

Helicopter Emergency Flotation System Crashworthiness

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HARP

Helicopter Airworthiness Review Panel (HARP)

- **Joint UK industry panel.**
- **HARP Report (CAP 491, 1984):**
- **Recommendation 7**

A study should be initiated forthwith to identify suitable requirements for an improved standard of crashworthiness of the 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.

Early Research

UK Research (1)

Review of UK Military & World Civil Water Impacts, 1971 – 1992 (1)

- **Objective:**
 - To determine impact parameters and primary injury causing mechanisms.

	Number of water impacts* ¹	Number of fatalities	% fatalities due to drowning* ²
World civil (UK CAA)	98	338	56.8
UK military (RN AAIU)	61	46	82.6

*¹ excludes non-survivable impacts and those with inadequate information.

*² % of fatalities for accidents where cause of death was known.

UK Research (2)

Review of UK Military & World Civil Water Impacts, 1971 – 1992 (2)

- **Conclusions:**
 - Majority of fatalities in both world civil and UK military helicopter water impacts attributable to drowning where cause of death identified.
 - In 50% of impacts the helicopter inverted or sank before occupant evacuation had been completed.
 - Improved flotation considered to be the most significant factor in increasing occupant survival in helicopter water impacts.

UK Research (3)

Analysis of the Response of Helicopter Structures to Water Impact

- **Objective:**

- To investigate the response of helicopter structures to water impact and examine design techniques to improve occupant survival.

- **Conclusions:**

- Impact severity and probability of occupant survival dependent on impact velocity and response of structure.
- Drowning was the major cause of fatalities – fatalities due to excessive crash forces or collapse of structure on impact of secondary significance.
- Major cause of drowning due to inability to escape from inverted or submerged helicopter.
- Designing the airframe to remain afloat after impact long enough for occupants to evacuate vital if survival is to be improved.
- Mathematical modelling techniques potentially valuable but require validation.

FAA Research (1)

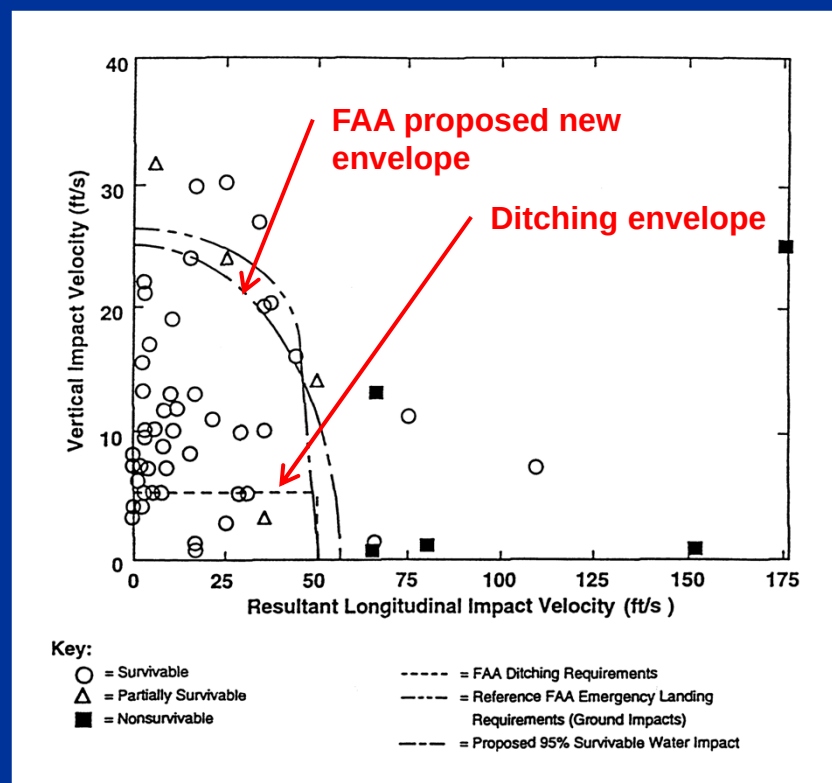
Rotorcraft Ditchings and Water-Related Impact, 1982 – 1989

- **Scope:**
 - review of 67 civil (from NTSB) and 10 Military (US Army) water impacts.
- **Conclusions:**
 - **drowning was the most significant post-impact hazard.**
 - **aircraft flotation equipment generally found to be inadequate.**
 - activation of flotation post impact by immersion switch would be an improvement.
 - structural failures did not contribute significantly to occupant injury.

FAA Research (2)

Survey and Analysis of Rotorcraft Flotation Systems (1)

- **Scope:**
 - Survey of civil and US Navy flotation technology.
 - Review of civil accident and incident data.
 - Definition of generic flotation system improvements.
 - Evaluation of available analytical methods for assessing flotation system performance.



Rotorcraft Water Impact Survivability

FAA Research (3)

Survey and Analysis of Rotorcraft Flotation Systems (2)

- **Key conclusions:**
 - Drowning found to be the leading cause of death.
 - Rotorcraft found to overturn immediately on impact in both ditching and water impact scenarios.
- **Key floatation system improvements suggested:**
 - Supplementary floats located near the top of the rotorcraft.
 - Automatic float activation systems that would not require pilot interaction.

RHOSS

Review of Helicopter Offshore Safety & Survival

- Joint UK industry panel, independently chaired.
- RHOSS Report (CAP 641, 1995)
- Recommendation [para. 14.2(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.”

Follow-On Research

Follow-On Research (1)

Crashworthiness of Helicopter Emergency Flotation Systems

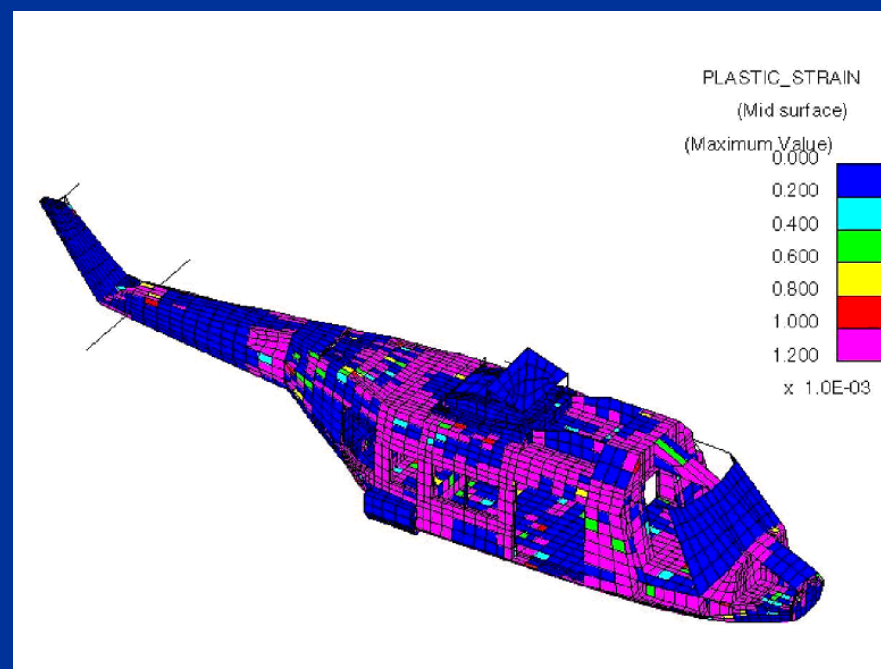
- **Objective:**
 - To establish the feasibility of improving the post crash operability of emergency flotation systems.
- **Methodology:**
 - FE modelling of three water impacts using LS DYNA3D.
 - Semi-empirical modelling using Monte-Carlo technique to establish range of impact loads.



Brent Spar 1990

Follow-On Research (2)

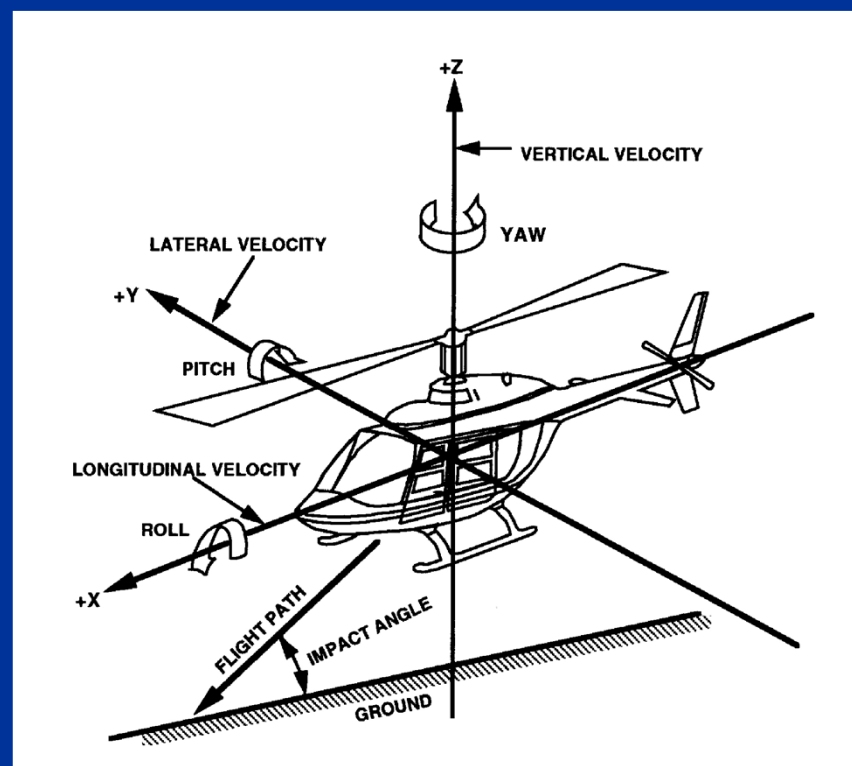
- **FE Modelling of Example Water Impacts:**
 - Brent Spar (vertical), Scilly Isles (horizontal) and Cormorant A (intermediate) accidents modelled.
 - Helicopter model validated well against drop test data.
 - Water model validated well for vertical impacts against NASA Gemini capsule data.
 - Water model validation for horizontal impacts using NASA Orbiter data disappointing.



Brent Spar - Plastic Strain

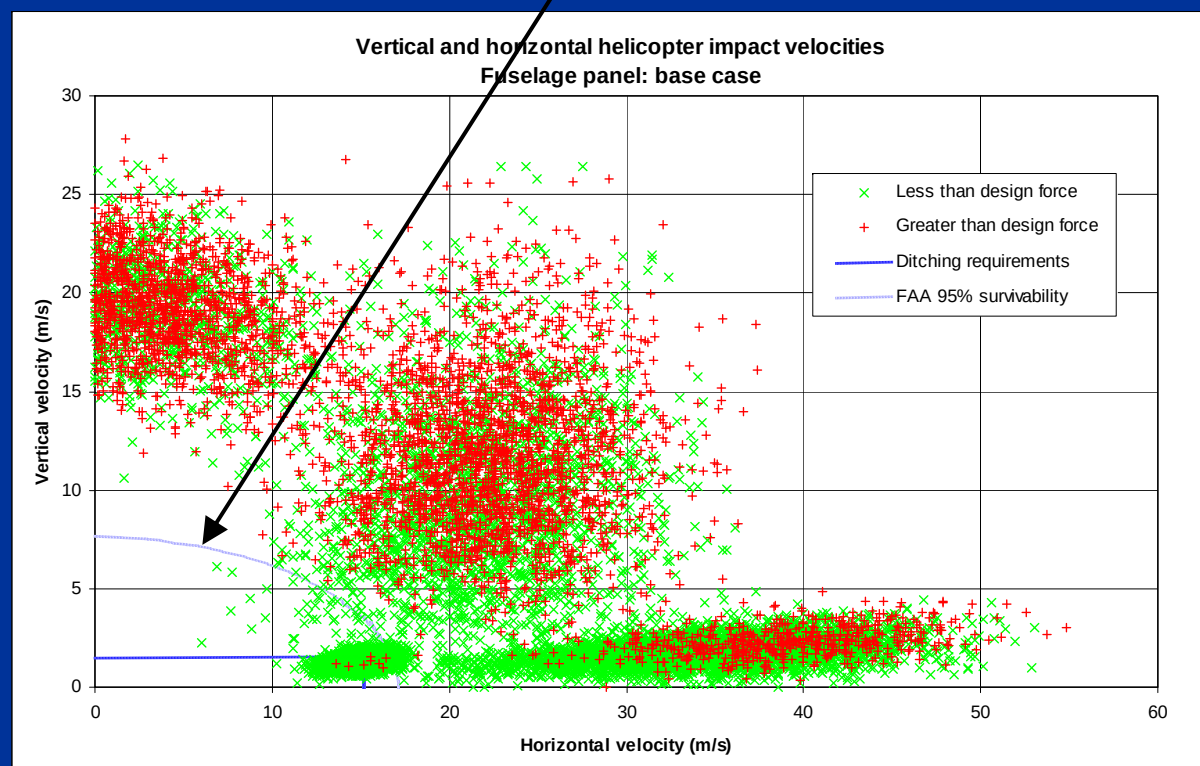
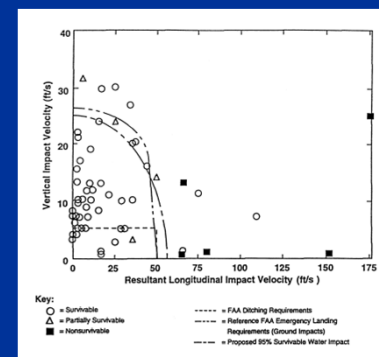
Follow-On Research (4)

- **Semi-Empirical Modelling (1):**
 - Monte Carlo simulation to investigate variability of impact loads for single fuselage panel and single S61 type sponson.
 - Scenarios based on Brent Spar, Scilly Isles and Cormorant A accidents plus ditching.
 - Impact angles and velocities, and sea states varied around nominal accident and ditching values.



Follow-On Research (5)

- **Semi-Empirical Modelling (2):**
- Most impact velocities (apart from ditching cases) exceed proposed FAA boundary.
- Relatively low proportion of failures for 'fly-in' case likely due to uncertainty regarding drag and planing forces.

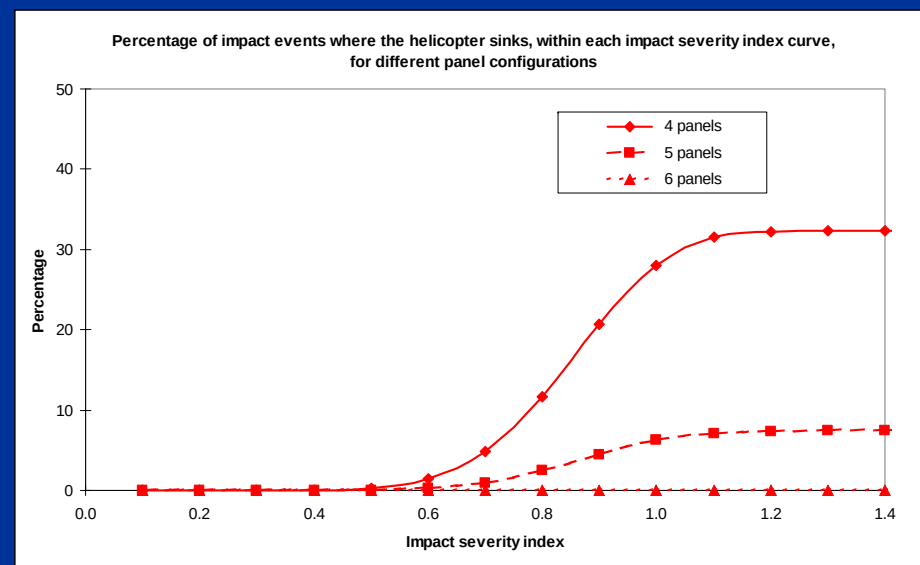


Scatter Plot of Flotation Unit Failure vs Impact Velocities

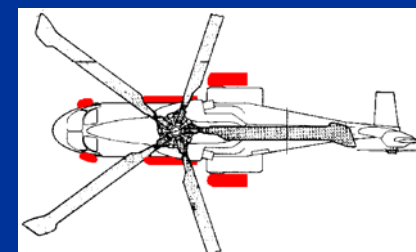
Follow-On Research (6)

Semi-Empirical Modelling (3):

- Monte Carlo simulation of full EH101-type flotation system.
- 100% increase in design strength gave only a modest improvement in crashworthiness.
- Simulation run for 3 floatation system configurations with varying levels of redundancy.
- Helicopter sank in 30% of cases with standard 4 float system.
- 6 float system (2 additional high mounted flotation units) remained afloat in all impacts modelled.



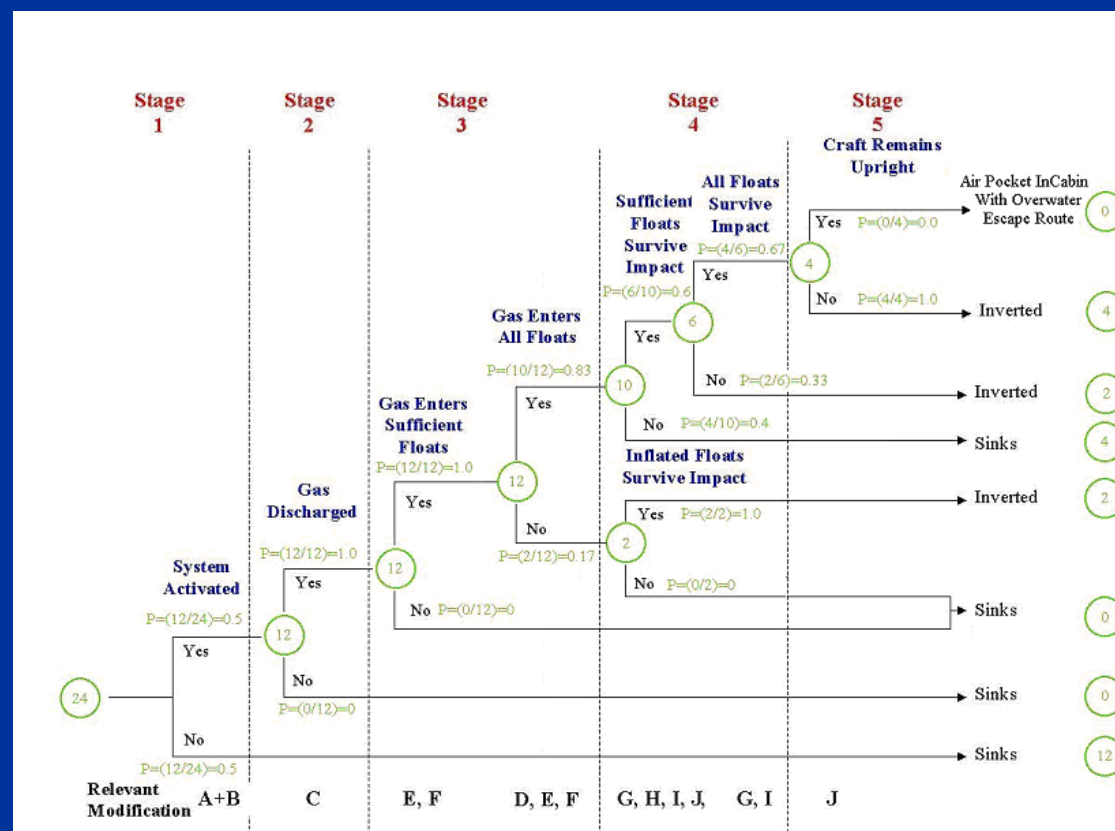
Percentage of Impacts Resulting in Sinking vs Impact Severity for 3 Configurations



Follow-On Research (7)

Analysis of Flotation System Performance (1):

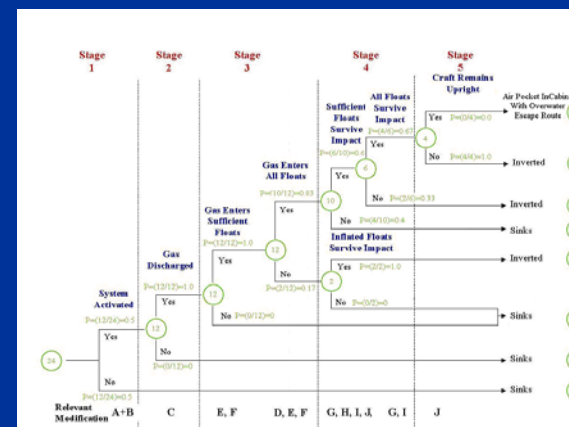
- Based on 20 accidents from NTSB data base + 4 UK accidents, all involving EFS failures and fatalities.
- Of 24 water impacts, 16 sank and 8 inverted.
- EFS not armed or not activated (50%).
- Floats damaged (25%).
- External factors (17%).
- All gas did not reach all floats (8%).



EFS Deployment Probability Tree

Follow-On Research (8)

Analysis of Flotation System Performance (2):



Modification		Stage	Number of lives saved	Estimated cost per life saved
A	Arm the system at all times, except when hazardous.	1	4.3	£250k
B	Automatic activation using immersion switches.			
C	Inflation bottle redundancy.	2	0	No benefit
D	Minimise the effect of varying ambient conditions on gas leaving bottles.	3	0	No benefit
E	Use flexible hoses to minimise impact damage.	3	0	No benefit
F	More even flow distribution and bag deployment.	3	0	No benefit
G	Increase float attachment design loads and protection from impact.	4	2.2	£1m
H	Relocate existing floats to regions less susceptible to damage.	4	2.2	£3.6m
I	Incorporate flotation unit redundancy.	4	2.2	£1m
J	Provide additional flotation so that the helicopter floats on its side	4 & 5	5.1	£1m

Conclusions

Conclusions

- **Largest cause of fatalities in survivable water impacts is drowning.**
- **Best way of enhancing safety is to improve post crash operability of the emergency flotation system.**
- **Most effective means of significantly improving post crash operability of helicopter emergency flotation systems is through the provision of flotation unit redundancy, ideally by adding high mounted floats to provide a side-floating attitude.**
- **Consequences of a significant proportion of water impacts could be mitigated by provision of automatic arming and deployment of emergency flotation systems.**
- **Addition of redundancy and automatic arming/deployment are affordable and cost effective (in terms of cost per life saved).**

Thank you for your attention...

Any questions?