassess the potential outcome of the event, had each of the options been previously implemented.

The outcome from this analysis is summarised in Tables 4.6 & 4.7 below.

**Table 4.6 — Safety benefit (primary database)**

REGULATORY APPLICATION	No of Fatal Accidents	No of LIVES LOST	POTENTIAL LIVES SAVED		
			Option 1	Option 2	Option 3
			Minimum change	Capsize mitigation	Irregular-wave testing
27	5	10	5	0	0
27A	1	2	2	0	0
29	6	44	3	23	0
Benefit	Reduced to 9 (from 12)	Reduced to 23(from 56)	10	23	0
			33		
Benefit/year	Reduced by 0.3	Reduced by 3.3	1	2.3	0
			3.3		



Key points to note are:

- the number of fatal accidents could have been reduced from 12 to 9 over the 10-year period;
- the number of fatalities could have been reduced from 56 to 23, potentially saving 33 lives;
- the number of potential lives saved per year is 3.3;
- Option 1 (minimum change) is applicable across all four scenarios and contributes potentially 1 life saved/year;
- Option 2 (capsize mitigation) provides a safety benefit for large rotorcraft(CS-29), contributing a potential 2.3 lives saved/year; and
- Option 3 has not been demonstrated to show any benefit from this accident data-driven approach; however, as explained in Chapter 4.1.1 above, the way helicopters are tested for their seakeeping performance today bears little resemblance to real sea conditions and has thus been discredited.

**Table 4.7 — Safety benefit (secondary database)**

REGULATORY APPLICATION	No of Fatal Accidents	No of LIVES LOST	POTENTIAL LIVES SAVED		
			Option 1	Option 2	Option 3
Baseline scenario for 29	6	42	Minimum change	Capsize mitigation	Irregular-wave Testing
Benefit	Reduced to 4 (from 6)	Reduced to 20 (from 42)	7	15	0
			22		
Benefit/year	Reduced by <0.1	Reduced by 0.8	0.3	0.5	0
			0.8		

Key points to note are:

- the number of fatal accidents could have been reduced from 6 to 4 over the 27-year period;
- the number of fatalities could have been reduced from 42 to 20, potentially saving 22 lives;
- the number of potential lives saved per year is 0.8;
- Option 1 (minimum change) contributes potentially 0.3 life saved/year;
- Option 2 (capsize mitigation) contributes potentially 0.5 life saved/year; and
- Option 3 has not been demonstrated to show any benefit from this accident data-driven approach.

In addition to the safety impact analysis in this Chapter, the safety risk assessment of Chapter 4.1.1. has also been taken into account.

The potential safety benefits associated with each option and with each scenario have been qualified and summarised in Table 4.8 below.



**Option 0 (baseline)**

This Option is considered neutral in terms of safety (no change in respect of the current situation).

**Option 1**

For CS-27 rotorcraft types, this Option is assessed as one providing a medium positive safety benefit because it would have prevented half of the fatalities in the assessed accidents.

For CS-27 Category A rotorcraft types, the safety benefit is assessed as a medium positive one. This is because although all fatalities in the primary database could have been prevented, there was in fact only one accident, and so a high level of confidence cannot be assigned to the safety benefit.

For CS-29 rotorcraft types, the safety benefit is proven to be very low positive because it was judged that only 10 fatalities out of 86 (primary and secondary databases combined) could have been prevented.

**Option 2**

A neutral safety benefit is assigned to CS-27 rotorcraft types because the proposed amendments to CS-27 include neither the provision for enhanced post-capsize survivability features, nor for the emergency flotation system design to maintain flotation with one complete flotation unit lost.

A low positive safety impact is assigned to CS-27 Category A rotorcraft types because although enhanced post-capsize survivability provisions are included in the proposals, the safety benefit is not backed up by accident data. No accidents were found where Option 2 would have provided benefit. However, with increased future use of CS-27 Category A rotorcraft types (see Chapter 4.1.3 above), there is reason to assume that such accidents will occur.

A medium positive safety benefit is assigned to CS-29 rotorcraft types. This is justified on grounds of an assessment that 38 fatalities out of 86 (primary and secondary databases combined) could have been prevented.

**Option 3**

No safety benefit for Option 3 could be directly assessed from accident data. This is because no accidents were found in which fatalities had occurred due to a ditched helicopter capsizing and preventing occupants from escaping. Rather, fatalities occurred in water impact accidents where an immediate capsizing is inevitable, irrespective of the sea conditions. On the other hand, as explained in Chapter 4.1.1 above, the way rotorcraft are currently tested for their seakeeping performance has been discredited due to it bearing little resemblance to real sea conditions. With a continuing increase in offshore helicopter operations, at increasing distances from land, and for widened purposes (e.g. hoisting operations onto windfarm installations), the associated risks for ditchings to occur provides justification for not allowing inadequate test methods for future certification substantiation. A low positive safety impact is thus assigned to all rotorcraft types with Option 3.



Table 4.8 — Qualitative impact on safety

		Option 0	Option 1	Option 2	Option 3
		Baseline	Minimum change	Capsize mitigation	Irregular-wave testing
<b>Assessment</b>		Safety will remain at the current level	Potential to save 1 life per year	Greatest improvement in safety (2.3 lives saved per year)	Potential to prevent capsizes following a ditching
<b>Score (unweighted)</b>	<b>27</b>	0	3	0	2
	<b>27A</b>	0	3	2	2
	<b>29</b>	0	1	3	2

#### 4.5.2. Environmental impact

No environmental impacts identified.

#### 4.5.3. Social impact

Recent offshore accidents have increased the focus on offshore helicopter safety and survivability within Europe. Those accidents have led to a loss of confidence in helicopter operations and in the specific helicopter types involved. Because of this, many workers at offshore locations find the transportation to work and back to be stressful experiences. Visible safety improvements, such as those found in Options 1 and 2, on helicopters used for these operations, will in turn lead to improvements in job quality.

Therefore, very low positive social impacts have been assigned to Options 1 and 2 for CS-27 Category A and CS-29 rotorcraft types only.



Table 4.9 — Qualitative social impact

		Option 0	Option 1	Option 2	Option 3
		Baseline	Minimum change	Capsize mitigation	Irregular-wave testing
Assessment		No impact	Improved safety in the NS will enhance confidence; for other areas, the impact is neutral.		Possibly more of a concern to flight crew and operators
Score (unweighted)	27	0	0	0	0
	27A	0	1	1	0
	29	0	1	1	0

#### 4.5.4. Economic impact

The costs associated with the implementation of each of the options identified are difficult to establish precisely, due to uncertainties in the technical solutions required for new products.

Industry estimates of costs are provided in Tables 4.10 and 4.11 below (source: major helicopter manufacturers).

Table 4.10 — Detailed rotorcraft development cost estimates by mitigating measures

Ditching/water impact	Option	Current regulation	New regulation cost impact
Water entry tests (behaviour)	1		€ 500,000
Additional cost for irregular instead of regular waves test	3		€ 200,000
Stability irregular waves tests (capsize)	3		€ 100,000
Normal floats (low position) supplier development		€ 2,000,000	
Side floats (symmetrical system) supplier development	2		€ 3,000,000
Normal EFS/actuation system supplier reused			
Actuation system supplier development (new system with new sensors)	2		€ 1,000,000
Normal floats system manufacturer development (integration of the system)		€ 1,500,000	
Side floats system manufacturer development (integration of the system)	2		€ 2,500,000
Specific flight tests (normal floats)		€ 100,000	
Specific flight tests (side floats)	2		€ 800,000
Total	–	€ 3,600,000	€ 8,100,000



**Table 4.11 — Cost estimate by options**

Costs	Option 1	Option 2	Option 3
	Minimum change	Capsize mitigation	Irregular wave testing
Total development cost per new TC	€ 500,000	€ 7,300,000	€ 300,000
Annual development cost per new TC	€ 100,000	€ 1,460,000	€ 60,000

Note: Annual development costs are calculated by dividing the above figures by 5, i.e. assuming a 5-year development cycle.

### Operators

The oil and gas industry relies heavily on support helicopters to transport workers and equipment to and from offshore rigs, and continues to invest money in helicopter equipment and in research activities to ensure the safety of its workforce. However, transport costs still represent only a very small percentage of the total costs in this industry sector. The market for offshore helicopters in the oil and gas sector is therefore less cost-sensitive than in other sectors.

### Manufacturers

In order to assess the significance of each identified increase in development costs per new type, this amount needs to be compared to a financial indicator that accurately represents the affected manufacturers.

The annual revenue of manufacturers is readily available in annual reports and can be used to compare the significance of various levels of costs or benefits. The thresholds expressed in percentages and the corresponding multi-criteria analysis scores are shown in Tables 4.12 and 4.13 below.

**Table 4.12 — Economic impact scores**

Impact	Score	Share of annual turnover	
		More than	No more than
Very high	5	1.00%	
High	4	0.60%	1.00%
Medium	3	0.20%	0.60%
Low	2	0.05%	0.20%
Very low	1	0.01%	0.05%
Insignificant	0	–	0.01%



**Table 4.13 — Economic impact of mitigating measures**

	Average revenue (2014, in million) <sup>1</sup>	€ 4,920
Option 1	Development cost per new type (in million)	€ 0.50
	Annual cost per new type <sup>2</sup>	€ 0.10
	Development cost as share of revenue	0.002%
	Impact score	Insignificant
Option 2	Development cost per new type (in million)	€ 7.30
	Annual cost per new type <sup>2</sup>	€ 1.46
	Development cost as share of revenue	0.030%
	Impact score	Very low
Option 3	Development cost per new type (in million)	€ 0.30
	Annual cost per new type <sup>2</sup>	€ 0.06
	Development cost as share of revenue	0.001%
	Impact score	Insignificant
Options 1, 2 & 3	Development cost per new type (in million)	€ 8.1
	Annual cost per new type <sup>2</sup>	€ 1.62
	Development cost as share of revenue	0.033%
	Impact score	Very low

Notes:

<sup>1</sup> Average value is based on the 2014 annual reports of the four largest relevant manufacturer in terms of number of aircraft delivered.

<sup>2</sup> Five-year development cycle assumed

The development cost of mitigating measures is no more that 0.01 % of the annual revenue of manufacturers in case of Option 1, which means an insignificant economic impact for these manufacturers. Option 2 could have a somewhat higher but still very low economic impact at 0.03 % of the annual revenue. Option 3 has the lowest economic impact, on average 0.001 % of the annual revenue, which means an insignificant economic impact.

The average development cost is estimated to be 0.033 % of the annual revenue if all three options are mandated, which is a very low negative economic impact for the majority of manufacturers in this comparison.

It can also be reasonably assumed that the initial development costs are going to be lower for new types that can adopt already available technology in the future. Furthermore, the choice of assuming a five-year development cycle is considered to be conservative.

The cost figures above, although appreciable in absolute terms, represent a small portion of the costs involved in the development and certification of a new helicopter type.

The proposed changes are appreciably less onerous overall, in regard to the technological challenges, for CS-27 non-Category A types (particularly with Option 2, because this option is not required for these types) compared to CS-27 Category A types and CS-29 types.



Therefore, in Table 4.14 below, an insignificant economic impact is selected for the former (only Options 1 and 3 applicable) and an insignificant negative economic impact (Options 1 and 3) to very low negative impact (Option 2) for the latter types.

**Table 4.14 — Qualitative economic impact**

		Option 0	Option 1	Option 2	Option 3
		Baseline	Minimum change	Capsize mitigation	Irregular-wave testing
Assessment		No impact	Low cost	Very low cost for CS-27 Category A and CS-29 types	Cost increase may depend on SS tested
Score (unweighted)	27	0	0	0	0
	27A	0	0	-1	0
	29	0	0	-1	0

#### 4.5.5. General aviation (GA) and proportionality issues

The consequences of a ditching or water impact are equally applicable to all rotorcraft, irrespective of size. However, RMG RMT.0120 recognised that two airworthiness standards apply. CS-29 applies to large rotorcraft, which are generally used for commercial air transport (CAT), carry up to 19 passengers and two crew, and are operated in hostile sea areas. This contrasts with CS-27 rotorcraft, which are generally smaller, carry up to no more than 9 passengers, and are often used offshore in aerial work operations. Unless certified as Category A rotorcraft, they are also restricted to non-hostile areas.

It is acknowledged that creating similar provisions for both CS-27 and CS-29 may result in small medium enterprises (SMEs) being unduly penalised due to the relative costs of compliance compared with the overall development and certification costs. With this in mind, the proposed changes are minimised for the CS-27 non-Category A rotorcraft types, with only CS-27 Category A and CS-29 rotorcraft types being required to meet the more challenging provisions. The latter types are only manufactured by the larger helicopter manufacturers and so effects on SMEs are reduced.

For these reasons, the only impacts assessed are very low in the cases of CS-27 non-Category A rotorcraft types for Options 1 and 2 (Option 3 excludes these types) and of CS-27 Category A types for Option 2 only because of the slightly higher technical challenges of developing workable designs in this area for these smaller types. It is to be noted that all CS-27 Category A rotorcraft manufacturers also produce CS-29 types, and thus much of the developmental work required for Option 2 would be useful for both types.

Overwater flights in the GA sector represent a small proportion of the total operations. Therefore, the impact of the new proposed CSs has been assessed as very low.

These impacts are shown in Table 4.15 below.



Table 4.15 — Qualitative impact on GA and proportionality

		Option 0	Option 1	Option 2	Option 3
		Baseline	Minimum change	Capsize mitigation	Irregular-wave testing
Assessment		No impact	Relative impact may be greater on smaller rotorcraft Note: Option 2 is not applicable to Part-27 non-Category A types		
Score (unweighted)	27	0	-1	0	-1
	27A	0	0	-1	0
	29	0	0	0	0

#### 4.5.6. Impact on ‘better regulation’ and harmonisation

The proposals contained in this NPA will create some new provisions in areas where currently, there are no previously developed solutions. This RMT started with the premise that a step change in safety was necessary, and this has been confirmed in the safety analysis forming part of this RIA. The proposed changes to the provisions have been based on a risk assessment and analysis of identified mitigations, in order to come up with a set of regulatory enhancements. The practicality of these changes has been assessed, in part through dedicated research activities, and no fundamental technical or economic impediments have been identified. However, it is acknowledged that some technical challenges will exist. Established certification procedures and practice will allow for some flexibility in application if the new proposed provisions are later found to be problematic.

In some areas, notably EFS and ditching water entry, the proposals simplify the existing rules.

FAA was part of the RMG developing this NPA. It is not expected that compliance with the proposed new certification specifications would create a barrier for validation by the FAA, and in time, it is hoped that FAA will adopt the changes following publication by the Agency.

For these reasons, a neutral impact has been assumed across the board.



Table 4.16 — Qualitative impact on ‘better regulation’ and harmonisation

		Option 0	Option 1	Option 2	Option 3
		Baseline	Minimum change	Water impact	Irregular-wave testing
Assessment		No impact	Differences with the FAA and other authorities will result, however, harmonisation can be expected in the future.		
Score (unweighted)	27	0	0	0	0
	27A	0	0	0	0
	29	0	0	0	0



## 4.6. Comparison and conclusion

### 4.6.1. Comparison of options

Combining the scores from each of the impact criteria, and for each of the scenarios, results in the overall impact. This is summarised in Table 4.17 below.

**Table 4.17 — Final scores of the qualitative impact**

	Option 0	Option 1	Option 2	Option 3
	Baseline	Minimum change	Water impact	Irregular-wave testing
<b>27</b>				
SAFETY	0	3	0	2
ECONOMIC	0	0	0	0
SOCIAL	0	0	0	0
GA & PROPORTIONALITY	0	-1	0	-1
BETTER REG. & HARM.	0	0	0	0
<b>TOTAL</b>	<b>0</b>	<b>2</b>	<b>0</b>	<b>1</b>
<b>27A</b>				
SAFETY	0	3	2	2
SOCIAL	0	1	1	0
ECONOMIC	0	0	-1	0
GA & PROPORTIONALITY	0	0	-1	0
BETTER REG. & HARM.	0	0	0	0
<b>TOTAL</b>	<b>0</b>	<b>4</b>	<b>1</b>	<b>2</b>
<b>29</b>				
SAFETY	0	1	3	2
SOCIAL	0	1	1	0
ECONOMIC	0	0	-1	0
GA & PROPORTIONALITY	0	0	0	0
BETTER REG. & HARM.	0	0	0	0
<b>TOTAL</b>	<b>0</b>	<b>1</b>	<b>3</b>	<b>2</b>



Reviewing each of the options proposed, the following conclusions can be drawn:

### Option 0

Option 0 has no impact on any of the three rotorcraft types investigated. The objective of this RMT was to enhance the safety level of offshore helicopters, so doing nothing is not an acceptable option.

### Option 1

Option 1 ranges from fairly positive for CS-29 rotorcraft types up to very positive for CS-27 rotorcraft types, both non-Category A and Category A. However, even for CS-29 types, the RMG concluded that the minimum change was still justified as many new designs were already voluntarily fitting these safety enhancing features. It is, therefore, necessary that the rules capture this increase in standards to ensure that those standards could be maintained and that those manufacturers applying those enhanced standards would not be unduly penalised.

### Option 2

Option 2 ranges from a very positive for CS-29 rotorcraft types to a lower positive outcome for CS-27 Category A rotorcraft types and is neutral for CS-27 non-Category A types.

The RMG recognised that for the first two types, there will be some design challenges in order to comply with the proposed new rules. Many of these challenges break new ground and create a level of uncertainty.

Furthermore, a review of the current European offshore helicopter fleet (see Table 4.3 above) shows that only a very small proportion thereof (4 %) are small rotorcraft. It is not expected that the future choice of rotorcraft used for offshore operations will be unduly influenced by the ditching/water impact provisions. With these factors in mind, the RMG concluded that restricting the more challenging capsizes mitigation provisions to CS-29 and CS-27 Category A would ensure that SMEs are not unduly impacted.

### Option 3

Option 3 scores are appreciably positive for all rotorcraft types.

Despite this, the RMG questioned whether irregular-wave testing should be limited in some way, either to hostile area operations or to the size of the rotorcraft (i.e. CS-27 or CS-29). However, the RMG concluded that there was no justification for perpetuating a model testing methodology that had been discredited, has no scientific basis, and was unrepresentative of actual sea conditions. While it was recognised that irregular-wave testing could create some additional complexity and cost to manufacturers, it was expected that these could be reduced once experience with irregular-wave testing and the implementation of the test specification were gained.

In conclusion, the following options have been selected and implemented in this NPA:

- Option 1 (Minimum change) applicable to CS-27 and CS-29;
- Option 2 (Capsizes mitigation) applicable to CS-29 and CS-27 Category A only; and
- Option 3 (Irregular-wave testing) applicable to CS-27 and CS-29.



## 5. Recommendations for future rulemaking

### 5.1. Retroactive implementation of airworthiness provisions

The safety gains resulting from this NPA's proposed rotorcraft design certification specifications amendments (i.e. changes to CS-27 and CS-29 as outlined in this NPA) can for many years only be realised by also making the related regulations, where feasible and appropriate, applicable to helicopter types currently in service or under development.

It is, therefore, recommended that the second phase of RMT.0120, proposing changes to Part-26/CS-26, be initiated and completed as soon as practicably possible.

### 5.2. Air operations regulation changes

The following recommendations for changes to the Air Ops Regulation have resulted from the deliberations of the RMG RMT.0120:

- limitations should be put in place to prohibit operations over sea conditions for which there is no realistic prospect of rescue following a ditching or survivable water impact;
- limitations should be put in place to prohibit operations, except for emergency purposes, over sea conditions more severe than those for which compliance with the flotation and trim requirements has been demonstrated;
- the wearing of survival suits meeting an ETSO should be required;
- EBS (meeting CAP 1034 Category A standard) should be mandated for carriage by all occupants;
- assessment of cockpit habitability issues by operators, and provision of appropriate flight crew survival suits (see Chapter 5.3 below) as well as rotorcraft environmental control systems should be required;
- requirements for the wearing of survival suits as a function of sea temperature should be revised, with staged limits versus immersion suit insulation levels (see Chapter 5.3 below); and
- in order to reduce the risk of life raft damage, the provision of an electrical strobe light instead of flares in the required survival equipment should be considered.

### 5.3. Changes to ETSOs

- ETSO C114 should be revised to require testing of all webbing elements under all loading conditions resulting from inversion of the rotorcraft, and in the case of rotary harness release devices, release by rotating in either direction should be required.
- ETSOs for immersion suits should be reviewed with a view to facilitating the following:
  - self-righting for all survival suits, i.e. whether combined with a life jacket or an integrated design, and for all insulation levels as below;
  - better habitability possibilities (particularly for flight crew) by including different insulation levels, for different intended water temperatures;
  - in the case of safety and rescue (SAR) crew/winchmen, the provision of a specific category of survival suit;



- if research provides positive results regarding the effectiveness of the 'active infrared (IR) detection' concept, inclusion of this in the survival suit ETSOs; and
  - the provision of a safety knife for flight crew suits (and consideration also for passenger suits).
- ETSOs for life rafts should be reviewed with a view to:
- improving the provisions for puncture resistance;
  - making them compatible with the fact that they will probably be used in a remotely activated design (current ETSOs assume that the raft will be manhandled into the water);
  - including provisions for two retaining lines (short and long), perhaps of varying lengths, to be compatible with different intended helicopter installations;
  - introducing testing provisions for deployment, including when fully submerged (if applicable, due to possible helicopter floating attitudes); and
  - improving instructions on the life raft for actions such as sea anchor deployment.
- A working group should be formed to develop technical content for an EBS ETSO.

#### 5.4. Research

Some areas were identified where further research was considered to be appropriate. Depending on the outcome of the research, regulatory activity might be identified:

- research should be undertaken to determine the safety benefits and feasibility of installing air bags for occupant protection in helicopters; and
- research of the feasibility and desirability of automatically deployed life rafts should also be considered.



## 6. References

### 6.1. Affected regulations

N/a

### 6.2. Affected CS, AMC and GM

- Decision No. 2003/15/RM of the Executive Director of the Agency of 14 November 2003 on certification specifications for small rotorcraft ('CS-27')
- Decision No. 2003/16/RM of the Executive Director of the Agency of 14 November 2003 on certification specifications for large rotorcraft ('CS-29')

### 6.3. Reference documents

- [UK CAA: CAP 491, Review of helicopter airworthiness, Report of the Helicopter Airworthiness Review Panel \(HARP\) of the Airworthiness Requirements Board, London, June 1984](#)
- [FAA: DOT/FAA/AR-07/8, The Development of Ditching and Water Impact Design Limit Curves for Civil Rotorcraft, Final Report, May 2007](#)
- [FAA: DOT/FAA/CT-92/13, Rotorcraft Ditchings and Water-Related Impacts that Occurred from 1982 to 1989, Phase I, Final Report, October 1993](#)
- [FAA: DOT/FAA/CT-92/14, Rotorcraft Ditchings and Water Related Impacts that Occurred from 1982 to 1989, Phase II, Final Report, October 1993](#)
- [UK CAA: CAP 641, Report of the Review of Helicopter Offshore Safety and Survival \(RHOSS\), 1st Edition, February 1995](#)
- UK CAA: CAA Paper 95010, Helicopter Float Scoops, London, December 1995
- [UK CAA: CAA Paper 96005, Helicopter Crashworthiness, London, July 1996](#)
- [FAA: DOT/FAA/AR-95/53, Survey and Analysis of Rotorcraft Flotation Systems, Final Report, May 1996](#)
- UK CAA: CAA Paper 97010, Devices to Prevent Helicopter Total Inversion Following a Ditching, London, December 1997
- JAA/FAA: Report of the Joint Harmonization Working Group on Water Impact Ditching Design and Crashworthiness (WIDDCWG), January 2000 (see Appendix G to UK CAA Paper 2005/06)
- JAA: HOSS Working Paper HOSS/WP-99/8.5, Helicopter Safety and Occupant Survivability Following Ditching or Water Impact, June 2000 (see Appendix F to UK CAA Paper 2005/06)
- UK CAA: CAA Paper 2001/2, Crashworthiness of Helicopter Emergency Flotation Systems, London, August 2001
- UK CAA: CAA Paper 2001/10, Helicopter Ditching Research, Egress from Side-Floating Helicopters, London, September 2001
- [UK CAA: CAA Paper 2003/13, Preliminary Study of the Implementation and use of Emergency Breathing Systems, 24 October 2003](#)



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- [UK CAA: CAA Paper 2005/06, Summary Report on Helicopter Ditching and Crashworthiness Research, Part A General, December 2005](#)
  - Taber, M.J. & McCabe, J.: An examination of survival rates based on external flotation devices: a helicopter ditching review from 1971 to 2005, SAFE Journal, Volume 35(1), p. 1–6, March 2007
  - [UK CAA: CAP 1034, Development of a Technical Standard for Emergency Breathing Systems, May 2013](#)
  - [EASA: ToR RMT.0120\(27&29.008\) Issue 1, Ditching Occupant Survivability, 24 October 2012](#)
  - [EASA: EASA.2007.C16, Study on Helicopter Ditching and Crashworthiness](#)
  - [UK CAA: CAP 1144, ADELTA review report, 27 February 2014](#)
  - [UK CAA: CAP 1145, Safety review of offshore public transport helicopter operations in support of the exploitation of oil and gas, 20 February 2014](#)
  - UK House of Commons Transport Committee: Offshore Helicopter Safety, 2nd Report, 30 June 2014



## 7. Appendices

### 7.1. Appendix A — Review of previous reports

#### Item 1 — [UK CAA: CAP 491, Review of helicopter airworthiness, Report of the Helicopter Airworthiness Review Panel \(HARP\) of the Airworthiness Requirements Board, London, June 1984](#)

Major joint industry review in the UK of helicopter airworthiness. 4 of the 15 recommendations are relevant:

(...)

***RECOMMENDATION 7.** A study should be initiated forthwith to identify suitable requirements for an improved standard of crashworthiness of the rotorcraft structure as a whole, landing gear, seats and possible restraint systems, having regard to possible military-civil cooperation in this area;*

***RECOMMENDATION 8.** Immediate steps should be taken to require better standards of crashworthiness of fuel tanks and fuel systems;*

***RECOMMENDATION 9.** We propose that draft requirements covering ditching be published at an early date to encourage technical consideration; and*

***RECOMMENDATION 10.** We propose that resolution of the problems of stability of a ditched helicopter be urgently pursued.*

(...)

Recommendations 7 and 8 led to the research reported in CAA Papers 96005, 2001/2 and 2005/06 (see Appendix B, Risk Matrix Items 7, 12 and 15 below).

Recommendations 9 and 10 led to the research reported in CAA Papers 95010, 97010, 2001/10, and 2005/06 (see Appendix B, Risk Matrix Items 5, 8, 12 and 14 below).

#### Item 2 — [Royal Air Force \(RAF\) Institute of Aviation Medicine \(IAM\) Report No 677, Helicopter Ditchings, British Military Experience 1972–88, March 1990](#)

Review of British military helicopter ditchings (nota bene for military operators, ‘ditchings’ include water impacts as well as deliberate landings on water) for the period 1972–1988, comprising 94 accidents involving 243 occupants. There were 58 fatalities and 41 injuries.

The greatest life-saving potential was found to be the introduction of more reliable and effective flotation systems to prevent sinking and delay capsizing. Lighting of underwater escape exits and emergency breathing systems were also identified as potential life-saving aids.

The recommendations were as follows:

1. *All military helicopters should be fitted with an efficient flotation system that prevents the helicopter from sinking at all weights, and delays or prevents the helicopter from inverting. The system should be automatically operated on ditching by 2 or more methods of activation, or by the crew. The system should remain functional following high speed water impacts, and be resistant to perforation and have more than one inflation source. Multiple buoyancy containers should be specified to provide system redundancy. Helicopter emergency flotation should also*



be provided by installing inflatable passenger seats in all military passenger/troop carrying helicopters in service (especially the Lynx), and in helicopters under development. Inflated air bags in redundant spaces of the helicopter interior should be considered as sources of buoyancy in all helicopters.

2. Helicopter escape door/hatch lighting systems and door/hatch locating devices should be standard features in future, and considered as modifications to all in-service, military helicopters.
3. Helicopter underwater emergency breathing devices (and suitable training schemes) should be considered for all helicopter occupants.
4. Improved restraint for helicopter passengers, powered escape door/hatch jettison devices, crashworthy seats and de-lethalized helicopter interiors should be provided in all future military helicopters and considered as modifications for all applicable in-service aircraft.
5. Gases other than carbon dioxide should be considered for the inflation of survival aids such as lifepreservers, dinghies and helicopter floatation systems.
6. Smaller and less bulky dinghies should be developed that would permit smaller personal survival packs to be used, or other methods of dinghy carriage should be investigated.

**Item 3 — [DOT/FAA/CT-92/13, Rotorcraft Ditchings and Water-Related Impacts that Occurred from 1982 to 1989, Phase I, Final Report, October 1993](#)**

Phase I of a two-phase programme commissioned by the FAA investigating rotorcraft ditching and water-related impacts during the period 1982-1989. Total of 77 survivable accidents analysed, 67 from the National Transportation Safety Board (NTSB), 10 from the United States (US) Army. Key conclusions were:

(...)

2. **Occupant Survivability Hazards:**
  - a. The two main impact hazards to occupant survivability were flailing and excessive decelerative loads.
  - b. The two main post-impact hazards to occupant survivability were drowning and exposure. Drowning was the most significant hazard, in terms of severity, found for the entire programme.
  - c. Post-crash fire was not found to be a hazard in this study. Although spilled fuel was noted in several cases, there were no recorded occurrences of fire.
3. **Aircraft and Personnel Flotation Equipment:**
  - a. Aircraft flotation equipment performance was generally found to be inadequate in keeping the rotorcraft upright and afloat, in both ditching and water impacts. Several cases of successful upright flotation were noted, however. A significant number of drowning occurrences were noted to occur in cases of immediate aircraft overturn.
  - b. Aircraft float inflation prior to impact seemed preferred for controlled ditching. In water impacts, however, aircraft floats inflated prior to impact are more likely to be torn from the aircraft or damaged by the generally more severe impact conditions. In these



*instances, an immersion sensor seems to be a preferred method of activating aircraft flotation.*

- c. Personal flotation equipment was generally found to be adequate, when utilised by the occupants, in aiding survivability. Several malfunctioning inflatable vests were noted, however. Disuse and malfunctions of personal flotation equipment were both found to contribute to drowning. Life rafts were generally not utilised by occupants in this study.*
- d. Inadequate awareness of egress procedures, such as restraint release and exit locations, can negatively affect post-impact survivability.*
- e. Unsatisfactory performance of Emergency Location Transmitters (ELT's), under TSO-C91a, was observed.*

**Item 4 — [DOT/FAA/CT-92/14, Rotorcraft Ditchings and Water-Related Impacts that Occurred from 1982 to 1989, Phase II, Final Report, October 1993](#)**

Phase II of a two-phase programme commissioned by the FAA investigating rotorcraft ditching and water-related impacts during the period 1982–1989. The focus was on the assessment of the effects of rotorcraft structure on occupant injury, determination of the specific modes of structural failure, and identification of the potential means to alleviate injury. Key conclusions were:

- a. The main occupant injuries suffered in water impacts were from flailing and excessive acceleration resulting from occupant interaction with the rotorcraft interior and insufficient structural energy absorption.*
- b. Drowning and exposure were the main post-impact hazards. Other post-impact injuries were minor in severity. Impact injuries infrequently impaired post-impact survivability.*
- c. Structural failures of the rotorcraft were not found to be significant contributors to occupant injury. The occupiable volume was generally preserved intact in the cases examined.*
- d. The performance of rotorcraft flotation equipment, as is currently deployed and used, does not adequately keep the occupiable area of the downed rotorcraft upright and afloat.*
- e. The techniques to alleviate injuries sustained in water impacts are similar to the techniques required to alleviate injuries sustained in rotorcraft accidents occurring on other terrain.*
- f. Techniques for alleviating occupant injury in rotorcraft water impacts include: better occupant restraint, delethalisation of the cockpit and cabin interior, energy-absorbing seats, improved performance and use of personal flotation devices, and improved performance of rotorcraft flotation equipment.*
- g. Analytical modeling the water impact of a rotorcraft is being evaluated.*

**Item 5 — [CAP 641, Report of the Review of Helicopter Offshore Safety and Survival \(RHOSS\), February 1995](#)**

Joint industry review in the UK of offshore helicopter safety and survival following recommendations made after the fatal helicopter accident at the Cormorant Alpha Platform in the NS in 1992. A key recommendation was:



- (g) *The CAA should accelerate and/or coordinate current studies into helicopter crashworthiness, flotation and stability parameters and the automatic activation of flotation gear, as indicated in Paragraphs 8.7, 9.6 and 10.3. Particular account should be taken of the need to improve provision for flotation after a severe impact, including the possibility of installing extra flotation devices specifically to cater for a crash, as suggested in Paragraph 10.9.*

The full list of recommendations is as follows:

- 14.1 *In the course of our review of the Safety and Survival System in Sections 6 to 12, we identified a number of shortcomings and discussed the work that has so far been done to remedy them; the most significant points were summarised in Section 13.*
- 14.2 *In the light of our review, we make the following recommendations, which are listed broadly in the order in which the relevant event occurs in the System Table.*
- (a) *OPITO should continue to monitor the content of initial and refresher survival training courses, and should ensure that lessons from actual emergencies are fed back, as suggested in Paragraph 6.5.*
  - (b) *Helicopter operators and UKOOA should continue to monitor the content of pre-flight briefings, and should ensure that the shuttle briefing concentrates on escape from the aircraft about to be flown in, as proposed in Paragraph 6.8.*
  - (c) *The CAA should consider extending the existing mandatory requirement for immersion suits to include offshore passengers as well as aircrew, as proposed in Paragraph 6.13, in order to ensure that all suits conform to the necessary standard and are compatible with other safety equipment.*
  - (d) *NATS and UKOOA should complete their joint programme for improving radio coverage in the North Sea, as outlined in Paragraphs 8.3 and 8.4.*
  - (e) *The HSSG should complete its research into improved communications between crew and passengers, taking into account alternative methods of attracting the attention of passengers in an emergency including those identified in Paragraph 8.5. The CAA should then consider issuing a more stringent requirement.*
  - (f) *The CAA should undertake a comprehensive study into the best method of liferaft carriage and release and should consider the issue of more specific requirements, taking account of all the conditions posed in Paragraph 8.9.*
  - (g) *The CAA should accelerate and/or coordinate current studies into helicopter crashworthiness, flotation and stability parameters and the automatic activation of flotation gear, as indicated in Paragraphs 8.7, 9.6 and 10.3. Particular account should be taken of the need to improve provision for flotation after a severe impact, including the possibility of installing extra flotation devices specifically to cater for a crash, as suggested in Paragraph 10.9.*
  - (h) *Helicopter operators should continue with their programme of up-dating helicopter seating to the highest reasonably practicable standards. HMLC/HSSG should complete the study into the universal fitment of UTR, described in Paragraph 10.5, and in the light of this the*



CAA should then consider making UTR a mandatory requirement and, if necessary, carry out further study into the associated brace position as suggested in Paragraph 8.15.

- (j) UKOOA and helicopter operators should complete current trials of cabin layouts, described in Paragraph 10.13, and operators should introduce any necessary improvement as quickly as possible into the present fleet of aircraft. In the light of these trials, the CAA should review its certification requirements in relation to the cabin layout of new types of aircraft, as suggested in Paragraph 10.14.
- (k) The BHAB should conclude its current study of emergency exit operation, mentioned in Paragraph 10.18, and the CAA should then review its requirements with the aim of defining one standard method of exit release.
- (l) The HSSG and DRA Centre for Human Sciences should continue their research into LSJ design in an attempt to find a more satisfactory standard.
- (m) The CAA should review its specifications for LSJs and immersion suits in order to achieve a closer degree of harmonisation and to eliminate the inconsistencies and shortcomings outlined in Paragraphs 11.8, 11.9 and 12.8. The new requirement should include a test for both items in an environment representing severe weather conditions in the open sea.
- (n) Oil companies should consider measures to ensure that all offshore passengers have adequate insulation under their immersion suits, if necessary through the issue of thermal liners to those who are not wearing suitable personal clothing as indicated in Paragraph 11.15.
- (o) Oil companies should review and amplify their guidance to managers concerning departure criteria for restriction of offshore flights in adverse conditions, with particular emphasis on the importance of comparing likely survival and rescue times at the most remote point of the flight, along the lines suggested in Paragraph 12.4 and Annex M.
- (p) The CAA should consider issuing a requirement for strobe lights to be carried as part of personal survival equipment, as suggested in Paragraph 12.7.
- (q) The HSE should coordinate continued research into means of locating and retrieving survivors from the sea, as suggested in Paragraph 12.15.
- (r) The AAIB should make arrangements to debrief all survivors of offshore accidents in order to feed back their experience into the safety and survival system, as suggested in Paragraph 12.16.

14.3 Finally, we would emphasise that RHOSS, as an ad-hoc group, has only been able to take a snapshot of offshore safety and survival as it stands in 1994. While in no way canvassing for permanent status, we believe that the CAA should consider establishing a mechanism through which the issues we have addressed could be kept under periodic review. In such a process, we suggest that the Event Tree and System Table appended to this report might provide a check-list against which future developments could be gauged. As well as monitoring progress on outstanding problems, we suggest that such a review would need to take account of any changes in the pattern of offshore operations, the potential benefits of new technology and the results of future research. It would also be important not to lose sight of the possibility that an improving



*flight safety record in offshore operations could eventually lead to a situation where some existing requirements for survival equipment and training might be relaxed.*

**Item 6 — CAA Paper 95010, Helicopter Float Scoops, London, December 1995**

Study commissioned by the UK CAA and performed by British Maritime Technology Fluid Mechanics (BMT FM) with assistance from Westland Helicopters to consolidate the state of the art regarding float scoops, and to estimate the costs of fitting them to a typical large transport helicopter. The key conclusions of direct relevance were:

(...)

2.2 *(...), it has been established from model tests that the fitting of scoops to existing helicopter flotation equipment results in an improvement in the resistance to capsize of most helicopters by about 1 sea state number. (In the southern North Sea this might approximately halve the probability of capsize following any random ditching incident from 26% to 14%.)*

(...)

2.3.5 *In the cases studied, adding scoops to the main floats of the EH101 increased the vertical forces by between 12% and 17% depending on the wave period assumed.*

(...)

2.6. *Based on the above range of increase in flotation loads [conservatively between 25% and 50%], a short design study was performed on the float scoops and the modifications likely to be required to the airframe to accommodate them. This study found that the cost of the helicopter airframe was likely to increase by about 1%, and the cost of the flotation bags themselves by 10%. This is expected to be reflected in an increase in the total cost of the helicopter of about 0.28%.*

2.7 *There will also be some increase in the weight of the airframe as a result of the structural modifications and flotation system modifications. This was estimated to be in the region of 25kg, which might typically equate to a cost of about 0.25% in terms of lost payload revenue.*

(...)

**Item 7 — [CAA Paper 96005, Helicopter Crashworthiness, London, July 1996](#)**

A review of 61 UK military and 98 world civil helicopter survivable water impacts over the period 1971–1992, and an analysis of the response of helicopter structures to water impact. The work was commissioned by the UK CAA and performed by Westland Helicopters. Key conclusions were:

i. *The majority of fatalities in both world civil (56.7%) and UK military helicopter water impacts (82.6%) were attributable to drowning where a cause of death had been identified. Although drowning was recorded as a cause of death in these instances, factors behind why these occupants drowned were invariably not investigated. Incapacitation due to injury and inability to escape through disorientation, entrapment and jammed/obstructed exits have been cited in some cases as probable cause of drowning in helicopter water impacts.*

(...)



- iv. *Compression fractures of the spine were found to be the most frequent non-fatal serious injury to occupants in UK military water impacts. Seat failures were identified as a significant hazard to occupant survival in both civil and military helicopter accidents. Improved occupant restraint and seat design to prevent occupants from experiencing injurious deceleration levels and also to prevent incapacitating contact injuries is considered to be a significant factor in increasing occupant survival.*
- v. *In helicopter water impacts, where information on flotation system effectiveness was available, over 50% of occurrences resulted in the helicopter inverting or sinking before evacuation of occupants was completed. A significant number of accidents, therefore, involved underwater escape. Previous studies have shown that an inrush of water, contributing to disorientation and difficulties in reaching and opening hatches, is the major hazard facing survivors in inverted or submerged helicopters.*
- vi. *Improved flotation is considered to be the most significant factor in increasing occupant survival in helicopter water impacts. This could be achieved by improving the robustness and reliability of current systems (flotation bags and inflation mechanisms) and ensuring that such systems are better able to withstand representative water impact conditions.*

(...)

**Item 8 — [DOT/FAA/AR-95/53, Survey and Analysis of Rotorcraft Flotation Systems, Final Report, May 1996](#)**

Study commissioned by the FAA to evaluate rotorcraft flotation system performance in water-related accidents, and identify areas of potential improvement regarding flotation system operation and occupant fatality reduction. Key conclusions were:

- a. *The NTSB accident data showed that occupants generally survived impact conditions more severe than those defined in the FAA ditching regulations. Drowning was found to be the leading cause of death, even in rotorcraft equipped with floats.*
- b. *Rotorcraft, in both ditching and water impact scenarios, were found to overturn immediately upon impact. Overturns occurred to rotorcraft both with and without deployed floats. Rotorcraft overturning can trap would-be survivors beneath the surface of the water.*
- c. *In addition to overturning, other design related float problems were identified. These problems include arming or activation methods, uneven deployment, and float separation on impact.*

(...)

- f. *The following solutions related to the design of rotorcraft flotation systems were suggested to increase occupant survivability during a water related accident or incident:*
  - *Supplemental floats located near the top of the rotorcraft.*
  - *Automatic float activation system which would not require pilot interaction.*
  - *Standard, high visibility colour for the fabric with contrasting stripes to assist aircraft spotting during search and rescue missions.*
  - *Tear-resistant fabric for the float construction.*



- *Handholds on the floats to supplement personal flotation regardless of rotorcraft orientation.*

(...)

**Item 9 — CAA Paper 97010, Devices to Prevent Helicopter Total Inversion Following a Ditching, London, December 1997**

Study commissioned by the UK CAA to investigate novel emergency flotation devices intended to prevent total inversion of helicopters following capsizes. The study developed 10 potential solutions, which were considered by a panel of experts and were narrowed down to three. These three solutions were then evaluated by means of model testing in a wave tank. The key conclusions were:

(...)

- 2 *The general effectiveness of the first two of the short-listed devices, the foam filled engine/gearbox cowling panels and the long tubular units attached to the cabin walls was established by the model tests in waves. The third device [tethered flotation units] was found to be ineffective.*

(...)

- 5 *Whilst these two systems performed well, there was a tendency to exhibit a two stage capsizes, with a transition between exposing the port side windows and the starboard side windows above the water level. The second stable attitude proved to be the more stable of the two attitudes and the model did not show a tendency to rotate again. Whilst this second rotation was not a violent transition, and the transition might not occur for many minutes, it is clearly undesirable, and would be disconcerting for those trying to make their escape from the helicopter at that time. The bi-stable behaviour is caused by the symmetry of the flotation system, and can be removed by providing the additional buoyancy on one side of the helicopter only. This asymmetric configuration was also tested and proved to be almost as effective as the symmetric configuration, but with the helicopter floating slightly lower in the water and with a subsequent increase in the water over the doors from the waves. It removed the second rotation found with the symmetric system.*

(...)

- 9 *Overall it is concluded that additional emergency flotation of this type can be effective in reducing the risks of escape from a capsized helicopter. They may also play an important role in reducing the perception of these risks amongst passengers.*

**Item 10 — JAA/FAA, Report of the Joint Harmonization Working Group on Water Impact Ditching Design and Crashworthiness (WIDDCWG), January 2000**

(See Appendix G of UK CAA Paper 2005/06)

International joint regulator/industry working group tasked with identifying areas of concern with current water impact and ditching provisions and/or advisory material, and developing recommendations for intervention strategies. Key recommendations were:

- (a) *Structural ditching requirements should not be expanded to consider crashworthiness due to:*



- *high variability of the impact loads, and*
- *impact loads in survivable accidents can be too high to design for in a practical manner.*
- (b) *The emergency flotation system should be automatically activated (either primary or secondary means) upon sensing water immersion.*
- (c) *During any flight over water, the possibility of the automatic float activation feature being disabled (e.g. deactivation of the system) should be minimised.*
- (d) *Float bag design should provide a means to minimise the likelihood of tear propagation between compartments.*
- (e) *Handhold/life lines should be installed where practical and feasible to allow persons to hold on to an upright or inverted rotorcraft.*
- (f) *The current interpretation of 27/29.801(d) ‘reasonably probable water conditions’ should be amended to address a broader consideration of regional climatic sea conditions.*
- (g) *Maintain present sea state 4 for emergency flotation systems and a higher sea state for ditching flotation systems.*
- (h) *The benefits to flotation stability of fitting scoops to flotation bags should be identified in guidance material.*
- (i) *For certification purposes model testing should use irregular waves and suitable guidance material should be developed that provides a specific test procedure with pass/fail criteria and defined test conditions.*
- (j) *Fuel jettison aspects should be removed from regulations.*
- (k) *Explicitly state in flight manual supplement, the capability and limitations of the flotation system installed on the aircraft.*
- (l) *HASG/JHWG should consider incorporating the concept of preventing total inversion following capsizes once research has been completed and if shown to be technically feasible and economically viable.*
- (m) *All apertures in the passenger compartment suitable for the purposes of underwater escape shall be equipped so as to be usable in an emergency.*
- (n) *Life rafts should be externally deployable regardless of whether the aircraft is upright or inverted.*

**Item 11 — JAA HOSS Working Paper HOSS/WP-99/8.5, Helicopter Safety and Occupant Survivability Following Ditching or Water Impact, June 2000**

(See Appendix F of UK CAA Paper 2005/06)

- a) *Revision of FAR/JAR 27 and 29.801 advisory material to indicate that **reasonably probable water conditions** for Ditching Equipment certification should be equivalent to Sea State 6, and Sea State 4 for Emergency Flotation Equipment (capsize boundary targets to be specified in terms of significant wave height, zero crossing period and wave spectrum).*



- b) *Revision of FAR/JAR 27 and 29.801 advisory material to indicate that flotation stability substantiation should be based on representative (model) testing in irregular waves, and that an associated standard test protocol should be developed and adopted.*
  - c) *Revision of FAR/JAR 29.1411 and associated advisory material to require design of life-raft installation and methods of deployment to take account of the ditching envelope w.r.t. sea conditions, and to be operable and accessible when the helicopter is both upright and capsized. Furthermore, projections on the exterior of the rotorcraft which may damage a deployed life-raft must be either moved or de-lethalised.*
  - d) *Revision of FAR/JAR 29.809 to add a new requirement that all apertures in passenger compartments suitable for the purpose of underwater escape shall be openable in an emergency, and that handholds should be provided adjacent to such apertures to assist their location and operation. Additionally, guidance should indicate that passenger seating should be arranged so that each seat row is aligned with a 'push-out' window, and that emergency exit marking systems should be automatically activated following flooding of the cabin.*
  - e) *Revision of FAR/JAR 29.1415 to require that any flotation system installed to meet ditching requirements, should be designed so as to automatically inflate upon water entry (to include automatic arming where appropriate).*
  - f) *Addition of new material to FAR/JAR to reflect current best practice in terms of emergency flotation system crashworthiness.*
- (...)
- a) *As a matter of urgency, establish the regulatory need and expected benefits/disbenefits of emergency breathing systems carried to enhance the prospects of successful egress from an inverted and flooded cabin.*
  - b) *Establish the costs and expected benefits/disbenefits of redundant flotation units configured so as to produce a 'side-floating' helicopter following capsize.*

**Item 12 — CAA Paper 2001/2, Crashworthiness of Helicopter Emergency Flotation Systems, London, August 2001**

Two complimentary studies commissioned by the UK CAA to investigate possible ways to improve crashworthiness of helicopter emergency flotation systems, both based on three UK survivable water impacts. The first study investigated a limited number of water impact scenarios and their effect on the helicopter airframe in general, and on the emergency flotation system in particular, using finite element modelling techniques. The second study evaluated the statistics and variability of a wide range of possible survivable crash scenarios and sea conditions using a Monte Carlo simulation based on simplified empirical and theoretical formulae. Key conclusions were:

- (a) *From the first study, cost effective EFS enhancements are:*
  - *Automatic arming of EFS.*
  - *Automatic activation of EFS.*
  - *Flotation unit redundancy.*



- Relocate floats to locations less susceptible to damage.
- (b) From the second study:
- There is a high probability of exceeding flotation system design loads in the survivable water impact scenarios modelled.
  - A sensitivity study confirmed that a 100% increase in design loads would result in only a modest improvement in crashworthiness.
  - Investigations into float redundancy demonstrated that there are clear benefits, in terms of crashworthiness, from having additional floats on the upper cabin walls. The largest improvement came when the first upper cabin float was added. There are possible advantages in this asymmetric float configuration, because it gives the helicopter a preferred stable attitude in the water, eliminating the risk of a second rotation while the occupants are trying to escape. [NB: See CAA paper 97010.]

**Item 13 — UK CAA Paper 2001/10, Helicopter Ditching Research, Egress from Side-Floating Helicopters, London, September 2001**

Study commissioned by the UK CAA to evaluate the human factors (HF) aspects of escape from side-floating helicopters compared to egress from a fully inverted helicopter. The study was based on trials performed in a helicopter underwater escape trainer (HUET) using naive test subjects. Key conclusions were:

- (a) *It can be concluded that the vast majority of subjects in this study found it easier to escape from a side-floating helicopter than from a fully inverted one without finding it anymore stressful. In the side-floating trial, more subjects were satisfied with how they coped and more were instilled with greater confidence in their ability to deal with a real helicopter ditching. These findings suggest there could be significant benefit in training people to escape from helicopters which were designed to float on their side after capsized.*
- (b) *The results of this study indicate why subjects found the side-floating trial easier than the fully inverted one. The provision of an air pocket and exits above the water were important factors in making escape easier. The air pocket in particular helped to mitigate the consequences of disorientation and meant that subjects did not need to hold their breath for so long. This latter point is important considering that, in a real helicopter accident, occupants may have to overcome the effects of cold shock which has been shown to reduce breath hold time to as little as 10 seconds. The additional air pocket reduced the required breath hold time by up to 50% compared to that required to escape from a fully inverted helicopter simulator. This difference may be even greater in a real capsized incident, where additional barriers to underwater escape may be present. This one factor could save a significant number of lives if side-floating buoyancy systems were introduced.*
- (c) *The task of locating an exit should be easier in a side-floating helicopter due to the likelihood that exits will be above the water on one side of the aircraft. This means that occupants will be less hampered in their attempts to reach and jettison an exit by poor visibility and their inherent buoyancy. Even if subjects are slowed by initial disorientation or are struggling to open an escape*



route, the presence of an air pocket will provide them with extra time in which to make their escape.

- (d) *Problems with life raft deployment have previously been described. Given the different orientation following capsizes, consideration needs to be given to the deployment of life rafts by individuals escaping from a side-floating helicopter.*
- (e) *There were only two problems with escape from a side-floating helicopter simulator which caused some concern. The most serious problem identified was the potential for an occupant on the upper side to release their harness and fall with force onto someone rising to the air pocket from the lower side. This would not be seen as a major hazard in a real helicopter accident. Injuries are possible in any capsizes, particularly if the harness has already been released prior to capsizes. The higher risk of injury during training does, however, require some attention. The release of the harness caused some difficulty, possibly due to the uneven load on the buckle. Further investigation relating to harness release is needed.*
- (f) *None of the problems with escape from a side-floating helicopter which were identified in this study are thought to be life-threatening. They do not outweigh the advantages that such a scenario has over escape from a fully inverted aircraft. On the contrary, the evidence suggests that the occupant of a side-floating helicopter has a much better chance of escape and survival than someone inside a fully inverted aircraft.*

NB: this document includes a brief review of 12 water-related accidents.

#### **Item 14 — UK CAA Paper 2003/13, Preliminary Study on the Implementation and use of Emergency Breathing Systems, 24 October 2003**

Study commissioned by the UK CAA to establish the extent of knowledge and testing performed on various forms of emergency breathing systems (EBSs) with a view to identifying any gaps. Key conclusions were:

- a) *EBS are capable of producing a significant extension to underwater survival time.*
- b) *EBS can provide a means of bridging the gap between breath-hold time and escape time.*
- c) *Emphasis should be placed on the deployment of EBS after landing on the water, but before submersion.*
- d) *Reliance on EBS for escape should be minimised; in the event that underwater deployment is necessary, occupants should attempt to gain maximum benefit from the breath hold time available and only use EBS if escape would otherwise be impossible.*
- (...)
- g) *A technical standard is needed to ensure that minimum acceptable levels of performance and health and safety standards are met. Any standard produced should incorporate clear pass/fail criteria for tests.*
- h) *Adequate training should be provided, to maximise the benefits of EBS and minimise the risk of human error. Training should include:*
  - *Progressive development of knowledge, competence and confidence in use;*



- *Dry and wet training.*

(...)

#### **Item 15 — UK CAA Paper 2005/06, Summary Report on Helicopter Ditching and Crashworthiness Research, Part A — General, December 2005**

Report commissioned by the UK CAA to summarise the research performed and published. A number of associated but previously unpublished papers and research reports are included as appendices. Key conclusions were:

##### **7.1 Ditching**

- *Demonstration of compliance with the certification requirements for helicopter ditching (JAR/FAR 27/29.801) in respect of flotation stability through model testing in **regular** waves is unreliable. The associated Advisory Circular (AC) material should be revised to specify testing in **irregular** waves with an appropriate exposure period and target probability of capsizing.*
- *The present reference to sea state 4 as the “reasonably probable water condition” in the ditching certification AC material is unsatisfactory as a global standard, and should be replaced with a requirement for the designer to select a sea state with an appropriately low probability of exceedance in the intended area of operation. The sea conditions should be defined in terms of a significant wave height, zero-crossing wave period and wave spectrum.*
- *Float scoops fitted to emergency floats can significantly enhance flotation stability at minimal cost and weight and should be recommended in the ditching certification AC material.*
- *Model tests on helicopters with raised floats (the 'wet floor' scheme) were inconclusive. The effect on static stability was found to be very variable, depending on helicopter weight and type. No consistent improvement in resistance to capsizing in waves was found either.*
- *The upper practical capsizing limit for helicopters lies in the region of sea state 5 or 6, but there is a significant risk of ditching in seas greater than sea state 6 in some areas of operation (e.g. the northern North Sea). Other circumstances, such as damaged or malfunctioning flotation equipment, or imperfect alighting onto the sea (e.g. due to tail rotor failure), may also lead to capsizing in more moderate seas.*
- *A potential way to mitigate the consequences of post-ditching capsizing would be to locate additional flotation devices high on the fuselage in the vicinity of the main rotor gearbox and engines, with the aim of preventing total inversion of the helicopter following capsizing. This 'side-floating' scheme serves to retain an air space within the cabin thereby removing the time pressure for escape, and ensuring that some of the doors and windows that form the escape routes remain above the water level facilitating egress.*
- *Practical trials of the human factors aspects of escape from a side-floating helicopter using a helicopter underwater escape trainer (HUET) concluded that “... the evidence suggests*



*that the occupant of a side-floating helicopter has a much better chance of escape and survival than someone inside a fully inverted aircraft”.*

## 7.2 Crashworthiness

- *The primary cause of loss of life in helicopter water impacts is drowning. Occupant fatalities resulting from excessive crash forces or as a result of structural collapse are a secondary issue.*
- *Designing the airframe to remain afloat for sufficient time to enable evacuation following a water impact should be a major objective if survival is to be improved.*
- *A high-level cost-benefit analysis based on historical accident data indicated that the most cost-effective means of significantly improving post water impact flotation is automatic arming and activation of emergency flotation systems. The provision of additional flotation equipment to prevent total inversion following capsizing (the 'side-floating' scheme) was judged to be the second most cost effective measure.*
- *A computer modelling study based on simplified empirical and theoretical formulae indicated that the most effective means of mitigating the consequences of survivable water impacts is through the provision of redundancy in the emergency flotation system. For the purposes of the study, redundancy was provided by the additional flotation bags required for implementation of the 'side-floating' scheme.*

## 7.3 General

- *Overall, the single most effective means of improving occupant survival in the event of a post-ditching capsizing or a survivable water impact is through the provision of additional flotation devices to prevent total inversion following capsizing.*
- *Further work is required to confirm the technical feasibility and economic viability of the side-floating scheme. This should consist of a detailed design study for the modification of the EFS of a specific helicopter type.*
- *Emergency breathing systems (EBS) are capable of significantly extending underwater survival time, and can provide a means of bridging the gap between breath-hold time and escape time. Although not considered to be as effective as the 'side-floating' helicopter approach, particularly in the event of water impact, EBS could provide short-term mitigation pending the implementation of the 'side-floating' scheme, or an alternate solution in the event that the 'side-floating' scheme proves to be impractical for retro-fit to existing helicopters.*

### **Item 16 — Taber, M.J. & McCabe, J.: An examination of survival rates based on external flotation devices: a helicopter ditching review from 1971 to 2005, SAFE Journal, Volume 35(1), p. 1–6, March 2007**

Study of 511 helicopter ditching cases to determine the effectiveness of external flotation devices in promoting survival of occupants. Key conclusions were:

- Survivability is linked to the position of the helicopter in relationship to the surface of the water.*
- A significant relationship was not found to exist between flotation devices and survivability.*



- (c) *It is important to take steps to ensure that the helicopter is kept at the surface (inverted or upright) until all surviving occupants have had sufficient time to egress.*
- (d) *Although survivability and the position of the aircraft are significantly linked, it is not clear that the provision of external flotation devices alone will significantly affect survivability in helicopter ditching.*

**Item 17 — [EASA.2007.C16, Study on Helicopter Ditching and Crashworthiness](#)**

Reports on the study of the ‘side-floating’ helicopter concept by Eurocopter (now Airbus Helicopters) and Aerazur commissioned by EASA. The main objectives of this work were:

- to establish the design objectives for additional flotation devices to implement the ‘side-floating’ concept;
- to identify possible retrofit solutions, using EUROCOPTER helicopters AS355 and EC225 as the basis;
- to analyse the safety benefits and economic impacts; and
- to study the technical feasibility of the ‘side-floating’ concept.

The study presents preliminary design solutions for a small FAA Part 27 helicopter type (EC155) and a large FAA Part 29 helicopter (EC225), covering both the symmetric and asymmetric solutions. Some integration aspects are addressed such as the attachment of the floats along the upper cabin walls on the EC225. The main constraints are identified, a first technical solution is proposed based on existing flotation systems, and the integration problems remaining unsolved are discussed, presenting possible further study areas.

In terms of conclusions, both symmetrical and asymmetrical configurations demonstrated their efficiency in terms of evacuation possibilities and airspace inside the cabin. For the symmetrical configurations, if not enough buoyancy is provided, the model was found to pass from one inclined position to the other one (symmetrical with respect to the fully inverted helicopter). This problem is solved by increasing the amount of buoyancy, or by having buoyancy in the cowling panels, i.e. the farthest possible from the centre of gravity.

Eurocopter’s preference was for a symmetric solution; the following reasons are stated:

- *The model test campaign showed the better behavior of the additional EFS configurations with foam-filled cowling panels together with symmetrical and asymmetrical floats.*
- *Floats in the upper part of the machine present risks due to the environment and the vicinity to the blades. The presence of foam filled cowling panel allows reducing the floats volume. The risks of floats damaged are therefore reduced.*
- *However, the foam-filled cowling panels can affect the engine and rotor performance. In this study, their thickness has been limited to 10cm.*
- *The symmetrical solution is preferred to the asymmetrical one for the following reasons:*
  - *Floats on one side have lower volume with a symmetrical configuration.*



- *The inclined position with a symmetrical configuration is higher in the water, with more airspace inside the cabin.*
- *An asymmetrical configuration implies that there is a different level of safety depending on the side of the helicopter.*
- *Better redundancy in cases of water impact with floats damage with a symmetrical configuration.*

	<i>Symmetrical C6</i>	<i>Asymmetrical C5</i>
+	<i>Redundancy in case of damage</i> <i>Independent of port/starboard capsizes</i> <i>Smaller floats on one side</i> <i>(lower probability of damage)</i> <i>No preferable seats</i> <i>Higher position in the water</i>	<i>Lower total buoyancy is needed (mass impact)</i> <i>Better stability of the inclined position</i> <i>Compatibility with hoist</i>
–	<i>Higher total buoyancy is needed (mass impact)</i> <i>Incompatibility with hoist</i>	<i>Bigger floats on one side</i> <i>(higher probability to damage)</i> <i>No redundancy in case of damage</i> <i>Dependence on the size of capsizes</i> <i>Preferable seats</i> <i>Lower airspace in the cabin</i>

**Table 9: Symmetric/asymmetric solutions**

The following conclusions are drawn from the study of retrofitting the symmetric side-floating scheme to the EC225:

- *Weight penalty of additional EFS is greater than 2 passengers.*
- *Temperature constraints need further developments to be solved. Emergency flotation balloon technologies compliant with the thermal constraints are not yet available.*
- *A complete new design of the cowling panels and the gas exhaust would be mandatory.*
- *Compatibility with other optional equipments has to be done.*
- *Safety analysis leads to a catastrophic event. It is a challenge to effectively reach 10<sup>-9</sup> probability of inadvertent deployment.*
- *Development costs for retro-fit are estimated to cost several millions euros.*

Finally, the following areas of further work are identified:

- *Developments of new tissues fabric due to the high temperatures in the upper part of the helicopter.*



- *Analysis, by modeling, of the interaction between the blades and the floats in the upper part of the helicopters at ditching.*
- *Evaluation of the blades' break possibility when the helicopter capsizes and the consequences for both standard and additional EFS.*
- *Aerodynamic study with the new cowling panels.*
- *Modeling of the inside of the cabin for ergonomic study of the egress in the inclined position.*
- *Life rafts deployment for both upright and inverted positions.*

**Item 18 — [Assessment of Hazards Associated With Pilots Wearing Helmets While Flying in the C-NL Offshore Area, Canada-Newfoundland and Labrador Offshore Petroleum Board \(C-NLOPB\), October 2011](#)**

Reports on the hazard assessment performed by the Offshore Helicopter Safety Inquiry (OHSI) Implementation Team to identify and, as necessary, address any hazards associated with flight crew helmet wear. This initiative was performed in response to Recommendation 15 of the OHSI. The hazard assessment identified six hazards associated with pilots not wearing helmets while flying, and five related to pilots wearing helmets. The risks associated with these hazards ranged from extremely low to moderate in significance.

*It was (...) concluded that helmets should be made compulsory for all aircrew operating First Response helicopters. To ensure effective helmet functionality in the event of an accident, and to minimize the negative Human Factors effects associated with helmet wear, conditional to this recommendation is that a helmet maintenance program be established for all aircrew who wear helmets in the C-NL Offshore Area. As a minimum, this program must include routine maintenance, proper fitting, and helmet support.*

*It was (...) also concluded that helmet use should remain non-mandatory for line operations flights in the C-NL Offshore Area, and that aircrew should be educated on both the pros and cons of helmet use. This recommendation was based on the fact that helmet wear by pilots does not significantly benefit passenger safety. (...) It was determined that the instances in which a helmet will provide additional protection to pilots – an uncontrolled ditching or unsuccessful landing – are also situations in which a pilot will not be expected to influence the outcome, due to the expected failure of the airframe and flight controls.*

*(...) the current practice guidance to pilots, which states that pilots should choose either a white or yellow helmet was also challenged. White helmets can be difficult to see in a frothy sea. It was considered that pilots should choose either yellow or Dayglo-orange (also known as Blaze Orange or Safety Orange) helmets, as these colours aid visibility and would assist any SAR effort.*

**Item 19 — [CAP 1034, Development of a Technical Standard for Emergency Breathing Systems, May 2013](#)**

This document includes reports on the experimental work commissioned by the UK CAA in support of the development of a technical standard for helicopter emergency breathing systems (EBSs) and also contains the resulting technical standard. Key conclusions were:



- *Requirements relating to the work of breathing need to comply with accepted safe limits of use, taking into account the conditions of use of EBS.*
- *For EBS to be easy to use in an emergency, deployment procedures must be simple and intuitive.*
- *Deployment actions should be kept to a minimum to allow users to be able to remember their instructions and carry out the tasks in the correct sequence.*
- *It should be possible to deploy the EBS with one hand, and with either the left or the right hand.*
- *Full deployment of any EBS should be achievable within 20 seconds. This time should include the time to break any security tags, open the pouch/pocket, locate and deploy the mouthpiece, deploy a nose clip and, in the case of rebreathers or hybrids, activate the system allowing the user to breathe into the counterlung.*
- *It must be possible to deploy EBS designed for underwater deployment during a breath-hold in cold water. Full deployment of this category of EBS (Category A) should therefore be achievable within 12 seconds. It should be possible to deploy the mouthpiece within 10 seconds.*
- *More work is needed to improve methods of nose occlusion. Where nose clips are used they need to be easy to open but secure when in place and when the skin is wet. Nose occlusion systems need to fit a wide range of face or nose sizes and shapes.*
- *Nose clips that are held in a relatively fixed position in relation to the mouthpiece appear to be easier to locate and deploy quickly than those that are not fixed.*
- *Any security tags or stitches provided to prevent tampering or inadvertent use of EBS should be provided as weak links that can easily be broken in the event of emergency deployment.*
- *It is desirable that components such as the mouthpiece are held in a fixed position so that they can be located with ease during deployment.*
- *Compatibility should be assessed using the shoulder and waist straps of typical helicopter seat harnesses, including four and five point harnesses.*
- *The face-down underwater swim (endurance trial) provided a means of checking endurance times when carrying out some physical activity. This would be impractical to carry out in cold water. The hand-over-hand action simulated the activity that would be undertaken in a real accident when crossing a submerged helicopter cabin.*
- *The endurance trial also provided a means of assessing the work of breathing, with higher levels of breathlessness reported in the prone (face-down) posture for the rebreathers.*
- *At least one turn in the face-down underwater swim test would allow an assessment to be made regarding the likelihood of the mouthpiece being displaced during manoeuvres underwater.*
- *Effective nose clips are needed to prevent water entry up the nose. The inversion test was effective in showing up problems with poorly fitting nose clips.*
- *When a hybrid device is assessed, it will be necessary to check that the gas cylinder fires reliably and provides the additional air to the user as specified.*
- *Snagging should be assessed during HUET submersion and capsize exercises. The term 'snagging' should be defined, and should be specific to problems caused by the EBS.*



- *The additional buoyancy provided by a hybrid EBS should not prevent escape from the helicopter through a minimum size exit window.*
- *For EBS to be deployed underwater the mouthpiece dead space, where water could collect, should be minimised. Users should be provided with instructions and training about how to deploy if underwater.*
- *A cold water test in water at a temperature of 12°C should be included in the technical standard. This test should involve submersion of the head to ensure that the effects of cold shock are experienced. Any hood or gloves should not be worn for the test unless they are normally worn during flights.*
- *Detailed servicing and maintenance procedures are needed to ensure reliability during operational use of EBS. Servicing and maintenance should be undertaken by a servicing station approved by the manufacturer.*

**Item 20 — [CAP 1145, Safety review of offshore public transport helicopter operations in support of the exploitation of oil and gas, 20 February 2014](#)**

Review performed by the UK CAA following five significant accidents in 4 years (2009–2013). Section C and Annex D cover the aspect of passenger safety and survivability. The following actions for CAA were proposed regarding passenger safety and survivability, which have all been implemented apart from emergency breathing systems for flight crew (due by 1 April 2016):

- A5 *With effect from 01 June 2014, the CAA will prohibit helicopter operators from conducting offshore flights, except in response to an offshore emergency, if the sea state at the offshore location that the helicopter is operating to/from exceeds sea state 6 in order to ensure a good prospect of recovery of survivors.*
- A6 *With effect from 01 September 2014, the CAA will prohibit helicopter operators from conducting offshore flights, except in response to an offshore emergency, if the sea state at the offshore location that the helicopter is operating to/from exceeds the certificated ditching performance of the helicopter.*
- A7 *With effect from 01 June 2014, the CAA will require helicopter operators to amend their operational procedures to ensure that Emergency Flotation Systems are armed for all overwater departures and arrivals.*
- A8 *With effect from 01 June 2014, the CAA will prohibit the occupation of passenger seats not adjacent to push-out window emergency exits during offshore helicopter operations, except in response to an offshore emergency, unless the consequences of capsize are mitigated by at least one of the following:*
- a) *all passengers are wearing Emergency Breathing Systems that meet Category ‘A’ of the specification detailed in CAP 1034 in order to increase underwater survival time;*
  - b) *fitment of the side-floating helicopter scheme in order to remove the time pressure to escape.*
- A9 *With effect from 01 April 2015, the CAA will prohibit helicopter operators from carrying passengers on offshore flights, except in response to an offshore emergency, whose body size,*



*including required safety and survival equipment, is incompatible with push-out window emergency exit size.*

*A10 With effect from 01 April 2016, the CAA will prohibit helicopter operators from conducting offshore helicopter operations, except in response to an offshore emergency, unless all occupants wear Emergency Breathing Systems that meet Category 'A' of the specification detailed in CAP 1034 in order to increase underwater survival time. This restriction will not apply when the helicopter is equipped with the side-floating helicopter scheme.*

In addition, the following recommendations in relation to passenger safety and survivability were made for the industry to act upon:

*R5 The CAA expects that offshore helicopter operators will address the following key items from the EASA RMT.0120 (27 & 29.008) draft NPA without delay:*

- Fitment of the side-floating helicopter scheme.*
- Implementation of automatic arming/disarming of Emergency Flotation Equipment.*
- Installation of handholds next to all push-out window emergency exits.*
- Standardisation of push-out window emergency exit operation/marketing/lighting across all offshore helicopter types.*
- Ensure that external life rafts can be released by survivors in the sea in all foreseeable helicopter floating attitudes.*
- Ensure that all life jacket/immersion suit combinations are capable of self-righting.*

*R6 It is recommended that the EASA Helicopter Ditching and Survivability RMT.0120 consider making safety and survival training for offshore passengers a requirement.*

*R7 The CAA expects that OPITO will review and enhance its safety and survival training standards with regard to the fidelity and frequency of training provided. (Delivery Q4/2014)*



**7.2. Appendix B — Risk assessment: risk and mitigation measures associated with helicopter ditching, water impacts and survivability**

**7.2.1. Table B-1 — Risk Matrix**

Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
1	Occupant incapacitation	Loss of consciousness	Crew/passenger Communications		G-TIGH G-REDU	CAP 641	There is a need to review the broader context of public-address (PA) systems before possibly proposing a related amendment to CS-29.  <b>No further action by this RMT.</b>
2			Crashworthiness of structure			CAP 491 DOT/FAA/CT-92/14 DOT/FAA/AR-07/8	(a) No change to the provisions. (b) AMC to be amended for loss of the tail boom/tail rotor, particularly in relation to flotation stability, occupant egress and the positioning of safety equipment, to be added.
3			Crashworthy seats		G-BEWL G-BEON	CAA 96005 DOT/FAA/CT-92/14	To be addressed in a separate RMT.  <b>No further action by this RMT.</b>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
4			'Delethalisation' of cockpit/cabin interior			DOT/FAA/CT-92/14	(a) Add additional guidance to AMC 27.801/AMC 29.801 to aid in 'delethalisation' of the cockpit/cabin for minimising the risk of flailing injuries.  (b) The Agency should undertake research to determine the safety benefits and feasibility of installing airbags for occupant protection in helicopters.
5			Upper torso restraint (UTR)		G-BEWL	CAA 96005 DOT/FAA/CT-92/14	None. <b>No further action by this RMT.</b>
6			Helmets		C-GZCH		None. <b>No further action by this RMT.</b>
7		Loss of use of a limb	Personal protective equipment (PPE) and exits operable one-handed				PPE one-handed operation is covered by existing CSs.  Add AMC to clarify that the existing provision of 'simple and obvious' will not be considered met if both hands are required for operation of an emergency exit.
8	Unable to breathe or	Capsize and/or sinking (cabin	Restricted operations	CAND-2011-003	C-GZCH	CAP 641 CAP 1145	See Item 58 below. <b>No further action by this RMT.</b>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
9	maintain breath-hold	flooding)	Prevent capsized	UNKG-2011-069 DFW05MA230	G-REDU N90421	CAP 641 DOT/FAA/AR-95/53 CAA Paper 2001/2	<p>(a) The Note in AC 27/AC 29.563(a)(1)(ii) should be deleted to reflect the change in the definition of ditching, and to take into account possible variations in water entry parameters.</p> <p>(b) Remove reference to 2/3 rotor lift from CS 29.801 and the relevant AMC.</p> <p>(c) FAA MG 10 should be removed as an option from AC 27 and AC 29.</p> <p>(d) AC 27/29.801 should be enhanced by adding tail boom failure in the list of probable damage to consider.</p> <p>(e) An applicant should determine the sea conditions used in a certification with ditching provisions. The approved conditions should then be stipulated in the RFM (performance information section).</p> <p>(f) The provisions should be amended to require enhanced post-capsized survivability features in a survivable water impact.</p> <p>(g) Enhance the integrity of the EFS by providing greater independence/ autonomy of individual flotation bags.</p>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
10			Improve certification of seakeeping performance		F-HJCS TF-SIF	WIDDCWG HOSS	<ul style="list-style-type: none"> <li>(a) Measures to mitigate the consequences of capsize should be required.</li> <li>(b) The probabilities of capsize should be adopted for the proposed wave tank testing.</li> <li>(c) The NS wave climate should be used as the default for demonstration of performance.</li> <li>(d) The significant wave height (<math>H_s</math>) selected by the applicant for demonstration of performance should be included as performance information in the RFM.</li> <li>(e) The geographic limits corresponding to any alternative sea climate used should be included in the RFM.</li> <li>(f) Where credit for any PPE, such as EBS, is assumed, this should be stated in the RFM.</li> <li>(g) The ditching performance information in the RFM should be treated as a hard operational limit for 'normal' (i.e. non-emergency) operations.</li> </ul>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
11			Move towards compliance with more realistic sea conditions			WIDDCWG HOSS	(a) Apply the developed methodology to establish the capsize probability in a five-minute exposure using model test results for a single-wave condition. That is a single combination of $H_s$ and $T_z$ .  (b) In view of the lack of validated analytical models, such methods should not be accepted for ditching certification unless and until they have been fully validated.
12			Enhanced EFS crashworthiness		C-GZCH G-BIJF G-BARJ	CAA 96005 DOT/FAA/CT-92/14 DOT/FAA/AR-95/53 WIDDCWG HOSS CAA Paper 2001/2	(a) Automatic arming and activation of EFS should be mandated.  (b) AMC should be developed to provide best design practice to improve EFS crashworthiness.
13			EFS protection from rupture		TF-SIF	HOSS	It is concluded that state-of-the-art designs provide acceptable resistance to rupture.  <b>No further action by this RMT.</b>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
14			Automatic EFS activation	ESTO-2008-001 UNKG-2011-065	OH-HCI G-REDU	CAP 641 DOT/FAA/AR-95/53 WIDDCWG HOSS CAA Paper 2001/2	(a) CS-27/CS-29 rule text should be introduced to require the fitment of automatic EFS activation systems.  (b) Because there is currently no provision for automatic EFS activation on in-service types, it is also recommended that Annex I (Part-26) to Reg. (EU) No 2015/640 and/or CS-26 be revised to introduce such a provision.
15			Automatic arming/ disarming of EFS			WIDDCWG	Introduce a provision that arming/ disarming of an EFS be automated.
16			Increase flotation stability by fitting float scoops/ remove fuel jettison aspects from the Air Ops Regulation.			CAA 95010 WIDDCWG	(a) The benefits of float scoops should be highlighted/promoted as a means of improving the seakeeping performance of ditched helicopters.  (b) Fuel jettison aspects should be removed from the rule.



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
17			Novel solutions (e.g. 'side-floating' concept)			CAA 97010 WIDDCWG HOSS	(a) The benefits of the side-floating helicopter EFS scheme should be highlighted/promoted as a means of mitigating the hazards presented by post-ditching capsizes and survivable water impacts.  (b) The provisions should be amended to enhance post-capsize survivability (e.g. an air pocket), in the event of post-ditching capsizes, accessible to and large enough for all passengers.
18			Float redundancy			CAA 97010 DOT/FAA/AR-95/53	In order to prevent sinking, it should be required that the rotorcraft remains afloat after loss of the largest single flotation unit.



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
19			Provide enhanced post-capsize survivability				(a) Add a provision for enhanced post-capsize survivability features for a post-ditching capsized, assuming (if applicable) that the EFS functions correctly except for failure of the critical float compartment. (b) Enhanced post-capsize survivability provisions should also mitigate the effects of a water impact scenario, although the size and accessibility may not be guaranteed due to the unknown level and location of the sustained impact damage.
20			EBS	CAND-2011-004	C-GZCH	HOSS CAA Paper 2001/10 CAA Paper 2003/13 CAP 1034	EBS meeting CAP 1034 Category A standard should be mandated by the Air Ops Regulation for all offshore helicopter operations. <b>No further action by this RMT.</b>
21		Cold shock	EBS	CAND-2011-004	C-GZCH	CAA Paper 2001/10 CAP 1034	See Item 20 above.



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
22	Unable to locate and operate an emergency exit	Disorientation (due to capsizing)	HUET training			CAP 1145	Outside of the Agency's competence. <b>No further action by this RMT.</b>
23		Darkness	Illuminated exit markings		CH149914	HOSS	CS-27 and CS-29 should be revised to better define exit markings required for rotorcraft equipped for ditching.
24		Poor visibility (underwater)	Goggles			RAF IAM 528	Goggles provide advantages when donned, but donning by passengers cannot be ensured. <b>No further action by this RMT.</b>
25		Insufficient exits	Ensure all suitable fuselage apertures are available for underwater escape			WIDDCWG HOSS	(a) CS 29.807 should be revised to require one Type IV emergency exit be provided on each side of the rotorcraft for each unit or part of a unit of four passengers.  (b) CS-27 should be changed to require one emergency exit (meeting the ellipse provision) be provided on each side of the rotorcraft for each unit or part of a unit of four passengers.



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
26		Access to exit	Cabin layout, and alignment of seat rows with exits			CAP 641	Seats must not be installed such that they overlap with any part of the required exit apertures. By requiring several Type IV exits in future designs, unobstructed access will be ensured through the existing CS 25.813(c).
27		Exit operation unclear	Ease of operation				AMC 29.809(c) and AMC 29.811(a) to be expanded to give additional guidance, and more clearly point out unsatisfactory design features.
28		Unable to apply sufficient force	Handholds adjacent to doors/windows			HOSS	Rules should be amended to require handholds be mounted adjacent to each push-out windows.
29		Exit blocked	Jettisoning of doors		G-CHCN		<p>(a) Helicopter sliding doors are commonly configured such that they overlap underwater escape exits when open.</p> <p>(b) Due to the new provision for enhanced post-capsize survivability features for types with such designs, jettisoning is not required.</p> <p>(c) However, the applicant should show that a viable egress option from the capsized rotorcraft does exist in such a case. AMC to be developed.</p>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
30		Unique features of helicopter type	Preflight briefing				None. <b>No further action by this RMT.</b>
31			Standardisation of emergency exits			CAP 641	AMC to be added requiring: (a) the location of pull tabs for push-out ditching emergency exits to be standardised, ideally immediately adjacent to the hand holds. (b) ditching emergency exit operating handles, pull tab, 'push here' markings etc. to be marked with black and yellow stripes.



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
32	Unable to escape from the helicopter	Difficulty releasing seat belt when inverted	Optimise seat belt design		G-BIJF	CAA Paper 2001/10	<p>ETSO-C22g and ETSO-C114 should be modified to:</p> <p>(a) require testing of the release mechanism for correct operation under all foreseeable loading conditions, including uneven loading; all of the harness straps must be correctly loaded, based on a passenger mass that is consistent with current anthropometric data and other ETSOs, such as those for life rafts.</p> <p>(b) specify that, where the release mechanism requires a twisting/torsional motion to operate, the mechanism must be bidirectional, i.e. it should operate whether turned clockwise or anticlockwise</p> <p><b>No further action by this RMT.</b></p>
33		Snagging of harness/PPE	Minimise harness/PPE snagging risk			RAF IAM 528	<p>It was concluded that the current state of the art in the design of PPE, harnesses etc. is acceptable.</p> <p><b>No further action by this RMT.</b></p>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
34		Buoyancy of PPE	Minimise PPE buoyancy		C-GZCH		See Items 40 and 50 below. <b>No further action by this RMT.</b>
35		Training	HUET training				See Item 22 above. <b>No further action by this RMT.</b>
36		Size of occupants	Size of occupants				All required exits should be at least as large as a Type IV exit. For non-rectangular exits or partially obstructed exits (e.g. by a seat back), the exit opening must be capable of admitting an ellipse of 660 mm x 483mm (26 in. x 19 in.).
37		Disorientation	HUET training				See Item 22 above. <b>No further action by this RMT.</b>
38	Unable to reach the surface	Depth of helicopter	EFS crashworthiness	ESTO-2008-001 UNKG-2011-065	OH-HCI G-REDU C-GZCH		See Items 9 and 18 above.



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
39	Unable to survive until rescue arrives	Helicopter evacuation	Evacuation procedures and ease of life raft boarding		G-JSAR TF-SIF		(a) Regulatory change to CS-29 should be made to require that passengers be able to step directly into the life rafts in a ditching.  (b) The Agency should consider researching into the feasibility and desirability of automatically deployed life rafts.
40		Effectiveness of life jackets	Life jackets self-righting capability		G-JSAR PP-MUM	DOT/FAA/CT-92/14	Self-righting should be a provision within ETSO-2C502 and ETSO-2C503 performance standards to enhance the level of protection from drowning.  <b>No further action by this RMT.</b>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
41		Unable to launch or use life rafts	External carriage and remote release of life rafts	NETH-2007-002 NTSB A-07-87 NTSB A-08-83 UNKG-2014-XX5	G-JSAR N90421 N407HH N211EL G-CHCN N22342	WIDDCWG HOSS	(a) The effect that damaged carbon fibre/carbon-reinforced plastic may have on the integrity of the life raft should be considered when designing life raft containers.  (b) AMC on the location of externally mounted life rafts should be developed with particular emphasis on protection from impact loads and damage.  (c) There should be three means of life raft release.  (d) There should be clear indicator markings showing the location of external deployment handles.
42			Reversible or self-righting life rafts				Current standards for life rafts incorporate reversibility/self-righting provisions.  <b>No further action by this RMT.</b>
43			Introduce double-chambered life rafts				Current standards for life rafts incorporate provisions for a double-chambered design.  <b>No further action by this RMT.</b>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
44			Use of a sea anchor to stabilise the rotorcraft				A sea anchor should not be relied upon to improve the seakeeping performance of a ditched helicopter. The use of a sea anchor in the scale model flotation/trim substantiation testing should be prohibited.
45			Provision of safety knife in flight crew suit		G-CHCN CH149914		A safety knife or belt cutter should be required by the Air Ops Regulation for all flight crew survival and flight suits. Consideration should be given to the provision of such a device for passenger survival suits or its attachment to each seat harness. <b>No further action by this RMT.</b>
46		Durability of life rafts/ 'delethalisation' of rotorcraft	Improve life raft resistance to puncture	UNKG-2011-068 UNKG-2011-069	G-REDU G-REDU		Materials with an improved resistance to puncture or tear, such as Kevlar or similar, should be considered in an amendment to ETSOs. <b>No further action by this RMT.</b>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
47			Ensure life raft floats at a safe distance	UNKG-2014-018	G-REDW G-CHCN		(a) Adopt 'retaining line' as the standard terminology. (b) Add AMC to adjust the length of the retaining line prior to installation in order to ensure that life rafts float at a safe distance from the helicopter.
48		Handholds	Add handholds to EFS and life rafts			DOT/FAA/AR-95/53 WIDDCWG	(a) Current life raft standards require 'lifelines'. (b) AC 27/AC 29.801 already require that consideration be made to the provision of handholds or lifelines to appropriate parts of the rotorcraft. <b>No further action by this RMT.</b>
49		Ease of access to emergency equipment	Design of survival bag and equipment	UNKG-2011-070	G-REDU		Life raft design standards have been revised to require survival equipment be accessible using cold/gloved hands. <b>No further action by this RMT.</b>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
50		Onset of hypothermia	Cockpit habitability and mandating of immersion suits			CAP 641	(a) The Air Ops Regulation should be amended to mandate the use of an ETSO-approved immersion suit. (b) The helicopter immersion suit ETSOs should be amended to relate the level of suit insulation to sea surface temperature. Two new categories of suits with lower/no-insulation provisions should be added. (c) Operators should be required to address cockpit habitability issues to prevent thermal stress in aircrew. <b>No further action by this RMT.</b>
51			Suitability of immersion suits		G-JSAR		(a) Change the Air Ops Regulation to increase the sea temperature when immersion suits must be worn from 10–12°C. (b) Provide two or more categories within ETSO-2C502 and ETSO-2C503 to allow different levels of insulation. (c) Consider a special category of suit with specific ETSO provisions for SAR crew/winchemen. <b>No further action by this RMT.</b>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
52	Timely rescue	ADELT, ELT	ELT installation, reliability and compatibility	ESTO-2008-002 SPAN-2012-037 UNKG-2009-065 UNKG-2011-071 C-FSIR 4.2.18	OH-HCI EC-KYR G-REDU G-REDU CH149914 C-GZCH G-REDW G-CHCN PP-MUM G-WNSB	DOT/FAA/CT-92/13	Location by rescuers of a helicopter and/or survivors post ditching/water impact is a crucial part of the survivability chain. However, in many accidents, (AD)ELT devices have not functioned effectively. Development of improved CS and AMC/GM is required.
53			Ensure usability of survival kit contents with cold/gloved hands.	UNKG-2011-070	G-REDU	CAP 641	(a) One life raft design standard is proposed for revision to require survival equipment be accessible using cold/gloved hands.  (b) It is recommended that both life raft standards (ETSOs) be updated to require this.  <b>No further action by this RMT.</b>
54		Helicopter conspicuity inverted	Improve paint scheme/ retroreflective markings	Recommendation 4.5 in accident report 10/82	G-BIJF	DOT/FAA/AR-95/53	To assist in location and orientation of upturned (capsized) rotorcraft, the underside of the rotorcraft should be marked with a series of high-visibility chevrons.



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
55		Life raft stability and drift	Deployment of sea anchor	UNKG-2011-066	G-REDU		See Item 44 above.
56		Immersion suit conspicuity	Require all occupants to wear high-visibility immersion suits	UNKG-2008-036	G-BLUN C-GZCH PP-MUM		The Agency should launch a research project to investigate the effectiveness of the 'active IR detection' concept, and if the results are positive, modify the relevant ETSO(s). <b>No further action by this RMT.</b>
57		Provide optimum signalling devices	Provision of PLBs, strobe lights.	NTSB A-07-88	N407HH		(a) PLBs in fact provide only limited utility and are thus not recommended to be mandated. (b) Strobe lights now exist with equivalent utility to flares, without the risk of damage to the life raft present with the latter. One ETSO life raft design standard is proposed for revision to require such a device. (c) It is recommended that both life raft standards (ETSOs) be updated to require this. <b>No further action by this RMT.</b>



Item	Safety Risk	Issues	Mitigation	Safety Recommendation	Aircraft Register	Study/Report	RMT Recommendation
58		Recovery of survivors	Handling of survivors	NETH-2010-002	G-JSAR G-TIGH		Offshore helicopter operations should not be permitted over sea conditions where a good prospect of recovery cannot be ensured. This should be applied as an H <sub>s</sub> higher than six metres or the H <sub>s</sub> to which the helicopter has been certified for the operating area in which the flight is to take place.  <b>No further action by this RMT.</b>



### 7.2.2. Discussion on Risk Mitigation

Each item of the above risk matrix is discussed in this section. Recommendations arising from these discussions are the basis for proposed changes to CS-27/CS-29 or related AMC. Other recommendations will be considered by the Agency for future rulemaking action and/or research.

#### Item 1 — Crew/passenger communications

Rotorcraft operations with cabin crew required by regulations are rare and there are no indications that this will change. Communications of interest are therefore only between flight crew and passengers.

A PA system is required by SPA.HOFO.150(a)<sup>24</sup> for all rotorcraft above nine passengers and for which direct flight crew-to-cabin voice communication cannot be demonstrated.

Despite the fact that in practice, the majority of CS-29 certified rotorcraft will therefore require a PA system, when operated in CAT, currently this CS makes no mention of such a system, unlike CS-25 which does, and which sets design standards.

However, the RMG found no indication in accident/incident reports that outcomes had been negatively affected by limitations on the ability of flight crew to communicate with passengers.

On the other hand, rotorcraft cabins are inherently noisy, and it is known that some passengers wear ear defenders or earplugs, and perhaps even both. In some cases, this equipment is provided by the operator. Other operators have installed wireless headphone systems which include an override feature to make PA announcements. GM to SPA.HOFO.150 (a) has been developed informing operators that intelligibility of PA announcements should be considered when providing passengers with ear defenders and/or earplugs.

#### Recommendation

There is a need to review the broader context of PA systems before possibly proposing an amendment to CS-29.

#### Item 2 — Crashworthiness of structure

##### Background

Structural ditching provisions are currently defined in terms of the horizontal and vertical velocities of the rotorcraft at the time of impact with the land/water. Research indicates that although impact velocity greatly affects impact loads, other impact parameters also have a significant effect. In particular, for water impacts, the attitude of the rotorcraft fuselage skin relative to the surface of the water at impact has a large effect on local impact loads. Earlier work, most notably that performed by WIDDCWG (see Chapter 5.3 above), specifically investigated the need for structural ditching provisions to be extended to consider greater crashworthiness loads. The results of this study, however, concluded that it was not practical to define an impact attitude envelope as this would depend on the condition of the water surface at the point of impact as well as on the attitude of the rotorcraft itself,

<sup>24</sup> See Annex V (Part-SPA) to the Air Ops Regulation.



and this envelope is therefore highly variable. Due to differences between the loading mechanisms involved with water impact and ground impact, the peak loads are generally larger in water impacts. Research into the range and variability of impact loads indicated that extremely high local impact loads can be generated in moderate (survivable) impacts. In the example studied, doubling the design strength was found to provide only a 15 % improvement in crash resistance.

DOT/FAA/CT-92/14 reports that in a review of US civil helicopter accidents, the most frequent forms of structural damage identified included tail boom/tail rotor and main rotor separation, together with breakage of windshield and chin windows. Damage that had the biggest potential to significantly affect occupant survivability included:

- transmission displacement,
- cabin deformation,
- seat separation, and
- door jamming/door frame deformation.

However, these damage types were only found infrequently within the accident data set.

A review of previous ditching/water impact events (see RIA above and Appendix C below) shows that the highest proportion of all events by occurrence classification are survivable water impacts at 39 % (or 44 % if only fatal events are considered), for all worldwide events over the 10 year period 2003–2012. Furthermore, the accident reports show that in a survivable water impact, the primary structure remains largely undamaged with no significant deformation of the cabin area.

Due to the impracticality of further increasing crashworthiness in water impact events, the approach adopted in this RMT was to primarily focus on survivability aspects of water impacts, including enhancing the integrity of the emergency flotation system and improving the ability of occupants to egress.

#### Recommendations

- (a) Water impact loads in a survivable water impact are too high and variable to design for in a practical manner. No change to the provisions is recommended.
- (b) Due to the frequent loss of the tail boom/tail rotor in ditching and water impact events, consideration should be given for this type of damage in the ditching and water impact provisions, particularly in relation to flotation stability, occupant egress and the positioning of safety equipment.

### **Item 3 — Crashworthy seats**

#### Background

Spinal compression injuries caused by excessive whole-body accelerations as a result of a water impact can significantly reduce an occupant's ability to egress the helicopter and subsequent survivability.

CS 27/CS 29.785 already requires seats to be designed to meet the emergency landing conditions of CS 27/CS 29.561 and the dynamic conditions of CS 27/CS 29.562. In particular, CS 27/CS 29.562, which was first introduced into FAA 14 Code of Federal Regulations (CFR) Part 27/29 in 1989



(Amendments 27-25, 29-29) and subsequently adopted into the first issue of Joint Aviation Regulation (JAR)-27/JAR-29 in 1993, effectively mandated the need for load-attenuating/stroking/crashworthy seats to be fitted.

Most modern helicopters operating offshore in support of oil and gas industry in Europe are fitted with crashworthy seats.

The following concerns have been raised with existing crashworthy seats:

- the emergency landing dynamic conditions of CS 27/CS 29.562 stipulate testing with an occupant, simulated by a 77-kg (170-lb) anthropomorphic test dummy; this is now unrepresentative of the NS offshore workforce; and
- the brace position used with crashworthy seats must take account of the stroking motion of the seat to avoid feet becoming trapped and lower-limb injuries that could impede escape and survival.

The regulatory choice to specify a 77-kg anthropomorphic test device (ATD) was made many years ago. The 77-kg ATD was an existing device widely available due to its use in the automotive industry. When developed, it was considered to represent the 50th percentile male mass. However, it is to be noted that the general population has increased markedly in the intervening years. Furthermore, there is evidence that the population of those working offshore exhibits a still higher mass distribution. For instance, the 50th percentile male mass of the NS workers' population has recently been assessed as being 95 kg (UK CAA FODCOM 2005/27). An additional figure of 7 kg would represent the additional mass of PPE worn by an NS worker on board a helicopter over and above the mass of normal clothing.

Most of the pass/fail criteria of CS 27/CS 29.562 are sensitive to the mass of the seat occupant, and it was proposed during RMG discussions for this NPA that in order to preserve the level of safety assumed when this rule was introduced, the regulatory figure of 77 kg should be reconsidered.

However, the increased safety benefit that would thus be achieved is not clear, neither are the costs in terms of increased developmental/certification work and helicopter weight penalty. Assessment of both the benefits and costs was considered to be a task that was outside of the RMG's competence and resources. Furthermore, the safety issue at stake is by no means related to water impact accidents alone. The issue is equally applicable to accidents involving crashing into terrain and to fixed-wing aircraft.

#### Recommendation

A recommendation is therefore made that a separate rulemaking task be planned to consider this issue and possibly propose an amendment to the related regulation.

#### **Item 4 — 'Delethalisation' of cockpit/cabin interior**

##### Background

CS 27/CS 29.801(b) currently requires that *(b) Each practicable design measure, compatible with the general characteristics of the rotorcraft, must be taken to minimise the probability that in an emergency landing on water, the behaviour of the rotorcraft would cause immediate injury to the occupants or would make it impossible for them to escape.* The associated GM does not contain any



guidance or means of compliance to this particular provision. However, CS 27/CS 29.561, CS 27/CS 29.562, CS 27/CS 29.785 and CS 27/CS 27.787 are also applicable. These provisions protect occupants from items of mass that could cause injury if not restrained, and from crash loads, including head impact. CS 27/CS 29.785, in particular, makes reference to ‘delethalisation’ of the cockpit/cabin, to be free from *‘(a) (...) potentially injurious objects, sharp edges, protuberances, and hard surfaces (...)’* so that an occupant *‘(...) will not suffer serious injury in an emergency landing(...)’*. Furthermore (e) states that *‘(e) Each projecting object that would injure persons seated or moving about in the rotorcraft in normal flight must be padded.’*

Flailing injuries can be a significant impediment to occupant egress and survivability following a ditching, or more likely, in a water impact event. The definition of ‘serious injury’ used by ICAO includes fracture of any bone, but excludes fingers, toes or nose. There is therefore a mismatch between CS 27/CS 29.801(b) which aims to avoid any immediate injury to occupants and the ICAO definition of ‘serious injury’. Even relatively minor injuries in a water impact event could restrict the ability of occupants to operate emergency exits and other safety equipment, to egress the rotorcraft and to enter a life raft.

The addition of air bags to helicopters that function similarly to automobile technology could be envisaged to further protect occupants in a survivable crash and water impact. However, there are some technical challenges that remain due to the potential for a water impact (or crash) at any attitude. Furthermore, there are significant concerns regarding the hazards that air bags might present, especially in a ditching or water impact scenario where the cabin may be submerged and the bag could constitute an additional hazard and hinder escape. Inadvertent deployment of air bags in flight would also be a concern if installed in the cockpit.

#### Recommendations

- (c) Add additional guidance to AC 27/AC 29.801 to aid in ‘delethalisation’ of the cockpit/ cabin interior in order to minimise the risk of flailing injuries that could impair occupant egress and survivability. Practical steps that could be taken include:
  - (1) locating potential hazardous equipment outside of the occupant’s flailing envelope;
  - (2) installing energy-absorbing padding or foam onto interior components;
  - (3) using frangible materials; and
  - (4) designs that exclude hard or sharp edges.
- (b) The Agency should undertake research to determine the safety benefits and feasibility of installing air bags for occupant protection in helicopters.

#### **Item 5 — Upper torso restraint (UTR)**

##### Background

UTR is provided either through single diagonal belts or four/five-point harnesses. Their prime function is to protect an occupant against head impact and spinal-column injury.

A UTR is currently required for all new rotorcraft types by CS 27/CS 29.785(b). The history of this provision can be traced to its first introduction by the FAA into 14 CFR Part 27/Part 29 in 1989 and its



subsequent adoption in the initial issue of JAR-27/JAR-29 in 1993 and CS-27/CS-29 in 2003. In the USA, special retroactive provisions for UTR were also introduced for new-build helicopters of existing types under Sections 27.2 and 29.2 in 1992. In Europe, CAT.IDE.H.205<sup>25</sup> requires all helicopters operated for CAT and first issued with a certificate of airworthiness (CofA) after 1.8.1999 to be so fitted. It can therefore be summarised that most helicopters worldwide will be fitted with UTR and certainly all those operated offshore for commercial purposes in Europe and USA.

The UTR will undergo testing in accordance with the emergency loading conditions of CS 27/29.561 and the dynamic conditions of CS 27/29.562, providing a high level of protection for occupants.

The only accident report that identified UTR as an issue was the S-62 (G-BEWL) NS accident in 1990. In this case, the seats were only fitted with a lap strap. No other issues concerning the use of UTR have been identified.

#### Recommendation

Existing regulations are providing an acceptable level of safety.

#### **Item 6 — Helmets**

Following the crash of Cougar 851 in 2011, one of the recommendations in the subsequent Offshore Helicopter Safety Inquiry was that the wearing of pilot helmets be made compulsory. This recommendation was subsequently reviewed by a Hazard Assessment Team (HAT), which concluded that helmet use should remain non-mandatory for line operations flights in the offshore environment although helmets should be mandatory for first-response flights such as SAR. This recommendation was based on the fact that helmet wear by pilots does not significantly benefit passenger safety. HAT determined that the instances in which a helmet will provide additional protection to pilots — an uncontrolled ditch or unsuccessful landing — are also situations in which a pilot will not be expected to influence the outcome, due to the expected failure of the airframe and flight controls (see Appendix A, Item 18).

#### Recommendation

No further action is required.

#### **Item 7 — Personal protective equipment (PPE) and exits operable one-handed**

PPE items required by regulations and of relevance to helicopter crew and passengers are life jackets and EBS.

Whilst many users may choose to employ both hands to deploy a life jacket inflation device or to quickly deploy an EBS, it is desirable that all such devices be capable of being deployed with only one hand if necessary, allowing the other hand to be used to steady themselves, and/or in the case of EBS, to maintain contact with the rotorcraft structure to aid in locating the nearest exit. This should be achievable with either hand. In addition, in a water impact, the user may be injured and may only have one functioning arm/hand.

<sup>25</sup> See Annex IV (Part-CAT) to the Air Ops Regulation.



In the case of life jackets, the applicable ETSOs for constant-wear types (integrated with immersion suits, and stand-alone devices) already require that the stored gas inflation means be operable by either hand, in or out of the water. However, no such stipulation is made for the backup oral-inflation device.

The ETSO for a life jacket not worn constantly does not require one handed operation of the stored gas inflation means or the backup oral-inflation means. However, this form of life jacket will need to be donned either before or after a ditching/water impact, and this cannot conceivably be done one-handed. Thus, there is no appreciable safety to be gained by revising the standard to require one-handed operation of the stored gas inflation devices. It is to be noted that normal inflation of existing devices can in fact be achieved by either hand, and it is likely that future designs will continue to facilitate this.

With regard to backup oral-inflation means, they would be more difficult to design for single-handed operation, by either hand.

In the case of current double-chambered designs, it is possible for one or the other of the two provided oral-inflation devices to be used with a given hand, thus ensuring at least one of the chambers can be orally inflated. However, neither ETSOs require a double-chambered design.

In the case of current single-chambered designs, inflation of the chamber by one hand (left or right, depending on the design) is possible. However, if the hand in question were not useable, no oral inflation would be possible.

Whilst centrally located oral-inflation devices, operable by either hand, might be feasible to mandate for a single- or double-chambered life jacket, this would complicate the design, and possibly compromise the usability, of other devices attached to the life jacket such as EBS, PLB.

After consideration, and bearing in mind that single-handed oral-inflation possibilities will and do result from the current standards (albeit not perfectly), the backup nature of the function, and that negative effects on other safety equipment might arise if a revised design standard were imposed, it is concluded that there is no justification to require full functionality by either single hand of life jacket oral-inflation means.

UK CAA CAP 1034, which includes a draft standard for EBS devices recommends that a future standard for these devices should require that they be operable with either the left or right hand. Devices have been successfully tested and approved by the UK CAA according to the CAP 1034 draft standard. It is to be expected that this provision will be retained when an ETSO standard is developed.

With regard to exits, both CS-27 and CS-29 currently require that the operation of all emergency exits be *simple and obvious* and *not require exceptional effort*. However, it is not specified in CS/AMC that this be possible one handed.

Elsewhere in this NPA, it is explained that handholds are proposed to be required adjacent to exits. This is primarily in order that passengers, particularly when floating free in a submerged cabin, are able to readily find something against which to react the force required to eject the common type of push-out window exit. Another benefit is that the passenger can take hold of this handhold before water entry and thus be well placed to maintain orientation relative to the exit, should capsize occur. This aid to orientation will clearly work best when the exit itself can be operated by the other hand only.



As with PPE, the risk of injury during a water impact provides further justification for requiring the capability of one-handed operation of emergency exits.

#### Recommendation

It is proposed that new AMC be added to both CS-27 and CS-29 to clarify that the existing provision of *simple and obvious* will not be considered met if both hands are required for operation of an emergency exit.

#### **Item 8 — Restricted operations**

See Item 58 below.

#### **Item 9 — Prevent capsizing**

##### Background

Due to their high centre of gravity in relation to their centre of buoyancy, most helicopters are inherently unstable when floating on water with a tendency to capsize and remain inverted or sink if not augmented with flotation aids. To counter this instability, most helicopters used in offshore operations are required by the Air Ops Regulation to be fitted with emergency flotation devices, normally in the form of inflatable bags that are only deployed immediately before or after water contact.

Capsizing creates a particular hazard to occupants that can jeopardise their ability to escape. The cockpit/cabin will quickly fill with water leading to the inability to breathe and thus creating an urgency to escape. Capsizing can also lead to disorientation, further increasing the time necessary to escape. In cold water, it is well established (see CAA Paper 2003/13, and Appendix A, Item 14 above) that the time necessary for escape can exceed an occupant's breath-hold capability. Operational experience has shown that drowning has been the greatest cause of death following capsizing (see DOT/FAA/CT-92/13 & 14, and CAA Paper 96005, as well as Appendix A, Items 3, 4 and 7 above).

The current airworthiness standards for emergency flotation systems are optional provisions, but are accepted as a means of showing compliance with the Air Ops Regulation. Two standards are currently available for type certification, which are identical for both CS-27 and CS-29: compliance with the ditching provisions of CS 27/CS 29.801, or the advisory material for substantiation of EFSs provided in AC 27/29 MG 10. The primary difference between the two standards are the water entry conditions: for ditching, 56 km/h (30 kt) forward speed and 1.5 m/s (5 ft/s) vertical speed is the necessary minimum to show compliance; for MG 10, it is assumed that water entry is gentle following autorotation, including the flare.

A third option to obtain certification, sometimes referred to as 'pop-out floats', is also available to enhance safety, but it is approved on a 'no-hazard, no-credit' basis and cannot be used to show compliance with the Air Ops Regulation.

The existing Air Ops Regulation in Europe makes a distinction between acceptance of certification with ditching provisions or emergency flotation equipment, depending on the performance class (PC) of the operation, whether the environment is hostile or non-hostile, as well as the distance from land. For PC 1 or 2, operating in a hostile environment at a distance from land exceeding 10 minutes flying time



at normal cruise speed, certification with ditching provisions is mandatory. For other scenarios, emergency floats substantiated in accordance with MG 10 are acceptable.

#### Discussion

Capsize can occur for various reasons. In a ditching, there are three potential areas of concern related to capsize prevention: water entry, EFS integrity, and flotation stability or seaworthiness. Furthermore, capsize in a water impact event is almost inevitable due to the uncontrolled nature of the water entry phase. Each of these areas of concern is addressed separately below.

#### Ditching — Water entry

Analysis of the accident database of Appendix C below showed that in most ditching cases, water entry was successfully achieved and the helicopter came to rest in an upright and stable position. In those cases where capsize was immediate, the environmental conditions were in excess of the certified ditching limit. The group, therefore, concluded that the existing rules governing the ditching envelope for water entry, as defined in CS 27/CS 29.563 and CS 27/CS 29.801 (30-kt forward speed and 5-ft/s vertical speed), are sufficiently robust and should be maintained. However, in recognition that while many ditching events had occurred from cruise and in relatively benign conditions where the flight crew had been able to optimise the approach and had good situational awareness, this may not be the case in less favourable operational conditions or in instrument meteorological conditions (IMC) or at night. Furthermore, the modified definition of 'ditching' now expands the number of failure cases considered, which may now necessitate different techniques for water entry or a non-optimum approach due to control or manoeuvrability restrictions. It is therefore recommended to delete the note in AC 27/AC 29.563(a)(1)(ii) that allows a lower forward speed to be used.

In some ditching events, the EFS was structurally damaged on water entry although the rotorcraft remained afloat. This led to a discussion within the RMG on whether MG 10 should be retained and, if so, whether it was appropriate for both CS-27 and CS-29 rotorcraft. In regard to the EFS, the main difference between an MG 10 and certification with ditching provisions are the conditions required for water entry. MG 10 does not stipulate any water entry criteria, so the structural integrity of the EFS, including flotation bags and supporting structure, is based on a combination of air loads (if inflated before water entry) and water loads resulting from an autorotative touchdown, including the flare. Rotorcraft certified to Category A standards can operate in all environments, including at night and in IMC, and be approved to operate over a hostile environment (less than 10 minutes from shore) with EFS approved according to MG 10. Furthermore, Category A rotorcraft generally have poorer autorotative performance than non-Category A rotorcraft due to their size and weight. The assumption in MG 10 of a gentle alignment on the water following an autorotative descent does not therefore fully account for realistic variations in water entry conditions, which could lead to the structural design and integrity of the EFS being compromised and the rotorcraft immediately capsizing if a ditching were attempted. The RMG, therefore, recommends that the approach currently allowed by both AC 27/AC 29 and MG 10 be removed from CS-29 and CS-27.

Currently, CS 29.801 requires model testing to verify water entry procedures and behaviour. This is based on water entry with a rotor lift of not more than two-thirds of the maximum design weight. Experience has shown that in order to achieve this lift on a test model, the only practical method is to



install a non-powered rotor, spun up externally prior to release of the model from the carriage. This complexity in CS/AMC has brought into question the safety intent of this provision.

At maximum all-up mass, two-thirds lift equates to a downwards acceleration of one-third G. For tests at maximum all-up mass, the free-spinning rotor results in a model descending towards the water with an acceleration varying as the rotor spins down, but aiming to achieve one-third G at point of impact, coincident with achieving a specified rate of descent. In practice, it is very difficult to achieve any accuracy or repeatability in the test points, and the system required to provide this is complicated. Furthermore, the difficulties are compounded due to the rotor's ground effect, particularly when ditching into waves. This can have a significant impact on pitch and roll attitudes upon entering the water. At water entry, rotor lift will rapidly decay in the full-scale helicopter and the test model (or the pilot may rapidly lower the collective to preserve rotor speed), hence (even if a two-third lift is achieved at the moment of water entry) it is not possible to control or specify the lift throughout most of the ditching event. A turning rotor may give some additional gyroscopic stabilisation, however, it is not clear how representative this is in a model. The most accurate and repeatable test will be one that prescribes fixed rates of descent, forward speeds and pitch/roll attitudes at impact, and then assumes the helicopter is free to move without constraint for the remainder of the ditching event. Whilst a rotor could be used to achieve this, it is not necessary to specify the test in such a way that this becomes the only option.

In summary, the overall effect of specifying a two-third rotor lift is a complicated, inaccurate and highly unrepeatable test that does not add anything compared to the simpler provision of specified forward speed, rate of descent and attitude. It is therefore recommended to remove the reference to the two-thirds rotor lift from CS 29.801 and the relevant AMC.

Another aspect discussed was whether or not there was justification for regulations to specify when a normally deflated EFS should be inflated, i.e. before or after ditching water entry. Currently, some manufacturers' RFMs instruct inflation to be initiated before water entry, some after.

From a review of accident evidence and consideration of other aspects, such as the risk of EFS damage during water entry due to unpredictable wave/wind combinations and HF, including the confidence gained by inflation prior to water entry, the RMG was unable to conclude whether one approach had any overall benefit over the other.

Therefore, the proposed changes to CS 27 and CS 29 do not provide indication in either direction for this aspect.

#### Ditching — Integrity of EFS

Analysis of the accident database shows that in most cases, the EFS has functioned successfully, when deployed, and the rotorcraft has remained afloat for many hours. Some incidences resulting from continuing-airworthiness issues have been noted (aged bonding and inadequate maintenance of floats, fitting of wrong pitot tubes leading to rubbing and failure of a flotation bag), but these are not discussed further here.

Some notable events that have been reported, where damage is related to initial airworthiness, include the following:



- B-MHJ: capsized after the occupants had egressed due to overloading of float bag bonded joints. The helicopter floated with an abnormal high nose-down attitude after detachment of the tail rotor gearbox.
- G-BGKJ: ditching in IMC. Although the flotation units became partially detached due to overload on water entry, the helicopter remained upright for in excess of one hour.

In response to the first of these events, it is recommended to further enhance the CSs by adding tail boom failure to the list of damage which should be considered. This is a common failure in water impact events and would encapsulate all tail boom/tail rotor failure modes. It will ensure that the additional loads due to the nose-down attitude of the rotorcraft are accounted for in the floats structural substantiation, and that emergency exits do not become obstructed and remain usable.

The second event illustrates the robustness of the existing EFS designed according to the ditching standards, and again supports the water entry conditions (30 kt, 5 fps) used for structural substantiation. It is not uncommon for a helicopter to stay afloat for many hours following a successful ditching.

No recent incidence of damage to a flotation bag as a result of fuselage hazards has been identified. As GM has already been introduced into AC 27/AC 29.1411 at Amendment 3 (2008) to highlight the issue, no further action related to 'delethalisation' of the fuselage to avoid float and life raft puncture is deemed necessary.

#### Ditching — Flotation stability

The objective of flotation stability is to ensure that the helicopter, once ditched and floating on the water, remains in an upright and stable position for sufficient time to allow occupants to egress into the life rafts. The experience to date in reaching this objective is mixed. In most ditchings, helicopters have remained upright for long periods of time, well in excess of the time needed for occupant egress, and in exceptional cases, in high-sea conditions<sup>26</sup>. However, most ditching experience has been in relatively calm conditions leading to uncertainties as to the appropriateness of the current rules and methods of compliance demonstration.

CS 27/CS 29.801(d) states that *(d) It must be shown that, under reasonably probable water conditions, the flotation time and trim of the rotorcraft will allow the occupants to leave the rotorcraft and enter the life rafts (...).*

The GM in AC 27/AC 29.801 interprets this provision by stating that SS4 is representative of reasonably probable water conditions to be encountered, and has de facto become the certification standard. The rationale for selecting SS4 is that it represents a moderate condition when assessed against global average sea conditions. The concern expressed by regulators, however, is that this standard does not adequately represent local sea conditions, and in certain areas where there is high helicopter activity, in particular in support of offshore oil and gas production (e.g. NS, East coast of Canada, etc.), the local conditions can exceed the global average over a large part of the year (see Appendix E1 to UK CAA Paper 2005/06, and Appendix A, Item 15 above). Authorities have imposed special conditions on recent type certification projects to address this concern and raise the certification standard.

<sup>26</sup> G-TIGK floated upright for 3.5 hours in waves of 6–7 m and winds of 30 kt in SS7. G-JSAR floated upright for 8 h in SS4.



A new methodology has been developed in this NPA that uses a probabilistic approach, which defines a safety target and then links the severity of capsizing to the expected sea conditions in the area of operation to derive a minimum certification standard. The RMG recommends that the rotorcraft should, in normal operations, not operate above its certified ditching capability. The applicant would be at liberty to select the sea conditions to be approved, provided that those conditions demonstrated are then stipulated in the RFM. More details on this approach can be found under Item 10 of this Appendix.

Furthermore, the method of showing compliance has been the subject of protracted debates. Model testing in regular waves has traditionally been the means of showing compliance, or by similarity based on previously accepted testing. The case of moving towards irregular-wave model testing, or the use of computer simulation, is presented under Item 11 of this Appendix.

One novel solution that has been proposed and tested is the 'side-floating' concept. This has the benefit that it prevents total inversion following capsizing, creates an air pocket in the cabin, and adds redundant flotation units high up on the cabin walls where they are less vulnerable to damage from water impact loads, thereby increasing the integrity of the EFS (see Item 17 below).

#### Water impacts

Experience shows that in a water impact event, it is common for the helicopter to capsize due to the uncontrolled nature of the impact, with high-pitch, -roll or -yaw attitudes, high impact speeds, and/or resulting damage to the EFS. Item 2 of this Appendix on crashworthiness of structure has already discussed the impracticality of designing structure to withstand the loads of a water impact. As a consequence, capsizing may be an inevitability in these events. The safety focus, therefore, shifts from preventing capsizing to mitigating the effects of capsizing.

Chapter 4.1.1 of the RIA clearly identified water impact as the prime area where enhanced safety standards are required. If capsizing is inevitable in such events, then the occupants must be given every opportunity to escape from an inverted and submerged cabin. In small (CS-27) rotorcraft, experience from the database indicates that this is probable, even in cold water. For larger helicopters, however, the experience is that the time taken to escape, particularly for middle-seat occupants, may exceed their breath-hold capability. The primary safety benefit, if fatalities in survivable water impacts are to be reduced, is therefore to provide occupants with the ability to breathe before making an escape. This can be accomplished in one of two ways: provide EBS to each occupant and/or ensure an air pocket is provided in the cabin. Part-SPA of the Air Ops Regulation (SPA.HOFO.155) has already been proposed to mandate the use of EBS that is capable of rapid underwater deployment in hostile sea areas. While this may provide a safety benefit, the RMG, based on the evidence available, were not convinced that the use of EBS alone would achieve the maximum safety benefit. It was contested that, irrespective of how well individuals are trained or experienced in the use of EBS, the shock and disorientation associated with a water impact event can lead to occupants panicking and reacting in a random or irrational manner. In interviews with survivors from previous water impact events, it was not uncommon for them to have no conscious memories related to the sequence of events that led to their escape. In many cases, it was only through the fortuitous existence of trapped air within the cabin, and finding themselves within this bubble, that they were able to take a moment to breathe and gather their thoughts before making their escape. The RMG were therefore of the opinion that for



continued survival, ensuring that occupants have easy access to sufficient air (e.g. an air pocket) within the capsized cabin was perhaps the most significant single safety enhancement that could be made and would save lives.

#### Water impact — Sustained damage

It is not feasible to define a level of rotorcraft damage for all possible survivable water impact scenarios that include all rotorcraft attitudes. The group, therefore, considered two alternative possibilities:

##### Single-float failure

Experience has shown that the float bag and its supporting structure that first comes into contact with the water may experience the full impact loads, which will be much higher than the ultimate load for which the float and its attachment were designed, resulting in failure. This option would therefore consider loss of all flotation in any one of four corners (when the rotorcraft is seen in plan view) but would only require suitable post-capsize survivability features (e.g. an air pocket) for a limited number of occupants, i.e. those not seated immediately adjacent to an emergency exit or push-out window.

##### 'Side-floating' concept

The 'side-floating' concept was one method devised to prevent post-ditching capsizing (i.e. complete inversion) with the rotorcraft intact. In using high-level redundant floats, the concept can also be applied to provide a significant benefit in terms of crashworthiness. Testing performed using an EH101 model (see UK CAA Paper 2001/2, and Appendix A, Item 12 above) showed that the concept was able to provide an air pocket within the cabin in many cases of multiple-bag failures.

Following discussions within the RMG, post-capsize survivability features meeting the efficacy of the second option (i.e. providing an air source to all passengers) was selected. Any assumption relating to the amount and position of damage sustained cannot truly be estimated with any level of confidence. Evidence from the accident data has shown that multiple bags have failed in a water impact event. The 'side-floating' concept has been shown to be capable of functioning following multiple failures, while still maintaining an adequate air pocket in the cabin. Furthermore, retaining a single concept that is capable of mitigating post-ditching capsizing and water impact will reduce the amount of testing/analysis required in type certification.

#### Water impact — Minimum air pocket

Provision of an air pocket was the only fully effective method identified to ensure post-capsize survivability and so detailed considerations were explored.

Due to the different floating levels and attitudes the rotorcraft may take up in the water as a result of variation in the amount and location of damage that will likely occur in a water impact, the air pocket's size and position within the cabin will vary. It is considered too onerous to require the applicant to design for the worst possible case, and the selection of any other impact scenario would essentially be arbitrary.

It is therefore proposed that if an air pocket design is selected, it should be large enough for all occupants with all of the EFS functioning apart from the most critical flotation unit compartment, i.e. design for the post-ditching capsizing scenario. This is detailed in Risk Matrix Item 19. It is accepted that



the resulting air pocket may be smaller in a water impact where more extensive EFS damage may be expected, however, research has shown (CAA Paper 2001/2) that a usable air pocket large enough for at least a proportion of the occupants could be expected in around 70–80 % of cases for the side-floating scheme investigated.

Possible means to ensure that an air pocket exists within the fuselage following a water impact event are through the use of passive-buoyancy devices or additional, redundant flotation bags located high up on the fuselage sides. This location would also protect the floats from damage resulting from water impact loads.

#### Water impact — EFS integrity

While it is considered that capsize may be inevitable in a water impact event, the functioning of the EFS remains essential to ensure that the rotorcraft remains on or close to the water surface. If the rotorcraft were to sink, then the benefit of providing an air source within the cabin may be ineffective as the occupant will have much further to travel to reach the surface. Experience has shown that a rotorcraft only sinks when the EFS has failed to deploy. There is evidence (e.g. PP-MUM) that successful deployment of only a single bag can be sufficient to prevent sinking. From a water impact standpoint, the integrity of the EFS can therefore be maximised through the distribution of system elements to provide independence/autonomy of each flotation unit. The fact that a synchronised discharge of flotation units may not occur would be of little concern in this scenario (as opposed to a ditching, where the synchronised discharge of flotation units will be essential to prevent capsize, but where it can be assumed there will be no or only minor damage sustained to the EFS).

Further discussion on how EFS integrity can be enhanced to cover water impact events is contained under Item 12 of this Appendix.

#### Recommendations

- (a) The Note in AC 27/29.563(a)(1)(ii) should be deleted to reflect the change in the 'ditching' definition, and to take into account possible variations in water entry parameters.
- (b) Remove the reference to two-third rotor lift from CS 29.801 and relevant AMC.
- (c) MG 10 should be removed from AC 29. In addition, only certification with ditching provisions should be available for CS-27 Category A rotorcraft.
- (d) AC 27/29.801 should be enhanced by adding tail boom failure in the list of probable damage to consider in a ditching.
- (e) An applicant should determine the sea conditions to be approved in the certification with ditching provisions. The approved conditions should then be stipulated in the RFM. The method of approval should be based on a probabilistic approach that defines a safety target and then links the severity of capsize to the sea conditions requested by the applicant.
- (f) CS(s) should be amended to require enhanced post-capsize survivability features in a survivable water impact.
- (g) Enhance the integrity of the EFS by providing greater independence/autonomy of individual flotation bags.



**Item 10 — Improve certification of seakeeping performance**General

The current ditching provisions refer to demonstration of ditching performance in *reasonably probable water conditions*, which is rational. Unfortunately, the associated GM indicates that sea state (SS) 4 ( $H_s = 2.5$  m) may be assumed to meet this provision, which is inappropriate for ‘hostile’ sea areas such as the NS where the majority of European offshore helicopter operations take place (see Appendix E1 to CAA Paper 2005/06 and Appendix A, Item 15 above).

Furthermore, the current provisions indicate testing in regular waves. Results from helicopter model capsize tests in regular waves are considered likely to be misleading, and should be discouraged. An undamaged helicopter will normally only capsize in breaking waves. The steepness at which regular waves break in a wave test basin depends primarily on the purity of the wave maker motion, the distance travelled by the waves, and the presence of spurious waves in the basin. Results from model tests in breaking ‘regular’ waves are therefore likely to depend more on the wave basin's properties than on characteristics of the helicopter. An irregular-wave criterion is considered to offer a more realistic measure of the likely actual performance of a helicopter ditched in the sea (see Appendix A, Item 15 above).

Testing in irregular waves is addressed in Risk Matrix Item 11, and requires a probabilistic approach with an overall objective of demonstrating a maximum probability of capsize. The purpose of this Risk Matrix Item is to generate appropriate probabilities of capsize. A rational approach to this exercise would be to set a target level of safety and use a risk assessment to determine the performance required. It is proposed that the CS 27/29.1309 methodology be used for this exercise.

Note: this Item addresses ditching/emergency flotation stability only and not the ditching at water entry case. However, the appropriate sea conditions must be applied to water entry through consideration of the range of water surface angles that could be presented to a ditching helicopter on contact with the water.

Severity of capsize<sup>27</sup>

The severity of a capsize event is established using the severity classifications of AC 29-2C at Change 4, which are reproduced in Table 1 below:

**Table 1 — AC 29-2C at Change 4: Severity classification**

Severity	Description
Catastrophic	Failure conditions which would result in multiple fatalities to occupants, fatalities or incapacitation to the flight crew, or result in the loss of the rotorcraft.
Hazardous	Failure conditions which would reduce the capability of the rotorcraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be: <ul style="list-style-type: none"> <li>— a large reduction in safety margins or functional capabilities;</li> </ul>

<sup>27</sup> Seakeeping performance corresponds to the ability to remain upright for a period of 5 minutes in the given wave climate, this being judged to be sufficient time to evacuate the helicopter.



	<ul style="list-style-type: none"> <li>— physical distress or excessive workload such that the flight crew's ability is impaired to where they could not be relied upon to perform their task(s) accurately or completely, or</li> <li>— possible serious or fatal injury to a passenger or a cabin crew member excluding the flight crew.</li> </ul> <p>Note: hazardous or severe-major failure conditions can include events that are manageable by the crew using proper procedures which, if not implemented correctly or in a timely manner, may result in a catastrophic event.</p>
Major	Failure conditions which would reduce the capability of the rotorcraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, or a significant increase in crew workload or in conditions impairing crew efficiency, in physical distress to occupants, possibly including injuries or physical discomfort to the flight crew.
Minor	Failure conditions which would not significantly reduce rotorcraft safety, and which involve crew actions that are well within their capabilities. Minor failure conditions may include, for example, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, such as routine flight plan changes, or some physical discomfort to occupants.
No Safety Effect	Failure conditions that would have no effect on safety; for example, failure conditions would not affect the operational capability of the rotorcraft or increase the crew workload, however, could result in an inconvenience to the occupants, excluding the flight crew.

The primary hazard in the event of capsizing is drowning. The cabin rapidly fills with water and the occupants must usually make an underwater escape, often in very difficult circumstances, e.g. disorientation due to the rotation of capsizing, poor visibility (underwater without a face mask or goggles and sometimes at night), shock and panic. Even when equipped with immersion suits, breath-hold times in typical sea water temperatures (and especially hostile areas such as the NS) are less than 20 seconds and can be as little as six seconds, limited primarily by the effects of cold shock. Evidence from escape trials in helicopter underwater escape trainers (HUETs) indicate escape times ranging from 27 to 92 seconds, the longer times corresponding to occupants in inboard seats who have to wait their turn to escape.

There is therefore a demonstrated and acknowledged mismatch between breath-hold time and escape time for at least the occupants of seats not immediately adjacent to escape exits/openable windows. Without any change to existing rules and helicopter designs, drowning can therefore be reasonably expected for at least a proportion of the occupants, which supports the present CS 29.1309 severity classification of 'catastrophic' (i.e. (...) *multiple fatalities to occupants, fatalities or incapacitation to the flight crew* (...)).

The mismatch between breath-hold time and escape time can be addressed by measures such as:



- (a) the provision of EBSs which offers an air supply to extend underwater survival time; or
- (b) a rotorcraft design feature that will provide guaranteed post-capsize accessibility to an air source, e.g. modification of the EFS to ensure that an air pocket is retained in the cabin, thus removing the time pressure to escape, and, ideally, the provision of an above-water escape path additionally (e.g. the so-called side-floating helicopter scheme).

NB: due to the air pocket being to date the only such identified solution, this second approach is hereinafter referred to as the ‘modified EFS’.

Through application of either or both of these measures, it is considered reasonable to assume that the risk of drowning can be significantly reduced. In terms of the effects on occupants, in the case of provision of effective EBSs, it is assumed that the severity of capsizes is reduced to ‘hazardous’, i.e. ‘possible serious or fatal injury to a passenger or a cabin crew member excluding the flight crew’. For the modified EFS, it is assumed that the severity of capsizes for the occupants would equate to a CS-29 severity of ‘major’, i.e. ‘physical distress to occupants, possibly including injuries or physical discomfort to the flight crew’.

A lower severity is adopted for the modified EFS compared to EBS in recognition of the greater effectiveness expected of the modified EFS due to lower reliance on passenger survival skills — note that survival training is currently not mandated.

In summary, the effects on the occupants are:

- in a capsizes **without** EBS or modified EFS, ‘catastrophic’;
- in a capsizes **with** provision of effective EBS, ‘hazardous’; and
- in a capsizes **with** modified EFS, ‘major’.

Frequency of capsizes

If the target level of safety of CS 29.1309 is adopted, the maximum frequency of capsizes allowed can be determined by selecting the corresponding event severity and considering the safety objectives of CS 29.1309 and AC 29.1309, as presented in Table 2 below. Note that the trivial case of ‘No Safety Effect’ has been omitted for simplicity.

**Table 2 — CS 29.1309: Risk Matrix**

		Severity			
		Catastrophic	Hazardous	Major	Minor
Frequency	Reasonably probable	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	ACCEPTABLE
	Remote	UNACCEPTABLE	UNACCEPTABLE	ACCEPTABLE	ACCEPTABLE
	Extremely remote	UNACCEPTABLE	ACCEPTABLE	ACCEPTABLE	ACCEPTABLE
	Extremely improbable	ACCEPTABLE	ACCEPTABLE	ACCEPTABLE	ACCEPTABLE



For the case of capsizing **with current equipment standards** (i.e. catastrophic), the maximum frequency should be no worse than **extremely improbable**.

For the case of capsizing **with EBS** (i.e. hazardous), the maximum frequency should be no worse than **extremely remote**.

For the case of capsizing **with modified EFS** (i.e. major), the maximum frequency should be no worse than **remote**.

Frequencies are quantified in AC 29.1309, and are summarised in Table 3 below.

**Table 3 — CS 29.1309: Probability classification**

Frequency Category	Qualitative Description	Quantitative Description
REASONABLY PROBABLE	Reasonably probable events may be expected to occur several times during the operational life of each rotorcraft that are based on a probability of the order of $10^{-3}$ – $10^{-5}$ .	Failure condition frequency is between $10^{-5}$ and $10^{-3}$ per aircraft flight hour.
REMOTE	Remote events are expected to occur a few times during the total operational life of a random single rotorcraft of a particular type, but may occur several times during the total operational life of a number of rotorcraft of a particular type, that are based on a probability of the order of $10^{-5}$ – $10^{-7}$ .	Failure condition frequency is between $10^{-7}$ and $10^{-5}$ per aircraft flight hour.
EXTREMELY REMOTE	Extremely remote events are not expected to occur during the total operational life of a random single rotorcraft of a particular type, but may occur a few times during the total operational life of all rotorcraft of a particular type, that are based on a probability of the order of $10^{-7}$ – $10^{-9}$ .	Failure condition frequency is between $10^{-9}$ and $10^{-7}$ per aircraft flight hour.
EXTREMELY IMPROBABLE	Extremely improbable events are so unlikely that they need not be considered to ever occur unless engineering judgment would require their consideration. A probability of the order of $10^{-9}$ or less is assigned to this classification.	Failure condition frequency is less than $10^{-9}$ per aircraft flight hour.



Thus, the CS 29.1309 target frequencies for the corresponding severities are:

- for capsize **without EBS or modified EFS**:  $F_C$  = less than  **$10^{-9}$  per flight hour**;
- for capsize **with EBS**:  $F_C$  = less than  **$10^{-7}$  per flight hour**; and
- for capsize **with modified EFS**:  $F_C$  = less than  **$10^{-5}$  per flight hour**.

Seakeeping performance

General

The frequency of capsize ( $F_C$ ) is the product of the frequency of ditching ( $F_D$ ) and the probability of encountering sea conditions severe enough to capsize the helicopter ( $P_{SS}$ ), i.e.  $F_C = F_D \times P_{SS}$ . The latter term,  $P_{SS}$ , is a function of the seakeeping performance of the helicopter and the wave climate over which it is operating.

The frequency of ditching may be estimated from UK historical data for which accurate and reliable operating-hour data is available. During the period 1976–2012, there have been 12 ditchings over the 3.5 million (approx.) flight hours flown (see Appendix C below). This gives:

**frequency of ditching =  $3.4 \times 10^{-6}$  per flight hour**

The maximum probability of encountering sea conditions severe enough to capsize the helicopter may then be obtained by dividing the frequency of capsize by the frequency of ditching, i.e.  $P_{SS} = F_C / F_D$ . This means that the probabilities of encountering sea conditions severe enough to capsize the helicopter ( $P_{SS}$ ) should be:

- **without EBS or modified EFS**,  $P_{SS} \leq 0.029$  %;
- **with EBS**,  $P_{SS} \leq 2.9$  %; and
- **with modified EFS**,  $P_{SS} > 100$  %.

It is proposed that the helicopter designer/manufacturer be permitted to select the sea conditions for which compliance with the ditching provisions is to be demonstrated. This will be defined in terms of an  $H_s$  which will be incorporated in the RFM as performance information.

The NS wave spectrum (JONSWAP spectrum) is proposed as the default for demonstration of seakeeping performance in view of the fact that it represents a relatively severe and therefore conservative climate. It is concluded that successful capsize resistance demonstration in the JONSWAP spectrum will, for the  $H_s$  chosen, cover all other global sea areas.

Demonstration of performance in sea conditions for other, more benign sea areas is to be permitted in order to improve operability where desired. Some sea areas may exhibit longer wave periods for a given  $H_s$ , which would likely result in a higher capsize limit in terms of  $H_s$  for a given rotorcraft. Thus, an operational constraint based on the  $H_s$  for the JONSWAP spectrum might be unnecessarily penalising for operations in those sea areas. In order to take account of this, testing with such an alternative wave spectrum would be required in order to confirm the  $P_{SS}$  for a given rotorcraft design, and to possibly allow a higher  $H_s$  to be quoted in the RFM. In such cases, however, the geographical limitations corresponding to the wave spectrum adopted must be included in the RFM. Note that no geographical limitations are required in the RFM in the case that the default NS wave climate is used, but only the value of  $H_s$  selected for the model testing.



## Probability of capsize with an operating limit

In the event that an airworthiness authority sets any prohibition on operations of helicopters over sea conditions exceeding their demonstrated ditching performance, the  $H_s$  demonstrated by the helicopter designer/manufacturer would form a hard limit.

The helicopter operator would be required to access wave forecast information prior to every flight as part of the flight planning function to ensure that the aircraft would not overfly any areas where the sea conditions exceed the demonstrated limit for the helicopter. This information is provided by meteorological services, commonly with an internet service. The application of this operational restriction means that the probability of encountering seas with a higher  $H_s$  would be zero.

It is proposed that scale model wave tank testing be designed such that the demonstrated probability of capsize effectively covers all sea conditions up to the  $H_s$  selected. In order to comply with the safety target defined by application of the CS 27/29.1309 methodology, the probability of capsize ( $P_c$ ) that must be demonstrated in the selected  $H_s$  conditions is therefore:

- **without** EBS or modified EFS,  $P_c \leq 0.029 \%$ ;
- **with** EBS,  $P_c \leq 2.9 \%$ ; and
- **with modified EFS**,  $P_c > 100 \%$ .

## Probability of capsize without an operating limit

If no operational limitations are set for operations of helicopters over sea conditions exceeding their demonstrated ditching performance, there will be an additional risk of capsize due to the possibility of a ditching occurring in sea conditions exceeding the demonstrated  $H_s$ .

Based on the data presented in Annex 1 to Item 10 below, the probabilities of exceeding the range of sea conditions for the selected NS default climate are presented in Table 4 below.

**Table 4 — Probabilities of exceeding SSs in the NS**

Probability of exceeding SS $P_{ss}$ (%)	SS Code and Upper $H_s$ Limit				
	3	4	5	6	7
	1.25 m	2.5 m	4 m	6 m	9 m
<b>Aberdeen to Block 211/27 in the UK sector of the NS, 34 years of 3-hourly data</b>	72.3*	29.4	8.1	1.2	0.04

\* *Linear interpolation between probabilities for 1.0-m and 1.5-m  $H_s$  has been used.*

For the 'no operating limit' case, assuming that the probability of capsize in sea conditions exceeding the value of  $H_s$  selected for demonstration by the helicopter designer/manufacturer is 1, then the probability of capsize demonstrated during the wave tank testing presented above must be reduced by the probability of the sea conditions exceeding the value of  $H_s$  in the wave climate for the area of operation ( $P_{ss}$ ).



It is not considered to be feasible to design a helicopter to resist capsize beyond  $H_s = 6$  m in the default NS wave climate, so testing in  $H_s > 6$  m is unlikely to be appropriate. In addition, demonstration of compliance for a probability of capsize less than 2.9 % is very likely to be too time-consuming and expensive to be practical. If these assumptions are accepted, then:

- the ‘no mitigation’ (i.e. no EBS or modified EFS provided) case is not viable because the required probability of capsize ( $P_C \leq 0.029$  %) is significantly less than 2.9 % and thus highly impractical to demonstrate; and
- for the EBS case ( $P_C \leq 2.9$  %), selecting  $H_s = 6$  m gives  $P_{SS} = 1.2$  % (see Table 4 above), leading to  $P_C = 2.9 - 1.2 = 1.7$  %, i.e. not impossible but very likely to be impracticable to demonstrate in a wave tank test programme; selection of a lower value for  $H_s$  would lead to even smaller values of  $P_C$  and an even longer and more expensive wave tank test programme.

This effectively means that modified EFS ( $P_C > 100$  %) is required in order to ensure that the risk of capsize meets CS 29.1309 targets although this will not present an additional burden because modified EFS is required in any case to address survivable water impacts (see Risk Matrix Item 17). Conversely, where a helicopter has been successfully tested for a probability of capsize that is low enough to take account of the probability of occurrence of more severe sea conditions than those selected for ditching certification, then no operating limit would be required.

However, it has been suggested that the additional risk presented by exposure to sea conditions exceeding the demonstrated performance could be justified in certain circumstances. While this might be the case for SAR operations and emergency evacuations, it is less clear for ‘normal’ operations.

#### ‘Damaged flotation’ case

Demonstration of satisfactory flotation stability with the most critical flotation compartment failed is required under the present CS/AMC, that is demonstration in SS 2 ( $H_s = 0.5$  m). This is considered to be non-conservative and somewhat arbitrary. A more meaningful approach would be to set the sea conditions based on a statistical argument, i.e. by factoring the probability of capsize ( $P_C$ ) for the ‘normal’ test case by the probability of EFS failure ( $P_F$ ), giving  $P_{CF} = P_C \times P_F / F_D$ .

As no comprehensive data on flotation system failure rates is readily available, it is proposed that a failure rate of 1 : 10 or 10 % be assumed for  $P_F$ , giving the following values for  $P_{CF}$ :

- **without** EBS or modified EFS,  $P_{CF} \leq 0.29$  %;
- **with EBS**,  $P_{CF} \leq 29$  %; and
- **with modified EFS**,  $P_{CF} > 100$  %, i.e. no testing required.

Alternatively, the probabilities for  $P_C$  as indicated above may be retained for  $P_{CF}$ , and a sea condition corresponding to a 10-times increase in probability of occurrence over the  $H_s$  selected by the helicopter designer/manufacturer for the serviceable EFS case may then be used for demonstration of performance. This approach should be applied whether for the default case of the NS or a more benign sea area.



## Discussion

### General

Wave tank testing experience suggests that most helicopters are capable of achieving SS 4–5 ( $H_s = 2.5\text{--}4\text{ m}$ ) with the present EFS, and that SS 5–6 ( $H_s = 4\text{--}6\text{ m}$ ) is feasible with the addition of float scoops (UK CAA Paper 2005/06); SS 7 ( $H_s = 9\text{ m}$ ) is considered to be impractical for the default NS wave climate. In addition, model testing in wave tanks to demonstrate probabilities of capsize less than 2.9 % would be very time-consuming and expensive. It is therefore suggested that in order to meet the CS 29.1309 target safety levels proposed, it will be necessary to address the consequences of capsize in some way. As previously stated, there are essentially two approaches to mitigating capsize: EBS and modified EFS.

### Mitigation of capsize using EBS

EBS is currently mandated by some national aviation authorities (NAAs) (e.g. UK CAA: Safety Directive SD-2015/001) and is deployed voluntarily for the majority of other European offshore operations. With reference to CAP 1034, this equipment is likely to meet at least Category B of the proposed technical standard and therefore be suitable for mitigating the ditching scenario. Retrospective application of this element is therefore very likely to be practical and cost-effective although EBS would need to be mandated for all European offshore operations, and the proposed technical standard in CAP 1034 should ideally be developed into a formal standard, i.e. an ETSO. Any EBS deployed to implement a mandate would need to be approved according to an appropriate standard, ideally an ETSO.

Mitigation of capsize using EBS reduces the severity of capsize to ‘hazardous’, leading to a maximum acceptable probability of capsize of 2.9 % (with an appropriate operational limit), which is considered to be both achievable in terms of rotorcraft design and practical to demonstrate by means of scale model wave tank testing.

### Mitigation of capsize using modified EFS

Although extensively researched and evaluated in the form of the side-floating helicopter scheme through wave tank test programmes and HUET trials, a modified EFS is not currently available. Incorporating this scheme in new helicopter designs is likely to be much easier than retrofitting it to existing aircraft, but several design issues would need to be addressed (see Risk Matrix Item 17).

Mitigation of capsize using modified EFS reduces the severity of capsize to ‘major’, which theoretically obviates the need for any demonstration of performance. In other words, it could be argued that capsize in all ditchings would be acceptable because of the low frequency of ditchings combined with the low-level adverse safety effects imposed on the rotorcraft occupants even when forced to escape from a capsized rotorcraft. Following this philosophy could result in a high capsize rate which, although acceptable in principle, would be undesirable. For example:

- injuries to passengers could occur during capsize;
- passengers’ survival prospects are enhanced if they can avoid getting wet and enter the life raft directly, i.e. without first entering the sea; and
- deployment and boarding of life rafts is much easier from an upright helicopter; capsize of the helicopter while passengers are boarding the life rafts could be hazardous.



It is therefore proposed that a maximum acceptable probability of capsizing of 29 % be required, which is equivalent to a CS 27/29.1309 frequency of  $10^{-6}$ , i.e. the middle of the acceptable range for severity classification of 'major' and one order of magnitude higher than that allowed for mitigation via EBS.

#### Mitigation of survivable water impacts

It is the case, for example, that no fatalities have resulted from ditching in NS operations. However, at 12 events, the sample size is very limited in statistical terms and the sea conditions at the time of the ditchings were unrepresentatively benign in relation to the wave climate as a whole. Nevertheless, this is not helpful in gaining support for improvements to the ditching CSs.

On the other hand, many fatalities have resulted from survivable water impacts, but there are no current related CSs to improve. Defining a survivable water impact would be problematic and it will never be possible to guarantee an outcome; it is only possible to be confident of improving occupants' prospects of survival on average. For these and possibly other reasons, it would be difficult to produce CSs of a similar form to the ditching CSs.

Immediate capsizing and/or sinking occurs in almost all water impacts, and accounts, for example, for all of the drownings in NS operations. The measures available to mitigate survivable water impacts are therefore very similar to those proposed for post-ditching capsizing, i.e. EBS to mitigate capsizing, and modified EFS for flotation system redundancy to prevent sinking and to mitigate capsizing.

If EBS were to be the chosen mitigation, CAP 1034, Section 8, Category A equipment would be required, which is capable of rapid underwater deployment and represents a higher standard than a Category-B one, the minimum standard providing mitigation of ditching (i.e. in a ditching, the need for immediate underwater deployment is alleviated). The EBS equipment currently deployed in some operational regimes is of doubtful compliance with the Category A standard and thus is unlikely to be suitable for survivable water impacts. However, if Category A EBS is provided, then both ditchings and water impacts may be addressed by the same mitigation.

For a modified EFS, the provision of a post-capsizing air pocket is equally applicable to both ditching and survivable water impacts. The provision of an air pocket could also involve the provision of redundant flotation which would also mitigate impact damage to the EFS. Hence, again, mitigating ditchings automatically addresses survivable water impacts albeit to a lesser extent in some circumstances (see Risk Matrix Item 17).

So, a rational approach to addressing survivable water impacts would be to improve the ditching CSs. In other words, regulate for the survivable water impact case implicitly, by improving the ditching CSs explicitly. This being the case, it would be entirely appropriate to take credit for the survivable water impact fatalities that could be prevented in assessing post-ditching capsizing mitigations such as EBS and modified EFS.

#### Seakeeping performance

In effectively representing the 'worst case' in terms of severity, the NS wave climate should be adopted as the default standard for demonstration of performance. Helicopter manufacturers should, however, be permitted to:

- select the  $H_s$  for the NS wave climate for which compliance is to be demonstrated; and/or



- select an alternative sea area/areas as the basis for demonstration of compliance.

The probability of capsizing to be demonstrated should be linked with the mitigation(s) incorporated in the design of the helicopter. Where the mitigation employed does not form part of the airworthiness certification of the aircraft, e.g. personal protective equipment such as EBS, appropriate information should be included in the RFM.

Demonstration of performance for the 'damaged flotation' case should meet the same safety target as for the 'undamaged' case. A probability of failure of the critical flotation unit compartment of 0.1 should be assumed for this purpose. It is considered unlikely that sufficient data will be available in the foreseeable future to provide a more reliable figure.

#### Application

It is normal practice in aviation regulation that higher standards are applied to larger aircraft where the potential for loss of life is greater, and the cost and weight penalties of additional/enhanced equipment or systems are proportionately lower. This is reflected in the difference in severity classification between CS 27.1309 and CS 29.1309. In the case of CS 27.1309, a 'small number' of fatalities remains within the definition of hazardous, whereas the same number would be catastrophic in the case of CS 29.1309.

It is also necessary to take account of the operating environment, i.e. whether the operation is over hostile or non-hostile sea areas; sea temperatures, for example, will normally be significantly colder in hostile sea areas, which will impact survivability.

The probabilities of capsizing derived above should therefore be applied to all CS-29 helicopters used for offshore operations, and to all helicopters operated over hostile sea areas. For CS-27 helicopters operating over non-hostile areas, it is proposed that the consequence of capsizing be reduced in severity by one level (e.g. from 'hazardous' to 'major'), resulting in an increase in the probability of capsizing ( $P_c$ ) allowed of two orders of magnitude (i.e.  $\times 10^2$ ).

#### Conclusions

CS-27/29.1309 have been used together with UK offshore ditching statistics to form a rational basis for setting target probabilities of capsizing for both a fully serviceable EFS and a 'defined damaged EFS' case for the purposes of demonstrating seakeeping performance by means of scale model tank testing. The probabilities of capsizing ( $P_c$ ) proposed are detailed in Tables 5 and 6 below:

**Table 5 — Probability of capsizing for all CS-29 helicopters, and CS-27 helicopters certified for Category A operation with ditching provisions**

	Probability of capsizing (%)	
	Serviceable EFS	Critical float compartment failed
<b>No mitigation</b>	0.029	0.29
<b>EBS</b>	2.9	29.0
<b>Modified EFS</b>	29.0	> 100



**Table 6 — Probability of capsizes for CS-27 helicopters operating over non-hostile sea areas**

	Probability of capsizes (%)	
	Serviceable EFS	Critical float compartment failed
<b>No mitigation</b>	2.9	29.0
<b>EBS/modified EFS</b>	29.0	> 100

The analysis has demonstrated the need to address the consequences of capsizes to meet the corresponding CS 29.1309 target safety level for all but CS-27 non-hostile operations. This could take the form of deployment of the EBS to increase underwater survival time, or modification of the EFS to ensure that an air pocket is retained in the cabin, removing the time pressure to escape, and also, ideally, to provide an above-water escape path. (NB: if the air pocket solution is adopted and does not provide an above-water escape path, EBS meeting at least CAP 1034 Category B should be required.) These measures are also applicable to the 'survivable water impact' case, and credit for the dual benefit should be accorded to these measures.

Note that to take credit, a currently deployed EBS would need to be mandated, i.e. assessed and approved against a formal specification. This is already the case for UK offshore operations, but currently not in other areas. Note also that modified EFS is not yet available and not likely to be in the short term.

It is proposed that in representing a 'worst case', the NS wave climate be used as the default for demonstration of seakeeping performance in scale model tank testing. Helicopter designers/manufacturers should be able to select the desired seakeeping performance within that climate (value of  $H_s$ ), and/or should have the option to demonstrate performance in other wave climates. The probabilities of capsizes summarised in Tables 5 and 6 above must be applied in every case however, and appropriate performance information ( $H_s$  and geographical limits where the NS wave climate is not used) must be included in the RFM. The performance information should, ideally, form a hard operating limit except where justified by the mission, e.g. SAR or emergency evacuation of an offshore installation.

#### Recommendations

It is recommended that:

- (a) measures to mitigate the consequences of capsizes be required;
- (b) the probabilities of capsizes detailed in Tables 5 and 6 above be adopted for the proposed wave tank testing;
- (c) the NS wave climate should be used as the default for demonstration of performance;
- (d) the  $H_s$  selected by the helicopter manufacturer for the demonstration of performance should be included as performance information in the RFM;
- (e) the geographic limits corresponding to any alternative sea climate used for the demonstration of performance should be included in the RFM;



- (f) where credit for any personal protective equipment such as EBS is assumed for the demonstration of performance, the requirement for this equipment should be stated in the RFM; and
- (g) the ditching performance information in the RFM should be treated as a hard limit for 'normal' (i.e. non-emergency) operations.

#### References

- UK CAA: CAA Paper 2003/13, Preliminary Study of the Implementation and use of Emergency Breathing Systems, 24 October 2003 (see Appendix A, Item 14 above)
- [UK CAA: Safety Directive SD-2015/001, Offshore Helicopter Operations, 28 January 2015](#)
- EASA Airworthiness Directive (AD) No 2014-0188R1, 7 November 2014
- EASA Airworthiness Directive (AD) No 2014-0244, 7 November 2014
- UK CAA: CAA Paper 2005/06, Summary Report on Helicopter Ditching and Crashworthiness Research, Part A General, December 2005 (see Appendix A, Item 15 above)
- UK CAA: CAA Paper 95010, Helicopter Float Scoops, London, December 1995 (see Appendix A, Item 6 above)
- [UK CAA: CAP 1034, Development of a Technical Standard for Emergency Breathing Systems, London, May 2013 \(see Appendix A Item 19 below\)](#)

#### Annex 1 to Item 10

Wave data for a 'hostile' helicopter route

##### Introduction

Wave climate data was obtained from the UK Met Office for a typical 'hostile' helicopter route. The route selected was from Aberdeen to Block 211/27 in the UK sector of the NS.

Data tables were derived by the UK Met Office from an analysis of 34 years of 3-hourly wave data generated within an 8-km, resolved wave model hindcast for European waters. This hindcast uses the third-generation spectral wave model WAVEWATCH III, tuned in line with settings used in the present UK Met Office operational wave forecast system. Driving winds for the hindcast were obtained from instances of the UK Met Office 'Unified Model'. Data from 24 model grid points were used to cover the analysed route.

##### Further analysis

The objective of the further analysis was to derive a significant wave height  $H_s$  and mean period that would represent a sea condition with a 2.9 % probability of exceedance over the whole year.

From the data, it was noted that a wave height of  $H_s = 5$  m had a probability of exceedance of 3.1 % (see Table 1 below).

Whilst it was possible to interpolate a significant wave height  $H_s$  with an exceedance probability of precisely 2.9 %, it was considered that a wave height specified to centimetre or millimetre precision would give an unrealistic impression of the accuracy of the process, and so  $H_s = 5$  m was selected.



It was also desired to determine appropriate zero crossing periods  $T_z$  for a range of significant wave height  $H_s$  values. At each value of significant wave height  $H_s$ , the mode and the median value of the distribution of  $T_z$  was determined. A polynomial was fitted to each  $T_z$  value to permit the interpolation of a mode or median  $T_z$  value for any significant wave height  $H_s$ . These are plotted in Figure 1 below, which also shows the coefficients of the fitted polynomials.

Table 2 shows the median and mode values of  $T_z$  for selected  $H_s$  values.

Recommendation

It is recommended that the wave condition to be used for capsize model testing of helicopters operating in hostile conditions should be:

$$H_s = 5 \text{ m and } T_z = 7.3 \text{ s}$$

$H_s = 5 \text{ m}$  has been shown to have a 3.1 % probability of exceedance on the route from Aberdeen to Block 211/27 in the NS, and  $T_z = 7.3 \text{ s}$  is the median zero crossing wave period to accompany such a wave height  $H_s$ . There will be a 50 % equal probability of experiencing a steeper or less steep sea at this wave height  $H_s$ .

If it is desired to certify the helicopter according to different wave heights  $H_s$ , then it is recommended that the median  $T_z$  values given in Table 2 should be used.

It is further recommended that a JONSWAP wave spectrum should be used, as being considered representative of limited fetch-wave conditions experienced in the NS.

Hs (m) >=	Hs (m) <	TOTAL	Prob.	Hs (m)	Prob non-exc	Prob exc
0.0	0.5	41745	0.017507	0.0	0.000000	1.000000
0.5	1.0	365823	0.153420	0.5	0.017507	0.982493
1.0	1.5	506620	0.212468	1.0	0.170928	0.829072
1.5	2.0	435329	0.182570	1.5	0.383396	0.616604
2.0	2.5	332903	0.139614	2.0	0.565966	0.434034
2.5	3.0	237995	0.099811	2.5	0.705580	0.294420
3.0	3.5	162841	0.068293	3.0	0.805392	0.194608
3.5	4.0	108918	0.045678	3.5	0.873685	0.126315
4.0	4.5	71863	0.030138	4.0	0.919363	0.080637
4.5	5.0	46487	0.019496	4.5	0.949502	0.050498
5.0	5.5	28581	0.011986	5.0	0.968997	0.031003
5.5	6.0	17829	0.007477	5.5	0.980984	0.019016
6.0	6.5	10737	0.004503	6.0	0.988461	0.011539
6.5	7.0	6599	0.002768	6.5	0.992964	0.007036
7.0	7.5	4040	0.001694	7.0	0.995732	0.004268
7.5	8.0	2492	0.001045	7.5	0.997426	0.002574
8.0	8.5	1610	0.000675	8.0	0.998471	0.001529
8.5	9.0	974	0.000408	8.5	0.999146	0.000854
9.0	9.5	539	0.000226	9.0	0.999555	0.000445
9.5	10.0	257	0.000108	9.5	0.999781	0.000219
10.0	10.5	145	0.000061	10.0	0.999888	0.000112
10.5	11.0	89	0.000037	10.5	0.999949	0.000051
11.0	11.5	23	0.000010	11.0	0.999987	0.000013
11.5	12.0	3	0.000001	11.5	0.999996	0.000004
12.0	12.5	4	0.000002	12.0	0.999997	0.000003
12.5	13.0	2	0.000001	12.5	0.999999	0.000001
<b>TOTAL</b>	<b>13.0</b>	<b>2384448</b>	<b>1.000000</b>			

Table 1 — Significant wave height  $H_s$  probability: Aberdeen to Block 211/27



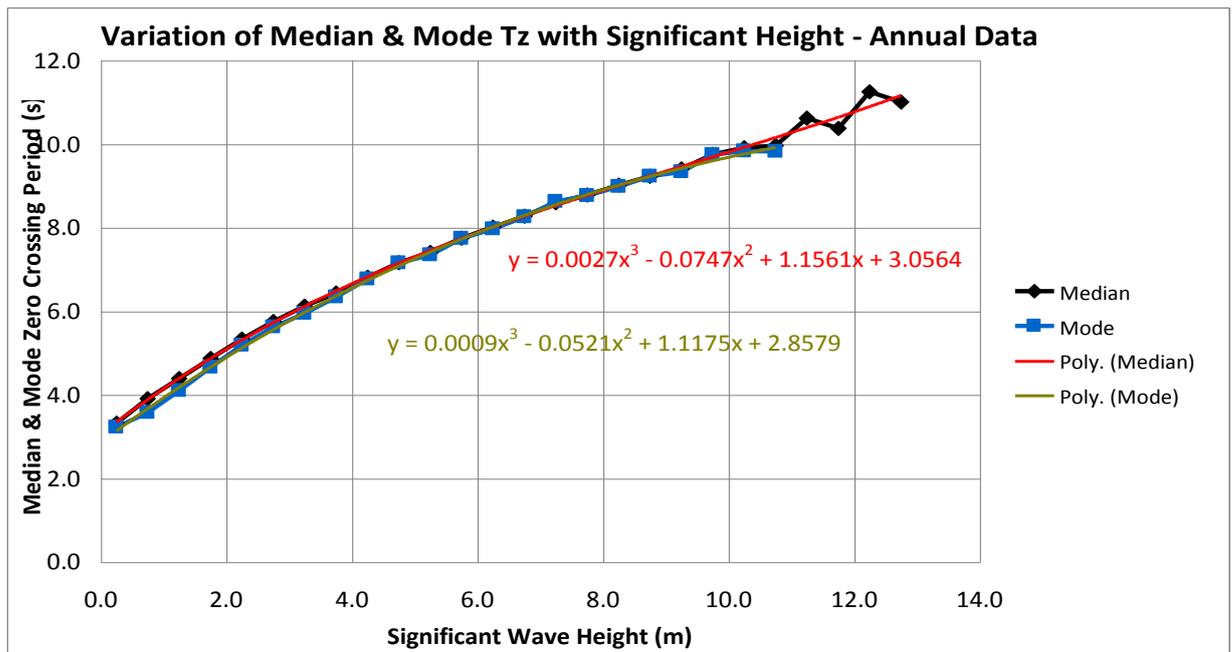


Figure 3 — Median and Mode T<sub>z</sub> Values

H <sub>s</sub> (m)	Median T <sub>z</sub> (s)	Mode T <sub>z</sub> (s)
1.25	4.4	4.2
2.50	5.5	5.6
4.00	6.7	6.8
5.00	7.3	7.3
6.00	7.9	7.8
9.00	9.3	9.1

Table 2 — Median and Mode T<sub>z</sub> for selected H<sub>s</sub> values

Item 11 — Move towards compliance with more realistic sea conditions

General

In the past, rotorcraft ditching model tests have mostly been performed in regular waves. However, capsizing of a rotorcraft with intact emergency flotation is only likely to occur in breaking waves (see CAA Paper 2005/06, Appendix A, Item 2.1.9, and also Appendix A, Item 15 above). The way in which steep regular waves decompose and eventually break is in large part a function of the wave maker and the test basin dimensions, and consequently, results of rotorcraft model capsizing tests performed in regular waves are likely to be misleading. They are likely to be more a measure of the performance of the wave basin than that of the rotorcraft. As a result, it has been recommended that all future rotorcraft ditching model tests should be performed in realistic irregular waves (see CAA Paper 2005/06, Appendix A, Item 2.2.1, and also Appendix A, Item 15 above).

It has also been determined that in future, the ditching certification of the rotorcraft should be based on the overall risk to the occupants, hence, acceptable maximum target probabilities of capsizing in five-minute exposure to a sea condition have been derived (see Risk Matrix Item 10 above). The objective



of the rotorcraft model tests should therefore be to determine the probability of capsize in five-minute exposure to a realistic irregular-wave condition, and a successful certification will result therefrom when the determined probability of capsize is less than or equal to the target probabilities.

As well as using regular waves in the past, model tests have been performed using a variety of different test techniques. In order to ensure that future rotorcraft ditching certification tests are performed in directly comparable conditions, a model test specification has been developed, and future model tests should be performed according to this specification.

The rotorcraft designer/operator should be at liberty to select the  $H_s$  of the sea conditions according to which his rotorcraft is to be certified for ditching, and this  $H_s$  limit should ultimately be noted in the performance section of the RFM (see Risk Matrix Item 10 above). The default wave climate for certification should be that of the NS, and the irregular waves used in the model test should be generated according to the JONSWAP wave spectrum with a peak enhancement factor  $\gamma = 3.3$ . Example combinations of  $H_s$  and  $T_z$  have been determined for a typical NS helicopter route, and these are provided in the draft model test specification.

The rotorcraft designer/operator should be at liberty to select an alternative or additional sea area. However, in this case, the certified  $H_s$  limit noted in the RFM must be accompanied by the geographical limits corresponding to the sea area selected. When a wave climate for an alternative sea area is being used for ditching certification, the wave  $T_z$  should be selected to be the median value associated with the  $H_s$  selected, and the wave spectrum selected as appropriate for that sea area.

#### Recommendations

- (a) Ditching certification model tests should in future be performed in realistic irregular waves.
- (b) The rotorcraft designer/operator should be at liberty to select the sea condition (in terms of  $H_s$ ) according to which his rotorcraft is to be certified, and the  $H_s$  limit is to be noted in the performance section of the RFM.
- (d) The default wave spectrum should be appropriate for the NS wave climate (i.e. JONSWAP with peak enhancement factor  $\gamma = 3.3$ ). The rotorcraft designer/operator should be at liberty to select an alternative or additional sea area, however, in this case, the certified  $H_s$  limit must be accompanied by the geographical limits corresponding to the sea area selected.
- (d)  $T_z$  should be selected to be the median value associated with the  $H_s$  and the wave spectrum selected as appropriate to that sea area.
- (e) The output of such model tests should be the probability of capsize in five-minute exposure to the sea condition, which is to be shown to be less than or equal to the required target probabilities to demonstrate compliance, as recommended in Risk Matrix Item 10 above.
- (f) The model tests should be performed in accordance with the attached specification.



## Application of analytical/computational methods

### Background

Ever since, engineers gained access to powerful computers in the 1960s, fluid dynamicists have been using them to solve fluid-flow problems, and a very wide range of different solution methods and flow applications has been developed over the intervening decades.

With the massive increase in computing power and the reduction in cost, these methods have come within the reach of many technologists and engineering consultancies, and a large number of different software products have also been developed and marketed.

Most of these products may best be regarded as 'kits of tools' because they usually contain a wide range of different flow-analysis and structural-response modules that may be called upon depending on the precise flow problem to be analysed.

As with any kit of tools, the quality of the outcome is as much, if not more, dependent on the skill of the craftsman as it is on the quality of the tool. And, as too many technologists or consultancies can now afford to purchase computer hardware and such software, it is absolutely essential to ensure that those producing results from such tools for engineering design or analysis are competent and qualified to do so.

It is also important to understand that there is tough commercial competition in flow-modelling products, and certain software vendors or users might be tempted to promote their tools for applications for which they might be unsuited or, if potentially suitable, perhaps not validated.

Having said this, such computational methods have rightly gained a major place in engineering design and analysis. For example, in the case of mainly streamlined bodies such as aircraft and ship hulls, computational fluid dynamics (CFD) now plays a major role in design development, reducing, but usually not completely eliminating, the need for wind tunnel and tank testing.

In other engineering applications, such tools have made possible the analysis of systems or events that were hitherto completely impossible by other means. A good example here is the analysis of the possibly explosive consequences of a hydrocarbon release on an offshore platform. CFD is now routinely used to estimate explosion overpressures, and thus, help to design structures that can withstand a credible explosion event.

Such computational methods are generally more readily applied to steady-state or static-flow solutions, rather than dynamic flows and responses. A tall-building designer is more likely to use wind tunnel testing than CFD to help determine its dynamic response to the wind or the dynamic peak pressures on cladding panels. And this might be for economic as well as technical reasons.

There is a natural tendency to assume that a computational method is likely to be cheaper and quicker to use than any physical testing, but this is not always the case. The process of constructing and validating a numerical model can be time-consuming.

Although most modellers will today have the advantage of starting from computer-aided design (CAD) drawings of the design to be tested, translating this into a flow model involves discretisation of the geometry of the design and of the surrounding fluid in some way. The flow/response calculations are



then performed in these discrete cells or on discrete panels or in moving 'particles' or eddies in the surrounding fluid.

The speed of the computer solution depends critically on the number of such cells, panels or particles, and so, from a computational efficiency point of view, one would like the number to be as small as possible. However, considering the accuracy of the flow solution, one would like to have the number as high, and thus, discretisation as fine as possible. Consequently, there is usually a need to balance the accuracy of the flow modelling against the cost/time involved in the solution.

Once automatic 'meshing' tools have been run to convert the CAD files into a flow model, experienced flow modellers will spend time ensuring that they are using their finest cell resolution in the parts of the model that require the best flow accuracy. They may sometimes perform repeat runs with different cell resolutions to check for any differences in the outcome before they are satisfied that their computational model is adequate for the task in hand. This can be a very lengthy and expensive process if the computation is challenging.

#### Application to helicopter capsizing

The capsizing of a helicopter floating in the sea on its emergency flotation system (EFS) is a very complex and non-linear phenomenon. It involves a sequence of waves, including a breaking wave, of sufficient strength to tip over the helicopter. The wave sequence immediately preceding the breaking wave may be important in 'setting up' the motion of the helicopter such that it finally succumbs to the overturning impact of the breaking wave.

The response of the helicopter floating on the water is highly non-linear. The roll-righting moment provided by the EFS bags and the immersed part of the fuselage is reasonably linear for the initial angles of roll, but when the EFS emerges from the water on one side, and becomes completely immersed on the other side, the roll-restoring moment abruptly stops increasing, and the application of any significant further roll-overturning moment will almost certainly result in capsizing.

Naval architects and hydrodynamicists have been experimenting with numerical models of non-linear and breaking waves for some years. Applications of interest in the oil and gas field include predicting water run-up on column legs and, breaking-wave impact forces on structures, and simulating the flow of water coming onto the deck of floating production systems.

As far as is known, no such model has been applied to, or validated for, the capsizing of a helicopter floating on the sea. A brief literature search has also failed to identify any validated approach to a similar application such as, for example, the capsizing of a small boat or yacht.

The validation of a numerical model for this application would be a significant task, requiring physical-model test data from a number of different helicopter types at various weight/loading conditions, and in a variety of different wave conditions. A similar number of numerical simulations would need to be performed to compare with these results in order to demonstrate that the numerical models adequately represented the reality. More than one numerical method might need to be investigated and compared. However, it is likely that such a validation exercise would result in the generation of a large quantity of valuable guidance information on how the numerical models should be used to best effect.



If such validation is performed, and the capsizing predictions delivered by the numerical model found to be satisfactory, there is still a further major problem to overcome. The numerical model will have most likely delivered the helicopter capsizing performance for a time series representing a single breaking wave, or a short sequence of waves including a breaking wave. This raises several questions:

- how was this particular wave time series selected;
- what is the probability of experiencing this particular time series in the ocean; and
- what is the response of the helicopter to all the other possible wave time series.

The overall objective in the ditching certification is to establish a specific level of safety, or low risk of capsizing, in any randomly occurring ditching event.

In the application of physical-model testing, since we do not know the precise kinematics of breaking waves in a given sea condition, or which of these sequences is likely to be most critical for capsizing, we have determined that it is necessary to perform a seakeeping test in a long non-repeating sequence of realistic irregular waves. It can be shown that in order to demonstrate an adequately low probability of capsizing (say 3 %) with a reasonable level of confidence (say 95 %), a continuous exposure of about 8 hours (full-scale time) to the specific sea conditions without capsizing is required. The model will experience some 4 000 individual waves during this test.

Performing numerical simulations of this duration is likely to be impractical and, as with the model test, would also only deliver an estimate of the capsizing probability in the single sea condition tested. (Note, however, that Annex 1 to Item 11 below describes an approximate method for using the results from a single sea condition to estimate the overall risk of capsizing.)

Clearly, a major potential benefit of having a validated numerical model of helicopter capsizing would be its contribution to understanding the exact mechanism of capsizing, and the helicopter design parameters that help to avoid it. It is even conceivable that such a high level of confidence might be generated in this understanding that standards for helicopter EFS design parameters (e.g. range of stability, area under the righting-moment curve etc.) might be developed which if followed by the designer, might permit ditching certification without recourse to specific physical or numerical modelling, much as long-established simple static-stability rules are used in ship design.

Indeed, for these reasons, the development of such a model was recommended in 1993 in BMT Offshore Report No 44011r12, but has not been pursued to date because of the anticipated magnitude and cost of the research effort required to achieve it, and the lack of certainty for a positive outcome.

#### Recommendation

In view of the lack of validation of numerical methods in their application to helicopter ditching certification, it is recommended that such methods should not be accepted for ditching certification unless and until they have been fully validated.

#### References

- [EASA ToR RMT.0120 \(27&29.801\), Issue 1, Ditching Occupant Survivability, 12 October 2012](#)
- BMT Offshore Report No 44011r12, Review of Helicopter Ditching Performance, July 1993 (reproduced as Appendix A to CAA Paper 2005/06)



[Annex 1 to Item 11](#)Helicopter ditching certification

A pragmatic single-wave-condition approach

## Introduction

Using established safety objectives (CS 27/29.1309), values have been derived for acceptable probabilities of capsizing in waves following a random helicopter ditching event. A technique for determining the probability of capsizing for a helicopter in waves using model testing has been proposed in a draft model testing specification.

The overall risk of capsizing within the five-minute period is made up of two components: the probability of capsizing in a given wave condition, and the probability of experiencing that wave condition in a ditching event.

If it is assumed that a ditching event occurs at random, and is not linked with weather conditions, the overall risk of a capsizing can be established by combining two pieces of information:

- The wave climate scatter table, which shows the probability of meeting any particular combination of significant wave height  $H_s$  and zero crossing period  $T_z$ . An example scatter table is shown in Figure 1 — Example of all-year wave scatter table. Each cell of the table contains the probability of experiencing a wave condition with significant height  $H_s$  and zero-crossing period  $T_z$  in the range shown. Thus, the total of all cells in the table adds up to unity.
- The probability of capsizing in five-minute exposure for each of these  $H_s/T_z$  combinations. This probability of capsizing is different for each helicopter design and for each  $H_s/T_z$  combination, and is to be established through model testing using the method defined in.

In theory, a model test should be performed for the helicopter design in the full range of  $H_s/T_z$  combinations covering all the cells in the scatter table. Clearly,  $H_s/T_z$  combinations with zero or very low probabilities of occurrence might be ignored. It might also be justifiably assumed that the probability of capsizing at very high wave heights is unity, and at very low wave heights zero. However, there would still remain a very large number of intermediate  $H_s/T_z$  combinations that would need to be investigated in model tests, and it is considered that such a test programme would be too lengthy and costly to be practical.

The objective, here, is therefore to establish a justifiable method of estimating the overall five-minute capsizing probability using model test results for a single-wave condition. That is a single combination of significant wave height  $H_s$  and zero-crossing period  $T_z$ .

Such a method can never be rigorously linked with the safety objective, but it is proposed that such a method may be regarded as a conservative approximation.

## The procedure

The proposed procedure is as follows:

The helicopter designer selects a significant wave height limit  $H_{sL}$  for ditching certification of his helicopter. This wave height limit  $H_{sL}$  will eventually be noted in the performance section of the RFM.



In some jurisdictions, the helicopter will not be permitted to fly if wave heights along the route exceed this limit.

Using wave climate data for an appropriate region of the ocean for the anticipated flight operations, a zero-crossing period  $T_zL$  is selected to accompany the  $H_sL$ . It is proposed that this zero-crossing period  $T_zL$  should be typical of those occurring with  $H_sL$  as determined from the wave scatter table for the region. The mode or median of the  $T_zL$  distribution at  $H_sL$  may be used.

A wave spectrum shape will also be selected as appropriate to the region of the ocean for the intended flight operations.

Model tests are performed in the sea condition  $H_sL$   $T_zL$  with the selected spectrum shape using the proposed tank testing method, and the five-minute probability of capsizing  $P_c$  established in this sea condition.

The way in which the probability of capsizing  $P_c$  varies for other values of  $H_s$  and  $T_z$  is known because model tests have not been performed in all the other possible combinations. Furthermore, no theoretical methods exist to translate a probability of capsizing from one sea condition to another.

However, it is known that the probability of capsizing is related to exposure to breaking waves of sufficient height, and that this is in turn linked with wave steepness. Hence:

- the probability of capsizing is likely to be higher for wave heights just less than  $H_sL$  but with wave periods shorter than  $T_zL$ ; and
- the probability of capsizing will be lower for the larger population of wave conditions with wave heights lower than  $H_sL$  and with wave periods longer than  $T_zL$ .

So a reasonable and conservative assumption is that the same probability of capsizing  $P_c$  on average holds good for all wave conditions with heights equal to or lower than  $H_sL$ .

A further conservative assumption is that  $P_c$  is unity for all wave heights greater than  $H_sL$ .

Using these assumptions, a comparison of the measured  $P_c$  in  $H_sL$   $T_zL$  against the target probability of capsizing  $P_cT$  can be performed.

In the case of jurisdictions where flying is not permitted when the wave height is above  $H_sL$ , the helicopter will have passed the ditching certification criteria provided that:  $P_c \leq P_cT$ .

In the case of jurisdictions where flying over waves greater than  $H_sL$  is permitted, the helicopter will have passed the ditching certification criteria provided that:  $P_c \leq P_cT - P_e$ , where  $P_e$  is the probability of exceedance of  $H_sL$ . Clearly, in this case, it can be seen that it would not be permissible for the helicopter designer to select a  $H_sL$  which has a probability of exceedance greater than  $P_cT$ .

Example using northern NS data

Taking the case of a helicopter that is to be operated with capsizing mitigation in the form of emergency breathing systems (EBS), the following target capsizing probabilities for the intact EFS condition can be determined:  $P_cT = 0.029$  (or 2.9 %).

Taking the 'default' worldwide operating area as the Northern NS and using the wave data for the route from Aberdeen to Block 211/27, Figure 1 below shows the all-year wave scatter determined for this helicopter route, which has been derived from 34 years of three-hourly wave model hindcast data.



If a significant wave height limit  $H_sL = 6$  m is selected for the ditching certification of the helicopter, Figure 2 below shows the probability of exceedance of significant wave height, from which it can be seen that 6 m are exceeded with a probability of 0.012, or for 1.2 % of the time. This means that in a flying jurisdiction that prohibits flights in wave heights above this value, on average 1.2 % of flights are likely to be lost.

It also means that if the flying jurisdiction permits flights in wave heights higher than the  $H_sL$ , 0.012 needs to be subtracted from the target probability of capsize when comparing it with the actual probability of capsize measured in the model test.

Figure 3 below shows the distribution of  $T_z$  for  $H_sL = 6$  m; it can be seen that the mode (peak) of the distribution is at 7.8 s. Thus,  $T_zL = 7.8$  s has been selected. The JONSWAP wave spectrum with peak enhancement factor  $\gamma = 3.3$  has been selected, which is regarded as an appropriate wave spectrum shape for this region of the ocean.

Therefore, to certify the helicopter for ditching in the  $H_sL = 6$  m sea condition, the helicopter model tests need to be performed in this wave condition according to the proposed specification, determining the probability of capsize  $P_c$ . In jurisdictions prohibiting flights in waves higher than  $H_sL$ , the helicopter will have achieved the ditching provision, provided that:  $P_c \leq 0.029$ .

In jurisdictions where flights at wave heights above  $H_sL$  are permitted, the helicopter will have meet the ditching provision, provided that:  $P_c \leq 0.029 - 0.012 = 0.017$ .

In this context, it should be noted that in order to demonstrate the  $P_c \leq 0.029$  case at a likelihood of 95 %, as required in the proposed model test specification, a model test of 8.5-hour duration (full-scale time) without capsize will be required. The model scale time required will be  $8.5 \times 1/\sqrt{k}$  h, where  $k$  is the linear model scale. The  $P_c \leq 0.017$  case will be significantly more time-consuming, requiring a total test duration of approximately 15 hours (full-scale time) without capsize.



Hs (m) >= Hs (m) <															TOTALS														
12.5	12	11.5	11	10.5	10	9.5	9	8.5	8	7.5	7	6.5	6	5.5	5	4.5	4	3.5	3	2.5	2	1.5	1	0.5	0	0.0000	0.0000	0.0000	
12																													0.0000
11.5																													0.0000
11																													0.0000
10.5																													0.0000
10																													0.0001
9.5																													0.0001
9																													0.0002
8.5																													0.0004
8																													0.0007
7.5																													0.0010
7																													0.0017
6.5																													0.0028
6																													0.0045
5.5																													0.0075
5																													0.0120
4.5																													0.0195
4																													0.0301
3.5																													0.0457
3																													0.0683
2.5																													0.0998
2																													0.1396
1.5																													0.1826
1																													0.2125
0.5																													0.1534
0																													0.0175
Tz (s) >=	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12					1.0000		
Tz (s) <	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12								

Figure 1 — All-year wave scatter table

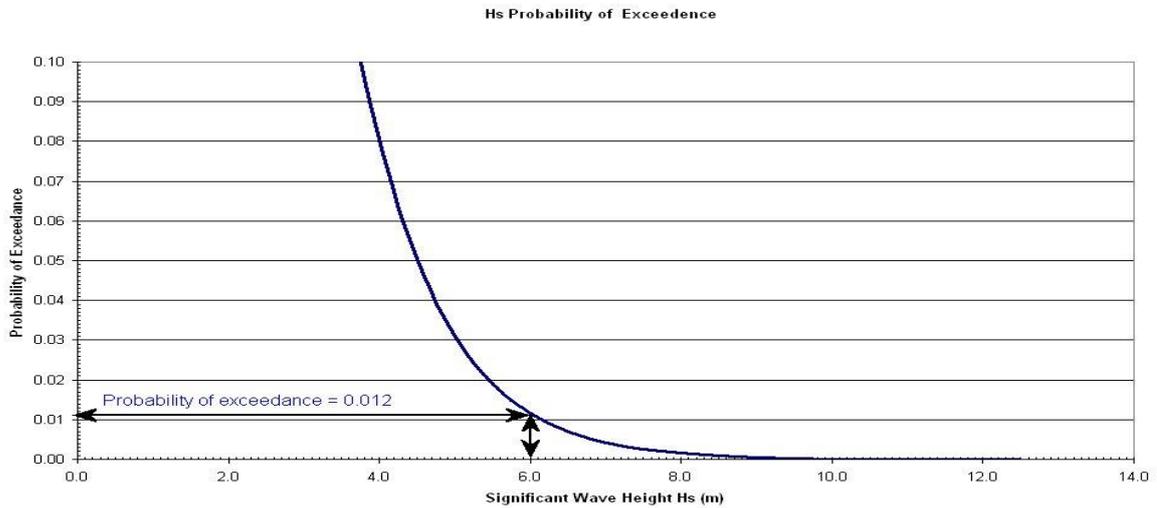


Figure 2 — All-year wave height exceedance probability

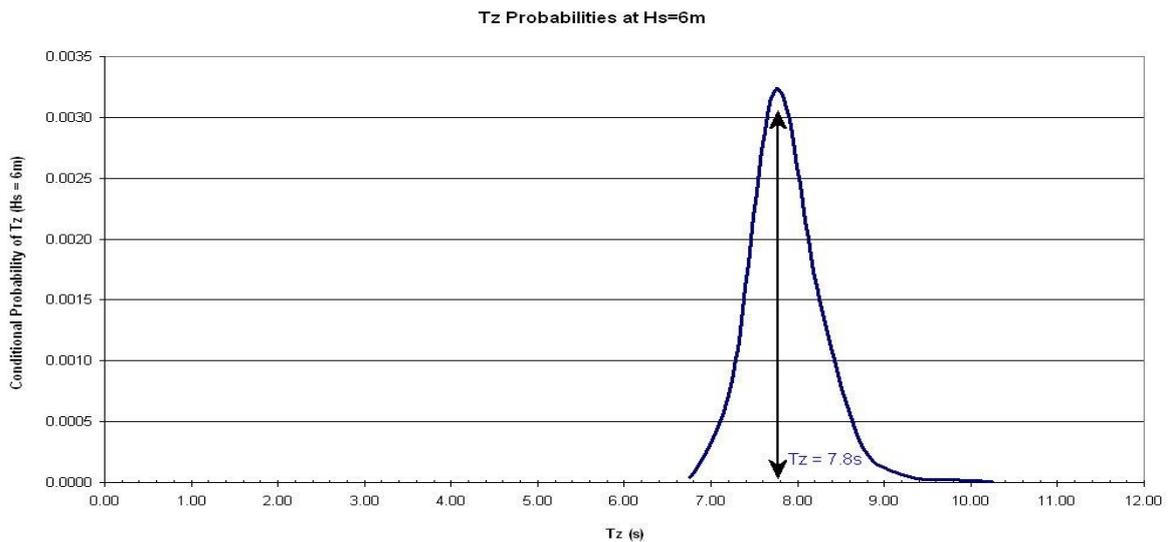


Figure 3 — Tz corresponding to Hs = 6 m



**Item 12 — Enhanced EFS crashworthiness**

For survivable water impacts, with reference to Appendix A (see Items 2, 3, 4, 7 and 8 above), all of the studies performed in both the UK and the USA covering civil and military operations have concluded that:

- drowning is the major cause of fatalities; the major cause of drowning is due to the inability to escape from an inverted and/or submerged helicopter in a timely manner;
- improving operability of the emergency flotation systems (EFSs) is vital if survivability is to be improved.

The primary purpose of the EFS is to keep the helicopter afloat following a controlled landing on water, i.e. a ditching. Historically, these systems tend to be much less effective when a helicopter crashes onto water, however, either because they are damaged by the impact, or because they have to be manually activated by the pilot who may be incapacitated by the impact.

A study of water impacts where EFS failures contributed to fatalities (see Appendix A, Items 12 and 15) highlighted the following opportunities for improvement:

- (a) arm the system at all times, except when hazardous to do so;
- (b) activate the system automatically by means of immersion switches;
- (c) provide inflation bottle redundancy;
- (d) minimise the effect of varying ambient conditions on gas bottles;
- (e) provide flexible hoses to minimise impact damage;
- (f) provide more even flow distribution and bag deployment;
- (g) increase float attachment design loads and protection from impact;
- (h) relocate existing floats to regions less susceptible to damage;
- (i) incorporate flotation unit redundancy, in addition to existing floats; and
- (j) provide additional flotation so that the helicopter floats on its side.

Of these, implementing (a) and (b) together was considered to be highly effective, improving survivability in around 50 % of the accidents. Most helicopters engaged in offshore operations in European waters are already equipped with automatic EFS activation (e.g. automatic float deployment system (AFDS)) despite the lack of a related CS, and the safety benefit of this system was dramatically demonstrated in the accident to G-REDU in February 2009 near the Eastern Trough Area Project (ETAP) platform in the NS. However, no helicopters, apart from the Airbus Helicopters EC175, are known to have automatic arming/disarming. These measures are further addressed in Risk Matrix Items 14 and 15 below.

Although desirable, the improvement in survivability that would likely accrue from implementing items (c), (d), (e) and (f) was judged to be of second order, and it was noted that most of these aspects were already addressed in modern EFS designs.

As regards increasing the float attachment design loads (Item (g)), the present implementing rules (IRs)/CSs/AMC do not address water impacts, only ditching. It was suggested that water impacts could be accommodated by increasing the 30-kt, 5-fps water entry envelope prescribed for ditching (see also



Risk Matrix Item 9). Analysis of three example survivable water impacts (see Appendix A, Items 12 and 15), however, demonstrated that it would be impractical to design for the very significant impact loads that could be expected, effectively ruling out Item (g) even though it was judged to be effective in saving lives. This view has been endorsed by the industry (see Appendix A, Item 10).

Relocation of existing floats (Item (h)) could be achieved by mounting the existing floats higher on the sides of the fuselage, moving them further away from the most likely point of impact. Additional structure would likely be required to provide attachments strong enough to bear the float loads, and care would need to be taken that the floats do not obstruct any exits, especially when inflated. Furthermore, raising the floats could have a detrimental effect on the stability of the helicopter, especially during the period from first alighting on the water until the aircraft 'sinks' to its design floating level.

A better alternative might be to provide additional, redundant floats attached to less vulnerable locations on the airframe, i.e. away from the underside where the highest impact loads are typically experienced. This would have the same effect as moving the existing flotation devices but would not affect the ditching performance. It would also effectively combine Items (h) and (i), both of which were judged to each be as effective in improving survivability as Item (g). Item (i) is considered further in Risk Matrix Item 18 below.

Items (h) and (i) could be combined even more effectively in the form of the so-called 'side-floating' helicopter scheme (Item (j)). This approach includes the added benefit of providing an air pocket in the cabin and was judged to be more effective in saving lives than Items (a) and (b) together. This measure is considered further in Risk Matrix Item 17 below.

#### Recommendations

- (a) automatic arming and activation of EFS should be mandated; and
- (b) for CS-29 and CS-27 Category A rotorcraft, the rule should require EFS to be designed to be crashworthy, and current best-design practice in terms of providing EFS crashworthiness, such as by eliminating single-point failures, should be encapsulated in GM.

#### **Item 13 — EFS protection from rupture**

This issue has been covered in Item 9 above, which concludes that no further action is required.

#### **Item 14 — Automatic EFS activation**

The reliance on flight crew manual activation of EFS alone has long been proven by accident experience to be inadequate.

In the event of a water impact, the time for flight crew to react before impact may be very short, and after impact, they may be incapacitated.

Rotorcraft operating in the NS have had voluntarily installed automatic EFS activation systems for many years now and service experience has not revealed any problems.

#### Recommendations

- (a) For these reasons, it is recommended that new text be introduced to CS-27/CS-29 to require the fitment of automatic EFS activation systems.



- (b) Because there is currently no provision for automatic EFS activation to be installed on existing in-service types, it is also recommended that Annex I (Part-26) to Regulation (EU) No 2016/640 and/or CS-26 also be amended to introduce such a provision.

#### **Item 15 — Automatic arming/disarming of EFS**

Inadvertent activation of the rotorcraft's EFS in flight must either be shown to present no unacceptable hazard at any possible flight condition or the probability of inadvertent inflation must be shown to be commensurate with the likely hazard. This is most usually achieved by flight test evidence of the benign effects of deployment up to a certain airspeed and by instruction to the flight crew to manually disarm the system above a speed which is somewhat below this.

With the disarmed system's probability of inadvertent deployment being significantly lowered, the overall safety objective is achieved.

However, availability of the system when needed relies on the flight crew manually rearming the system when lower speeds are again reached. In the case of water impact in particular, there is no guarantee that this can be performed in time.

#### Recommendation

It is proposed to introduce a provision that arming/disarming of a rotorcraft EFS be automated.

#### **Item 16 — Increase flotation stability by fitting float scoops/remove fuel jettison aspects from the Air Ops regulation**

##### **Float scoops**

Float scoops are routinely used on inflatable life rafts to improve stability, and were investigated as a means of improving the resistance of helicopters to capsize in a work programme reviewed in Appendix A to CAA Paper 2005/06 (see also Appendix A, Item 15). The model tank tests performed demonstrated a consistent improvement in seakeeping performance of one SS for all but one (Sikorsky S6; this was considered to be due to the unusually small size of the floats, and hence float scoops, for the size of the helicopter) of the nine helicopter types evaluated.

Float scoops work in two ways:

- Firstly, they trap water and therefore add weight to a float which is pulled out of the water as the helicopter heels over. They, therefore, add a righting moment by increasing the slope of the righting-moment curve, thus increasing the peak righting moment. In all cases, they were also found to increase the range of stability (the heel angle at which the righting moment reduces to zero), and in some cases they even increased the angle of the peak righting moment.
- Secondly, scoops add roll damping and roll inertia by increasing the effective size of the floats.

The merits of float scoops were further investigated to consolidate the state of the art and, specifically, to estimate the weight and cost implications of fitting scoops to a typical large transport helicopter. This work was performed by BMT FM in collaboration with Westland Helicopters and has been reported in CAA Paper 95010 (see Appendix A, Item 6).



An outline design for float scoops was produced for the AgustaWestland AW101 (EH101) civil-transport helicopter. The increased float forces resulting from the addition of float scoops were estimated, and these loads were compared with design calculations for the original helicopter in order to establish the structural and cost implications for helicopter, floats and float fixings. These were all found to be very modest.

It is therefore considered that float scoops represent a practical and effective means of providing a significant improvement in the seakeeping performance of ditched helicopters, and that this is achievable at commensurate cost and weight.

Text promoting the use of float scoops was added to AC 27/29.1411 as part of AC 2006.

#### Recommendation

The benefits of float scoops should be highlighted/promoted as a means of improving the seakeeping performance of ditched helicopters.

#### **Fuel jettison**

Jettisoning of fuel after the rotorcraft has landed on the water serves only to pump fuel into the sea around the rotorcraft, creating a significant additional hazard for the survivors, and to increase the volume of air in the fuel tanks (as the tanks are open to atmosphere through the vent lines). Moreover, since the fuel tanks on most helicopters are located under the floor, reducing the fuel load will raise the centre of gravity of the aircraft and reduce its stability on the water.

#### Recommendation

Fuel jettison aspects should be removed from the Air Ops Regulation.

#### **Item 17 — Novel solutions (e.g. 'side-floating' concept)**

A modification to helicopter EFSs involving the installation of additional, redundant flotation units high up on the side or sides of the helicopter has been proposed. In this scheme, the high-mounted floats provide a reversionary side-floating attitude in the event of capsizing. This serves to retain an air pocket in the cabin (see Risk Matrix Item 19) and ensures that some of the doors and windows remain above water level facilitating egress. The latter point is important as other means of providing an air pocket, such as raising all of the existing flotation units, may require the use of EBS in order to escape from the air pocket.

This solution, known as the side-floating helicopter scheme, was first proposed and tested during a comprehensive programme of wave tank testing conducted in the UK in the late 1980s to mitigate the consequences of post-ditching capsizing (summarised in Appendix A of CAA Paper 2005/06, see also Appendix A, Item 15 above). Further work was performed in the mid-1990s, following a refocusing of attention on survivable water impacts (as opposed to ditchings) in response to the accident to G-TIGH in 1992 near the Cormorant Alpha Platform in the NS and to the subsequent joint industry review of safety and survival (see RHOSS, Appendix A, Item 5).

The further work involved the investigation of a range of design solutions culminating in wave tank testing of the three most promising candidates (see CAA Paper 97010, Appendix A, Item 9 above). A human-subject trial was then performed in an HUET to investigate the effectiveness of the scheme in a



back-to-back comparison with an inverted helicopter cabin (see CAA Paper 2001/10, Appendix A, Item 13 above). Both streams of work indicated that the scheme was practical and effective and showed great promise.

In parallel to the above, this scheme was also cited as a potential means of improving post-crash operability of EFS in research performed in the USA (see Appendix A, Item 8 above), and later in the UK (see Appendix A, Item 12 above). The scheme provides additional redundant flotation at a location away from the most likely points of impact, and also an air pocket in the cabin in the event of capsize (virtually certain in the case of water impacts).

This single solution, therefore, mitigates both post-ditching capsize (Risk Matrix Item 10), and survivable water impacts by addressing Risk Matrix Items 12, 18, 19 and 38.

The side-floating helicopter scheme can be implemented using passive buoyancy (e.g. by increasing the thickness of cowling panels, by sealing off unused internal space in the upper fuselage area) or an active scheme (e.g. by using inflatable bags attached to the fuselage near to the cabin roof) or a combination of the two. There are advantages and disadvantages to both approaches, and the best solution for any particular helicopter will likely be specific to that type. As a general rule, however, it can be said that it would be much easier to implement the scheme on a new design than to retrofit it to an existing type, especially in respect of providing passive buoyancy.

A key design choice is whether to provide a symmetric or an asymmetric system. In general, a symmetric system will be double the cost, weight and drag of an asymmetric system, and will also provide two stable side-floating attitudes which can result in a potentially hazardous second roll while occupants are making their escape. With an asymmetric system, escape provisions such as life raft release can be optimised for the one possible side-floating attitude. Although, on balance, an asymmetric system is likely to offer a better solution for the 'post-ditching capsize' case, a symmetric system provides greater redundancy and is therefore likely to be more effective for a greater proportion of survivable water impacts. The choice between the two solutions should ideally be based on best-cost/benefit ratio, and this may be different for implementation in new designs and retrofit to existing types.

Some concerns regarding the side-floating scheme have been expressed by the industry, however. In particular, the potentially catastrophic consequences of inadvertent deployment in flight have been raised. This is already an issue for existing EFS, but could be even worse with flotation bags located near the main rotor and the engine intakes. A combined passive/active scheme could be employed to minimise the size of any inflatable bags, and a high-integrity arming and activation system (e.g. using either a rotor speed switch and/or a tilt switch for the upper floats in addition to the safety barriers for the existing floats) could constrain the risk to an acceptable level.

Although it is recognised that there are design issues to be solved for the side-floating scheme to represent a practical proposition, it is believed that there are no problems that could not be solved given the motivation. In addressing both the post-ditching capsize and the survivable water impact scenarios with a single solution, it is considered that the effort required would be worthwhile.



### Recommendations

- (a) The benefits of the side-floating helicopter EFS scheme should be highlighted/promoted as a means of mitigating the hazards presented by post-ditching capsizes and survivable water impacts.
- (b) Given the availability of a practical means, the rules should require the provision of enhanced post-capsize survivability features, e.g. an air pocket, in the event of post-ditching capsizes, available to all passengers.

### **Item 18 — Float redundancy**

With reference to Risk Matrix Items 12/38, studies of three survivable water impacts reported in CAA Paper 2001/02 and summarised in CAA Paper 2005/06 (Appendix A, Items 12 and 15) demonstrated the impracticality of designing EFSs to withstand the impact loads likely to be experienced in a wide range of potential scenarios. This work was reviewed by the FAA/JAA Joint Harmonization Working Group on Water Impact Ditching Design and Crashworthiness (WIDDCWG), which supported this conclusion in its report (see Appendix A, Item 10). Accepting that premise, it is considered reasonable to assume that the lower flotation unit on the corner of the helicopter closest to the point of impact (viewed from above, i.e. plan view) would be lost in a survivable water impact.

It is apparent from accident data that helicopters almost always capsize in water impacts. Worse still, the helicopter may sink, and the loss of a flotation unit will only increase the chances of this occurring. It is considered impractical to prevent capsizes in survivable water impacts, however, prevention of sinking through the provision of sufficient redundant flotation would undoubtedly improve the survival prospects of the occupants by maintaining the helicopter cabin on or close to the sea surface.

One means of achieving this could be by increasing the size of the existing flotation units such that the remaining floats, following the assumed impact damage, would be sufficient to keep the helicopter afloat. This would not necessarily result in a large, or even any, increase in the volume of the floats compared to existing designs. The floats are sized such to provide the post-ditching stability required as well as the buoyancy to ensure that the helicopter will float. This requires larger floats than those that would be required solely to prevent the helicopter from sinking, which is all that is required in the case of a survivable water impact. In addition, current EFSs already possess a degree of redundancy due to the requirement to withstand a failure of the critical flotation unit compartment (albeit with reduced stability). Conversely, increasing the size of the existing floats to provide sufficient redundancy in order to prevent sinking in the event of loss of half of the flotation would likely improve the post-ditching seakeeping performance of the helicopter, i.e. it would provide a 'spin-off' benefit.

However, the opportunity to increase the size of the existing EFS floats may be limited to some extent through consideration of exit blockage. An alternative approach would be to provide additional flotation units and mount them on the fuselage in locations that would be less vulnerable to damage in the event of a survivable water impact. This arrangement could be configured to ensure the provision of an air pocket in the cabin, which would confer additional benefits as described in Risk Matrix Item 19.



### Recommendation

The rules should require the provision of sufficient flotation redundancy to ensure that the helicopter does not sink following the loss of the most critical (i.e. largest) of the lower flotation units provided for ditching stability in the upright floating attitude.

#### **Item 19** — Provide enhanced post-capsize survivability

Capsize can be expected to occur in all water impacts, and may occur following a ditching due to adverse sea conditions or imperfect alighting on the water. The primary hazard in the event of capsize is drowning. The cabin rapidly fills with water and the passengers must usually make an underwater escape, often in very difficult circumstances, e.g. disorientation due to the rotation of capsize, poor visibility (underwater without a face mask or goggles and sometimes at night), shock and panic.

Even when equipped with immersion dry suits, breath-hold times in typical sea water temperatures (and especially hostile areas such as the NS) are less than 20 seconds and can be as little as 6 seconds (see CAA Paper 2003/13, and Appendix A, Item 14 above), limited primarily by the effects of cold shock. Evidence from escape trials in HUETs indicate escape times ranging from 27 to 92 seconds (see CAA Paper 2003/13, and Appendix A, Item 14 above), the longer times corresponding to passengers in inboard seats who have to wait their turn to escape. There is therefore a demonstrated and widely known and accepted mismatch between breath-hold time and escape time for at least the middle-seat passengers.

Although this hazard can be mitigated to some extent through the deployment of an EBS (see Risk Matrix Items 20/21), the reliance on passenger survival skills and the lack of any mandate for survival training for passengers renders this solution less than ideal.

A better mitigation has been proposed in the form of the provision of an air pocket in the cabin into which passengers can rise before making their escape. This would give passengers time to overcome disorientation, shock and panic, and is precisely the safety feature employed in a number of the HUETs that the offshore workforce are exposed to during the training mandated by their employers. In addition, it is understood that an air pocket was fortuitously available in the accident to the G-WNSB in August 2013 (due to failure of one of the forward floats and detachment of the tail boom), which prevented a larger number of fatalities.

Providing an air pocket in the cabin large enough for and accessible to all passengers in the event of a post-ditching capsize with all of the EFS assumed to be functioning correctly has been demonstrated to be possible (see CAA Paper 97010, and Appendix A, Item 9 above, as well as EASA.2007.C16, Study on Helicopter Ditching and Crashworthiness) and effective (see CAA Paper 2001/10, and Appendix A, Item 13 above).

Achieving the same result in a survivable water impact with the EFS failures expected would present more of a challenge, both from the perspective of design and rulemaking. In particular, the nature and extent of damage to be accommodated could not sensibly be defined. A study performed on a scheme designed to provide an air pocket for all passengers (see CAA Paper 2001/02, and Appendix A, Item 12), however, indicated that a useful air pocket could be expected in around 70–80 % of survivable water impacts. Although the air pocket may not be large enough for all passengers to use in every case, it would still represent a significant improvement. This assertion assumes that passengers



seated immediately next to the push-out windows (underwater escape exits) would be able to quickly and efficiently make a successful escape and would therefore have less need for an air pocket.

Note that the validity of this assumption would be enhanced, were the recommendations of Risk Matrix Items 22–36 to be implemented.

The minimum size of an air pocket required for the ‘post-ditching capsized’ case should be determined from the size and shape of airspace required by each individual passenger, and should be provided where it can be directly accessed by the passenger from the seated position following seat belt release. The height of the air pocket needs to be sufficient to accommodate the height of the occupants’ heads. Anthropometric data indicates the 95th percentile head height to be 25.5 cm, hence an air pocket height of 30 cm would be reasonable. In terms of the horizontal area required, logically and for consistency, this should take the form of an ellipse of 26 x 19 in. This results in a volume of 75 l for each passenger, with a minimum height of 30 cm.

#### Recommendation

Although a prescriptive CS containing the provision for an air pocket should not be proposed, due to the possibility of other as yet unidentified acceptable solutions, suitable AMC should be developed to specifically address the air pocket due to it being the only currently identified design solution.

#### **Item 20 — EBS**

EBS has the potential to mitigate the consequences of capsized following a ditching or a water impact by helping to overcome cold shock and extending underwater survival times. EBS was first considered for civilian use by a joint industry review (see CAP 641, hereinafter the ‘RHOSS Report’, and Appendix A, Item 5 above), following the fatal accident to G-TIGH near the Cormorant Alpha Platform in the NS in 1992. Although already deployed by military operators, the conclusion at that time was that there was no clear advantage to be gained from the introduction of EBS and that, on the evidence available, the UK CAA would not be justified in pursuing this as a regulatory measure. The review considered that the chances of successful underwater escape might be more reliably improved by measures aimed at facilitating egress. The review of EBS is summarised in Annex L to the RHOSS Report (see Appendix A, Item 5 above).

Nevertheless, the offshore oil and gas industry voluntarily developed and deployed EBS for its workforce. This led to a detailed review of the implementation and use of EBS reported in CAA Paper 2003/13 (see Appendix A, Item 14 above). The UK CAA concluded from the review that, given the benefits and potential issues with EBS, there was no compelling case to either mandate or ban the use of EBS. If EBS were to be used, however, care should be taken to ensure that the equipment and associated training are designed and implemented in a manner that will truly provide a net safety benefit; compatibility with other safety and survival equipment and systems is particularly important. The equipment should also be fit for purpose, and its limitations should be made clear to users.

The UK CAA was therefore of the view that a technical standard was needed, and that any EBS deployed should meet that technical standard. Work on producing a technical standard was consequently commissioned, and was completed and published in CAP 1034 in May 2013 (see Appendix A, Item 19 above). The technical standard encompasses two versions of EBS which reflect two levels of performance, Categories A and B. The key differences between the two versions are:



- Category A EBS is deployable underwater and within the expected breath-hold time of 10 seconds (12 seconds including the nose clip); and
- Category B EBS is deployable in air within 20 seconds (judged to represent a reasonable period of notice in the event of a ditching).

Category A EBS is designed to mitigate the water impact scenario where little or no notice of capsizing and rapid submersion is to be expected, and a capability for underwater deployment is therefore required. Category B EBS is only capable of addressing the ditching scenario where the opportunity for above-water deployment will usually be available.

Despite its limitations, EBS is considered to have the potential to mitigate the safety risk associated with water impact/post-ditching capsizing in the short-to-medium term, pending availability of design solutions such as improved EFSs (i.e. air pocket). EBS is available and relatively inexpensive; two products have been certified as compliant with Category A by the UK CAA against the CAP 1034 technical standard, and a third is presently in process. In addition, EBS does not require any modification to the aircraft to deploy so it is equally suitable for both new aircraft and the existing fleet.

Finally, EBS, in one form or another, is already used in all European offshore helicopter operations and, following its review of offshore helicopter operations published in CAP 1145 (see Appendix A, Item 18 above), the UK CAA mandated CAP 1034 Category A EBS for UK operations.

#### Recommendation

EBS meeting CAP 1034 Category A standards should be mandated by the Air Ops Regulation for all offshore helicopter operations.

#### **Item 21 — EBS**

See Item 20 above.

#### **Item 22 — HUET training**

While the Agency has a role in ensuring passenger briefings are given prior to flight, it is not at all clear that the issue of passenger training, in relation to their experience and ability to operate safety equipment, falls within the Agency's remit. Furthermore, putting the obligation of training passengers on the operators would appear to be an undue burden.

If passenger training is a concern, it could be seen as the responsibility of the employer (the oil and gas industry in the case of most NS operations) to train their employees appropriately against all hazards that they are likely to face as part of their employment, including flying if this is an essential part of the job.

Basic offshore safety induction and emergency training (BOSIET) or equivalent, which includes use of EBS, sea survival and helicopter underwater escape training, is mandated by employers for most offshore employees. The Agency should not be directly involved.

No recommendation is made.



**Item 23 — Illuminated exit markings**

Both CS-27 and CS-29 require that exits be marked in order to aid in their location and operation, and that the markings remain visible in darkness.

Both CSs also specifically require the markings (for rotorcraft certified for ditching) to remain visible with the rotorcraft capsized and the cabin submerged.

In the case of a capsized and flooded cabin, an occupant will become rapidly disorientated. In such circumstances, visually locating, moving towards, and operating an emergency exit will be best aided by illuminated markings which outline the entire exit aperture and which provide a clear highlight as to the exact location of the operating device (handle, pull tab etc.). The current rules do not specify markings with these characteristics.

However, such markings have been installed on rotorcraft equipped for ditching for many years in response to NAA action (e.g. UK CAA AWN 27), but the current CS-27 and CS-29 do not specify such a standard.

In addition, the RMG considered that further improvements to the definition and standardisation of the markings could be made.

**Recommendation**

It is recommended that CS-27 and CS-29 and related AMC be amended to better define exit markings required for rotorcraft equipped for ditching.

**Item 24 — Goggles**

A significant factor in making an underwater escape from a submerged/flooded helicopter cabin is the ability to see properly underwater. The availability of a diving mask or swimming goggles would address this issue at low cost, and could also help survivors once on the surface in rough seas. Furthermore, a diving mask could provide a better solution to the nose occlusion issue associated with EBSs (see CAP 1034, and Appendix A, Item 19 above).

In Canada, diving masks have been mandated for all passengers flying offshore since 2009. The masks are stowed under the seat while not in use, however, most passengers wear the mask on their sleeve during transit after adjusting it for fit. Use of the mask is included in the preflight briefing and in the safety and survival training.

To some extent, designing a mask that would fit a wide range of face shapes and sizes would be as difficult as the nose clip problem. There is also the issue of deploying the mask underwater. The mask would need to be cleared, as scuba divers need to, which would effectively dictate the use of compressed-air EBS. Goggles cannot be cleared underwater so they would only be effective if deployed prior to submersion.

Although the benefit of a mask or goggles, once correctly deployed, is undeniable, the question is how likely it is that passengers will be able to deploy the equipment effectively in a real emergency. If a mask is used as a means of nose occlusion then there is also the issue of the overall deployment time for the EBS to consider; the CAP 1034 specification stipulates a maximum total deployment time of 12 seconds.



In view of the uncertainty regarding the practicality of realising the benefit of masks or goggles, it is considered appropriate that their use remains a choice for individual states and/or operators to make.

#### Recommendation

No further action by this RMT.

#### **Item 25 — Ensure all suitable fuselage apertures are available for underwater escape**

The human breath-hold capability, particularly in cold water, is incompatible with escape from a capsized rotorcraft unless egress can be made quickly.

For this reason, and for many years now, the Air Ops Regulation has required that all suitable openings (i.e. windows) in rotorcraft be made openable and thus available for escape, i.e. in addition to the emergency exits required by the current rules. This pragmatic approach to increasing safety does, however, beg the question as to what constitutes a suitable opening for escape. Rotorcraft are provisioned with windows of varying sizes and shapes. Various minimum dimensions have been proposed as those below which windows should remain unopenable due to the risk of occupants becoming trapped. The choice of minimum dimensions has always been complicated by the dilemma that whilst a large person attempting to escape through a particular opening may become trapped, a smaller person might find the opening perfectly adequate. The optimum choice for a particular window is thus far from clear.

On the other hand, this RMT is primarily concerned with the creation of amended rules applicable only to future new rotorcraft designs for which the designer can anticipate such issues.

A review of recent rotorcraft designs shows that in the case of CS-29 types several emergency exits meeting at least the minimum dimensions of the Type IV have been provisioned. Work in connection with CAP 1145 has confirmed that even with the large spread of body size in the offshore workforce population, the Type IV exit is sufficiently large to provide an adequate underwater escape facility for all.

It is to be noted that the current rule for ditching exits, in fact, requires a Type III exit on each side of the rotorcraft for seating capacities above nine (note that two Type IV exits on each side have been accepted via an equivalent safety finding) although the 'non-ditching exits' rule (CS 29.807(b)) does not require any exit larger than a Type IV until a seating capacity of above 19. It is not clear why the ditching exit rule has this higher-size provision. In regard to the ability to board the life rafts, the RMG could see no reason why specifying this size of exit provided for good characteristics, and the studies performed in connection with CAP 1145 did not indicate that Type IV exit dimensions were in any way inadequate for underwater escape. It is therefore proposed that no ditching exit above the size of a Type IV be required.

It is therefore proposed that the amended CS 29.807 will require that one Type IV emergency exit be provided on each side of the rotorcraft for each unit or part of a unit of four passengers. The reason for specifying it this way is in order to be possible to arrange the seats in the cabin such that all passengers can then have the opportunity to be no later than the second person to escape through an exit, i.e. with a nominal four-abreast seating layout. This latter aspect is proposed to be covered under CS 29.813 (see Item 26 below).



Although the review of recent rotorcraft designs indicated that the installation of only apertures meeting the dimensions of the Type IV exit would not be a problem, it is to be noted that some types do offer five-abreast seating, i.e. the centre-seat occupant(s) must wait for two other persons to make their escape before being able to do so themselves. The RMG was in agreement that this should not be an acceptable design in the future due to the fundamental breath-hold problem.

The proposed new rule text will allow for pairs of exits large enough to allow the simultaneous egress of two passengers side by side, which will be given credit equal to two exits, i.e. for a unit of eight passengers.

In the case of CS-27, the current rule requires one emergency exit on each side of the cabin readily accessible to each passenger. This exit must provide an unobstructed opening that will admit a 0.48 m x 0.66 m (19 in. x 26 in.) ellipse. These two-axis dimensions are the same as the width and height dimensions required for a Type IV exit. Work in connection with CAP 1145 has confirmed that when necessary, an emergency exit meeting this ellipse provision can also be considered sufficiently large to provide an acceptable underwater escape facility for even the largest person. In the context of CS-27, it is therefore considered acceptable to leave this part of the rule unchanged.

However, the provision of only one exit per side of the cabin is questionable. A CS-27 rotorcraft can have a passenger seating capacity of up to nine, and it is not conceivable that this number of persons could all make an underwater escape through only two exits.

On the other hand, rotorcraft not capable of carrying more than four passengers will align with the concept discussed above of no occupants being in a position worse than the second person to egress through an exit, without the need for any rule change.

Rotorcraft that are capable of carrying five to nine passengers do need more consideration. In order to provide a basis of comparison, a review of such existing CS-27 types was made. It was concluded that only relatively small changes would have been necessary for those types, i.e. to incorporate a second unobstructed opening in each side of the cabin admitting the required ellipse. Accommodation of nine passengers would most likely be achieved by three rows of three seats, in which case three ellipse openings per side would be required anyway by the existing rule. A layout of one row of five seats and one row of four would present a problem, and it was concluded that for similar reasons to those discussed above for CS-29, such a layout should be prohibited.

#### Recommendations

- (a) CS 29.807 should be amended to require that one Type IV emergency exit be provided on each side of the rotorcraft for each unit or part of a unit of four passengers.
- (b) CS-27 should be amended to require that one emergency exit (meeting the ellipse provision) be provided on each side of the rotorcraft for each unit or part of a unit of four passengers.

#### **Item 26 — Cabin layout, and alignment of seat rows with exits**

As discussed in Item 25 above, a good number and size of emergency exits can only provide for good underwater escape capability if the seating layout relative to the exits is optimised. In an underwater escape situation, occupants need to be able to make very rapid and instinctive movements towards their nearest exit.



### Recommendation

Seats must not be installed such that they overlap with any part of the required Type IV exit apertures. Some overlap of seat backs with openable windows has been a questionable feature of some rotorcraft in the past because these exits were not required by CS-27 and CS-29 but by the Air Ops Regulation. By requiring several Type IV exits in the future, this practice will be prohibited by the existing provision (CS 25.813(c)) that unobstructed access be provided to Type IV exits.

### **Item 27 — Ease of operation**

It is of paramount importance that when an occupant approaches an exit, its means of operation is clear. CS-27 and CS-29 require that the means of opening each emergency exit be simple and obvious and do not require exceptional effort. Furthermore, both CSs also require that emergency exits be clearly marked, including in darkness.

There are, however, several design pitfalls by which these objectives might be compromised, such as configurations that cannot be operated one-handed, inadequate illuminated markings, operating handles remote from the exit, operating handles/pull tabs that cannot be grasped with a gloved or cold hand, and designs which require a push force that cannot be easily produced by a person floating free in a submerged cabin.

### Recommendation

AMC to CS 29.809(c) and CS 29.811(a) is proposed in order to more clearly point out unsatisfactory design features.

### **Item 28 — Handholds adjacent to doors/windows**

#### Background

Timely escape from a capsized helicopter is essential for survival. Escape time can be affected by a number of factors including ease of exit location and operation, and by buoyancy, as follows:

- Exit location: exit location is hindered by disorientation due to the rotation of capsized, poor visibility while being underwater without goggles or a face mask, and sometimes, darkness. The workforce is trained to maintain hand contact with their adjacent push-out window to assist orientation. This is possible in HUETs as they are usually not fitted with windows, but not feasible in an actual rotorcraft because the window is in place and there is nothing to hold on to.
- Exit operation: most occupants make their escape via the underwater escape exits (push-out windows). In water impacts, survivors often have no recollection of opening exits, and it is suspected that push-out windows are usually forced out in the impact. However, some difficulties in opening push-out windows have been reported, and it might be difficult to apply sufficient force to the window without a handhold, especially if the occupant is floating free in the cabin.
- Buoyancy: the human body is naturally buoyant and this buoyancy is significantly increased by the immersion dry suits that are worn. Until out of the helicopter, buoyancy can be very unhelpful. Once the seat belt is released, the occupant will float up away from the exit unless a



firm handhold is maintained. The higher the window on the cabin wall, the deeper it will be following capsizing, and the greater the difficulty to reach it due to buoyancy.

All of the above problems can be mitigated by the provision of a handhold for each occupant adjacent to their underwater escape exit, reducing escape time and improving survivability. The handhold provides an anchor for exit location and operation, and enables the occupant to pull himself down to the exit against his buoyancy. Handholds should be mounted close to the bottom edge of each push-out window such that they fall easily to hand for the seated occupant, and are reachable for an occupant in the capsized rotorcraft, immediately above the ditching emergency exit (flooded, capsized cabin). They must also be solidly attached to the fuselage structure.

In addition, the potential confusion caused by the lack of standardisation of the location of the operating tabs for push-out windows could be addressed by locating them next to the handhold. The occupant then has only to find his hand on the handhold, and with his other hand, to locate the operating tab.

#### Recommendation

Rules should be amended to require handholds be mounted adjacent to each push-out window.

#### **Item 29 — Jettisoning of doors**

A fairly common design configuration for helicopters comprises a sliding door on each side of the fuselage for normal entry/egress. These doors are such that when open, they overlap one or more windows, removing the possibility to use them as underwater escape exits.

In the event that a sliding door were to be opened prior to, or soon after, a ditching, and the helicopter were then to capsize when occupants were still on board, some occupants may be unable to escape.

This NPA includes proposals that the normal entry/exit doors be opened and used in order to aid post-ditching life raft entry. In the light of this apparent contradiction, it was considered that perhaps such sliding doors should be mandated to be jettisonable.

However, in the case of CS-29 and CS-27 Category A types, enhanced survivability features are required post capsizing, thus providing a mitigation of this relatively unlikely situation, and CS-27 non-Category A types tend not to have such exit configurations.

It is thus concluded that there is no need to introduce rules requiring certain exit layout designs to incorporate jettisoning features.

On the other hand, were occupants to find themselves in a capsized helicopter with a sliding door overlapping their immediately available escape route (e.g. a push-out window), there must still be a viable egress option. This may be by making their way to the opened sliding door aperture, or if push-out windows in the fuselage and opened sliding doors are by design aligned, by operating two push-out windows in succession.

#### Recommendation

It is thus recommended that AMC be developed to indicate that the applicant should assess and substantiate that a viable egress option is available from a capsized CS-29 or CS-27 Category A helicopter.



**Item 30 — Preflight briefing**

A preflight briefing is mandatory for all passengers (CAT.OP.MPA.170), as is provision of a safety card showing the operation of emergency equipment and exits likely to be used by passengers. In offshore operations, the required demonstration of the safety harnesses' and life jackets' use is provided by video before each flight (in the unlikely event that a video is not available offshore, a member of the flight crew is required to demonstrate these). The safety cards are specific to aircraft type and, if necessary, to airframe if, for example, the location of emergency equipment or operation of emergency exits is different. Ditching procedure, and operation of the emergency exits, push-out windows and life rafts, are also covered in the video briefing. This briefing is only valid for one day so if a flight is cancelled and the passenger has to fly the following day, they must watch the video again.

**Recommendation**

No further action is required.

**Item 31 — Exit standardisation**

When considering the ease of use and operation of exits, one of the main problems is the wide range of mechanisms found in different helicopter types, their various positions in relation to the exit and the different directions of operation (see RHOSS Report, 10.18 and 14.2 (k), and Appendix A, Item 5). The RHOSS Report recognised that it must be possible to operate emergency exits in a crash scenario when individuals *may not act in a deliberate and rational manner*. A review by Brooks and Bohemier (1997) of helicopter door and window jettison mechanisms for underwater escape identified 23 different door, hatch and window release mechanisms in 35 different types of helicopter. They found neither standardisation between helicopter types nor any standardisation in individual designs of helicopter. Some exits required rotation of a lever in a clockwise direction, some in an anticlockwise direction, some a pull, some a push action. While many required single action, some needed a double one. The position of the operating mechanism differed widely.

The RMG discussed the safety advantages and feasibility of introducing airworthiness provisions aimed at creating more standardisation among different designs. It was considered that reduced variation in designs should provide safety benefits in terms of reduced confusion and opening delay in the situation of a capsized and flooded cabin, particularly bearing in mind the fact that passengers may fly on a number of rotorcraft types. However, after more careful consideration, it was concluded that suitable standardised design characteristics that could be specified for exits of a more mechanical configuration (sliding, hinged, removable hatch etc.) were not obvious, and that putting emphasis on the provision of good markings, highly visible in a capsized and flooded cabin, with a visual highlight on the operating handle, represented the most practical way of improving safety.

As regards ditching emergency exits, however, the majority of designs include lanyards or beading that must be removed before the window can be pushed out. Pull tabs are often located in many different positions, but it would be quite straightforward to modify that location. Standardisation of the location for these types of exits is therefore considered to be practical, and selection of a location adjacent to the handholds, as proposed in Risk Matrix Item 28, would appear to be logical as this would give the passenger the best possible chance of finding the pull tab in an emergency.

A design characteristic that was agreed for all exits, however, was that the operating handle, tab, 'push here' sign etc. be marked with black and yellow stripes.



### Recommendation

AMC to be created requiring:

- the location of pull tabs for push-out ditching emergency exits to be standardised, ideally immediately adjacent to the handholds; and
- ditching emergency exit operating handles, pull tabs, 'push here' signs etc. to be marked with black and yellow stripes.

### Reference

- Brooks C.J. and Bohemier A.P.: Helicopter door and window jettison mechanisms for underwater escape: ergonomic confusion, *Aviat Space Environ Med.*, 68 (9): 844-857, September 1997

### **Item 32 — Optimise seat belt design**

During the side-floating helicopter egress trials, some problems were observed when subjects tried to release their harness buckle under an uneven load, requiring the application of more force to open it (see CAA Paper 2001/10, and Appendix A, Item 13). This was observed when subjects were suspended mostly out of the water on the upper side of the helicopter simulator after capsized. In two cases, subjects were completely unable to release the harness without the assistance of the training officer. This problem is not specific to the side-floating situation, with similar problems occasionally being encountered during standard training in the inverted simulator. It was considered that the regular immersion of the seat belts in the helicopter simulator could be a factor, but further investigation was recommended.

The specifications for seat belts are contained in ETSO-C22g and ETSO-C114 and, to a large extent, use the standards contained in Society of Automotive Engineers (SAE) International, Aerospace Standard (AS) Document No AS 8043, 'Torso Restraint Systems', issued in March 1986. The standard specifies the maximum force for operation of the seat belt release, but this is currently tested with only the lap strap part of the harness loaded. The load of 170 lb (76 kg) specified apparently represents the weight of a passenger 'hanging' on the lap belt portion of the harness, and it may have been assumed that the shoulder belts will not be loaded (after the initial impact) when inverted. In most cases, the shoulder straps are provided with locking retractors which are disengaged in the absence of any deceleration. This being the case, the assumption would seem reasonable. However, rather than to assume this, it would be better to make certain.

There is also the possibility of uneven loading in the event of the aircraft being neither fully upright nor fully inverted either by design (e.g. side-floating EFS) or due to a partial EFS failure. It would therefore be appropriate to modify the ETSOs to require testing of the release mechanism for correct operation under all foreseeable loading conditions, including uneven loading. This might be achieved by installing the harness on a representative aircraft seat and by using a manikin of an appropriate mass. As regards the mass, consideration should be given to increasing the current mass of 76 kg to reflect the general increase in passenger mass, e.g. to 98 kg, in line with other specifications such as for life rafts.

In addition, the ETSOs do not specify that where the release mechanism requires a twisting/torsional motion to operate, the mechanism should be bidirectional, i.e. it should operate whether turned clockwise or anticlockwise.



### Recommendation

ETSO-C22g and ETSO-C114 should be modified to:

- (a) require testing of the release mechanism for correct operation under all foreseeable loading conditions, including uneven loading; all of the harness straps must be correctly loaded, based on a passenger mass that is consistent with current anthropometric data and other ETSOs such as those for life rafts;
- (b) specify that where the release mechanism requires a twisting/torsional motion to operate, the mechanism must be bidirectional, i.e. it should operate whether turned clockwise or anticlockwise.

### **Item 33 — Minimise harness/PPE snagging risk**

Given the very limited time available for escape, anything that can slow progress must be avoided. Problems have been encountered in releasing seat belts and entanglement with seat belts, particularly with UTR and additional PPE such as EBS. However, it was concluded that the state-of-the-art design of PPE minimises this risk.

In the past, another issue has been the inability to release headset cables and/or entanglement with headset cables, which has caused at least one fatality, so wireless headsets are now used. Again, it was concluded that this risk has been recognised and mitigated.

No recommendation for further action was identified.

### **Item 34 — Minimise PPE buoyancy**

See Items 40 and 50 below.

### **Item 35 — HUET training**

See Item 22 above.

### **Item 36 — Size of occupants**

A significant concern that has relatively recently emerged is the adequacy of the minimum exit sizes specified and, in particular, the minimum size of push-out windows, these typically being the smallest exits. The reason for the concern is the increase in passenger size since the minimum exit size was set, due both to a general increase in average body size of the offshore workforce and also an increase in the bulk of the PPE worn.

This has been addressed in the UK in response to Action A9 of CAP 1145 (see Appendix A, Item 20), and the following scheme has been mandated under UK CAA SD-2015/001 (extract from Annex 3 to SD-2015/001):

- 3.1 *Evidence from trials indicates that, for unobstructed rectangular exits, persons whose bi-deltoid (shoulder) width is less than the diagonal taken between the corner radii and whose maximum thorax (chest) depth is less than the width will be able to escape when wearing all required personal protective equipment (PPE – e.g. survival suits, life jackets, emergency breathing system).*



- 3.2 *The minimum aperture size acceptable for use as an underwater escape exit is defined as a diagonal measurement between the corner radii of 559mm (22") and a width of 356mm (14"). These minimum dimensions apply to the aperture available following operation of the exit as briefed (e.g. with the rubber seals in place for push-out windows, unless passengers are briefed to remove them prior to egress or it can be demonstrated that they will detach with the window). For non-rectangular exits or partially obstructed (e.g. by a seat back) exits, the exit must be capable of admitting an ellipse of 559mm x 356mm (22" x 14").*
- 3.3 *Passengers whose bi-deltoid (shoulder) width is greater than 559mm (22") must be allocated to seats having direct access to a Part-29.807 Type IV size (480mm (19") wide x 660mm (26") high) or larger exit. Means should be provided for readily confirming that larger passengers are correctly seated; this could be achieved through the use of patterned and/or colour-coded arm bands and matching seat headrests.*
- 3.4 *The means of opening underwater escape exits should be rapid and obvious, and involve no more than one simple action to release the exit prior to ejection of the exit. Underwater exit operation should be standardised at least within each helicopter type. Passenger safety briefing material should include instructions on the use of such escape facilities.*

This scheme has been developed to address the issue of passenger size/exit size compatibility for the existing NS helicopter fleet. It was implemented in the UK on 1 April 2015 and, thus far, there have been no significant problems. However, the need to segregate passengers by shoulder width presents logistical issues and is less than ideal; it would be better if all exits were large enough for the largest passenger.

Over 60 000 members of the offshore workforce have been measured during the implementation of SD-2015/001 with the following results:

Average shoulder width: = 49.7 cm

Maximum shoulder width: < 55.9 cm

From this data, it may be concluded that the size of a CS 29.807 Type IV exit is easily large enough for the largest passenger, obviating the need to measure passengers.

#### Recommendation

All required exits should be at least as large as a Type IV exit, as defined in CS 29.807. For non-rectangular exits or partially obstructed (e.g. by a seat back) exits, the exit must be capable of admitting an ellipse of 660 mm x 483 mm (26 in. x 19 in.).

#### **Item 37 — HUET training**

See Item 22 above.

#### **Item 38 — EFS Crashworthiness**

See Items 9 and 18 above.



## Item 39 — Evacuation procedures and ease of life raft boarding

### Introduction

Life rafts can significantly extend survival time for people in the water and are seen as an essential element of the ditching equipment carried in rotorcraft. Although passengers, when travelling offshore over hostile sea areas, are required to wear immersion suits which provide some protection should they end up in the water, their survival prospects will be much enhanced by being in a life raft.

In the course of reviewing the accident database, however, the usability and effectiveness of life rafts was highlighted as an area requiring further study.

The ease of boarding a life raft, with the helicopter rolling, pitching and heaving in the sea conditions, was considered to be questionable for some current designs. For instance, in many cases, the design requires that passengers enter the life raft by climbing through push-out windows.

### Discussion

A review of helicopters currently in service revealed that in some cases, life raft boarding did not require excessive agility whereas in others, whilst the intended procedure did involve potentially difficult manoeuvres, such as climbing through push-out windows and dropping into the raft, there was in fact a sliding door which could be used to greatly reduce difficulties.

The current provision that ditching exits be above the waterline has probably contributed to manufacturers not considering the opening of sliding doors, which, in most cases, would lead to a 'wet floor'. The RMG could see no reason to prohibit a wet floor and agreed that ditching exits no longer be required to be above the waterline, and that it was justifiable to require that passengers be able to step directly into the life rafts.

It was agreed, however, that due to the basic layout of helicopters, it would be impracticable to require that flight crew be provided with this ease of boarding and that with CS-27 types, realisation of the intent, even for passengers, may be unduly burdensome.

Automatic deployment of life rafts was also considered and concluded as potentially being a valuable feature, particularly in water impact events where manual deployment of the life raft from within the helicopter cannot be relied upon. Any design would need to consider the possible consequences of inadvertent deployment in flight. Possible damage from rotors or other debris would also need to be taken into account in the design but might be overcome by incorporating a delay in deployment once the rotorcraft enters the water or a link to the rotor speed. A water pressure switch to deploy the life raft, if the helicopter sinks, may also be a safety feature to consider.

However, it was concluded that sufficient evidence did not yet exist regarding the overall feasibility and desirability of automatic deployment to justify regulatory change at this time.

### Recommendations

- CS-29 should be amended to require that passengers be able to step directly into the life rafts in a ditching.
- The Agency should consider performing research into the feasibility and desirability of automatically deployed life rafts.



## Item 40 — Life jackets self-righting capability

### Aim

This item addresses the provision for self-righting within the helicopter immersion suit and constant-wear life jacket standards (ETSO-2C502, ETSO-2C503 and ETSO-2C504), and aims to address inconsistencies within the provisions of these standards.

NB: in February 2014, the UK CAA issued CAP 1145 'Safety review of offshore public transport helicopter operations in support of the exploitation of oil and gas'. This report included a recommendation (R5) *that offshore helicopter operators will address the following key items (...) ensure that all life jacket/immersion suit combinations are capable of self-righting.*

### Life jacket performance

A life jacket is an item of personal life-saving equipment designed to protect the wearer from drowning. To achieve this protection, the life jacket performs a number of functions:

- Buoyancy over the chest of the wearer provides a turning force which will turn the wearer from a face-down to a face-up position in the water. The turning force is dependent upon the distance between the centre of gravity of the body and the centre of buoyancy of the life jacket; the greater the distance, the greater the force.
- The buoyancy of the life jacket will also help to support the wearer in the water. However, when a life jacket is worn with a suit, the inherent buoyancy of the suit will support the person in a near horizontal position on the water surface. Uplift will be provided by the buoyancy which remains in the water; in most inflatable life jackets worn with an immersion suit, this means the buoyancy under the head and around the shoulders.
- Airways protection: buoyancy behind the head can be used to lift the level of the mouth above water level, reducing the likelihood of water ingestion. Buoyancy on either side of the head will also reduce exposure to wave splash as will the provision of a spray-hood.
- Stability: with the correct distribution of buoyancy, a life jacket can help to maintain the wearer in a face-up position.

Within general terminology, a life jacket is defined by its ability to turn an unconscious wearer into the face-up position in the water (a buoyancy aid will not turn the wearer).

Self-righting is the term used to describe a turning force which will turn the life jacket wearer from a face-down to a face-up position without any effort on the part of the wearer. Self-righting ability is affected by factors such as the amount and distribution of buoyancy in the life jacket, as well as the posture and the body angle of the wearer in the water. Optimum turning performance is generally achieved with a body trunk angle close to 45° below the horizontal. Self-righting can be difficult to achieve when an immersion suit is worn with the life jacket. The inherent buoyancy of the immersion suit, due to air trapped under the suit and clothing, may oppose the buoyancy and turning forces of the life jacket. An immersion suit will also generally place the wearer in a near horizontal position in the water, making it more difficult for turning to be achieved. It is therefore important to assess life jacket and immersion suit compatibility.



### Is self-righting performance necessary in a helicopter life jacket and immersion suit system?

When a life jacket is worn with an immersion suit, there is an expectation that the life jacket will turn the wearer and that self-righting can be achieved. There is little point in having a large amount of buoyancy on the chest of the wearer unless this is to serve the function of turning the wearer over into the face-up position.

It has been argued that self-righting performance is unnecessary in a helicopter life jacket. This view is based on the assumption that the occupants must be conscious to escape from the helicopter and inflate the lifejacket, and if conscious, can turn themselves onto their back. This does not take into account occupants who are badly injured or fatigued. In the case of the accident near the Cormorant Alpha Platform in 1992, one of the non-survivors was found floating face-down with his life jacket deflated due to a tear in the buoyancy chamber (AAIB, 1993, p. 31). This individual, therefore, successfully escaped from the helicopter and inflated his lifejacket, but later succumbed to drowning. Without a functioning life jacket, he failed to remain in a face-up position. Survivors in that accident reported being swamped by waves breaking over their heads (AAIB, 1993, p. 58). It is therefore possible that wave action had turned the non-survivor over. Alternatively, this may have occurred during a rescue attempt as one passenger was lost during this attempt (AAIB, 1993, p. 59).

It has previously been recognised that impact injuries frequently impair post-impact survivability (DOT/FAA/CT-92/14, 1993). An immersion suit with its inherent buoyancy is equally stable in the face-down and face-up postures. A badly injured or fatigued survivor may find it difficult to turn themselves onto their back and maintain that position, particularly in severe wave conditions. If they can manage to inflate the life jacket, it will do the work of turning them and keeping them in a stable face-up position. DOT/FAA/CT-92/13 (1993) pointed out that *the shock of a severe impact can impair occupant activity* and that *impact injuries can limit occupant performance*. In addition, survivors who are unable to board a life raft or are ejected from a life raft may become fatigued or lose consciousness due to exposure, and may therefore be unable to right themselves. Under such circumstances, a self-righting system could improve the likelihood of survival.

### Life jacket and immersion suit compatibility

To overcome the buoyancy of a suit, life jackets designed to be worn with a suit tend to be highly buoyant, in excess of 150 N. It is unfortunate that the higher the insulation level provided by a suit, the more difficult it is to provide self-righting performance. This means that a compromise may have to be made between design and performance, balancing the thermal performance of the suit (providing protection from the risks of exposure to cold) against the desire for self-righting (providing protection from the risk of drowning).

The preferred design of helicopter immersion suits varies in different jurisdictions and user groups. Where operations occur in areas with very cold sea temperatures, protection from cold and thermal insulation are given precedence over self-righting performance. For example, helicopter operations in Norway may result in exposure to very low sea temperatures, and helicopter passengers generally wear a high-insulation helicopter immersion suit, approved according to ETSO-2C502, with an integrated manually inflatable buoyancy lung which provides buoyancy behind the head (a buoyancy aid). These suits are very warm when cabin air temperatures are high. To help reduce the risk of thermal stress, the suits have a neck seal allowing the zip to be opened during flight. This could compromise survival chances in accidents with little warning and rapid capsizing. It would be difficult to



achieve self-righting given the insulation level in these suits. In this design of suit, used in areas with very low sea temperatures, the need for greater thermal protection against cold shock and hypothermia has been prioritised over the risk of drowning whilst awaiting rescue.

Somewhat higher sea temperatures over the year are experienced in the UK sector of the NS. Helicopter passengers in this jurisdiction generally wear an ETSO-2C503-approved helicopter immersion suit, with less insulation than the Norwegian-style suit, but which is worn fully sealed during flight. The UK-style suit is worn with a compatible ETSO-approved life jacket. Whilst self-righting can be achieved with this generic combination, there is uncertainty whether an ETSO-2C504 life jacket plus ETSO-2C503 suit combination is required to provide self-righting performance. This will depend on whether the provisions of the life jacket ETSO or suit ETSO are seen to take precedence over one another as ETSO-2C504 requires self-righting while ETSO-2C503 and ETSO-2C502 do not. Compatibility of a suit when worn with a life jacket is a provision in each of the standards.

#### Current ETSO provisions

The helicopter constant-wear life jacket standard (ETSO-2C504) has a scope which applies to life jackets designed to be worn with or without an approved immersion suit. Clause 5, compatibility, states that certification of a life jacket according to this specification shall take into account the compatibility between the life jacket and any approved immersion suit that is intended to be worn with it. This implies that the provision of ETSO-2C504 will apply to any life jacket and suit combination, as well as to a life jacket worn without an immersion suit. When considering self-righting performance, ETSO-2C504 states that *the inflated lifejacket shall automatically turn an unconscious wearer from a face down position into the position required by paragraph 8.1 within 5 seconds*. This suggests that whether worn alone or with an immersion suit, the life jacket is required to right the wearer. This approach is consistent and it would be hard to argue that a lifejacket should right a helicopter occupant wearing normal clothing but not one wearing an immersion suit.

Conversely, in both of the helicopter immersion suit standards (ETSO-2C502 and ETSO-2C503), it is stated that the suit, whether inflated or worn with an inflated life jacket, shall allow the wearer to turn from a face-down position into a stable face-up position within 5 seconds. This requires effort on the part of the wearer, who must therefore be fully conscious and physically capable of turning over in the suit under all wave conditions, throughout the survival phase. This is different to the performance provision within the helicopter constant-wear life jacket standard.

ETSO-2C502 applies to integrated immersion suits which are defined as those which incorporate the functionality of a life jacket. The wearing of a separate life jacket is not required. As the functionality of a life jacket would normally be understood to include self-righting ability, this suggests that turning performance would be expected. However, there is no provision for an integrated immersion suit to turn the wearer without any effort on the part of the wearer. This is inconsistent with the provisions of ETSO-2C504 where the functionality of a life jacket is defined by its performance provisions.

SPA.HOFO.155, Additional procedures and equipment for operations in a hostile environment, in its reference to life jackets, also suggests that an integrated survival suit should meet the combined provisions of a suit and life jacket: *Life jackets shall be worn at all times by all persons on board unless integrated survival suits that meet the combined requirement of the survival suit and life jacket are worn.*



### Conclusion

Aviation life jackets are required to provide self-righting performance. The current rules suggest that the functionality of a life jacket should be provided whether or not a separate life jacket is worn with the helicopter immersion suit.

When considering the current ETSOs, it is not clear whether a life jacket, when worn with an immersion suit, is required to turn the wearer.

Injured and fatigued survivors, in particular, may find it very difficult to turn and maintain themselves in the face-up position in severe wave conditions. A provision for self-righting performance for both integrated suits and life-jacket and suit combinations could improve the likelihood of survival.

The only exception to this provision should be, when the prevailing sea temperatures are low enough, to require a suit with a high level of thermal insulation that would not allow self-righting to be achieved.

### Recommendations

Self-righting should be a provision within the ETSO-2C502 and ETSO-2C503 performance standards to enhance the level of protection from drowning.

ETSO-2C502 applies to integrated immersion suits which incorporate the functionality of a life jacket. It is therefore recommended that ETSO-2C502 should be amended to ensure that self-righting is required by the integrated immersion suits, and that it is consistent with the provisions of ETSO-2C504:

*9.4 The inflated suit shall ~~allow the wearer to~~ automatically turn an unconscious wearer from a face down position into a stable face up floating position within 5 seconds. This shall be demonstrated by testing to paragraph 3.2 of Appendix 2. 5.6.6.3, the leg release righting test of EN ISO 12402-9: 2006\* or equivalent.*

ETSO-2C503 applies to helicopter crew and passenger immersion suits that are designed to be used with an approved life jacket. It is therefore recommended that ETSO-2C503 should be amended to ensure that self-righting is required by the life jacket and suit combination, and that it is consistent with the provisions of ETSO-2C504:

*4.4 The immersion suit ~~when worn with the~~ and inflated lifejacket combination shall ~~allow the wearer to~~ automatically turn an unconscious wearer from a face down position into a stable face up floating position within 5 seconds. This shall be demonstrated by testing to paragraph 3.2 of Appendix 2. 5.6.6.3, the leg release righting test of EN ISO 12402-9: 2006\* or equivalent.*

\* NB: the references to EN ISO standards need to be updated in all three related ETSOs.

### References

- [Air Accidents Investigation Branch \(AAIB\): Report on the accident to AS 332L Super Puma, G-TIGH, near the Cormorant 'A' platform, East Shetland Basin, on 14 March 1992, Report No 2/93. London: HMSO, April 1993](#)
- [UK CAA: CAP 1145, Safety review of offshore public transport helicopter operations in support of the exploitation of oil and gas, 20 February 2014](#)
- [FAA: DOT/FAA/CT-92/13, Rotorcraft Ditchings and Water-Related Impacts that Occurred from 1982 to 1989, Phase I, Final Report, October 1993](#)



- [FAA: DOT/FAA/CT-92/14, Rotorcraft Ditchings and Water Related Impacts that Occurred from 1982 to 1989, Phase II, Final Report, October 1993](#)
- [EASA: \(2006a\), ETSO-2C502, Helicopter Crew and Passenger Integrated Immersion Suits](#)
- [EASA: \(2006b\), ETSO-2C503, Helicopter Crew and Passenger Immersion Suits for Operations to or from Helidecks Located in a Hostile Sea Area](#)
- [EASA: \(2006c\), ETSO-2C504, Helicopter Constant-Wear Lifejackets for Operations to or from Helidecks Located in a Hostile Sea Area](#)

#### Item 41 — External carriage and release of life raft

Life rafts can significantly extend survival time and are therefore very important. For maximum benefit, survivors should avoid getting wet if at all possible and enter the life raft nominally 'dry-shod' (although a 'wet floor' is accepted in the proposed AMC to CS-27 and CS-29).

As a result of difficulties encountered in accessing and deploying life rafts stowed within the cabin, many offshore helicopters now carry externally mounted life rafts. Although provision is made for external deployment, the location of the operating handles on most helicopters is such that they are underwater after the rotorcraft has capsized; hence, this needs to be addressed. There have also been some issues with deployment involving tangling of mooring lines and survival pack lines, and the need for improved deployment assessment/testing as well as a formal technical standard for external life rafts has been identified. The current ETSOs are written on the assumption that the life raft will be manhandled to a door and manually launched. As explained below, it is concluded that this should not be acceptable for future designs and, thus, the ETSO should be amended to cover such designs. In addition, although life rafts are designed to cope with conditions up to SS 6 ( $H_s = 6$  m), they can be very difficult to deploy in wind speeds normally associated with these sea conditions.

Extract from the RHOSS Report, 1995:

(...)

8.8 *Life rafts are carried as aircraft equipment, in accordance with Scale K of Schedule 4 of the ANO, but there are no detailed airworthiness requirements for the method of installation and release. The raft must be capable of being launched under all circumstances in which a successful ditching may be performed, but this may be demonstrated by throwing the raft from an upright helicopter on dry land. There are at present a number of possible mounting and launching options, but none appears to cater for all possible eventualities. The arguments over internal versus external carriage are finely balanced – external mounting makes it more likely that the raft will be available if the aircraft sinks quickly, but leaves it vulnerable to damage in a heavy ditching and might make it unreachable if the aircraft does not float on an even keel. Internal carriage is likely to improve a raft's survivability in a heavy impact and might make it possible to launch it from either side of the aircraft; however, it would require a certain amount of manhandling by passengers or crew and would preclude automatic and/or remote launching. We endorse the view, expressed in both the AIB and Sheriff's reports, that an externally mounted raft is more likely to be of use in the case of an unexpected and/or violent impact with the sea; under such circumstances it is highly desirable that the life raft should be released automatically without the need for any action by crew or passengers.*



- 8.9 *We believe that there are five conditions which need to be catered for in a future requirement, namely:*
- (a) A facility for the crew to launch the liferaft by a single action from their normal crew position; this would not require any passenger involvement.*
  - (b) A facility for the raft to be launched from within the passenger compartment with the aircraft in an upright attitude. This might be performed by a crew member or, if a crew member were not available, by a passenger.*
  - (c) In the event of failure of a. and b. above, and perhaps with the rotorcraft capsized, the raft(s) should be capable of release by a crew member or passenger from outside the hull.*
  - (d) As a 'last chance', if all three of the above measures had failed, the raft should be released automatically after a certain period of immersion or at a predetermined depth if the aircraft sinks.*
  - (e) Finally, it should be possible for a helicopter to drop at least one of its rafts to survivors from another helicopter which has ditched or crashed.*
- 8.10 *Some research into methods of life raft carriage is already being undertaken by one operator under the auspices of HSSG, but we believe that this topic is of sufficient importance for the CAA to commission a comprehensive study with a view to issuing more specific regulations for life raft carriage and release. Guidance is needed on the general principles to be met when designing life raft systems, along the lines indicated above, and the requirement should include the need to demonstrate each system in typical situations, for example using something similar to the Den Helder facility recently employed by Shell for cabin evacuation trials.*

(...)

[Extract from UK AAIB, Air Accident Report 1/2011 G-REDU \(ETAP\):](#)

Reference is made to CAA paper 2005/06 which in turn makes reference to HOSS/WP-99/8.5 and includes, on the subject of 'life raft installation', the proposals that:

(...)

- 'a) FAR/JAR be amended to require design of life-raft installations incorporating the following principles:*
- primary deployment by single action from normal crew positions.*
  - secondary deployment from passenger compartment with the cabin in an upright attitude, and*
  - deployment possible from outside the helicopter when in either an upright or capsized attitude.*

(...)

These deployment options will only be of use if the life raft can in fact deploy successfully and reliably from its enclosure with the rotorcraft in any floating attitude. In case the rotorcraft is capsized, this may present challenges because the life raft installation location may be underwater. Depending on the chosen floating attitude when capsized (for example if a side-floating scheme is chosen), the life



raft stowage location will need to be carefully chosen in order to assure that the life raft can deploy onto the water surface without becoming trapped by the general shape of the rotorcraft or by any other feature which might snag or otherwise hinder the life raft making its way to the water surface, fully inflated and undamaged. Various possibilities of capsized floating attitude were considered and it was concluded that design of suitable stowage locations and deployment/inflation methods will be feasible.

#### Conclusion and recommendations

Consideration should be given to the location on the rotorcraft of any externally mounted life raft(s) with particular emphasis to protection from impact loads and damage and to reliable deployment of each life raft with the rotorcraft in any foreseeable floating attitude.

There should be three means of release:

- (a) in the cockpit, accessible to either crew member from their normal position;
- (b) accessible from the passenger cabin (and if in the cabin, protected by transparent frangible cover to prevent inadvertent deployment); and
- (c) externally, adjacent to the life raft container and accessible from the water in any foreseeable floating position.

There should be clear indicator markings showing the location of external deployment handles.

#### **Item 42 — Reversible or self-righting life rafts**

There are two standards for life rafts, ETSO-2C70b (to be replaced with ETSO-C70b) and ETSO-2C505.

The first of these is intended for fitment on any type of aircraft, with fixed or rotary wings, and allows for the raft to be either reversible (i.e. directly usable irrespective of the orientation it assumes upon inflation) or such that if it were to assume an upside-down orientation, a single person in the water would be able to right it.

The second of these standards is intended for fitment only to rotorcraft operating to or from helidecks located in a hostile sea area, and requires the design to be reversible or self-righting in the fully inflated condition.

#### Recommendation

It is not proposed that any changes need be made to these standards.

#### **Item 43 — Introduce double-chambered life rafts**

The standards for life rafts, ETSO-2C70b (to be replaced with ETSO-C70b) and ETSO-2C505, all require a multiple-chambered design, and that occupancy up to the overload capacity be supported with the critical chamber deflated.

#### Recommendation

It is proposed that these standards need not be amended in this regard.



**Item 44 — Use of a sea anchor to stabilise the rotorcraft**

It is clear from wave tank model tests that helicopters demonstrate a greater resistance to capsize in the presence of wind. This is due to a tendency to act as a weathervane, i.e. turn into the wind and waves. It follows that any device which promotes the adoption of a nose-to-wave heading would be beneficial to the survival of the helicopter.

Sea anchors work by providing a source of drag, which, when applied to the nose of the helicopter, will add to the weathervane forces turning the helicopter into the waves. Sea anchors are usually made of cloth, shaped like a parachute or cone, and rigged so that the larger end points in the direction of the helicopter's movement. When deployed, this type of sea anchor floats just under the surface, and the water moving past the sea anchor keeps it filled.

There are practical difficulties in deploying sea anchors, however. They take time to deploy and do not provide any benefit until fully deployed. There has been at least one reported incidence of a helicopter fitted with a sea anchor capsizing before the anchor fully deployed (see Annex D to Appendix A to CAA Paper 2005/06, and Appendix A, Item 15 above). Sea anchors can therefore not be relied upon to reduce the occurrence of capsize and they are not widely used in practice.

**Recommendation**

A sea anchor should not be relied upon to improve the seakeeping performance of a ditched helicopter. It should be made clear that the required scale model wave tank testing for flotation/trim substantiation should not include a sea anchor even if one is to be provided.

**Item 45 — Provision of safety knife in flight crew suit**

It has always been standard practice to carry a knife attached to flying clothing in military operations, but this practice has not been widespread in civil operations (with the exception of SAR), recently in part because of the difficulties that would be presented due to standard airport security measures.

There have been various cases of life rafts failing to deploy properly because the painter and/or rescue pack lines had been tangled around the raft (for example, the port raft of G-CHCN, see [AAIB Report No 2/2014](#)) or had been blown up against the side of the aircraft and had had lines cut in an attempt to free the raft (for example, LN-OPB in 1996, see [AIBN Report No 1998/02](#)). In the case of G-CHCN, the co-pilot did not have a knife but managed to untangle the lines after a few minutes, which allowed the raft to deploy correctly. The commander did have a knife attached to his flying suit, which he used to cut the mooring lines of the starboard raft because the raft's knife had fallen overboard from its sheath (although it was later recovered by its securing line).

In recent years, 'seat belt cutters' or variations thereof have come into widespread use in motor vehicles as well as in other professional operations such as diving and fire and rescue. These cutters have shielded safety blades such that they cannot cause injury but they can quickly cut thin lines, seat harnesses, webbing or similar material. CHC Helicopter is in the process of issuing such a device for all UK flight crew, looking at a worldwide roll-out.

**Recommendation**

A safety knife or belt cutter should be required by the Air Ops Regulation for all flight crew survival and flight suits. Consideration should be given to the provision of such a device for passenger survival suits, or to it being attached to each seat harness.



**Item 46 — Improve life raft resistance to puncture**

A significant issue with life rafts has been damage and contact with sharp objects in the water, such as the helicopter structure or debris from the helicopter including doors that have been jettisoned. The helicopter structure is already required to be 'delethalised'. Whereas this may be effective in respect of an essentially intact helicopter, it would not be reasonable to expect that provision to be extended to a rotorcraft that has been damaged in an impact. However, consideration might be given to minimising the use of carbon fibre in areas vulnerable to damage in water impact; carbon fibre debris is especially hazardous due to sharp edges and because it normally does not sink. In addition, the puncture resistance of the life rafts could be increased although this may also unhelpfully increase their weight and packed size.

Extract from the RHOSS Report, 1995:

(...)

11.3 *As a result of previous shortcomings in the performance of liferafts carried in helicopters, the new 'Heliraft' was developed in 1985 and is now in service throughout the offshore fleet. Its reversible design is based upon a double inflatable ring with a floor sandwiched between, and a hood which can be erected on either side, with all equipment and attachments duplicated; it thus avoids the problem of inverted inflation suffered by previous designs. It has a high level of tolerance to accidental damage (as was demonstrated in the Cormorant Alpha accident), is of a size and weight that permits it to be handled by one person in reasonable wind and sea states, and is more readily boardable by survivors from the sea by means of a ramp and straps.*

(...)

Extract from UK AAIB Air Accident Report 1/2011 G-REDU (ETAP):

(...)

*Experience on earlier offshore accidents showed that inflatable life rafts were frequently punctured as a result of contacting sharp projections on the exterior of floating helicopters. (...)*

*Subsequent examination and re-inflation of the life rafts confirmed that the lower ring of the left life raft was torn and deflated.*

(...)

References to life rafts in CS-29 are the following:

- CS 29.1411(b)(2): *Protect the safety equipment from inadvertent damage.*
- CS 29.1411(d): *Liferafts. Liferafts must be stowed near exits through which the rafts can be launched during an unplanned ditching. Rafts automatically or remotely released outside the rotorcraft must be attached to the rotorcraft by the static line prescribed in CS 29.1415.*
- CS 29.1415(b), which states that each life raft must be approved.

In addition:

- AC 29.1411(a)(1)(iii): *Stowage locations for all required safety equipment will adequately protect such equipment from inadvertent damage during normal operations.*



- AC 29.1411(b)(5): *Service experience has shown that following deployment, life rafts are susceptible to damage while in the water adjacent to the rotorcraft due to projections on the exterior of the rotorcraft such as antennas, overboard vents, guttering, etc. Projections likely to cause damage to a deployed life raft should be modified or suitably protected to minimize the likelihood of their causing damage to a deployed life raft. Relevant maintenance information should also provide procedures for maintaining such protection for rotorcraft equipped with life rafts.*
- AC 29.1415 (§ 29.1415 (Amendment 29-30) DITCHING EQUIPMENT.), (b)(1) Procedures, states that life rafts must be of an approved type to comply with ditching provisions. Reference is made to TSO-C12.
- TSOs/ETSOs for life rafts (minimum performance standards) are the following:
  - [TSO C70a, LIFERAFTS \(REVERSIBLE AND NONREVERSIBLE\)](#) (FAA);
  - [ETSO 2C70a, LIFERAFTS \(REVERSIBLE AND NONREVERSIBLE\)](#);
  - [ETSO 2C505, HELICOPTER LIFERAFTS FOR OPERATIONS TO OR FROM HELIDECKS LOCATED IN A HOSTILE SEA AREA](#) (no FAA equivalent); and
  - UK CAA Specification No 2, INFLATABLE LIFERAFTS, Issue 2, November 1985.

#### Conclusion and recommendations

The use of carbon fibre in helicopter construction is becoming more prevalent and, with it, the increased risk of damage to life rafts by debris. The effect that damaged carbon fibre/carbon-reinforced plastic may have on the integrity of the life raft should be considered when designing life raft containers. AMC material should be developed to highlight this.

CS-29 and AC 29 state that *life rafts must be approved*, and the minimum performance standards are addressed by ETSO 2C70b (to be replaced by 2C70b and 2C505). Improvements to material specifications and resistance to puncture should be contained within amendments to these ETSOs.

Proposed AMC1 SPA.HOFO.155(d) — Additional procedures and equipment for operations in hostile environment addresses life raft installation with regard to external projections.

#### **Item 47 — Ensure life raft floats at a safe distance**

Life rafts are tethered to the helicopter by two lines attached to suitably secure points on the aircraft fuselage. One short line to keep the raft close to the aircraft and a long line which, once the short line has been released or cut, allows the raft to move away from the aircraft but stay attached to aid location by rescuers. There are different terminologies used for these lines: ‘mooring line’, ‘static line’, or ‘painter (line)’.

Without the provision of a short line in ditching conditions, the raft could blow away from the aircraft or be blown aft towards the tail rotor making boarding both difficult and hazardous.

Extract from UK AAIB Air Accident Report 1/2011 G-REDU (ETAP):

(...)



Once the liferafts deploy, they remain attached to the helicopter by two lanyards. The shorter lanyard enables the life raft to remain close to the helicopter, thereby assisting and simplifying the task of the passengers and crew in boarding. Procedures call for this lanyard to be cut as soon as the passengers are all on board. The second lanyard is a 12 m line designed to keep the life raft with the helicopter, thereby assisting location, but sufficiently clear to limit the chances of it becoming damaged by contact with the helicopter.

(...)

Reference to a single life raft 'trailing line' is currently to be found in CS 29.1415(b)(2) which states: *Each raft must have a trailing line, and must have a static line designed to hold the raft near the rotorcraft but to release it if the rotorcraft becomes totally submerged.*

AC 29.1411, § 29.1411 SAFETY EQUIPMENT — GENERAL, and, in particular, (b)(4)(i)(B)(iii) states: *Rotorcraft fuselage attachments for the life raft static lines required by § 29.1415(b)(2) must be provided.*, and AC 29.1411(b)(4)(B)(iii)(C) states: *Life rafts that are remotely or automatically deployed must be attached to the rotorcraft by the required static line after deployment without further action from the crew or passengers.*

AC 29.1415, § 29.1415 (Amendment 29-30) DITCHING EQUIPMENT, states in (b)(1)(ii)(C): *Each life raft must be equipped with both a trailing line and a static line to be used for securing the life raft close to the rotorcraft for occupant egress. The static line should be of adequate strength to restrain the life raft under any reasonably probable sea state condition but must be designed to release before submerging the empty raft to which it is attached if the rotorcraft sinks.*

CS-27 provisions are similar.

TSO/ETSO for life rafts (minimum performance standards) are the following:

- [TSO C70a, LIFERAFTS \(REVERSIBLE AND NONREVERSIBLE\)](#) (FAA);
- [ETSO 2C70a, LIFERAFTS \(REVERSIBLE AND NONREVERSIBLE\)](#);
- [ETSO 2C505, HELICOPTER LIFERAFTS FOR OPERATIONS TO OR FROM HELIDECKS LOCATED IN A HOSTILE SEA AREA](#) (no FAA equivalent); and
- UK CAA Specification No 2, INFLATABLE LIFERAFTS, Issue 2, November 1985.

In addition, ETSO-2C70a, Appendix 1, STANDARD FOR LIFERAFTS (REVERSIBLE AND NONREVERSIBLE), addresses mooring/trailing lines:

(...)

5.1 Mooring line. *A nonrotting mooring line at least 6m (20 feet) in length must be attached at one end to the raft, with the remainder of the line held flaked to the carrying case. The mooring line must be capable of keeping the raft, loaded to maximum rated capacity, attached to a floating aircraft, and not endanger the raft or cause the raft to spill occupants if the aircraft sinks. The line may be equipped with a mechanical release linkage. The breaking strength of the line must be at least 2200 N (500 pounds), or 40 times the rated capacity of the raft, whichever is greater, but need not exceed 4450 N (1,000 pounds).*

(...)



5.4 *Heaving-Trailing Line.* At least one floating heaving-trailing line not less than 23 m (75 feet) in length for Type I rafts and not less than 10.6 m (35 feet) in length for Type II rafts, and at least 1100N (250 pounds) strength, must be located on the main flotation tube near the sea anchor attachment. The attach point of the line must withstand a pull of not less than 1.5 times the line rated strength without damage to the raft. A heaving-trailing line must be accessible in any inflated position of a reversible liferaft.

(...)

UK CAA Specification No 2 (November 1985) refers to a single *painter line* that shall be of a length which is compatible with the operation and inflation of the raft, but shall be not less than 6m (20 feet).

[ETSO-2CS505, HELICOPTER LIFERAFTS FOR OPERATIONS TO OR FROM HELIDECKS LOCATED IN A HOSTILE SEA AREA, 18.7.2006](#) (hostile environments, as defined in JAR OPS 3) is basically a ‘mirror’ of UK AA Specification No 2:

(...)

## 9.2 Painter Line

9.2.1 *A painter line which can easily be attached to the aircraft shall be provided. The line shall be of a length which is compatible with the operation and inflation of the liferaft, but shall be not less than 6m (20ft) nor greater than 20m (65ft) with the inflation point at least 4.5m (15ft) from the free end of the line. The painter shall be distinctly coloured to indicate to the person inflating the liferaft the position of the inflation initiation point within 3m (10ft).*

*N.B. The painter line should be a minimum of 9.5mm (3/8in) diameter under load to provide satisfactory graspability.*

(...)

### Recommendations

Several terms are used for a line intended to keep a life raft attached to the helicopter (mooring, static, painter). Current CS-27/29 provisions only require one line, whereas the established standard is to provide two lines, one short, one long.

- (a) It is therefore proposed that the rule be revised to require both the long and short line, and that the term be standardised on ‘retaining line’.
- (b) Furthermore, it is recommended that CS-27 and CS-29 should highlight the purposes of the two static lines, namely to ease boarding and to keep the raft attached to the helicopter (short static line), but at a safe distance (long static line). Associated AMC should also be developed to further clarify the intent of the CSs.

### **Item 48 — Add handholds to EFS and life rafts**

Life rafts are already required by ETSOs to have ‘lifelines’, and text was added to ACs 27.801 and 29.801, as part of AC 2006, requesting that consideration be given to the provision of handholds or lifelines to the rotorcraft.



### Recommendation

Although two new AMC (27.801 and 29.801), to replace AC 27.801 and 29.801, have now been proposed in order to cover other issues, it is recommended that the text concerning consideration of handholds or lifelines on rotorcraft be retained in these new AMC.

### **Item 49 — Design of survival bag and equipment**

Problems have been encountered where life raft occupants were unable to extract survival equipment from the packaging due to it being incompatible with cold or gloved hands.

### Recommendation

See Item No 53 below.

### **Item 50 — Cockpit habitability and mandating of immersion suits**

#### Current policy

The policy for use of helicopter immersion suits in hostile sea areas is provided in the Air Ops Regulation:

(...)

*CAT.IDE.H.295 Crew survival suits*

*Each crew member shall wear a survival suit when operating:*

- (a) *in performance class 1 or 2 on a flight over water in support of offshore operations, at a distance from land corresponding to more than 10 minutes flying time at normal cruising speed, when the weather report or forecasts available to the commander indicate that the sea temperature will be less than plus 10 °C during the flight, or when the estimated rescue time exceeds the estimated survival time;*
- (b) *in performance class 3 on a flight over water beyond autorotational distance or safe forced landing distance from land, when the weather report or forecasts available to the commander indicate that the sea temperature will be less than plus 10°C during the flight.*

(...)

*CAT.IDE.H.310 Additional requirements for helicopters conducting offshore operations in a hostile sea area*

*Helicopters operated in offshore operations in a hostile sea area, at a distance from land corresponding to more than 10 minutes flying time at normal cruising speed, shall comply with the following:*

- (a) *When the weather report or forecasts available to the commander indicate that the sea temperature will be less than plus 10°C during the flight, or when the estimated rescue time exceeds the calculated survival time, or the flight is planned to be conducted at night, all persons on board shall wear a survival suit.*

(...)



NB: it is proposed that the above policy, amended as appropriate, shall be incorporated into the above-mentioned Regulation as a new Subpart K, Helicopter offshore operations (HOFO), and, in particular, SPA.HOFO.105 and SPA.HOFO.155 relating to hostile environments.

#### The problem

When considering use of immersion (survival) suits, concern has been raised that the sea temperature limit of 10°C is set too low. There is particular concern for crew who are not required to wear an immersion suit if the sea temperature exceeds 10°C. If an immersion suit is not worn in sea temperatures above 10°C, in the event of water immersion, the flight crew will be exposed to increasing levels of risk from drowning (due to cold shock) and/or hypothermia, the lower the sea temperature. This is not an issue for passengers flying to offshore installations in the NS as they are required by their employers to wear suits at all times.

The problem is compounded by the fact that the regulations to date have not required the use of an 'ETSO-approved' immersion suit. This means that, at present, even when sea temperatures are below 10°C, an uninsulated immersion suit could be worn by an occupant, who has little or no control over the insulation or clothing worn under the suit. The insulation level provided may therefore be insufficient to protect the individual. Inadequate clothing worn under his immersion suit was thought to have contributed to the onset of hypothermia and subsequent fatality of the co-pilot in the Cormorant Alpha Platform accident (AAIB, 1993, p. 31). Again, this is less of a problem for passengers as suit standards and levels of insulation are dictated by their employers.

At a sea temperature of 10°C, severe 'cold shock' is likely to be experienced by anyone not wearing an immersion suit. In the event of submersion or capsizing, helicopter occupants not carrying EBS must be able to hold their breath for sufficient time to complete an underwater escape. If suffering from cold shock, the individual is unable to control breathing and breath-hold time is likely to be very short, greatly reducing the likelihood of making a successful escape and increasing the risk of drowning. Further, skin temperatures below 12°C will be perceived as being painfully cold. Under the current rules, therefore, occupants can be directly exposed to this painfully cold water. Anecdotal evidence from accidents suggests that survivors may not perceive severe cold distress during the initial high-stress phase of the accident, but do so once out of the helicopter awaiting rescue (see RHOSS Report, Annex D, 1995). The policy limit for wearing a suit should therefore be no lower than 12°C sea surface temperature.

When considering the range of sea surface temperatures between 15°C and 12°C, when use of an immersion suit is not currently required by the rules, the degree of cold shock is likely to be greater, the colder the water. Research has shown that breath-hold duration following sudden immersion decreases linearly with a reduction in water temperature (Hayward et al., 1984). At water temperatures less than 15°C, breath-hold times of individuals not protected by a suit were less than 30 seconds and only 25–50 % of pre-submersion breath-holds. Brooks (1989) reported the cases of two US coastguard helicopter accidents in water temperatures of 13°C and 14°C respectively. Only 3 of the 9 crewmen successfully escaped from the inverted aircraft. Effects of cold on breath-hold capability were implicated as a possible cause of drowning.

The use of EBS will go some way towards mitigating the initial effects of exposure and cold shock, enabling the user to breathe whilst making an underwater escape. However, occupants are unlikely to have time to deploy EBS before submersion, in an immediate capsizing scenario, meaning that they must



deploy underwater and within their breath-hold time. Without the protection offered by a suit, breath-hold times will be short. Further, if compressed air EBS were to be used (this being the most likely option), the air supply will be used much more quickly by an individual who is not wearing a suit and who is therefore likely to be experiencing a significant cold-shock response. It is understood that aircrew moving to and from offshore helidecks in the European sector of the NS do not carry EBS to date although this will be mandatory in the UK sector as from 1 April 2016 (UK CAA, 2014). EBS was mandated for passengers by the UK CAA as from 1 January 2015.

In the event of a long period of immersion following escape from the helicopter and whilst awaiting rescue, an immersion suit will ideally provide thermal insulation, either through inherent insulation, a thermal-liner garment or clothing worn under the suit, which will preferably be kept dry. This insulation will protect the wearer both from early peripheral cooling of limbs and hands, and from the gradual development of hypothermia, thereby significantly increasing survival times. The ETSO (2C502 and 2C503) provisions include thermal performance and the need to prevent water leakage, keeping undergarments dry and thus maintaining insulation values at the desired level. The individual wearing an immersion suit will be more capable of carrying out self-rescue actions such as climbing into a life raft, and more capable of deploying a spray-hood or reacting to wave action, thus also reducing the risk of drowning.

In view of the above, it is believed that there is a good case for requiring suits to be worn when the sea surface temperature is below 15°C.

#### Cockpit thermal stress

The benefits of wearing an immersion suit in the event of cold-water immersion are well accepted. However, suits are not always worn when sea temperatures are low due to the thermal discomfort caused by high air temperatures within the aircraft.

When considering the effects of the immersion suit policy, the benefits of providing adequate thermal protection in the event of cold-water immersion must be balanced against the risk of thermal stress in the cockpit when ambient air temperatures are high, particularly when flights are operated in sunny conditions where the cockpit transparencies can produce a 'greenhouse' environment.

If thermal stress and discomfort are experienced by the aircrew, this may result in fatigue and impaired performance, thus affecting the safety of the flight. This is less of an issue for passengers who simply have to tolerate the environmental conditions. When air temperatures are high, there is a danger that crew will reduce the level of clothing worn under an immersion suit or wear the suit with the zip open, compromising their level of thermal protection in the event of sudden cold-water immersion.

If the suit wearers are exposed to high air temperatures, then, sweating and increased blood flow to the skin will occur, both being mechanisms to increase heat loss. Sweating is undesirable as it can cause discomfort and will reduce the insulation of the clothing worn under the suit in the event of cold-water immersion.

A representative study of the thermal environment for helicopter aircrew in civil operations over the NS reported cockpit air temperatures ranging from 7°C to 27°C (Kirkpatrick et al., 1987). Temperatures often increased during the second half of flights when the aircraft were flying south and the sun was shining directly into the cockpit. As a result, globe (radiant) temperatures as high as 46°C were recorded, but these were not associated with particularly high air temperatures, or changes in the



body temperatures of the crew. At the time of this study, there was no air conditioning in the cockpits. The authors found that under the cockpit conditions experienced and with external air temperatures up to 15°C, *the wearing of [uninsulated] immersion suits produced no more thermal stress than the normal flying clothing assembly.*

Research into the effects of high cockpit temperatures on helicopter pilots, studying the threshold temperatures when thermal discomfort and thermal stress may be experienced, have been conducted both in Norway (Færevik et al., 2001) and Canada (Ducharme, 2006). In both cases, measurements were taken during flight operations as well as in chamber studies under simulated conditions, with aircrew wearing an immersion suit, liner and clothing system with 2.2 clo insulation in air (0.8 immersed clo). Both studies showed that flight crew were in thermal comfort at air temperatures up to 18°C, at which temperature they were feeling warm. Above this temperature, ratings increased, with the flight crew reporting thermal discomfort and heat stress at 25°C (Ducharme, 2006; Færevik et al., 2001), as well as significant sweating (Færevik et al., 2001). A cabin temperature of 18°C, therefore, appears to represent the upper limit for thermal comfort with an insulated suit. The upper limit is likely to be higher for an uninsulated suit, and the suit insulation may account for some of the apparent difference in findings compared to the Kirkpatrick study.

The thermal discomfort problem is at its worst when sea temperatures are low and ambient air temperatures are high, as might be experienced during the spring months of April and May. Periods when the aircraft is holding on the runway awaiting take-off are a particular problem. If the airport is busy the aircraft may be kept waiting for up to an hour; if sitting in the sun, the cockpit, in particular, could get very warm, even with some ventilation. Passengers could also get very warm if sitting next to a window facing the sun.

Some designs of immersion suits allow the user to leave a zip open, providing some relief from thermal discomfort. The disadvantage of this is that if the zip is not fully secured during flight, in the event of a sudden immersion, water will enter the suit and significantly reduce insulation level provided. The UK offshore industry changed to a suit that remains fully sealed in flight, following the Cormorant Alpha Platform accident, when leakage into the suits was found to be a problem during the survival phase (AAIB, 1993).

An effective mitigation would be to provide air conditioning within the aircraft for operations where ambient temperatures can cause thermal stress. An improvement in the habitability of the aircraft should mean that aircrew would not have to make a choice between a safe working environment in the cockpit and an adequate level of thermal protection in the event of water immersion. It is understood that air conditioning is provided in some aircraft, but is not provided in all due to the weight penalty. However, this is a very good solution and could increase flight crew usage of immersion suits and potentially save lives.

Alternatively, introducing a range of insulation levels for immersion suits, as described in Risk Matrix Item 51, would provide a means of balancing the risks associated with cold-water immersion and the flight crew HF risks introduced by thermal stress.

#### Night-time flights when sea temperatures are in excess of 15°C

The requirement for all persons on board to wear an immersion suit regardless of sea temperature, when the flight is planned to be conducted at night, also needs some careful consideration. While the risk of an accident is higher at night, the level of risk directly associated with the sea temperature is the



same as in daylight. It is certainly true that evacuation and escape will be much more difficult in darkness, but the main issue is the additional time needed to locate and rescue survivors in the dark. The additional risk presented by night flights may therefore already be covered by the requirement to wear immersion suits when estimated rescue time exceeds the calculated survival time although a less subjective requirement would be better.

The requirement to wear suits during night flights does not affect suit usage when sea temperatures are low as suits would be worn anyway. At sea temperatures up to 15°C, the wearing of an immersion suit at night should be mandated due to the extended rescue times that might be expected.

Mandated use of suits at night could cause considerable problems in high air temperatures when sea temperatures are above 15°C as immersion suits would otherwise not be required to be worn. This problem was highlighted in the comments received on the draft HOFO rule: SPA.HOFO.105 Operating procedures (EASA: [CRD 2013-10](#)). The European Helicopter Association (EHA) commented:

1. *This rule applies to any aircraft on an EASA member state AOC. So for an operator operating in the Caspian Sea, the Black Sea, Asia (this is not exhaustive) in the summer, the crew would be wearing a survival suit at night with water temperatures of plus 25 degrees and OAT [outside air temperature?] around 30 and above. We need additional guidance for a combination of warm water and high OATs.*

(...)

The use of an immersion suit in high air temperatures could certainly cause severe heat stress. It is also questionable whether an immersion suit is necessary at sea temperatures as high as 25°C. Under these conditions, the most important mitigation of a long rescue time is likely to be a life jacket that will support the person in the water in the event of being unable to enter a life raft.

The case of night-time flights over the NS, when air temperatures are in excess of 20°C, is less clear. Water temperatures are unlikely to exceed 18°C (southern NS) and at this temperature, without a suit and with longer expected rescue times, body cooling could prejudice survival for at least a proportion of helicopter occupants. It is therefore recommended that suit use should be mandated for passengers for night flights when sea temperatures are between 15°C and 25°C. For aircrew, suit use should be optional under these circumstances, allowing a balance between rescue time and thermal comfort to be achieved whilst working.

#### Current use of ETSO-approved suits

Currently, both ETSOs relating to helicopter immersion suits (ETSO-2C502 and ETSO-2C503) require the provision of thermal protection equivalent to that of an EN ISO 15027: 2002 Class B suit. The suit, worn over standard clothing, must perform adequately during a four-hour immersion in water at 2°C. Immersion suits that meet this standard are generally provided with a thermal liner, giving a relatively high insulation level.

There is currently no option for an ETSO-approved suit with a lower insulation level that might provide sufficient protection against the prevailing sea temperatures and offer a better solution when air temperatures are high. This has led to uninsulated suits (approved to national standards with grandfathered rights) being worn at the current time, with a wide range of clothing (from very little to specialised thermal undergarments) worn underneath.



This problem would be addressed by the introduction of a range of insulation levels for immersion suits, as described in Risk Matrix Item 51 and outlined below.

The suggested options for better matching the insulation level provided within the suit to the sea temperature will have the added benefit that it will be easier to achieve self-righting performance in a much higher proportion of cases (see Risk Matrix Item 40). Insulation increases suit buoyancy, which can oppose the buoyancy of a life jacket worn with the suit. High insulation levels also make a suit bulky and may increase the difficulty to egress through an escape window. Allowing suits with less insulation, when appropriate for the sea temperatures experienced, provides some mitigation of this problem.

#### Conclusions on immersion suits

Helicopter occupants (both crew and passengers) would be better protected from the potential threat of water immersion if the rules required that suits should be worn when sea temperatures are less than 12°C rather than the current limit of 10°C.

An increase in the limiting sea temperature to 15°C will increase the number of days/months during which a suit must be worn, and could increase the problems of thermal stress.

If the policy is also changed to require the use of an ETSO-approved suit, the fact that the current standards only allow for a relatively well insulated suit is likely to cause further thermal-stress problems. Any change in policy to reduce the risks associated with cold-water immersion must therefore also address the thermal-stress issues although this is mainly an issue for flight crew and rear crew members.

One means of addressing the risks associated with immersion, without maintaining the risks due to thermal stress, would therefore be to introduce suits with more than one insulation level. The highest insulation level (i.e. the current EN ISO 15027: 2002 Class B standard) would be required (as a minimum) for the lowest range of sea temperatures (up to 7°C), and an intermediate insulation level for sea temperatures between 7°C and 12°C (i.e. the current EN ISO 15027: 2002 Class C standard). It is proposed that for passengers, an uninsulated suit (as a minimum) should be mandated for sea temperatures up to 15°C. For aircrew, use of an approved suit is recommended but not mandated to allow some discretion when air temperatures are high. Use of an uninsulated suit would be also an option. See Risk Matrix Item 51 for further details and discussion.

The ETSO should therefore be amended to make provision for different insulation levels. The uninsulated suit would meet all the provisions of the existing ETSOs with the exception of thermal protection (the ability of the suit to keep the wearer dry would be critical). Thermal liners could then be added to raise the insulation to a level achieving either Class C or B thermal performance for use in colder water temperatures.

For passengers, thermal discomfort is less of a problem so suits with higher insulation levels are currently worn in practice.

#### Air conditioning

Modern offshore helicopters have air conditioning as an option. In some, it may be a contractual requirement regardless of geographical location and in others, it may depend on the location. For this RMG, the area of interest for this item is operations over hostile sea areas where use of a survival suit



is mandated by the Air Ops Regulation and/or by customer requirements. Survival suits are not generally required for flight over non-hostile sea areas.

Passengers on offshore flights are required to wear survival suits throughout the year. In UK, they are also required to wear three layers of clothing underneath the suit in winter, and two layers in summer. Cabin temperatures are always above ambient due to the presence of up to 19 people in an enclosed space and occasional sunlight through the windows (which are becoming larger with the introduction of newer helicopter types). In addition, the cabin tends to become uncomfortable without air conditioning once the outside air temperature increases above 18°–20°C. Air conditioning can normally reduce the cabin temperature to around 16°C (if the ambient temperature is below that, the system will normally just supply ambient air to the ventilation system). On the other hand, passengers are not normally in the aircraft for longer than 2 hours every 2–3 weeks.

Flight crew are exposed to similar temperature ranges (and more sunlight as there are more windows in the cockpit), and they may well be exposed for six to 8 hours in a working day. They are also required to maintain concentration and carry out their normal flight tasks throughout this time. Arguably, therefore, the need for air conditioning is stronger for the cockpit than it is for the cabin. Currently, flight crew do have the option to not wear a survival suit under certain conditions when the weather is warm, but this becomes a personal risk assessment for them between the certainty of heat problems in the cockpit and the remote possibility of a ditching in water which is still well below swimming pool temperature. The provision of survival suits with appropriate thermal capability (perhaps due to variable undergarment insulation) and air conditioning would give the flight crew a more comfortable working environment, and would therefore help to persuade them to wear a survival suit even if not mandated by the Air Ops Regulation.

In a modern heavy helicopter, the air conditioning system normally weighs about the same as a passenger. Hence, there is also a commercial aspect to this discussion, and it may be that for range/payload reasons, a customer will wish not to have air conditioning installed if it is optional. If the proposal for revised policy on immersion suit use is adopted (see Risk Matrix Item 50), the need for air conditioning can be better adapted to the ambient conditions. For sea temperatures of +12°C and below (where all occupants are required to wear immersion suits) with ambient air temperatures of +18°C and below, use of ambient air for cabin and cockpit cooling should be sufficient to ensure an acceptable crew working environment, depending on the level of insulation worn under the suit. Indeed, with cold ambient air temperatures, a serviceable heater is a necessary item of equipment. Once the ambient air temperature increases above +18°C, the outside air is no longer cold enough to provide adequate cooling without air conditioning. Depending on the operating region, there may be significant periods of the year when the sea temperature remains at or below +12°C, so crew are required to wear immersion suits even if the ambient air temperature rises above +18°C (and these crossover periods will be significantly longer than those where the sea temperature is at the previous limit of +10°C or less). The advantages of increasing the minimum sea temperature for crew to wear immersion suits (reduced exposure to cold shock and increased breath-hold times in the [remote] event of a ditching or water impact) are then potentially outweighed by the detrimental effect of heat stress throughout every flight. This discrepancy would of course be worse if the minimum sea temperature were set at the 'ideal' value of +15°C (in terms of cold shock and associated problems at water entry). This justifies the provision of air conditioning for those periods of the year where the crew are required to wear immersion suits when the ambient air temperature is above +18°C. As the



passengers may be required to wear immersion suits throughout the year even if the crew are not, then air conditioning should be mandated for operations at any time the ambient air temperature is above +18°C. This would permit deferral of the system under the minimum equipment list (MEL) through the winter, if required.

#### Conclusion

Air conditioning should be considered for offshore operations where the wearing of immersion suits is mandatory and cockpit habitability cannot be assured in any other way.

#### Recommendations

- (a) The Air Ops Regulation should be amended to mandate the use of an ETSO-approved immersion suit, as described in Table B47-1 below.
- (b) The level of immersion suit insulation required should be related to sea surface temperature.
- (c) The current helicopter suit ETSOs should be amended to reflect the above, adding two new categories, one with a lower insulation level than a Class B suit (e.g. EN ISO 15027-3: 2012 Class C), and a second with no provision for suit insulation (see Risk Matrix Item 51: ETSO thermal-protection levels).
- (d) The Air Ops Regulation should be amended to require an assessment of cockpit habitability issues for each helicopter intended for operations requiring flight crew to wear immersion suits in order to ensure that thermal stress will be prevented.

**Table B47-1 — Summary of proposed mandate for suit usage**

Sea temperature (°C)	Minimum level of suit insulation allowed		Rule
	Crew suits	Passenger (pax) suits	
< 7	Class B	Class B	Mandatory
≥ 7 to < 12	Class C	Class C	Mandatory
≥ 12 to < 15	Uninsulated	Uninsulated	Mandatory for pax for all flights; mandatory for crew for night flights only.
≥ 15 to < 25	Uninsulated	Uninsulated	Mandatory for pax for night flights only; optional for crew.
≥ 25	Uninsulated	Uninsulated	Optional

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- [EASA: \(2006b\), ETSO-2C503, Helicopter Crew and Passenger Immersion Suits for Operations to or from Helidecks Located in a Hostile Sea Area](#)
- [EASA: \(2006c\), ETSO-2C504, Helicopter Constant-Wear Lifejackets for Operations to or from Helidecks Located in a Hostile Sea Area](#)
- [EU: Commission Regulation \(EU\) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation \(EC\) No 216/2008 of the European Parliament and of the Council \(OJ L 296, 25.10.2012, p. 1\)](#)
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### Item 51 — Suitability of immersion suits

The current ETSO thermal-protection provision

The current ETSOs (ETSO-2C502 and ETSO-2C503, 2006), applicable to helicopter crew and passenger immersion suits, only provide for one level of thermal protection. The standards state: *The suit shall provide the user with thermal protection in the water that at least satisfies the test requirements of paragraph 3.8 of EN ISO 15027-3: 2002 as a class B suit system.* EN ISO Class B suits are tested for 4 hours in a water temperature of < 2°C.

Environmental conditions of use

In the NS where most of the European offshore operations take place, monthly average sea surface temperatures generally get as low as 2°C in small areas along the Norwegian and Danish coasts, for 1 or 2 months during the winter period. Some worst-case and representative mean monthly sea surface temperatures are provided in Figure 1 below, and the minimum and maximum mean monthly sea



surface temperatures along two representative helicopter routes are given in Figure 2 below. Whilst more northerly sea areas such as the Norwegian Sea are also likely to reach such low sea surface temperatures, in the northern UK sector of the NS around Shetland, the monthly average sea surface temperatures rarely fall below 7°C (but also rarely go much above 13°C in summer months). The Dutch coast and UK areas such as the Norfolk coast and Irish Sea may experience temperatures as low as 3–4°C. The level of thermal protection currently provided in an ETSO-approved suit is therefore based on the worst-case exposures within Northern European waters.

The problem of having a single high-thermal rating on the suit is that thermal stress may be experienced when cockpit/cabin temperatures are high in the spring and summer months but sea temperatures are still low enough to be a problem in the event of a water immersion. This is a much larger problem for crew than for passengers due to the effects of sun in the cockpit (pilots) and of physical activity during flights (SAR rear crew). It is also the case that the crew have to work under these conditions on a daily basis, unlike the passengers who are sitting passively during transport to and from work and are exposed to those conditions for only a few hours a month.

In civil operations over the NS, reported cockpit air temperatures have been shown to range from 7°C to 27°C (a slightly wider range of cockpit/cabin temperatures of 3°C–28°C has been reported from Canada). Studies in Norway (Færevik et al., 2001) and Canada (Ducharme, 2006) show that aircrew wearing representative clothing and insulated (0.8 clo) immersion suits (designed to provide six-hour protection in icy waters) remain in thermal comfort up to a cockpit air temperature of about 18°C. Above this temperature, thermal comfort decreased, subjects felt warmer and experienced some sweating. At air temperatures of 25°C, aircrew experienced thermal discomfort and heat stress (Ducharme, 2006; Færevik et al., 2001) with significant sweating (Færevik et al., 2001). In an uninsulated suit with no thermal liner, it is likely that the upper limit for maintaining thermal comfort will be above 18°C. See Risk Matrix Item 50 above for a similar discussion.

Ducharme (2006) went on to show that under simulated conditions in air temperatures of 25°C, the mean skin temperature of flight crew increased over a 1.3-hour period, but there was no increase in mean core temperature or heart rate. However, during a further hour simulating the activities of SAR crew flight engineers, significant heat stress was experienced with increases in mean skin and core temperatures, heart rate and sweating. Ducharme concluded that for flight crew with a low metabolic rate, heat strain and performance decrements were unlikely to occur until air temperatures of 25°C were reached, but for SAR (rear) crew with higher metabolic activity, wearing an insulated suit, such an air temperature could result in significant performance decrements.

#### Helicopter crew suit usage

This conflict between thermal protection in cold water and thermal discomfort during operational use has a significant effect upon decisions made by aircrew to wear a cotton flight suit rather than an immersion suit in warm weather and, when an immersion suit is worn, to wear the type of suit and/or garments and clothing under the suit. This is not an issue for passengers as the suit insulation and clothing policies are regulated by their employers.

The main issue is how to provide the optimum insulation level to protect crew members in the prevailing sea temperatures, without causing thermal stress and the consequent risk of decrements in crew performance during normal flights when cockpit temperatures are high. This problem has been recognised for many years. In 1995, the RHOSS Report (1995) stated: *It is clearly undesirable for an*



*item of survival equipment to be so uncomfortable in routine use that the wearer is tempted to compromise its effectiveness or, in the case of aircrew, becomes so distracted by discomfort that a flight safety hazard is introduced.* More recently, two crew members involved in a ditching cited potential thermal discomfort as a reason for not wearing immersion suits despite a sea surface temperature of 11°C and an air temperature of only about 9°C (AAIB, 2014). Both pilots reported that *immersion suits were uncomfortable to wear, despite the current model being more lightweight than previous versions, and that a balance had to be struck between the protection they afforded and the risks they presented due to discomfort and heat stress* (AAIB, 2014).

It is understood that some aircrew wear immersion suits all year round whilst others choose to wear flight coveralls during summer months or on particularly hot days. Some immersion suits are uninsulated whilst others have insulating thermal liners. The undergarments and clothing worn under the suit appear to vary widely dependent upon environmental conditions. Some helicopter operators have their own preferred thermal undergarments.

Many crew members currently wear suits that are not ETSO-approved. The current regulations (e.g. the Air Ops) require a survival suit to be worn, but do not state that this should be an approved one. Whilst the immersion suits used by crew are all thought to be approved by at least an NAA, many have grandfathered rights and are not ETSO-approved (although that situation is believed to be changing, with several operators currently planning to adopt an ETSO-approved suit). There is resistance to wearing an ETSO-approved suit when conditions are warm due to the high level of thermal insulation required by the current standards (ETSO-2C502 and ETSO-2C503, 2006). Heavily insulated suits tend to be bulky, which can be restrictive for both pilots and rear (SAR) crew. This is not thought to create any significant problem for passengers during normal operations, but could affect ease of underwater escape. New fabrics have improved this somewhat, but there is still a potential problem. The SAR crew are particularly concerned about thermal stress and ease of movement due to the fact that they are much more active when working as winchmen. Whilst air conditioning may help passengers and pilots, it does not help the SAR crew.

Use of survival/immersion suits is currently only mandated when sea temperatures fall below 10°C. Aircrew could therefore be exposed to sea temperatures as low as 10°C without the protection offered by an immersion suit. Temperatures below 12°C are painfully cold to the skin. While hypothermia takes time to develop, cold shock has an immediate effect on survivability, affecting the person's ability to successfully escape in the event of a water impact and capsize/submersion. The magnitude of the cold-shock response will increase as skin temperatures decrease from 15°C down towards 10°C; at a skin temperature of 10°C, cold-shock responses are likely to be pronounced.

There is therefore a need to increase the likelihood that helicopter crew will wear an immersion suit throughout the year. It would be preferable for the immersion suits worn to be EASA-approved ones. For this to happen, it is proposed that rule changes are considered (see Risk Matrix Item 50 above), and that a range of immersion suit options be allowed within the ETSOs by creating a number of categories in relation to thermal insulation. This might take the form of a basic uninsulated suit that meets all the provisions of the standard with the exception of thermal performance (the ability of the suit to keep the wearer dry would be critical). For cold water areas, the suit would be approved with a thermal liner that had to meet the thermal-performance requirements of an EN ISO 15027 Class B suit as is currently required in the ETSOs. A third category might be a thermal liner that had a lower insulation level,



meeting the thermal performance requirements of an EN ISO 15027 Class C suit (tested for 2 hours at 5°C). It would be desirable to extend the time requirement to 4 hours to cover realistic rescue times.

#### Recommendations

- (a) Change the Air Ops Regulation to increase the sea temperature when immersion suits must be worn from 10°C to 12°C (see Risk Matrix Item 50 — Cockpit habitability and mandating of immersion suits).
- (b) Provide two or more categories within ETSO-2C502 and ETSO-2C503 to allow different insulation levels so that end users match thermal performance with environmental conditions of use (sea and air temperatures).
- (c) Further, consider the option of a special category of suit with specific ETSO provisions for SAR crew/winchemen.

#### **Annex 1 to Item 50 — Proposed levels of thermal protection to be defined within amended suit ETSOs**

##### Category 1

- An uninsulated suit that meets the provisions of either ETSO-2C502 or ETSO-2C503 with the exception of the thermal provision, but which is designed to be worn sealed during flight, with minimal water leakage.
- Suit to be tested with the minimum level of undergarments recommended by the manufacturer, or standard clothing, as defined in EN ISO 15027-3: 2012.

##### Category 2

- A suit that meets the provisions of either ETSO-2C502 or ETSO-2C503 and, at least, the thermal-protection test requirements of an EN ISO 15027 Class C suit.
- Thermal-protection test provision: a decrease in body temperature of  $\leq 2^{\circ}\text{C}$  when tested for 4-hours<sup>28</sup> in water at 5°C.
- Suit to be tested with the minimum level of undergarments recommended by the manufacturer, or standard clothing, as defined in EN ISO 15027-3: 2012.

##### Category 3

- A suit that meets the provisions of either ETSO-2C502 or ETSO-2C503 and, at least, the thermal-protection test requirements of an EN ISO 15027 Class B suit.
- Thermal-protection test provision: a decrease in body temperature of  $\leq 2^{\circ}\text{C}$  when tested for 4-hours in water at 2°C.
- Suit to be tested with the minimum level of undergarments recommended by the manufacturer, or standard clothing, as defined in EN ISO 15027-3: 2012.

<sup>28</sup> 2 hours in the EN ISO standard test method, extended to 4 hours to cover possible rescue times.



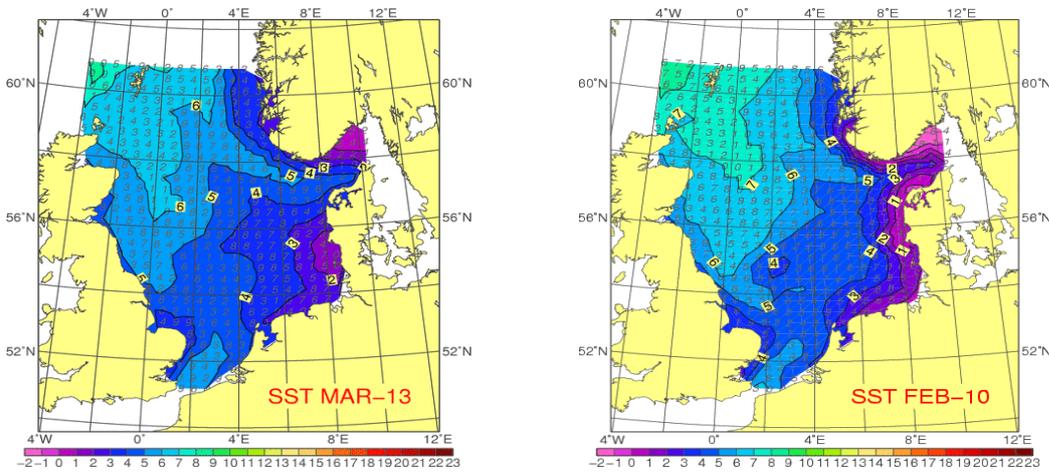
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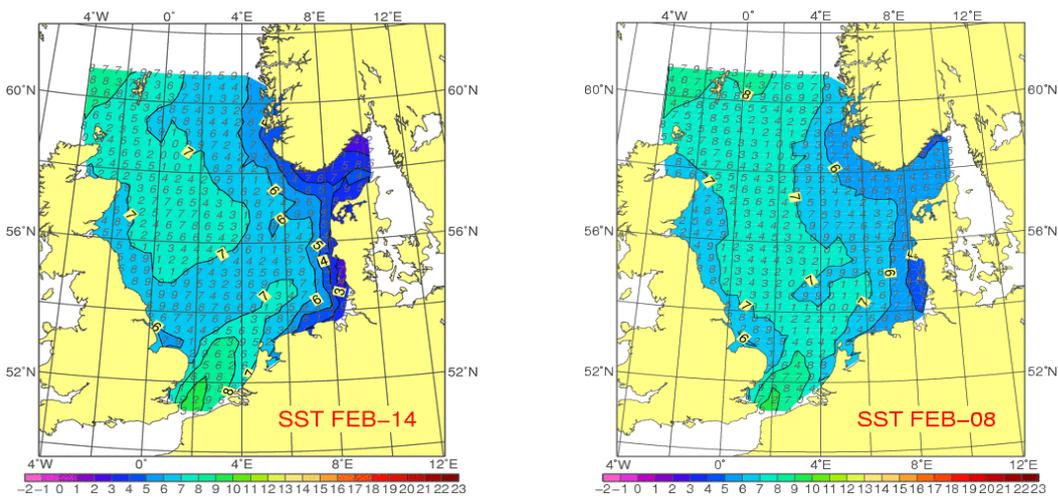


Figure 1 — Annex 1 to Item 50 — Average monthly sea surface temperatures in the NS

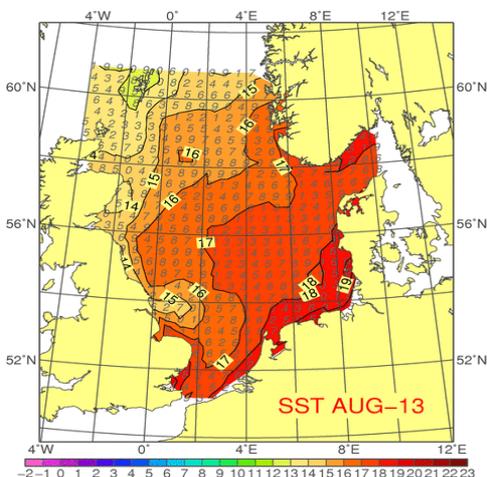
**Worst-case average monthly sea surface temperatures in the NS (2004–2014)**



**Average monthly sea surface temperatures in the NS in milder winters (February)**



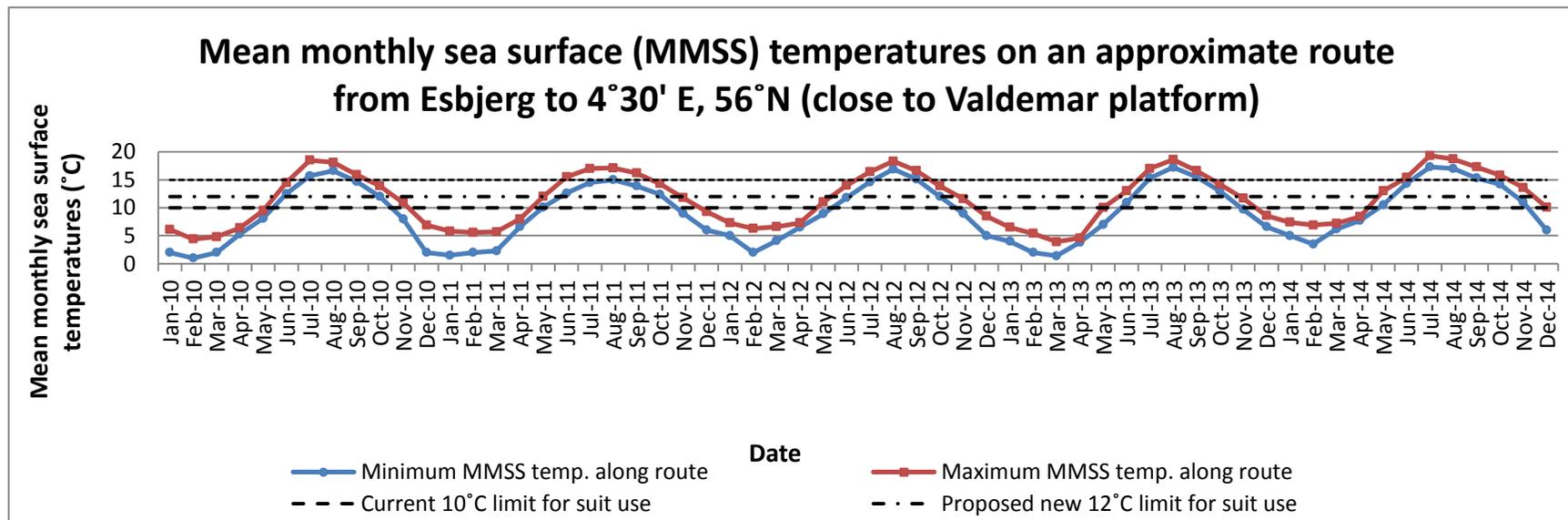
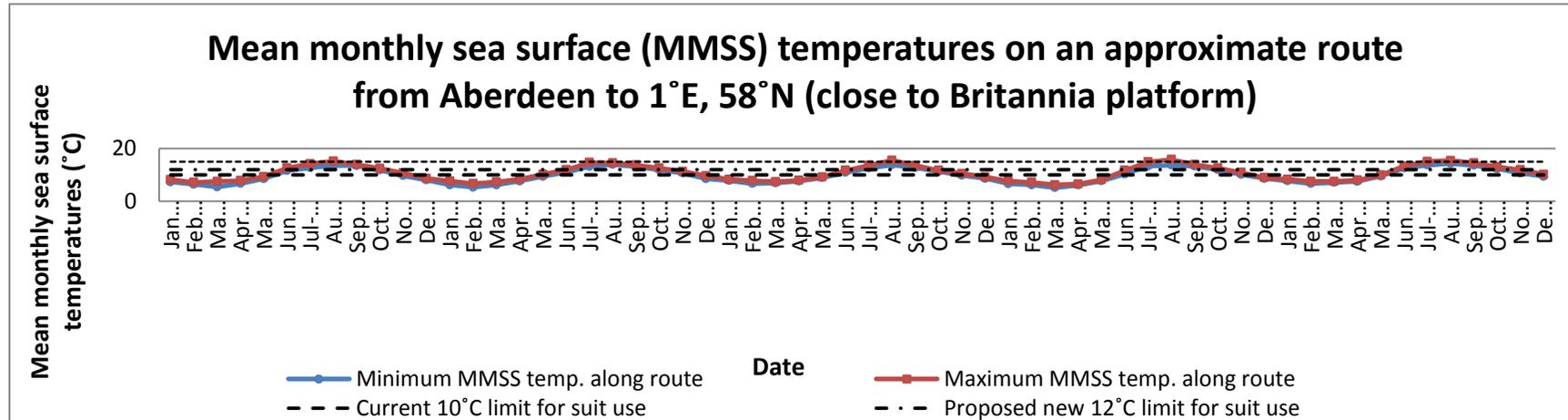
**Example: summer average monthly sea surface temperatures in the NS (August 2014)**



Information made freely available online by the Federal Maritime and Hydrographic Agency of Germany (Bundesamt für Seeschifffahrt und Hydrographie (BSH))



Figure 2 — Annex 2 to Item 50



**Item 52 — ELT installation, reliability and compatibility**

Offshore helicopters are fitted with an automatically deployable emergency locator transmitter (ADELT), and the life raft survival packs contain a manually deployable ELT. In addition to this equipment that the helicopters are required to carry, the oil and gas companies issue each passenger with a PLB. All of these devices operate on the same frequencies (121.5 and 406 MHz, 243 MHz optional), and care is required to ensure that the operation of one device does not compromise that of another. In particular, PLBs should be switched off once the survivor is safely in the life raft and the ELT has been deployed as multiple transmissions can, by design, adversely affect the performance of some locator systems.

However, accident experience has shown that the devices do not always deploy as intended (ADELT) and/or transmit effectively.

**Recommendation**

It is therefore recommended that related regulations and AMC thereto be developed in order to better set design standards for these devices.

**Item 53 — Ensure usability of survival kit contents with cold/gloved hands**

Accident experience (see [AAIB Bulletin: 10/2011](#), Safety Recommendation 2011-070) has shown that some current survival-kit contents (sea sickness tablets are specifically mentioned, but the issue applies to all items) cannot be easily accessed/used in practice due to survivors' hands being chilled or gloved.

The new ETSO-C70b, as currently proposed, will include a reference to Society of Automotive Engineers (SAE): ARP1282, Revision B, Survival Kit — Life Rafts and Slide/Rafts. This ARP defines 'chilled hand' and 'gloved hand' tests which assess the ability to open/operate survival-kit contents with respectively chilled and gloved hands.

This should ensure that survival-kit contents within an ETSO-C70b-approved life raft can be used by occupants experiencing conditions of cold or when wearing gloves.

However, this link is not currently proposed for inclusion in ETSO-2C505 (the standard for life rafts fitted to rotorcraft operating over hostile areas)

It is to be noted that whilst there is no provision in either ETSO for survival kits to be part of the approved life raft, such kits are commonly part of the life raft design because they are required by the Air Ops Regulation.

**Recommendation**

It is recommended that ETSO-2C505 be updated to refer to ARP1282 Rev B.

**Item 54 — Improve paint scheme/retro-reflective markings**

Location and orientation of an upturned (capsized) rotorcraft is greatly aided if the underside of the rotorcraft is marked with a series of high-visibility chevrons. These should be of a contrasting colour and 'pointing' towards the nose of the rotorcraft.



These markings were introduced by the NS operators in 1987 in response to a Safety Recommendation by the UK CAA regarding the accident to Bell 212 G-BIJF ([Aircraft Accident Report 10/82](#)). The Recommendation can also be found for S.61N G-BBHN ([Aircraft Accident Report 8/78](#)).

The recommendation related to G-BIJF was worded and handled as follows:

*4.10: High visibility paint schemes be applied to helicopters to facilitate location after ditching, particularly if the aircraft is floating inverted.*

Response : this recommendation has been drawn to the attention of operators through the Helicopter Operations Liaison Group and the North Sea Operators Technical Committee. All offshore operators have agreed to comply and all helicopters engaged in regular offshore operations are now so painted.

#### Recommendation

It is recommended that both CS-27 and CS-29 be revised to include a provision that helicopters approved for ditching be marked on their underside with chevrons as described above.

#### **Item 55 — Deployment of sea anchor**

See Item 44 above.

#### **Item 56 — Require all occupants to wear high-visibility immersion suits**

##### Background

This proposal follows a safety recommendation made to the Agency by the AAIB in [Aircraft Accident Report 7/2008](#) on the accident to Aerospatiale SA365N, registration G-BLUN, near the North Morecambe gas platform, Morecambe Bay, on 27 December 2006:

##### *2.6 Search and rescue*

*The search and rescue crews commented that the yellow immersion suits worn by the passengers were noticeably more conspicuous, when using the SAR helicopter's searchlight in the darkness, than the blue immersion suits worn by the pilots. The flight crew were difficult to locate in this accident because they were neither able to inflate their life jackets nor operate any of their location devices. In this situation, they were completely reliant on the conspicuity of their clothing to be located. However, the immersion suit and un-inflated lifejacket are designed to have low reflectivity in order to reduce internal reflections in the cockpit during night time flight operations. Previous trials have examined ways of enhancing the conspicuity of survival suits but have not reached any definitive conclusions. It is possible that enhancing the infra-red reflectivity of the survival suit would provide the most beneficial results since most SAR helicopters use infrared sensors to assist the search; however, other methods may prove to be more effective. Therefore:*

*It is recommended that the European Aviation Safety Agency (EASA) investigate methods to increase the conspicuity of immersion suits worn by the flight crew, in order to improve the location of incapacitated survivors of a helicopter ditching. (Safety Recommendation 2008-036)*

##### Discussion

As pointed out by the AAIB, increasing conspicuity of flight crew immersion suits by adding standard visible light-reflective stripes can lead to internal reflections in the cockpit. This problem is exacerbated



on modern helicopters due to large curved transparencies and an increasing area of glass displays on the instrument panel.

New technology, developed for the armed forces, could offer a solution to increase conspicuity without creating internal reflections: IR-reflective tape, commonly known as 'GLINT tape', has been developed as a means to identify friend or foe, appears dark to the naked eye and reflects only IR light.

The AAIB emphasises that SAR aircraft are typically equipped with forward-looking infrared (FLIR) cameras that allow a passive detection of objects emitting in the IR band. As immersion suits are designed to thermally isolate the wearer, a victim in the water will however have a low IR signature. Most modern searchlights or FLIR cameras offer the possibility to illuminate in the IR band and, in conjunction with IR-reflective panels on the suit, could increase the probability of detection using FLIR cameras or night vision goggles (NVG) through active IR detection.

Performing the search in the IR band only might provide the added benefit of preserving the SAR crew night vision adaption to increase probability of detection of an eventual life vest strobe light, and would also allow the crew to fly and scan wearing NVG without the risk of blooming from white light.

#### Challenges

- The effectiveness of the 'active IR detection' concept in a maritime SAR environment needs to be assessed through sea trials.
- Availability of this military-controlled technology for civilian use needs to be evaluated.
- Benefits of increasing IR reflectivity on other equipment than immersion suits, e.g. life rafts, to be also considered.

#### Recommendations

The Agency should launch a research project to investigate the effectiveness of the 'active IR detection' concept, and if the results are positive, modify the relevant ETSO.

#### **Item 57 — Provision of PLBs, strobe lights**

It is the current practice of some operators to provide personal locator beacons (PLBs) on customer request. However, in the case that survivors are together in a life raft, such equipment provides no benefit, and in the case of multiple separated survivors, it is not feasible for SAR teams to distinguish between several signals. It was therefore concluded that no recommendation would be made regarding PLB provision.

As noted in Item 53 above, it is currently proposed that the new ETSO C70b will include a reference to ARP1282 Rev. B. Rather than mention flares, this document refers to AS513 — Aviation Distress Signal. This AS document provides performance standards for a high-intensity stroboscopic light source with equivalent utility to a flare, as an aid to SAR, which eliminates the potential hazards posed by traditional pyrotechnic devices. The Agency agrees that a change to this type of signalling device is appropriate.

However, this link is not currently proposed for inclusion in ETSO-2C505 (the standard for life rafts fitted to rotorcraft operating over hostile areas)



It is to be noted that whilst there is no provision in either ETSO for survival kits to be part of the approved life raft, such kits are commonly part of the life raft design because they are required by the Air Ops Regulation.

#### Recommendation

It is recommended that ETSO-2C505 be updated to refer to ARP1282 Rev B.

#### **Item 58 — Handling of survivors**

Prior to the issue of UK CAA SD-2015/001, there were no regulatory restrictions on operations over sea conditions where a reasonable prospect of safe rescue cannot be assured. SD-2015/001 introduced an upper limit of 6 m  $H_s$  for UK operations, which Ireland and Canada have also implemented. Such a limit was also recommended in Norway around 2000, but has not yet been introduced.

There is otherwise no consistent or recognised standard across all helicopter operators. One operator allows the flight crew to make their own decision regarding whether to launch or not the operation, but most rely on the declaration by the safety boat at the destination that there is a 'good prospect of recovery' from the sea in the event of a ditching. This generally implies a  $H_s$  up to 7 m which falls within the World Meteorological Organization (WMO) range for (SS) 7. SSs at the higher end of this range recovery would likely be reliant on use of a 'Dacon rescue scoop', a mechanical device that uses a net to 'fish' the survivor out of the water, which is not favoured by flight crews.

The effects of SS and weather conditions on survival and rescue were highlighted for review following the fatal accident to G-TIGH near the Cormorant Alpha platform in the NS in 1992 when six occupants successfully escaped from the helicopter but then perished in the sea before they could be rescued. The subject of weather criteria was subsequently debated by RHOSS, which is summarised in Annex M to the RHOSS Report (see also Appendix A, Item 5 above). The conclusion of RHOSS was that an overall limit was not appropriate.

One aspect taken into account by RHOSS was the lack of information on the sea condition along the whole route of the helicopter. However, forecasts in the form of  $H_s$  contour plots are now readily available on the UK Met Office 'OhWeb' service, routinely used by helicopter operators for other meteorological information.

It was also assumed that a SAR helicopter could retrieve survivors in any weather conditions. Although that may be possible, there is no doubt that the time required to locate and recover each survivor increases as surface conditions deteriorate. The ability of a SAR helicopter to rescue a full complement of up to 21 occupants within its loiter time in the severest of conditions is considered to be questionable, especially at night.

RHOSS also compared operations over hostile seas to onshore operations over areas such as forests and mountainous regions where a safe forced landing could not be assured. While it is undoubtedly true that such onshore operations do take place and are generally considered satisfactory, the amount of such flying and hence exposure to the risk is significantly less than for offshore operations.

Finally, there are good arguments to prohibit flight over sea conditions exceeding the demonstrated ditching performance of the helicopter. No civil helicopter is currently certified for sea conditions exceeding SS 6 ( $H_s = 4-6$  m) in the NS wave climate, and tank tests in irregular waves (see Appendix A, Item 15) suggest that this level of performance is likely to be optimistic in practice. Hence, an overall



operating limit of 6-m H<sub>s</sub> would have no effect on the operability of any current helicopter in the NS operating within its ditching performance.

However, it is recognised that helicopters may be successfully certified for higher H<sub>s</sub> in other, more benign sea areas. It would be reasonable to assume that rescue of survivors from the sea would be easier in more benign sea areas, hence, a higher H<sub>s</sub> could be accepted. So, a practical and proportionate approach would be to prohibit helicopter operations over sea conditions exceeding the ditching performance of the helicopter for the operating area in which the flight is to take place.

A 'floor' of 6-m H<sub>s</sub> could be retained to allow helicopters certified for less than 6-m H<sub>s</sub> to operate beyond their demonstrated ditching performance.

#### Recommendation

Offshore helicopter operations should not be permitted over sea conditions where a good prospect of recovery cannot be assured. This should be applied as an H<sub>s</sub> higher than 6 m, or the H<sub>s</sub> for which the helicopter has been certified for the operating area in which the flight is to take place



### 7.3. Appendix C — List of helicopter ditching/water impact occurrences

The data that follows relates to helicopter ditchings and water impact events. It is limited to those occurrences where an EFS would normally have been fitted to the helicopter in compliance with the Air Ops Regulation.

Occurrence classes used:

- ditching;
- survivable water impact (SWI); and
- non-survivable water impact (NSWI).

Data sources:

- (a) UK-CAA MORS database;
- (b) Aircraft Accidents Investigation Board (AIBs), e.g. UK AAIB;
- (c) National Transportation Safety Board (NTSB) database;
- (d) EASA ADREP database; and
- (e) ECR.

**Table 1 — UK/NS accidents before 2003**

  denotes a fatal accident.

State Of Occurrence/ Location		Occ. Class	Date	Type	Aircraft Reg.	Fatalities (Crew + Pax)	Primary Cause
UK	NS	Ditching	8.3.1976	S-58	G-ATSC	0/1 + 0/13	Engine failure
UK	NS	Ditching	1.10.1977	S-61N	G-BBHN	0/2 + 0/1	Blade failure
NOR	NS	NSWI	26.6.1978	S-61N	LN-OQS	2/2 + 16/16	
NOR	NS	SWI	31.7.1979	B-212	LN-ORL	0/3	Loss of control
UK	NS	Ditching	31.7.1980	S-61N	G-BEID	0/2 + 0/13	Main gear box (MBG) failure
UK	NS	SWI	12.8.1981	B212	G-BIJF	0/1 + 1/13	Loss of control
UK	NS	NSWI	13.8.1981	Wessex 60	G-ASWI	2/2 + 11/11	Loss of control
UK	NS	NSWI	14.9.1982	B212	G-BDIL	6/6	Controlled flight into terrain (CFIT)
UK	NS	Ditching	11.3.1983	S-61N	G-ASNL	0/2 + 0/15	MGB failure



UK	Isles of Scilly	SWI	16.7.1983	S-61N	G-BEON	1/3 + 19/23	CFIT
UK	NS	SWI	24.12.1983	B212	G-BARJ	0/2	Winch entanglement
DEN	NS	SWI	2.1.1984	B-212	OY-HMC	2/2 + 1/1	Tail rotor (T/R) drive failure
UK	NS	Ditching	2.5.1984	BV234LR	G-BISO	0/3 + 0/44	Control system failure
UK	Skegness	SWI	24.7.1984	BO-105D	G-AZOM	0/1 + 0/2	T/R drive failure
UK	NS	NSWI	20.11.1984	B212G	G-BJJR	2/2	Loss of control
UK	NS	Ditching	15.5.1986	B214ST	G-BKFN	0/2 + 0/18	Control system failure
UK	NS	NSWI	6.11.1986	BV234LR	G-BWFC	2/3 + 43/44	MGB failure
UK	NS	Ditching	13.7.1988	S-61N	G-BEID	0/2 + 0/19	Engine Fire
UK	Handa, Scotland	SWI	17.10.1988	S-61N	G-BDII	0/4	CFIT
UK	NS	Ditching	10.11.1988	S-61N	G-BDES	0/2 + 0/11	MGB failure
UK	NS	Ditching	25.4.1989	B105D	G-BGKJ	0/1 + 0/1	Engine failure
UK	NS	SWI	25.7.1990	S-61N	G-BEWL	2/2 + 4/11	Collision with obstacles
UK	NS	SWI	14.3.1992	AS332L	G-TIGH	1/2 + 10/15	HF
UK	NS	Ditching	19.1.1995	AS332L	G-TIGK	0/2 + 0/16	Lightning strike
NOR	NS	Ditching	18.1.1996	AS332L1	LN-OBP	0/2 + 0/16	Blade failure
NOR	NS	NSWI	8.9.1997	AS332L1	LN-OPG	2/2 + 10/10	MGB failure
NL	near Den Helder	SWI	20.12.1997	S-76B	PH-KHB	0/2 + 1/6	CFIT
UK	Kyle of Lochalsh, Scotland	SWI	12.1.2002	SA365N	G-PDGN	0/1 + 0/5	CFIT
UK	NS	NSWI	16.7.2002	S-76A	G-BJVX	2/2 + 9/9	Blade failure



Table 2 — Worldwide accidents 2003–2012

State of occurrence/ location		Occ. Class	Date	Type	Aircraft Reg.	Fatalities Crew+Pax	Primary Cause
Nigeria Brass terminal		SWI	3.1.2003	AS365N2	5N-BBS	2/2 + 2/10	T/R failure
Greece		SWI	11.2.2003	A109	SX-HDV	4/4	Electrical system failure
USA	GoM	SWI	16.2.2003	B-407	N407HH	1/1 + 1/4	Engine failure
USA	GoM	Ditching	11.5.2003	B-407	N491PH	0/1 + 0/3	Engine failure
Brazil		NSWI	5.7.2003	S-76A	PT-YVM	2/2 + 3/3	Collision with obstacles on take-off (T/O)
India Agatti Island		SWI	3.10.2003	SA365N	VT-ELF	0/2 + 1/3	Loss of control
USA	GoM	Ditching	16.11.2003	B-407	N405PH	0/1 + 0/2	Engine failure
USA	GoM	NSWI	1.12.2003	B-407	N457PH	1/1	Engine failure
Norway		SWI	18.12.2003	B212	LN-OLK	0/2	CFIT
USA	GoM	NSWI	23.3.2004	S-76A++	N579EH	2/2 + 8/8	CFIT
Brazil		SWI	22.7.2004	S-76	PP-MYM	0/2 + 6/9	MGB failure
Nigeria		Unknown	26.7.2004	B412EP	5N-BDZ	4/4	Unknown
Sweden		SWI	18.9.2004	S-76C	SE-JUJ	0/5	CFIT
USA	GoM	SWI	17.12.2004	B-407	N976AA	0/1 + 1/3	Collision with obstacle
Japan Sado Island		Ditching	10.1.2005	S-76C	JA6903	0/6	Engine failure
China		SWI	10.2.2005	MD-902	B-2116	0/1 + 3/3	Collision with ship
Canada	BC	SWI	7.5.2005	BO-105	C-GCHX	0/1	Loss of control
USA	Alaska	Ditching	11.5.2005	AS350	N60618	0/1 + 0/4	Engine failure
USA	NY	SWI	17.6.2005	S-76C+	N317MY	0/2 + 0/6	Loss of Control
Malaysia		Ditching	18.6.2005	AS332L1	9M-STT	0/2 + 0/8	T/R failure
Mexico		NSWI	17.7.2005	B-412	XA-VVD	2/2	HF



Estonia Tallinn Bay		SWI	10.8.2005	S-76C+	OH-HCI	2/2 + 12/12	Failure of main control actuator
USA	GoM	SWI	6.9.2005	S-76A	N90421	0/2 + 0/10	In-flight fire
France English Channel		SWI	8.9.2005	SA365N3	F-GYPH	1/1 + 1/1	CFIT
Canada NFL		SWI	7.12.2005	BO105	C-GGGC	1/1 + 1/1	CFIT
Brazil		SWI	15.12.2005	B-412	PT-HUV	0/2 + 0/7	MGB failure
USA	GoM	SWI	19.2.2006	B-222B	N306CH	0/2 + 0/0	CFIT
Indonesia		Ditching	1.3.2006	SA365	PK-TSX	0/2 + 0/4	T/R failure
USA	GoM	SWI	5.5.2006	EC120B	N514AL	0/1 + 0/0	Loss of Control
USA	NY	Ditching	28.5.2006	369HS	N9244F	0/1 + 0/1	Engine failure
Canada		SWI	13.7.2006	CH149 (EH101)	CH14991 4	3/7	Loss of control
USA	OR	NSWI	13.8.2006	R44 II	N168PT	2/2 + 1/1	CFIT
USA	NC	Ditching	30.9.2006	R44	N140JM	0/1 + 0/2	Engine failure
USA	GoM	SWI	22.10.2006	S-76A++	N22342	0/2	CFIT
Malaysia		Ditching	5.11.2006	AS332	9M-SPA	1/2 + 0/19	Unknown
NL	NS	Ditching	21.11.2006	AS332L2	G-JSAR	0/4 + 0/13	Engine failure
UK	NS	NSWI	27.12.2006	SA365N	G-BLUN	2/2 + 5/5	CFIT
Malaysia Kuala Lumpur		Ditching	30.1.2007	SA332L2	9M-STR	0/2 + 1/8	Hydraulic system failure?
USA	GoM	NSWI	12.2.2007	EC120B	N690WR	1/1 + 1/1	Collision with obstacle
USA	GoM	SWI	11.5.2007	B-206B	N3RL	0/1 + 0/3	Loss of control
USA	NY	Ditching	7.7.2007	EC130B4	N453AE	0/1 + 0/7	Blade structural failure
Iceland		Ditching	16.7.2007	SA365N	TF-SIF	0/3 + 0/0	Engine failure
USA	GoM	SWI	22.7.2007	B206L-3	N330P	0/1 + 0/2	Loss of control
USA	FL	NSWI	11.9.2007	B206B	N261BH	0/1 + 2/2	CFIT



USA	GoM	SWI	29.12.2007	B206L1	N211EL	0/1 + 1/3	Loss of control on approach
Brazil Rio de Janeiro		SWI	26.2.2008	AS332L2	PP-MUM	1/3 + 4/17	Loss of control
UAE		NSWI	3.9.2008	B212	AV-ALV	2/2 + 5/5	Collision with obstacles on T/O
USA	Hawaii	NSWI	4.9.2008	HH-65	CS-6505	4/4	Snagging during winching
USA	FL	Ditching	6.9.2008	R44 II	N144SA	0/1 + 0/3	LTE
Australia		SWI	25.9.2008	B-407T	VH-NSH	0/1 + 0/6	Engine failure
USA	GoM	NSWI	11.12.2008	B206L-4	N180AL	1/1 + 4/4	CTIF
UK	NS	SWI	18.2.2009	EC225LP	G-REDU	0/2 + 0/16	CFIT
Canada East coast		SWI	12.3.2009	S-92A	C-GZCH	2/2 + 15/16	MGB Lube failure
UK	NS	NSWI	1.4.2009	AS332L2	G-REDL	2/2 + 14/14	MGB failure
USA	GoM	Ditching	24.7.2009	R44 II	N645JC	0/1 + 0/2	Engine failure
USA	Maine	SWI	1.8.2009	EC130B4	M-BOAT	0/1 + 0/3	Loss of control
USA	GoM	Ditching	1.11.2009	B206	N272M	0/1 + 0/1	Engine failure
Nigeria		Ditching	11.12.2009	AS332L1	5N-BKJ	0/2 + 0/16	Unknown
Sweden Stockholm		SWI	11.1.2010	R44	SE-JGA	0/1	CFIT
Spain Almeria coast		NSWI	21.1.2010	AW139	EC-KYR	3/4	CFIT
USA	FL	Ditching	28.3.2010	R22	N72377	0/2	Loss of control
USA	Lake Huron	SWI	20.4.2010	HH-65C	CS-6523	0/3	Loss of control
Mexico	GoM	Ditching	1.6.2010	Bell 412	XA-HSI	0/2 + 0/9	T/R failure
USA	WA	Ditching	8.6.2010	B47G-4A	N7069J	0/2	HF
USA	GoM	Ditching	10.6.2010	B206L3	N108PH	0/1 + 0/2	T/R failure
China	HK	Ditching	3.7.2010	AW139	B-MHJ	0/2 + 0/11	T/R failure



USA	WA	NSWI	7.7.2010	MH-60T	CG-6017	3/4	Collision with obstacle
USA	CA	Ditching	22.8.2010	R44	N7186Z	0/1	HF
USA	NY	Ditching	22.9.2010	B412	N412PD	0/2 + 0/4	Drive system failure
China	HK	Ditching	27.12.2010	AS332L2	B-HRN	0/3	Engine failure
Argentina		Ditching	31.1.2011	BK117C2	N245AF	0/1 + 0/1	Collision with obstacles on T/O
Myanmar Andaman Sea		SWI	11.7.2011	S-76C++	F-HJCS	1/2 + 2/9	Engine failure
Brazil Campos Basin		NSWI	19.8.2011	AW139	PR-SEK	1/1 + 3/3	T/R blade detachment
USA	AL	NSWI	28.2.2012	MH-65D	CG-6535	4/4	CFIT
USA	GoM	Ditching	17.4.2012	S-76B	N56RD	0/1 + 0/6	Engine failure
UK	NS	Ditching	10.5.2012	EC225LP	G-REDW	0/2 + 0/12	MGB shaft failure
Mexico	GoM	Ditching	29.6.2012	B-412EP	XA-ICL	0/1 + 0/2	Unknown
Canada Langara Island		Ditching	13.8.2012	S-76A	C-GHJT	0/1 + 0/1	Engine failure
UK	NS	Ditching	22.10.2012	EC225LP	G-CHCN	0/2 + 0/17	MGB shaft failure
Germany Baltic Sea		Ditching	5.12.2012	AS350BA	LN-OMY	2/2	Engine failure
Brazil Campos Basin		Ditching	27.3.2013	B-412	PT-HUW	0/3	
Australia Queensland		Ditching	31.7.2013	B206B	VH-SMI	0/1 + 0/2	Loss of control (loss of T/R effectiveness)
UK	NS	SWI	23.8.2013	AS332L2	G-WNSB	0/2 + 4/16	HF



**Summary Table — NS 1976–2002**

	Ditching	SWI	NSWI	Total
Number of occurrences	11	11	7	29
Fatal accidents	0	6	7	13
Number of fatalities/occupants	0/188	42/99	107/109	149/396

**Summary Table — Worldwide 2003–2012**

	Ditching	SWI	NSWI	Total
Number of occurrences	32	31	16	79
Fatal accidents	3	15	16	34
Number of fatalities/occupants	4/215	68/205	78/81	150/501

**Summary Table — Total database**

	Ditching	SWI	NSWI	Total
Number of occurrences	43	42	23	108
Fatal accidents	3	21	23	47
Number of fatalities/occupants	4/403	110/304	185/190	299/897

