Rotorcraft Loss of Control In-Flight:

The need for research to support increased fidelity in flight training devices, including analogies with upset recovery for fixed-wing aircraft

Dr Mark D White

The University of Liverpool

Dr Sunjoo Advani

IDT

UK VERTICAL LIFT NETWORK

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Overview

- Rotary wing accident trends
- Fixed wing LOC-I/UPRT activities
- Rotary wing safety initiatives
- Simulation fidelity research
- Opportunities in current modelling & simulation, training
- Concluding remarks and future activities

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ROTORCRAFT ACCIDENT TRENDS

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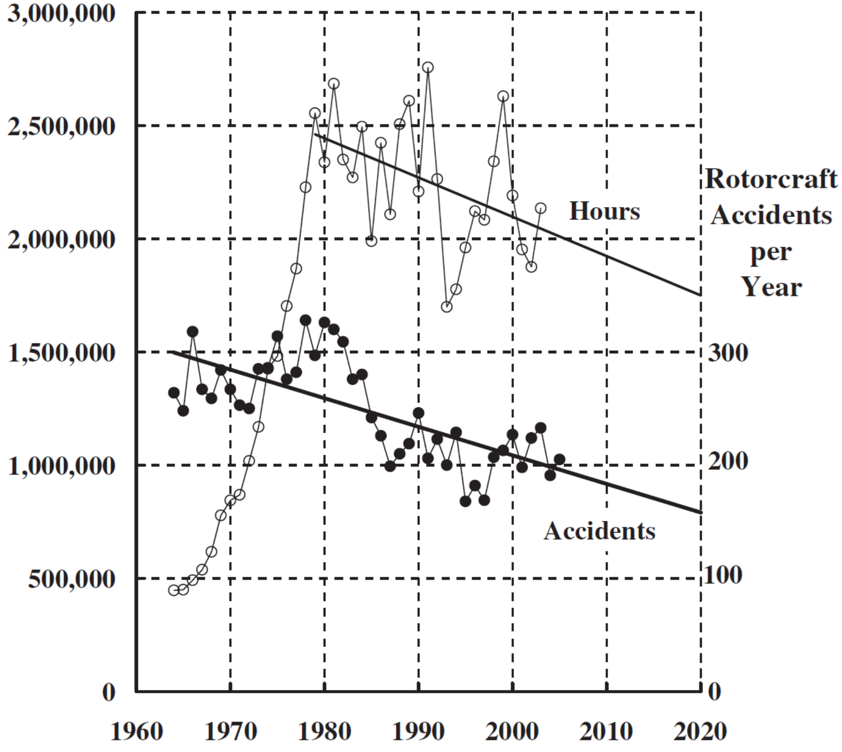
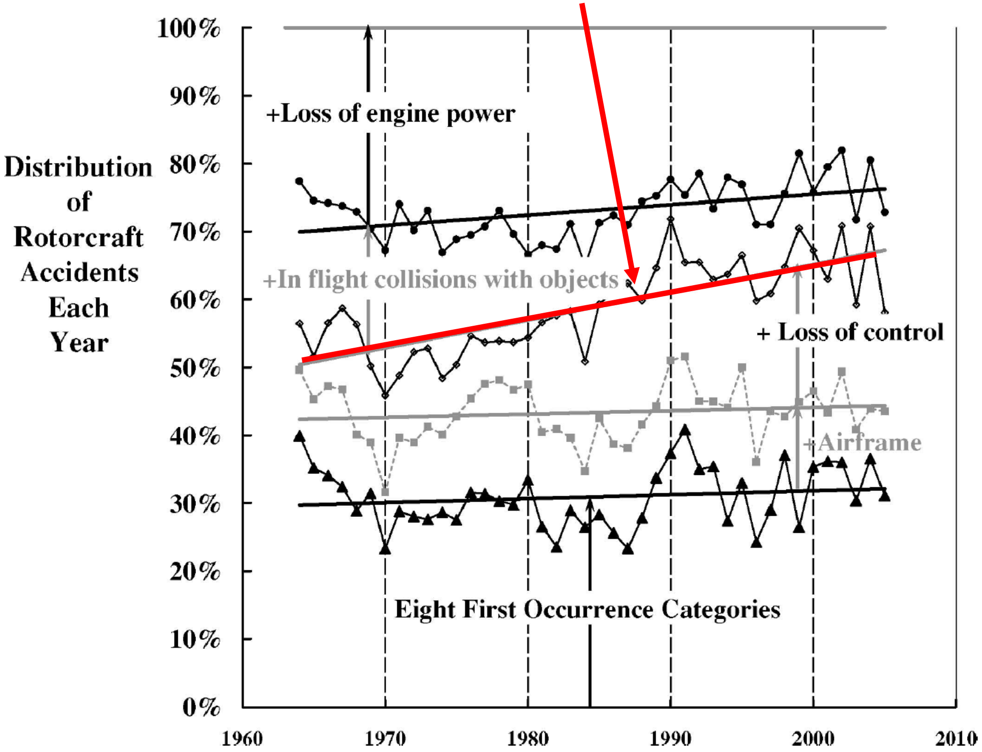
No Accidents – *That's* the Objective
Franklin D Harris, 26th Alexander A. Nikolsky Lecture



Doubling over time period

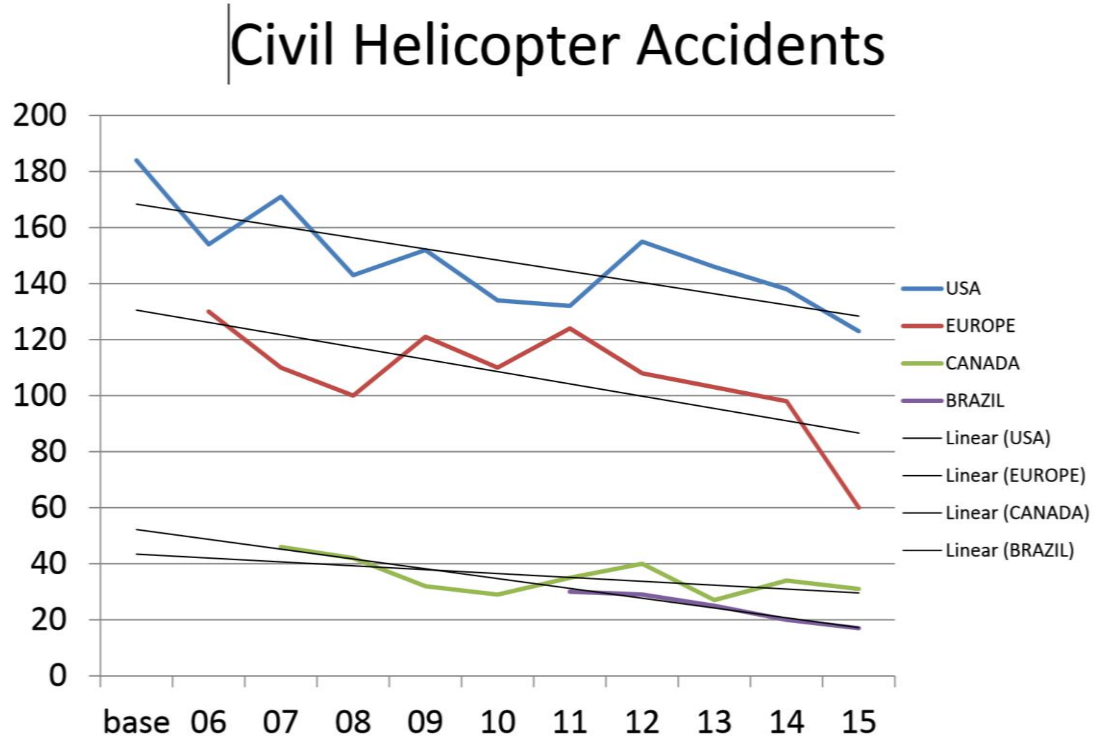


Harris, F. D., Kasper, E. F., and Iseler, L. E., "U.S. Civil Rotorcraft Accidents, 1963 through 1997," NASA/TM-2000-209597

Recent Rotary Wing Accident Statistics

IHST International Helicopter Safety Team
Our Vision: An International Civil Helicopter Community With Zero Accidents

IHST initiated a program with the goal to reduce the worldwide helicopter accident rate by 80% in 10 years (by 2016)



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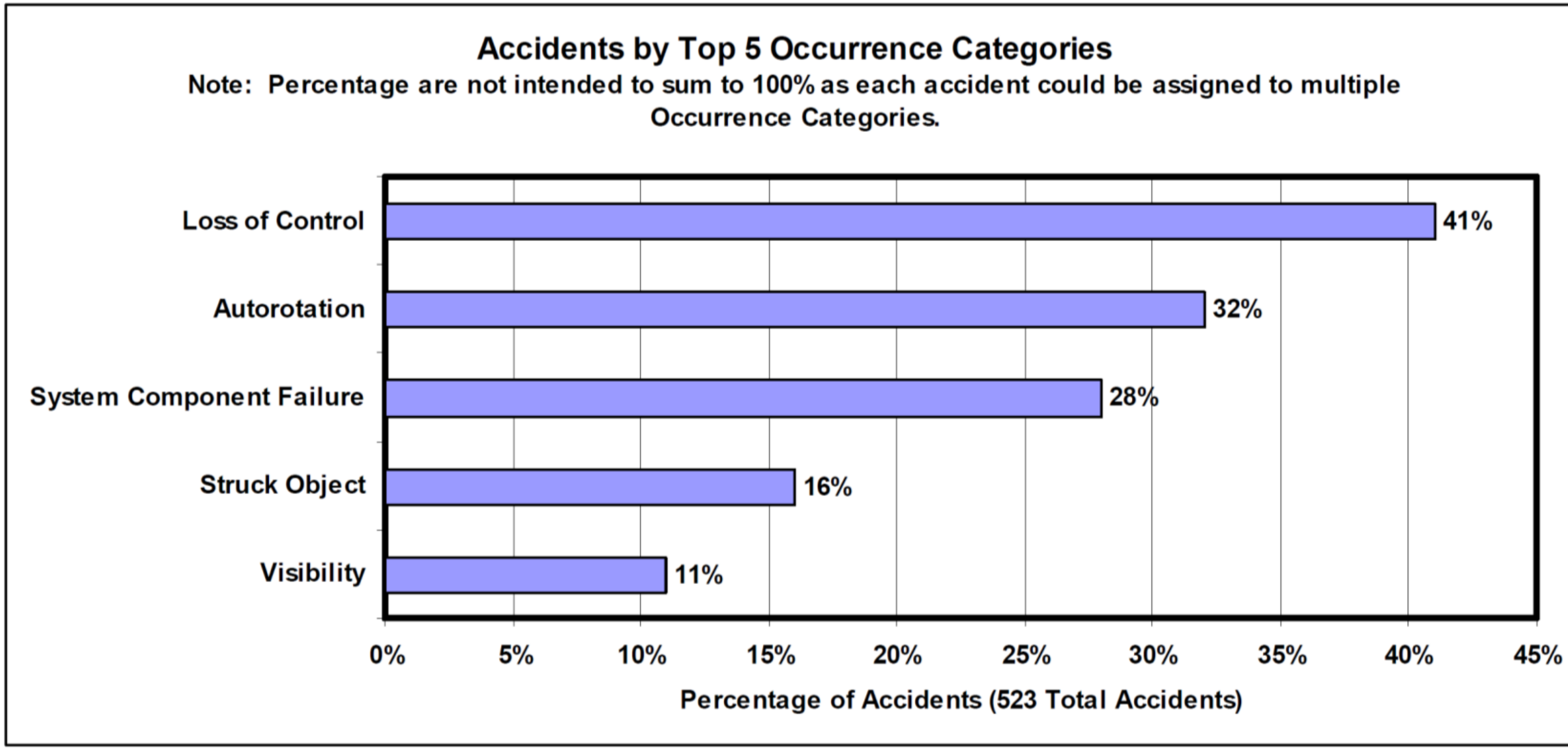
Accident Categorisation

- USJHS analysis team completed an analytical review of three years of U.S. helicopter accident data from 523 different accidents.



U.S. Joint Helicopter Safety Analysis Team, “The Compendium Report: The U.S. JHSAT Baseline of Helicopter Accident Analysis: Volume I”.

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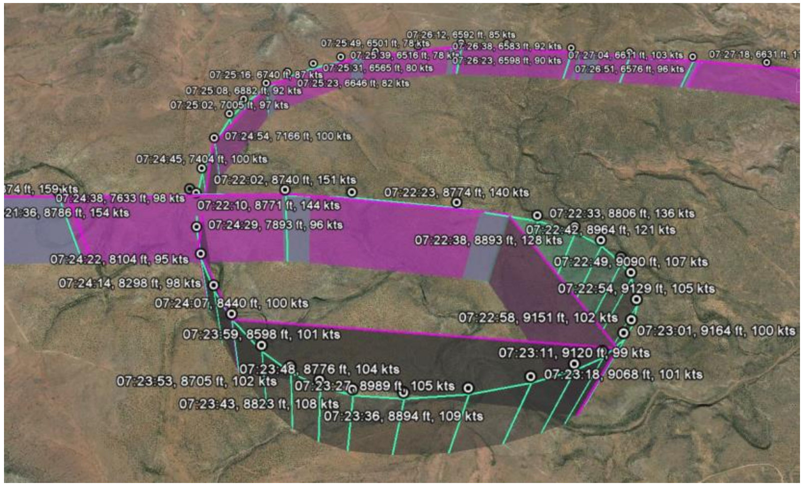
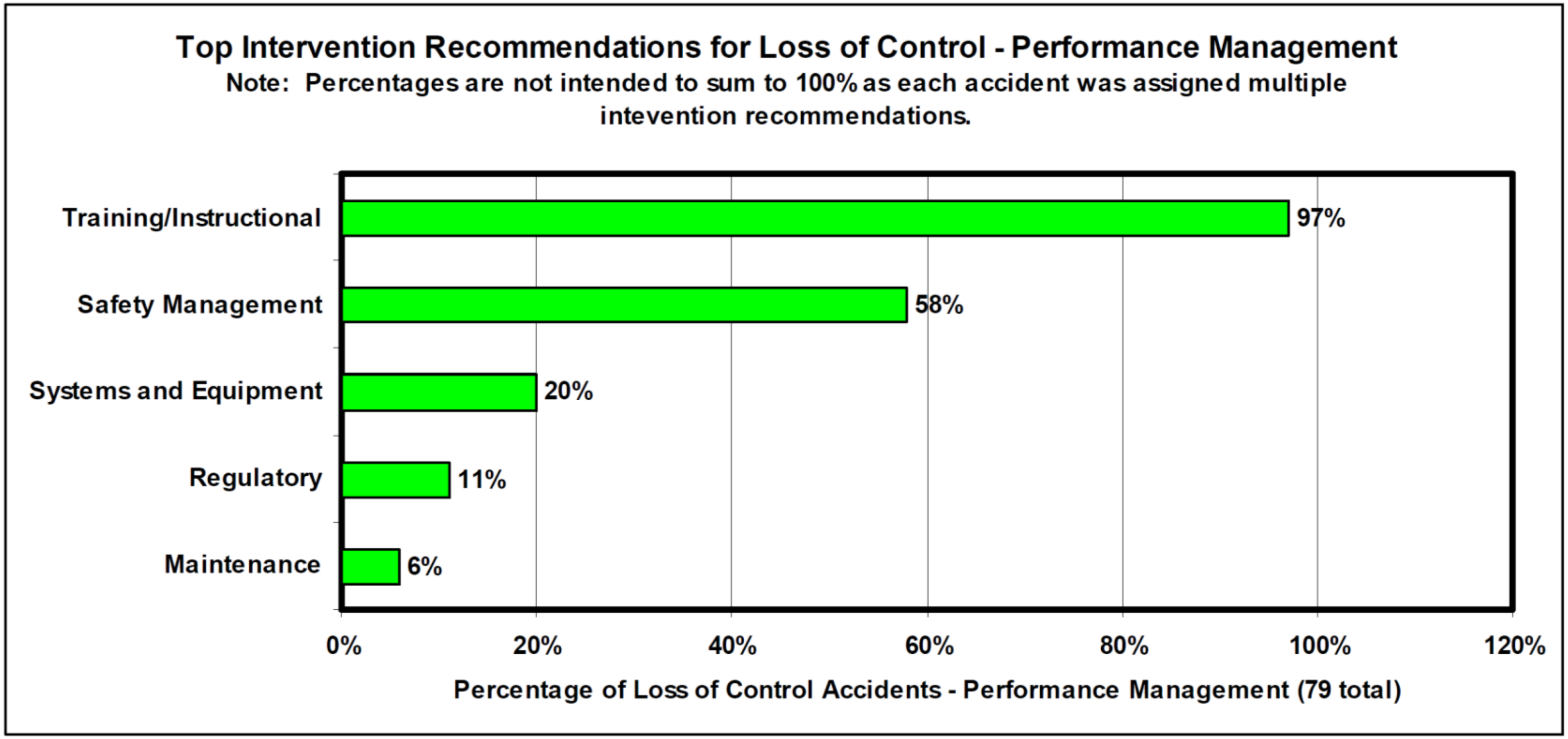
Example accident - NTSB Identification: CEN10FA509

- Dark night instrument meteorological conditions prevailed at the time of the accident.
- The last minute of data depicted a turn to the left, a turn to the right, a reversal to the left, a reversal back to the right, and then a final reversal to the left.
- "…probable cause(s) of this accident [may be] the pilot's **loss of aircraft control, due to spatial disorientation,** resulting in the in-flight separation of the main rotor and tail boom"



Intervention Strategies



- *"Inadequate pilot judgment and the subsequent poor decision(s) or non-decision were found to be pervasive in most non-material failure types of accidents and must be addressed."*
- Inflight Power/Energy Management Training
- **Simulator Training - Advanced Manoeuvres**
- Enhanced Aircraft Performance & Limitations Training
- CFI Training and Refresher on Advanced Handling, Cues, and Procedures
- Emphasis for Maintaining Cues Critical to Safe Flight

DEVELOPMENT OF A FIXED WING UPSET PREVENTION AND RECOVERY TRAINING (UPRT) PROGRAMME

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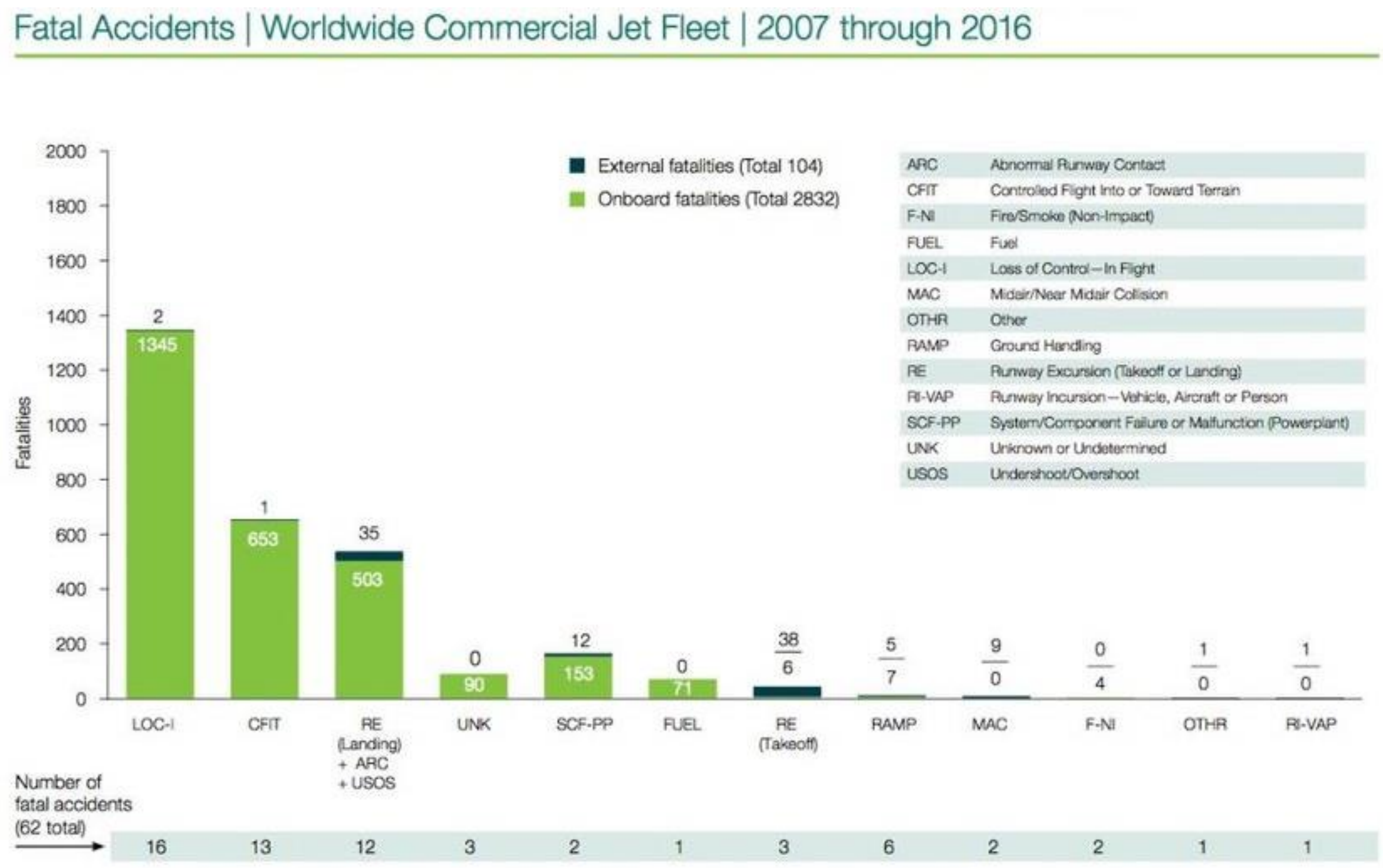
Fixed Wing Accident Rates/Causes



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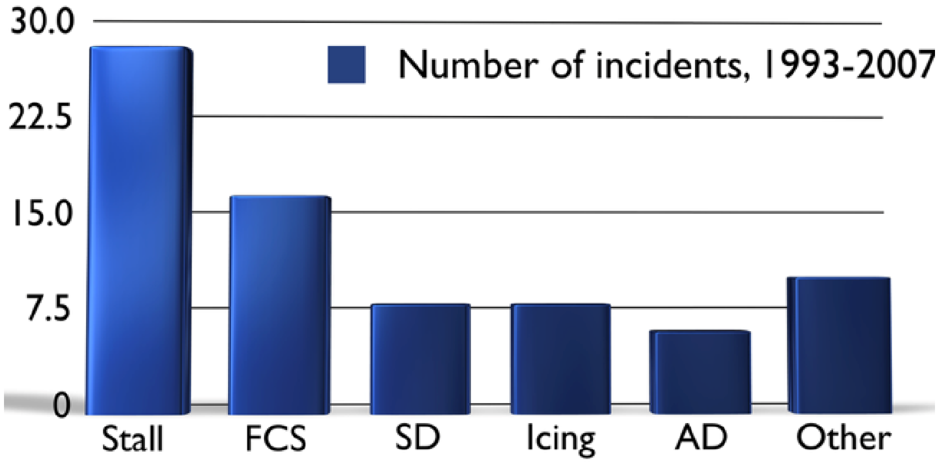
CATEGORAISATION OF F/W LOC-I

- LOC-I is a loss of aircraft **control whole, or deviation from intended flightpath, in flight**.
- LOC-I accidents result from **failure to prevent or recover** from a stall or **upset**
- Three causal categories:
- **Environmental** (windshear, icing, wake vortex)
- **System failure** (autopilot, flight control system)
- **Pilot Induced** (disorientation, misuse of controls/automation)

– z

Significant LOC-I Accidents & Causes

- In 2008, Lambregts concluded that Stall is the primary causal factor to LOC-I.
- Since 2008, the following LOC-I accidents were reported, all of which involved stall or low energy:
  - Colgan 3407
  - Turkish 1951
  - Air France 447
  - AirAsia 8501
  - Air Algérie 5017
  - Asiana 314



FCS = Flight Control System
SD = Spatial Disorientation
AD = Atmospheric Disturbance

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International Committee for Aviation Training in Extended Envelopes ICATEE (2009 -)

- 80+ members: **manufacturers**, airlines, **national aviation authorities and safety boards**, simulator manufacturers, training providers, research institutions and pilot representatives

- ICATEE thoroughly analysed the causes of LOC-I and addressed both the training and technology solutions.

- Technology includes:
  - **Enhanced flight dynamics models** of post-stall behaviour
  - Mathematical models to represent effects due to icing (not just weight increase)
  - **Type-representative models** (models do not need to be exact per aircraft type, but support the training objectives)

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Industry Reaction

- Analysis of the causal factors:
  - Improper/inadequate training, including maintaining altitude during stall recovery
  - Lack of emphasis on reducing AoA in stalls; emphasis on wrong recovery techniques
  - **Limited attention to awareness and recognition**, and too much on “recovery”
  - Limitations in academic knowledge of instructors and pilots
  - Lack of regulations or consistent training standards
  - **Limitations in flight simulator fidelity beyond the normal flight envelope**
  - Inadequate models and validation of flight simulators regarding engine/airframe icing
- RAeS ICATEE drove changes, incorporated into ICAO 10011 “Manual of Aeroplane UPRT”
- Adopted provisions into regulations (FAA, EASA, others), requiring structured UPRT & Stall training

Current ICAO regulations

- ICAO 10011 requires:
  - **Enhanced academics for all pilots and instructors (bridge training)**
  - Repeat of UPRT exercises on recurring basis every 2-3 years
  - **Ensure that simulator-based training is conducted within valid simulator envelope: avoid negative training**
  - **Develop competencies**, since UPRT is not a “testing” requirement

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Lessons Learned from Developing UPRT

- Required an **integrated approach** across the fixed wing community – **including training medium**
- Type Representative models are suitable for UPRT. This is about **enhancing current training practices**, not “perfecting” simulators
- **Academics!**
- **Enhancements require validation by SME pilots**, who must be properly qualified to assess the enhancements
- Don’t miss the forest for the trees: Enhance the training benefits!

- EASA 2017-13 Update of flight simulator training devices requirements
  - The European Plan for Aviation Safety highlights the importance of training tools modernisation

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Can F/W UPRT be directly applied to R/W?

- Transferable
  - Focus on prioritization through causal factors
  - 3D Mental Model
  - Startle Management
  - Development of skills for better awareness and recognition
  - Apply proper CRM where applicable
  - LOC-I contributing factors similar
  - Academics!
- Non-Transferable
  - Helicopters are different and varied!
  - Push-Roll-Power-Stabilise F/W approach could be dangerous
  - Differing levels of augmentation

CURRENT ROTORCRAFT SAFETY INITIATIVES

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USHST Helicopter Safety Enhancements (H-SE)*

81 Improve Simulator Modelling for Outside-the-Envelope Flight Conditions

127A Training for Recognition/Recovery of Spatial Disorientation (SD)

- 52 fatal accidents (2009-2013) where LOC-I occurred during **basic manoeuvres** (*e.g.* hover) and during **unsuccessful attempted recovery from potentially unsafe conditions** (*e.g.* LTRE)
- FAA, industry & academia to review and provide **recommendations for improving simulator mathematical/physics models**
- Create helicopter unique SD training products to **include simulation technology.**
- **Define SD scenarios** for emphasis in training products
- http://www.ushst.org/

*U.S. Helicopter Safety Team (USHST), Report Helicopter Safety Enhancements: *Loss of Control – Inflight, Unintended Flight in IMC, and Low-Altitude Operations* October 2017

European Activities & Training Materials

EHEST

- “Training and Testing of Emergency and Abnormal Procedures in Helicopters”
- “Safety Considerations: Methods To Improve Helicopter Pilots’ Capabilities”
- HeliOffshore
  - Operational Effectiveness e.g. HTAWS, APM
  - Reliability and Resilience, e.g. HUMS
  - Safety Intelligence
  - info@helioffshore.org

HeliOffshore
Safety Through Collaboration

NITROS
ENGINEERING FOR ROTORCRAFT SAFETY

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ROTORCRAFT FLIGHT SIMULATION RESEARCH OPPORTUNITIES

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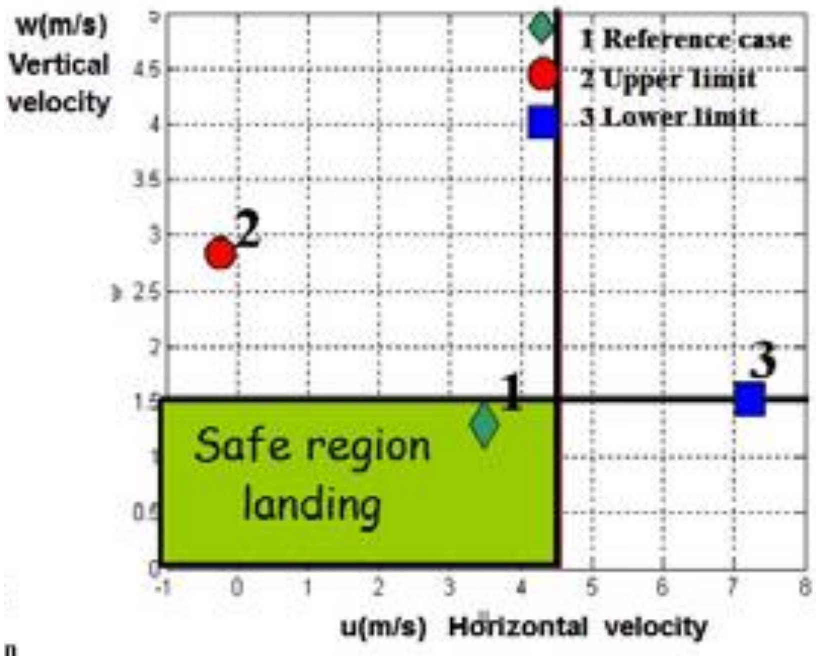
Simulation Fidelity: GARTEUR AG-12

Validation Criteria for Helicopter Real-Time Simulation Models[1]

- Appropriateness of some CS-FSTD H criteria should be questioned
- Required tolerances for high fidelity sensitive to nature of manoeuvre flown
- **A model that satisfies CS tolerances may give different HQs compared to flight test**
- Need to bridge the gap between pilot subjective opinion and formal metrics
- Determine an objective means for assessing overall fidelity of a simulator
- Off axis response

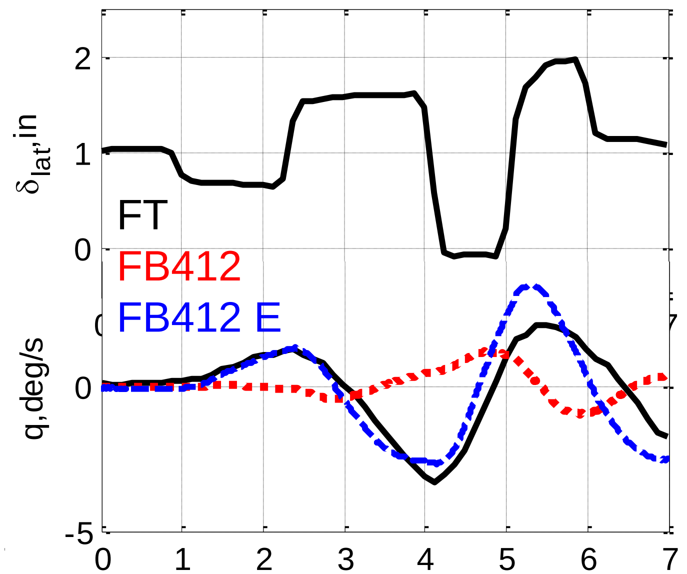


Footprint for a helicopter during the flare manoeuvre with sensitivity of simulator tolerances

Pavel MD, White MD, Padfield MD, Roth G, Hamers M, and Taghizad A, "Validation of mathematical models for helicopter flight simulators current and future challenges ", *The Aeronautical Journal*, Royal Aeronautical Society, Volume 117, Number 1190, pp. 343 – 388 April 2013

Simulation Fidelity: Lifting Standards

- Flight Test Database for Predictive and Perceptual Fidelity Assessment
- Predictive fidelity research:
  - Use a System Identification approach, to explore the fidelity of existing rotorcraft simulation models and to produce a rational, <u>**physics based approach**</u> to simulation fidelity improvement
- Perceptual Fidelity+
  - Development of metrics
  - **Simulation Fidelity Rating Scale**

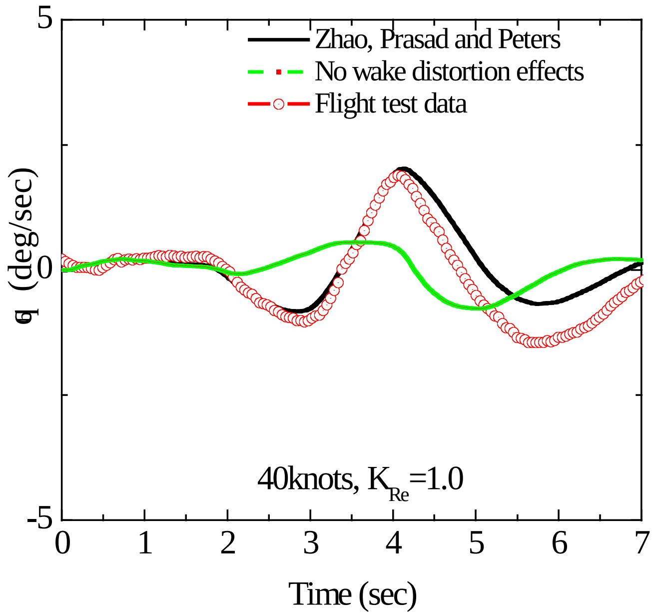


*Lu L, Padfield GD, White, MD, Perfect, P "Fidelity Enhancement of a Rotorcraft Simulation Model Through System Identification", *The Aeronautical Journal*, Volume 115, No. 1170, pp. 453-470 August 2011

+Perfect P, Timson E, White MD, Padfield GD, Erdos R and Gubbels AW, "A Rating Scale for the Subjective Assessment of Simulation Fidelity", *The Aeronautical Journal*, August, Volume 11, No 1206, pp. 953 – 974, 2014

Opportunities in Current Modelling & Simulation, Training

- **Completely physics based, "high fidelity" real-time simulation models**
  - Blade modelling
  - Interactional aerodynamics
  - Inflow and wake modelling
  - Datasets for model validation
- **Simulator Training**
  - Effective scenarios
  - Cueing
  - Subjective assessments



https://www.researchgate.net/project/A-Novel-Approach-to-Rotorcraft-Simulation-Fidelity-Enhancement-and-Assessment

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Concluding Remarks & Future Work

- Excellent work has been undertaken internationally to reduce rotorcraft accident rates
- LOC-I is still one of the main contributing factors in rotorcraft accidents
- The fixed wing community developed UPRT programme to mitigate LOC-I accidents
- Some elements of UPRT can be transferred to rotorcraft

Future work...

- Development of an international co-ordinated programme, similar to ICATEE, to identify key simulation areas to enhance rotorcraft safety
- Dedicated technical conference
- Improvements in rotorcraft physics based modelling & standards
- Increased use of flight simulation for LOC-I training across all platforms
- Use of new technologies e.g. VR to support safety improvements

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Questions?

Dr Mark D White, The University of Liverpool
mdw@Liverpool.ac.uk

Dr Sunjoo Advani, IDT
s.advani@idt-engineering.com

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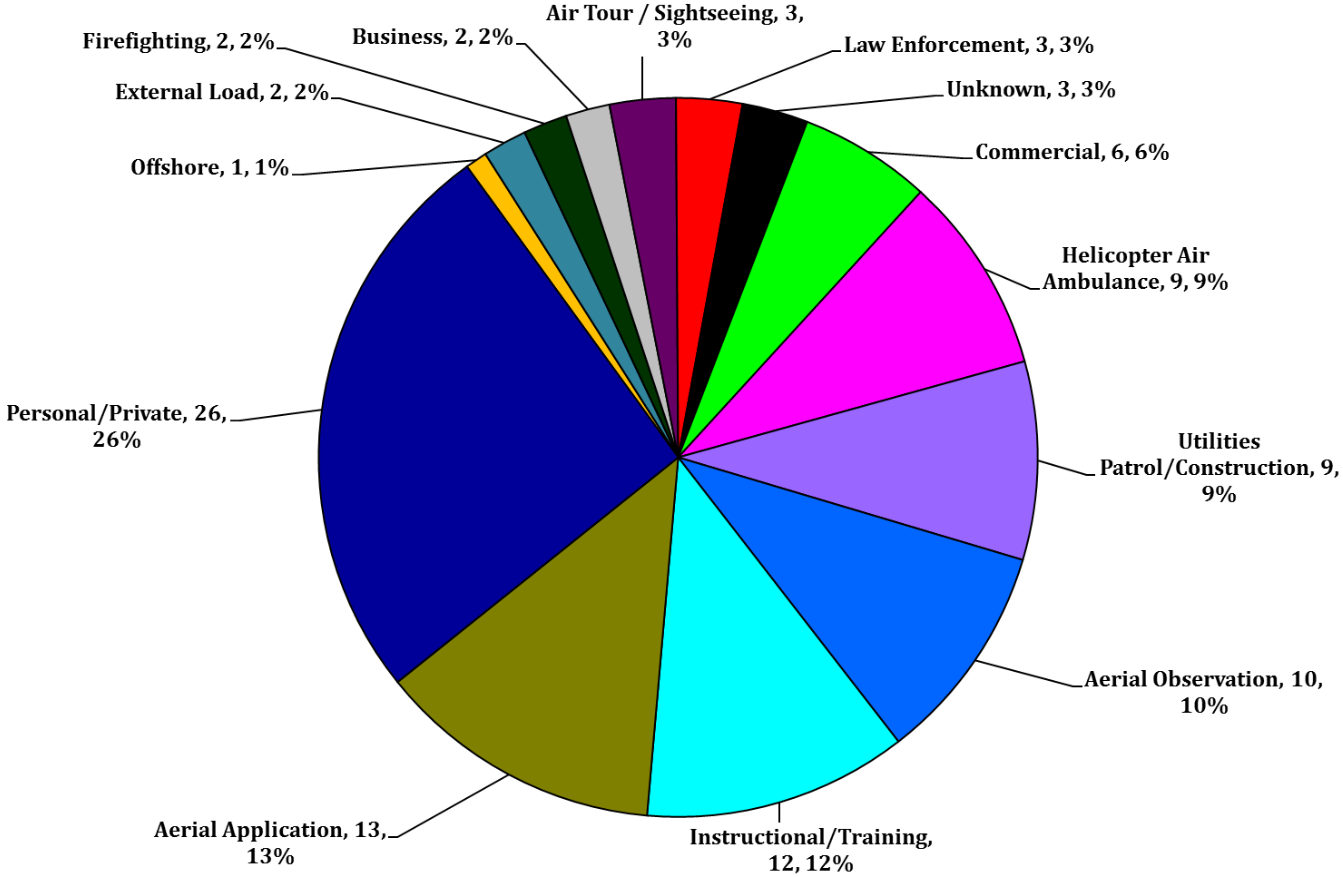
FY 18 – Total Accidents by Industry (Oct 2017 - July 2018)



FAA Rotorcraft Standards Branch AIR-680 Monthly Accident Briefing July 2018

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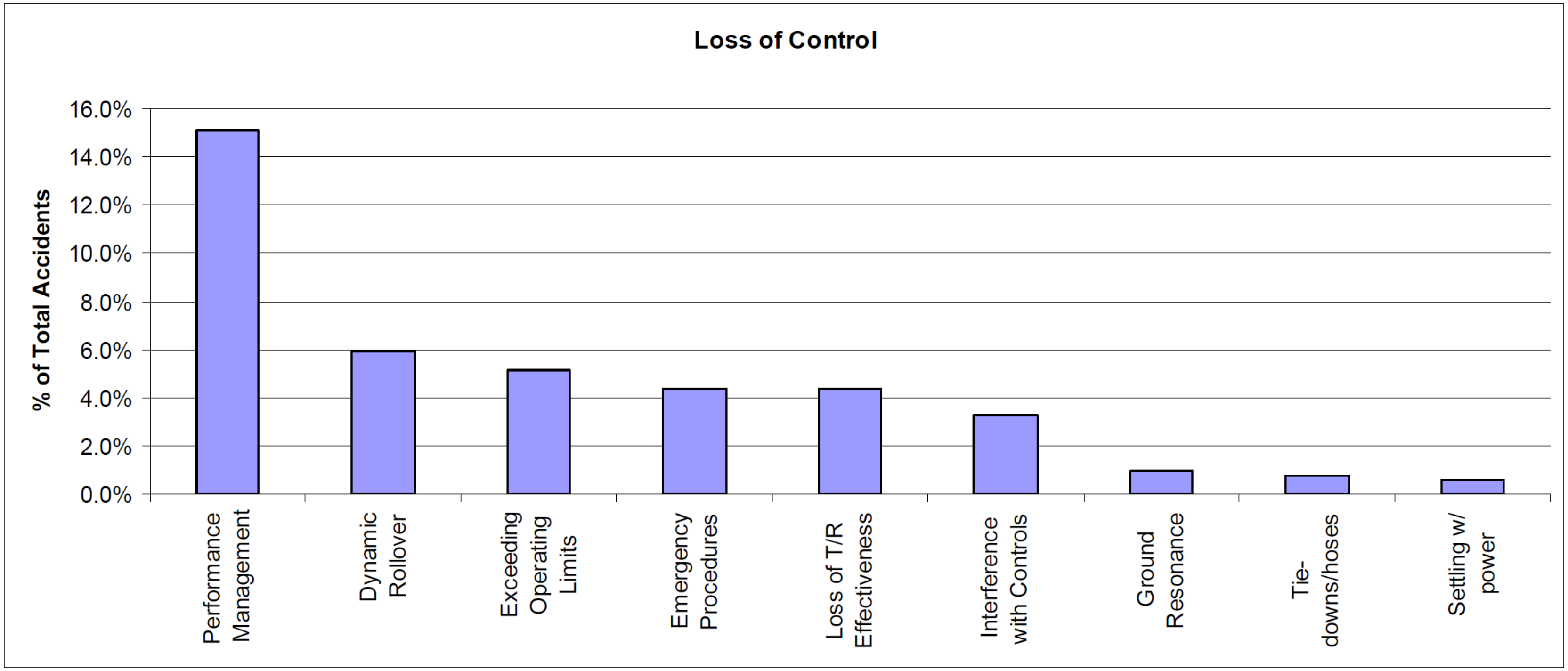
LOC-I Occurrence Category



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USHST Helicopter Safety Enhancements

- Safety Culture
- Detection and Management of Risk During Flight
- Pre-flight Inspection
- Autorotation Training – new research?
- SAS Autopilots in Light Helicopters
- Flight Data Monitoring
- Enhanced Vision Systems
- Improved transition training
- Competency based training
- http://www.ushst.org/