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HELICOPTER SAFETY IN THE OIL AND GAS BUSINESS

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Key words: Safety, ALARP, Accident, Mitigation, Design Standards

Abstract: One of the major safety goals of the International Association of Oil and Gas Producers (OGP) is that their helicopter operations should be as safe for the passenger as scheduled airline flying. It is estimated that the achievement of such a goal would result in the prevention of over 200 fatalities globally within the offshore industry over a 10-year period. The fact that there is both a clearly identified problem and the mechanisms exist to address the problem, mean that there is a clear moral and ethical imperative to improve helicopter safety.

In some areas of the industry work to improve safety is well advanced. As an example, twelve years ago Shell set what were then challenging targets to reduce the 5-year average Fatal Accident Rate (FAR) for air operations within the company from a level of 15 per million flying hours to less than 5 by the year 2000. Three years ago, Shell reviewed its goals and set intermediate targets to reduce the 10-year average FAR from 4.0 per million flying hours at the time, down to less than 2.0 by 2008 and to less than 1.0 by 2013.

This paper considers the background to the establishment of such goals and targets within the offshore industry and demonstrates how they may be achieved by progressive implementation of risk mitigation measures.

1 INTRODUCTION

The current offshore helicopter safety record in the oil and gas business is an order of magnitude worse than the global average for airlines. This falls far short of the OGP's own target of making their helicopters as safe for passengers as scheduled airline flying. However, this need not be the case. As the airline industry has shown over the last thirty years, detailed analysis of the cause of accidents coupled with proactive measures to mitigate the identified risks can result in significantly improved safety. A similar approach has been utilised in the offshore helicopter industry and it is anticipated that, with the proactive support of all stakeholders, similar improvements in safety can be achieved. The approach taken within the helicopter environment has been to:

- Review published studies to determine accident trends, generic causes and potential mitigation factors.
- Review the Federal Aviation Authority's (FAA) Notice of Proposed Rule Making (NPRM) documentation relevant to amendments to helicopter design requirements (FAR/JAR 29), and determine their impact on safety.
- Review helicopter accident and incident causes in detail and make recommendations on the likely effectiveness of both proven and predicted mitigation measures.
- Assess which combination of measures offers the best prospect of achieving the desired risk reduction.
- Determine whether such measures meet the As Low As Reasonably Practicable (ALARP) criterion.

This paper considers the background to the establishment of the helicopter safety goals and targets within the offshore industry and demonstrates how they may be achieved by progressive implementation of risk mitigation measures.

2 SAFETY GOALS

2.1 Industry Realities

The poor safety record of the helicopter industry is well documented and many studies have been carried out to analyse the causes. There is broad consistency and agreement in much of the analysis work and the causes of each new accident rarely come as a surprise to the industry. Indeed, there is a belief, endemic within certain parts of the industry, that helicopters are, by design and operating concept, less safe than fixed wing aircraft.

Helicopters are certainly less tolerant of flaws or error, whether in design or operating procedure. However, there is no reason why the inherent safety of helicopters, designed and manufactured to the stringent standards applied to airliners and operated in the public transport category within a well-regulated business framework, should not result in a similar level of safety to global airlines operating relatively modern fixed wing jets. For both helicopters and fixed wing aircraft, system design requirements are such that the probability of failure resulting in a catastrophic event, where there is loss of the aircraft and/or fatalities, must be extremely remote. This means it is unlikely to occur when considering the total operational life of a number of aircraft of the type, but nevertheless has to be considered as being possible. Generally, this is assessed as a probability in the order of 1 in 10^-8 to 10^-9.

The safety record of public transport helicopters now is no worse than the airline industry of 30 years ago. However, whilst the global airline safety record continues to improve, the accident rate on offshore helicopters is actually getting worse. Unfortunately, a large proportion of the helicopters operating offshore at present were designed and are operated to the same criteria and procedures as the airliners of 30 years ago. Indeed, many of the helicopters themselves were built over 30 years ago. The question that must be asked is: has the helicopter industry embodied the equivalent improvements in design, manufacturing processes, equipment, operating procedures, training, maintenance etc., which we now see on modern airliners? The answer, by and large, is no, or at least not yet. The following extract from a learned aviation magazine [Ref. 1] is of note:

“Analysts trying to identify the secret of Western carriers’ success in reducing their accident rate to almost nothing generally conclude it is the result of a combination of factors: greater engine reliability in the generation of aircraft produced since the early 1980s; improved cockpit technology that has provided flight crews with better situational awareness – once they have been accustomed to working in a digital cockpit – and technological advances such as enhanced ground proximity warning system (EGPWS), generically known as a terrain awareness and warning system (TAWS)”.

In addition, crew resource management (CRM) is now an accepted part of airline pilot training culture, with few exceptions, even though its wider introduction was greeted with scepticism 20 years ago.

These are all probable factors in improved safety, as is the use of flight operations data monitoring (FODM) – known in the USA as flight operations quality assurance (FOQA) or simply as Flight Data Monitoring (FDM). It has long been recognised that modern aircraft have a better safety record than those built before the advent of the glass cockpit, but analysts say there is now a measurable difference between the safety rates of Western airlines that have been using FODM for many years and those that have not.

To the above could be added a wide range of equipment and programmes that have all contributed to airline safety. The question must therefore be asked – if it is good enough for the airline industry, why are we not embodying similar improvements in offshore helicopter operations? Although some of the equipment programmes and training improvements have filtered into the helicopter industry, it has been sporadic and the take up has often been poor. An illustration of this is the Helicopter Operations Monitoring Programme (HOMP), the helicopter equivalent of FOQA or FODM, which was first funded by Shell in 1997 and the final report for which was issued in 2002 - deemed to be a great success by all stakeholders (operator, regulator, sponsor). The take up by the industry has, so far, been limited and primarily in the UK. However, Shell has made HOMP a requirement for its own operations and this system is slowly being taken as the standard by the industry.

Of course, it can be argued that the return for investment in safety is much greater with an airliner. The aircraft utilisation and payloads are much greater, and any major accident involving multiple fatalities can put an airline out of business as well as having a major impact on the public psyche (TWA B747 New York; Swissair DC10 Nova Scotia; Pan Am B747 Lockerbie). Lack of safety is seen as a major business risk. The comparison with the helicopter industry is stark. Principally because of working patterns in the offshore industry, and their relatively limited range and passenger capacity, offshore helicopter utilisation is low compared with airliners. The investment in safety, whether involving equipment or training, is therefore seen as a higher proportion of the equipment and operating costs (and therefore the passenger seat mile costs). A significant number of fatal accidents per year is also viewed as ‘normal’, certainly according to the documented views of some helicopter associations; they rarely causes major shock within the industry or with the public at large, and even more rarely do they put a helicopter operator out of business.

The oil industry, in general, with the honourable exception of a few of the larger oil companies, has been willing to accept this status quo, even though the knowledge, and more recently the equipment, has been readily available to reverse the trends and improve safety. What is most often lacking is the commitment and funding by the contracting organisations. However, if even the long-term fatal accident rate in the North Sea (which is generally accepted as having the most demanding regulatory requirements and operating standards) was reflected in the offshore industry globally, then the average of 24 fatalities per year involving offshore helicopters contracted by companies belonging to the OGP would reduce to about 8. Further improvements in line with airline standards would more than halve this again.

Put starkly, the amortization over 10 years of safety improvements for the offshore helicopter fleet to a standard that is equivalent to that employed by the airline industry, would be an investment that could save about 200 lives. If the offshore traveller pays for his own ticket to travel with an airline, he can be confident that he is buying a high level of safety. If the oil industry pays for his ticket to travel offshore on their business (encumbered in survival suit, lifejacket and air breather) his level of risk is about 10 times higher – even though the knowledge and, increasingly the equipment, is available to mitigate most of this risk.

Regulation in the sector is also an issue as few of the regulators have been in the van in driving forward improved safety. Few require higher standards for offshore operations despite recognising that the offshore environment can be significantly more demanding. Moreover, full harmonisation of requirements between European regulators and the FAA is not a reality for helicopters, particularly in respect of operational requirements. Therefore neither the regulatory or operating parts of the industry appear likely to resolve these issues. The oil industry associations such as OGP must therefore play a major role in influencing the other stakeholders, with the major players taking a lead. What is clear, however, is that unless the oil companies (as the customers) work with the Regulators, the Original Equipment Manufacturers (OEMs) and the operators the ultimate goal is unachievable.

2.2 Initiatives to Date

In the early 1990s, Shell’s offshore helicopter accident record was worse than the industry as a whole and a strategy was developed by Shell’s aviation department to tackle the problem. A target was set for 2000 to better the industry safety record and ultimately to achieve a level of risk for passengers equivalent to that of regional commuter airlines. In pursuit of achieving this risk level Shell has, over the past 11 years, instigated and supported the development of a range of risk mitigation programmes within the industry, often through focused research. The principal examples are:

- Development of an industry standard for an aviation Safety Management System (SMS) – incorporating systematic hazard assessment, management of the interfaces, senior management accountability and changing the safety culture.
- Quality Assurance in maintenance.
- Progressive development of operating, maintenance and training standards in line with industry best practice – minimising human error and changing the culture. This includes, inter alia, simulator training including CRM and Line Oriented Flight Training (LOFT), Human Factors (HF) training for air and maintenance personnel and the requirement for Duplicate Inspections.

- Health and Usage Monitoring Systems (HUMS) on contracted or owned aircraft and the subsequent development of a minimum specification for HUMS/Vibration Health Monitoring (VHM) for the industry – targeted at monitoring the machine and human error in maintenance.
- Underwater egress trials, cabin re-configuration and the development of Helicopter Underwater Escape Training (HUET) standards – improving survivability for passengers and crew in the event of a ditching.
- The development of improved aircraft performance standards and the standardisation of Take Off and Landing profiles.
- Helicopter Operations Monitoring Programme (HOMP) - a version of FDM, targeted at monitoring the pilot and his conduct of the operation in accordance with Flight Manual and Operations Manual requirements, and enhancing training effectiveness through confidential feedback loops.
- Progressive upgrade of equipment fit – enhanced operational management and defensive aids (such as TCAS, AVAD/EGPWS), but still on old airframes.
- Adoption of industry best practice for the management of helideck operations – managing the air operator's interface.

These programmes and standards are now reflected and published in Shell's Standards & Guidance for Air Operations (SGAO) and summarised in the company's Minimum HSE Standard: Air Transportation. Most importantly, however, they are now being adopted by the OGP and included in its management guide. Within Shell they were supported by the development of more precise contracting requirements and enhanced audit procedures. The net result for Shell has been a significant improvement in Fatal Accident Rate that has been reduced from a high in the early 90s of 15 fatal accidents/million flying hours to the current rate of 4. However, full implementation of the improved standards has not yet been achieved (e.g. HOMP), and there has been a growing realisation that deficiencies in the basic design standard of helicopters on contract will always inhibit any attempt to achieve the OGP safety goal. Much of this study was therefore focussed on this aspect of helicopter safety, particularly as the industry is in process of introducing new equipment over the next few years, which might enable the OGP to achieve its long-term goal.

2.3 Future Goals.

The focus of most of the work in Shell leading the way over the past 11 years was on multi-engine helicopter operations, which generated its major risk exposure. Nevertheless, the company also has a significant single engine exposure, both offshore in GOM and onshore in North America on pipeline and seismic operations. A Bell 206 accident in GOM in October 2003 generated much debate on the merits or otherwise of single engine operations offshore and this was fuelled the appalling accident record suffered by single engine helicopters generally, and during 2003 in particular. Against this background, the safety targets set by the company, which related to air vehicle accident rate and fatal accident rate, were challenged from within on the basis that these accident rates were not a valid way of comparing a single engine Bell 206 carrying few passengers with a Boeing 747 carrying 350.

This issue has been reviewed within the company and, in order to provide an equitable comparison, their top level Group goal for air safety has now been defined as follows:

"The goal is to ensure that, per period of flying exposure, the individual risk to a passenger flying in a helicopter having a Certificate of Airworthiness in the Transport Category (Passenger), and operated in accordance with FAR Part 135/JAR-OPS 3 or equivalent, should be no greater than that experienced in a FAR/JAR 25 certificated airliner operated in accordance with FAR Part 121/JAR-OPS 1 or equivalent".

This goal has been reflected in the latest OGP goal for air safety:

"The individual risk per period of flying exposure for an individual flying on OGP contracted business should be no greater than on the average global airline."

Inherent in these statements is the recognition that FAR Part 135 and JAR-OPS 3 procedures and equipment standards will inevitably require reinforcing through contract and oversight against best in class standards. In addition, it is unlikely that early FAR/JAR 29 design standard helicopters will meet the inherent airworthiness standards of the later FAR/JAR 25 airliners. The gap analysis is part of this study.

The individual risk defined above will be determined by two factors:
- The fatal accident rate of the air vehicle per period of flying exposure – typically per million hours.
- The probability of any passenger being a fatality in a fatal accident – i.e. what proportion of passengers are fatalities in a fatal accident.

This latter point gave rise to much speculation, but for virtually all categories of air operations, whether small, medium or large helicopters or regional or major airline carriers, the proportion falls into the 55-75% band. Therefore to a first order, the key comparator between fixed wing passenger operations and helicopter passenger operations, in terms of passenger risk, is the air vehicle fatal accident rate. The targets developed were therefore re-affirmed, namely a 10-year fatal accident rate less than 2 per million hours by 2008 and less than 1 per million hours by 2013. Whilst the best Western airline carriers are achieving much better than this, the long-term target is better than the regional airlines and is equivalent to the safety performance of the average global airline.

2.4 Safety Management System.

The basic framework around which safety performance may be achieved is provided by the Aviation Safety Management System (SMS), which defines how the management of air safety should be conducted as an integral part of any operating company's business management objectives through effective systematic risk management. The SMS reflects quality management principles and requires compliance with relevant regulatory requirements. It describes the principles and processes required to manage risk and eliminate or otherwise control hazards and is documented in a Safety Management Manual. The SMS should be continually updated in the light of accidents, incidents and regular reviews.

2.5 Safety Case.

A Safety Case is produced for specific business activities (discrete function, operation, system, facility or project) to provide documented evidence that the major hazards generic within aviation and specific to the activity have been identified and are being managed in compliance with the SMS.

2.6 ALARP Concept.

Zero risk may be impossible to achieve, but analysis of accidents shows that most could have been avoided. The question is: "What effort and cost can be justified to prevent further occurrences?" The ALARP concept provides the answer: risk should be reduced to a level As Low As Reasonably Practicable. Similarly, FAR AC 29-547A calls for the likelihood of an accident to be reduced to the least possible amount that can be shown to be both technically feasible and economically justifiable. Costs associated with accidents are difficult to quantify, but must take account not only of material losses, but also loss of reputation, loss of production and the costs of litigation and compensation. For the purposes of this paper, therefore, the cost of an accident to a medium or large helicopter involving multiple fatalities will be assumed to be in excess of $50 million

3 ACCIDENT TRENDS

The following populations of accident (fatal and non-fatal) data have been investigated to determine trends:

- Accident rates for twin turbine helicopters in the USA [Ref.2]
- Accident rates for twin turbine helicopters in the North Sea [**Ref. 3**]
- Accident rates for all helicopters in the Gulf of Mexico [Ref. 4]

Accident rates for selected twin turbine helicopters typical of those used in the oil industry in the USA [Ref. 5]

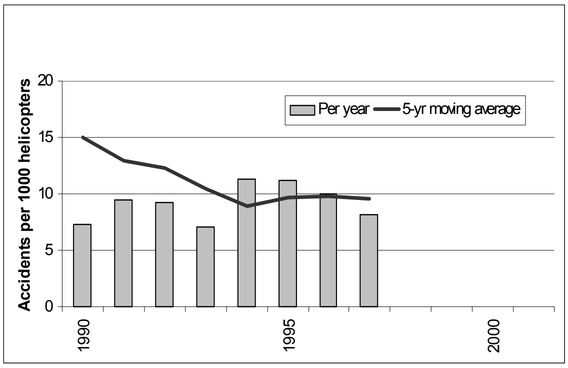

Figure 1: Accidents (Twins) – USA [Ref.2]

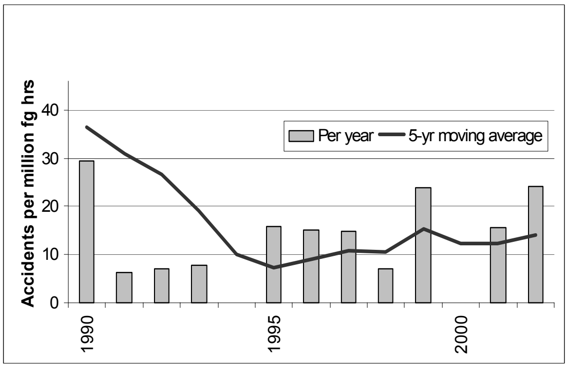

Figure 2: Accidents (Twins) - North Sea [Ref.3]

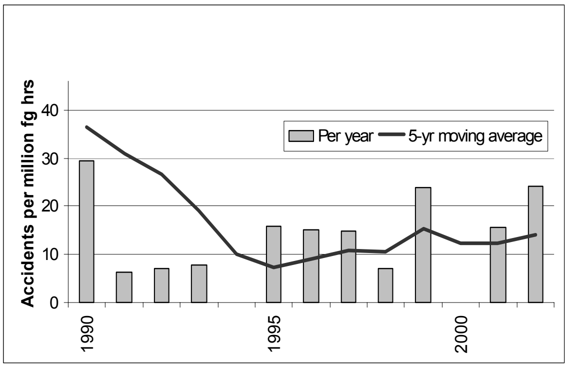

Figure 3: Accidents (all helicopters) - Gulf of Mexico [Ref.4]

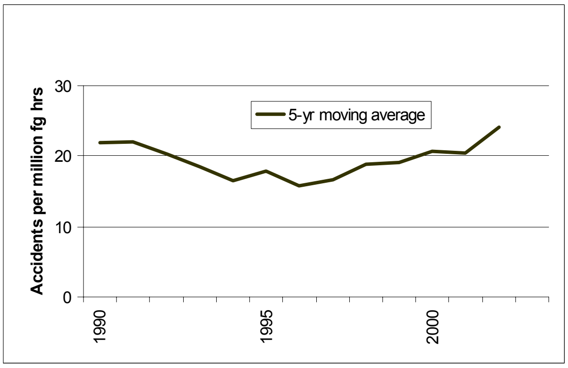

Figure 4: Accidents (Twins) - USA [Ref.5)]

3.1 All Accidents (Fatal And Non-Fatal).

The accident rates show similar trends, with a steady decrease until the mid-1990s followed by a disturbing upward trend in recent years. 2003 was a particularly bad year for accidents in the Gulf of Mexico, although all were on single engine helicopters. In recent years, the overall accident rate for a representative sample of twin turbine helicopters has averaged about 20 per million flying hours in the USA and about 12 per million in the North Sea. Despite strenuous and continuous efforts by some oil companies and operators to reduce accidents, the trend of overall accident rates, also reflected in the 5-year Fatal Accident Rate average, shows a very disturbing upward trend in the last few years.

The conclusion therefore is that there must be a breakthrough in risk reduction.

4 ACCIDENT CAUSES AND MITIGATION

Although References 2, 3 & 4 each used different ways of categorising accidents, system failure (including engine failure), hitting objects, and flying into the ground featured prominently as the main causes and accounted for about 70% of all accidents. The following causes, some of which have design implications, will be analysed and means of mitigation will be considered:

- Airframe system failures
- In flight collision with objects
- Loss of control
- Loss of engine power
- In flight collision with terrain

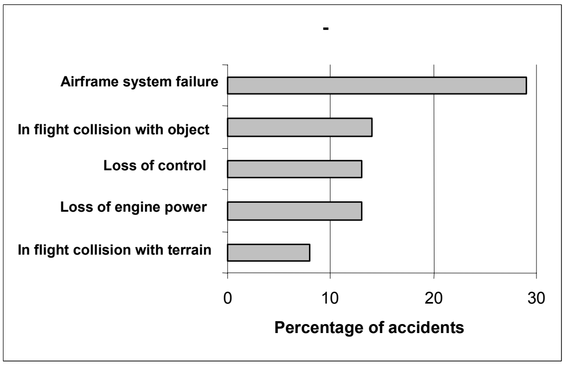

Figure 5: Causes of Accidents USA [Ref.2]

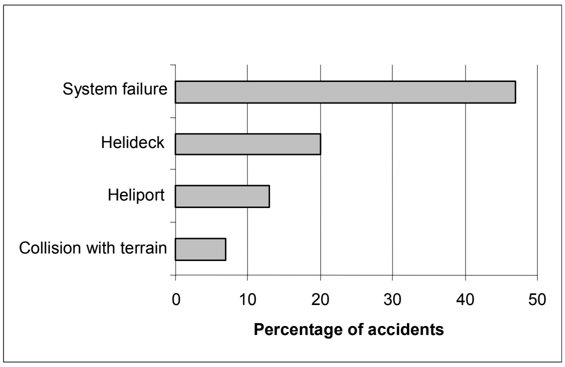

Figure 6:Causes of Accidents – North Sea [Ref.3]

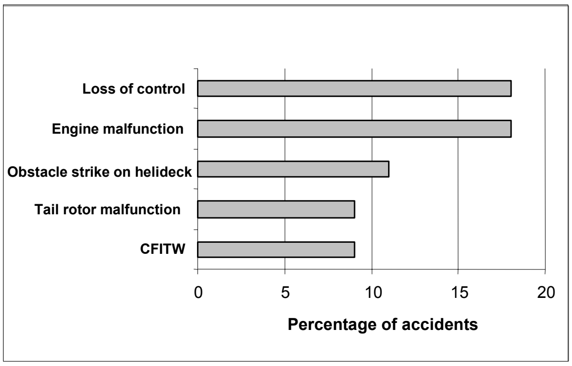

Figure 7: Causes of Accidents – Gulf of Mexico [Ref.4]

5 REVIEW OF DESIGN REQUIREMENTS

Most of the helicopters currently in service were certified to design requirements that were current in the mid-1970s and included FAR/JAR 29 revisions up to about amendment 29-11 dated May 1976. All the subsequent revisions up to amendment 29-47 have been reviewed and classified according to the degree of impact that they might have on accident rates. A summary of each revision and its categorisation is at Appendix 1.

6 AIRFRAME SYSTEM FAILURES

6.1 Causes.

Most of the airframe system failures reported in Ref. 2 occurred in the rotor, transmission and control systems. Metal fatigue or other material failure caused about three quarters of these failures and thus accounted for about 20% of all accidents. In Ref. 3, about one fifth of all accidents were attributed to a design deficiency, most of which related to damage tolerance of rotor systems and flight controls. Given that the current Fatal Accident Rate is between 2 (North Sea) and 6 (Gulf of Mexico) per million flying hours, the corresponding Fatal Accident Rate for airframe systems is thus between 0.4 and 1.2 per million. This should be compared to the intention of design requirements that an accident should be extremely remote (defined as between 1.0 per 10 million flying hours and 1.0 per 1000 million flying hours). Clearly there is a substantial gap between the standard set by the design requirements and what has actually been achieved in service.

This is in marked contrast to the record for airliners on which structural and system failures have been all but eliminated as a cause of accidents because industry responded to the political imperative to reduce accidents and developed the necessary technical solutions such as redundancy and damage tolerance. Admittedly, redundancy is difficult to build in to a helicopter, particularly in the rotor, drive train and control systems, with the result that helicopters have many more critical, safe-life components than airliners. However, a significant impediment to progress has undoubtedly been the fact that helicopter accidents do not attract significant media attention and there has never been the political imperative to make the necessary improvements.

Consequently, current helicopters have been allowed to remain in service although they were designed to requirements that are now 30 years old. Even new versions have retained grandfather rights such that their designs were neither pushed, by regulation, towards fail safe solutions through redundancy (the preferred option where practicable) nor to higher "simplex" integrity through detailed design assessment.

6.2 Tail Rotor Failures.

Of all system failures, tail rotor failure deserves to be singled out due to the extreme and rapid loss of control that can accompany the failure; yet awareness among pilots of the possible consequences of such a failure is, in general, very limited. A study by the Flight Safety Foundation [Ref. 6] found that 16% of the 147 accidents investigated were caused by partial or total loss of tail rotor control. Failure of the drive shaft accounted for one third of these accidents, the others being caused by the tail rotor striking or being struck by an object (see paragraph 6] and the inability of pilots to maintain control of the helicopter. Assuming a standard pilot intervention time of 2 seconds, a tail rotor drive failure is likely to result [Ref.7] in:

- at high speed, a sideslip that will cause structural failure.
- in the hover and at low speed, spin entry that is virtually impossible to avoid.

The standard of advice given to pilots in Flight Manuals is generally poor as is the standard of simulators and associated training.

6.3 Mitigation of Airframe System Failures.

Design Requirements. The first priority should be to minimise the possibility of a system failure occurring by improving the design requirements. The following recommendations were made in Refs 2, 3 and 6:

- Re-evaluate design and certification criteria for transmission components, adopt more conservative fatigue design criteria and incorporate additional fail-safe modes. [Ref. 2]
- Rotor systems and flight control systems should be more redundant [Ref. 3]
- Rotor control systems must be subject to a design assessment to show that no single failure, or combination of failures not shown to be extremely improbable, could cause an accident - i.e. similar to the requirements of FAR 25.671 for airliners [Ref. 6].

These recommendations were made as a result of the poor accident record of existing helicopters, most of which were designed to 30-year-old requirements. The following table lists the significant revisions that have been made to FAR 29 since then:

Table 1 Relevant Airframe System FAR 29 amendments (see Appendix 1)

FAR	Title	Amdt	Date	Change introduced
29.547	Main and tail rotor structure	29-40	Aug 96	Requires a design assessment and failure analysis of main and tail rotor structure, including associated rotating parts, together with compensating provisions such as redundancy or high integrity to prevent accidents.
29.571	Fatigue evaluation of structure	29-28	Oct 89	Adds flaw tolerance requirements along the lines of 25-571 introduced in Dec 78 for airliners
29.602	Critical parts	29-45	Oct 99	Formalises existing critical parts procedures
29.610	Lightning & static electricity protection	29-40	Aug 96	Introduced improved protection
29.685	Control system	29-12	Feb 77	To account for the effect of freezing moisture
29.863	Flammable fluid fire protection	29-17	Dec 78	New requirements
29.917	Rotor drive system design	29-40	Aug 96	Formalises existing design data
29.1309	Equipment and systems	29-24	Dec 84	Comprehensive failure analysis and tests
29.1529	Instructions for continued airworthiness	29-20	Oct 80	Introduces new instruction in Appendix A

Amendments 29-28 and 29-40 implement the recommendations made in Refs 2 and 3 above. The UKCAA is also pursuing the implementation of the recommendation in Ref. 6 above (to bring FAR 29-671 into line with FAR 25-671) through the new European Aviation Safety Agency (EASA).

Detection of Incipient Failure

The second priority should be to minimise the possibility of a system failure occurring by detecting incipient failure. The Health and Usage Monitoring System (HUMS) was universally recommended in Refs 2, 3 and 7 as a means of doing this.

The helicopter maintenance programme also helps to eliminate failures. The use of Maintenance Steering Group (MSG3) analysis, which determine maintenance requirements by a logical process based on actual or predicted reliability, was recommended in Ref. 3. These have been used on airliners for many years and have been instrumental in reducing structural and systems failures. It is extraordinary that helicopter maintenance is still largely based on historical practice rather than a rigorous assessment of the inspection necessary to ensure the continued satisfactory performance of systems. MSG3 analyses can be applied retrospectively and would provide a worthwhile benefit for newer types.

Mitigation of Tail Rotor Failures

There are a number of design solutions that would mitigate the impact of a tail rotor failure ranging from deployable drag chutes to duplex drive shafts. Ref. 7 recommended the following:

- The tail rotor control system should incorporate a fail-safe pitch mechanism.
- Further studies into increased fin effectiveness and duplex drives should be carried out.

Survival Following Failure

If a system does fail, then the occupants should be given a good chance of surviving the incident. The following recommendations were made in Refs 2, 3 and 7:

- Comprehensive advice covering all possible incidents, validated at least by means of the best available engineering calculations coupled with piloted simulation, should be provided in Flight Manuals.
- Training should be enhanced using more realistic simulators.

7 IN-FLIGHT COLLISION WITH OBJECTS

7.1 Causes.

Collision with objects, including helidecks, caused 14% of the accidents in the USA [Ref. 2] and 11% of accidents in the Gulf of Mexico were caused just by obstacle strikes on helidecks [Ref. 4]. Limited data suggested that tail rotor strikes were twice as common as main rotor strikes [Ref. 2] and half of tail rotor accidents were caused by tail rotor strikes [Ref. 7]. Contributing factors included human factors, operating procedures, the design of helidecks with their close proximity of obstacles, hot gases from turbines and turbulence.

Landing on a helideck is a challenging task, which currently relies heavily on the skill of the pilot and the helideck environment. The risks can be reduced by improving helideck design, standardising take-off and landing profiles and procedures, and by introducing new equipment. Helicopters with improved handling qualities and operating to Performance Class 1, so that they can Hover Out of Ground Effect (HOGE) with One Engine Inoperative (OEI), will also mitigate against helideck impacts.

Although not a predominant feature of helicopter operations, in-flight collision with other aircraft is inevitably catastrophic and in busy offshore operating areas where air traffic services, communications and weather may be variable, the risks undoubtedly increase.

7.2 Mitigation.

Helideck Design

- Clearly, the size and design of the helideck is a key factor and accidents could be prevented by improving their design and the operational management of the helideck.
- Best practice is currently published in ICAO Annex 14 and UK CAP 437 [Ref.8], although some nations such as Norway also have more stringent requirements in relation to helideck size [Ref.9].

New Equipment

- Ref. 2 recommended that a sensor system should be developed to, in effect, cocoon the helicopter and provide the pilot with sufficient warning to avoid obstacles.
- A scanning laser tip strike warning system was proposed for this purpose in Ref. 6.

- The Enhanced Ground Proximity Warning System (EGPWS) also provides a warning of fixed, land-based obstacle hazards such as power lines and towers, and fitment of collision avoidance systems such as TAWS can undoubtedly be justified in busy offshore environments where the risk of mid-air collision rises.

Operating Procedures

- Operational procedures are continually improved in the light of reported incidents and accidents.
- Amendments to ICAO Annex 6 and JAR-OPS 3 are currently in train to introduce the concept of Enhanced Performance Class 2, which will ensure that, for the vast majority of flights, engine failure accountability will have been established.
- Deck edge miss is assured and drop down following engine failure will have been calculated.
- A HOMP programme can also highlight problems with approach patterns and helideck operating procedures, helideck design and associated turbulence problems (see also Mitigation below).

8 LOSS OF CONTROL

8.1 Causes

Loss of control caused 13% of the accidents in the USA [Ref. 2] and 18% in the Gulf of Mexico [Ref. 3], the main contributory factors being spatial disorientation and improper operation of the controls, particularly the inability to control anti-torque in all phases of flight. The handling qualities design standards applicable to the current helicopter fleet date back to the 1950s and Ref.10 commented that, although generally tolerated, the stability and control characteristics of most helicopters in service appeared to be quite unsatisfactory.

8.2 Mitigation.

Design Standards

The first priority should be to make helicopters more inherently stable and easier to fly. The following recommendations were made in Ref. 2:

- Training, and evaluation criteria be reviewed, with particular emphasis on aircraft handling issues, especially in marginal-weather conditions.
- Handling quality standards for all future helicopters be raised to levels consistent with what modern technology can provide.
- Aircraft certification criteria be modified to ensure that undesirable flying characteristics encountered in real-world operational use are included in pre-certification testing and corrected before final certification.

The following relevant revisions have been made to FAR 29:

Table 2 -
Relevant Handling Qualities FAR 29 amendments

FAR	29.181
Title	Dynamic stability
Amendment	29-24
Date	Dec 84
Change introduced	Positive damping of short period oscillation

Although this revision introduced only minimal changes to the handling qualities design requirements since existing helicopters were designed, technology has moved ahead, with the result that current designs are significantly easier to fly.

Operations Monitoring

Training and operational procedures are continually improved in the light of accidents and other reported incidents. However, for every reported incident, it is believed that several hundred incidents go unreported. Obtaining information on incidents enables action to be taken to reduce risks before they result in serious incidents or accidents. Current philosophy is that, in an already well-regulated industry, safety can be improved most effectively not by regulating more, nor punishing more, nor by increasing training but by obtaining better information on operational risks and by providing positive feedback to improve procedures and systems. HOMP continuously monitors operations and highlights adverse trends in operational behaviour, weaknesses in helicopters and crews as well as problems with the helideck operational environment, approach patterns and helideck design. HOMP has been adapted for helicopters from the fixed wing FOQA/FODM programmes that have been very effective in improving the flight safety of commercial airliners.

9 LOSS OF ENGINE POWER

9.1 Causes.

In Ref. 2, 13% of accidents were caused by loss of engine power, 5% being the result of engine structural failure, 6% the result of fuel or air supply problems and 2% due to unknown causes. Total loss of power occurred in 60% of the loss of engine power accidents. Most of these accidents were exacerbated by the inability of pilots to land successfully following a full or partial power failure. Current helicopters provide marginal or inadequate auto-rotational capability for the average pilot to complete the final flare and touchdown successfully and training is generally inadequate.

In the Gulf of Mexico [Ref. 4], single-engine helicopters comprise 66% of the fleet but accounted for 90% of accidents and hence engine malfunction caused a higher percentage (18%) of accidents.

In Ref. 6, engine failures occurred in 40 of the 147 accidents investigated, but only 3 of these involved twin-turbine helicopters. In each case, the pilot was unable to maintain level flight after a power loss occurred in one engine and conducted an autorotative landing that resulted in substantial damage. In one of the accidents, the pilot had not turned on the fuel pumps prior to take off.

9.2 Mitigation

Engine Malfunction

The first priority should be to minimise the possibility of an engine malfunction. The following recommendations were made in Ref 2:

- Immediate reinforcement of fuel management and mission planning according to current FAA regulations.
- Re-examination of currently installed fuel quantity measurement and display hardware for accuracy and applicability to rotorcraft operations.

The following relevant revisions have been made to FAR 29:

Table 3 - Relevant Engine FAR 29 Amendments

FAR	29-67	29.901	29.903
Title	Climb: One engine inoperative	Engine installation	Engines
Amd	29-26	29-36	29-36
Date	Oct 88	Jan 96	Jan 96
Change introduced	New continuous OEI rating	No single failure or combination of failures to jeopardize operation of rotorcraft	Hazards in event of engine rotor failure to be minimised

FOM/HOMP is likely significantly to reduce the possibility of engine malfunction due to improper operation of fuel or engine controls. The latest designs of helicopters have Full Authority Digital Engine Controls (FADEC) linked through the Flight Management System (FMS) to a 4-axis autopilot, which also minimises the mis-handling of the engine controls.

Survival Following Loss of Engine Power

If an engine does fail, then the occupants should be able survive the incident. This can best be achieved by ensuring that there is adequate one-engine-inoperative (OEI) performance to recover from an engine failure in virtually all modes of flight, i.e. Performance Class 1 or enhanced Performance Class 2. For existing helicopters which have inadequate OEI performance (singles and some light twins) and which may rely on successful autorotation for survival following a single engine failure, the following recommendations were made in Ref.2:

- Reinstatement of full power-off autorotation to touchdown as an industry standard for pilot training.
- Re-examination of autorotational capabilities with the objective of reducing height-velocity restrictions to a level consistent with average piloting skills, and more representative emergency landing sites.

In general, all the data on power loss frequency indicates that the continuing use of single engine passenger transport helicopters for offshore use should be restricted to an absolute minimum if the long-term safety goal of the OGP is to be met. Power loss frequency on helicopters (from all causes) is accepted by the industry to be about 1 per 100,000 hours, from which can be derived a single engine helicopter accident rate from this cause alone of 10 per million hours and a fatal accident rate of about 2. Following a fatal accident in GOM in Oct 2003, a study of all Bell 206 accidents substantiated the 1 per 100,000 hours figure

10 IN FLIGHT COLLISION WITH TERRAIN

10.1 Causes.

In most of these accidents (also known as Controlled Flight Into Terrain or Water CFIT/W), the helicopter was under control and flew into the ground/water, usually in poor weather, because the pilot was not aware of the impending collision.

10.2 Mitigation

The Enhanced Ground Proximity Warning System is designed to prevent CFIT/W accidents. Although less effective, a radio altimeter linked to an Automatic Voice Alerting Device (AVAD), also provides mitigation against CFIT/W accidents.

11 IMPACT OF MITIGATION MEASURES

Each mitigation measure can be expected to reduce the number of accidents. In this section, each of the mitigation measures is considered in turn and an assessment is made of the percentage of accidents that it would avert.

11.1 Design Requirements (Late FAR) (see Appendix 1).

Since the majority of current helicopter designs entered service some 30 years ago, the following key amendments, which are assessed to have a significant impact on accident rates, have been made to FAR 29:

Table 4: Key FAR 29 amendments relevant to accident prevention

FAR	Title	Amd	Date	Change introduced
29.547	Main and tail rotor structure	29-40	Aug 96	Requires a design assessment and failure analysis of main and tail rotor structure, together with compensating provisions such as redundancy or high integrity.
29.571	Fatigue evaluation of structure	29-28	Oct 89	Adds flaw tolerance requirements along the lines of 25-571 introduced in Dec 78 for airliners
29.903	Engines	29-36	Jan 96	Hazards in event of engine rotor failure to be minimised

The FAA cost benefit analysis estimated that, for a fleet of 100 helicopters, Amendment 29-28 would save about one accident every 2 years and would reduce overall costs by about $10 million. For Amendment 29-40, the FAA concluded that, "the safety benefits of these changes are expected to easily exceed the incremental costs". In the benefit analysis for Amendment 29-36, which addresses the secondary effects of engine structural failure, the FAA estimated that, for the period 1984 to 1989, the Fatal Accident Rate for twin-turbine helicopters due to uncontained turbine rotor failures was about 0.7 per million flying hours. This package of amendments, which is referred to as "late FAR", will significantly reduce accidents due to airframe system failures and engine rotor bursts and it is assessed that 50% of such accidents would be prevented.

11.2 Design Requirements (Late FAR plus enhanced Handling Qualities and advanced cockpit design).

In some areas the design of helicopters has actually moved well ahead of design requirements. For example, high reliability FMS with duplex 4-axis autopilot has improved helicopter stability, especially in IMC and emergencies. Cockpit design has also been much improved with Electronic Flight Information Systems and more ergonomically designed controls. The result is that many of the latest designs of helicopter are much easier to fly. It is assessed that the Late FAR plus enhanced Handling Qualities and advanced cockpit design improvements would prevent 60% of loss of control accidents.

11.3 Training.

Enhanced training also has an impact on many aspects of accident prevention. The most significant enhancement is provided by the use of more realistic simulators that meet FAA AC 120-63 Level C as a minimum standard. Much better advice should be given to pilots in Flight Manuals with the response to all incidents being validated at least by means of the best available engineering calculations coupled with piloted simulation. Pilot performance is also being enhanced with Crew Resource Management (CRM) training, which ensures that there is a clear understanding of the interface between crewmembers, and Line Oriented Flight Training (LOFT), which inserts training into the relevant operational environment. It is assessed that this enhanced training coupled with annual Level C simulator training could prevent 45% of accidents related to handling and response to emergencies.

11.4 Health and Usage Monitoring System.

HUMS was introduced in the early 1990s, mainly as a result of Shell's and other operators' initiatives and with little involvement of the helicopter manufacturers. The development of HUMS was largely co-funded by the UK industry in early days although the US military now appear to be committed. In Ref. 7, it was estimated that half the tail rotor drive shaft failures (18% of all tail rotor accidents) could have been prevented by the current standard of HUMS and further development of HUMS could prevent a further 5% of tail rotor accidents. A Cost Benefit Analysis carried out by the CAA [Ref. 11) estimated that HUMS would detect 69% of defects in critical rotating parts before failure and would cost about £433,000 per life saved over the next 15 years. In this assessment claims for effectiveness have been consistently conservative and it is assessed that HUMS could prevent 65% of rotor/drive train failure accidents.

11.5 SMS/Operational Control (OC)/Quality Assurance (QA).

SMS/OC/QA includes structured Safety Management System (SMS), including a hazard analysis documented in a Safety Case, enhanced operational procedures (e.g. FAR121 equivalent/JAR Ops 3), an effective quality management system and improved design and management of helidecks. SMS/OC/QA has an impact on many aspects of accident prevention and it is assessed that 55% of accidents could be prevented.

11.6 Flight Data Monitoring (FDM)/Helicopter Operations Monitoring Programme (HOMP)

HOMP continuously monitors operations and highlights adverse trends in operational behaviour, weaknesses in helicopters and crews as well as problems with the helideck operational environment, approach patterns and helideck design (see paragraph 9.2.3). FDM/HOMP requires minimal equipment in addition to that fitted for HUMS and provides a benefit that is proving to be increasingly effective as its deployment is widened, for low cost. As with HUMS, the development of FDM/HOMP has been largely co-funded by Shell and the CAA. It is assessed that HOMP could prevent 50% of accidents caused by operations outside Flight Manual or Operations Manual limitations.

11.7 EGPWS/TCAS.

EGPWS has proved to be extremely effective in airline operation in preventing CFIT/W accidents and is likely to be equally effective in helicopters. Although most offshore oil operations are less susceptible to CFIT/W than other helicopter operations, in fact half of such accidents on the S-76 occurred over water and CFIT/W accounted for 7% of all accidents in the North Sea and 9% of all accidents in the Gulf of Mexico. EGPWS can also provide a warning of fixed land-based obstacle hazards such as power lines and towers.

TCAS has also proved to be extremely effective in airline operation in preventing mid-air collisions and is likely to be equally effective in helicopters. Mid-air collisions account for only 2% of helicopter accidents but fatality rates are high and TCAS is assessed as likely to prevent 65% of such accidents. This will be particularly effective in high traffic density operations such as those in the Gulf of Mexico.

Allowing for some non-availability of equipment, EGPWS/TCAS has been assessed as a package of equipment fit covering the whole range of collision avoidance and is assessed as likely to prevent 75% of CFIT/W accidents and mid-air collisions.

11.8 Performance Class 1/2 (Enhanced).

With Performance Class 1, the helicopter has full single engine failure accountability at any stage of flight. With Class 2 performance, there is a short period of operation during take off and landing when the helicopter may have insufficient OEI performance and an engine failure will necessitate a forced landing. With enhanced Class 2 (2E) performance, drop down following engine failure is taken into account and the exposure time is reduced to virtually zero. It is assessed that Class 1/2E performance is likely to prevent 65% of accidents resulting from single engine failure in a twin turbine helicopter.

11.9 Impact Warning System.

Helicopters often have to operate in confined spaces and it should be possible to develop a sensor system to, in effect, cocoon the helicopter and provide the pilot with sufficient warning to avoid obstacles. Although some work has been done on such a device, suitable equipment is unlikely to be available for several years. Nevertheless, it is assessed that an impact warning system would prevent 50% of accidents caused by hitting objects.

11.10 Summary

A summary of the mitigation measures is provided in Table 5. The detailed methodology used to determine the overall impact of mitigation is shown in Appendix 2.

Table 5 - Effectiveness of Mitigation Measures

Mitigation Measure	Abbreviation	Effectiveness
Design Requirements to late amendment FAR/JAR 29	DR	50%
Handling Qualities/advanced cockpit design + late FAR 29	DR/HQ	60%
Full flight simulator level C/D +CRM +LOFT	Training	45%
Health and Usage Monitoring System	HUMS	65%
JAR Ops 3/SMS/QA/CAP 437 Helideck design and management	SMS/OC/QA	55%
Flight Data Monitoring/Helicopter Operations Monitoring Programme	FDM/HOMP	50%
Enhanced Ground Proximity Warning System/Traffic-alert and Collision Avoidance System	EGPWS/TCAS	75%
Performance Class 1 or enhanced Performance Class 2	PC1/2E	65%
Impact Warning System	IW	50%

12 POTENTIAL FOR ACCIDENT PREVENTION

12.1 Scheduled Airline – lessons learned.

The downward trend in fatal airline accidents continues, with no fatal crashes involving Western-operated large passenger airliners for the last two years. It is thus even more imperative that the accident rate for helicopters should be further reduced. The following reasons for the reduction in accidents were suggested in Ref. 1:

- Greater engine and systems reliability in aircraft produced since the 1980s.
- Improved cockpit technology that provides the aircrew with better situational awareness.
- Crew Resource Management (CRM) is now an accepted part of the training culture.
- Flight Operations Management Programmes (equivalent to HOMP).
- EGPWS, which has reduced the CFIT risk by a factor of 100.

CRM, HOMP and EGPWS can all be adopted with existing helicopters but the advantages of increased engine and system reliability and improved cockpit technology can only be obtained on helicopter types built to the latest design standards.

Although not mentioned in Ref 1, the availability of post accident data on scheduled airliners for review and analysis via download from Flight Data Recorders (FDR) and Cockpit Voice Recorders (CVR) far exceeds that from helicopters. Helicopters are generally served poorly by the regulator in this respect with FDRs mandated by few globally.

12.2 Helicopter Accidents - Baseline.

The NASA study reported in Ref. 2 covers accidents to US-registered twin-turbine helicopters that are typically to an early FAR 29 standard for the period 1963 to 1997. The last 10 years worth of the NASA study data has been used as a baseline for a breakdown of causes of accidents. Unfortunately, it does not relate accidents to flying hours and hence data from Breiling [Ref. 5), representative of twin turbine helicopters used for offshore oil operations has been used. However, it has been determined that the two data sources are very similar where they overlap in the mid 1990s. In 1990, the accident rate was about 20 per million flying hours and the fatal accident rate was about 7 per million flying hours. Over the period 1992 to 2002, the ratio of fatal accidents to all accidents was about 0.35. These figures have been used as the baseline for potential improvement through implementation of various packages of mitigation measures.

12.3 Impact of Mitigation.

The impact of mitigation has been determined, using the method described in Appendix 2 for:

- Accidents to twin-turbine helicopters (typically to an early FAR 29 standard) reviewed in the NASA study [Ref. 2) for the period 1987 to 1997 (Appendix 3).
- All S332 and S-76 accidents reported in the World Airline Accident Survey (WAAS) covering the period 1980 to 2003 (Appendix 4). The S-76 and AS332 are types in general use within the oil industry and therefore some of their safety performance will have been improved by mitigation measures introduced in the 1990s in the North Sea contracts in particular.

In summary, a primary mitigation measure is assigned to each category of accident (Appendix 3) or individual accident (Appendix 4). Secondary and tertiary mitigation measures, which may have an impact, albeit less effective, are also assigned. The individual percentage effectiveness of each mitigation measure is taken from Table 5 and applied to each accident or category of accident in turn. In all cases the estimate of effectiveness assigned was conservative. This was used to produce an overall assessment of the percentage of accidents that could have been avoided if the full suite of mitigations had been in place, indicating that up to 84% of accidents in the databank could have been avoided.

12.4 Impact of Individual Mitigation Measures.

Having applied the estimated effectiveness of each mitigation measure to the population of accident data, it was possible to assess the projected percentage reduction in accidents that could be attributed to each measure.
The impact of each mitigation measure acting in isolation, with the others set at zero is shown in the following graphs:

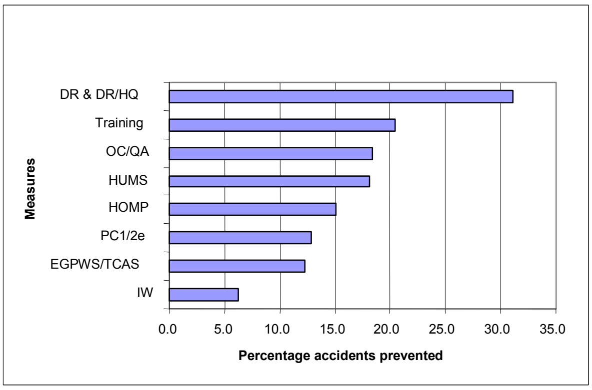

Figure 8: Percentage accidents reported in NASA study prevented by individual mitigation measures

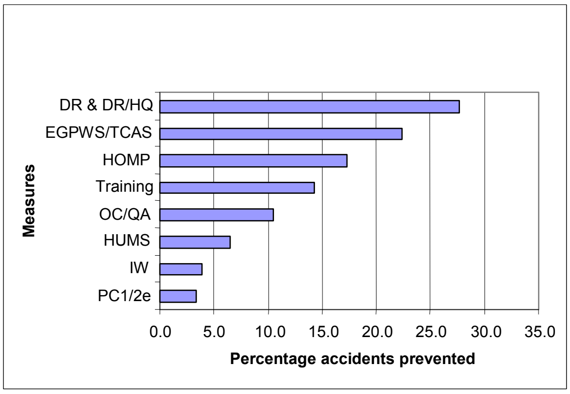

Figure 9: Percentage AS332 and S-76 accidents prevented by individual mitigation measures

From this analysis, design requirements to the latest amendment combined with enhanced handling qualities, which of course can only be obtained with new types of helicopter, would prove to be the most effective mitigation to prevent accidents. The NASA study covers an earlier period that ends in 1997 whereas the AS332 and S-76 analysis includes a further 6 years up to 2003. The charts indicate that mitigation provided by Training, OC/QA, HUMS and PC1/2E are all lower for the AS332 and S-76 accidents than for the NASA study. This feature may be indicative of improvements that have progressively been introduced over the last 10 years to the AS332/S-76, two helicopters that predominate in offshore operations. The only really significant difference between the two analyses concerns EGPWS/TCAS.

This can be accounted for by the very high number of CFIT accidents suffered by the S-76 which has driven industry to deliver the S76C model equipped with EGPWS as standard fit.

12.5 ALARP.

Many of the mitigation measures have already been deployed to a varying extent in the different regions in which the oil companies operate. In order to illustrate the trends in accident reduction in relation to operating costs, and hence whether the changes have met the ALARP principle, the impact of a number of packages of mitigation measures has been considered.

Package A - Baseline

Package A provides the baseline with no mitigation measures and is representative of twin turbine helicopters operated globally, including off-shore oil operations, in the late 1980s and early 1990s. The baseline accident rate used is 20 per million flying hours, although recent trends indicate that this may be rising. Using the ratio of 0.35 between fatal accidents and all accidents gives a baseline Fatal Accident Rate of 7 per million flying hours. The corresponding operating cost was about $2.5 million per year based on annual standing charges per medium twin airframe and 1000 flying hours per year.

Package B

Package B comprises the following mitigation measures:
- Mix of Performance Class 2 and Class 3
- HUMS - part implemented
- Training – simulator training part implemented with some LOFT
- Partially enhanced SMS/OC/QA with elements of a structured SMS and helideck management

Implementation of this package of measures is representative of twin turbine helicopters operating in the mid 1990s in the North Sea and currently in most other OGP regions. Aircraft types will generally be S76A^{++}, Bell 212, AS365N, AS332L/L1 and S61. Applying these mitigation measures to the model in Appendix 2 results in the following projected accident rates:
- 15.1 accidents per million flying hours
- 5.3 fatal accidents per million flying hours

The corresponding operating cost for the medium twin helicopters in this group for future contracts is $4.6 million per year based on an annual standing charge per airframe and 1000 flying hours per year.

Package C

Package C comprises the following mitigation measures:
- Retrofit HUMS with associated effectiveness
- Performance Class 2
- SMS/OC/QA - full JAR Ops 3/QA to JAR145, effective SMS with safety case and helideck management to CAP437
- Design Requirements - part implemented e.g. equivalent levels of safety beyond that claimed in the TCDS
- HOMP - fully implemented
- Training – simulator training implemented
- TCAS/EGPWS fitted

Implementation of this package of measures is representative of most of one major oil operator's twin turbine helicopter operations in the late 1990s to early 2000s, and all North Sea operations with such aircraft as the S76C+, Bell 412, AS332L2, and EC155.
Applying these mitigation measures to the model in Appendix 2 results in the following projected accident rates:

- 6.19 accidents per million flying hours
- 2.17 fatal accidents per million flying hours

The corresponding operating cost for the helicopters in this group is $5.03 million per year.

Package D

Package D comprises all the mitigation measures and is representative of future twin-turbine helicopters such as AW139, S92, EC225 and EC155B1.
Applying these mitigation measures to the model in Appendix 2 results in the following projected accident rates:

- 3.2 accidents per million flying hours
- 1.1 fatal accidents per million flying hours

The corresponding operating cost for the helicopters in this group is estimated to be $5.76 million per year, but it should be possible to reduce this figure with smart procurement, improved utilisation, sharing etc.

Package E

This extension to Package D is a prediction of the potential safety level, which might be achieved in the next 10 to 15 years with derivative technology (fly-by-wire; enhanced cockpit management; enhanced flaw/damage tolerant design) and more rigorous monitoring and operational controls. It assumes that:

- FAR 29 design requirements have closed the gap with FAR 25
- Operations are being conducted to the more stringent requirements of 14CFR Part 121 or JAR-OPS 3/NPA 38 (or equivalent)
- HUMS analysis employs machine learning techniques and has been extended into the rotor system
- All operations are being conducted to Performance Class 1 to no smaller than 1D helidecks configured in accordance with CAP437

Although it is difficult to predict actual costs, it is assumed that a premium of at least 20% over the Package D annual costs would be conservative for an equivalent aircraft. The effectiveness of the appropriate mitigation measures for the various enhancements have been adjusted upwards by between 5% and 10%. Applying these upgraded mitigation measures to the model in Appendix 2 results in the following projected accident rates:

- 2.34 accidents per million flying hours
- 0.82 fatal accidents per million flying hours

The corresponding operating cost for the medium helicopters in this group is projected to be $6.9 million per year based on an annual standing charge per airframe and 1000 flying hours per year. As in Option D, it should be possible to reduce this figure with smart procurement, improved utilisation, sharing etc.

Overall ALARP Assessment

The ALARP assessment plot shows that in the last decade, in both theory and practice, progress has been made in reducing accident rates through the implementation of some of the mitigation measures. Where there has been more extensive implementation, as in the North Sea, accidents rates have been reduced further. Recent contract rates quoted for old aircraft (Option B) and for new versions of old design (Option C) do not now show the significant difference that existed, say five years ago, and the significant reduction in accident rates clearly justifies the additional cost. However, Option C represents the status quo and is unlikely to enable the OGP to achieve its long-term safety goals. These can only be achieved with the introduction of new design aircraft (Option D). Although Option D shows a premium of up to 15% in terms of annual cost for a medium, 12-seat helicopter, the potential exists to reduce accident rates by 50%. Option E, which looks ahead to the further development of the later versions of the S92, EC225 and AB139, or to the next generation of helicopters, is likely to increase costs by a further 15% - 20% and the mitigation assessment shows an improvement of about 25% in safety. This would indicate that we would be entering the laws of diminishing returns and that the ALARP point, which coincides with the projected safety goal, is Option D.

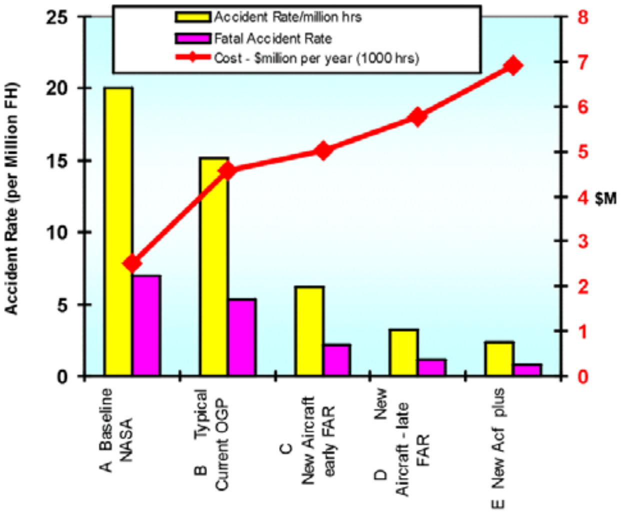

Figure 10: The ALARP Assessment Plot

13 CONCLUSIONS

The OGP companies contract for helicopters within an industry that has generally been under funded and, arguably, complacent in the past 15 years. There has been insufficient change in regulation, and the regulators globally are not harmonised in their approach to offshore helicopter operations and safety. However, as contracted helicopters have aged so, coincidentally, has the accident rate risen. This should cause no surprise since it reflects the previous experience of the airline industry. The fixed wing industry in the more progressive parts of the world has tackled the safety problem in a comprehensive and generally successful manner through a series of programmes, not least of which has been the introduction of new models of aircraft incorporating more stringent design standards.

Whilst in a number of areas mitigation has been introduced with improvements in training, equipment, safety management and operational control, these measures cannot, by themselves, deliver the OGP's safety goal. However, the opportunity now exists for the helicopter industry to learn the lessons from and emulate the success of the airlines and the fixed wing industry. This study demonstrates what can be achieved and supports the establishment of the OGP goals for air safety. However, it is very unlikely that the target could be met without the mitigation offered by all the projected further improvements, including introduction of new types. "Business as usual" is therefore not an acceptable option.

The cheapest option which offers a significant move towards enhanced safety targets is to implement all the mitigation measures on old types, i.e. with the exception of those that require the acquisition of new helicopters either to existing designs or new designs to the latest standards. However, this would only go part way to meeting the goal. Moreover, in the event of an accident, the OGP companies would become increasingly vulnerable to the charge that they are continuing to operate helicopters with a basic design, already 30 years old, which is too old to be acceptable. This option could, therefore, only be a short-term solution, having consequent amortization disbenefits.

An alternative would be to acquire new helicopters to existing (old) designs such as the S-76C+/C^{++}, Bell 412EP, or AS332L2. This would go some way to meeting the OGP's goal but, again, would leave the OGP companies vulnerable to the charge of operating helicopters with a very old basic design standard. However, this option might be beneficial as an interim measure until the new designs had proven themselves in service.

The only option that will enable the long-term OGP goal to be met would be to acquire new helicopters, such as the S92, EC225 or AB139 to the latest design standard.

14 RECOMMENDATIONS

It is recommended that, in order to achieve the stated safety goal, OGP companies should commit to the implementation of the OGP Aircraft Management Guide and actively support:

- Transition to new aircraft built to the latest design standards on new contracts.
- Requirement for annual training in flight simulators to practice crew coordination during emergency procedures.
- Fitting of all helicopters with Vibration & Health and Engine Monitoring Systems such as HUMS/VHM/EVMS.
- Fitting of all helicopters with EGPWS or TAWS and TCAS
- Requirement for operators to implement quality and safety management systems.
- Requirement for operators to implement FDM/HOMP.
- Requirement for operators to fly profiles that minimize the risks of engine failure.

Work together to ensure that:

- Manufacturers support HUMS/VHM/EVMS & the latest design standards (FAR 29 - 47)
- Operators adopt proven global best practices as their minimum standard
- Regulators support proven global best practices, including HUMS/VHM/EVMS

15 LIST OF APPENDICES

1. Review of FAR29 amendments 29-12 to 29-47.
2. Method of Determining Impact of Means of Mitigating Accidents.
3. Mitigation Factors NASA Study.
4. Mitigation Factors all AS332 and S-76 accidents.

16 REFERENCES

[1] *"Safer Six Months*", Flight International, 3-9 August 2004, page 34.
[2] *US Civil Rotorcraft Accidents, 1963 through 1997*, NASA/TM-2000-209597 dated December 2000
[3] *Helicopter Safety Study 2, STF38 A99423* dated 15 December 1999 (SINTEF Study)
[4] HSAC (Helicopter Safety Advisory Conference) Offshore Oil Industry Helicopter Operations and Safety Performance Review 1998 - 2003, (Gulf of Mexico)
[5] *Annual Turbine Aircraft Accident Review*, Robert Breiling Associates Inc
[6] *Flight Safety Digest* Vol. 22 No 1 dated January 2003
[7] *Helicopter Tail Rotor Failures*, CAA Paper 2003/1 dated November 2003
[8] *Offshore Helicopter Landing Areas* - Guidance on Standards CAP 437.
[9] Helicopter deck on offshore installations NORSOK Standard C-004
[10] *Civil Helicopter Handling Qualities requirements: Review and Investigation of Applicability of the ADS-33 Criteria and Test Procedures*, CAA Paper 980004 dated June 1998.
[11] *Helicopter Health Monitoring - A Cost Benefit Analysis*, CAA Paper 97002 dated January 1997

Safety Benefit Impact of FAR Part 29 Amendments Generic Model.

Date	Sec	Title	Change	Impact on Safety	Currency
09-May-01	**29-47**	**Technical amendments**			
Summary		Technical amendment to correct an error in Amendment 29-12			
	29.397	Limit pilot forces and torques.	80R pounds changed to 80R inch-pounds	Nil	Current
21-Jan-00	**29-46**	**Flight Plan Requirements for Helicopter Operations Under Instrument Flight Rules**			
Summary		Revised flight planning requirements for helicopters to take account of their unique operating characteristics			
	91-259		Removes SFAR 29.4 and introduces relaxed rules for helicopters in FAR 91-259 adding revised weather and fuel minima requirements under IFR flight rules.	Low - but only if accepting flights made under FAR 91`-167 or 169 rules	Current
25-Oct-99	**29-45**	**Harmonization of Critical Parts Rotorcraft Regulations**			
Summary		Defines critical parts and requires a critical parts list with control procedures			
	29.602	Critical parts	Formalises procedures & harmonises with JAA	High	Current
17-Nov-99	**29-44**	**Transport Category Rotorcraft Performance**			
Summary		Several no substantive clarifications and correction of errors in performance section in amendment 29-40			
	29.59	Takeoff path: Category A.	Editorial re-ordering of paragraphs	Nil	Current
	29.62	Rejected takeoff: Category A.	Clarification	Nil	Current
	29.67	Climb: One-engine-inoperative (OEI).	Consistency with 29-1521	Nil	Current
	29.77	Landing Decision Point (LDP): Category A	Clarification	Nil	Current
	29.81	Landing distance: Category A.	Removal of unnecessary requirement	Nil	Current
	29.85	Balked landing: Category A.	Improved text	Nil	Current
	29.1323	Airspeed indicating system.	Consistency with other sections of Pt 29	Nil	Current
	29.1587	Performance information.	Correction of errors	Nil	Current
05-Oct-99	**29-43**	**Rotorcraft Load Combination Safety Requirements**			

Summary		Improved safety of people carried external to rotorcraft			
	29.25	Weight limits	Uprated standards to reflect current operational needs	Not applicable accept for winching operations	Current
	29.865	External loads	Uprated standards to reflect current operational needs		Current
11-Sep-98	**29-42**	**Harmonization of Miscellaneous Rotorcraft Regulations**			
Summary		Cockpit indication of autopilot mode, burn test requirements for electrical wiring and fitting factor for berths			
	29.625	Fitting factors.	No known incidents but requirement for 1.33 fitting factor for attachment of berths codifies factor used in most current designs	Low	Current
	29.785	Seats, berths, litters, safety belts, and harnesses.	Align with new 29.625	High	Current
	29.923	Rotor drive system and control mechanism tests.	Correction of error	Nil	Current
	29.975	Fuel tank vents and carburettor vapour vents.	Removes "unless rollover is extremely remote"	High	Current
	29.1329	Automatic pilot system.	Requires cockpit indication of autopilot operating mode and codifies standard of current equipment.	Low	Current
	29.1351	General.	Correction of error	Nil	Current
	29.1359	Electrical system fire and smoke protection.	Clarifies burn test requirements for electrical wiring and codifies standard currently used on Pt 29 rotorcraft. Several incidents, one Pt 27 helicopter destroyed.	High	Current
28-Nov-97	**29-41**	**Miscellaneous non substantive corrections**			
Summary		Several non-substantive changes			
	29.351	Yawing conditions.	Text	Nil	Current
	29.391	General.	Removes references	Nil	Current
	29.562	Emergency landing dynamic conditions.	Text	Nil	Current
	29.621	Casting factors.	Correction of error	Nil	Current
	29.1125	Exhaust heat exchangers.	Text	Nil	Current
	29.1521	Power plant limitations.	Text	Nil	Current
08-Aug-96	**29-40**	**Rotorcraft Regulatory Changes Based on European Joint Aviation Requirements**			
Summary		Changes based on European Joint Aviation requirements			

	29.547	Main and tail rotor structure.	Formal identification and assessment of critical component failures	High	Current
	29.610	Lightning and static electricity protection.	Improved lightning and static protection	High	Current
	29.629	Flutter and divergence.	"Divergence" added to cover aeroelastic instability other than flutter of aerodynamic surfaces - codifies current practice.	Medium	Current
	29.631	Bird strike.	New requirement for bird strike test or analysis. In period 1983-1991, 2 accidents, one with injuries and damage to rotorcraft, one with no injuries but destroyed rotorcraft.	High	Current
	29.917	Design.	New requirement to formalise existing design data for rotor structure and drive.	High	Current
	29.923	Rotor drive system and control mechanism tests.	Removes possible inconsistencies in rules and increases testing for 2 minute OEI from one to two runs per cycle.	Medium	Error corrected by 29-40
	29.1305	Powerplant instruments.	Oil pressure indicator for pressure-lubricated gearboxes	Low	Current
	29.1309	Equipment, systems, and installations.	Removal of unnecessary reference following change to 29.610	High	Current
	29.1351	General.	Enhanced electrical power failure requirements	High	Error corrected by 29-40
	29.1587	Performance information.	Inclusion of climb gradient data in Flight Manual	Medium	See 29-44
	B29.8	VIII. Equipment, systems, and installation.	Reference to new 29.1351	High	Current
10-Jun-96	**29-39**	**Transport Category Rotorcraft Performance**			
Summary		Factors for determining take-off, climb and landing performance defined more clearly. The changes provide an improved level of safety associated with recent technological advances			
	29.1	Applicability	Following re-designation of Sec 29.79 to 29.87	Nil	Current
	29.49	Performance at minimum operating speed	Sec 29.73 redesignated as Sec 29.49 and revised	Low	Current
	29.51	Takeoff data: General	References re-numbered to align with new amendments	Nil	Current
	29.53	Takeoff: Category A	Text for Category A separated from decision point	Nil	Current
	29.55	Takeoff decision point (TDP): Category A	New section to redefine TDP	Low	Current
	29.59	Takeoff path: Category A.	Takeoff path more clearly defined	Low	See 29-44
	29.60	Elevated heliport takeoff path: Category A	New requirements for operation from rooftops	Low	Current

	29.61	Takeoff distance: Category A	Takeoff distances more clearly defined	Low	Current
	29.62	Rejected takeoff: Category A	Separation of text from takeoff path and imposition of primary controls only	Low	See 29-44
	29.64	Climb: General	Clarifies climb requirements	Low	Current
	29.65	Climb: All engines operating	General requirement to determine Category A climb performance	Low	Current
	29.67	Climb: One Engine Inoperative (OEI)	Rate of climb requirements	Low	See 29-44
	29.73	Redesignated	Now 29.49	Nil	Current
	29.75	Landing: General	Specific requirements separated	Nil	Current
	29.77	Landing decision point: Category A	New requirement to codify current practice	Low	See 29-44
	29.79	Landing Category A	Minor revision put in separate section - Impact of landing distance required for OEI rejected T/O or landing case	Low -	Current
	29.81	Landing distance: Category A	New requirement for landing distances from specific heights	Low	See 29-44
	29.83	Landing: Category B	Re-arrangement of text	Not applicable	Current
	29.85	Baulked landing: Category A	Text moved from 29.77 and revised	Low	See 29-44
	29.87	High velocity envelope	29.79 redesignated as 29.87 and revised engine power conditions	Low	Current
	29.1323	Airspeed indicating system.	Term "height-speed" changed to "height-velocity"	Nil	See 29-44
	29.1587	Performance information.	Revised to conform to other changes plus inclusion of OGE data	Low	See 29-44
11-Jun-96	**29-38**	**Occupant Protection in Normal and Transport Category Rotorcraft**			
Summary		Increase in static design ultimate inertia load factors for restraining heavy items during crash landings			
	29.561	General.	12g forward and downward, 6g sideward 1.5g rearward. FAA study "Analysis of Rotorcraft Crash Dynamics for Improved Crashworthiness Design" **(Report DOT/FAA/CT-85/11 dated Jun 85)** identified penetration of heavy items into occupied areas as one of 14 hazards associated with survivable accidents resulting on one moderately severe injury per year. Safety enhancement of new requirement difficult to quantify.	High	Current
28-Dec-95	**29-37**	**Revision of Authority Citations**			
Summary		Changes to comply with current law			

	Preamble	Authority citation	Updated	Nil	Current
31-Jan-96	**29-36**	**Rotorcraft Engine Rotor Burst Protection**			
Summary		Adverse effects of turbine engine rotor failure to be minimised			
	29.901	Engine Installation	No single failure or combination of failures to jeopardize operation of rotorcraft	High	Current
	29.903	Engines	Hazards in event of an engine rotor failure to be minimised. Based on 527 flight hours per year, probability of substantial damage or destruction of twin-engined rotorcraft is about 0.00066. In 8.8 million twin engine flight hours, rule could prevent 3 fatalities, 1 serious injury and 2 minor injuries.	High	Current
02-Nov-94	**29-35**	**Crash Resistant Fuel Systems in Normal and Category Transport Rotorcraft**			
Summary		Comprehensive new crash resistant fuel system design and test criteria			
	29.952	Fuel system crash resistance	New requirements. Post crash fires (PCF) main cause of fatalities in other wise survivable accidents. Nearly all PCFs are caused by crash-induced fuel leaks. During a 5-year study, there were 63 accidents involving a PCF with 113 fatalities, 27 serious injuries and 5 minor injuries. The new requirements would reduce these to 83 fatalities, 32 serious injuries and 24 minor injuries.	High	Current
	29.963	Fuel tanks: General	Parallel new requirements	High	Current
	29.967	Fuel tank installation	paragraph (e) deleted	Nil	Current
	29.973	Fuel tank filler connection	Parallel new requirements	High	Current
	29.975	Fuel tank vents and carburettor vapour vents.	Parallel new requirements	High	See 29.42
17-Oct-94	**29-34**	**New Rotorcraft 30-second/2-minute One Engine Inoperative (OEI) Power Ratings**			
Summary		Optional OEI power ratings for multi-engine, turbine-powered rotorcraft that enhance safety after an engine failure by providing higher OEI power. Permits higher payloads and operation from smaller heliports.			

	29.67	Climb: One engine inoperative	For rotorcraft certified for the 30 sec/2 min OEI power, only 2 min OEI may be used to comply with 100 ft/min rate of climb requirement	Low - Not applicable to earlier design types with 2.5 minute power rating. Consider implications for increased benefits in new types	See 29.44
	29.923	Rotor drive system and control mechanism	Consequent additions to endurance test schedule	Low - Not applicable to earlier design types with 2.5 minute power rating. Consider implications for increased benefits in new types	See 29.42
	29.1143	Engine controls	Automatic control of 30 sec OEI power	Low - Not applicable to earlier design types with 2.5 minute power rating. Consider implications for increased benefits in new types	Current
	29.1305	Powerplant instruments.	Pilot alert and usage record	Low - Not applicable to earlier design types with 2.5 minute power rating. Consider implications for increased benefits in new types	See 29.40
	29.1521	Powerplant limitations.	Any damage after usage must be readily detectable	Low - Not applicable to earlier design types with 2.5 minute power rating. Consider implications for increased benefits in new types	See 29.41

	29.1549	Powerplant instruments.	Markings associated with 30-sec/2 min OEI limit	Low - Not applicable to earlier design types with 2.5 minute power rating. Consider implications for increased benefits in new types	Current
21-Jun-94	**29-33**	**Emergency Locator Transmitters (ELT)**			
Summary		Improved design for new ELTs			
	29.1415	Ditching equipment	Requires fitment of approved ELT (To TSO 91a in lieu of TSO 91). 81 fewer fatalities expected in the 20 years following promulgation	Low - SAI requirement is to have TSO91a or TSO126.	Current
16-Sep-91	**29-32**	**Shoulder Harnesses**			
Summary		Installation and use of shoulder harnesses at all seats			
	29.2	Special retroactive requirements	Installation and use of shoulder harnesses at all seats. Fewer than 20% of accidents are due to design or material faults and hence improved occupant protection is warranted. Shoulder harness will enhance safety in 52% to 68% of rotorcraft impacts.	Low - SAI requirement to retrofit older types with 4 point UTR harness is relevant.	Current
22-Oct-90	**29-31**	**Rotorcraft Regulatory Changes Based on European Joint Aviation Requirements**			
Summary		Improved safety, clarification and standardization of terminology			
	29.401	Auxiliary rotor assemblies	Removed, load requirements adequately covered elsewhere	Nil	Current
	29.403	Auxiliary rotor attachment structure	Removed, load requirements adequately covered elsewhere	Nil	Current
	29.413	Stabilizing and control surfaces	Removed, load requirements adequately covered elsewhere	Nil	Current
	29.427	Unsymmetrical loads	Removal of reference to 29.413	Nil	Current
	29.775	Windshields and windows	Clarification that transparencies other than glass may be used if they will not break into dangerous fragments	High	Current

	29.783	Doors	Means to secure a non-jettisionable door in the open position during emergency egress in a ditching	Low - SAI requirement for jettisionable windows and escape paths should alleviate this requirement	Current
	29.787	Cargo and baggage compartments	Occupant protection for all emergency landing loads on cargo and baggage	Low - SAI requirement for separation between cargo and passengers and the cargo to be adequately restrained should alleviate this requirement	Current
	29.811	Emergency exit markings	Emergency lighting must be lighted and visible if the rotorcraft is submerged	Low - training plus use of HEEL or similar is more effective	Current
	29.903	Engines	Clarification of in-flight restarting of engines	Medium - Check what is meant by a independent means of restarting the engines in flight means when fitted with starter generators.	See 29.36
	29.923	Rotor drive system and control mechanism tests.	Qualification testing of lubricants used in rotor drive system and control mechanism defined	Low	See 29.42
	B29.8	Airworthiness criteria for helicopter instrument flight	Thunderstorm lights must be included	Medium - Check implications of defective storm lights where used to meet this requirement.	See 29.40
05-Apr-90	**29-30**	**Rotorcraft Regulatory Review Program Amendment No 4**			
Summary		Last in a series of amendments issued as part of the Rotorcraft Regulatory Review Program. Most amendments reflect current technology			
	29.307	Proof of structure	Clarification that strength requirements must account for environmental conditions	High - Change of operational usage	Current

	29.337	Limit manoeuvring load factor	Clarification and harmonisation of Pts 27 & 29	Nil	Current
	29.391	Control Surface and System Loads General.	Consequential references to 29.427	Medium	
	29.395	Control system	Clarification and an increase in minimum load to account for possible jamming, ground gusts, inertia and friction	Medium	Current
	29.427	Unsymmetrical loads	Application of unsymmetrical loads when evaluating horizontal stabilizing surfaces	Medium	See 29.31
	29.501	Ground loading conditions: Landing gear with skids	Reduction of inward and outward side loads for skid landing gears	Low	Current
	29.519	Hull type rotorcraft	Requires consideration of wave profiles	Low - Applicable to S61N	Current
	29.563	Structural ditching provisions	Extensive revisions to provide a consistent basis for design	Medium	Current
	29.613	Material strength properties and design values	Harmonisation with aeroplane standards	Low	Current
	29.629	Flutter	Clarification that flutter applies to aerodynamic surfaces	Low	See 29.40
	29.663	Ground resonance prevention means	Proof that a failure of a single means will not cause ground resonance	Medium	Current
	29.674	Interconnected controls	Continued operation after malfunction/jamming of any auxiliary interconnected control	Medium	Current
	29.727	Reserve energy absorption drop test	Clarification	Low	Current
	29.755	Hull buoyancy	Removal of superfluous standards	Nil	Current
	29.783	Doors	Clarification	Low	See 29.31
	29.803	Emergency evacuation	Demonstration requirements	Low	Current
	29.805	Flight crew emergency exits	Crew exits must not be obstructed in the event of a ditching	High	Current
	29.807	Passenger emergency exits	Options allowing smaller transport rotorcraft to have only side-of-fuselage exits	Low	Current
	29.809	Emergency exit arrangement	Consideration of descent arrangements with landing gear damaged or rotorcraft on its side	Low	Current
	29.811	Emergency exit markings	2-inch coloured band outlining each exit release lever	Low - Check compliance on individual aircraft	See 29.31
	29.855	Cargo and baggage compartments	Allows small, accessible cargo and baggage compartments to be lined with passenger compartment materials rather than fire resistant materials	Nil	Current

	29.861	Fire protection of structures, controls and other parts	Allows use of fireproof materials in areas affected by Powerplant fires in normal and transport Category B rotorcraft without further qualification	Not applicable	Current
	29.865	External load attaching means	Allows use of design factor of less than 3.5 g provided the lower factor is unlikely to be exceeded by virtue of the rotorcraft capabilities	Low	See 29.30
	29.1415	Ditching equipment	Harmonization of equipment and operating rules	Low - SAI requirement for 2 reversible liferafts or more with a 50% overload capacity exceeds this requirement	See 29-33
	D29.1	Criteria for demonstration of emergency evacuation procedures under Sec 29.803	Detailed demonstration requirements	Low	Current
13-Dec-89	**29-29**	**Occupant Restraint**			
Summary		Additional dynamic crash impact design conditions for seat and occupant restraint systems and increased static design load factors for seats and items in the cabin. Part of FAA Aircraft Crash Dynamics program and based on Report DOT/FAA/CT-85/11 "Analysis of Rotorcraft Crash Dynamics for Development of Improved Crashworthiness Design Criteria", June 1985. Expected to reduce fatalities and injuries in otherwise survivable crashes from between 30% to 85%. **(8g, 4g, 2g).**			
	29.561	General.	Static design load factors	High	See 29.38
	29.562	Emergency landing dynamic conditions	Statement of conditions	High	See 29.41
	29.783	Doors	Prevention of jamming	High	See 29.31
	29.785	Seats, berths, safety belts, and harnesses.	Torso restraint requirements	High	See 29.42
	29.809	Emergency exit arrangement	Prevention of jamming	High	See 29.30
27-Nov-89	**29-28**	**Structural fatigue**			
Summary		Addition of flaw tolerance requirements and extension of fatigue evaluation to all critical structure			
	29.571	Fatigue evaluation of structure	Flaw tolerant requirements. Expected to avoid 4 accidents per year	High	Current

18-Aug-90	**29-27**	**Revision of General Operating and Flight Rules**			
Summary		Consequential Part 29 amendments following amendment of Part 91			
	29.4	Airworthiness limitations section	Change in cross reference	Nil	Current
03-Oct-88	**29-26**	**Rotorcraft Regulatory Review Program Amendment No 3**			
Summary		A series of amendments issued as part of the Rotorcraft Regulatory Review Program. Most amendments reflect rapidly advancing technology			
	29.67	Climb: One engine inoperative	New continuous OEI rating. Benefits for off-shore operators	High	See 29.44
	29.361	Engine torque	Torque loads associated with emergency operation of governor-controlled tuboshaft engines and also sudden stoppage of turbine engines. Current practice (Max continuous power + 1.25)	High	Current
	29.549	Fuselage and rotor pylon structures	Editorial	Nil	Current
	29.901	Installation	Requirements to minimise the effects of incorrect installation through cross connection or incorrect orientation.	High	See 29.36
	29.903	Engines	Clarification of crew action and new requirement for restart capability throughout the flight envelope	Medium	See 29.36
	29.908	Cooling fans	Safe operation following fan failure	Medium	Current
	29.923	Rotor drive system and control mechanism tests.	Editorial changes, clarification and additional endurance test criteria	Medium	See 29.42
	29.927	Additional tests	Significant continued flight capability following lubrication system failure	Medium	Current
	29.954	Fuel system lightning protection	Design to prevent ignition of fuel vapour following lightning strike. Current practice	Medium	Current
	29.955	Fuel flow	Re-organisation plus new requirements reflecting current practice	High	Current
	29.961	Fuel system hot weather protection	Simplification and clarification of fuel system hot weather qualification requirements in line with current practice (temperatures over 110F deg. Causing vapour lock situations).	Medium	Current
	29.963	Fuel tanks: General	Maximum temperature of components in fuel tanks	Medium	See 29.35
	29.967	Fuel tank installation	Paragraph (f) deleted - adequately covered by 29.963	Nil	See 29.36
	29.969	Fuel tank expansion space	2% expansion space	Low	Current

	29.971	Fuel tank sump	Drainage of hazardous quantities of water in any ground attitude	Low	Current
	29.975	Fuel tank vents and carburettor vapour vents.	Design to minimize spillage of fuel onto ignition source in the event of a rollover. Current practice	High	See 29.42
	29.991	Fuel pumps.	Rationalisation and extension	Low	Current
	29.997	Fuel strainer or filter	Changed to align with current practice	Low	Current
	29.999	Fuel system drains	Complementary to 29.971	Low	Current
	29.1001	Fuel jettisoning	Certification standards if fuel jettisoning is installed	High if fitted	Current
	29.1011	Engines: General	Clarification	Nil	Current
	29.1019	Oil strainer or filter	Editorial	Nil	Current
	29.1027	Transmission and gearboxes: General	Includes requirements deleted from 29.1011 plus additional requirements to align with current practice	Medium	Current
	29.1041	General.	Clarification	Low	Current
	29.1043	Cooling tests	Clarification	Nil	Current
	29.1045	Climb cooling test procedures	Tests applicable to new continuous OEI rating	Low	Current
	29.1047	Takeoff cooling test procedures	Tests applicable to new continuous OEI rating	Low	Current
	29.1093	Induction system icing protection	Editorial	Nil	Current
	29.1141	Powerplant controls: General	Clarification	Low	Current
	29.1143	Engine controls	Editorial	Nil	See 29.34
	29.1163	Powerplant accessories	Simplification	Low	Current
	29.1181	Designated fire zones: Regions included	Re-instatement of requirement deleted by Amendment 29-3	Low	Current
	29.1189	Shutoff means	Changed to align with current practice	Low	Current
	29.1193	Cowling and engine compartment covering	Redundant retention following failure of normal cowling fastening. Current practice	Medium	Current
	29.1305	Powerplant instruments.	Simplification and additional warnings	Medium	See 29.40
	29.1337	Powerplant instruments.	Chip detectors	High	Current
	29.1521	Powerplant limitations.	Limitations introduced by new OEI ratings	Medium	See 29.41
	29.1549	Powerplant instruments.	Markings applicable to new OEI ratings	Medium	See 29.34
	29.1557	Miscellaneous markings and placards	Permits use of flight manual references in lieu of decals	Nil	See 29.36
11-Oct-88	**29-25**	**Cockpit Voice Recorders (CVR) and Flight Recorders**			
Summary		Requirement for digital flight data recorders and CVRs to provide more information to accident investigators			
	29.1459	Flight recorder	Installation of enhanced recorders specified in 135.151 and 135.152	High	Current

06-Dec-84	**29-24**	**Rotorcraft Regulatory Review Program Amendment No 2**			
Summary		A series of amendments issued as part of the Rotorcraft Regulatory Review Program and necessitated by the phenomenal growth of the rotorcraft industry			
	29.21	Proof of compliance	Editorial	Nil	Current
	29.45	General.	Pre-flight power-assurance check	High	Current
	29.59	Takeoff path: Category A.	Clarification and harmonisation with Pt 25	Low - use of 35Ft obstacle clearance required and possible use of balance field requirements considered but not enforced	See 29.44
	29.67	Climb: One engine inoperative	Clarification	Nil	See 29.44
	29.77	Baulked landing: Category A	Adds a 35-foot minimum height requirement	Nil	See 29.44
	29.141	General.	Clarification	Nil	Current
	29.143	Controllability and manoeuvrability	Clarification	Nil	Current
	29.151	Flight controls	Control system design characteristics	High	Current
	29.161	Trim control	Collective trim in level flight	High	Current
	29.173	Static longitudinal stability	Clarification	Nil	Current
	29.175	Demonstration of static longitudinal stability	Changes to align with 29.173	Nil	Current
	29.177	Static directional stability	New directional stability requirement	High	Current
	29.181	Dynamic stability: Category A rotorcraft	Positive damping of short period oscillation. Codifies current certification standard	High	Current
	29.610	Lightning protection	Lightning protection equivalent to that for airplanes	High	See 29.40
	29.671	General.	Means to allow full control movement of all primary flight controls prior to flight	High	Current
	29.672	Stability augmentation, automatic and power-operated systems	New criteria for approval of those stability augmentation, automatic, and power-operated systems whose performance is essential to flight safety.	High	Current
	29.673	Primary flight controls	New requirement for full control movement or an alternate means of determining full control authority of all primary flight controls before flight	Low	Current
	29.729	Retracting mechanism	Clarification	Low	Current
	29.735	Brakes	Clarification	Nil	Current

	29.771	Pilot compartment	Modification to require flight and Powerplant controls to be designed in a manner that prevents confusion or inadvertent operation when pilots switch from one pilot position to another	Medium	Current
	29.779	Motion and effect of cockpit controls	New requirement which standardizes requirements for direction of motion for flight controls, engine power controls, and landing gear controls	Low	Current
	29.785	Seats, berths, safety belts and harnesses	Changes to establish a level of safety for rotorcraft seats, berths, safety belts, and harnesses equivalent to that previously established for transport airplanes	High See later requirements	See 29.29 and 42
	29.811	Emergency exit marking	Editorial to align with 29.812	Nil	See 29.31
	29.812	Emergency lighting	To afford the same level of safety in emergency evacuation at night as passengers flying in transport category airplanes	Medium (HEEL or EXIS lighting requirements)	Current
	29.855	Cargo and baggage compartments	To permit the use of smoke detectors as well as fire detectors	Medium	See 29.30
	29.1303	Flight and navigation instruments	Instrumentation needed if unmistakable pilot cues are not available	Medium	Current
	29.1309	Equipment, systems, and installations.	Comprehensive systematic failure analysis, supported by appropriate tests, similar to 25.1309	High	See 29.40
	29.1323	Airspeed indicating system.	Revised airspeed system accuracy requirements	Medium	See 29.44
	29.1325	Static pressure and pressure altimeter systems	To relax tolerances to be substantially identical to tolerances in Sec. 25.1325 (e).	Nil	Current
	29.1329	Automatic pilot system.	Clarification and additional requirements for autopilots when interconnecting them with other systems similar to Part 25..	Medium	See 29.42
	29.1331	Instruments using a power supply	To provide a more positive indication of inadequate instrument power which, if undetected, could cause a pilot to make improper control movements. Would bring transport category rotorcraft up to the standard now required of other transport category aircraft. Instruments with integral power adequacy indicators have been state-of-the-art for many years.	Medium	Current
	29.1333	Instrument systems	To reflect the increased complexity of instrumentation currently available	Medium	Current
	29.1355	Distribution system	Clarification	Nil	Current
	29.1357	Circuit protection devices	Clarification and harmonisation with 25.1357	Nil	Current
	29.1505	Never-exceed speed	Consideration of Mach No effects	Medium	Current
	29.1525	Kinds of operations	Clarification	Nil	Current
	29.1555	Control markings	Clarification and harmonisation with Pt 25	Nil	Current

	29.1559	Limitations placard	Improved wording	Low	Current
	29.1583	Operating limitations	Implements an existing practice by specifying ambient temperature as an operating limitation	Low	Current
	29.1585	Operating procedures	Cat B requirements for airspeed and rotor speeds	Nil	Current
	29.1587	Performance information	A number of separate changes	Medium	See 29.44
26-Nov-84	**29-23**	**Flammability requirements for seat cushions**			
Summary		A significant enhancement of aircraft fire safety			
	29.853	Compartment interiors	Requirement for material that meets more realistic flammability tests	High	Current
26-Mar-84	**29-22**	**Aero engine Regulatory Review Program**			
Summary		Update and modernize technical requirements to take into account state-of-the-art and service experience			
	29.997	Fuel strainer or filter.	Clarification that if a fuel strainer or filter is provided as part of the engine, there is no need for the aircraft manufacturer to duplicate them.	Nil	See 29.26
	29.1019	Oil strainer or filter.	Clarification that if an oil strainer or filter is provided as part of the engine, there is no need for the aircraft manufacturer to comply with present Sec. 25.1019(a)	Nil	See 29.26
	29.1021	Oil system drains.	Permits use of multiple drains	Low	Current
	29.1093	Induction system icing protection.	Re-wording	Nil	See 29.26
	29.1163	Powerplant accessories.	Clarification	Nil	See 29.26
	29.1183	Lines, fittings, and components.	Applies to piston engines	Not applicable	Current
	29.1189	Shutoff means.	Clarification	Low	See 29.26
02-Mar-83	**29-21**	**Rotorcraft Regulatory Review Program Amendment No 1**			
Summary		Amendments issued as part of the Rotorcraft Regulatory Review Program that update existing rules to recognise significant improvements in rotorcraft capabilities, current usage, current technology and future projections			
	29.1	Applicability.	Upgrading requirement for rotorcraft with 10 or more passengers to multi-engine category A configuration	Nil	See 29.39
	29.79	Limiting height-speed envelope.	Definition of need for height-speed envelope	High	See 29.39
	29.141	General.	New requirement covering complete control system failures	High	See 29.24

	29.877	Reserved.	Transferred to new 29.1419	Nil	Current
	29.1321	Arrangement and visibility.	Requirement for the flight Instrumentation to follow a basic T principle	High	Current
	29.1419	Ice protection.	Minimum safety standards for flight in icing conditions	High	Current
	29.1517	Limiting height-speed envelope.	In conjunction with 29.1587 and related to 29.1	Low	Current
	29.1587	Performance information.	Flight Manual content corresponding to 29.1	Low	See 29.44
	B29.1	I. General.	New Appendix B - Airworthiness Criteria for Helicopter Instrument Flight	High	Current
	B29.2	II. Definitions.	New Appendix B - Airworthiness Criteria for Helicopter Instrument Flight	High	Current
	B29.3	III. Trim.	New Appendix B - Airworthiness Criteria for Helicopter Instrument Flight	High	Current
	B29.4	IV. Static longitudinal stability.	New Appendix B - Airworthiness Criteria for Helicopter Instrument Flight	High	Current
	B29.5	V. Static lateral-directional stability.	New Appendix B - Airworthiness Criteria for Helicopter Instrument Flight	High	Current
	B29.6	VI. Dynamic stability.	New Appendix B - Airworthiness Criteria for Helicopter Instrument Flight	High	Current
	B29.7	VII. Stability augmentation system (SAS).	New Appendix B - Airworthiness Criteria for Helicopter Instrument Flight	High	Current
	B29.8	VIII. Equipment, systems, and installation.	New Appendix B - Airworthiness Criteria for Helicopter Instrument Flight	High	See 29.40
	B29.9	IX. Rotorcraft Flight Manual.	New Appendix B - Airworthiness Criteria for Helicopter Instrument Flight	High	Current
	C29.1	Icing certification.	New Appendix C - Icing Certification	High	Current
14-Oct-80	**29-20**	**Airworthiness Review Program**			
Summary		Ninth and last in a series of amendments issued as part of the Airworthiness Review Program			
	29.571	Fatigue evaluation of flight structure.	Editorial changes to align with introduction of new Appendix A	Nil	See 29.28
	29.783	Doors.	Clarification	Nil	See 29.28
	29.1529	Instructions for Continued Airworthiness.	New instructions in new Appendix A	High	Current
	A29.1	General.	New Appendix A - Instruction for Continued Airworthiness	High	Current
	A29.2	Format.	New Appendix A - Instruction for Continued Airworthiness	High	Current
	A29.3	Content.	New Appendix A - Instruction for Continued Airworthiness	High	Current
	A29.4	Airworthiness Limitations section.	New Appendix A - Instruction for Continued Airworthiness	High	See 29.27

09-Jun-80	**29-19**	**Technical Standard Order (TSO) Revision Program**			
Summary		New public procedure to expedite issuance of TSOs			
	29.1415	Ditching equipment	Editorial to replace 37.200 with TSO - C91	Nil	See 29.33
06-Mar-80	**29-18**	**Airworthiness Review Program**			
Summary		Amendment No 8: Cabin Safety and Flight			
	29.853	Compartment interiors	Requirements relating to smoking	Not Applicable - unless smoking allowed. not acceptable to SAI	See 29.23
01-Dec-78	**29-17**	**Airworthiness Review Program**			
Summary		Seventh in a series of amendments issued as part of the Airworthiness Review Program			
	29.75	Landing	Horizontal distance from 50 feet	Medium	See 29.39
	29.603	Materials.	Materials to take into account environmental conditions expected in service	High Review Implications of change of usage	Current
	29.605	Fabrication methods.	New aircraft fabrication methods must be tested to determine their soundness	High see also 29.571 for future requirements	Current
	29.613	Material strength properties and design values.	Permits use of alternative design values	Nil	See 29.30
	29.675	Stops.	Clarification of locations for stops	Low	Current
	29.853	Compartment interiors.	Upgraded flammability requirements for compartment interior materials	High	See 29.23
	29.863	Flammable fluid fire protection.	Protection from a flammable fluid or vapour fire	High	Current
	29.901	Installation.	Clarification that Subpart E contains provisions applicable to APU installations.	Nil	See 29.36
	29.923	Rotor drive system and control mechanism tests.	Revised to reference torque inputs to the rotor drive system rather than power inputs and more realistic torque conditions during the required tests	Medium	See 29.42
	29.927	Additional tests.	Revised to reference torque inputs to the rotor drive system rather than power inputs	Medium	See 29.26
	29.1091	Air induction.	Revised air induction requirements	Medium	Current
	29.1103	Induction systems ducts and air duct systems.	More comprehensive standards for APU induction system ducts	Medium	Current

	29.1142	Auxiliary power unit controls.	Controllability of APUs from flight deck	Medium	Current
	29.1195	Fire extinguishing systems.	To show that an adequate fire extinguishing agent discharge concentration exists under flight conditions	Medium	Current
	29.1522	Auxiliary power unit limitations.	To clarify that limits established under the TSO for an APU must be made applicable to the installation in the helicopter.	Low	Current
	29.1545	Airspeed indicator.	Airspeed limitation marks to be located at the corresponding indicated airspeeds instead of at the calibrated airspeeds	Low	Current
	29.1583	Operating limitations.	Transfer information concerning the meaning of the zero fuel indication from the operating limitations section of the Flight Manual to the operating procedures section	Low	See 29.24
	29.1585	Operating procedures.	Transfer information concerning the meaning of the zero fuel indication from the operating limitations section of the Flight Manual to the operating procedures section	Low	See 29.24
04-Dec-78	**29-16**	**Airworthiness Review Program**			
Summary		Amendment No 8: General Operating and Flight Rules			
	29.1413	Safety belts: Passenger warning device.	Use of metal-to-metal latching device to avoid problems with metal-to-fabric types	Nil SAI standard for metal to metal buckles with preference for 90 degree opening device supersedes this requirement	Current
01-Mar-78	**29-15**	**Airworthiness Review Program**			
Summary		Amendment No 6: Flight Amendments			
	29.29	Empty weight and corresponding centre of gravity.	Simplify weight & balance	Nil	Current
	29.33	Main rotor speed and pitch limits.	Main rotor low speed warning	Medium	Current
	29.45	General.	Consideration of power losses due to the installation and power absorbed by the accessories and services	Low	See 29.24
	29.65	Climb: All engines operating.	Revised VNE requirements	Low	See 29.39
	29.143	Controllability and manoeuvrability.	Revised VNE requirements	Low	See 29.24
	29.175	Demonstration of static longitudinal stability.	Requires the lower speed limit for demonstration of static longitudinal stability in autorotation to be 0.5 times the speed for minimum rate of descent.	Low	See 29..24

	29.1043	Cooling tests.	Harmonisation of cooling test requirements	Nil	See 29.26
	29.1353	Electrical equipment and installations.	Alignment with AD 72-19-4	Low	Current
	29.1501	General.	Clarification	Low	Current
	29.1505	Never-exceed speed.	Revised VNE requirements	Low	See 29.24
	29.1521	Powerplant limitations.	Harmonisation of cooling test requirements	Nil	See 29.41
	29.1527	Maximum operating altitude.	Revised VNE requirements	Low	Current
	29.1545	Airspeed indicator.	Revised VNE requirements	Low	See 29.17
	29.1581	General.	Clarification	Low	Current
	29.1583	Operating limitations.	Harmonisation of cooling test requirements	Nil	See 29.24
	29.1585	Operating procedures	Revised VNE requirements	Low	See 29.24
01-Sep-77	**29-14**	**Airworthiness Review Program**			
Summary		Amendment No 5: Equipment and Systems			
	29.1303	Flight and navigation instruments.	Conditions for non-fitment of gyro rate of turn instrument	Nil	See 29.24
	29.1309	Equipment, systems, and installations.	System requirement following engine failures	High	See 29.24
	29.1321	Arrangement and visibility.	Scope broadened	Low	See 29.21
	29.1325	Static pressure and pressure altimeter systems.	Harmonisation of static icing requirements	Low	See 29.24
	29.1335	Flight director systems.	Indication of current mode of operation of the flight director system	Medium	Current
	29.1351	General.	External power and operation without normal electrical power	Medium	See 29.42
	29.1353	Electrical equipment and installations.	Clarification	Nil	See 29.15
	29.1355	Distribution system.	Clarification	Nil	See 29.24
02-May-77	**29-13**	**Airworthiness Review Program**			
Summary		Amendment No 4: Powerplant Systems			
	29.571	Fatigue evaluation of structure	Clarification that 29.571 applies to portions of the rotor drive system.	High	See 29.28
	29.901	Installation.	Engine installation as per instructions provided by the engine manufacturer.	Low	See 29.36
	29.903	Engines.	Change to align with 29.908	Nil	See 29.36
	29.908	Cooling fans.	Requirement applies to the entire cooling fan, whether or not a part of the engine, if the fan is a part of the Powerplant installation.	Medium	See 29.26
	29.965	Fuel tank tests.	A more meaningful test value	Low	Current

	29.991	Fuel pumps.	Harmonisation	Nil	See 29.26
	29.995	Fuel valves.	Harmonisation	Nil	Current
	29.1093	Induction system icing protection.	Clarification that effect of ice accumulation on components of the inlet system as well as on engine components must be considered.	Medium	See 29.26
	29.1121	General.	Clarification	Nil	Current
	29.1141	Powerplant controls: General.	Clarification	Nil	See 29.26
	29.1145	Ignition switches.	Prevention of inadvertent shutdown of engines	Not applicable Piston powered helicopters only.	Current
	29.1193	Cowling and engine compartment covering.	Harmonisation	Not applicable Category B helicopters only.	See 29.26
	29.1195	Fire extinguishing systems.	Clarification	Nil	See 29.17
	29.1197	Fire extinguishing agents.	Editorial	Nil	Current
	29.1199	Extinguishing agent containers	Rationalisation	Nil	Current
	29.1337	Powerplant instruments.	Requirement that those instruments and lines that use flammable fluid be installed and located so that leakage of the fluid would not create a hazard	High	See 29.26
01-Feb-77	**29-12**	**Airworthiness Review Programme**			
Summary		Amendment No 3: Miscellaneous Amendments			
	29.25	Weight limits.	Transfer from Part 133	Nil	See 29.43
	29.63	Takeoff: Category B.	Horizontal distance to clear 50 feet	Not applicable Category B only	Current
	29.67	Climb: One engine inoperative.	Clarification	Low	See 29.44
	29.71	Helicopter angle of glide: Category B.	Not applicable to Cat A	Nil - Category B	Current
	29.75	Landing	Clarification	Nil	See 29.39
	29.141	General.	Clarification and rationalisation	Nil	See 29.24
	29.173	Static longitudinal stability.	Clarification and rationalisation	Nil	See 29.24
	29.175	Demonstration of static longitudinal stability.	Inclusion of more realistic landing gear position during the demonstration	Low	See 29.24
	29.397	Limit pilot forces and torques.	More complete requirements for rotorcraft controls	Medium	See 29.47
	29.563	Structural ditching provisions.	To correspond with 29.801	High	See 29.26

	29.603	Materials.	To include parts that may not be in the structure but are subject to stresses or environmental conditions that could cause a failure with an adverse effect on safety	High	See 29.17
	29.685	Control system details.	To account for the effects of freezing moisture	High	Current
	29.733	Tires.	To take into account the tire production tolerance and size increases expected to result from service	Low	Current
	29.787	Cargo and baggage compartments.	To prevent direct contact between a hot bulb and cargo	Low	See 29.31
	29.801	Ditching.	Enhanced requirements	High	Current
	29.807	Passenger emergency exits.	Enhanced requirements aligned to 29.801	High	See 29.30
	29.813	Emergency exit access.	Harmonisation	Low	Current
	29.815	Main aisle width.	Harmonisation	Low	Current
	29.865	External load attaching means.	Transfer from Part 133	Nil	See 29.43
	29.903	Engines.	Fire resistant engine stopping systems and controls to prevent compromise of turbine rotor structural integrity	Nil	See 29.36
	29.917	Design	Cooling fans to be considered as a part of the rotor drive system.	Low	See 29.40
	29.931	Shafting critical speed.	New requirement	High	Current
	29.939	Turbine engine operating characteristics.	Must be shown that no hazardous torsional instability exists.	Medium	Current
	29.951	General.	Fuel system design for APUs	Low	Current
	29.971	Fuel tank sump.	Removal of requirement made redundant by 29.999. Note: replaced by amdt 29-26	Nil	See 29.26
	29.977	Fuel tank outlet.	Enhanced requirements	Low	Current
	29.979	Pressure refuelling and fuelling provisions below fuel level.	To cover strength requirements for fuel systems to cover surge pressures during refuelling and defuelling	Low	Current
	29.999	Fuel system drains.	Requirement to install quick actuation type drain valves. The absence of a quick actuation type drain valve has been suggested as a contributing factor in accidents caused by water contamination of fuel. Most helicopters already have quick actuation drain valves.	Medium	See 29.26
	29.1041	General.	More comprehensive cooling requirements	Low	See 29.26
	29.1043	Cooling tests.	Harmonisation	Nil	See 29.26
	29.1093	Induction system icing protection.	Carburettor icing	Not applicable	See 29.26
	29.1125	Exhaust heat exchangers.	Piston engines	Not applicable	See 29.41
	29.1143	Engine controls.	To prevent the power and thrust control from being inadvertently moved into the cut-off position	High	See 29.34

	29.1165	Engine ignition systems.	To isolate engine ignition systems from other electrical systems	Medium	Current
	29.1189	Shutoff means.	Deletes requirement for shut off system for oil systems	Low	See 29.26
	29.1197	Fire extinguishing agents.	Prescribes the objective rather than the use of specific agents	Nil	See 29.13
	29.1303	Flight and navigation instruments	Permits the use of approved digital clocks	Nil	See 29.24
	29.1307	Miscellaneous equipment.	Removal of requirements covered elsewhere	Nil	Current
	29.1322	Warning, caution, and advisory lights.	Standardisation of colours for warning lights	Medium	Current
	29.1549	Powerplant instruments.	Change to cover vertical tape instruments	Medium	See 29-26 & -34
	29.1555	Control markings.	More relevant information than the present rule	Low	See 29.24
	29.1557	Miscellaneous markings and placards.	Marking of maximum permissible pressure differentials for both fuelling and de-fuelling at pressure fuelling points	Medium	See 29.26
	FAR29	**Airworthiness Review Programme, exemptions and equivalences in pre AL 29.12 requirements**			

APPENDIX 2:

METHOD OF DETERMINING IMPACT OF MITIGATION MEASURES

A detailed breakdown of accident causes taken from the NASA study (Ref 1) is shown in Table 6. A primary mitigation measure is then assigned to each of these accident causes. Secondary and tertiary mitigation measures, which may have an impact, albeit less effective, are also assigned. The individual percentage effectiveness of each mitigation measure is taken from Table 5 and applied to each accident cause in turn.

To illustrate the method, the accident cause **In flight collision with terrain** will be used as an example. From Table 6, **In flight collision with terrain** accounts for 5.7% of accidents. The most effective means of mitigation is likely to be **EGPWS** and this is listed under Primary Mitigation in Table 6. From Table 5 it is estimated that **EGPWS** would save 75% of such accidents. Secondary Mitigation (**HOMP** in this case from Table 6) would also have an impact. To account for the fact that Secondary Mitigation has less impact than Primary Mitigation, a reduction factor of 0.85 is applied to all Secondary Mitigation. Thus, as Primary Mitigation, it is estimated that **HOMP** (Table 5) would save 50% of accidents. As Secondary Mitigation, it is therefore estimated that **HOMP** would save 0.85 x 50% = 43% of those accidents not prevented by **EGPWS**. The Tertiary Mitigation is **Training**. A reduction factor of 0.75 is applied to Tertiary Mitigation and it is estimated that **Training** would further reduce accidents not prevented by **EGPWS** and **HOMP** by an estimated 0.75 x 45% = 34%. These mitigating factors are applied in turn. Thus, for **In flight collision with terrain** accidents:

Primary Mitigation (EGPWS):	75%
Proportion of accidents prevented by Primary Mitigation	0.75
Proportion of remaining accidents	1.0 - 0.75 = 0.25
Secondary Mitigation of remaining accidents by HOMP	0.25 x 0.85 x 0.5 = 0.11
Proportion of remaining accidents	0.25 - 0.11 = 0.14
Tertiary Mitigation of remaining accidents by Training	0.14 x 0.75 x 0.4 = 0.04
Total mitigation	0.75 + 0.11 + 0.04 = 0.90
Percentage of collision with terrain accidents before mitigation	5.7%
Percentage of such accidents prevented by mitigation	0.90 x 5.7% = 5.1%
Percentage of collision with terrain accidents after mitigation	(1.0 - 0.90) x 5.7% = 0.6%

This calculation is performed on each of the accident causes. When all the mitigation measures are applied (Package E), the total proportion of all accidents prevented by mitigation comes to 83.4%. Thus, applying this to the baseline of 20 accidents per million flying hours, the application of all the mitigation measures would save 16.7 accidents and the accident rate would be reduced to 3.3 per million flying hours.

Taking data over a long period, the ratio of fatal accidents to total accidents is about 0.35. Hence applying all the mitigation measures would result in a fatal accident rate of 1.1 per million flying hours.

APPENDIX 3:
MITIGATION FACTORS NASA STUDY

Generic Twin NASA Summary of Results

Mitigation	% accidents prevented (individual measure only)
IW	6.3
EGPWS/TCAS	12.2
PC1/2e	12.8
HOMP	15.1
HUMS	18.1
OC/QA	18.3
Training	20.4
DR & DR/HQ	31.1

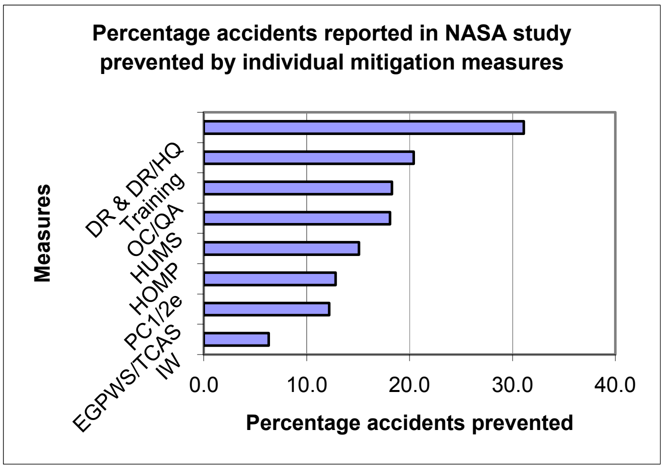

Table of AS332 and S-76 Accidents 1990 to 2003 WAAS DR and DR/HQ only

Date	NTSB Category	Narrative		Level 1 Mitigation	MF1	Level 2 Mitigation	MF2	Level 3 Mitigation	MF3	Overall MF	Accidents prevented %
18-Sep-90	Airframe/ component/ system failure	While hovering, pilot reported strong vibration before helicopter went out of control and crashed into sea	AS332	DR/HQ	0.60	HUMS	0.00	Training	0.00	0.60	0.60
06-Dec-90	Airframe/ component/ system failure	Fire in vicinity of main gear box, caused by leakage of hydraulic fluid, resulted in total hydraulic failure and loss of control	AS332	DR	0.50					0.50	0.50
11-May-92	Airframe/ component/ system failure	Helicopter crashed during crew training. The IGB bearing developed a fault due to lack of lubrication due to omission of hole in casing	AS332	DR/HQ	0.60	HUMS	0.00	Training	0.00	0.60	0.60
05-Nov-92	Airframe/ component/ system failure	Ditched after suffering tail rotor problems during a practice rescue mission	AS332	DR/HQ	0.60	Training	0.00		0.00	0.60	0.60
24-Oct-93	Airframe/ component/ system failure	En route, a high frquency vibration was felt in cabin and shortly after, the helicopter began to lose height in a spiralling turn until impact with the water. Assumed to be tail rotor drive	AS332	DR/HQ	0.60	HUMS	0.00	Training	0.00	0.60	0.60
10-Nov-94	Airframe/ component/ system failure	En route, crew heard an unusual noise and slight vibration. During final stages of approach, helicopter started to rotate around its axis	AS332	DR/HQ	0.60	HUMS	0.00	Training	0.00	0.60	0.60
16-Nov-94	Airframe/ component/ system failure	While en route, helicopter developed severe vibration. Helicopter began to rotate and lose height. Crew tried to maintain control but were unable to reach landing area. Tail rotor assy and gearbox separated in flight	AS332	DR/HQ	0.60	HUMS	0.00	Training	0.00	0.60	0.60
19-Jan-95	Airframe/ component/ system failure	Lightning strike on tail rotor was followed by severe vibration. En route to nearest landing site, load crack and helicopter yawed rapidly, rolled and pitched down. Pilot shut down both engines and landed gently on the sea	AS332	DR	0.50		0.00		0.00	0.50	0.50
18-Jan-96	Airframe/ component/ system failure	While en route, helicopter developed severe vibration. Pilot successfully force landed in the sea. Main rotor LE erosion strip had delaminated	AS332	HUMS	0.00	OC/QA	0.00	DR	0.38	0.38	0.38
27-Feb-96	Airframe/ component/ system failure	Lightning was followed by considerable vibration. Pilot maintained control and landed safely	AS332	DR	0.50		0.00		0.00	0.50	0.50
12-Dec-97	Airframe/ component/ system failure	Lightning strike on main rotor blades followed by vibration. Pilot reduced power and landed safely	AS332	DR	0.50		0.00		0.00	0.50	0.50
21-Mar-80	Airframe/ component/ system failure	Failure of main rotor spindle, crashed in sea	S-76	DR	0.50	HUMS	0.00		0.00	0.50	0.50
14-Sep-83	Airframe/ component/ system failure	Failure of tail rotor control cable due to rubbing caused by incorrect installation. Aircrew began autorotation but helicopter hit water with 40kt forward speed, listed 10 deg, then rolled over and sank	S-76	OC/QA	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51

22-Sep-84	Airframe/ component/ system failure	Tail rotor drive shaft failed following contact with firewall following incorrectly installed modification. Pilot reduced power and landed successfully	S-76	OC/QA	0.00	DR/HQ	0.51	HUMS	0.00	0.51	0.51
09-Sep-86	Airframe/ component/ system failure	About 12 secs after take off, tail rotor paddle blade spar failed and separated due to manufacturing defect. A precautionary landing was successful	S-76	HUMS	0.00		0.00		0.00	0.00	0.00
01-Nov-89	Airframe/ component/ system failure	Rotor brake fire on run down. No 2 engine shut down, precautionary evacuation	S-76	DR	0.50		0.00		0.00	0.50	0.50
07-Aug-92	Airframe/ component/ system failure	Preflight check failed to ensure engine cowling latched. Cowling came undone and contacted main rotor blades and contacted tail rotor drive shaft. Friction caused high temperature and failure of drive shaft. Autorotation and landing attemped on hilly terrain and helicopter came to rest in a ravine.	S-76	OC/QA	0.00		0.00		0.00	0.00	0.00
25-Apr-94	Airframe/ component/ system failure	Following maintenance, rear cover of hydraulic module became detached and struck and ruptured hydraulic lines. Control pedal locked, helicopter yawed to right and landed heavily	S-76	OC/QA	0.00				0.00	0.00	0.00
30-Jun-94	Airframe/ component/ system failure	Following a load bang, pilot landed in sea. #1 engine gear train had failed from fatigue cracks in helical gear across 12 attaching bolt holes caused by under-torqued bolts during manufacture. Both gear box oil pumps seized from debris that had by-passed filters and #2 engine pinion failed from overheating due to lack of oil.	S-76	HUMS	0.00		0.00		0.00	0.00	0.00
03-Apr-97	Airframe/ component/ system failure	One minute after takeoff, helicopter experienced mechanical problems. Pilot attempted a forced landing but helicopter landed very hard	S-76	DR/HQ	0.60		0.00		0.00	0.60	0.60
16-Jul-02	Airframe/ component/ system failure	Fatigue failure of main rotor blade titanium spar. Fatigue initiated from a combination of a manufacturing anomoly aggravated by thermal damage resulting from a lightning strike.	S-76	DR	0.50	HUMS	0.00		0.00	0.50	0.50
22-Nov-02	Airframe/ component/ system failure	On a test flight following an inspection and oil filter change as a result the chip detector light for the no. 1 engine being illuminated, a bang was heard and the helicopter began to spin out of control. The helicopter crashed on a farm and the crew exited; the helicopter was destroyed in the impact and a subsequent fire	S-76	DR/HQ	0.60	Training	0.00		0.00	0.60	0.60
05-Jul-96	Fire/explosion	Caught fire while taxiing	AS332	DR	0.50		0.00		0.00	0.50	0.50
15-Jul-03	Fire/explosion	Engine fire followed by hard crash landing	AS332	DR/HQ	0.60		0.00		0.00	0.60	0.60
31-Oct-97	Hard landing	During crew training, helicopter entered fog as it began landing flare, pilot lost visual reference with ground and touched down hard	AS332	DR/HQ	0.60		0.00		0.00	0.60	0.60
20-Mar-86	Hard landing	Damage to pylon leading edge and scuff marks on main rotor blade caps discovered after takeoff and landings by trainee pilot	S-76	DR/HQ	0.60		0.00		0.00	0.60	0.60

06-Feb-93	Hard Landing	Following ILS approach in reduced visibility, helicopter touched down heavily. Weather was below landing minima, and crew were arguing	S-76	EGPWS/TCAS	0.00	OC/QA	0.00		0.00	0.00	0.00
23-Apr-94	Hard Landing	On approach to helideck, hard landing following an excessive rate of descent. Helicopter was damaged but pilot regained control and landed in the sea. Calm sea, insufficient visual clues	S-76	DR/HQ	0.60	HOMP	0.00		0.00	0.60	0.60
11-Mar-02	Hard landing	During training for rejected take offs, helicopter landed heavily and was damaged	S-76	DR/HQ	0.60		0.00		0.00	0.60	0.60
17-Sep-02	Hard landing	Practicing single engine approach to a helipad, main rotor rpm dropped and helicopter landed heavily	S-76	PC1/2a	0.00	DR/HQ	0.51		0.00	0.51	0.51
14-Mar-03	Hard landing	During training, helicopter touched down hard and caught fire	S-76	DR/HQ	0.60		0.00		0.00	0.60	0.60
11-Sep-91	In flight collision with object	Main rotors struck a building on landing and helicopter crashed	AS332	EGPWS/TCAS	0.00	IW	0.00	OC/QA	0.00	0.00	0.00
25-Mar-92	In flight collision with object	Shortly after take off, main rotor blades struck trees in thick fog	AS332	EGPWS/TCAS	0.00	IW	0.00	HOMP	0.00	0.00	0.00
30-Nov-92	In flight collision with object	Slung cargo flew up and struck tail rotor. Pilot lost control and helicopter crashed	AS332	DR/HQ	0.60	OC/QA	0.00		0.00	0.60	0.60
05-Mar-84	In flight collision with object	Hit trees during landing. Weather IMC with low cloud and fog	S-76	EGPWS/TCAS	0.00	IW	0.00	HOMP	0.00	0.00	0.00
23-Jun-88	In flight collision with object	Hit power lines shortly after take-off	S-76	EGPWS/TCAS	0.00	IW	0.00	HOMP	0.00	0.00	0.00
27-Mar-89	In flight collision with object	Pilot was advised to land on a spot that was too small for it. Pilot mis-judged clearance from another helicopter and main rotor blades intermeshed. FAA advisories did not require markings for max rotor size	S-76	OC/QA	0.00	IW	0.00	HOMP	0.00	0.00	0.00
21-Jun-94	In flight collision with object	Helicopter was delivering packages to ship. Originally intended to lower packages one at a time from 15 ft to a crewman. This took time and pilot was concerned about crew fatigue so decided to lower height to 6 ft to drop packages safely onto deck. Pilot saw objects flying about, felt vibration through cyclic and landed immediately. Sunbeds had escaped from their lashing because of downwash.	S-76	OC/QA	0.00		0.00		0.00	0.00	0.00
20-Feb-98	In flight collision with object	Helicopter collided with ship during training rescue	S-76	IW	0.00		0.00		0.00	0.00	0.00
19-May-01	In flight collision with object	Shortly after take off from a crash site, helicopter hit power lines	S-76	EGPWS/TCAS	0.00	IW	0.00	OC/QA	0.00	0.00	0.00

05-Jul-01	In flight collision with object	Helicopter hit communication tower en route in heavy rain and fog and crashed into sea	S-76	EGPWS/TCAS	0.00	IW	0.00	OC/QA	0.00	0.00	0.00
10-Jul-01	In flight collision with object	No details	S-76		0.00		0.00		0.00	0.00	0.00
31-Aug-02	In flight collision with object	On take off from a helipad, pilot was distracted and main rotors hit building	S-76	EGPWS/TCAS	0.00	IW	0.00	OC/QA	0.00	0.00	0.00
05-Jul-03	In flight collision with object	Hit ship's mast on approach to land on helideck	S-76	IW	0.00	OC/QA	0.00		0.00	0.00	0.00
27-Mar-90	In flight collision with terrain	Helicopter flew into ground on route	AS332	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
16-Apr-94	In flight collision with terrain	Struck hillside in thick fog following a mechanical problem	AS332	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
19-Sep-97	In flight collision with terrain	Second helicopter in a formation of 2 struck hillside and crashed in fog and heavy rain	AS332	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
11-Apr-99	In flight collision with terrain	Crashed into mountain while checking international border markers	AS332	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
20-Apr-02	In flight collision with terrain	In deteriorating weather with rain and low cloud, flew into side of valley and crashed	AS332	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
18-Nov-03	In flight collision with terrain	During SAR training, crashed into sea	AS332	EGPWS/TCAS	0.00	OC/QA	0.00		0.00	0.00	0.00
28-Apr-82	In flight collision with terrain/water	Crashed into sea in reduced visibility	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
07-Nov-83	In flight collision with terrain/water	Helicopter crashed into sea shortly after take off	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
19-Feb-85	In flight collision with terrain/water	Helicopter impacted ground in a level attitude on approach in fog	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
05-Apr-86	In flight collision with terrain/water	Helicopter was manoeuvring at low speed over glassy sea at night looking for a capsized boat when it impacted the water	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
01-Jun-87	In flight collision with terrain/water	Struck water during low level cruise and sank	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
01-Aug-90	In flight collision with terrain/water	Helicopter apparently flew into the side of a hill in low cloud	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00

21-Nov-92	In flight collision with terrain/water	Crashed on takeoff, high altitude, high gross weight, possibly over max allowable, pilot inexperience.	S-76	OC/QA	0.00		0.00		0.00	0.00	0.00
14-Jun-93	In flight collision with terrain/water	Whilst flying low along a river, apparently filming, helicopter briefly touched the water. Pilot attempted to gain height but lost control and helicopter crashed inverted.	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
08-Nov-94	In flight collision with terrain/water	During approach in low cloud and fog, helicopter crashed into sea 2 miles from shore	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
09-Apr-96	In flight collision with terrain/water	On return from an off shore platform, helicopter crashed on island in poor visibility and strong winds	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
12-Dec-96	In flight collision with terrain/water	Helicopter flew into ground en route in bad weather	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
22-Sep-97	In flight collision with terrain/water	Following take off, helicopter was seen in a high hover before disappearing in fog. Helicopter impacted at a shallow angle with gear retracted.	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
04-Oct-97	In flight collision with terrain/water	Helicopter disappeared en route in maginal IMC	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
20-Dec-97	In flight collision with terrain/water	On its second approach to helideck, helicopter apparently flew into sea in darkness, good weather and calm sea state	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
18-Mar-98	In flight collision with terrain/water	Helicopter apparently flew into side of hill on approach in IMC	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
24-Jun-98	In flight collision with terrain/water	While practicing night takeoffs from ship helipad on a dark night with few visual references, as helicopter transitioned to forward flight, it lost height and impacted the sea	S-76	EGPWS/TCAS	0.00	HOMP	0.00		0.00	0.00	0.00
14-Jun-99	In flight collision with terrain/water	Helicopter crashed shortly after takeoff in darkness, IMC and fog	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
02-Aug-00	In flight collision with terrain/water	Helicopter apparently flew into a mountain while en route in IMC and dense fog	S-76	EGPWS/TCAS	0.00	HOMP	0.00	Training	0.00	0.00	0.00
30-Apr-90	Loss of control	During a training flight at night, on approach to a Fixed Storage Vessel, rate of descent increased rapidly and helicopter crashed into sea	AS332	DR/HQ	0.60	HOMP	0.00	Training	0.00	0.60	0.60
14-Mar-92	Loss of control	After take off from a helideck, helicopter entered a climbing right hand turn. 15 secs later began to lose height while still in right hand turn. Weather was poor with strong gusty wind, heavy hail and snow showers. Pilot failed to recognise rapidly changing relationship between airspeed and ground speed while turning downwind in strong wind.	AS332	DR/HQ	0.60	HOMP	0.00	Training	0.00	0.60	0.60

18-Dec-92	Loss of control	Crashed during practice autorotation	AS332	DR/HQ	0.60	HOMP	0.00		0.00	0.60	0.60
18-Mar-96	Loss of control	On approach in strong wind, helicopter went out of control at low height	AS332	DR/HQ	0.60	HOMP	0.00	Training	0.00	0.60	0.60
31-Mar-81	Loss of control	Instructor reduced No 1 engine to flight idle to simulate engine failure contrary to manufacturers recommendation. Helicopter landed hard and was destroyed	S-76	OC/QA	0.00		0.00			0.00	0.00
30-Apr-82	Loss of control	Pilot reported directional control problems at 5000ft, started descent but lost control at 1000ft	S-76	DR/HQ	0.60	HOMP	0.00	Training	0.00	0.60	0.60
28-Jun-85	Loss of control	Following landing, wheel ran off helideck. Pilot attemped to lift off but helicopter went of platform and fell inverted into water. Limited space on helideck because a Bell 206 was already parked on it	S-76	OC/QA	0.00		0.00		0.00	0.00	0.00
06-Jun-86	Loss of control	While cruising in IMC at 6000 ft, pilot lost control and helicopter crashed in a steep, high speed descent	S-76	DR/HQ	0.60	HOMP	0.00	Training	0.00	0.60	0.60
04-Feb-87	Loss of control	Pilot inadvertently entered IMC, asked for ILS data from Ops. Vectors were provided by ATC but was unable to get established on approach. 3 attempts were made. Ground speed varied from 108 kts to 28 kts. Just before crash, pilot reported an altitude problem.	S-76	DR/HQ	0.60	HOMP	0.00	Training	0.00	0.60	0.60
22-Feb-89	Loss of control	Pilot lost control following inadvertent VMC to IMC. Helicopter finally hit trees with main rotors	S-76	DR/HQ	0.60	HOMP	0.00	Training	0.00	0.60	0.60
17-Jun-91	Loss of control	During landing on a helideck, pilot allowed helicopter to drift and put right wheel off platform. After 2 unsuccessful repositioning attempts, pilot decided to take off. During take off, helicopter turned right around vertical axis. Co-pilot interpreted this as loss of directional control and, without telling pilot, reduced power to idle on both engines. Main rotor blades struck platform and helicopter crashed into sea.	S-76	DR/HQ	0.60	HOMP	0.00	Training	0.00	0.60	0.60
28-Apr-97	Loss of control	While practicing single engine failure in hover, helicopter touched down with significant aft speed and rolled over.	S-76	PC1/2a	0.00	DR/HQ	0.51	HOMP	0.00	0.51	0.51
22-Aug-03	Loss of control	While hovering with autopilot disengaged, pilot lost control	S-76	DR/HQ	0.60	HOMP	0.00	Training	0.00	0.60	0.60
14-Jul-91	Loss of engine power	Crashed into sea after reporting low on fuel	AS332	OC/QA	0.00	DR/HQ	0.51	HOMP	0.00	0.51	0.51
08-Sep-97	Loss of engine power	Uncontained failure of #2 engine turbine disk. Debris penetrated #1 engine and flight controls. Helicopter immediately went out of control and began to break up	AS332	DR	0.50	HUMS	0.00		0.00	0.50	0.50
28-May-81	Loss of engine power	Engine malfunction/failure followed by fire during take off	S-76	DR	0.50		0.00		0.00	0.50	0.50
08-Nov-83	Loss of engine power	#1 engine failed explosively during cimb. Gear collapsed on landing	S-76	DR	0.50	PC1/2a	0.00		0.00	0.50	0.50
13-Nov-83	Loss of engine power	One engine failed and shortly after the other engine started to lose power. Successful forced landing in sea but one float deflated and helicopter rolled over and sank during the tow in	S-76	DR	0.50		0.00		0.00	0.50	0.50

01-May-84	Loss of engine power	Left hand engine failed explosively due to fatigue failure of compressor to turbine coupling. Shrapnel penetrated right engine which also failed. Schrapnel caused total electrical failure, severed tail rotor drive shaft and caused a fire in transmission area. Autorotation was successful but electrically operated flotation gear failed to deploy and helicopter rolled over	S-76	DR	0.50	HUMS	0.00		0.00	0.50	0.50
11-Aug-84	Loss of engine power	Left hand engine turbine wheel burst due to high cyclic fatigue. Shrapnel had penetrated RH engine and severed tail rotor control cables and drive shaft. Helicopter dropped suddenly, recovered then veered sharply right and crashed	S-76	DR	0.50		0.00		0.00	0.50	0.50
16-Aug-84	Loss of engine power	Engine first stage turbine wheel burst due to abnormal rub introduced during rebuild. Debris disabled other engine and severed tail rotor drive shaft.	S-76	DR	0.50		0.00		0.00	0.50	0.50
01-Nov-84	Loss of engine power	Engine first and second stage turbine wheels burst	S-76	PC1/2a	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51
14-Jul-85	Loss of engine power	On approach, pilot noticed a high sink rate at 100 ft and increased collective. At 20 ft, pilot noticed a decrease in rpm and realised loss of engine power. Tail cone contacted helipad damaging tail rotor drive shaft.	S-76	PC1/2a	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51
15-May-90	Loss of engine power	#1 engine fire warning light came on, pilot shut down engine and fired extinguishers but light stayed on. Pilot decided to land in sea	S-76	DR	0.50		0.00		0.00	0.50	0.50
26-Jun-99	Loss of engine power	Following problem with #1 engine, helicopter was damaged landing on rough ground	S-76	PC1/2a	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51
27-Oct-93	Mid-air collision	2 helicopters collided during a flying display	AS332	EGPWS/TCAS	0.00	OC/QA	0.00		0.00	0.00	0.00
19-May-01	Mid-air collision	Crashed after colliding with Cessna 172	AS332	EGPWS/TCAS	0.00		0.00		0.00	0.00	0.00
11-Jun-85	Mid-air collision	Low level collision during training	S-76	EGPWS/TCAS	0.00	OC/QA	0.00		0.00	0.00	0.00
24-Mar-88	Propeller/rotor contact to person	Despite having been shown a video and being given specific instructions to bend over to lower his height, passenger was struck on the head by the rotor blade	S-76	OC/QA	0.00		0.00		0.00	0.00	0.00
20-Mar-01	Propeller/rotor contact to person	Passenger hit by rotor	S-76	OC/QA	0.00		0.00		0.00	0.00	0.00
14-Jan-96	Rollover/noseover	While taxiing slowly in a gentle arc, helicopter rolled to left, main rotors struck ground and helicopter rolled over	AS332	HOMP	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51
02-Jul-99	Rollover/noseover	While en route helicopter encountered some problem and landed on water and subsequently rolled over	AS332	DR/HQ	0.60		0.00		0.00	0.60	0.60
10-Nov-01	Rollover/noseover	While on helideck on ship with rotors turning and in heavy wind, helicopter suddenly rolled over	AS332	HOMP	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51
19-Apr-03	Rollover/noseover	Helicopter caught by strong winds while on ground with rotors turning and rolled over	AS332	HOMP	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51
03-Sep-80	Rollover/noseover	Skidded off steel landing pad due to incorrect operation of brakes and rolled over	S-76	HOMP	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51

05-Jan-86	Rollover/noseover	Helicopter rolled over while deplaning passengers onto a moving barge in a high cross wind	S-76	HOMP	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51
07-Aug-88	Rollover/noseover	Helicopter ran off taxiway, its wheel stuck in soft ground and it rolled over. Rollover met several of the criteria described in FAA circular on dynamic rollover	S-76	HOMP	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51
12-Dec-95	Rollover/noseover	Pilot disembarked but left rotors turning. Helicopter got airborne and rolled onto side	S-76	OC/QA	0.00		0.00		0.00	0.00	0.00
12-Nov-98	Rollover/noseover	Helicopter ran off taxiway during training at night	S-76	HOMP	0.00	DR/HQ	0.51	Training	0.00	0.51	0.51
21-Jul-01	Rollover/noseover	Pilot left cockpit to close a rear cabin door with rotors turning. Before pilot could regain control helicopter yawed to left and rolled over	S-76	OC/QA	0.00		0.00		0.00	0.00	0.00
06-Jan-91	Unknown	No details	AS332		0.00		0.00		0.00	0.00	0.00
16-Aug-91	Unknown	No details	AS332		0.00		0.00		0.00	0.00	0.00
19-Aug-95	Unknown	Crashed en route following main transmission change. Maintenance error assumed	AS332	OC/QA	0.00		0.00		0.00	0.00	0.00
12-May-90	Unknown	No details	S-76		0.00		0.00		0.00	0.00	0.00
30-Jan-03	Unknown	No details	S-76		0.00		0.00		0.00	0.00	0.00
29-Sep-81	Weather	Blown over by high winds	S-76		0.00		0.00		0.00	0.00	0.00
						Factor	**0.85**	**Factor**	**0.75**		
Total accidents prevented											**31.63**

Key	
EGPWS	Enhanced Ground Proximity Warning System
TCAS	Traffic Alert & Collision Avoidance System
DR	Design requirements - late amendt FAR/JAR 29
DR/HQ	Handling qualities/advanced cockpit design + late FAR 29
IW	Impact warning system
HUMS	Health & Usage Monitoring System
HOMP	Helicopter Operational Monitoring Programme
Helideck	Helideck management as per CAP 437
Training	FFS level C/D + CRM + LOFT
OC/QA	JAR Ops 3 /SMS/QA
PC1/2e	Perf Class 1 or enhanced Perf Class 2
CRM	Crew Resource Management
LOFT	Line oriented flight training
SMS	Safety Management System

Effectiveness of mitigation measures %		
EGPWS/TCAS	0.00	
DR	0.50	Late FAR
DR/HQ	0.60	Late FAR + HQ
IW	0.00	Impact warning
HUMS	0.00	Incl effective mgt
HOMP	0.00	Incl effective mgt
Training	0.00	Sim/CRM/LOFT
OC/QA	0.00	Enhanced SMS/QA/Helideck
PC1/2e	0.00	

Number of accidents	**114**
Accidents prevented	**31.63**
Percentage accidents prevented	**27.7%**